ISSN 2808-3229
Journal of Biodiversity and Biotechnology. 5(2), 46–50,
2025 URL: https://jurnal.uns.ac.id/jbb/article/view/109980
doi: http://dx.doi.org/10.20961/jbb.v5i2.109980

Phenology Dynamics: Flowering and Fruit Development of Prabu Bestari Grape Variety in Denpasar

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Abstract
This research aimed to identify the critical phenological stages and establish harvest quality standards for the local superior grape variety, 'Prabu Bestari', given the limited scientific data available for optimizing lowland cultivation. The study was conducted at the Faculty of Agriculture's Experimental Garden, Udayana University, at an elevation of (0–9) meters above sea level (masl) from June to October 2024. Floral induction was achieved through environmental and nutritional manipulation, commencing with total water stress for 30 days before pruning, followed by the application of 50g NPK fertilizer (with a high P and K ratio) and a subsequent water shock. Production pruning (cane pruning) was performed by retaining 3-5 buds per spur. This research aimed to identify the critical phenological stages and establish harvest quality standards for the local superior grape variety, 'Prabu Bestari', given the limited scientific data available for optimizing lowland cultivation. The study was conducted at the Faculty of Agriculture's Experimental Garden, Udayana University, at an elevation of 0–9 meters above sea level (masl) from June to October 2024. Floral induction was achieved through environmental and nutritional manipulation, commencing with total water stress for 30 days before pruning, followed by the application of 50 g NPK fertilizer (with a high P and K ratio) and a subsequent water shock. Production pruning (cane pruning) was performed by retaining 3 to 5 buds per spur.

Keywords: Floral Induction; Lowlands; Phenology; Prabu Bestari Grape; Vitis vinifera

Cite this as: Sari, N.K.K., Febriayanti, D.A.A., Murtiyah, N.N.A.P., Marsadi, D. (2025). Phenology Dynamics: Flowering and Fruit Development of Prabu Bestari Grape Variety in Denpasar. 5(2), 45–50. doi: http://dx.doi.org/10.20961/jbb.v5i2.109980

Introduction

Phenology is a branch of biology that studies the natural growth, changes, and development of an organism, as well as its relationship with seasons and climate. In the context of plants, phenology plays a crucial role in understanding the dynamics of growth phases that recur annually. Phenological stages in grapes, such as bud burst, bloom (flowering), fruit set (fruit formation), veraison (onset of ripening), and harvest (picking), serve as essential benchmarks in vineyard management practices. Applying phenological concepts can support various aspects of vineyard management, such as canopy regulation, nutrient monitoring, and efforts to prevent pests and diseases more effectively and efficiently. The application of phenological concepts is crucial for optimizing various aspects of vineyard management, such as irrigation scheduling, nutritional application, and the timing of phytosanitary interventions (pest/disease control) to ensure effectiveness and efficiency (1,2). This aligns with the view that the progression of phenological phases is significantly influenced by environmental factors, especially air temperature, duration of solar radiation, and water availability (which

correlates with humidity) (1,3). Furthermore, the accuracy of phenological timing is closely linked to reproductive success, including the processes of pollination and sugar accumulation, which are highly dependent on optimal climatic conditions (4).

Recording phenological data has strategic significance for the sustainability of grape cultivation. First, phenological data enables the application of cultivation practices that are aligned with the plant's growth phase, thereby increasing the efficiency of labor use, reducing production costs, and maintaining plant health. Second, historical records provide an opportunity for more accurate prediction of future growth stages. Thus, time management can be optimized, ensuring that crucial activities such as pruning, fertilization, and harvesting can be performed precisely on time.

One of the superior grape varieties that requires attention in phenological studies is Prabu Bestari. This variety is an introduction derived from the Red Prince variety from Australia in 1986, and began to be cultivated in Banjarsari, Probolinggo, in 1991. Its superiority was officially recognized through a variety of releases by the Minister of Agriculture of the Republic of Indonesia on November 7, 2007, via Ministerial Decree (5). Prabu Bestari grapes have a number of prominent agronomic characteristics, such as large fruit size, thick flesh, sweet taste, and adaptability to lowlands up to an altitude of 300 masl. Morphologically, the fruit is dark red, round to slightly oblong, and seeded, with a harvest age of approximately 120 days after pruning (5).

In addition to possessing superior agronomic characteristics, Prabu Bestari is also rich in bioactive compounds beneficial to human health, such as resveratrol, proanthocyanidins, and procyanidins (6). Resveratrol contained in the fruit skin is known to have antioxidant and anti-inflammatory activity, as well as anti-aging effects (7). This makes Prabu Bestari valuable not only as an agricultural commodity but also possess a functional value as a health fruit. Economically, this fruit can be consumed fresh as a table grape or processed into various value-added products such as vinegrape, raisins, juice, and other derived products.

The limited information regarding the phenological aspects, particularly the generative phases (flowering and fruit set), of the local superior grape variety 'Prabu Bestari' constitutes a significant constraint in formulating optimal cultivation strategies and enhancing its competitiveness. Therefore, this research aims to provide a comprehensive scientific basis by identifying and describing the critical phenological stages of this variety, spanning from floral induction to fruit maturation. Specifically, the study focuses on analyzing the time duration required to complete each post-pruning phase, as well as establishing the physical and chemical quality parameters of the fruit at harvest to serve as a reference standard for table grape cultivation in lowland areas.

Material and Methods

Observations of the phenology of Vitis vinifera var. Prabu Bestari was carried out on 5 spurs/shoots, which had been previously pruned and already contained bud breaks. The observation started from the emergence of shoots (bud burst) until harvest. The research was conducted at the Faculty of Agriculture's Experimental Garden, Udayana University, at an altitude of 0 – 9 masl. This study took place from June to October 2024. The observation methods for phenological activity included bud burst, shoot length, leaf opening, flowering (bloom), fruit set (fruit formation), ripening and coloring (veraison), and fruit maturation (harvest).

Floral induction was achieved through environmental and nutritional manipulation, commencing with total water stress applied for 30 days before pruning to induce artificial dormancy. In the third week of this stress period, an application of 50 g NPK fertilizer (with a high P and K ratio) was administered for reproductive stimulation, followed by a water shock one day before physical pruning. Production pruning (cane pruning) was then performed, retaining 3 to 5 buds per spur to remove apical dominance and maximize the flowering potential.

Phenological observations were systematically recorded (daily to weekly, based on phase velocity), encompassing bud burst, anthesis, fruit set, veraison, and harvest maturity. Quantitative fruit quality was periodically assessed using a caliper (for berry diameter) and a digital balance (for cluster weight). The final harvest maturity was determined based on physical and chemical criteria, with the sweetness level (Total Soluble Solids/TSS) measured using a refractometer and expressed in degrees Brix ($^{\circ}$Brix).

Furthermore, climatic data (temperature, rainfall, solar radiation) were logged using a data logger to analyze their correlation with the duration of each phenological phase.

Results and Discussion

The results of phenological observations on several individual grape clusters began with the phase from bud burst to the emergence of flowers (flowering), which lasted for 18–19 days. The complete bloom phase lasted for 1 day. The phase from flowering to fruit set lasted 1–3 days, while the period from fruit set to harvest was 48 days (120 days after pollination). The complete observations are presented in Table 1 and Figure 1.

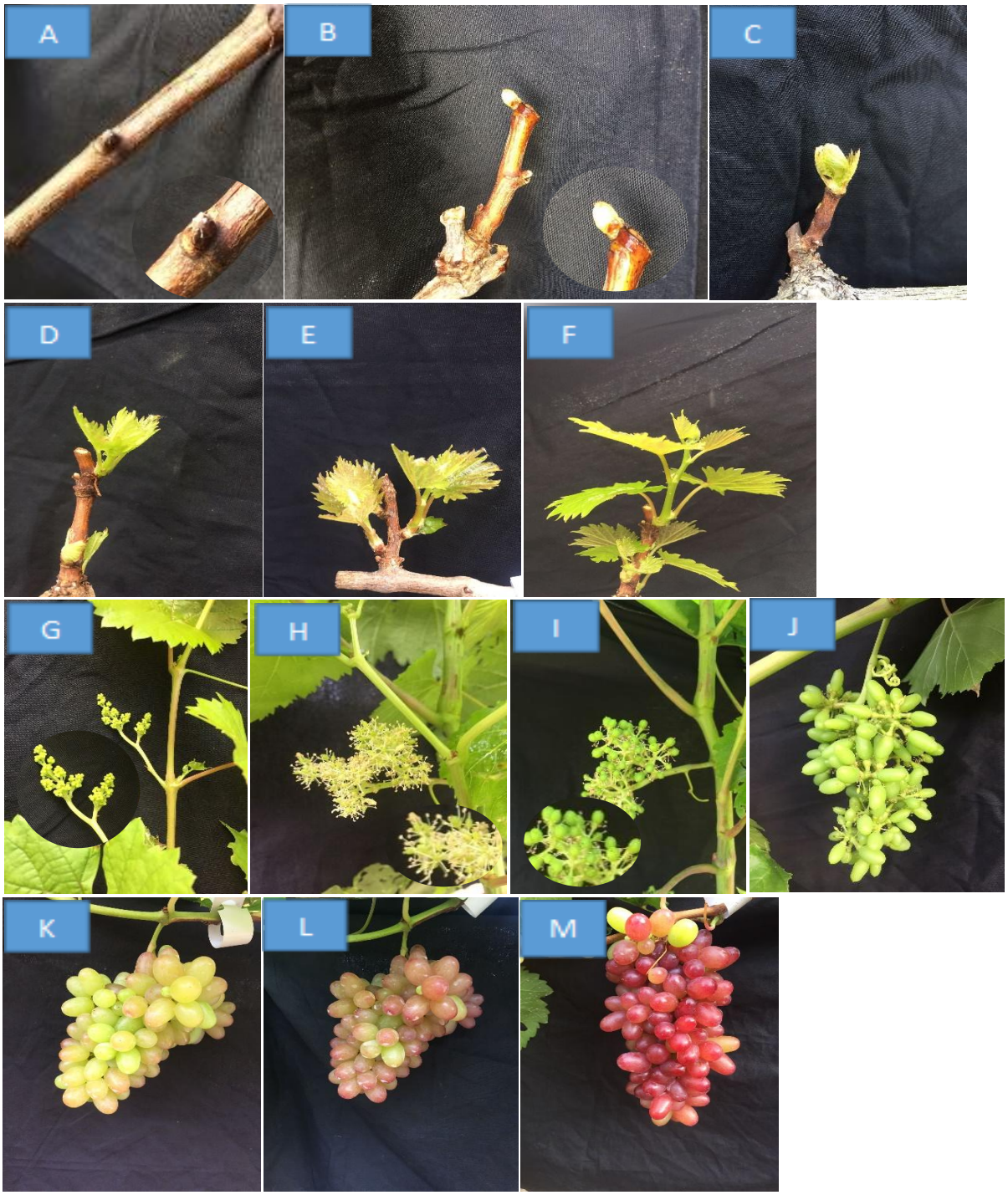

Figure 1. Stages of the Flowering and Fruiting Phases of Grape (Vitis vinifera L.) var. Prabu Bestari; (A) Winter Dormancy condition before pruning, (B) Wool (Doeskin stage) on Day 6, (C) Day 7-8, (D) Day 9, (E) Day 13 – 14, (F) Day 15 – 17, (G) Flowering on Day 18, (H) Anthesis (Full Bloom) on Day 38, (I) Fruit Set on Day 39, (J) Day 51, (K) Veraison (Ripening) on Day 73, (L) Day 98, (M) Maturity on Day 120.

Table 1. Tabulation of Phenological Observations of Flowering and Fruiting of Grape (Vitis vinifera L.) Var. Prabu Bestari

Time (DAP)	Phase / Organ / Part	Size (cm)	Notes
0	Snow Bud (Dormant Bud)	-	Located on the nodes of the grape vine branch, with fine, shiny white threads resembling snow/silk threads.
6	Bud Burst (Shoot Emergence)	0,2	Round to slightly oblong shape, light green, with fine white threads visible
7-8	Bud Burst is starting to open	1	Leaves are almost open (not yet fully expanded).
9	Bud burst	1,8	Leaves are starting to open.
	Leaf	0,9	Still light green in color.
13-14	Bud burst	4	-
	Leaf	1	Starting to widen and showing a reddish-green color.
15-17	Bud burst	7	
	Leaf	2,5	The first leaves are starting to become dark green.
18-37	Inflorescence growth (Flower cluster)		-
	Inflorescence	2-4,5	Serrated shape, resembling a snail's egg.
38	Full Bloom (ANTHESIS)	6	Full bloom occurs only within a period of 1 x 24 hours.
39	Fruit Initials beginning, Fruit Set phase	7,7-8	Fruit enlargement begins.
40-72	Fruit Set phase	8-17,9	
73	Maturity phase (Ripening)	18	Color change of the grape skin to reddish begins.
74-119	Maturity phase	18	
120	Harvest (Picking)	18	Fully ripe with a sweetness level of 18° – 20° Brix.

Phenological observations were preceded by production pruning, which aimed to induce the shoots bearing fruit buds to grow well and profusely (8). According to (9), pruning is an activity carried out by removing negative shoots, diseased branches, and canopy arrangement, and stimulating flowering. Production pruning was carried out at the end of June to avoid harvesting during the rainy season.

Following pruning, the grapevines enter the vegetative phase, which includes bud burst (as seen in Figure 1). This phase occurs very rapidly because the newly emerging shoots contain abundant meristematic tissue, particularly at the shoot tips. Meristematic tissue is actively dividing tissue (10). The grape bud burst gradually develops, with leaves unfolding one by one until fully open, typically taking a period of 2 to 3 weeks post-pruning. The appearance of the inflorescence (flower cluster) usually occurs after 8 to 9 leaves have developed. During the inflorescence phase, the flowers grow; they are green and remain closed, with the flower cluster measuring 2 to 3 cm in length and accompanied by 14 leaves.

The anthesis phase is very rapid, lasting only 24 hours after the first flower cap opens, which typically occurs when approximately 10% of the flowers in the cluster have bloomed (38 DAP - days after pruning). Following the anthesis phase, the fruit set occurs, known as berry set. The resulting berries are initially tiny (around 2 mm). Cell elongation and enlargement continue, along with seed development within the berries. At 51 DAP, the fruits are very firm (turgid), and the clusters begin to compact and remain green.

Entering the Berry Ripening phase at 79 DAP (Days After Pruning), a faint red color becomes visible on some berries. During the process of maturation (berry ripening), weather plays a significant role, as the color development in the fruit requires sufficient light and heat. The veraison (ripening) phase continues until the berries within the cluster achieve uniform coloring and their skins become slightly translucent. Specifically for the

'Prabu Bestari' grape variety, the fruit can be harvested after 120 days, characterized by: uniform berry color, translucent berry skin, a slightly soft texture, and a sweetness level reaching ±17°Brix, which meets the required standards for fresh table grapes. Timely harvesting is crucial for grapes, as they are a non-climacteric fruit. Non-climacteric fruits do not undergo a surge in respiration and an increase in glucose levels after being harvested (11).

Conclusion

Phenology Control and Production Cycle Timing: The phenological cycle of the 'Prabu Bestari' grape variety exhibits a rapid duration, completing in 120 Days After Pruning (DAP), which underscores the necessity of precise timing management in cultivation. The swift transition from bud burst to floral initiation (18–19 days) constitutes a critical phase requiring the timely application of nutritional and specific treatments to optimize production potential. Post-Pruning Quality Optimization via Climatic Factors: The timing of production pruning must be aligned with the dry season to ensure the fruit maturation phase (veraison) is exposed to high solar radiation intensity and temperature. This exposure is essential for the induction and accumulation of pigments (color) and for achieving an optimal Total Soluble Solids (TSS) level of ±17°Brix consistent with non-climacteric table grape standards.

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