Morphological observation on the inflorescence development of *Tridax procumbens*, *Eclipta prostrata*, *Eleutheranthera ruderalis*, *Synedrella nodiflora* (Asteraceae, Heliantheae)

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Abstract. Asteraceae is one of the cosmopolitan flowering plants spread in various regions, including Indonesia. *Tridax procumbens*, *Eclipta prostrata*, *Eleutheranthera ruderalis*, and *Synedrella nodiflora* are commonly found at Universitas Indonesia Campus, Depok. The research was conducted to describe the development stages of flowers and fruit forms from the four species of the Heliantheae tribe. Samples were taken by purposive sampling technique at several locations at Universitas Indonesia Campus, Depok. All stages of flower buds start from the smallest until the dry up fruit stages are collected and observed using the Dinolite device and the Dino capture 2.0 application. The results showed that there were variations in the number of stages of inflorescence-fruit development in the four species observed, with a range 9-16 stages. The flowering stage divided into four groups, namely pre-anthesis, beginning of anthesis, anthesis, and senescence. In the pre-anthesis stage, the inflorescence is still in the bud form and green; at the beginning of anthesis, the buds begin to open, and the corolla begins to appear; the anthesis stage is marked with a fully open corolla; while the senescence stage is characterized by a change in the corolla into brown and dries out. The four species observed have achene (cypsela) fruit with sizes ranging from 3-4 mm. The fruits have Achene (cypsela) with pronounced and a reduced part of distribution accessories. Seed distribution accessories are winged peripheral, lanceolate shaped central, capillary bristle, and reduced pappus.

1. Introduction

Asteraceae, also known as Compositae, is the second-largest family in the kingdom of Plantae, comprise 17 tribes with members of about 23,000 species [1]. This Asteraceae family is a cosmopolitan plant, is known to dominate vegetation on earth and is spread almost throughout the world, including Indonesia, due to its ability to colonize and adapt to various ecological habitats so that many of them are invasive species [2]. The distinctive feature of Asteraceae is its inflorescence structure, which is called the flower head or capitulum. The capitulum consists of a very dense flowering system, in which the unit of flower (floret) attached to a receptacle that is surrounded by involucral bracts [3]. The capitulum of an Asteraceae is usually composed of three different lateral organs: Phyllaries, ray florets, and disc florets that always in the order respectively. The phyllaries (bracts), are modified leaves and mimic the sepals of a solitary flower. Ray florets are bilaterally symmetric, while disc florets are radially symmetrical [4]. While the order of lateral organs in the
flower head rarely changes, the number of layers of each lateral organ varies from species to species. The fruit of Asteraceae family is also very different from fruits of other families, but show high similarity in morphology among species. The fruit called as cypsela and achene [5].

Heliantheae is one of the tribes of the Asteraceae family whose distribution is mainly in regions with warm temperatures and tropical regions. Heliantheae is a perennial plant with herbs, shrubs, vines, or trees. This tribe has the characteristics of a corolla which is usually yellowish or sometimes white (rarely orange to reddish), pale receptacles with palea wrapping achene, smooth or striated achene (cypsela) surfaces, with pappus having horns or scales, and in branching stylus, there are hairs [4].

*Tridax procumbens, Eclipta prostrata, Eleutheranthera ruderalis, and Synedrella nodiflora* are plants that can be found on the University of Indonesia campus, Depok. Previous research by Agasi in 2010 at the UI Campus in Depok showed that the Asteraceae species with the highest dominance index was *Synedrella nodiflora*, followed by *Mikania micrantha*, and then *Tridax procumbens*, where two of the three species are species in the Heliantheae group [5].

*Tridax procumbens* is a native American herb that distributed in the tropics and subtropics, can grow to a length of 20-75 cm and is an annual flowering plant that has a bright yellow crown. *Eclipta prostrata* is a native Asian herb that distributed in the tropics, subtropics, and warm temperatures, can grow up to 90 cm and are flowering plants throughout the year that have white crowns [6]. *Eleutheranthera ruderalis* is a native American herb (tropical America) that distributed in tropical or subtropical regions, can grow up to 70 cm and is an annual flowering plant that has a yellow crown [6]. *Synedrella nodiflora* is a native American plant that spread in regions with warm temperatures, which are found in many tropical or subtropical countries. This *S. nodiflora* can grow 30-80 cm long and is a flowering plant with a yellow crown [6]. This study was conducted to describe and compare the development of flowers and fruit shape of those four species of Heliantheae tribe, with the hope that this information will give a contribution to the characterization of each species and tribe.

2. Materials and Method

All stages of flower buds from the smallest to developing fruits of *Tridax procumbens, Eclipta prostrata, Eleutheranthera ruderalis, and Synedrella nodiflora* were collected by purposive sampling technique from several locations at the Universitas Indonesia (UI) Campus, Depok. All samples were observed using a dino lite microscope and dinocapture 2.0 application. The scale used for measurement varies from 14x-29x for inflorescence shooting and 30x-37x for cypsela (achene) image capture. The stage of flower development was categorized based on the openness of corolla in the inflorescences.

3. Results and Discussion

There are two types of flower head observed in the four species of Heliantheae Tribe studied here. The heterogamous, or radiate type that has two type flowers, in which the margin of the capitulum is occupied by showy ray flowers while the center with less conspicuous disc flowers. The homogamous heads have only single-flower types [7]. Homogamous heads were observed in *Eleutheranthera ruderalis*, while heterogamous heads in *Tridax procumbens, Eclipta prostrata, and Synedrella nodiflora*. The members of the Heliantheae Tribe that were observed had various stages of flower development, from 9-16 stages. The number of flower development of *Tridax procumbens, Eclipta prostrata, Eleutheranthera ruderalis, and Synedrella nodiflora* is 14, 16, 9, and 14 respectively. The diversity of stages of development between one species with other species, allegedly due to differences in species abundance found at the UI Campus, Depok.

Valtierra et al. [8] divided Capitulum and floret phenology in *Baccharis aliena* (Asteraceae, Astereae) into six phenological stages that could be categorized into four groups, namely Pre Anthesis, Beginning of Anthesis, Anthesis, and Senescence. The Pre Anthesis-stage is when flower buds are still closed and green. The beginning of Anthesis stage is marked by an emergence of a crown, but still yellow-greenish. The anthesis stage is defined as the length of time during which the individual buds
remain open with fresh-looking perianths, pistils and stamens. The senescence stage is marked by the start of the crown and the change in colour of the crown or pistil to brown. Based on the number of flower stage in each species/individual plant, Anthesis could be divided into more than two stages, and also senescence.

*Tridax procumbens* has 14 stages of flower development (Figure 1). The flower buds still close tightly in stage 1, while in stage 2, the phyllaries (bracts) of the flower bud begins to open at the top part. Stage 3-5: the tip of the phyllaries increasingly exposed so that the inner part of the flower that looks yellow began to appear; in stage 5 the pink part of inner layer start to emerge; Stage 6-8: the size of inner floret increased, and in that part, the yellow and pink colour begins to appear. Stage 1-8 is the pre-anthesis stage. Stage 9: the corolla of ray florets begins to appear, which is the beginning of the flower anthesis. Stage 10: part of the ray and disc florets begins to emerge, and the pistil started to appear in the middle. Stage 11 and 12: ray florets fully opened, but the development of pistil of disc florets still not perfect yet. Stage 13: the flower is fully blooming. Stages 10-13 are anthesis. Stage 14: achene (cypsela) is visible and fused to form a ball shape. Stage 14 is the senescence stage.

*Eclipta prostrata* has 16 stages of flower development (Figure 2). In stages 1 and 2, the flower bud were enclosed by bracts. In Stages 3 and 4, the size of the bracts elongated, and the tips of phyllaries begin to split, that makes the inner florets buds begin to appear. In step 5, the phyllaries split wider, and the florets in the inner layer are about the same size as the phyllaries height. In stage 6, the phyllaries begin to open. Stage 1-6 is the pre-anthesis stage. In stage 7, the capitulum increasing in size, and corolla begins to appear. Stage 7 is the beginning of the anthesis stage. At stage 8-10 corolla looks increasingly elongated and higher than calyx size. At stage 11, the flower fully blooms, with the pistils visible. Stage 8-11 is the anthesis stage. In stages 12 and 13, the corolla and pistil begin to fall, and some florets turn to brown. At stage 14, the corolla part has fallen, the ovary part of the flower begins to develop into a fruit. At stage 15, the fruit arranged in the receptacle begins to break. In stage 16, brown-coloured achene (cypsela) is seen, and the fruit begins to fall from the receptacle. Stage 12-16 is the senescence.

*Eleutheranthera ruderalis*, which has a homogamous capitulum, has nine stages of flower development (Figure 3). In Stage 1, all parts of the bud are still closed. In stages 2 and 3, the bracts that protect the flower buds start to open, so that in stage 3, the florets inside the bracts begin to appear. Stage 2-3 is the pre-anthesis stage. In Stage 4, a yellow part starts to emerge in the centre of the flower head, which is a disc floret. Stage 4 is the beginning of the anthesis stage. In Stages 5 and 6, corollas have appeared, and the part of the pistil is seen in steps 6. Stages 5-6 are the anthesis stage. In Stage 7, some corollas are brown, and some others have fallen. At Stage 8, the corolla has fallen completely, and the achene (cypsela) is still inside the bracts. At stage 9, bracts have fully opened, and achene has been released. Stage 7-9 is the senescence stage.

*Synedrella nodiflora* has a heterogamous capitulum that consists of 14 stages of flower development (Figure 4), where stages 1-6 are the development of ray florets in the outer circle of the inflorescence. In Steps 1-2, the flower buds are still closed with bracts that are getting higher in size. Stage 1-2 is the pre-anthesis stage. In stage 3, the upper part of the central bud begins to open and is marked as the beginning of the anthesis stage, while in Stage 4, where the upper tips of bracts bloom, is the anthesis stage. In stage 5, the ray florets have fallen, and the horn tips of achene (cypsela) started to appear. Stage 5 is the senescence stage of ray florets. Stage 6-14 is the developmental stage of the disc florets in the inner circle. In stage 6, the corolla of disc florets starts to emerge, which is beginning anthesis of disc florets. In stages 7-10, the number of discs florets that blooming increased, and in stage 10, the disc florets emerge higher than the bracts involucrum. In Stage 11, the pistil pops out from the centre of the disc florets. Stage 7-11 is the anthesis stage of disc florets. In stage 12 the perianthium of disc florets has fallen, and the disc florets turn brown. In stage 13, the remained part of disc florets still attached in the bracts, and the achene (cypsela) begins to appear. In stage 14, all parts of the flower perianthium have fallen. Steps 13 and 14 are senescence stage of disc florets.

The fruit in the Heliantheae tribe is called achene and or cypsela with the addition of accessory organs for seed dispersal (Figure 5). *Tridax procumbens* has cypsela, which consists of seeds with an
accessory structure (pappus) in the form of hairlike feathers (Figure 5a). Synedrella nodiflora has dimorphic achene (cypsela) with pappus in the form of winged peripherals on ray floret seeds and the form of lanceolate shape central on floret disc seeds. (Figure 5d) [7]. Eclipta prostrata (Figure 5b) and Eleutheranthera ruderalis (Figure 5c) have achene (cypsela) with reduced pappus structures.

Tridax procumbens has brown achene (cypsela) with white wing-shaped distribution accessories. Achene of T. procumbens has a very light weight that allows distribution with the help of wind. Eclipta prostrata has brown and green-brownish achenes with an elongated shape and a rough structure on the seed wall. Achene of E. prostrata has a reduced pappus but the rough seed wall structure allows achene to be attached to animals or human clothing.

Eleutheranthera ruderalis has achene with several levels of colour, ranging from brown or blackish-brown with an elongated seed shape and has a rough structure on the seed pericarp. The accessory seeds of E. ruderalis do not experience a reduction, but the rough structure of the wall allows achene to be attached to animals or human clothing like seeds from E. prostata. Synedrella nodiflora has two kinds of achene with two different forms of distribution accessories. There are achenes with horns (winged peripherals) that have a green-brown colour, and there are also achenes with central lanceolate shape structure which is green-grey. The existence of these two achene structures is thought to be the cause of S. nodiflora is one of the dominant Asteraceae species on the UI campus in Depok.

Figure 1. Developmental stages of Tridax procumbens. Images (i-viii) represent Pre Anthesis (S1) stage; image ix is the beginning stage of Anthesis (S2), images x–xiii are the stage of Anthesis (S3), and image xiv is Senescence stage (S4)

Figure 2. Developmental stages of Eclipta prostrate: S1 (Pre Anthesis), S2 (Beginning of anthesis), S3(Anthesis), and S4 (Senescence)
Figure 3. Flower development stage of *Eleutherathera ruderalis*: S1 (Pre Anthesis), S2 (Beginning of anthesis), S3 (Anthesis), and S4 (Senescence)

Figure 4. Flower development stage of *Synedrella nodiflora*: S1 (Pre Anthesis), S2 (Beginning of anthesis), S3 (Anthesis), and S4 (Senescence)

Figure 5. Achene (Cypsela)
A. Achene (cypsela) of *Tridax procumbens*; B. Achene (cypsela) of *Eclipta prostrata*; C. Achene (cypsela) of *Eleutheranthera ruderalis*; D. Achene (cypsela) of *Synedrella nodiflora*

4. Conclusions
The four Asteraceae species in the Heliantheae tribe, *Tridax procumbens*, *Eclipta prostrata*, *Eleutheranthera ruderalis*, and *Synedrella nodiflora* have different stages of flower development. *Eleutheranthera ruderalis* has the smallest number of stages, the biggest number found in *Eclipta prostrata*. The four species are also known to have Achene (cypsela) with a pronounced and a reduced part of distribution accessories.

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