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Phenological of Cutleaf Groundcherry (*Physalis angulata* L.) Based on BBCH Scale

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ABSTRACT

Cutleaf groundcherry (*Physalis angulata* L.) is a plant that belongs to the Solanaceae family. In Indonesia, this plant grows spread in various regions and has different names in each region. However, this plant is rarely cultivated and is generally considered a weed by farmers. Recently many studies have shown that cutleaf groundcherry contains many substances that are beneficial for the health sector, so it has the potential to be developed as a cultivation plant for exotic fruit sources that function as nutraceuticals. Plant breeding programs can be a solution in responding to these problems. As the first step in developing cutleaf groundcherry through a breeding program, the Plant Breeding Laboratory, Faculty of Agriculture, Brawijaya University, collected accessions of cutleaf groundcherry from various regions in Indonesia. The phonological stage of its growth is one piece of information that is useful in better understanding the cutleaf groundcherry life cycle and, as a result, simplifying cutleaf groundcherry cultivation management. This research aims to provide practical knowledge on the cutleaf groundcherry life cycle to develop a more efficient plant management approach for cultivation, including plant breeding initiatives. The BBCH scale was used to make observations (Biologische Bundesanstalt, Bundessortenamt und CHemische Industrie). The descriptive statistics obtained from observations and presented in descriptive narrative form using the BBCH scale with 3-digit coding numbers and documentation images were used in the data analysis. The results showed that the BBCH scale was used to define and describe cutleaf groundcherry phenology, which included germination (stage 0), leaf development (stage 1), side shoot formation (stage 2), the emergence of inflorescence (stage 5), flowering (stage 6), fruit development (stage 7), fruit and seed ripening (stage 8) and senescence (stage 9).

Keywords*: Cutleaf Groundcherry, Physalis angulata, Phenology, Growth stage, BBCH scale*

1. INTRODUCTION

Cutleaf groundcherry (*P. angulata* L. Solanaceae)is a plant that grows in Indonesia and is known by various names, such as leletop, daun boba, daun kapo-kapo, daun lato-lato, leletep, depuk-depuk (Sumatera), cecendet, ciplukan (Java), leletopan, leletokan, daun kopo-kopo, daun loto-loto, lupareho, valanpanga, kateo-teo, roiye, toto (Sulawesi), karuhux, antokop, daun leletup (Kalimantan), angket, kepok-kepokan, keceplokan (Bali), daun boba, lapinonat, lapunonat, dagameme (Maluku), nyornyoran, yoryoran, (Madura), kaciputan (Bawean), kenampokan, dedes (Lombok), telak (Flores), and kakuto, gekatomato (Papua) (Waluyo et al., 2019). Despite its widespread distribution throughout Indonesia, this plant is rarely cultivated, and farmers regard it as a weed because it grows wild around cultivated crops. Numerous studies showed that cutleaf groundcherry contains various health and pharmacology-related compounds. The natural antioxidant found in its stems, leaves, and flowers has anti-cancer, anti-mycobacterial, and anti-leukemia properties and has been used to treat diseases like malaria, asthma, hepatitis, dermatitis, liver problems, and rheumatism (Sutjiatmo *et al*., 2011). Furthermore, Fisalin B, Fisalin D, and Fisalin F can inhibit the growth of *Mycobacterium tuberculosis*. Cutleaf groundcherry is also anti-diabetic, anti-hypertensive, analgesic (pain reliever), diuretic (diuretic), toxic neutralizer, cough reliever, anti-cancer, and anti-tumour (Silva *et al*., 2005)

Based on the numerous advantages of cutleaf groundcherry, this plant has much potential to be developed as an exotic fruit source culture plant that can be used as a nutraceutical and pharmaceutical with a lot of nutritional value (Faronny *et al*., 2019). One of the approaches that can address these issues is the plant breeding program. As a preliminary step in generating cutleaf groundcherry plants through a breeding effort, the Faculty of Agriculture at Brawijaya University has collected accessions from several places in Indonesia. The next step is to research these cutleaf groundcherry accessions to learn more about them. The growth stage is one of the details. Studying phenology using the BBCH scale will aid a more practical understanding of these plants' life cycles, making crop management methods easier. Furthermore, the BBCH scale has the advantage of having identical coding standards for all sorts of plant species, whether annual, biennial, or perennial (Meier, 1997; Valdivia-Mares et al., 2016). This makes it easier for researchers to communicate with one another and provides a more practical and transparent exchange of research data. This research aims to provide practical information about the cutleaf groundcherry life cycle to develop a more efficient plant management method for cutleaf groundcherry cultivation, including plant breeding programs.

2. MATERIALS AND METHODS

The research was carried out from June to September 2021 at the experimental greenhouse of the Faculty of Agriculture, Brawijaya University, located in Jatimulyo, Malang, East Java, Indonesia, with the coordinate (Latitude: -7.939998 and longitude: 112.615216). The environment grows at temperatures in the range of 25–30°C, and The relative humidity is in the range of 70-76%. The materials used in this research included 30 accessions of cutleaf groundcherry. Table 1 shows the accessions and their origins. Universitas Brawijaya collects all accessions. Manure, urea fertilizer, SP36, KCl, and carbofuran. At the same time, the tools used were glass and plastic seedlings, polybags, buckets, sickles,

bamboo stakes, ropes, research boards, stationery, and cameras.

The randomized block design (RBD) set up the experiment, which included 30 cutleaf groundcherry accessions and three replications. Each plot had three plants. The BBCH (Biologisch Bundesanstal, Bundessortenamt und CHemische Industrie) scale was used to track plant growth from germination to harvest.

Descriptive statistics derived from observational data were used to analyze the data in this study. The data is presented in a descriptive narrative format using the BBCH scale and a three-digit coding number in the phenological observation. The first digit denotes the primary growth stage of the plant, the second the message, and the third the second growth stage.

Table 1. Thirty cutleaf groundcherry accessions and their islands of origin

No.	Accessions	Origin
1.	A0101	Sumatera
2.	A0102	Sumatera
3.	A0103	Sumatera
4.	A0201	Sumatera
5.	A0202	Sumatera
6.	A0203	Sumatera
7.	A0301	Sumatera
8.	A0302	Sumatera
9.	A0303	Sumatera
10.	A0401	Sumatera
11	B2001	Java
12	B2002	Java
13	B2003	Java
14	B2101	Java
15	B2102	Java
16	B2201	Java
17	B2301	Java
18	C0101	Bawean
19	C0102	Bawean
20	C0103	Bawean
21	K0101	Sulawesi
22	K0201	Sulawesi
23	K0202	Sulawesi
24	M0101	Lombok
25	M0102	Lombok
26	M0103	Lombok
27	M0104	Lombok
28	M0201	Lombok
29	M0202	Lombok
30	N0101	Papua

3. RESULTS AND DISCUSSIONS

The growth stage of cutleaf groundcherry includes the growth cycle of plants ranging from germination to harvesting and senescence. This growth stage is described using a BBCH scale that uniformizes each growth stage of the entire

plant using a number code. Cutleaf groundcherry refers to solanaceous fruit with eight main growth stages (Table 2).

Stage 0 (germination) includes the initial stage of dry seeds until the appearance of cotyledons on the soil surface, Stage 1 (leaf development) involves the complete unfolding of the cotyledons to the unfolding of several true leaves on the main stem. Stage 2 (formation of side shoot) starts from the appearance of the first primary apical side shoot to the appearance of the tertiary apical side shoot and so on. Stage 5 (Inflorescence) starts from the first flower buds' appearance. Stage 6 (flowering) starts from the first blooming period until the next flower. Stage 7 (fruit development) starts from the period when the first fruit reaches a typical size until the next fruit. Stage 8 (ripening of fruit and seeds) includes changing the fruit's colour until it finally shows a distinctive ripe color. Stage 9 (Senescence), where the plant is ready to be harvested, shows signs of senescence and dies.

Principal growth stage 0: Germination

Sexual propagation with seeds and asexual propagation with tissue culture and grafting are two methods for propagating *Physalis* (Muniz *et al*., 2014). However, sexual propagation is currently the most common method of *Physalis* propagation. The primary growth stage 0 is germination, which begins with dry seed (stage 000), progresses to initial imbibition (stage 001), and finally to complete imbibition (stage 003). The appearance of the radicle (stage 005) is followed by cotyledons and hypocotyls breaking the seed coat (stage 007) (Figure 1), with this stage occurring in the 3 to 8 days after showing (DAS) time range in this study. The cotyledons are the last to penetrate the soil surface (stage 009). According to Fischer (2011), *Physalis* has a high germination rate: 85 to 90%, and germinates between 10 and 15 DAS, which is slower than the results of this study. Environmental conditions, particularly waterlogging or soil clumping, can inhibit the germination stage in plants. As a result, careful consideration and implementation of microclimate management during the germination phase are required (Setter and Waters, 2003). Muniz *et al*. (2014) added that seed emergence is influenced by biological and biochemical characteristics, environment, and germination efficiency. Humidity, temperature, light, and oxygen are all factors that must be considered for successful seed propagation.

Principal growth stage 1: Leaf development

The leaf development is the cutleaf groundcherry's growth stage in stage 1. This stage begins with a perfectly unfolded cotyledon (stage 100). Then proceed with the first pair of leaves that develop simultaneously and open perfectly (Figure 2). This stage occurs at 4 to 9 DAS in this study. Then open the second leaf, then the 3rd, and so on. The perfect open leaves in this study have a length of 4.5 - 12 cm and a width of 3 - 10 cm. Cutleaf groundcherry has alternate leaves, meaning each stem node has one leaf.

Table 2. Description of cutleaf groundcherry growth stages using the BBCH scale

BBCH Code	Description
Principal growth stage 0: Germination	
000	Dry seeds
001	Beginning of seed imbibition
003	Seed imbibition complete
005	Radicle emerged from the seed
007	Hypocotyl with cotyledons breaking through the seed coat
009	Emergence: cotyledons break through the soil surface
Principal growth stage 1: Leaf development	
100	Cotyledons completely unfolded
101	The first true leaf on the main shoot fully unfolded
102	2nd leaf on the main shoot unfolded
103	3rd leaf on the main shoot unfolded
10.	Stages continuous till . . .
109	Nine or more leaves on the main shoot unfolded
Principal growth stage 2: Formation of side shoots	
201	First primary apical side shoot visible
202	2nd primary apical side shoots visible
20.	Stages continuous till . . .
209	Nine or more apical primary side shoots are visible
221	First secondary apical side shoot visible
22.	Stages continuous till . . .
229	9th secondary apical side shoot visible
231	First tertiary apical side shoot visible
23.	Stages continuous till . . .
2NX	Xth apical side shoot of the Nth order visible
Principal growth stage 5: Inflorescence	
501	First inflorescence visible
502	2nd inflorescence visible
503	3rd inflorescence visible
50.	Stages continuous till . . .
509	Nine or more inflorescences are visible
Principal growth stage 6: Flowering	
601	First flower open
602	2nd flower open
603	3rd flower open
60.	Stages continuous till . . .
609	9th flower open
610	10th flower open
619	19th flower open
Principal growth stage 7: Development of fruit	
701	The first fruit has reached typical size and form
702	2nd fruit has reached typical size and form
703	3rd fruit has reached typical size and form
70.	Stages continuous till . . .
709	Nine or more fruit has reached the typical size and form
Principal growth stage 8: Ripening of fruit and seed	
801	10% of fruits show typical fully ripe colour
802	20% of fruits show typical fully ripe colour

BBCH Code	Description
803	30% of fruits show typical fully ripe colour
804	40% of fruits show typical fully ripe colour
805	50% of fruits show typical fully ripe colour
806	60% of fruits show typical fully ripe colour
807	70% of fruits show typical fully ripe colour
808	80% of fruits show typical fully ripe colour
809	Fully ripe: fruits have typical fully ripe colour
Principal growth stage 9: Senescence	
907	Plants dead
909	Harvested product

Principal growth stage 2: Formation of side shoots

The main growth stage 2 is the formation of side shoots. This stage includes the formation of side shoots originating from the apical bud of the main stem and then forming the canopy. Then after the formation and development of side shoots, branch development on each shoot. At maturity, the side shoots can usually reach and often overtake the height of the main stem. In cutleaf groundcherry, the formation of side shoots usually occurs simultaneously with the emergence of flowering (stage 5). Because flowering on the main stem is more profitable, the development of side shoots can be reduced by pruning. On each plant, many side shoots and branches depend on the plant's density in the field and environmental conditions. Therefore the number of secondary branches can vary between 3,4,5 if the density of the plant is high and the climate conditions are detrimental, but if the density of the plant is low and has favorable climatic conditions, the feeding can reach more branches (Martinelli *et al*., 2015). Furthermore, according to Kowalczyk and Kobryń (2003), the formation and development of side shoots are influenced by favorable climatic conditions for plant vegetative growth, including high humidity and high soil nitrogen levels.

Principal growth stage 5: Inflorescence

Principal growth stage 5 describes the morphology of the flowering process. The first event of this stage is the appearance of the first flower candidate with a still-blown bud (Figure 4), usually located at the point or the first branch. In this research, cutleaf groundcherry accession has different flower buds, varying between 38-44 DAS, with the most event mode occurring at 38 DAS. The second flowering appears at the second branching point and continues until nine or more inflorescence with visible flower buds.

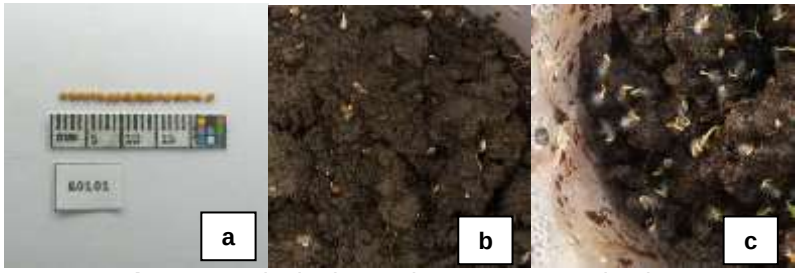

Figure 1. Principal growth stage 0: Germination
Stage 000, (b) stage 005, (c) stage 007

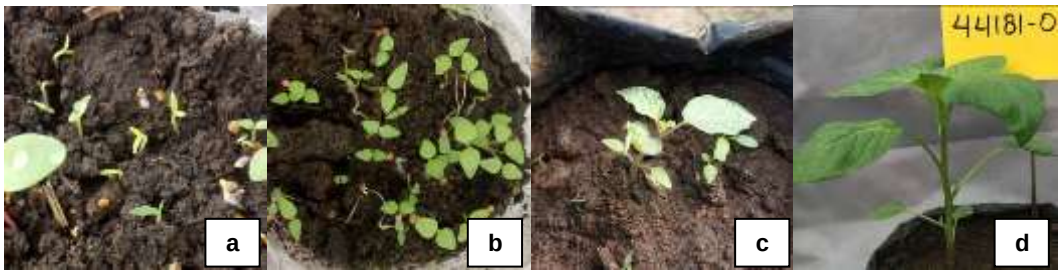

Figure 2. Principal growth stage 1: Leaf Development
(a) stage 100, (b) stage 101, (c) stage 103, (d) stage 10.

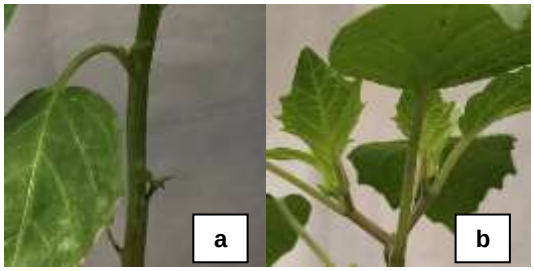

Figure 3. Principal growth stage 2: Formation of Side shoot
(a) stage 201, (b) stage 209

Figure 4. Principal growth stage 5: Inflorescence
Stage 501

Figure 5. Principal growth stage 6: Flowering
Stage 601

Figure 6. Principal growth stage 7: Development of fruit
Stage 701

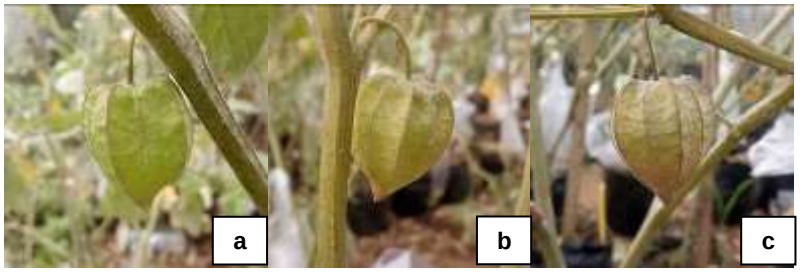

Figure 7. Principal growth stage 8: Ripening of fruit and seed
(a) stage 801, (b) stage 802, (c) stage 809

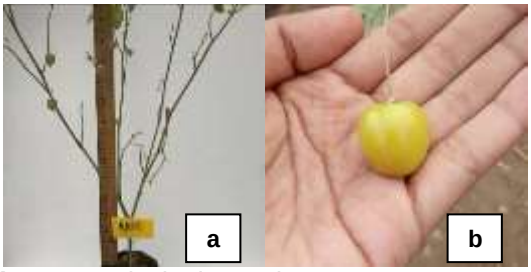

Figure 8. Principal growth stage 9: Senescence
(a) stage 905, (b) stage 809/907

Principal growth stage 6: Flowering

At this stage, the first flower blooms or has fully opened, then continues with the second, third, fourth, and so on (Figure 5). This stage is also known as the flowering period. Cutleaf groundcherry flowers during the reproductive phase until senescence (Figueiredo et al., 2020). In this research, the flower bloom or perfectly opened the fastest occurs at 39 DAS A0103 accession and the latest at 48 DAS in B2102 and M202 accession. This result is in contrast to previous research by Sadiyah et al. (2020), who found that the fastest time for cutleaf groundcherry flowering was at 48 DAS and the slowest at 61 DAS. This result could be due to differences in the accessions used or the research environment's conditions. Flowering is a stage that involves major changes in a plant. Environmental conditions strongly influence this stage, and each plant has a different ideal environmental variation mechanism to support the flowering process. The petals of the cutleaf groundcherry flower are yellow, and the center of the flower is purple. In this research, the blooming cutleaf groundcherry flowers had an average diameter of 0.98 – 1.16 cm. Flowers open in the morning until noon in the range of 06.00 AM to 2.00 PM and begin to close in the late afternoon. The anther opens and releases pollen for fertilization as soon as the flower opens (Fenske et al., 2018). The opening rhythm of this flower is generally related to pollinator activity with pollinators. Changes in environmental conditions such as light, temperature, and nutrient levels can affect the rhythm of flower opening and closing (Horibe, 2018). The quantitative characters of thirty Ciplukan accessions related to the plant growth phase are shown in Table 3, and the qualitative characters are shown in Table 4.

Table 3. Quantitative characters of thirty accessions of cutleaf groundcherry concerning plant growth phase

Accessions	Germination (cotyledons and hypocotyls breaking the seed coat) (DAS)	Leaf development (first pair leaf open) (DAS)	Inflorescence (flower bud appears) (DAS)	Flowering (flower perfectly open) (DAS)	Development of fruit (first fruit appears) (DAS)	Ripening of fruit and seed (harvest time) (DAS)
A0101	3	4	39	45	50	81
A0102	3	4	38	44	48	84
A0103	4	5	37	39	44	78
A0201	3	4	38	42	46	81
A0202	3	4	38	42	45	82
A0203	4	6	38	42	46	81
A0301	3	4	39	45	51	82
A0302	3	4	39	42	47	81
A0303	3	4	38	42	46	81
A0401	3	4	38	41	44	81
B2001	4	5	39	44	50	82
B2002	4	5	41	43	47	84
B2003	3	4	39	44	50	87
B2101	4	5	39	42	49	84
B2102	3	4	44	48	57	92
B2201	6	9	42	45	50	83
B2301	3	4	39	42	47	82
C0101	4	5	40	47	54	87
C0102	5	9	44	47	57	87
C0103	5	6	40	44	53	85
K0101	4	5	38	43	47	81
K0201	3	4	38	43	47	82
K0202	5	8	38	43	47	85
M0101	8	9	38	43	46	83
M0102	3	4	39	44	49	83
M0103	7	8	38	43	46	82
M0104	5	8	39	44	51	86
M0201	5	6	39	42	46	84
M0202	5	6	40	48	51	86
N0101	5	6	38	42	47	84

Principal growth stage 7: Development of fruit

The fruiting began to vary between 44 to 57 DAS in this research. Fertilization occurs after the flower has bloomed perfectly, and pollination occurs. At this stage, the flower will dry out so that the petals will fall or turn into a calyx covering the fruit. According to McAtee et al. (2013), this process occurs for three days and marks the beginning of the main growth stage 7. Subsequently, there is the development of the ovaries, known as the fruit (Figure 6), followed by cell division and the development of the size and weight of the fruit until it reaches a typical size. Air temperature and humidity become the most dominant environmental factor in determining success in the development of fruit in the Solanaceae family (Shamshiri et al., 2018)

Principal growth stage 8: Ripening of fruit and seed

Growth stage 8 describes the ripening of fruit and seeds, where this stage determines the harvest time, which is indicated by a change in the color of the fruit. According to Hatfield and Prueger (2015), temperature enhances the phenological development of plants by increasing the ripening process. The reproductive phase is more sensitive to temperature increases than the vegetative phase. Physical and chemical changes characterize the ripening process.

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Table 4. Qualitative characters of thirty accessions of cutleaf groundcherry concerning plant growth phase

Accession	Anthocyanin of hypocotyl	Anthocyanin of internodes	Leaf shape	Leaf color	Attitude of flower pedicel	Fruit color	Flesh color	Seed color
A0101	present	present	medium elliptic	yellowish-green	intermediate	purple	green	brown yellow
A0102	present	present	broad elliptic	green	intermediate	green	green	brown yellow
A0103	present	present	broad elliptic	green	intermediate	green	green	brown yellow
A0201	present	present	medium elliptic	yellowish-green	erect	purple	greenish-yellow	brown yellow
A0202	present	present	medium elliptic	yellowish-green	erect	green	green	brown yellow
A0203	present	present	medium elliptic	yellowish-green	erect	purple	greenish-yellow	brown yellow
A0301	present	present	broad elliptic	yellowish-green	erect	green	green	brown yellow
A0302	present	present	broad elliptic	yellowish-green	erect	yellow	greenish-yellow	brown yellow
A0303	absent	present	medium elliptic	yellowish-green	erect	purple	greenish-yellow	brown yellow
A0401	present	present	medium elliptic	yellowish-green	erect	yellow	greenish-yellow	brown yellow
B2001	present	present	medium elliptic	yellowish-green	erect	green	green	brown yellow
B2002	present	present	medium elliptic	yellowish-green	erect	green	green	brown yellow
B2003	absent	present	broad elliptic	green	intermediate	purple	greenish-yellow	brown yellow
B2101	present	present	medium elliptic	green	erect	green	green	brown yellow
B2102	present	present	broad elliptic	green	erect	purple	greenish-yellow	brown yellow
B2201	absent	present	medium elliptic	yellowish-green	erect	green	greenish-yellow	brown yellow
B2301	present	present	medium elliptic	yellowish-green	erect	green	green	brown yellow
C0101	present	present	medium elliptic	yellowish-green	erect	purple	greenish-yellow	brown yellow
C0102	absent	present	medium elliptic	yellowish-green	erect	green	green	brown yellow
C0103	present	present	medium elliptic	yellowish-green	erect	green	green	brown yellow
K0101	present	present	medium elliptic	yellowish-green	erect	green	green	brown yellow
K0201	present	present	medium elliptic	yellowish-green	erect	purple	green	brown yellow
K0202	present	present	medium elliptic	yellowish-green	erect	purple	greenish yellow	brown yellow
M0101	present	present	medium elliptic	yellowish-green	erect	yellow	greenish yellow	brown yellow
M0102	present	present	medium elliptic	yellowish-green	erect	green	green	brown yellow
M0103	present	present	medium elliptic	yellowish-green	erect	green	greenish-yellow	brown yellow
M0104	present	present	broad elliptic	green	erect	yellow	greenish-yellow	brown yellow
M0201	present	present	broad elliptic	green	erect	yellow	greenish-yellow	brown yellow
M0202	present	present	broad elliptic	green	erect	yellow	greenish-yellow	brown yellow
N0101	present	present	broad elliptic	green	erect	yellow	greenish-yellow	brown yellow

At this stage, there were physical changes, including size, weight, and color (Figure 7). In this research, the ripe fruit had a length of 2.5-3.45 cm, and a calyx like a balloon sheath had five ribs with an average weight of 1-2 grams per fruit. The increase in weight and size indicates dry weight accumulation in fruits and seeds. In addition to changes in size and weight, the main change as a harvest indicator is the color changes in the calyx from green to yellow and then browning. At this stage also occurs, softening of the fruit. According to the results of research conducted by Susanti et al. (2020), seed dry weight at yellow and brown ripening levels was significantly higher than at green. At the level of yellow and brown ripening levels, cutleaf groundcherry has a high content of food reserves in the seeds and has reached physiological maturity, which is indicated by the maximum dry weight of the seeds. In this research, cutleaf groundcherry began to show physiological maturity and was ready to be harvested at 61-75 DAP DAP or 78-92 DAS

Principal growth stage 9: Senescence

The main growth stage 9 describes the plant's aging after fruit ripening at the end of the growth stage (Figure 8). Aging begins at the basal leaves and continues to the top, but the stem organs are still green. Then, the remaining leaves will dry, and the stems will turn brown. Moreover, in the end, the whole plant will dry up and die.

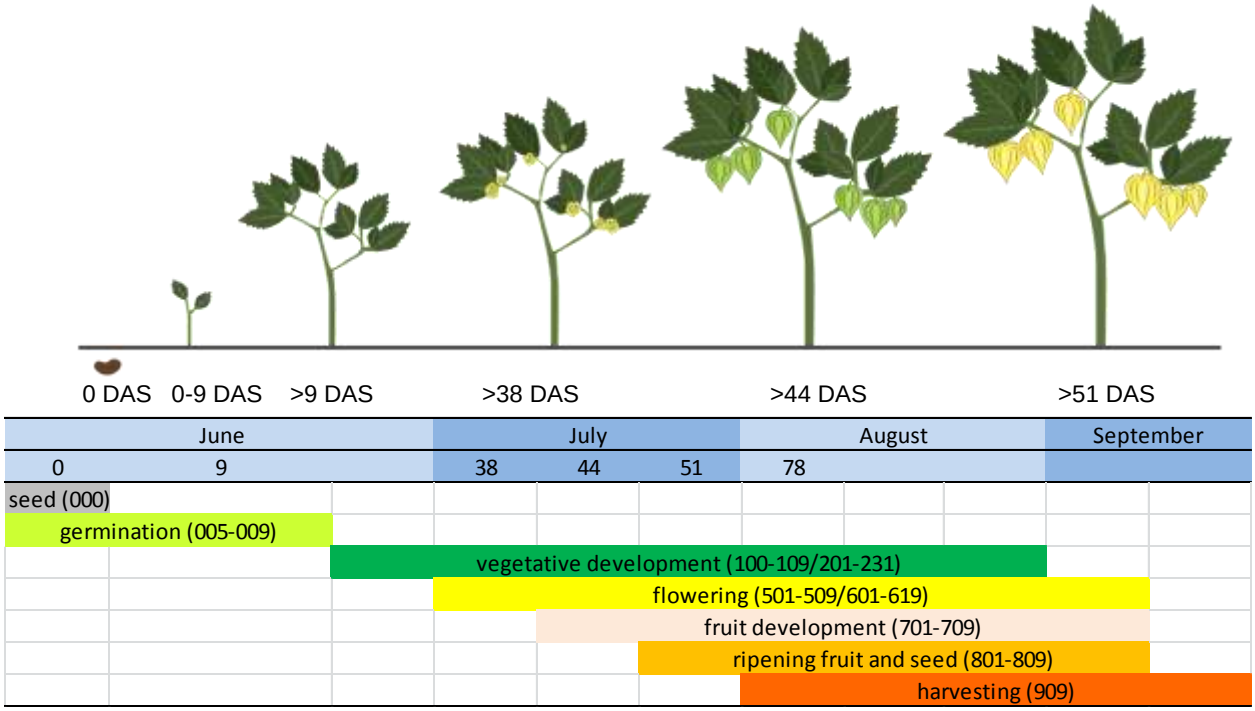

Figure 9. Principal growth stage "Germination to Senescence" of cutleaf groundcherry

The phenology of fruit trees is studied to determine the periodicity of their life cycles so that they can be utilized and applied for agronomic management. The BBCH scale can provide a more detailed and accurate description of the main phenological events of cutleaf groundcherry. BBCH scale on cutleaf groundcherry does not have a major growth stage 3 (stem development)

because, in cutleaf groundcherry, this stage occurs in parallel with the principal growth stage 5 (flowering). Furthermore, there is no principal growth stage 4 (the development of the vegetative part of the plant that can be harvested) because, in cutleaf groundcherry, the part of the plant that is harvested is the fruit organ.

4. CONCLUSION

In this research, the growth stage of cutleaf groundcherry phenology using the BBCH scale was determined and described as 8 out of 10 principal growth stages. Information related to the phenology of the cutleaf groundcherry growth stage can be used as basic information to facilitate the practice of cutleaf groundcherry cultivation management and for the benefit of breeding programs concerning improving genetic quality.

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