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Phenological growth stages of 'Kanzi' apple according to the BBCH scale

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Abstract
The accurate identification and codification of phenological growth stages are essential for optimizing management practices in apple orchards. This study presents a detailed phenological characterization of the 'Kanzi' apple cultivar (*Malus domestica* Borkh.), using the BBCH (Biologische Bundesanstalt, Bundessortenamt and Chemical industry) scale. Observations were conducted over two annual growing seasons (2022-2023) in a temperate-climate orchard, monitoring the cultivar's development from bud dormancy through fruit maturity and post-harvest senescence. Each principal and secondary growth stage was recorded and described with photographic and morphological references, emphasizing cultivar-specific traits such as delayed bud break, condensed flowering period, and firm fruit development. Results showed that 'Kanzi' exhibits unique timing and morphological markers within certain BBCH stages, particularly in flowering (stage 60–69) and fruit development (stage 70–89), when compared to standard cultivars. This codification provides a standardized framework to support research, crop modeling, and precision horticulture practices applied to 'Kanzi' apples.

Keywords: BBCH code, phenology, flowering, fruit development, climate conditions

Introduction

'Kanzi' apple (*Malus x domestica* 'Nicoter'), a controlled-club apple cultivar developed in Belgium from a cross between 'Braeburn' and 'Gala', has gained increasing commercial relevance in premium apple markets due to its distinctive combination of high firmness, crisp texture, and a balanced sweet–tart flavor profile [26]. The cultivar's advantages include extended postharvest storability, attractive bicolored skin, and consistent fruit size, making it highly desirable for long-distance export and premium retail positioning. Its disadvantages primarily relate to cultivation constraints: 'Kanzi' is grown under strict licensing agreements that limit orchard participation, requires high-input orchard management for optimal fruit coloration, and is sensitive to climatic variations that may affect flavor balance and firmness [12]. From agronomic point of view, 'Kanzi' performs best in temperate climates with sufficient winter chilling and moderate summer temperatures, as excessive heat can lead to reduced coloration and textural degradation. However, there is an increasing interest in extending harvest seasons to achieve profitable fruit supply outside the traditional marketing window. This has led to the expansion of production areas into both warmer and cooler climates, as well as the breeding and selection of new cultivars with broader harvest periods [12,27].

Optimal cultivation of 'Kanzi' apple involves high-density planting systems, regulated deficit irrigation, and precise thinning to maintain fruit size and quality. Due to its premium positioning and climate sensitivity, 'Kanzi' is considered a high-risk, high-return cultivar that can provide significant economic benefits for licensed growers in suitable production zones.

Nevertheless, with the extension of cultivation areas, various environmental changes often result in

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irregular cropping and phenological alterations, which can limit the potential benefits of new market opportunities.

Phenological disturbances and fruit set problems are also occurring in established apple-growing regions, likely linked to the impact of global warming on the reproductive biology of temperate fruit trees [2,13]. In apples, inadequate chilling and elevated spring temperatures have been associated with asynchronous flowering, reduced pollination success, and lower yields [1,6,15]. As with other pome fruit, apple trees require a sufficient accumulation of winter chilling hours to ensure proper floral initiation and uniform budbreak [3,21]. Climate change has led to a decline in winter chill accumulation, which can disrupt flower development, cause delayed or uneven blooming, and reduce fruit set [14]. Moreover, warm conditions during late floral development may impair the synchrony of anther dehiscence and stigma receptivity, further shortening the effective pollination period [11].

This evolving climatic scenario has renewed the interest in detailed phenological characterization and cultivar adaptability studies in apple. However, the lack of a cultivar-specific, consensus-based phenological scale for Kanzi apple hampers consistent comparisons across studies. The BBCH scale (Biologische Bundesanstalt, Bundessortenamt und Chemische Industrie) provides a unified decimal coding system for the developmental stages of both herbaceous and woody crops [17], and has been successfully adapted for several fruit species including peach [19], apricot [20], and mango [9].

While the BBCH scale standardises observations across species and covers the entire plant cycle, it does not fully address detailed flower development stages, which are particularly sensitive to climate variability.

The BBCH scale is a species-specific adaptation of the BBCH system that subdivides the standard codes into more precise developmental sub-stages, often adding floral organ development or fruit maturity gradations that are not visible externally in the regular scale [10]. This level of detail is particularly valuable for research into flower biology, pollination ecology, and climate-change sensitivity.

Therefore, the main aim of this study was to presents a detailed phenological characterization of the 'Kanzi' apple cultivar (*Malus domestica* Borkh.), using the BBCH scale integrating the reproductive growth and detailed floral development stages into the coding system to improve the accuracy of climate impact assessments and cultivar adaptation studies.

Material and Method

1. Experimental site

The current research has been carried out in a private high-density apple orchard located in Iaz (47°06′48″N; 22°38′33″E), Sălaj County at an average elevation of 365 m. This area has a temperate continental climate and is characterized by warm to hot summers and cold winters, with a significant amount of rainfall year-round, especially in the warmer months**.** Climate data from the last 30 years for this region [18,25] show an average annual temperature of 10.46 °C, an average maximum temperature of 30.46 °C in July and an average minimum temperature of -9.18 °C in January, with an annual average rainfall of 510.87 mm.

2. Plant material and phenological evaluation

The trees were grafted on M9 rootstock and planted in 2011 at a distance of 3.5 m between the rows and 1 m between the trees and their canopies were trained as spindle. Ten, trees were randomly selected from the orchard and subjected to phenological observations. For each tree, four branches from each side of the crown were selected and monitored during two annual growing seasons (2022-2023). Phenological observations and data gathering for reproductive stages were carried out from bud dormancy after fruit harvest to the beginning of the next dormancy once or twice a week, depending on the developmental stage.

3. The BBCH scale

The BBCH scale described in this study for *Malus x domestica* ‘Kanzi’ includes five out of the ten principal stages, starting with bud development (stage 0) and ending with the maturity of fruit and seed (stage 8) focusing more on reproductive phenology. Secondary stages were also numbered from 0 to 9 which represent a percentage of a growth value or different qualitative stages within the main stage. Therefore, in this study, 35 secondary stages were defined.

Results and Discussion

The phenological growth stages of ‘Kanzi’ apple trees were described according to the growth stages indicated for mono and dycotyledonous plants as suggested by [8]. The BBCH scale is critical for high-resolution phenological research, particularly in the context of global warming, where minor shifts in flowering timing or floral organ development can significantly affect pollination success, fruit set, and final yield.

According to the BBCH scale, the phenological growth stages of *Malus x domestica* 'Kanzi' are divided in vegetative and reproductive stages (Figure 1). For vegetative growth, out of the four principal growth stages (bud development-stage 0, leaf elongation and development-stage 1, shoot growth-stage 3 and senescence and beginning of dormancy-stage 9) only bud development (stage 0) was evaluated in this study. The other four growth stages were related to reproductive phenology which included inflorescence emergence (stage 5), flowering (stage 6), fruit growth (stage 7), and fruit maturity (stage 8). Stage 4 was excluded because it is not applicable to woody plants.

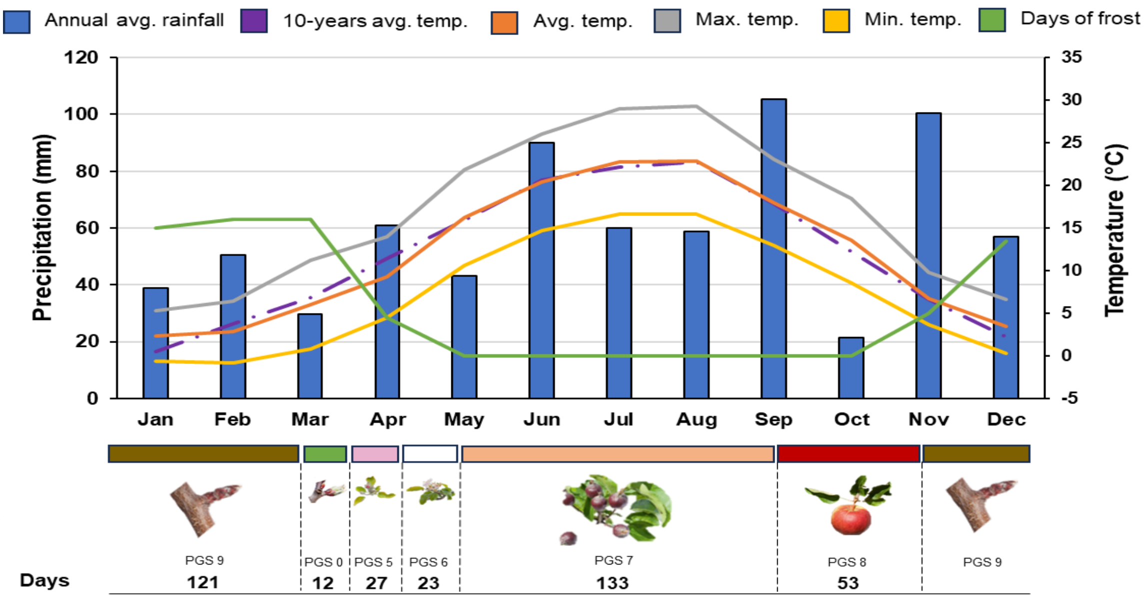

Figure 1. Principal growth stages (PGS) of *M. domestica* 'Kanzi' according to the BBCH scale.
Horizontal bars indicate the time elapsed in each stage.

Principal growth stage 0: Bud development

The observations revealed that the time taken for bud development was approximately 12 days. The buds remained dormant until 18th of March and then sprouted quickly at the end of the month (27th March). Floral differentiation was also induced during this period.

00. The buds were still in dormant. Both leaf and inflorescence buds were closed and covered by brown scales (Figure 2).

00 Dormancy **01** Leaf bud swelling **07** Beginning of bud break **09** Green leaf tips

Figure 2. Stages of bud development of 'Kanzi' apple according to the BBCH scale

01. Buds began to swell and elongate in mid- to late- March. The scales that covered the buds were still brown.

03. End of leaf bud swelling. Bud scales started to separate slightly.

07. Beginning of bud break. Buds continued to elongate and the first green leaf tips became visible

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(Figure 2).

09. The buds reached their maximum length, stopped elongating and the 5-mm green leaf tips were folded out above bud scales (Figure 2).

Principal growth stage 5: Inflorescence emergence

Inflorescence emergence took 27 days, from the end of March to late April.

50. The reproductive buds began to swell (both terminal and lateral buds swelled).

51. The inflorescence buds swelled with elongated bud scales and light-colored patches (Figure 3).

52. The end of bud swelling. Bud axes reached their final length and bud scales became visible and densely covered by hairs (Figure 3).

53. Bud burst. The green leaf tips became visible enclosing the flowers (Figure 3).

54. Mouse-ear stage. The first tiny green leaf tips separated from the bud and grew about 10 mm above the bud scales (Figure 3).

55. The first flower buds became visible but closed tightly (Figure 3).

56. Green bud stage. Single flowers started to separate but still closed with pink tips of the sepals.

57. Pink bud stage. The individual flower buds within the cluster became clearly visible and slightly open uncovering the petals (Figure 3).

59. Most flowers with petals forming a hollow ball. The petals of the individual flower buds have been fully expanded but still closed forming a round, 'balloon-like' shape (Figure 3).

51 Bud swelling | **52** End of bud swell | **53** Bud burst | **54** Mouse-ear stage

55 Flower buds visible | **56** Green bud stage | **57** Pink bud stage | **59** Hollow ball

Figure 3. Stages of inflorescence emergence of 'Kanzi' apple according to the BBCH scale

Principal growth stage 6: Flowering

The flowering stage started from mid-April to the beginning of May, lasting for approx. 3 weeks.

60. The first flowers opened (Figure 4).

61. Beginning of flowering: about 10% of flowers were open. Flowers from the middle of the clusters opened first.

62. About 20% of flowers opened.

63. About 30% of flowers opened.

64. About 40% of flowers opened (Figure 4).

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65. Full flowering. 50% of flowers were opened and the first petals started to fall (Figure 4).
67. Flowers started to fade; the majority of petals has been fallen.
69. Flowering ended with all petals fallen. Fruits started to be visible (Figure 4).

60 First flowers open | **64** Abt. 40% of flowers open | **65** Flowers fading | **69** End of flowering

Figure 4. Stages of flowering of ‘Kanzi’ apple according to the BBCH scale

Principal growth stage 7: Development of fruit

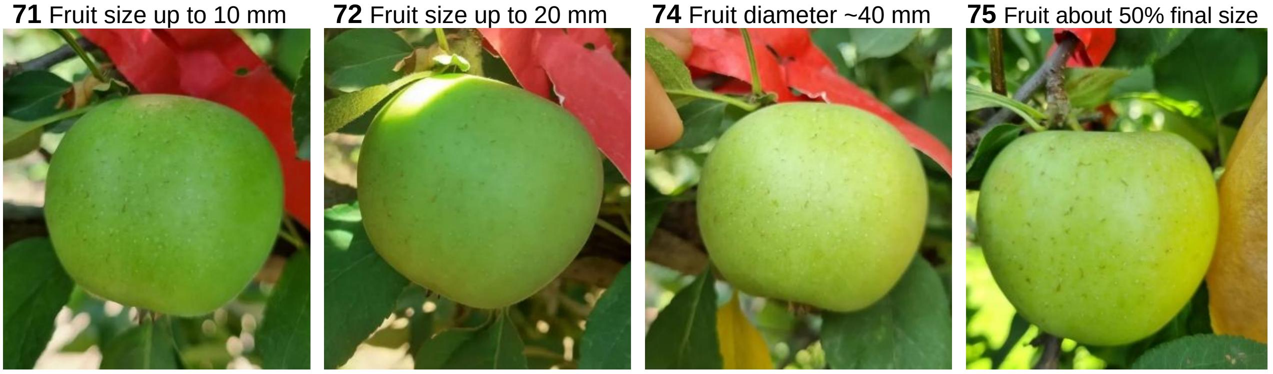
Fruit development extended from early May to mid-September lasting for 133 days.

70. Fruit set but no ovary growth was visible.

71. Fruit size reached up to 10 mm and were covered by hair. Fruits with diameter less than 10 mm fell or stopped growing (Figure 5).

72. Fruit size up to 20 mm (Figure 5).

71 Fruit size up to 10 mm | **72** Fruit size up to 20 mm | **74** Fruit diameter ~40 mm | **75** Fruit about 50% final size



76 Fruit about 60% final size | **77** Fruit about 70% final size | **78** Fruit about 80% final size | **79** Fruit about 90% final size

Figure 5. Development of fruit of ‘Kanzi’ apple according to the BBCH scale

74. Fruit diameter up to 40 mm (figure 5). Fruits were still hairy and the lenticels on the fruit skin started to become visible.

75. Fruit reached about 50% of the final size and lost the hair from its skin (Figure 5).

76. Fruit size reached about 60% of the final size (Figure 5).

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77. Fruits were about 70% of their final size. The fruits continued to develop. The skin was smooth and bright green.

78. Fruits were about 80% of their final size and turned to bright yellow. The lenticels became more visible.

79. Fruits reached about 90% of their final size and the skin was smooth and turned to bright yellow.

Principal growth stage 8: Maturity of fruit and seed

The maturation of fruits and seeds extended from mid-September to mid-November.

81. The fruits began to ripen and the first appearance of the cultivar-specific red color was observed in patches on the fruit skin (Figure 6).

85. Advanced ripening of fruits: the intensity of cultivar-specific color increased (Figure 6).

87. The fruit maturation continued and the fruits became ripe for picking (Figure 6).

89. Fruits were fully developed and ripe for consumption. The skin colored turned red and the pulp had typical taste and firmness (Figure 6).

81 Beginning of ripening: first appearance of cultivar-specific colour

85 Advanced ripening: increase in intensity of cultivar-specific colour

87 Fruit ripe for picking

89 Fruit ripe for consumption: fruit have typical taste and firmness

Figure 6. Maturity of fruit and seed of 'Kanzi' apple according to the BBCH scale

In the present research, five principal growth stages of *M. domestica* 'Kanzi' were codified and described across two growing seasons (2022-2023) in a commercial high-density orchard, providing a clear chronological reference including bud development (approx. 12 days; dormancy to green tip from 18-27 March), inflorescence emergence (approx. 27 days; late March-late April), flowering (3 weeks; mid-April-early May), fruit development (133 days; early May-mid-September) and fruit maturity (mid-September-mid-November. In addition, 35 secondary stages were codified and described. The BBCH scale provides a precise description of this important apple cultivar regarding its adaptability to certain environmental conditions and reproductive stages which could help to establish a correct agricultural practice schedule.

The proposed 'Kanzi' BBCH scale might enable synchronized timing of crop protection, nutrient applications, and growth regulators together with a better planning for pollination and frost/heat risk management by narrowing the effective pollination period and vulnerable periods. However, to elaborate a more precise fruit-thinning, irrigation, and harvest schedule cross-region comparisons are still needed for modeling its performance. Since 'Kanzi' targets premium markets, this phenological calendar might serve as a practical guidance for maintaining firmness, color development, and size while mitigating year-to-year climatic challenges [4].

The work also highlights the climate sensitivity of 'Kanzi': small advances or delays in the reproductive sequence can cascade into pollination efficiency, fruit set, and yield outcomes. As production expands into non-traditional areas, the cultivar-specific coding presented here offers a common language to quantify such shifts and to assess adaptation strategies.

The results of this research are in accordance with those obtained by [16] who evaluated the phenological stages of Pero de Cehegín" (*Malus domestica* Borkh.) cultivated in Murcia, Spain using the same two-digit code observation. Slight differences were observed between the duration of the principal growth stages which were influenced first by different climate conditions and cultivar. Similar phenological studies have been carried out on other species as well, such as *Prunus avium* L. [5], *Juglans regia* L. [23], *Corylus avelana* L. [24], *Diospyros kaki* Thunb. [7] aiming to characterize correctly and improve orchard management practices. All these scales described by the forementioned authors will serve as a good reference for growers and scientists to provide important data on flower biology, facilitate data on the influence of climate change in order to improve growing techniques. Both phenological and climatic characterizations are the two main tools which provide growers valuable information and help them select the most suitable varieties to be grown and cultivation practices to be applied in a certain area [22]. However, a plant's inherent capacity to adapt to the climate is the ultimate factor controlling its potential for production and maintaining ecological balance [28].

Conclusions

In this study, the first phenological characterization of 'Kanzi' apple was conducted according to BBCH scale which revealed that *M. domestica* 'Kanzi' was able to go through a full developmental cycle. According to the BBCH scale, this apple cultivar clearly distinguished all the five main reproductive stages. Understanding the phenology of this valuable apple cultivar is important for future breeding programs to improve fruit quality and their commercial value. To overcome the limitations of this study, future research should be carried out to evaluate phenological stages on different rootstocks, site setting and training system focusing also on vegetative stages as well beyond bud development. Overall, the BBCH scale of 'Kanzi' presented here provides a robust reference for researchers and growers, improving the precision of orchard operations and strengthening climate-readiness for this high-value cultivar.

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