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Brief Research Report

Phenological stages of *Macadamia integrifolia* x *tetraphylla* cv Beaumont according to the BBCH scale in a Mediterranean climate

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Abstract: The macadamia nut (*Macadamia integrifolia* Maiden and Betche, *Macadamia tetraphylla* L. and their hybrids) are increasingly cultivated outside its native range in subtropical eastern Australia, where it thrives in specific climatic conditions. Given its expansion into diverse climates, particularly Mediterranean regions, understanding macadamia's phenological response to non-native conditions has become essential. This study examines the adaptability of *M. integrifolia* x *tetraphylla* cv. 'Beaumont' within the Mediterranean environment of northwest Sicily, Italy. Focusing on phenological phases, we applied the BBCH scale to categorize growth stages from vegetative bud initiation to fruit ripening. Field observations and measurements over 16 months revealed that macadamia phenology in Sicily exhibits distinct responses to Mediterranean temperature and precipitation patterns, affecting growth stages such as leaf development, flowering, and fruit maturation. The phenological data, standardized via the BBCH scale, provide valuable insights for agronomic management, aiming to optimizing yields and adapting cultivation practices. These findings offer essential guidance for macadamia cultivation in similar environments and underscore the importance of phenological monitoring in managing climate-related risks to productivity and yield stability.

Keywords: BBCH scale; phenology; growth development; Macadamia; nut tree species; climate change.

1. Introduction

Macadamia nut, also known as *Macadamia integrifolia* Maiden and Betche, is an evergreen fruit tree of the Proteaceae family (Munck et al., 2020). The genus Macadamia includes four tree species endemic to the rainforests and rainforest fringes of subtropical eastern Australia (Mast et al. 2008; Neal et al., 2010; Shapcott e Powell 2011). Commercially grown species include *M. integrifolia* Maiden and Betche and *Macadamia tetraphylla* L.A.S. Johnson and their hybrids, since they contain low levels of cyanogenic glycosides in their mature kernels as compared to the other two species, *Macadamia jarsenii* and *Macadamia ternifolia. M. integrifolia* is the principal species under cultivation in the tropical areas whereas *M. integrifolia* appears better adapted to areas with lower temperature during the winter (Nagao et al., 1992). Macadamia nuts are labeled as one of the most expensive nuts in the global market and are valued for their oil content, fiber, and nutrients by individual consumers and industries. In the last decade, the global demand for macadamia nuts increased by 59% (Admin 2022). The top two exporters were South Africa and Australia, which accounts for 31%, and 23% of the global market, respectively. The main destination for South African overseas shipments are the USA (34%), the European Union and the UK (33%), and Asia, primarily Vietnam (11%) and China (7%) (*Statistical*

Yearbook 2022/2023). In its areas of spread, it is grown extensively in commercial plantations. Orchards typically include two or more cultivars, often with a principal cultivar and the other cultivars planted in 'pollinator' rows. However, macadamia is sometimes planted in partial or complete blocks of a single cultivar (Ito e Hamilton 1980; Trueman et al., 2002). *M. integrifolia* can reach considerable size, up to 18 m in height and 15 m in crown diameter. The species is monoecious, forming axillary racemes that exhibit protandry and occurrences of self-incompatibility. For this reason, in macadamia orchards, pollen transfer occurs predominantly with insects. The fruit is a follicle, a round nut with a smooth shell, consisting of a dehiscent pericarp (the husk) which encloses the lignified testa (the shell) and the embryo (the kernel) (Hartung, 1939; Strohschen, 1986).

Regarding the ecological requirements, optimum diurnal and seasonal temperatures for macadamia are within the range of 14 °C by night and 30 °C by day, with prolonged periods outside this range having adverse effects on growth, yield, and quality (Nagao, 2011; Stephenson and Gallagher, 1986; Trochoulias and Lahav, 1983). For this reason, *M. integrifolia* x *tetraphylla* hybrids are generally grown in cooler and more temperate environments such as Mediterranean areas (Nagao et al., 1992). Regarding precipitation, macadamia grows healthy and is productive in areas with well-distributed rainfall, totaling an average of 1500 mm per year (Britz, 2015). Water stress during nut maturity has negative impacts on the yield and quality of macadamia (Stephenson et al., 2003). To stimulate flowering and nut set, macadamias require strong temperature contrasts and mild water stress for up to four months (Stephenson et al., 2003; Stephenson and Gallagher, 1986b). Conversely, geographical parameters such as altitude, aspect, and slope are only considered important in terms of affecting temperature and water requirements (Powell, 2009).

Being native to the subtropical areas of eastern Australia, the species is vulnerable to sudden changes in temperature and precipitation patterns compared to the current and historical growth conditions found in its natural habitat. Additionally, in the context of ongoing climate change, during which significant alterations in the planet's climate patterns are occurring, entire bioclimatic zones may shift, or within the same bioclimatic zone, there may be a temporal shift in the vegetative and reproductive physiological processes of plants. Many tropical fruit crops spread out from the origin countries to mediterranean areas (Farina 2018; Tinebra et al., 2022). Therefore, understanding plant responses to such climatic variations in different regions of the world becomes essential for comprehending the response mechanisms and implementing effective strategies for crop adaptation.

Phenology is an important aspect of plant growth and has been studied in many horticultural crops. Knowledge of the plant phenology, intended as the recurring sequence of plant developmental stages, is a fundamental tool for its agronomical management (Scuderi et al., 2024). In horticultural crops, phenology is used to organise crop management, predict harvests, prevent the risk of frost damage, and predict pest populations according to the plant stage (Bregaglio et al. 2016; Ascari et al. 2020; Bregaglio et al., 2021). In ecology, it is used to assess the impact of extreme events (e.g., meteorological), species interactions and population migration (Koch et al., 2007). Thus, it is of fundamental importance to understand the timing of phenological events, which has considerable consequences on the plants productivity and ecosystem relations, in the different cultivation areas and environmental conditions (Rajan et al., 2011; Piao et al., 2019; Scuderi et al., 2023). For this reason, the BBCH scale has been used for categorising the growth stages of a variety of annual, biennial and perennial plants, both tropical fruit plants and dried fruit species, including pecan (*Carya illinoensis*) (Han et al. 2018), hazelnut (*Corylus avellana* L.) (Paradinas et al., 2022), longan (*Dimocarpus longan*) (Pham et al., 2015), mango (*Mangifera indica*) (Hernández Delgado et al., 2011) and avocado (*Persea americana*) (Alcaraz et al., 2013). The use of a BBCH scale allows standardization of phenological monitoring and communication in plant industry (Meier et al., 2009), through observation and recording periodically recurring growth phases and the study of the regularity and dependence of annual cycles development on environmental conditions (Koch et al., 2007). Thus, phenological events are ideal indicators of the impact of local and global changes in weather and climate on crops (Meier et al., 2009).

The BBCH scale is divided into 10 principal growth stages, identified using two- to three-digit codes. The first digit indicates the main growth stage, starting from 0, for bud development, to 9 for leaf senescence. The second digit corresponds to a short development phase within the main stage.

Thus, the aim of this study is to explore the adaptation of *Macadamia integrifolia* x *tetraphylla* cv. 'Beaumont' in the southern Mediterranean environment through the observation and study of phenological phases. The objective is to analyse how Macadamia responds to specific climatic conditions and how these influence its phenological cycle through the development of a BBCH scale. This study will provide crucial information for the sustainable management of this species, considering the challenges and opportunities associated with the introduction of tropical species in growing areas different from their natural habitat. Moreover, to date, this is the first study that defines and presents the BBCH scale according to a temporal view, from the beginning of vegetative resumption to fruit ripening.

2. Materials and Methods

2.1. Study Area and Plant Material

The study was conducted in a collection orchard located at the Department of Agricultural, Food, and Forest Sciences (SAAF) of the University of Palermo, northwestern Sicily, Italy (20 m above sea level, 38°06'24"N 13°20'58"E). The climate of the area is defined as Mediterranean (Csa), characterized by temperate conditions with dry and hot summers, according to the Köppen classification, with an average annual precipitation of 885 mm and a mean annual temperature of 18.6 °C (Peel et al., 2007). According to the classification of Rivas-Martínez (1985) the temperatures average is comprised between 16-18 °C and the average rainfalls is in the range of 600-700 mm per year. Under the bioclimatic aspect, the area is referred to the upper thermos-Mediterranean lower subhumid bioclimatic belt (Rivas-Martínez, 1985).

The phenological stages were observed on three trees of *Macadamia integrifolia* x *tetraphylla* cv. 'Beaumont', approximately 10 years old. Trees were managed in an open field and under ordinary maintenance cares. These practices included proper pruning to maintain the natural tree structure, weed control to promote aeration and root development and pest and disease control. At the beginning of the study, vegetative buds were identified on each plant for monitoring. Buds were chosen in the directions of the main cardinal points (north, south, east and west), and the remaining in the directions of the secondary cardinal points (northwest, southwest, northeast, and southeast). Specifically, four vegetative buds were randomly chosen on each plant and each primary and secondary exposure, totalling 32 buds. The purpose was to increase the number of observable data to be statistically reliable. Each bud was marked with an identification tag (Fig. 1).

Figure 1. Methodology used to identify the shoots subject to the phenological study.

2.2. Monitoring Phenological Stages

Significant bud development stages were observed and recorded weekly from bud dormancy after fruit harvest until the beginning of the subsequent dormancy. These observations were conducted for 16 months (from January 2023 to February 2024). Climatic data were recorded by a weather station of the Sicilian Agrometeorological Information Service (SIAS) located in Palermo (long. 13.327593 lat. 38.129799).

Visual observations were conducted, and phenological surveys were carried out using a digital camera (Reflex – Nikon D40). The collected images were divided into groups corresponding to the main phenological stages. Subsequently, meteorological data were downloaded via the SIAS portal and processed using XLStat 2020.3.1 software for Excel (Addinsoft, New York, USA). Secondary phenological stages were described based on digital calliper measurements (Turoni TR53307, Forlì, Italy), a meter (Metrica, 22091, Milan, Italy) and photographic material observations.

2.3. BBCH scale characteristics

Obtaining recognizable and distinguishable phenological data is necessary to accurately define stages and compare observations of the same species in different growing environments and conditions. Using the Meier's (1997) extended BBCH reference scale, constructed from Zadoks (1974) grain code, the uniform coding system of similar phenological growth stages of all mono- and dicotyledonous plant species, the development of macadamia trees was described with the major stages numbered from 0 to 9. The numerical order is not mandated, but the scale follows chronologically. The BBCH scale is set with a two-digit numerical code: the first digit identifies the principal growth stage (0–9) while the second specifies the secondary growth stage (0–9). The principal growth stages correspond to the 10 main development stages of the plant—i.e., vegetative bud development (0), leaf development (1), formation of side shoots/tillering (2), shoot development (3), development of harvestable vegetative plant parts or vegetatively propagated organs/booting (4), inflorescence emergence (5), flowering (6), development of fruit (7), maturity of fruit (8), and beginning of dormancy (9). Depending on the type of plant species or period of observation, it may be the case, for example, that the flowering stage (6) may occur before leaf development (1) as in some fruit trees, or, because of the very different plant species, some stages may be omitted.

3. Results

3.1. Climatic conditions of the growing area

Table 1 shows the monthly average values of daily minimum, mean, and maximum temperatures and the monthly total precipitation recorded from January 2023 to February 2024 during the study of macadamia phenology.

The average temperature values ranged from 10 to 28 °C, with the highest temperatures recorded between June and August. The coldest minimum temperatures were recorded between January and February. During the entire observation period, the daily minimum temperature was ≤5 °C on only 11 days. A significant increase in thermal values was observed from mid-April, stabilizing around an average of 28 °C during the summer months, and then gradually decreasing until the end of December. Maximum temperatures above 30 °C were recorded from late May to mid-September, totalling 73 days during this period. The absolute maximum temperature of the year was recorded in mid-August, with a value of 42.9 °C.

Table 1. Climatic data at the study site measure by SIAS meteorological station, Palermo, Sicily, Italy. Data are expressed as a monthly average from daily measurements ± standard deviation.

Month	Tot. Precip. (mm)	Min Temp (°C)	Avg Temp (°C)	Max Temp (°C)	Min RH (%)	Max RH (%)
Jan	85.6±5.9	7.42±2.1	10.05±1.5	14.34±2.0	48.06±12.3	85.77±7.3
Feb	39.4±4.4	7.73±1.8	11.93±1.3	16.08±2.1	37.21±10.0	79.32±9.4
Mar	35.8±2.9	8.37±2.7	12.26±2.8	16.00±3.3	39.22±9.9	78.87±9.3
Apr	63.2±8.2	11.12±1.9	15.40±2.2	19.44±2.8	35.96±10.8	79.46±11.4
May	44.0±4.4	14.88±2.6	20.41±3.3	25.18±4.2	32.51±15.1	80.25±10.6
Jun	3.20±0.5	21.26±1.8	26.53±1.9	31.37±2.6	28.26±11.8	74.73±12.0
Jul	0.40±0.0	23.51±0.9	28.14±1.0	32.20±1.5	31.80±8.7	71.58±5.5
Aug	64.2±7.0	23.41±1.8	27.97±1.8	32.00±2.5	34.90±9.8	73.47±10.0
Sep	58.0±6.3	21.67±2.6	25.82±2.4	29.85±2.9	34.00±9.3	73.73±10.6
Oct	38.0±3.5	16.19±1.4	20.55±0.8	25.25±1.4	43.67±12.2	84.90±8.6
Nov	13.0±8.2	13.49±1.8	17.17±2.2	20.96±2.9	47.23±8.6	86.43±6.0
Dic	16.0±2.1	10.85±2.6	15.18±2.5	19.87±2.3	46.87±10.6	85.67±8.5
Jan	90.2±4.9	8.15±2.5	11.92±2.3	15.89±2.3	46.46±7.8	85.00±6.7
Feb	66.4±5.6	7.20±1.9	11.16±2.5	14.96±3.2	45.10±12.9	82.67±10.3

3.2. Phenological stages of Macadamia integrifolia

Through observations and recordings of the developmental stages, the timing and growth patterns of the vegetative-reproductive organs of *M. integrifolia* x *tetraphylla* cv. 'Beaumont' were determined at the specific site under study (Fig. 2). To delineate the phenology of *M. integrifolia* x *tetraphylla* cv. 'Beaumont', we identified and used seven main growth stages. In developing the BBCH scale, a vegetative flush and a reproductive flush were taken into account.

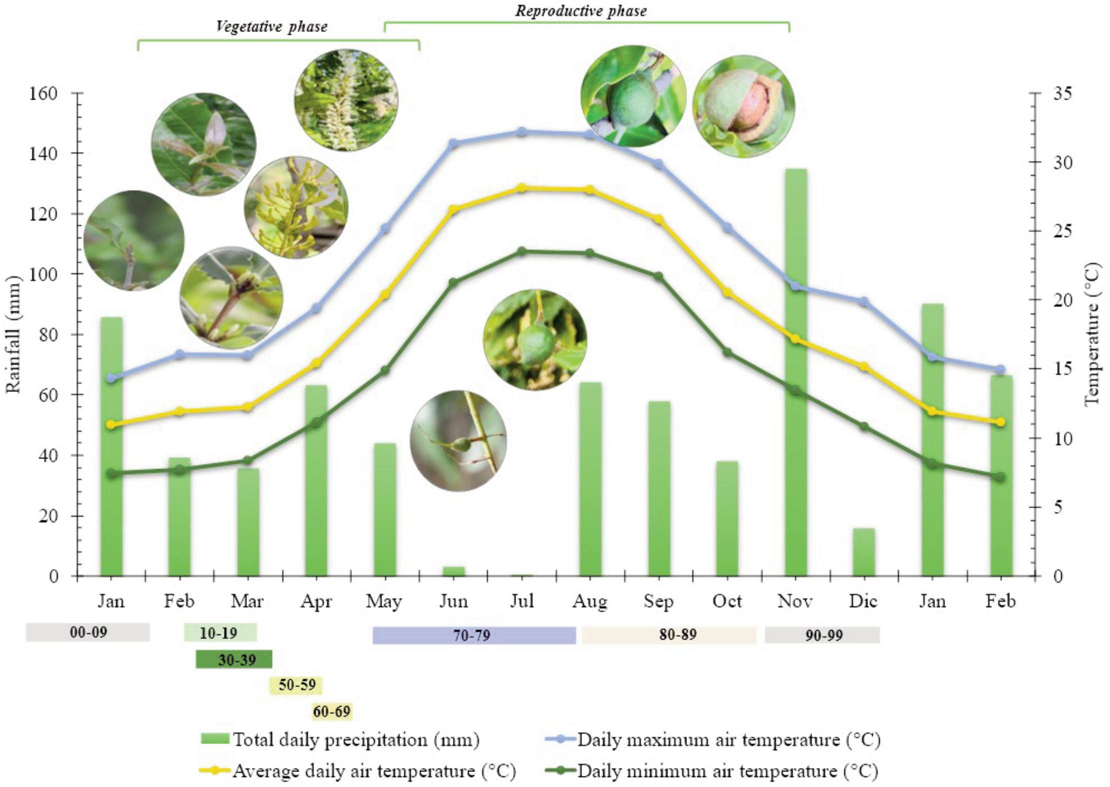

Figure 2. Main phenological stages of *Macadamia integrifolia* x *tetraphylla* cv. 'Beaumont' according to the BBCH scale. The horizontal bars represent the elapsed time at each stage. Monthly average data of precipitation and average, maximum and minimum temperatures.

3.3. BBCH Scale for Macadamia integrifolia x *tetraphylla* cv. 'Beaumont'

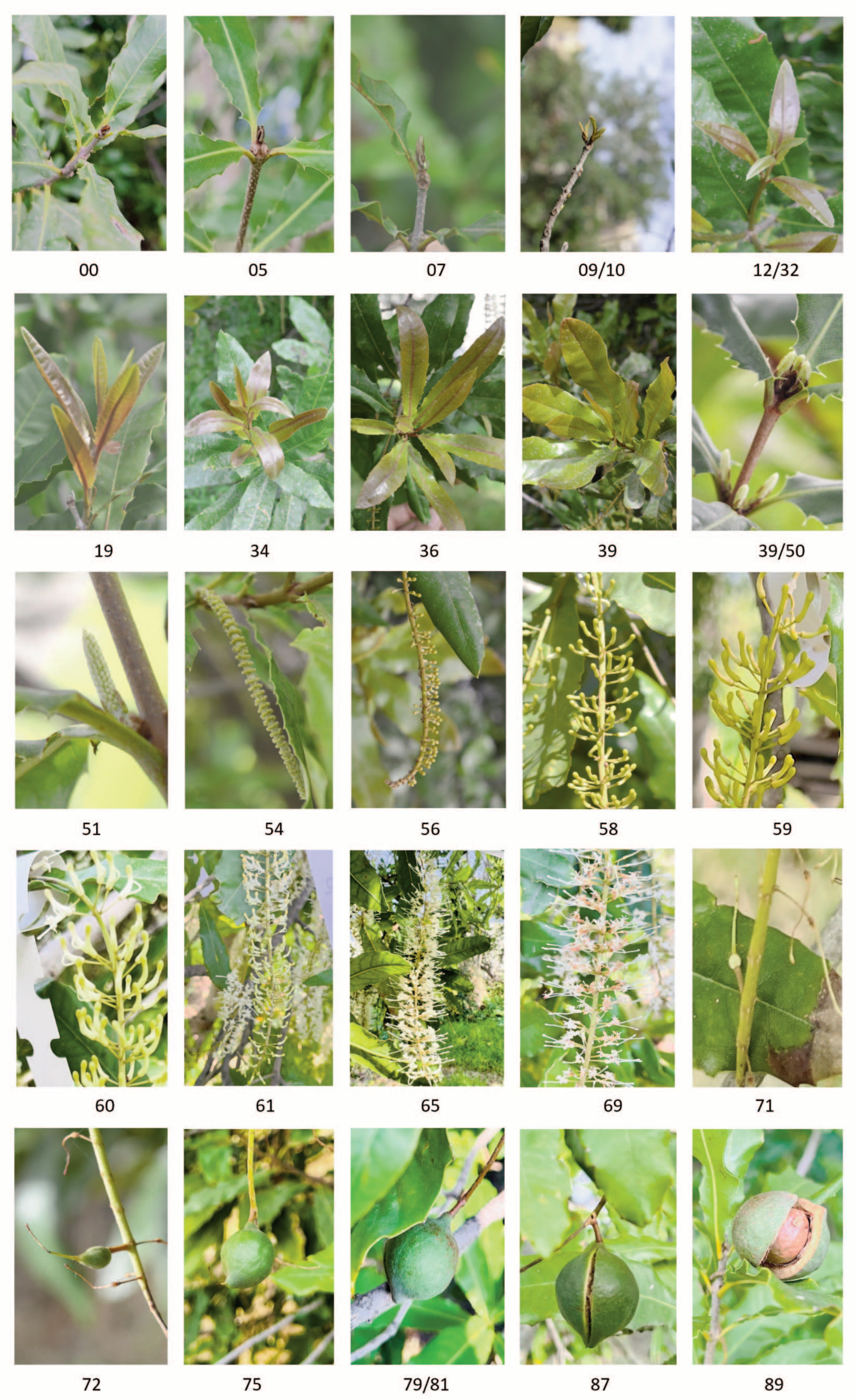

Figure 3. BBCH scale for *Macadamia integrifolia* x *tetraphylla* cv. 'Beaumont' trees.

Table 2. Description of the phenological stages of *Macadamia integrifolia* x *tetraphylla* cv. 'Beaumont' and the corresponding stages of the BBCH scale. The first number represents the main growth stage while the second number indicates the specific development stage within the main one.

BBCH code	Description	Date for *M. integrifolia* in Sicily, Italy
Principal Growth Stage 0: Bud Development		
0	Dormant buds: Apical buds are flat, closed, and covered by scales above the surface.	From mid-December to the beginning of February.
5	Bud swelling: Vegetative buds swell, and the scales covering the buds are completely separated.	
7	Bud burst: The bud continues to elongate. The scales are completely green. Leaf primordia are visible on the bud.	
9	End of bud burst: Buds reach their final length and stop elongating. Tomentose leaves are exposed.	
Principal Growth Stage 1: Leaf Development		
10	First simple leaves separated: Green leaves are 8±2 mm taller than the bud scales. Leaves are fully exposed and separated from the main axis.	From mid-February until mid-March.
12	More leaves open: Petioles develop, and more leaves separate from the main axis and open; the blades of the first leaves represent 20% of their final area.	
14	More leaves open: All leaves separate from the main axis, and more leaves separate; the blades of the first compound leaves occupy 40% of their final area.	
19	All leaves open and petioles elongate to final size: Leaves thicken, and their color changes from green-red to dark green.	
Main Growth Stage 3: Shoot Development		
30	Beginning of shoot elongation: The shoot axis becomes visible and starts to develop as the first leaves separate.	From the last week of February until the end of March.
32	20% of the final shoot length: The shoots elongate and thicken.	
34	40% of the final shoot length: The shoots elongate and thicken further.	
35	60% of the final shoot length: The shoots continue to elongate and thicken.	
39	90% or more of the final shoot length: The shoots are thickened, hardened, and fully developed. At this stage, they are light green with reddish hues at the tip and near the leaf margins.	
Main Growth Stage 5: Inflorescence Emergence		
50	Beginning of reproductive bud swelling: Reproductive buds appear in the axils of the first 2-4 leaves and at the internodes, swelling as "whitish points".	From late March to mid-April.
51	End of bud swelling and bud burst: The bud reaches its full size; the bracts separate and gradually turn light green.	
52	Elongation of the primary axis: The inflorescence axis elongates up to 10% of its final length. Secondary buds are visible and begin to swell.	
54	The secondary lateral axes elongate to about 10% of their final length: The secondary lateral axes continue to extend. The primary axis extends up to 70% of its final size.	
56	The secondary lateral axes elongate to about 40% of their final length: The secondary lateral axes continue to develop. Up to three secondary lateral axes can be distinguished from each bud. Flower buds are visible and begin to develop.	
58	The secondary lateral axes elongate to about 80% of their final length: The secondary lateral axes approach their final length. Flower buds are almost fully developed.	
59	End of elongation of both axes: The inflorescences develop and reach their final size; the first fully developed flowers reach their final size.	

continue

Table 2. Description of the phenological stages of *Macadamia integrifolia* x *tetraphylla* cv. 'Beaumont' and the corresponding stages of the BBCH scale. The first number represents the main growth stage while the second number indicates the specific development stage within the main one.

BBCH code	Description	Date for *M. integrifolia* in Sicily, Italy
Main Growth Stage 6: Flowering		
60	The first flowers bloom.	From mid-April to late April.
61	Beginning of flowering: 10% of the flowers open.	
65	Full bloom: More than 50% of the flowers have opened. This is the best stage to admire the beauty of the flowers.	
69	End of flowering: 90% or more of the flowers have opened. All functional female flowers have fruited, while most functional male flowers fall, except for a few still in bloom.	
Main Growth Stage 7: Fruit Development		
70	No ovary development: This stage occurs during the flowering period of functionally female flowers, where petals and sepals do not fade. Each ovary contains two ovules.	From mid-May until mid- August.
71	Ovary development: The ovary turns light green, and petals and sepals around it wither and fall off after fertilization. The fruits expand to about 10% of their final size.	
72	20% of the final fruit size: The ovary continues to expand. Trichomes appear on the surface of the pericarp.	
75	50% of the final fruit size: The fruits continue to develop and become spherical in shape.	
79	90% of the final fruit size: The green fruits are sufficiently large and have a smooth surface.	
Main Growth Stage 8: Fruit and Seed Maturity		
81	Beginning of maturation: The fruits enlarge, and the pericarp becomes greener with reddish streaks.	From late August to late October.
87	Advanced maturation: Fruits continue to mature, and the pericarp begins to split open.	
89	Fully developed and mature: The pericarp fully opens. The fruits are ready for harvest.	

As shown in Figure 3, during the initial dormancy the buds remained dormant until late January, with rapid expansion and differentiation continuing until early February. Leaves began their development from mid-February to mid-March, with a gradual increase in size and morphological differentiation. At the same time, shoot development continued until late March, reaching its final length. From late March to mid-April, inflorescence development marked the transition to the reproductive phase, characterized by elongation of the primary and secondary axes and the appearance of flower buds. Flowering-whose average duration is 12 days in the second half of April-is another crucial phase of the cycle, after which male flowers fall while female flowers develop into fruits. Fruit development, from mid-May to mid-August, consists of a gradual increase in size and morphological ripening, characterized by the appearance of striations and the acquisition of a spherical shape. Finally, fruit and seed maturation, from mid-August to late October, ends with the opening of the pericarp and the preparation of the fruit for harvest. Once fruit ripening is over and as the temperature gradually drops, the species enters dormancy until the start of a new cycle.

4. Discussion

The BBCH scale for macadamia describes the developmental stages of the *Macadamia integrifolia* x *tetraphylla* cv. 'Beaumont' species in 32 phases. Although it is the first phenological scale currently developed for macadamia species, the number of identified stages appears to be consistent with those observed in other species. For instance, the BBCH scales for hazelnut, pecan, and walnut include 38, 48, and 55 stages, respectively (Han et al., 2018; Paradinas et al., 2022; Robin et al., 2024). Such classification will make it possible to standardize observations in orchards and harmonize research work across different regions and countries, allowing for the comparison of different cultivars.

Several critical environmental factors influence the vegetative and reproductive development of macadamia, including soil fertility (Stephenson et al., 1986), precipitation (Stephenson et al., 2000), solar radiation (Wilkie et al., 2009), and general climatic conditions. According to Allan (Allan, 1972), the optimal temperatures for plant growth and development range from 23 to 25 °C, but macadamia can tolerate temperatures up to over 40 °C (Westree, 1956). However, prolonged exposure to temperatures above 30 °C can severely compromise vegetative growth, causing widespread chlorosis (Nagao et al., 1992). Cold resistance varies depending on the cultivar, with some being able to withstand frosts down to -5 °C. Some researchers (Schroeder, 1954; Storey, 1957) believe that macadamia's adaptability to climate is similar to that of avocados. Regarding precipitation, studies suggest a tolerable annual rainfall range of 510-4,000 mm (Barrueto et al., 2018). With an average annual rainfall of about 738 mm in Palermo, precipitation is not expected to be a limiting factor.

Results from characterizing the macadamia growing environment in the Mediterranean climate compared to the Australian climate highlight differences in the plant's phenological stages. In the Mediterranean climate, the coldest minimum temperatures are recorded between January and February (3 °C), while the highest maximum temperatures occurred between June and August (42 °C). This seasonal variation can directly influence macadamia's phenological stages, such as delaying bud development in winter and accelerating vegetative growth and flower development in summer.

In the Mediterranean climate, bud dormancy persists until the last week of January, whereas in Australia, it may be less prolonged due to milder winter temperatures. However, both climates show a bud awakening, visible with the opening of the scales, and budding phase coinciding with the beginning of spring, when temperatures start to rise. The leaf growth period began from mid-February to mid-March in the Mediterranean climate, while in Australia, it might start slightly earlier due to warmer spring temperatures. Major vegetative flowering peaks occurred in early spring (March in Hawaii and August-September in Australia) and late summer (September-October in Hawaii and mid-January to March in Australia) (Carr, 2013). The flowering phase started in mid-April in the Mediterranean climate, with an average duration of 12 days. This might differ slightly from the Australian climate due to seasonal variability in temperatures and precipitation. In Eastern Australia, Moncur et al. (1985) found that when inflorescence buds begin to form in May with minimum temperatures of 11-15 °C, it takes about five months from bud initiation to anthesis. Although there was an advance in the onset of anthesis compared to a reference study, with full anthesis occurring in early May, this advance may be due to slightly higher temperatures than in the reference study. Despite this advance, the negative correlation observed by Nagao et al. (Nagao et al., 1992) was maintained, suggesting that cultivars that flower later tend to have a shorter flowering period.

Finally, fruit development and maturation occurred from mid-May to the end of August in the Mediterranean climate, while in Australia, these events might occur at different times due to seasonal climatic differences. In Australia, fruit development is complete from the eighth to the twelfth week after fruit set, while in South Africa, it extends to the fourteenth week (Bringhenti et al., 2023). Additionally, fruit abscission occurred with a delay of about 7-8 weeks compared to what is observed in Hawaii and Australia (Nagao et al., 1992). Overall, the Mediterranean climate affects the phenological stages of macadamia differently than the Australian climate due to differences in seasonal temperatures and precipitation variability. These factors can influence the timing and rates of plant growth and impact overall fruit yield.

In this first attempt at identifying and standardizing phenological stages, the focus was placed on the major developmental phases of the plant occurring in a Mediterranean environment. Further studies are needed to explore aspects related to the flowering phase and fruit ripening over time, in a

Mediterranean environment. A good understanding of macadamia phenology and the development of a complete BBCH scale are tools for comprehending the behaviour of the species, organizing cultivation practices, evaluating the species' response to various cultivation environments in the context of climate change and the detection of anomalies of physiological characters (Martínez et al. 2019). Plant phenology responds to climate variability in ways that differ based on location and crop species. The extent of climatic impact and a plant's intrinsic ability to adapt are key factors that ultimately shape its productivity and ecological stability.

5. Conclusions

The BBCH scale presented in this study is the first to detail *Macadamia integrifolia* x *tetraphylla* cv. 'Beaumont' phenofases in 32 stages from bud development to ripening of fruit and seed. The use of a two-digit code, rather than the use of an alphanumeric code, has the advantage of avoiding ambiguity during phenological monitoring and especially during the archiving of computer files or in statistical processing, such as the creation of graphs or tables. The proposed phenological scale is expected to provide support in characterizing global germplasm and in initiating advanced studies on macadamia adaptation to climate change. Although the collection of data from diverse ecologies, along with its analysis, is necessary and could contribute to further refinement of the scale. In the meantime, even in the absence of such additional information, the current initiative provides effective support to ensure consistent recording of phenological data across various locations and their subsequent analysis.

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