4.2 CHRONOLOGY AND SEQUENCE OF DEVELOPMENT OF FLOWER AND FRUIT

4.2.1 *Alternanthera sessilis* (red and green leaf forms)

Inflorescence development and longevity (Tables 8 & 9)

On an inflorescence spike, the flower development of *A. sessilis* (the red and green leaf forms) is in acropetal succession. Thus, within an inflorescence, flower formation, flower anthesis and fruit set could occur simultaneously (Figure 26A). The inflorescences take about 4–10 days in the red leaf form and 3–13 days in the green leaf form to attain maturity and start blooming after the initiation of the buds. The red and green leaf forms take about 18–68 and 18–58 days respectively for all the flowers within an inflorescence to reach full bloom. Thus the life span of an inflorescence is approximately 22–78 days for the red leaf form and 21–71 days for the green leaf form.

The average length of the inflorescence when the first flower reach anthesis is almost the same in both leaf forms and the difference is not significant ($p > 0.05$) (Appendix 4.2.1.2A). The average length is 2.90 ± 0.53 mm (range 2.00–4.00 mm) in the red leaf form and 2.70 ± 0.44 mm (range 1.87–3.50 mm) in the green leaf form.

The average length of a fully anthesized inflorescence in the red leaf form is significantly longer than the green leaf form ($p < 0.05$) (Appendix 4.2.1.2A). The average length of the inflorescence is 5.65 ± 2.03 mm (range 3.30–9.30 mm) in the red leaf form and 4.06 ± 0.79 mm (range 2.65–5.77 mm) in the green leaf form.

The length of a mature flower in the red leaf form is also significantly longer than that of the green leaf form ($p < 0.05$) (Appendix 4.2.1.2B). The average length of a mature flower in the red and green leaf forms is 1.78 ± 0.17 mm (range 1.40–2.10 mm) and 1.66 ± 0.20 mm (range 1.30–2.00 mm) respectively.

Although the fully anthesized inflorescence of the red leaf form is longer than that of the green leaf form, the difference in the number of flowers in an inflorescence between these two leaf forms is small and not significant ($p > 0.05$) (Appendix 4.2.1.2A). The average number of flowers per inflorescence is 25.12 ± 9.26 (range 9–45) in the red leaf form and 27.83 ± 9.51 (range 13–53) in the green leaf form.

Flowering phenology (Table 8)

Within an inflorescence, usually only one flower reaches anthesis at any one time, although occasionally, two to three flowers may open simultaneously. Anthesis of flower commences between 0730–0800 hours in both leaf forms. The peak hour of anthesis in the red and green leaf forms ranges from 0730–0800 hours and 0800–0900 hours respectively.

In both leaf forms, anther dehiscence accompanies flower anthesis. Dehiscence does not occur simultaneously among the three anthers in a single flower. Anther dehiscence begins at about 0800 hours with the appearance of a slit on an anther lobe which results in the liberation of a yellowish mass of pollen grains. By 1100 hours, dehiscence is complete when all the anthers in a flower have opened and released their pollen grains (Figures 26B & D). Occasionally, the anthers begin to dehisce only in the afternoon (1300–1400 hours) or evening (1600–1700 hours) as seen in the red leaf form.

Normally, the anthers bend down and touch the surface of the stigma when the flowers are about to close between 1600–1700 hours. However, in the green leaf form; most of the anthers are observed to touch the stigma between 1400–1500 hours and occasionally at 1000 hours.

The stigma of both leaf forms becomes receptive once the flowers open (Figures 26F.). Throughout flower anthesis, the stigmas are shiny, wet and give positive results when tested with 3% hydrogen peroxide. Thus, both leaf forms are homogamous as the stigma and anther reach anthesis simultaneously.

In both leaf forms, the flowers are ephemeral and the life span is only one day. The flowers start to close at about 1600 hours and will be completely closed at about 1700 hours. However, rainfall could extend the life span of the flowers. For instance, some of the flowers of both leaf forms did not close even after 1800 hours on rainy days and eventually close before 0730 hours the next morning. The correlation test showed that the correlation between rainfall and life span of a flower is positive ($p < 0.05$) (Figure 24).

Fruit development

In both leaf forms, the shape of the fruits is obreniform and the increase in width is faster than the increase in length. The fruit increases in size and takes about 11–13 days (red) and 13–15 days (green) to develop into a mature fruit. Thus, the mature fruit is obcordate, scarious, compressed in both leaf forms; and red in *A. sessilis* ‘Red’ and creamy in *A. sessilis* ‘green’. The fruit of both leaf forms contains only one seed which is round, compressed, shiny, glabrous and brown (Figure 105E).

On the first day after flower anthesis, the average size of the ovary of the red leaf form is 0.60 ± 0.10 mm in width and 0.48 ± 0.09 mm in length. The ovary increases in size consistently and it is about 1.85 ± 0.17 mm in width and 1.60 ± 0.16 mm in length when the fruit is mature. For the green leaf form, the average width and length of the ovary one day after flower anthesis is 0.60 ± 0.10 mm and 0.53 ± 0.12 mm

respectively. The size gradually increases and the width is about 1.73 ± 0.26 mm and the length is 1.38 ± 0.21 mm when the fruit is mature (Figure 25 & Appendix 4.2.2).

During flower anthesis, the ovary of *A. sessilis* 'Red' is red except where the light green colour of the ovule shows through the translucent ovary wall. As the fruit matures (about 11 days after flower anthesis), the ovary wall becomes more and more opaque and the seed (ovule) becomes less visible. The colour of the ovary remains red upon maturation whereas the area with the seed gradually turns from light green to creamy and finally brown (Figures 28A–C).

Similar to *A. sessilis* 'Red', the ovary wall of *A. sessilis* 'Green' is also translucent and the whole ovary is light green. About seven days after flower anthesis, the ovary wall becomes more and more opaque and the seed (ovule) becomes less visible. The colour of the ovary (except the area with the seed) gradually changes from light green to creamy. The colour of the area with the seed then changes from light green to creamy and finally brown (Figures 28D–F).

The anthers gradually drop off or degenerate 3–5 days after flower anthesis and by the eleventh day, they have completely abscissed. The colour of the anthers changes from yellow to light yellow or creamy and eventually brown which indicates degeneration. The colour of the stigma is yellow or white on the first day after flower anthesis. When all the anthers have completely abscissed, the stigma would have also degenerated; its colour changing creamy or light brown and finally brown.

4.2.2 *Alternanthera brasiliana*

Inflorescences development and longevity (Tables 8 & 9)

The parent plants and offsprings show similar results in the inflorescence development and flowering phenology. *A. brasiliana* is a perennial plant which blooms at the end of the year. In the present study, the flowering period of the parent plants was from November 2009 to March 2010; whereas, the flowering period of the offsprings (seedlings germinated from the seeds of the parent plants) was from October 2010 to April 2011.

On an inflorescence raceme, the flower development of *A. brasiliana* (parent plants and offsprings) is in acropetal succession. The inflorescences of the parent plant take about 13–53 days to attain maturity and start flowering after bud initiation (Figure 29). The parent plants show a high abortion percentage where the flowers degenerate before reaching anthesis (89.02 ± 10.18%). The inflorescences degenerate after 39–80 days after bud initiation. Therefore, the life span of an inflorescence is 52–133 days in the offsprings.

In the parent plants, the average length of an inflorescence when the first flower blooms is 5.88 ± 0.82 mm (range 4.30–7.08 mm) and the average length of a mature flower is 2.51 ± 0.09 mm (range 2.35–2.70 mm). The average length of the degenerated inflorescence is 5.55 ± 2.05 mm (range 3.12–11.25 mm). The average number of flowers in a degenerated inflorescence is 37.62 ± 13.14 (range 20–70). Initially, the colour of a healthy flower is white. As the flower degenerates, the colour gradually becomes creamy or light brown and eventually the flower wilts (Figure 29E).

Flowering phenology (Table 9)

Flower anthesis is divided into three stages: (1) mature bud opens slightly, the stigma and anthers could not be seen as the opening is tiny; (2) mature bud opens more, only the stigma can be seen and (3) mature bud opens to expose the stigma and anthers.

A complete flower anthesis process (from stage 1 to stage 3) takes about three days. On the first day, as the diameter of the open flower is very small, neither the stigma nor anthers could be seen (stage 1). The flower continues to open and the stigma could then be seen on the second night, approximately from 2200–2300 hours (stage 2). However, instances of stage 2 are seen to have occurred on three singular occasions; at 1000–1100 hours, 1200–1300 hours as well as 1900–2000 hours. Occasionally, the flowers would continue to open on the morning of the third day. At this time, the anthers and stigma are exposed (stage 3) (Figure 30A). Rarely, flower anthesis takes more than three days to complete. There was only one instance where the flower took 8 days to reach stage 2 and 9 days to complete flower anthesis.

Anther dehiscence is not observed in the present study. In fact, all the five anthers show abnormal characteristics such as membranous, brown in colour, indehiscent and devoid of pollen grains. On the other hand, all the five pseudostaminodes are yellow during the stage 3 of flower anthesis (Figure 30B). The yellow colour of the pseudostaminodes lasts only one day and the colour slowly fades away and eventually the pseudostaminodes become transparent.

The stigma is receptive once the flowers reach stage 2 and stage of 3 anthesis. The stigma is shiny, wet and gives positive result when tested with 3% hydrogen peroxide (Figure 30D). Although the flowers remain open after flower anthesis, the receptivity of the stigma starts to decrease two days after flower anthesis. Therefore, the life span of a flower is about 2–3 days.

A flower that has reached flower anthesis is quite difficult to identify owing to a few reasons. Firstly, the fully anthesized flower barely opens wide and does not close after flower anthesis. Secondly, the colour of the petal in the anthesized flower is the same as the young bud, which is creamy white. Thirdly, the anthesized flower does not attract insect visitors as it does not produce any food or scent.

Fruit development

The flowers do not close after flower anthesis but remain open during fruit development (Figure 31C). Nine to eleven days after flower anthesis, the mature fruit is obovoid, glabrous, dark brown and scarious. The perianth parts of the flowers remain attached to the fruit even during dispersal. The fruit consists of a single seed which is brown, obovoid, shiny and glabrous (Figure 107).

On average, the length of the ovary is 0.96 ± 0.16 mm three days after flower anthesis. The length gradually increases to 1.77 ± 0.12 mm 9 days after flower anthesis and 2.05 ± 0.05 mm 11 days after flower anthesis (Figure 25 & Appendix 4.2.2).

The colour of the stigma, ovary wall and seed changes throughout fruit development. Initially, the colour of the stigma is light green and it slowly turns light brown five days after flower anthesis. Similar to *A. sessilis*, the ovary wall is translucent; it is light green during flower anthesis, turning into light brown five days after flower anthesis and brown upon maturation (Figure 31).

4.2.3 *Alternanthera bettzickiana*

Inflorescence development and longevity (Tables 8 & 9)

The flower development of *A. bettzickiana* on an inflorescence spike is in acropetal succession (Figure 32A). The inflorescence takes about 3–18 days to attain maturity and start flowering after the initiation of the buds. The average length of the inflorescence when the first flower reach anthesis is 4.41 ± 0.23 mm (range 3.87–4.90 mm) and the average length of a mature flower is 3.80 ± 0.41 mm (range 3.20–4.60 mm).

Most of the flowers of *A. bettzickiana* degenerate before flowering which result in a high abortion percentage of 74.36 ± 14.61% (range 33.33–91.67) (Figure 32B). The average length and number of flowers of degenerated inflorescences is 4.75 ± 0.50 (range 3.85–5.56 mm) and 11.67 ± 1.66 (range 7–15) respectively.

Flowering phenology (Table 9)

In the inflorescence, only a single flower reaches flower anthesis at any one time. Flower anthesis commences between 0700–1200 hours and the peak hour of flower anthesis ranges from 0800–0900 hours. The flowers of *A. bettzickiana* are ephemeral and the life span is only one day. The flowers start to close at about 1600 hours and will be completely closed at about 1700 hours. Occasionally, the flowers start to close as early as at 1400 hours or they remain opened until the next morning.

Two types of anthers, normal and abnormal, are observed. The normal anthers partially dehisce and dry up before the flowers are closed. The pollen grains are not exposed in the partially dehisced anthers. The abnormal anthers are shrunken, brown and have never been observed to dehisce. All the five pseudostaminodes are yellow

during flower anthesis with the yellow colour lasting for only one day before slowly fading away (Figure 32C).

The stigma is receptive once the flowers reach flower anthesis. The stigma is shiny, wet; and gives positive result when tested with 3% hydrogen peroxide. Although the flower remains open after anthesis until the mature fruit is formed, the stigma receptiveness decreases drastically. The stigma turns brown or black and gives negative result when tested with 3% hydrogen peroxide.