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# Post-pollination developments and seed ecology of *Abroma augusta* (L.) L. *f.*

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## ABSTRACT

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The paper deals with the post-pollination developments and seed ecology of *Abroma augusta* (L.) L. *f.*, a valuable medicinal plant belonging to the family Sterculiaceae. The plant bears pendulous flowers in axillary scorpioid cymes close to the apices of slender branches. Loculicidally dehiscent capsular fruits are produced from the flowers. The overall fruit-set percentage of the species is about 16.61%, which is quite low. Since the day of pollination to mature into its state of dehiscence, a fruit requires about 32 to 49 days and that varies in different months of the flowering season. The number of healthy seeds per fruit varies from 64 to 216.75, in different months of the flowering season. The Indian squirrel *Funambulus palmarum* is seen to feed on the soft, tender seeds of undehisced or freshly dehisced fruits of the plant, thereby acting as a seed predator. Maturity of embryo in a seed is acquired prior to the attainment of seed coat maturity. Seeds of freshly dehisced fruits are with soft seed coat. Such seeds occasionally exhibit viviparous germination during the rainy seasons. Once the seeds become mature, a coat-imposed primary dormancy develops in them. Scarification with $H_2SO_4$ is required for their germination.

**Key-words:** Post-pollination developments, seed ecology, *Abroma augusta*.

## INTRODUCTION

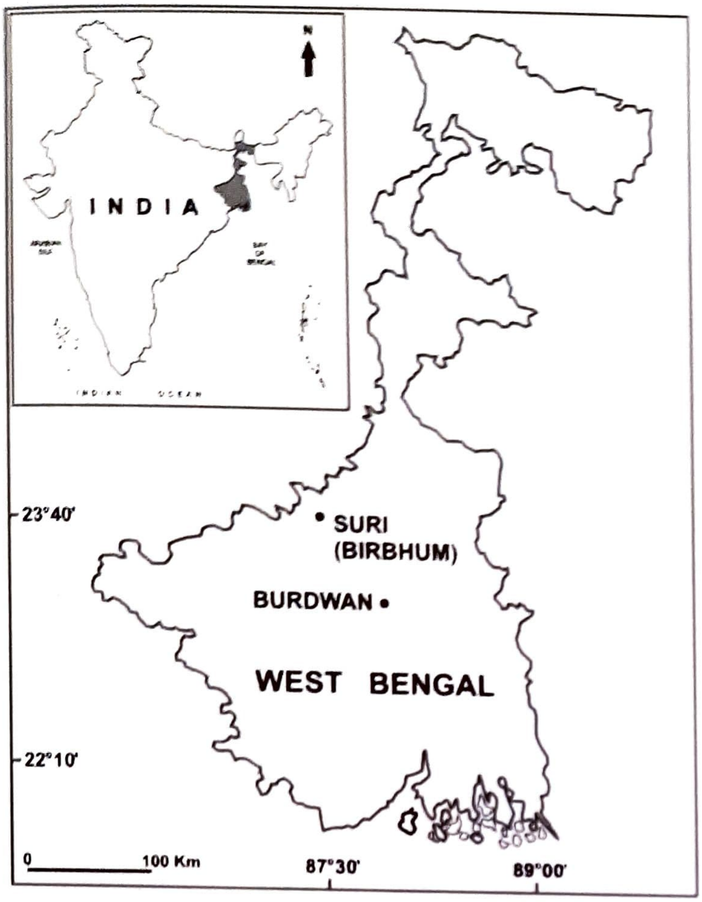
Successful pollination and seedling establishment are the two most critical steps in the sexual reproduction of flowering plants. Though most angiosperms have an alternative means of propagation, sexual reproduction is essential for the long-term perpetuation of a species as it provides the necessary variation required for adaptation to the environment. Pollination, followed by fertilization of the ovules, triggers a series of physiological and biochemical events in the ovary, that convert it into a young fruit. The changes, which mark the transition of the flower into a young fruit, are collectively referred to as fruit-set (Leopold & Kriedemann 1975). In course of time, the young fruit becomes mature, containing viable seeds. The morphological changes of the ovary that take place after pollination are therefore a matter of great interest with respect to the reproductive biology of a plant. Seeds are the sexually derived propagules of flowering plants. Each seed carries within it a precious embryo, the future sporophyte. The embryo remains well protected by the seed coat which is developed from the integument of the ovule. Depending on the nature of the fruit, seeds are liberated, either by dehiscence or by decay of the fruit wall. The successful destination of a seed is the suitable environment where it can germinate to give rise to a new individual. Seeds are released from the parent sporophyte almost entirely at the mercy of nature. The successful destination of a seed is the suitable environment where it can germinate to give rise to a new individual. The reproductive success of a species is solely dependent on the ecological success of its seeds and as a matter of fact it is very important in formulating strategies for its conservation and successful propagation. The percentage of seed-set, overall seed production, seed structure, seed dispersal, seed predation (if any), germination behavior including dormancy (if any), vivipary (if any), methods of breaking the dormancy (if any), etc. are important parameters in understanding the seed ecology of any given plant species.

*Abroma augusta* (L.) L. *f.* is a large perennial shrub belonging to the family Sterculiaceae and is commonly referred to as 'Ulatkambal' in Bengali and Hindi vernaculars. It is a valuable medicinal plant which has long been used in our indigenous system of medicine. The commercial drug derived from profusely branched woody roots, is considered to be a uterine tonic, an emmenagogue, an abortifacient and an anti-fertility agent. As it shows contractile action on the uterus, it is used for the treatment of dysmenorrhoea, amenorrhoea and other menstrual disorders (Kirtikar & Basu 1935, Joshi 2000). Leaves of the plant are also reported to be useful in treating uterine disorders, diabetes, rheumatic pains of joints and headache with sinusitis. The cold aqueous infusion of the fresh leaves and twigs is reported to be demulcent and very efficacious in gonorrhoea. The seed oil of *A. augusta* has an important dietary role in the control of arteriosclerosis because of its ability to lower the cholesterol level in blood. Khan et al. (2003) found that the seed oil of *A. augusta* possesses a moderate antifungal activity against the human pathogens *Trichophyton schoenleinii*, *Candida albicans*, *Aspergillus niger* etc. and the animal pathogens *Microsporum canis* and *Trichophyton simii*. The highest inhibition effects were found for *T. schoenleinii* (56%) and *M. canis* (50%). Thus, the seed oil of this plant has the potential to be used as an antifungal agent against these two fungi. Chemical constituents identified from various parts of the plant include abromine, choline, betaine, β-sitosterol, stigmasterol, friedelin, picrate, a fixed oil, taraxerol and its acetate, β-sitosterol acetate, an aliphatic alcohol ($C_{32}H_{66}O$), octacosanol and probably, a mixture of long chain fatty diols (Dasgupta and Basu 1970, Mazumdar et al. in Chadha 1985). Six fatty acids have been identified in a fixed oil obtained from the seeds (Ahmad et al. 2003). Due to its profound medicinal properties, the plant finds usage in a number of modern medicines viz., Mensural (Ralson Remedies), Abort (Hahnemann Pharmacy and Laboratory), Mensolin (Hahnemann Laboratory Ltd.), Gynical (Allen), Menstrol (Allen), Leucocure (Allen) etc. The plant is also the source of some homoeopathic medicines like Abrotanum, Abroma Augusta, Abroma Radix, etc. Minofil, a herbal formulation containing *A. augusta* as one of its ingredients, is considered as an alternative to Hormone Replacement Therapy in the treatment of post-menopausal syndrome (Nanda 1997).

*Abroma augusta* is known to occur in India, Nepal, Bhutan, China, Philippines, Indonesia and Malaysia. In India, the species is reported to be widely distributed throughout the hot and moist parts of the country, from Punjab and Uttar Pradesh, eastwards to Sikkim, Arunachal Pradesh, Assam, Meghalaya and Tripura, ascending to 1200 m altitude and southwards in peninsular India (Hooker 1872, Willis 1966, Malick 1993). The plant is found to grow sporadically as isolated individuals and sometimes in small populations growing as escapes along roadsides, on banks of ponds, left-out private plots, fallow lands, etc. The plant requires deep, alluvial soils with good drainage and well-distributed rainfall. However, a recent survey has indicated that the plant has become threatened, at least in Gangetic West Bengal. Formulation of strategies for conservation of the invaluable species requires a thorough knowledge of its reproductive biology. Basu and Pal (2009) have made a few observations regarding the floral biology of the plant while Basu et al. (2009) have reported agromyzid pollination in the species. Post-pollination developments and seed ecology of the species, which were hitherto unknown, have been dealt with in the present paper.

## MATERIAL AND METHODS

The work is based on three small populations and six isolated individuals growing wild in Burdwan and Suri areas (Text figure 1) of Burdwan and Birbhum districts respectively and four plants grown in the experimental garden of Department of Botany,




**Text figure 1.** Map of South West Bengal showing the location of collection sites.

University of Burdwan, West Bengal.

In order to ascertain the percentage of fruit-set, the number of tagged flowers in open-pollinated condition which ultimately developed into mature fruits was noted in each month of the flowering season. The work was repeated in two consecutive seasons.

To observe the changes that take place during the course of fruit maturity since pollination, fifty flowers were tagged on different days in each month through the flowering season. Day-to-day morphological changes of the gynoecium and the number of days required for fruit maturity were noted in each case. The work was repeated in two consecutive seasons. Finally, the mean number of days required for fruit maturity in each month was calculated.

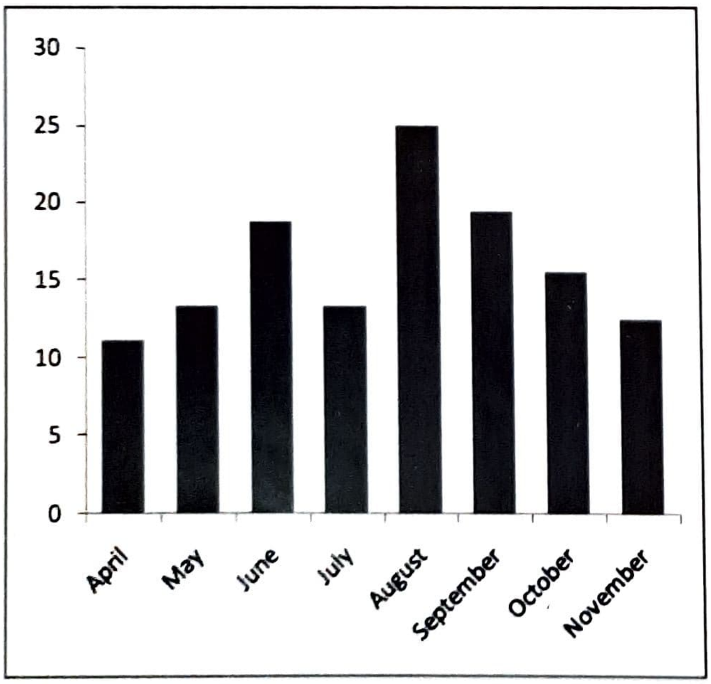
The number of ovules produced per flower and the number of seeds produced per fruit were determined throughout the flowering season. Ten flowers as well as ten mature fruits were randomly plucked every week. Fruits were always plucked on the day of fruit dehiscence and kept within separate polythene bags to ensure that no seeds were lost. The number of ovules in each flower and the number of healthy seeds in each fruit were then carefully counted. The average number of ovules per flower and average number of healthy seeds produced per fruit was determined for every month of the flowering season as well as for the overall flowering season. Finally, based on the seed-ovule ratio, the percentage of seed-set of the species was calculated.

Germination experiments were carried out as per the rules of International Seed Testing Association (1996). The experiments were carried out on material of mature seeds randomly collected from individuals of different locations. Freshly collected seeds were sun-dried (35 ± 2°C) for 5 hours each, on 3 consecutive days. The seeds were divided into a number of sets of 50 seeds each in Borosil glass containers with bakelite caps and stored under laboratory condition (27 ± 2°C) in ±11 hours of diffused natural light. To study germination, each seed lot containing 50 seeds was allowed to germinate in distilled water in a Petri dish (Borosil, 10 cm in diameter). The Petri dishes were placed under diffused natural light at room temperature (30 ± 2°C) and germination was recorded during the following consecutive days. Each experiment was repeated four times during the entire course of study. The well-known scarification methods viz., hot water treatment and acid scarification with concentrated $H_2SO_4$, were employed (Copeland & Mc Donald 2001). In case of hot water treatment, dry seeds were initially treated with hot water at 40°C for various time durations. For acid scarification, different concentrations [18(N), 24(N), 30(N) and 36(N)] of $H_2SO_4$ were used for different durations (10 to 110 minutes) to optimize the acid concentration along with the corresponding duration of treatment required for germination. After the scarification treatment, seeds were made acid-free by repeated washing in distilled water. Finally, the seeds were soaked in distilled water in Petri dishes for germination.

For various details of observations in field, 10x and 18x hand lenses were used, as and when required. Photographs of fruits were taken with a Canon Power Shot S 80 digital camera. Seed structure was studied by sectioning followed by observations under a WILD M3B Leica (Switzerland) stereobinocular microscope and a Leica (Germany) DMLB bright-field compound microscope with a Leica DFC 295 digital camera attachment.

## OBSERVATIONS AND DISCUSSION

**Fruit-flower ratio and percentage of fruit-set:** *A. augusta* produces pendulous flowers in axillary scorpioid cymes close to the apices of slender branches. Simultaneous with the elongation of a lateral branch, newer inflorescence primordia develop towards its apex. Flower abscission and juvenile fruit abscission are quite high in the species. All the fruits initiated do not reach maturity; quite a few are shed from the plant. Generally, one mature fruit develops from each of the three to five flowered inflorescences, giving rise to a series of erect fruits of increasing maturity behind, on a flowering twig. However, in 33.86% of the inflorescences, it was noticed that 2 fruits have developed from the flowers of a single inflorescence (Plate 1, Text figure 1). Very rarely (7.42%), three flowers from the same inflorescence have been observed to produce mature fruits. The fruit-set percentage ranges from 11.11% to 25.00%, varying with seasons (Text figure 2). Highest percentage of fruit-set, 25.00% was noticed in August, which was close




**Text figure 2.** Graphical representation of the fruit-set percentages of *Abroma augusta* through the months of the flowering season.

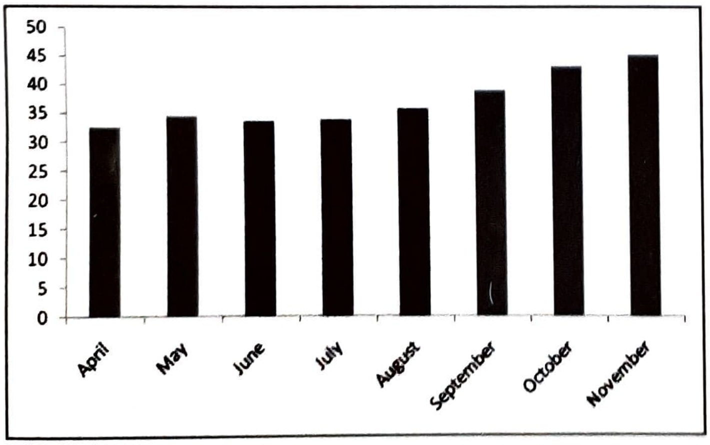
to the peak flowering season of the plant. The overall fruit-set percentage of the species is 16.61% (±4.34%) which is quite low.

Certain species are characterized by quite low fruit-set values. While only 6.6% of the flowers produce mature fruits in *Yucca elata* (James et al. 1994), the value is 10% in *Aesculus californica* (Newell 1991) and 8 - 22% in *Cornus sanguinea* (Guitián et al. 1996). A low fruit-flower ratio, indicating the failure of a large number of flowers to mature into fruits, is clearly an expenditure for the plant, causing a considerable wastage in the reproductive process. Fenner and Thompson (2005) inferred that the excess flowers may function as a reserve of ovaries for the plant, which can be used when resources are abundant but discarded with minimum loss if resources are scarce. They also opined that the production of flowers in excess is a means to overcome the loss caused by predation. That high flower mortality is linked with low fruit abortion has been experimentally demonstrated in *Cornus sanguinea* by Guitián et al. (1996). In majority of species, even in case of optimal resource and pollination levels, the fruit-flower ratio is less than unity (Fenner and Thompson 2005). This may be due to the evolution of specialized functions within the inflorescence. For example, some non-fruiting hermaphrodite flowers may only help in attracting pollinators for the whole inflorescence or they may only act as males by disseminating pollen.

**Post-pollination developments:** *A. augusta* is characterized by one-day flowers. Flowers of this species are pendulous while the fruits are erect. The corolla together with the androecial cup is abscised at the end of the day. The gynoecium, at the centre of the persistent calyx, is retained on the plant. After the abscission of the corolla, perhaps due to the release of pressure previously enforced by the petal bases, the sepals come quite close to each other and protect the very young fruit. Since pollination, ± 3 days are required for the ovary to achieve the appearance of a young fruit. The young fruit is obviously inverted as it develops from a pendulous flower (Plate 1, Text figure 2). In course of fruit maturity, the soft, slender pedicel responsible for the pendulous nature of a flower gradually becomes strong and stout, due to the development of mechanical tissue in it. The fruit finally becomes totally erect. Approximately 10 days are required from flower opening till the fruit erection. The mature fruits are five-chambered, loculicidal capsules, obpyramidal in shape with five prominent flange-like extensions developed from the major (dehiscence) ridges of the ovary, running along the midpoints of its chambers. The minor ridges of the ovary corresponding with the partition walls become obliterated in course of fruit maturity.

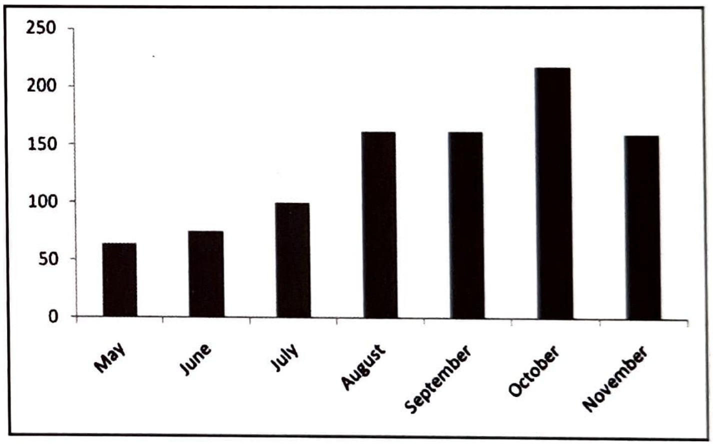
Varying in different months of the flowering season, a fruit requires about 32 to 49 days, with an average value of 37.32 (±4.51) days, since the day of pollination, to mature into its state of dehiscence. Fruits initiated towards the beginning of the flowering season mature a little faster than those produced in the later part of the flowering season (Text figure 3). A day before dehiscence, the mature obpyramidal fruit becomes 3.6-5.3 cm wide and ±4.2 cm in length and turns brown in colour. The browning starts on the general surface and gradually extends to the auriculate ridges. Simultaneous with the browning of the fruit, the persistent sepals also turn greenish yellow in colour. On the day of fruit dehiscence, the distal parts of the sepals become brown with their proximal parts remaining yellow, subtending the dark brown fruit at the centre (Plate 1, Text figure 3).

In clear sunny weather, fruit dehiscence occurs on the very day it turns brown, while in cloudy weather, it usually dehisces on the next day. A fruit does not become wide open as soon as dehiscence takes place (Plate 1, Text figure 4). Rather, opening occurs gradually due to gradual desiccation of the walls of the dehisced fruit. When the weather is clear and sunny, a fruit that has dehisced in the morning usually becomes fully open by afternoon (Plate 1, Text figure 5). In cloudy or rainy weather, this phenomenon is noticeably delayed by ± 24 hours. It is often seen that a dehisced fruit that had become wide open again turns back to a less open configuration after receiving a heavy shower. The overall morphological changes that take place in a developing fruit, through 'days after pollination' (DAP) till its dehiscence, have been depicted in Table 1.




**Text figure 3.** Graphical representation of the number of days required for fruit maturity of *Abroma augusta* in open-pollinated condition.

**Seed production and seed-set percentage:** In different months of the flowering season, the number of healthy seeds per fruit of *A. augusta* varies from 64 to 216.75 (Text figure 4), with 133.80 (± 86.84) as the mean value of the overall flowering season.




**Text figure 4.** Graphical representation of the number of healthy seeds produced per fruit of *Abroma augusta* in different months of the flowering season.

The number of ovules per ovary varies from 325 to 413 with 374.29 (± 28.22) as the mean value. Therefore, the seed-ovule ratio of this species is 1: 2.8, i.e., 5: 14 and the percentage of seed-set is 35.71.

**Seed dispersal:** On the day of fruit dehiscence, the upwardly directed dehisced fruit contains its seeds attached to the axile placentae on the inner surface of the fruit wall, in the midst of densely crowded, silky, fibrous hairs. Since fruit dehiscence, about 8 to 14 days, varying with seasons, are required for the commencement of detachment of seeds from the fruit wall and the loosened seeds initially remain in the upwardly directed, cup-like dehisced fruits and get dried in the sun. Individuals of *A. augusta* are quite large

Table 1. Morphological changes in a developing fruit of *Abroma augusta* since the day after pollination (DAP) till its dehiscence.

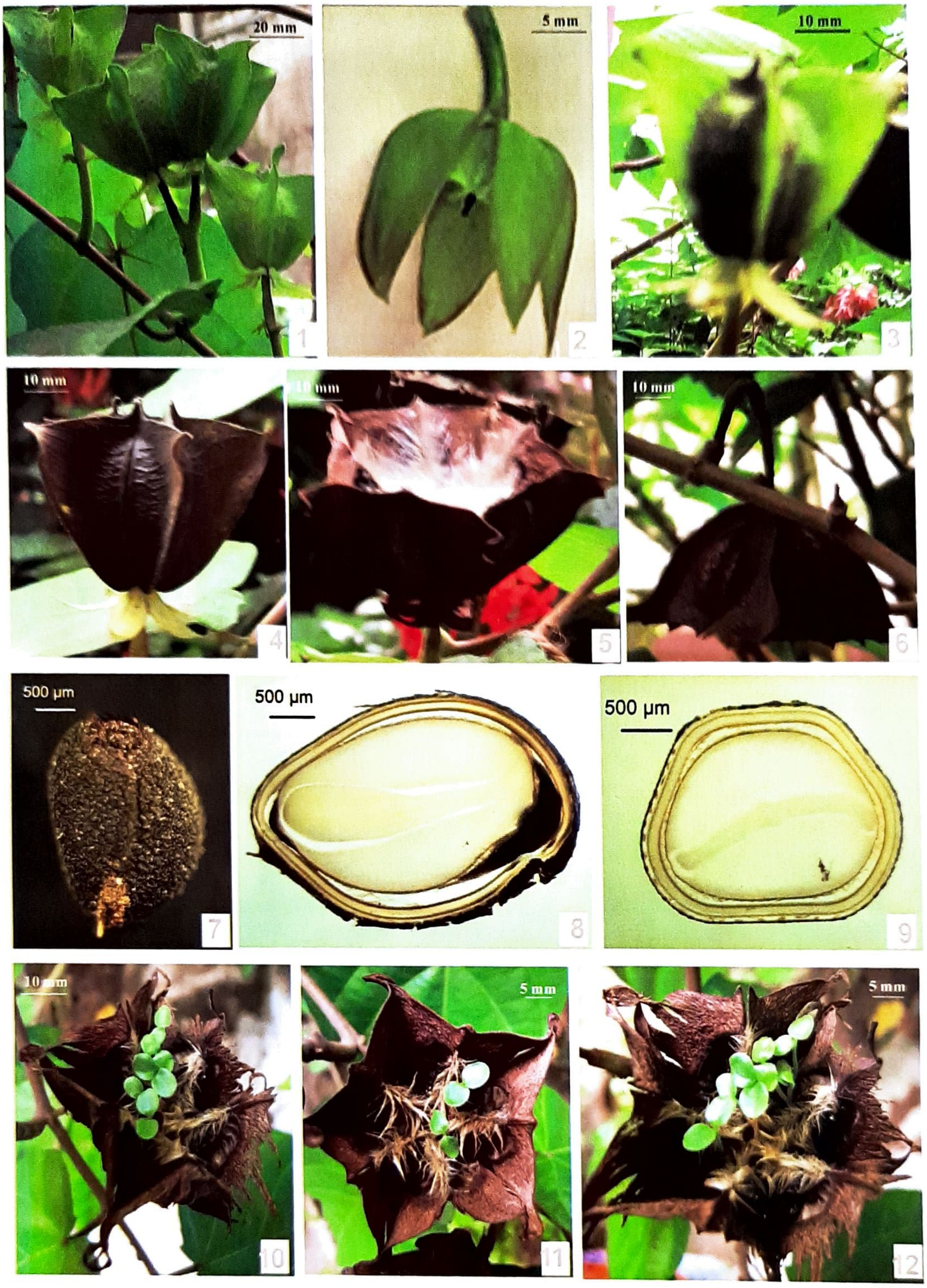
| DAP | Morphological Events |
|---|---|
| 1 | The calyx with gynoecium is still inverted. |
| 2 | The structure is still fully pendulous. The stigma and style, though brown and withered, are still recognizable and the five major ridges of the ovary exhibit development into flange-like extensions. |
| 3 | The structure is still fully pendulous. The withered style and stigma are still visible and recognizable. The ovary has become greenish, approaching a young fruit in appearance, obpyramidal in shape, nearly 5 mm in height and nearly the same in diameter, with five prominent ear-like extensions developed from the ridges, each running along the mid-point of each ovary chamber. |
| 4 | The young fruit has become slightly less pendulous, indicating the tendency to become erect. The withered style and stigma are still visible and recognizable at the apex. |
| 6 | The sepals have slightly spread outward making the young fruit partially visible. The pedicel has moved further upward. The withered style and stigma are still visible and recognizable at the apex. |
| 7 | The sepals have spread out further. Upward movement of pedicel continues, making the fruit almost horizontal. The withered style and stigma are still visible and recognizable at the apex. |
| 10-12 | The young fruit has become fully erect with the spread-out green sepals attached to its base. The sepals are horizontal to slightly reflexed with their tips pointed upward. |
| 31-48 | Commencement of browning of the fruit, extending from the general surface to the auriculate ridges and the yellowing of the sepals. |
| 32-49 | Dehiscence of the fruit. |

shrubs with slender flexible branches. When a branch bearing dehisced fruits sways to and fro in the blowing wind, majority of the loosened seeds present within the fruit 'cups' are dispersed far and wide. The remainder of the loosened seeds and those that are still not detached from the fruit wall are dispersed when the fruit ultimately becomes inverted due to gradual degeneration of the tissue of the pedicel (Plate 1, Text figure 6).

**Seed predation:** The three-striped Indian squirrel, *Funambulus palmarum*, was observed to feed on the soft, tender seeds of undehisced or freshly dehisced fruits. Whether it only acts as a seed predator or also helps in seed dispersal to some extent, was ascertained through close observations of the feeding behaviour of the animal. A squirrel was maintained in a cage with a polythene tray placed below the cage. It was fed with *Abroma augusta* seeds. It was observed that while feeding on the seeds, the animal chewed those thoroughly instead of swallowing those intact. Moreover, when the faecal pellets recovered from the polythene tray were dissolved in water, shreds of tissues of seed coat were noticed, but not a single intact *Abroma* seed was obtained. Therefore, feeding on *Abroma* seeds by the squirrel is a case of mere predation.

**Seed structure:** Mature healthy seeds of *Abroma augusta* are black in colour, bilaterally symmetrical, oval, ± 2.5 mm in length and ± 1.5 mm wide (in the broadest part). The micropylar end is relatively narrow and the chalazal end is broadly rounded. There is a prominent raphe ending in an oval-shaped hilum, often with a peg-like, small remnant of the funiculus (Plate 1, Text figure 7). Seeds develop from anatropus, bitegmic ovules. Structurally, the seed coat comprises an outer testa and an inner tegmen. The testa, made up of a few layers of isodiametric cells, is relatively thin, black, hard and brittle. The tegmen is constituted of a thick layer of palisade cells which develops from the outer epidermis and represents the mechanical tissue of the seed coat. The seed is albuminous. Internal to the innermost layer of the seed coat, is a layer of very scanty perisperm followed by the endosperm enclosing the embryo bearing a pair of thin orbicular cotyledons (Plate 1, Text figures 8, 9). Such seeds in which the outer epidermis of the tegmen gives rise to the mechanical tissue of the seed coat are regarded as exotegmic seeds (Corner 1976).

At the micropylar end, inner to the seed coat, there exists a dark brown, lid-like 'micropylar plug'. At the time of germination, when the radicle grows out, the




## Plate 1

1-12 *Abroma augusta* (L.) L.*f.* 1. A portion of a flowering twig, showing a few green, undehisced fruits borne in a row; second from the right are a pair of fruits attached to a common peduncle, indicating their development from the flowers belonging to the same inflorescence. 2. An inverted young fruit, surrounded by the partially spread out sepals; the withered stigma and style are visible at the apex of the fruit. 3. An almost mature, about-to-dehisce fruit. 4. A mature, freshly dehisced fruit, subtended by the persistent sepals, still green in colour. 5. A mature fruit after a few days of dehiscence; the dry fruit wall with silky, fibrous hairs developed from its inside and the shrivelled-up, persistent sepals at its base. 6. A dehisced dry fruit that has become inverted due to partial disorganization of the tissues of the pedicel. 7. Surface view of a mature, healthy seed, showing a relatively narrow micropylar end (below), a broadly rounded chalazal end (above) with a crater-like depression on one side, a prominent raphe ending in an oval-shaped hilum that shows a peg-like, small remnant of the funiculus. 8. Longitudinal section of a mature, healthy seed, showing the micropylar plug as a dark brown lid-like structure, internal to the innermost layer of the seed coat at the micropylar end and the chalazal apparatus as a thick, black mass of tissue at one side of the chalazal end. 9. Transverse section of a mature, healthy seed, showing the outermost black, warty seed coat layer followed by the inner sclerified layers, a layer of very scanty perisperm and finally the endosperm enclosing the embryo with a pair of cotyledons. 10-12. Panoramic view of mature, dehisced fruits, showing viviparously developed seedlings inside; the walls of the two fruits in figs 10 and 12 have become torn and degenerated.

structure is seen to remain attached to the side of the protruded radicle. At the chalazal end, outwardly at one side, there exists a crater-like depression. Sectional view reveals a crater-like opening surrounded by a rim-like thickening with a semi-lunar mass of dark-coloured tissue just below the opening (Plate 1, Text figure 8). The overall structure is generally referred to as the 'chalazal apparatus'. Such a chalazal apparatus is a characteristic feature of many other members of Malvales (Nandi 1998). As it was noted initially in *Bixa orellana*, this type of chalazal apparatus is often referred to as bixoid chalazal apparatus. The structure is known to be involved in the regulation of water entry into the seed (Baskin et al. 2000).

**Dormancy:** Seeds in a freshly dehisced fruit are found to possess quite soft seed coats. During the time the seeds remain inside the dehisced fruit without getting detached from it, seed coats gradually become hardened. In course of 8-14 days since fruit dehiscence, when the seeds normally start getting detached from the fruit-wall, they develop quite hard coats around them. When such seeds are soaked in distilled water for germination, they are unable to do so. However, Tetrazolium-test imparted positive results in 98% of such seeds, indicating the existence of a sort of primary dormancy in them. On the other hand, seeds harvested either a day before fruit dehiscence or on the day of fruit dehiscence, possess quite soft seed coats and readily germinate without any scarification treatment. The phenomenon indicates the attainment of embryo maturity much before the seed coat maturity. Once the seed coat becomes mature, a sort of dormancy develops.

**Vivipary:** Because of the attainment of embryo maturity much before the seed coat maturity, the plant exhibits viviparous germination of seeds, occasionally in rainy seasons. During periods of prolonged showers, an upwardly directed dehisced fruit, containing seeds and abundant hairs, accumulates rain water inside it. When such a fruit is a freshly dehisced one, its seeds with soft seed coats imbibe water and germinate *en masse* giving rise to a bunch of seedlings inside the fruit (Plate 1, Text figures 10, 11, 12). In a season, such vivipary was noticed in only 17.24 - 21.43 % of the fruits, with a mean value of 19.09% (± 1.24), as revealed from the observations among eight individuals.

The plant sends off slender branches and the lower ones occasionally flop onto the ground. Viviparously developed seedlings in the fruit(s) of such a branch come in contact with the ground soil and eventually establish themselves there. However, viviparous sprouting of seeds followed by their establishment in ground soil by above-mentioned means requires a prolonged rainy weather, at least for several days. Otherwise, even a day of the scorching sun is enough to destroy all the seedlings in a fruit. Therefore, establishment of such seedlings in nature is rather uncommon and the role of viviparous germination of seeds in the overall reproductive biology of the plant is not very significant. However, when such seedlings were carefully excised and transplanted to ground soil, they successfully developed into healthy individuals. Therefore, the phenomenon can be successfully used for large scale propagation of the species.

**Scarification requirements of freshly harvested mature seeds:** Mature seeds of *A. augusta* are primarily dormant and scarification with $H_2SO_4$ is required to bring about their germination. Seed germination is epigeal. Scarification with different concentrations of $H_2SO_4$, for different durations,

**Table 2. The germination (%) of *Abroma augusta* seeds obtained by scarification with different concentrations of $H_2SO_4$ for different durations.**

| Conc. of $H_2SO_4$ (N) \ Duration (min) | 10 | 15 | 20 | 25 | 30 | 40 | 50 | 60 | 80 | 110 |
|---|---|---|---|---|---|---|---|---|---|---|
| 36 | 25 | 65 | 98 | 45 | 35 | - | - | - | - | - |
| 30 | - | - | 61 | 68 | 72 | 56 | 56 | 50 | - | - |
| 24 | - | - | - | 42 | 48 | 44 | 32 | 20 | 14 | - |
| 18 | - | - | - | - | - | 8 | 12 | 15 | 12 | 9 |

revealed that 36(N) $H_2SO_4$ for 20 minutes imparts the highest result, bringing about 98% germination, followed by 30(N) $H_2SO_4$ for 30 minutes, giving rise to 72% germination. The germination obtained with different concentrations of $H_2SO_4$ for different durations are shown in Table 2. The coat-imposed primary dormancy of seeds is an adaptation for overcoming the intense summer of the tropics.

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