REPRODUCTIVE BIOLOGY OF THE GENUS *MAERUA* FORSSK. IN THAILAND

PRATTANA MAPORN

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ชีววิทยาการสืบพันธุ์ของพืชสกุลแจงในประเทศไทย

นางสาวปรารถนา มาพร

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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REPRODUCTIVE BIOLOGY OF THE GENUS *MAERUA* FORSSK. IN THAILAND

Suranaree University of Technology has approved this thesis submitted in partial fulfillment of the requirements for a Master's degree.

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ปรารถนา มาพร : ชีววิทยาการสืบพันธุ์ของพืชสกุลแจงในประเทศไทย (REPRODUCTIVE BIOLOGY OF THE GENUS *MAERUA* FORSSK. IN THAILAND) อาจารย์ที่ปรึกษา : ผู้ช่วยศาสตราจารย์ ดร. สันติ วัฒฐานะ, 81 หน้า

คำสำคัญ : พืชสกุล *Maerua* ชีพลักษณ์ของดอก ระบบการผสมพันธุ์ การงอกของเมล็ด

พืชสกุล *Maerua* เป็นพืชที่พบได้ในประเทศไทย โดยในประเทศไทยพบได้สองชนิดคือ แจงสยาม (*M. siamensis*) และแจงสุรนารี (*M. koratensis*) ซึ่งแจงสยามเป็นหนึ่งในพืชที่เข้าข่ายพืชที่ถูกคุกคาม เนื่องจากการทำลายป่าและการนำพืชออกจากพื้นที่ป่าเพื่อใช้ปรับภูมิทัศน์ในสวน ในขณะที่ชนิดที่สองหรือแจงสุรนารีเป็นชนิดที่หายากและพบเฉพาะถิ่นของประเทศไทย การศึกษาชีววิทยาการสืบพันธุ์จึงเป็นสิ่งจำเป็นอย่างยิ่ง ในการอนุรักษ์ของพืชทั้งสองชนิด โดยการศึกษาครั้งนี้มีวัตถุประสงค์ คือ 1) เพื่อเปรียบเทียบชีพลักษณ์ของดอก (floral phenology) และระบบการผสมพันธุ์ (breeding system) 2) เพื่อศึกษาลักษณะทางสัณฐานวิทยาของผลและเมล็ด และ 3) เพื่อเปรียบเทียบการงอกของเมล็ดและการพักตัวของเมล็ดที่เตรียมเมล็ดก่อนเพาะด้วยวิธีการต่าง ๆ ของแจงสยามและแจงสุรนารี แจงสยามมีรายงานครั้งแรกว่าดอกมีหลายประเภท ซึ่งประกอบด้วยดอกย่อยที่สมบูรณ์เพศเป็นส่วนใหญ่ มีดอกเพศผู้และดอกเพศเมียบางส่วน ในขณะที่แจงสุรนารีมีดอกประเภทเดียว ซึ่งเป็นดอกสมบูรณ์เพศ แจงทั้งสองชนิด สามารถผสมพันธุ์ในต้นเดียวกัน เนื่องจากมีการติดผลจากการผสมของดอกในต้นเดียวกัน จากคนละดอก และไม่มีการติดผลเมื่อไม่ได้รับการผสม การติดผลของทั้งสองชนิดอยู่ในระดับต่ำ แสดงว่าอาจเป็นการผสมแบบที่ต้องอาศัยพาหะในการผสมข้ามดอก การทดลองการผสมเกสรด้วยมือ ทั้งการผสมเกสรข้ามต้นและการผสมเกสรในต้นเดียวกัน และการศึกษานิเวศวิทยาของดอกและผู้ผสมเกสร เป็นสิ่งจำเป็นสำหรับการศึกษาต่อไปในอนาคต เมล็ดทั้งสองชนิดจัดเป็นเมล็ดที่ไม่มีการพักตัว เนื่องจากเวลาของผลที่สุกสอดคล้องกับการเริ่มต้นของฤดูฝน จากการศึกษาการงอกของเมล็ด พบว่า การทำให้เป็นแผลด้วยขลิบมีอัตราการงอกสูงสุดในทั้งสองชนิด สำหรับแจงสยาม วิธีทดสอบการงอกของเมล็ดแบบที่ควบคุม หรือแบบที่ไม่ต้องเตรียมก่อนเพาะเมล็ดเป็นตัวเลือกสำหรับการผลิตต้นกล้า เนื่องจากการประหยัดค่าใช้จ่าย แจงสยามคาดว่าเป็นเมล็ดแบบออร์โธด็อกซ์เนื่องจากเมล็ดที่เก็บไว้ในตู้เย็น 1 ปี ยังคงมีอัตราการงอกที่สูง จึงเป็นชนิด ที่สามารถนำเมล็ดแจงไปเก็บรักษาในธนาคารเมล็ดพันธุ์ได้ แต่ต้องทำการตรวจสอบอัตราการรอดชีวิตในระยะยาวหลังจากการเก็บรักษาเพื่อทำธนาคารเมล็ดพันธุ์

สาขาวิชาชีววิทยา
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ลายมือชื่อนักศึกษา ปรารถนา มาพร
ลายมือชื่ออาจารย์ที่ปรึกษา
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PRATTANA MAPORN : REPRODUCTIVE BIOLOGY OF THE GENUS *MAERUA* FORSSK. IN THAILAND. THESIS ADVISOR : ASST. PROF. SANTI WATTHANA, Ph.D. 81 PP.

KEYWORD: The genus *Mearua*, Floral phenology, Breeding systems, Seed germination,

In Thailand, only two species in the genus *Maerua* are found; *M. siamensis* and *M. koratensis*. The first species seems to be the threatened tree species, due to forest destruction and over collecting for garden landscape use. While the second species is a rare and endemic species of Thailand. To conserve these two species, reproductive biology is crucially needed. The aims of this study are 1) to compare the floral phenology and breeding system, 2) to study morphological characteristics of fruits and seeds, and 3) to compare seed germination and dormancy after seed pre-treatment of *M. siamensis* and *M. koratensis*. *Maerua siamensis* is firstly reported that it is a polytypic flower consisting of mainly hermaphrodite, few females and few male flowers in the same individual. While, *M. koratensis* is a monotypic flower. They are self-compatible due to setting fruit in the same individual, geitonogamy but not apomixis. Natural fruit sets of both species are low, indicating that they are allogamy or xenogamy. The hand pollination experiment on cross and self pollination and other floral ecology are needed for further study, as well as pollinators. They are non-dormant seeds because the ripened time fits with the beginning of the rainy season. The mechanical scarification with nail clip gave the highest germination rate in both species. For *M. siamensis*, control treatment, or without any preparation is an option for producing seedlings due to cost saving. It seems to be an orthodox seed because seeds which were kept in refrigerator for one year gave high germination rate. This species may apply for seed banking, but it still needs to monitor long term survival rate after seed banking.

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LIST OF ABBREVIATIONS

DANARDC	Department of Agriculture Nakhon Ratchasima Agricultural Research and Development Center
GP	Germination Percentage
GS	Germination Speed
MDG	Mean Daily Germination
MGT	Mean Germination Time
RSPG	Plant Genetic Conservation Project Under the Royal Initiation of Her Royal Highness Princess Maha Chakri Sirindhorn

CHAPTER I
INTRODUCTION

1.1 Background and motivation

Capparaceae is a small plant family (0.2-0.3% of all flowering plant species). With only 40-45 genera, the entire diversity of Capparaceae is inside 700-900 accepted plant species names (Pax and Hoffman, 1936). Capparaceae are distributed in tropical, subtropical and temperate zones of both hemispheres (Pelotto and Del Pero Martínez, 1998). Capparaceae are more benefits for people, such as food, medicine and biological activities (Abd El-Ghani, M., El-Bous, M., and Kamel, W., 2009).

Some of Capparaceae are used for animal diseases and medicinal plants (Shad, A. A., Ahmad, S., Ullah, R., AbdEl-Salam, N. M., Fouad, H., Rehman, N. U., Hussain, H., and Saeed, W., 2014). Some species of the family are phytochemical plants. For example, *Capparis deciduathe* has hypercholesterolemic, anti- inflammatory, analgesic, antidiabetic, antimicrobial, antiplaque, antihypertensive, anthelmintic, and purgative potentials (El Karemy, Z., 2001).

Maerua Forssk. belongs to Capparaceae with about 90 species worldwide. In Thailand, only two species have been reported, *M. siamensis* (Kurz) Pax (Chayamarit, K., 1991) and *M. koratensis* Srisanga and Watthana (Srisanga, P., Muangsan, N., Choopan, T., Thangthong, J., Pratcharoenwanich, R., and Watthana, S., 2021). *M. siamensis* is found commonly in South East Asia. In Thailand, it is used as food and eaten with chili paste. *M. siamensis* is used for medicinal products such as toothache medicine, day or night blindness, malaria disease, conpress for muscle paralysis. Moreover, it can have a number of effects. Leaves and twigs extract inhibit acetylcholinesterase (Alzheimer's Disease) (Posri, 2017) and be used for fever medicine, analeptic, cure faint and blurred vision (Pongmuangmul, S., Katosod, J., Wuttiadirek, W., and Vittayanan, S., 2015). Root extract exhibit strong lipoxygenase (break unsaturated fatty acid) and contain 7-hydroxy-6-methoxycyclobrassinone that can inhibit *Mycobacterium tuberculosis*'s growth (Chadchen, N., 2010). Wood extracts have of analeptic, diuretic, paregoric (Pongmuangmul, S., Katosod, J., Wuttiadirek, W., and Vittayanan, S., 2015) and antioxidant properties (Chanthasri, W., Puangkeaw, N., Kunworarath, N., Jaisamut, P., Limsuwan, S., Maneenoon, K., Choochana, P., and Chusri, S., 2018), and can ease

toothache (Pongmuangmul, S., Katosod, J., Wuttiadirek, W., and Vittayanan, S., 2015). *M. siamensis* extract has the ability to kill larvae of *Aedes aegypti* which is dengue and dengue haemorrhagic fever carrier (Nobsathian, S., Bullangpoti, V., Kumrungsee, N., Wongsa, N., and Ruttanakum, D., 2018).

Recently, *M. siamensis* is probably a threatened species due to deforestation and over exploitation. The large trees of this species have been removed from natural habitat to ornamental gardens with high prices. However, it has never been evaluated for conservation status. While, the endemic *M. koratensis* has been found no more than 14 mature individuals without any seedlings. Its habitat is among *Cassava* plantations. Thus, it has been proposed by Srisanga *et al.* (2021) as Critically Endangered (CR), according to the IUCN category (IUCN Standards and Petitions Committee, 2019).

Plant reproductive biology studies of mechanism and process of sexual and asexual reproduction in plants (Sreekala, A. K., 2017) such as seed dispersal, germination capacity, survival rate of seedlings and adults, age at flowering, reproductive lifespan and number of flowers (Koul, M. and Bhatnagar, A. K., 2007). Reproductive biology impacts genetic variation distribution and populations. While, reproductive systems can determine the pattern and extent of population responses to natural selection on many other traits (Holsinger, 2000).

Angiosperms present reproductive flexibility, phyletic heritage, developmental and genetic constraints that can direct changes along particular evolutionary pathways (Barrett, 2013). The processes of gamete development, pollination, endosperm and embryo development and other reproductive features can provide important clues regarding the reproductive constraints of plants that need for conservation. Studies in reproductive biology will also help in developing strategies to preserve the genetic potential of rare species and are crucial for restoration and reintroduction (Koul, M. and Bhatnagar, A. K., 2007; Marbaniang, E. J., Venugopal, N., Verma, S., Raina, R., Khajuria, A., and Gautam, K., 2018). Another way for conservation designed from breeding systems influences genetic diversity within and among populations (Hamrick, J. L. and Murawski, D. A., 1990).

More information about each species' germination ecology can predict germination phenology studies. Seed germination rate is one of key results for species or population survival (Donohue, K., Casas, R., Burghardt, L., Kovach, K., and Willis, C., 2010). Germination rate relates to degree of dormancy loss and germination conditions

(Pritchard, H. W., 2000). Seeds germinate on different degrees of temperature, light and humidity according to each species. All conditions support all parts of fertilized seeds: embryos and protective coats (Kozlowski, T. T. and Gunn, C. R., 1972).

There is no information on reproductive biology of the genus *Maerua* Forssk. in Thailand. It urgently needs to know the natural history of this threatened genus in Thailand, so that we can do conservation management properly. Thus, I intend to study the phenology, breeding system and seed germination of *M. siamensis* and *M. koratensis* for being the basic information to apply for proper conservation management.

1.2 Research Objectives

1). To compare the floral phenology and breeding system of *M. siamensis* and *M. koratensis.*

2). To study morphological characteristics of fruits and seeds *of M. siamensis* and *M. koratensis.*

3). To compare seed germination and dormancy after seed pre-treatment of *M. siamensis* and *M. koratensis.*

1.3 Scope and Limitations

I focused on reproductive biological study to reveal the natural history of the genus *Maerua* in Thailand. Two species of this genus were compared on (1) phenology, (2) breeding system and (3) seed germination. This study was conducted in the fragment forest of the Department of Agriculture Nakhon Ratchasima Agricultural Research and Development Center (DANARDC), Nakhon Ratchasima Province, Thailand for *M. koratensis* and in fragment forest of the Suranaree University of Technology (SUT) for *M. siamensis*. The seed germination was experimented in the Plant Genetic Conservation Project Under the Royal Initiation of Her Royal Highness Princess Maha Chakri Sirindhorn (RSPG), Klong Pai, Nakhon Ratchasima, Thailand.

CHAPTER II
LITERATURE REVIEWS

2.1 Species classification

Maerua siamensis and *M. koratensis* belong to the genus *Maerua* Forssk., Capparaceae. According to (Stevens, P. F., 2017), they are classified as follows.

Kingdom: Plantae

Clade: Traceophytes

Clade: Angiosperms

Clade: Eudicots

Clade: Rosids

Order Brassicales

Family Capparaceae

Genus *Maerua* Forssk.

Species *Maerua siamensis* (Kurz) Pax

M. koratensis Srisanga & Watthana

M. siamensis is a small to medium tree 5-10 m high, sometimes a shrub. Its bark is smooth. Branches are glabrous. Leaves are spiral, 3-5 palmately compound leaves, rarely 4 leaflets. Leaf shape is obovate, oblong or linear, 2-12 cm long, 1-3 cm wide. Leave texture is subcoriaceous or papery. Leaf surface is glabrous on both sides. Leaves base is cuneate or obtuse. Leave apex is emarginate or rounded, with a short mucronate. Leaves nerves are very thin and finely reticulated. Petiole is slender, 1.5-6.5 cm long. Flowers are in terminal or lateral corymb or raceme inflorescence. It is on a short terminal panicle, or being a solitary flower in the axils of the upper leaves. Pedicels are 1.5-5.5 cm long. Bracts are linear, small. Sepals are ovate, 7-10 cm long, 2-3 mm wide. Sepal apex is acuminate, glabrous on both sides, woolly at the margin. Stamens present 9-12. Filaments are robust, 10-15 mm long. Anthers are oblong, 1.5-2 mm long, Anther apex is mucronate. Gynophore is robust, 1.5-2 cm long, and

2 mm long, Anther apex is mucronate. Gynophore is robust, 1.5-2 cm long, and glabrous. Ovary is cylindrical, 1.5-2 mm long and *ca.* 1 mm wide, glabrous. Fruits are ellipsoidal or rounded, 2-2.5 cm long and 1.3 -1.5 cm wide. Fruit stripes are 4.5 - 7.5 cm, slender. Seeds are reniform (Chayamarit, K., 1991).

M. siamensis distributed in Cambodia, Vietnam, Myanmar, Thailand and probably Laos (Figure 2.1). The species is present (and confirmed) in parts of northeastern, central and western Thailand (Figure 2.1). Evergreen forests, mixed deciduous forests and dry dipterocarp forests are the main habitats for *M. siamensis*. They live from 0-400 m elevation. They produce flowers from December-March and fruits between February-April (Chayamarit, K., 1991).

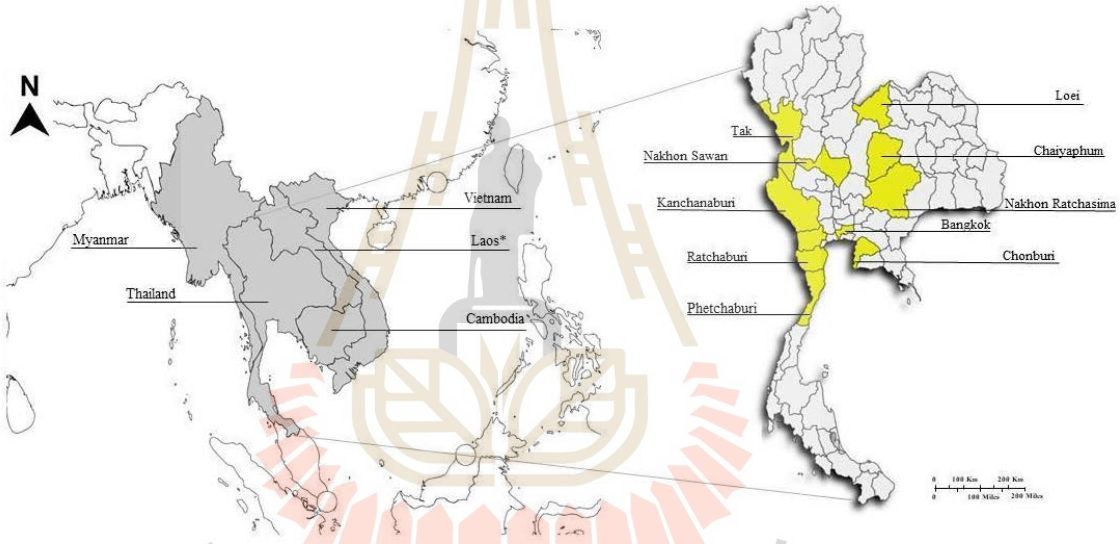

Figure 2.1 *M. siamensis* habitat in country scale and Thailand scale. (Adapted from flora of Thailand 5 (Chayamarit, K., 1991)).

M. koratensis is a woody scandent or subshrub, unarmed. Branches are slender, reddish-brond, glabrous, with lenticels. Leaves are simple and alternate arrangement, having petiolate. Lamina shape is narrowly oblong-lanceolate to lanceolate, (3.5–)5–9(–11) × (0.5–)1–2(–2.5) cm. Leaves texture are subcoriaceous. Leave surfaces are glabrous on both surfaces. Leaf apex varies from acute, mucronate, obtuse to retuse. Leaf margin is entire. Leaf base is broadly cuneate to obtuse. Midrib and lateral veins are flat above and raised beneath. Lateral veins are 5–7 pairs, distinct on both surfaces. Petioles are glabrous, 1.5-7 mm long, canaliculate with crenulate edges. Stipules are triangular, ca. 0.5 mm long. Inflorescences consist of 2-5 flowered in terminal lax raceme, or solitary in the axils of the upper leaves. Flowers are actinomorphic and pedicellate. Pedicels are glabrous, 13–40 mm. Receptacle is infundibular to narrowly campanulate, 3-4 mm long, 3-3.5 mm wide at mouth, with longitudinal ribs, glabrous

or sparsely puberulous. Floral discs are 2.5–3 mm long, pale green, glabrous. Floral tube is ca. 1 mm long, lobes 4, 1.5–2 mm long, laciniate at apex. There are 4 sepals. Sepal shape is elliptic, with distinct median nerve. Sepal shape is 15–17 mm long and 5–6 mm wide (7–8 mm wide when flattened). Sepal color is pale green. Sepal surface is glabrous. Sepal apex varies from acute to shortly acuminate. Sepal margin is shortly woolly. There are 4 petals. Petal shape is elliptic to obovate, with short stalk at base. Petal size is, 8–9 mm long and 3–4 mm wide. Petal color is pale greenish-white. Petal surface is glabrous. Petal apex is acuminate. Petal margin is slightly and irregularly crenulate towards apex. Androgynophore is 2–5 mm long, glabrous and exceeding the receptacle by 1–1.5 mm. Torus is ca. 2.5 mm wide. Stamens are 33–38. Filaments are 20–22 mm long, white, and glabrous. Anthers is oblong, subbasifixed, ca. 2.5 × 1 mm. Its color is pale green, dehiscing by longitudinal slits. Gynophore is 13–17 mm long, white, and glabrous. Ovary is oblong-cylindrical, 4.5–5 mm long, ca. 1 mm diam and consist of 1-locular. Ovary color is pale green. There are 2 placentas. Ovule number is up to 10. Stigma is capitate, green, sessile. Fruits are narrowly cylindrical, torulose to moniliform, 1.5-4.5 cm long, 0.6-1.1 cm diam., yellow when mature and indehiscent. Fruit surface is faintly colliculate, glabrous. There are 1-7 seeds, 6.5–8 mm long. Seed color is, black, covered with pulp (Srisanga, P., Muangsan, N., Choopan, T., Thangthong, J., Pratcharoenwanich, R., and Watthana, S., 2021).

M. koratensis was recently described and named in 2021 by Srisanga and Watthana (Srisanga, P., Muangsan, N., Choopan, T., Thangthong, J., Pratcharoenwanich, R., and Watthana, S., 2021). It is found as endemic to the eastern part of Thailand, in Nakhon Ratchasima or Korat Province (Figure 2.2). It usually grows in mixed-deciduous forest and disturbed forest near by cassava plantation at 200-280 m. from sea level. It flowers during January-March and fruits during February-April.

2.2 Floral phenology

The phenology of plants is the study of the leafing, flowering, fruiting and seedling stages of plants in each period of time (Fenner, M., 1998). It involves the study of the response of living organisms to seasonal and climatic changes of the environment in which they live (Koul, M. and Bhatnagar, A. K., 2007). The floral phenology and morphological structure are specific for sexual production and evolutionary ecology (Dafni, A., 1994). Plant phenology responses to rapid global climate change and expected relationships of plants and animals that depend on period and resources (Koul, M. and Bhatnagar, A. K., 2007). Comparing floral

characteristics among different Capparaceae species showed variation in the family (Table 2.1).

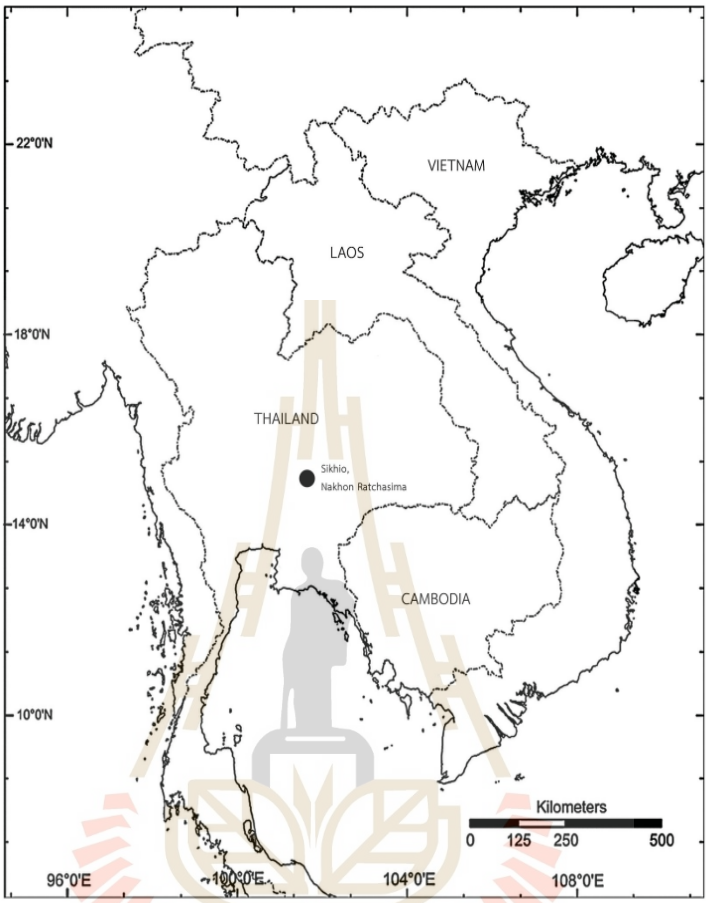

Figure 2.2 The distribution map of *Maerua koratensis* (Srisanga, P., Muangsan, N., Choopan, T., Thangthong, J., Pratcharoenwanich, R., and Watthana, S., 2021).

2.3 Breeding system

Breeding system influences evolution and genetic diversity with design and control genotype for a long duration in the wild state (Andrus, C., 1963). Breeding systems affect floral structure, morphological character and genetic set-up. Self-crossing may differ from outcrossing such as fewer and smaller flowers, fewer pollen grains, less scent and nectar (Dafni, A., 1994). In pollination biological study, the seed production derived from different pollination rate and type can explain the mechanisms of gene flow within and between populations (Dafni, A., 1994). This depends on sexual system as defined by (Dafni, A., 1994) as follows:

1) Hermaphroditic : individual plants have only bisexual flowers.
2) Monoecious : individual plants have male and female organs (flowers bisexual or unisexual).

3) Andromonoecious : individual plants have bisexual and male flowers (male flowers dominant).

4) Gynomonecious : individual plants have bisexual and female flowers (female flowers dominant).

5) Polygamomonoecious : individual plants have bisexual flowers, male and female flowers.

The seed production is derived by pollination in the same flower, self-pollination occurring, then self-fertilization or autogamy ensures. If pollination from the different individuals lands on the stigma of different flowers of different individuals, seed set means the cross-pollination occurs, then cross-fertilization or allogamy and also known as xenogamy or out breeding happens (Simpson, M. G., 2019; Willmer, P., 2011). Outbreeding is the phenomenon resulting in genetic exchange (Simpson, M. G., 2019).

Boscaiu, M. and Güemes, J. (2001) reported self-pollination treatments of *Cistus carthaginensis* that this species has inefficient fruit and seed production. Fruits were not produced with hand self-pollination and geitonogamy treatments. In cross-pollinations, it showed high fruit production more than 80%, with a seed production higher than 95%. Thus, it is a allogamous or xenogamous species.

The breeding systems of the genus *Maerua* has been reported in 2021 by Aluri, J. S. R. and Samareddy, S. (2021). They studied the pollination ecology of the *M. apetala* (Roth) M. Jacobs in the Ghats Forest, India. It is an obligately xenogamous species with a mix of the entomophily and zoophily, due to having supporting floral characters such as its flowers are large size, scent production, high number of exerted stamens, morning anthesis, massive pollen production and sufficient amount of nectar. Bee is the geitonogamy promotor. The bird is a pollinator for xenogamy. However, sunbirds are the nectar robbers. Barochory mode, by gravity alone, is typically fruit dispersion. Moreover, the seed germination in natural condition is rarely found indicating that this species is on the verge of extirpation.

2.4 Morphological characteristics of fruits and seeds

The morphological characteristic studies could confirm the type of fruit and seed (Grygorieva, O., Abrahamová, V., Karnatovská, M., Bleha, R., and Brindza, J., 2014). The information of fruit and seed traits are also used as basic phylogenetic studies to determine crop diversification patterns (Freudenstein, J. V. and Chase, M. W., 2015). In plant breeding, the results of characterization can be used as basic information about

diversity and classification that can show the level and relationship between cultivars (Hartati, S. and Muliawati, E. S., 2020).

Baskin, C. and Baskin, J. M., (2014) presented a key for type of seeds as in the Table 2.2. They classified and constructed the key by using the endosperm, embryo and cotyledon appearance and shape, which are broad, capitate, lateral, peripheral, undifferentiated, rudimentary, linear underdeveloped, spatulate underdeveloped, linear fully developed, spatulate fully developed, investing, bent and folded.

Hugh, H. I., Jocelyn, C. H., Theodore, S. C., and Kenneth, J. S., 2011- described fruit and seed of Capparaceae and depicted the macro morphology of *Crateva tapia* L. (Figure 2.3). They described the fruits and seeds of Capparaceae. "*Fruit is fleshy berry, globose to elongate, without a false septum but sometimes with endocarp intrusion and then axile placentation. Seeds are large, 5-15(-30) mm spherical to ovoid or ellipsoid, straight or broadly incurved to reniform-conduplicate. Testa is smooth, thick and hard to very thin, slippery and easily removed, often covered by a fleshy-oily, funicular aril or by a hair-infiltrated sarcotesta, or immersed in the red, orange, or cream to white endocarp pult. The testa is often shallow or not at all invaginated into the embryo (deeply so in Crateva, Capparis* spp.*), the two claws of the seed not conjoined by distinct cleft membraned. The embryo is green to ivory-white, variable, mostly conduplicate, with cotyledons incumbent, but often foliaceous, much enlarged and variously convoluted on inside the other and sometimes around the radicle. The germination type is epigeal. The cotyledons are often large, green and leaflike, or sometimes ivory or white and very thick and food storing, rarely quite unequal with one suppressed".*

Table 2.1 Floral phenology of each species in Capparaceae.

Species Name	Flower type	Description	Location	Ref.
Capparis herbacea	Male with green gynophore and perfect flower with yellow gynophore in difference length	Growth in mid-April, in summer (likely June or July) flower buds form in May-August.	Georgia	Shakarishvili, N. and Osishvili, L., 2013
Cleome spinosa	Three floral types: pistillate, staminate and hermaphrodite flowers. Trimonoecious (male, female and bisexual flowers on same plant), andromonoecious (bisexual and male flowers on same plant), and pistillate individuals	Inflorescences produce 37 flowers with 3 open flowers per day approximately. The flower morph is raceme, bilateral symmetry, with unguiculate white petals, extrose anthers, vinaceous filaments, and the gynoecium is elevated by a gynophore. The adult flowers have four sepals, four petals.	Brazil, University of Heidelberg	Erbar, C. and Leins, P., 1997
Polanisia dodecandra	Perfect flowers	The adult flower has four sepals, four petals and 9-18 stamens (all stamens are fertile). The superior ovary is bicarpellate.	University of Heidelberg	Erbar, C. and Leins, P., 1997
Cleome violacea	Perfect flowers	The adult flower has four sepals, four petals and six stamens in a single row. The superior ovary is bicarpellate.	University of Heidelberg	Erbar, C. and Leins, P., 1997

Table 2.2 Key for types of seeds presented by Martin, A. C. (1946) and Baskin, C. and Baskin, J. M. (2014).

Endosperm generally present and definitely starchy (endosperm lacking in certain Cactaceae and in *Salicornia*, *Sarcobatus* and *Salsola spp*., which have spirally coiled embryos); embryo peripheral or partly so in relation to endosperm

- Embryo globular, broader than high, seed globular..... **BROAD**
- Embryo capitate or turbinate ..... **CAPITATE**
- Embryo basal-lateral or lateral, evident from the exterior. ..... **LATERAL**
- Embryo evidently dicot (except in Claytonia and Abronia spp.), elongate or large ..... **PERIPHERAL**

Endosperm, if present, not definitely nonstarchy except among a few linear-embryoed forms; embryos not peripheral

- Embryo not differentiated into organs... ..... **UNDIFFERENTIATED**
- Embryo differentiated into organs
  - Embryo small in relation to endosperm/seed length
    - Embryo as wide as long ..... **RUDIMENTARY**
    - Embryo longer than wide..... **LINEAR UNDERDEVELOPED**
    - Embryo spoon-shaped ..... **SPATULATE UNDERDEVELOPED**
  - Embryo large in relation to endosperm, or endosperm lacking
    - Cotyledon(s) not expanded, embryo longer than wide..... **LINEAR FULLY DEVELOPED**
    - Cotyledons (2) expanded and wider than the stalk
      - Embryo erect
        - Stalk not invested by cotyledons or only slightly so. ..... **SPATULATE FULLY DEVELOPED**
        - Stalk invested by cotyledons for half its length or more..... **INVESTING**
      - Embryo jackknife-bent ..... **BENT**
      - Embryo with folded cotyledons..... **FOLDED**

**Perisperm present in some Cactaceae, e.g., Opuntia spp. (Bregman and Bouman, 1983). (from Baskin and Baskin 2007b).*

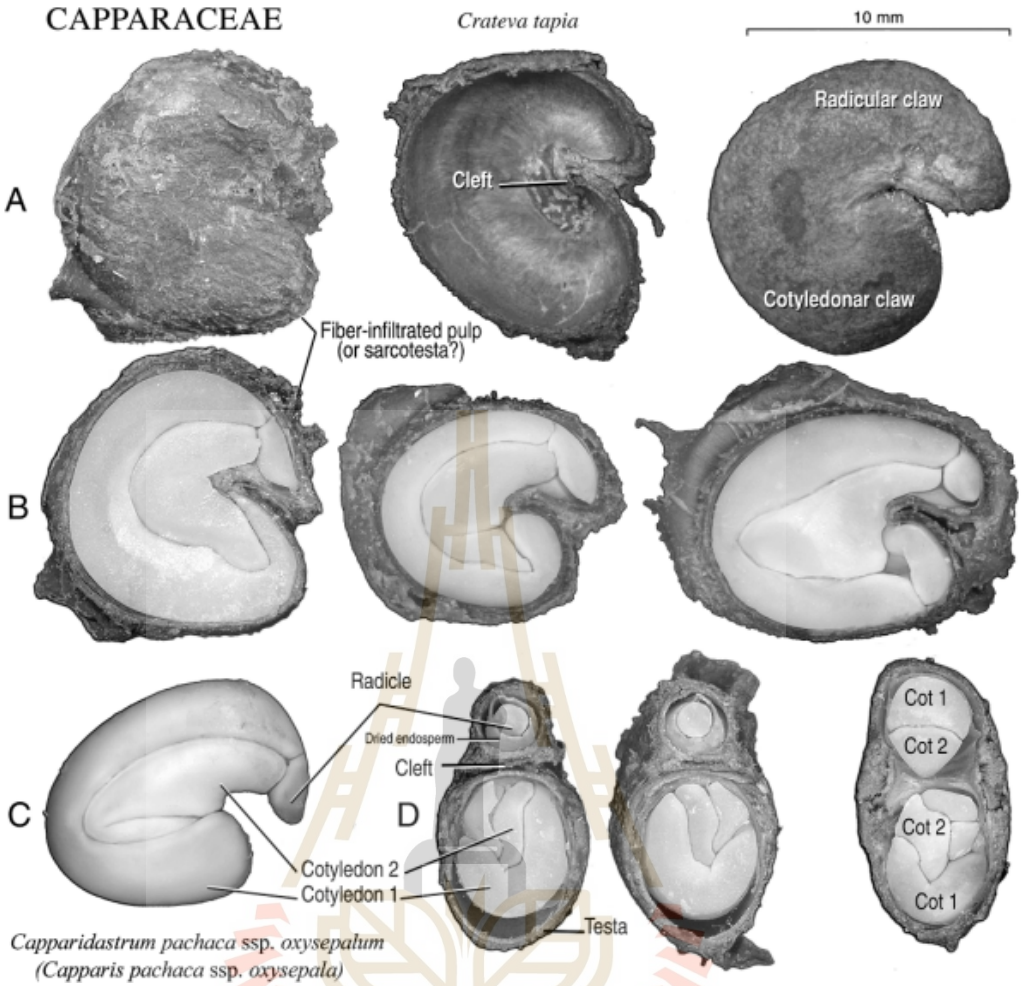

Figure 2.3 Seed morphology of *Crateva tapia* L. A—External seeds: nonuniform shaped, mushy, densely hair-seed coats. B—Longitudinal sections: taper sharply differentiated from the cotyledons; two asymmetrical cotyledons are connected to radicle. C—Embryo, with seed coat removed. D— Cross-sections of seeds: two halves of seed sectioned through the radicle and the J-shaped cotyledons, to show the J-shaped cotyledon (Hugh, H. I., Jocelyn, C. H., Theodore, S. C., and Kenneth, J. S., 2011).

2.5 Seed germination

Knowledge of seed germination is used for success on restoration in each forest. The variations such as soil moisture, light, temperature, nutrients and intensity of predation, significantly affect the seed and seedling traits in each species.

Meyer, S. E. and Monsen, S. B. (1991) did experiments in mountain big sagebrush seeds germination response to a temperature in autumn, varied environmental context at the collection site. Seed germinated slowly in winter, whereas germinated rapidly and completely in mild winters. Slow germination may become dormancy for prevention in autumn conditions. The seeds do not likely persist in optimum moisture and temperature in a few days, especially at the soil surface but the seeds require light. Buried seeds were safeguarded against autumn germination at cold winter sites. At warm winter sites, surface-lying seeds would germinate quickly as soon as moisture became non limiting, permitting establishment prior to the onset of spring drying.

Propagation from seed is a viable method for the ex-situ conservation of *Physoplexis comosa* and *Primula glaucescens*. *Physoplexis* has more stringent requirements for germination (i.e., a sterile environment and phytohormone supply) but *P. glaucescens* germinated in non-sterile conditions and without phytohormones which will allow widespread propagation by regional parks and botanic gardens (Cerabolini, Andreis *et al.* 2004).

The effects of temperature (5, 10, 15, 20, 25, 25/10 and 20/10°C), irradiance and gibberellic acid (250 and 500 ppm) on seeds germination show the significant effect of temperature on seed germination. In particular, seed germination for *Phyllolepidum rupestre* (Brassicaceae) and *Crepis magellensis* (Asteraceae) was 70.58 ± 3.75 % and 97.30 ± 3.13% at 20°C, respectively (Di Cecco, V., Di Musciano, M., Gratani, L., Catoni, R., Martino, L., and Frattaroli, A. R., 2017).

2.6 Seed dormancy

Seed dormancy of most seeds has a resting stage between development and germination. This resting stage begins with seed and fruit ripening, seed dispersing until external conditions (water, temperature, oxygen, and light) influences the embryo to germinate. Environmental problems cause a lack of seed germination. Seed dormancy relates to plant propagation. Seed dormancy sometimes is disadvantageous and at other times advantageous (Kozlowski, T. T. and Gunn, C. R., 1972). Baskin, C. and Baskin, J. M., (2014) presented the types of dormancies which are non-dominant, physiological

epicotyl dormancy, physiological regular dormancy, physiological epicotyl dormancy, combinational dormancy, morphological dormancy, morphophysiological dormancy, specialized morphological and specialized morphophysiological dormancy (Table 2.3).

Seed dormancy type consists of orthodox and recalcitrant. Orthodox seeds have a constant ability to germinate in low humidity (2-5%) and low temperatures, such as peas, corn, tomatoes (Elliott, S., Navakitbumrung, P., Kuarak, C., Zangkum, S., Anusarnsunthorn, V., and Blakesley, D., 2003). Recalcitrant seeds are sensitive to desiccation and low temperatures. The seeds must germinate in humidity lower than 60-70% including avocado, mango, mangosteen, lychee, cocoa, and aquatic plants (Elliott, S., Navakitbumrung, P., Kuarak, C., Zangkum, S., Anusarnsunthorn, V., and Blakesley, D., 2003).

Table 2.3 A dichotomous key to type of dormancy presented by (Baskin, C. and Baskin, J. M., 2014).

1. Embryo differentiated and fully developed	2
2. Seeds imbibe water	3
3. Root emergence occurs within about 4 wk (usually in a few days)	4
4. After root emergence, shoot emergence occurs within a few days	NONDORMANT
4. After root emergence, shoot emergence is delayed 34 wk or more	PHYSIOLOGICAL EPICOTYL DORMANCY
3. Root emergence requires more than 4 wk	5
5. After root emergence, shoot emergence occurs within a few days	PHYSIOLOGICAL REGULAR DORMANCY
5. After root emergence, shoot emergence is delayed 34 wk or more	PHYSIOLOGICAL EPICOTYL DORMANCY
2. Seeds do not imbibe water	6
6. Scarified seeds become fully imbibed (usually in 1 day) and germinate within about 4 wk (usually in a few days)	PHYSICAL DORMANCY
6. Scarified seeds become fully imbibed (usually within 1 day) but do not germinate within about 4 wk	COMBINATIONAL DORMANCY
1. Embryo undifferentiated or if differentiated it is underdeveloped	7
7. Embryo not differentiated	8
8. After seed dispersal, embryo differentiates and grows in imbibed seed	9
9. Seeds germinate within about 4wk	MORPHOLOGICAL DORMANCY
9. Seeds do not germinate within about 4 wk	MORPHOPHYSIOLOGICAL DORMANCY
8. After seed dispersal, embryo never differentiates into a root-shoot axis	10
10. Seeds germinate within about 4 wk	SPECIALIZED MORPHOLOGICAL DORMANCY
10. Seeds do not germinate within about 4 wk	SPECIALIZED MORPHOPHYSIOLOGICAL DORMANCY
7. Embryo differentiated but underdeveloped	11
11. After seeds are placed on a moist substrate, the embryo grows, and seeds germinate within about 4 wk	MORPHOLOGICAL DORMANCY
11. After seeds are placed on a moist substrate, the embryo does not grow, and seeds do not germinate within about 4 wk	MORPHOPHYSIOLOGICAL DORMANCY

CHAPTER III
METHODOLOGY

3.1 Sampling collection

Three individuals of the *M. siamensis* from the forested fragment in Suranaree University of Technology (SUT), Nakhon Ratchasima Province, Thailand and two individuals of the *M. koratensis* from the forested fragment in the Department of Agriculture Nakhon Ratchasima Agricultural Research and Development Center (DANARDC), Nakhon Ratchasima Province, Thailand, were selected for comparative studies. The methodology in this study is presented in Figure 3.1.

3.2 Floral morphology

I carefully observed and classified the flower forms of *M. siamensis* and *M. koratensis* in the field. The pictures of different forms of the flowers were taken to compare and presented. Then, I reviewed the previous literature especially on the floral morphology of the genus in Capparaceae and Cleomaceae for comparison and discussion.

3.3 Floral phenology

The light weight white 1 cm x 3 cm paper tags were used to tie carefully on each inflorescence for avoiding floral destruction during the study (Figure 3.2). I sampled 60 tags from 3 trees (20 tags from each tree) for *M. siamensis.* For two individuals *M. koratensis* were sampled with the same methodology as above in which 20 tags per individual. During January - March 2021, I observed and noted the floral change every day until the flower withering.

3.4 Breeding system

I did the bag experiment to exclude insects with fine nylon mesh covering flowers and inflorescences (Figure 3.2). Thirty flowers of *M. siamensis* and 30 flowers of *M. koratensis* covered with 6 cm x 10 cm black nylon mesh and used light thread to tie carefully on each pedicel to protect insect and for checking the fruit set in a flower. For testing the fruit setting in the same inflorescence or geitonogamy, 4 branches consisting of 499 flowerets were bagged with a 15 cm x 30 cm black nylon mesh. For testing the geitonogamy in *M. koratensis* 7 branches consisting of 20 florets were bagged by the nylon mesh, as same size as above. I collected all data for a total of 45 days for the fruit set.

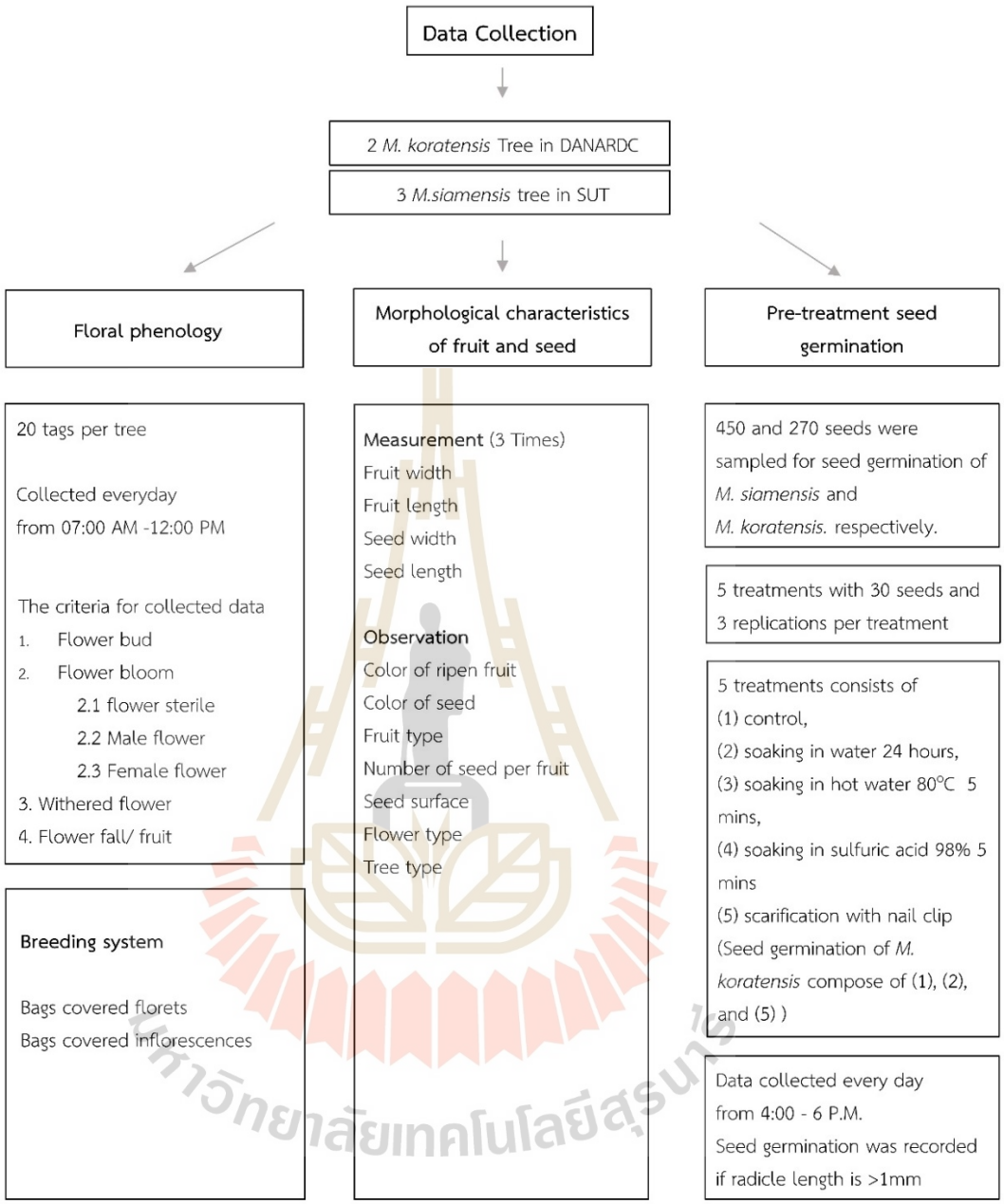

Figure 3.1 Flow chart of all experiments in this study.

Figure 3.2 Experimental process of floral phenology and breeding system**.** A—Researchers tied paper tags carefully in each inflorescence, B—paper tags were tied with inflorescence. C,D—*Maerua sp.* covered with nylon mesh for counting the number of fruit sets.

3.5 Fruit and seed traits

To compare the fruit and seed morphological characters, I carefully took pictures of fruit and seed of *M. siamensis* and *M. koratensis*. Seed weight was performed by measurement from 100 seeds by analytical balance with 3 replicates. The length and width of 100 seeds and 100 fruits of *M. siamensis* and *M. koratensis* were measured by Vernier caliper 3 times. I also counted the number of seeds per fruit with 100 fruits. The description and descriptive statistics, as well as illustration are given (Figure 3.2).

3.6 Seed germination and dormancy

3.6.1 Seed collection and storage

About 300 *M. siamensis* ripened fruits were collected from SUT. Two hundred *M. koratensis* ripened fruits collected from Klong Pai subdistrict. Fruits were immediately washed with tap water and then dry at room temperature. Sarcotesta was removed from the seeds by scrubbing with a towel. All seeds were sealed in polyethylene bags and transferred to the RSPG research lab for storage in the refrigerator (5^{o}C) before started the seed germination experiment in 7-14 days. One reason for using seeds shortly after storage was that they might change their germination responses during long-term dry storage at room temperature (Baskin, C. C. and Baskin, J. M., 1998).

3.6.2 Seed germination

Before performing the pre-treatment of seed germination test, all seeds were cleaned for reducing the bacteria and fungi. The seeds were soaked with Hydrogen peroxide (H_2O 10% v/v for 10 minutes, followed by soaked in Clorox 10% v/v for 10 minutes. Then, I used Phthalimide (Captacide 50) 1 gram per liter for 5 minutes to prevent fungi growth.

The pre-treatment of seed germination test was conducted in Completely Randomized Design (CRD) with 3 replicates containing 30 seeds, total 90 seeds in each treatment (Table 3.2). 450 seeds of *M. siamensis* were sampled for seed germination with 5 treatments (Table 3.1) i.e. (1) untreated seed as control, (2) soaking in water 24 hours, (3) soaking in hot water 80^{o}C for 5 mins, (4) soaking in 98% sulfuric acid for 5 mins, and (5) scarification with nail clip. The number of seeds of *M. koratensis* was not enough for all experiment, the treatment of *M. koratensis* determine by preliminary

results of *M. siamensis.* 270 seeds of *M. koratensis* were sampled for seed germination with 3 treatments i.e. (1) untreated seed as control, (2) soaking in water 24 hours, and (3) scarification with nail clip (Figure 3.3).

Thirty seeds were placed in plastic boxes (19 cm x 28 cm x 5.5 cm) with four layers of tissue paper (23 cm x 28 cm), moistened with distilled water. All experiments were kept at a temperature of 28 – 34°C in RSPG, Nakhon Ratchasima. During April - June 2020, I collected data daily at the same time started from 4-6 P.M. for 28 days. Seed germination was recorded if radicle length >1 mm. The germination indices (Czabator, F. J. 1962; Ellis, R. and Roberts, E. 1981; Rusdy, M. 2017) measured were:

1) Germination percentage

$$GP = \frac{\text{total number of germinated seeds}}{\text{total seeds}} x100$$

2) Mean daily germination (MDG) (calculated by Gordon, 1973)

$$MDG = \frac{\text{Final germination } (\%)}{\text{total number of days of test}}$$

3) Germination speed

$$GS = n1/d1+n2/d2+n3/d3+.... +n28/d28$$

where: n is number of germinated seeds

d is number of days

4) Mean germination time (MGT)

$$MGT = \frac{\sum nTi}{\sum n}$$

where Ti is the number of days from the beginning of the experiment

n is the number of newly germinated seeds on day Ti.

3.7 Statistical analysis

Collected data was input to Microsoft Excel with careful checking. Then, I analyzed the effect of different treatments on germination by one-way analysis of variance (ANOVA) along with the Least Significant Difference (LSD) test at $p<0.05$. The assumptions of ANOVA were used in the Duncan Post Hoc test and Turkey. Means and standard errors of germination percentages and viability tests were calculated. All statistical analyses were carried out using SPSS (version 20).

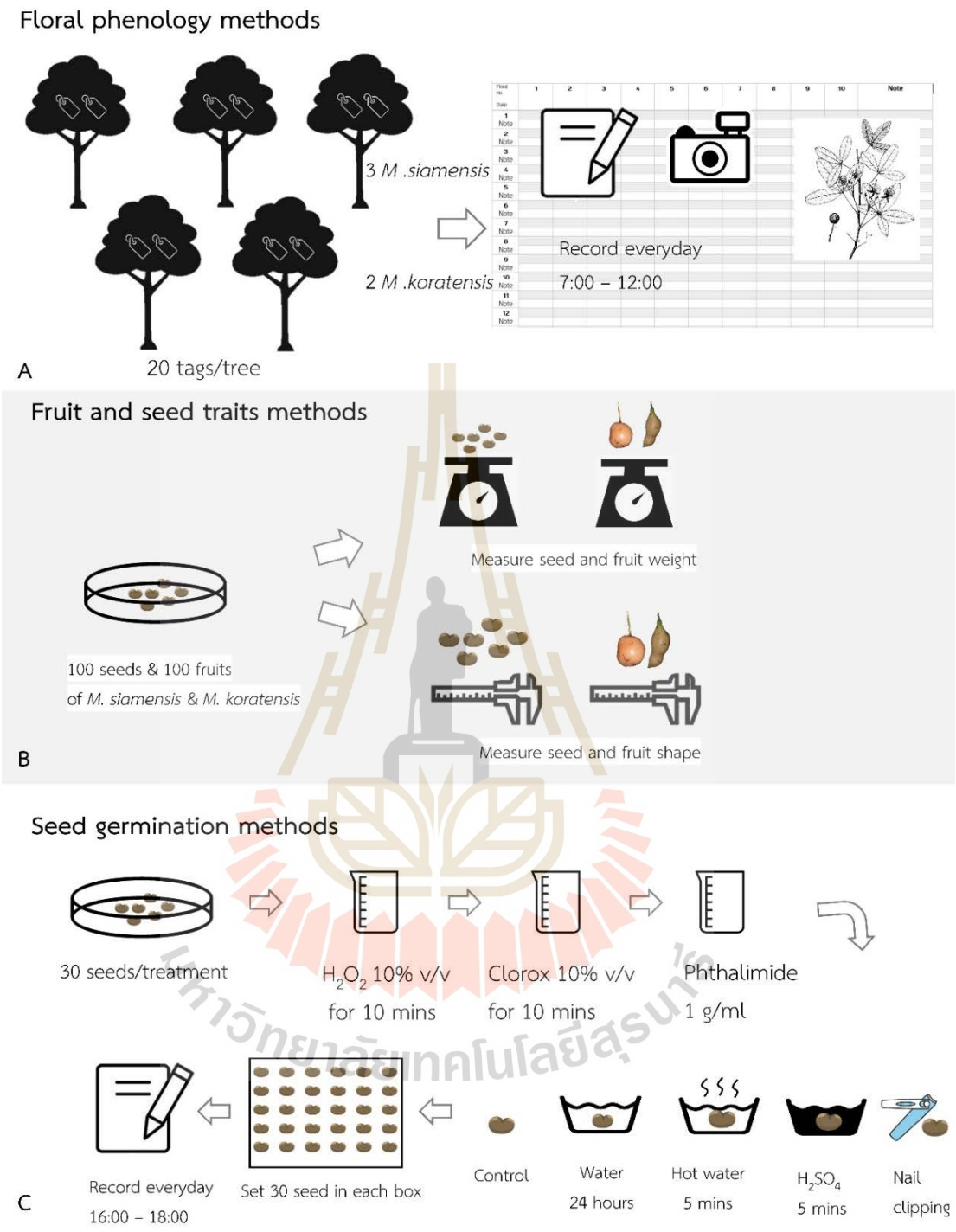

Figure 3.3 Methodology of floral phenology, fruit and seed traits and seed germination.

Table 3.1 The seed germination treatments in this study and the descriptions.

Seed germination treatment	Description
Control	Seeds were not prepared before the germination test.
Soaking in water	Seeds were soaked in normal tap water in a bottle glass and kept in a dry place at a temperature of *c.* 25°C. The soaking period was 24 h.
Soaking in hot water	Seeds were soaked in hot water in a beaker at a temperature of 80°C. The soaking period was 5 minutes.
Soaking in sulfuric acid	Seeds were soaked in sulfuric acid (98%) in a beaker at room temperature. The soaking period was 5 minutes.
Scarification by nail clip	The small part of the seed coat opposite the micropyle was removed with a nail clipper.

Table 3.2 Five pre-treatments in this study showing the number of seeds for each treatment.

Treatments	*M. siamensis*	*M. koratensis*
Control	30 seeds	30 seeds
Soaking in water	30 seeds	30 seeds
Soaking in hot water	30 seeds	Seed not enough
Soaking in sulfuric acid	30 seeds	Seed not enough
Scarification by nail clip	30 seeds	30 seeds

CHAPTER IV
RESULTS AND DISCUSSION

4.1 Floral morphology

The comparative study of flora trait of the genus *Maerua* in Thailand showed that there are different forms of flower in the species level. *M. siamensis* is a polytypic flower, consisting of two types of flower traits (Figure 4.1). It is monoecious with hermaphrodite, female and male flowers in the same plant. Hermaphrodite or perfect flowers consist of male and female reproductive structures fertile in the same flower (figure 4.1A). Male flowers consist of male reproductive structure, while female reproductive structure is not fully developed or abnormal (Figure 4.1B-C). The cross section of aborted ovary in the male flower compare with fertile ovary is shown in Figure 4.2. It is so clear that there is no ovule formation. Female flowers consist of fertile pistil with sterile stamen (Figure 4.1D). According to the flowering plant's sexual systems proposed by Dafni, A. (1994), this species is part of polygamomonoecous. However, this species is dominant of hermaphrodite flowers (44.1%), with few male flowers (5.8%), male flowers (0.7%) and sterile and non-developed flowers (49.5%). The proportion of floral type of *M. siamensis* shown in figure 4.3. Those sterile flowers are withered before anthesis and fertilization. Thus, none of them were developed into fruit sets. The different types of sterile flower shown in figure 4.1.

From this study, it can be concluded that *M. siamensis* shows 3 types of flowers (Perfect flower, male flower and female flower), different from *M. koratensis* having just one floral type (perfect flower). Compared to other genera in Capparaceae, *Capparis herbacea* have 2 floral types such as male flower and perfect flowers (Shakarishvili, N. and Osishvili, L., 2013). *Cleome gynandra* is functionally hermaphrodite with long gynoecium and *Cleome viscosa* is functionally hermaphrodite with long, medium and short gynoecium (Aluri, J. S. R. and Rani, D., 2016).

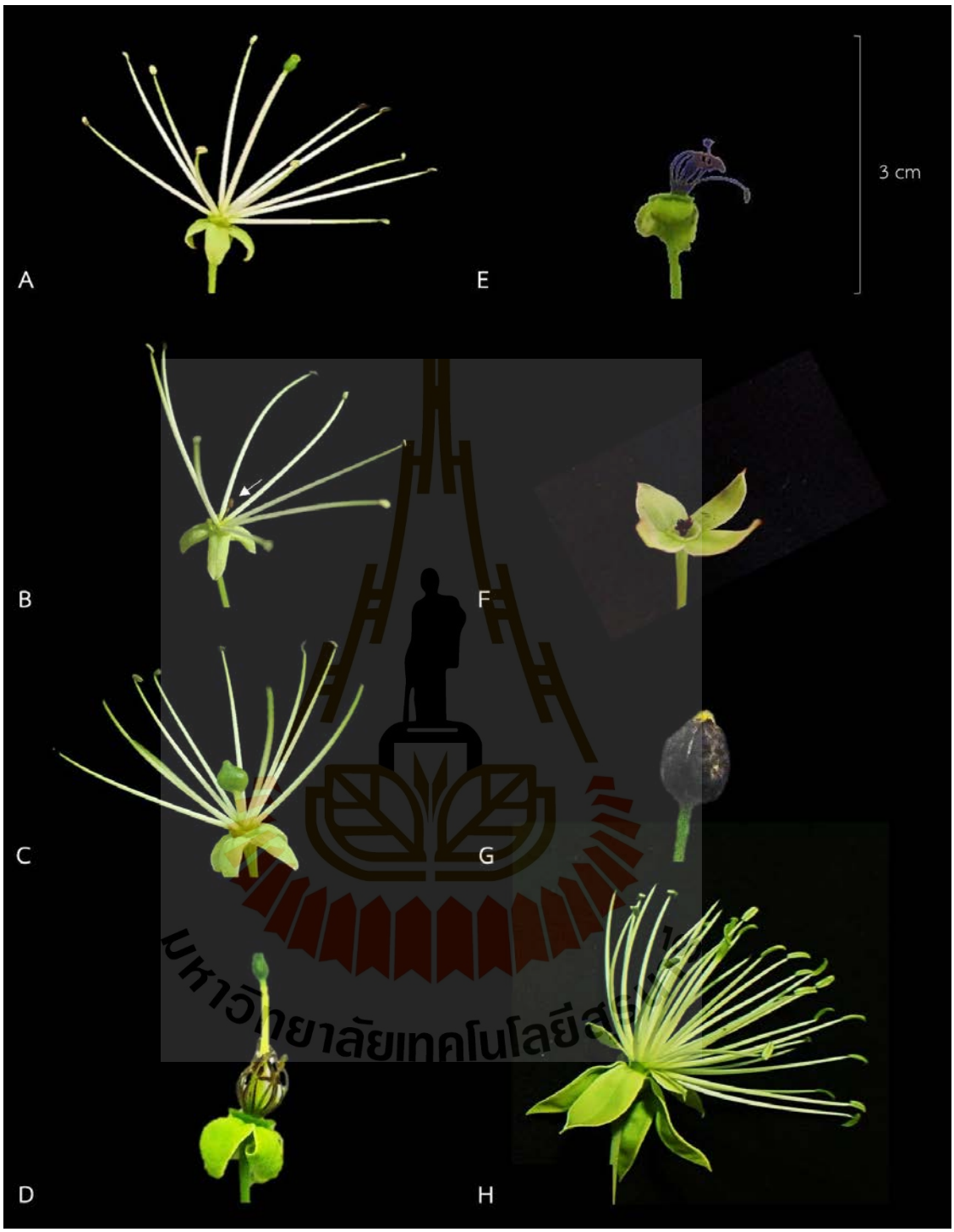

Figure 4.1 Floral traits of *Maerua siamensis* and *M. koratensis.* A-G: *M. siamensis*; A: perfect Flower. B-C: male flower with an abnormal ovary. D-G: different undeveloped flowers or sterile flower in *M. siamensis*. H: *M. koratensis*: perfect flower.

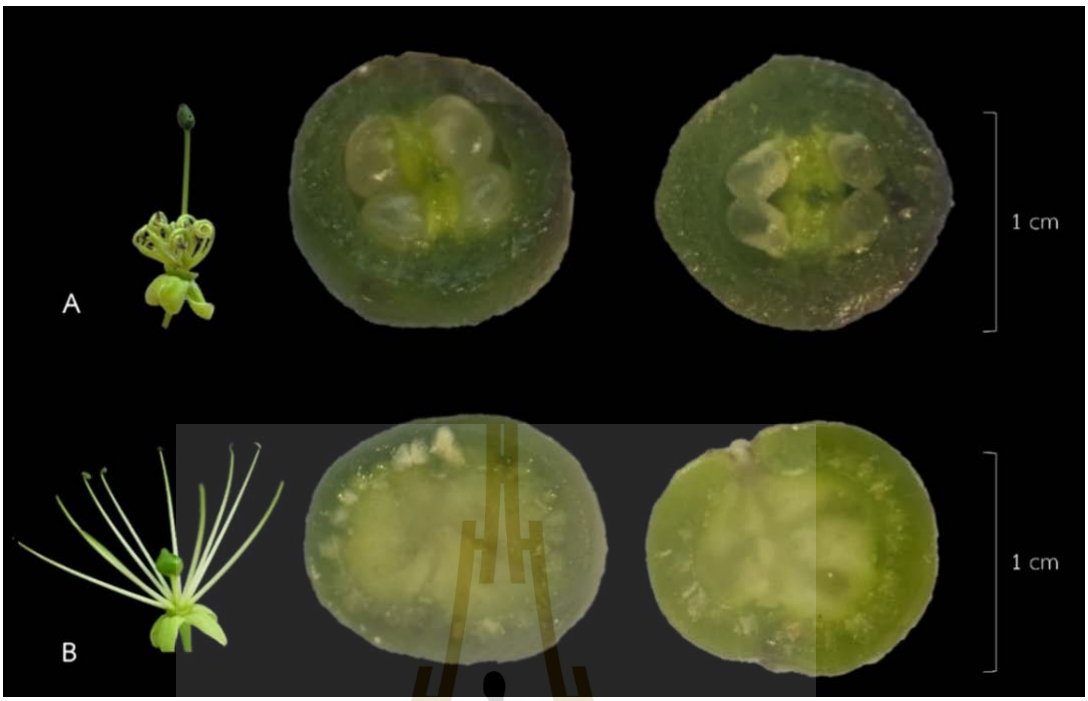

Figure 4.2 Placenta in perfect flower and male flower of *M. siamensis*.

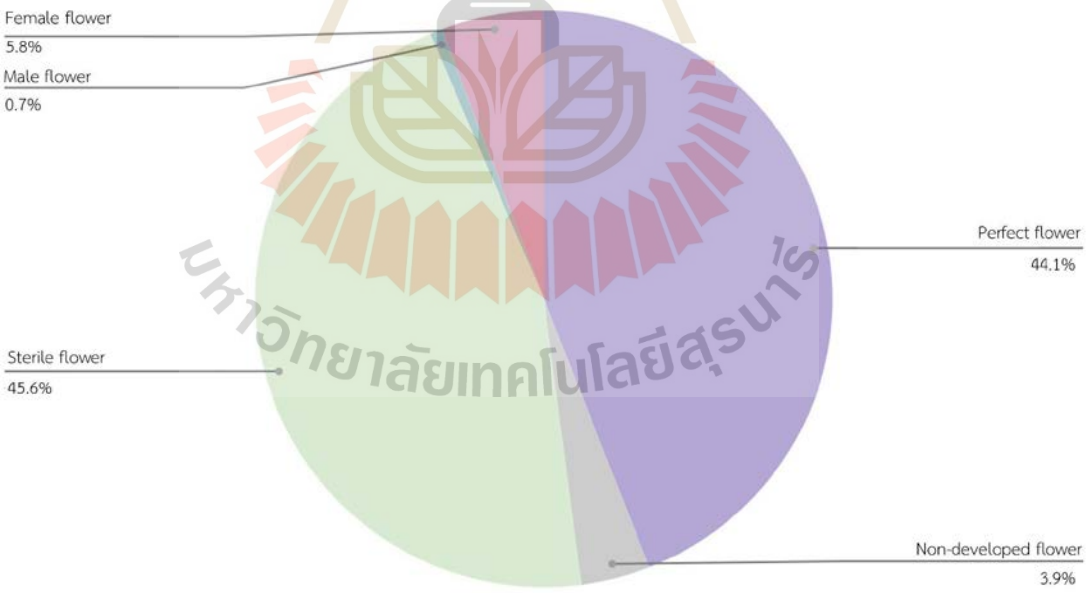

Figure 4.3 The proportion of floral type of *M. siamensis.* In 1505 florets of *M. siamensis* compose of 3 floral type such as perfect flower (44.1 %), male flower (0.7%) and female flower (5.8%). Non-denelopmet flower found 3.9% and sterile flower 45.6%.

4.2 Floral phenology

From field observation, I definded the floral development into 5 stages, which are:

1) *Floral buds*, sepal cover all of flower.

2) *Flower starts to open*, coiled filament and strength style

3) *Flower full open*, stretch long filament and long style,

4) *Flower starts to withered*, recurved filament and long style,

5) *Flower completely withered*, both stamens and style withered and fallen from the tree.

The floral development stages of *M. siamensis* and *M. koratensis* have shown on Figure 4.4. The comparative flower development period of *M. siamensis* and *M. koratensis* are shown in Table 4.1. The blooming period of *M. siamensis* is December-March longer than *M. koratensis* bloomed in December-January. The significantly different period of both species include Flower opened until flower withered .Blooming period (Stage 2-5). While Flower bloomed (Stage 3) of both species mostly in 1 day.

Figure 4.4 Floral development stages of A: *M. siamensis* and B: *M. koratensis*. Including: 1 = Floral buds, 2 = Flower start to open, 3 = Flower full open, 4 = Flower start to withered, 5 = Completely withered flower.

Table 4.1 Flower development period of *M. siamensis* and *M. koratensis*. * indicated as statistic significance, p > 0.05.

Flower development stages	*M. siamensis*	*M. koratensis*	Mean differentiation between two species
Flowering period (Stage 2-5)	December- March	December-January	-
Flower opened until flower withered days (Stage 2-5)	12.85 ± 0.14 Days	10.07 ± 0.47 Days	*
Flower start to open to stamens anthesis (Stage 2-3)	4.45± 0.10 Days	4.49 ± 0.24	*
Flower bloomed (Stage 3-4)	1.15± 0.16 Days	1 Day	-
Withered flower (Stage 4-5)	1.15±0.39 (Mostly1)	1.00±0.00	*
Fruit period	February - May	January - June	-
Natural fruit set percentage	26 fruits (4.3% of 601 perfect flowers or 1.7% of all flower types (1505 flowers))	2 fruits (5.00% of 40 perfect flowers)	-

4.3 Breeding system

Both species have no fruit set when protecting the insect implying that these species need vector or insect to pollinate in each individual species. However, when I bagged many flowers in both species in the same bags, it's has shown that some bags revealed fruit setting. In *M. siamensis* had fruit in all 4 bags (2, 2, 4 and 1 for each bag), while in *M. koratensis* had fruit in all 7 bags (2, 3, 2, 2, 3, 2 and 2 for each bag) (Figure 4.2). It indicated that geitonogamy (set fruit derived by male and female from the same individual) occurs without animal in both species. Showing some part of self-compatibility. These results also explain that the anther and stigma function in a different time. It can be concluded that both species are not apomixis, fruit set without pollination because there was no fruit when the flower individually bagged. Unfortunately, I have not yet tested the hand cross-pollination and self-pollination tests. It is needed for further study to proof the breeding system of these two species in Thailand.

The recently study by (Aluri, J. S. R. and Samareddy, S., 2021) on the pollination ecology of *M. apetala* showed that it is pollinated by bees and birds pollination. Breeding system of *M. apetala* is a xenogramy or cross-pollination and some part of geitonogamy but not apomixis. Fruit set occurs through geitonogamy and xenogamy only; it is 13% in geitonogamy and 87% in xenogamy.

4.4 Fruit and seed morphology

M. siamensis and *M. koratensis* seed characters are typically in Capparaceae such as fruit fleshy, seed often surrounded by sarcotests, large (5-30 mm) and elongate seed (Hugh, H. I., Jocelyn, C. H., Theodore, S. C., and Kenneth, J. S., 2011). Fruits of *M. siamensis* ripe during February-May. The ripened fruit surface is smooth and yellow (Figure 1). Fruit shape of *M. siamensis* is ellipsoidal or rounded, 2.22±0.5 cm in long (n=100) and 1.90±0.4 cm in diameter (n=100), 2. The type of fruit is berry. The unripe fruit surfaces are rough and green (Figure 4.5). The number of seeds per fruit is 1-8 seeds (usually 2 seeds). Seed size is 0.63±0.07 (n=30) long and 0.79±0.09 in diameter (n=30). The seed surfaces are rough and black (Figure 4.6).

Fruits of *M. koratensis* ripe during January - June. The ripened fruit surface is smooth and yellow (Figure 4.5). Fruit shape is cylindrical, torulose to moniliform. 3.14±0.80 cm in long (n=100) and 1.63±0.20cm in diameter (n=100), 2. The type of fruit is berry. The unripe fruit surfaces are smooth and green. The number of seeds per fruit is 1-7 seeds (almost 1). Seed size is 0.88±0.10 (n=30) long and 0.57±0.06 in diameter (n=30). The seed surfaces are rough and light brown (Figure 4.6).

The comparative reproductive parts between the *M. siamensis* tree and *M. koratensis* scandent is shown in Table 4.3.

Table 4.2 Results of breeding system *M. siamensis* and *M. koratensis.*

Treatment	Species	Number of flowers sampled	Number of flowers set fruits	Fruit set (%)
Inflorescences covered by bags	*M. siamensis*	499 (4 bags)	9	1.80 %
	M. koratensis	140 (7 bags)	16	11.43%
One floret covered by bags	*M. siamensis*	30	0	0.00%
	M. koratensis	30	0	0.00%
Open pollination	*M. siamensis*	601	26	4.30%
	M. koratensis	40	2	5.00%

Table 4.3 Results of seed and fruit traits of *M. siamensis* and *M. koratensis*.

Character state	*M. siamensis*	*M. koratensis*
Fruit width (cm)	1.90±0.40	1.63±0.20
Fruit length (cm)	2.22±0.50	3.14±0.80
Seed width (cm)	0.57±0.06	0.79±0.09
Seed length (cm)	0.63±0.07	0.88±0.10
Color of ripen fruit	Yellow	Yellow
Color of seed	Light brown	Black
Fruit type	Berry	Berry
Seed shape	Reniform	Reniform
Number of seed per fruit	1-10 (Mostly 2, 38%)	1-7 (Mostly 1, 49%)
Seed surface	Rough	Rough
Fruit surface	Rough/Smooth(Ripe)	Smooth
Inflorescence type	Inflorescence (raceme)	Inflorescence
Habit type	Tree	Scandent

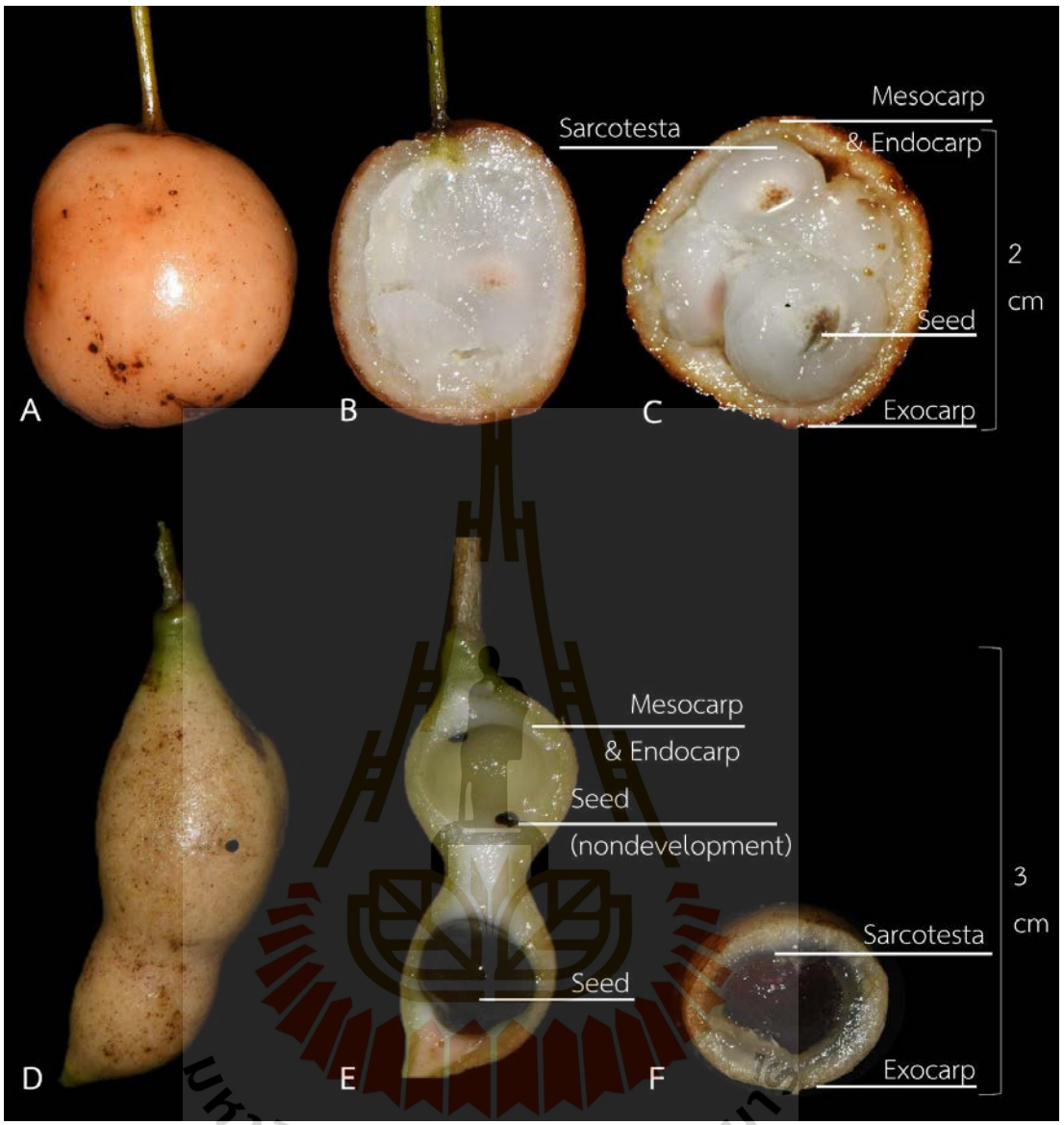

Figure 4.5 Fruit morphology of *M. siamensis*(A-C) and *M. koratensis*(D-F). A, D—External fruit: nearly round shaped, mushy, fleshy, smooth fruit surface.
B, E— Longitudinal sections: in mesocarp found sarcotesta cover seed.
C, F—Cross sections.

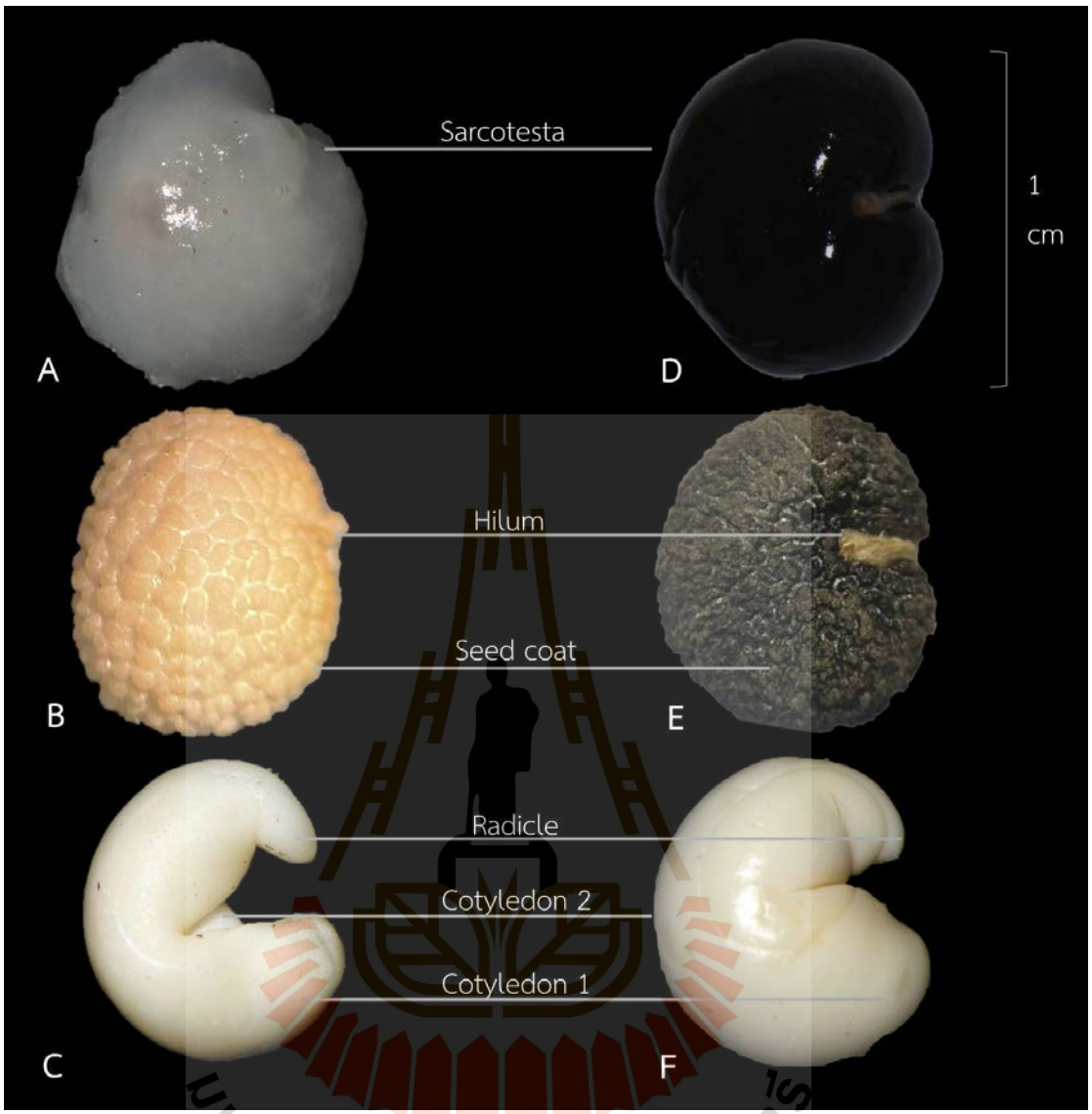

Figure 4.6 Seed morphology of *M. siamensis*(A-C). *and M. koratensis*(D-F). A, D—External seeds with sarcotesta. B, E— External seeds: cardioid shape, rough seed coat (testa). C, F— Embryo with seed coat removed, they have two asymmetrical cotyledons are connected to the radicle.

Table 4.4 Seed and fruit morphology of *Maerua* spp.

Characters	*M. siamensis*	*M. koratensis*	*M. triphylla*	*M. edulis*	*M. sebrabergensis*
Fruit shape	Ellipsoidal or rounded, smooth, yellow-brown when ripe	Cylindrical, torulose to moniliform, with faintly colliculate surface	Long stalks fruit, cylindrical, yellow-creamy brown, furry	Globose, smooth, yellow-orange when ripe	Cylindrical, slightly torulose; glabrous, green to maroon-green when ripe
Fruit size	1.8.-2.7 cm long 1.4-2.4 cm diam	1.5–4.5cm long, 0.6–1.1 cm diam.	5(–10) cm long	1-8-3 cm diam.	1.6–4.5 cm long, 0.4–0.6 cm diam
Seed shape	Seeds 1-8, reniform, rough surface, light brown	Seeds 1–7, reniform, black, covered with pulp.	kidney-shaped, brown	Seeds 1-4, discoid	Seeds not seen
Seed size	5.1-6.3 mm diam 5.6-7.0 mm long	6.5–8 mm long	3–7 mm diam.	up to 20 mm diam., 0-5 mm thick	Seeds not seen
References	(Chayamarit, K., 1991)	(Srisanga, P., Muangsan, N., Choopan, T., Thangthong, J., Pratcharoenwanich, R., and Watthana, S., 2021)	Mollel, N.P., (2013)	J.P. Roux, (2003)	(Swanepoel, W., 2015)

Each species in same genus has different seed and fruit morphology, *M. siamensis and M. edulis* are similar fruit shape (round and globose). *M. koratensis, M. triphylla,* and *M. sebrabergensis* are cylindrical fruit shape (Table 4.4). *M. siamensis* and *M. koratensis* are reniform seed shape. The seed shapes of other species are similar (kidney-shape, and discoid). Fruit and seed size are diverse in each species.

4.5 Seed germination

The comparative seed germination test of *M. siamensis* and *M. koratensis* with different pre-treatments and their results are shown in Table 4.5 and Table 4.6. Seed germination of *M. siamensis* showed the highest number of germination percentage in mechanical scarification (96.67%) and soaking in water 24 hours treatment (75.56%) respectively. While, the control showed 58.89% of seed germination. It was hardly germinated when conducting the pre-treatment with hot water (2.22%) and no germination found in sulfuric acid treatment (0.00%). Beside giving the highest seed germination percentage, the mechanical scarification method also promoted the mean daily germination, germination speed and mean germination time significantly different from other methods. For *M. koratensis*, the results showed that mechanical scarification increased seed germination to their respective control (92.22%). The control showed 70.00% of seed germination. While, soaking in water for 24 hours is ineffective in the species, seed germination percentage just shows as 35.56%. The other germination indices, mean daily germination, germination speed and mean germination time are significantly different from other methods, similar to *M. siamensis*.

The result from this study showed that both species have the highest germination rate in scarification with nail clip treatment (Figure 4.7 and Figure 4.8). It is the similar result of *Leucaena leucocephala* (Tadros, M., Samarah, N., and Alqudah, A., 2012), *Spondias mombin* (Oyebamiji, N. A., Fadimu, O. Y., and Adedire, M. O., 2014). Seed scarification can break hard structures around seeds and is permeable for absorbing more water and exchanging gas during the stratification period (Voyiatzis, D. and Porlingis, I. C., 1987), (Rostami, A. and Shasavar, A., 2009).

Soaking in cold water (25°C) can affect both negative and positive results, depending on species and seed characteristics. This pre-treatment for seed germination decreased physical seed dormancy of tomato (*Lycopersicum esculentum* Mill), yielding more seed germination (Sabongari, S. and Aliero, B., 2004). This pre-treatment can also enhance seed germination of *Azadirachta indica* (Owonubi, J., Otegbeye, G., and Nwokedi, C., 2005), *Adansonia digitata* (Ahmed, I. and Otegbeye, G. O., 2008).

In contrast, *Pouteria campachina* was poor germination rate when soaking in cold water, due to thick seed coat, but it was higher germination by mechanical scarification (Amoakoh, A., Nortey, D., Sagoe, F., Amoako, P., and Jallah, C., 2017). For *Maerua siamensis*, soaking in cold water increased a bit of seed germination when compared with the control treatment. The germination speed was significantly different from the control treatment. Surprisingly, this treatment gave lower germination on *M. koratensis*. It may be because the seed of *M. koratensis* is not water resistant due to ecological adaptation for arid areas. Moreover, the over-soaking seed in water may reduce germination rate through oxygen deficiency (Small, J. and Robertson, B., 1977) . Ibrahim and Otegbeye (2008) had also reported that the efficiency of seed germination rate by soaking in water highly depends on the testa characteristics (Ahmed, I. and Otegbeye, G. O., 2008).

High water temperature (80°C) can damage the seed embryo (Oyebamiji, N. A., Fadimu, O. Y., and Adedire, M. O., 2014) but it could promote seed germination in some species such as golden shower (*Cassia fistula* L.). Soaking in hot water at 100 °C for 6 minutes increased the germination percentage to 96% and 92% in two seasons of 2009/ 2010 and 2010/ 2011 (Soliman, A. and Abbas, M., 2013). Using this treatment to apply with *Maerua siamensis* seeds revealed a very low seed germination rate.

Sulfuric acid stopped *M. siamensis* seed germination (Table 4.5). However, the previous studies showed that sulfuric acid can enhance seed germination rate such as *Leucaena leucocephala* (Koobonye, M., Maule, B. V., and Mogotsi, K., 2018), *Cassia fistula* L. (Soliman, A. S. and Abbas, M. S., 2013), *Psoralea corylifolia* (Arya, P. and Gothalwal, R., 2017) and *Hippophae rhamnoides* (Olmez, Z., 2011). Time for soaking with sulfuric acid to promote higher rate of seed germination varies by species and depends on seed coat characteristics.

In *M. siamensis*, the first seed germination appeared on day 5, in mechanical scarification pre-treatment. It took 10 days for germination without any pre-treatment. This indicated the physical breaking of the seed coat promoted more germination, due to faster imbibition by means of water uptake into the seed. The seed germination experiment shows in Figure 4.9. However, soaking with water for 24 hours also gave a better germination than without any treatment but a bit slower than mechanism scarification (day 6). Thus, the seed coat of this species does not prohibit the water diffusion into the seed. For *M. koratensis*, it started to germinate on day 2 in mechanical scarification (Figure 4.7), while it took 10 days for non-pre-treatment. The control treatment of both species showed more than 50% seed germination and they took less than 4 weeks (Mean germination time, 17.52 for *M. siamensis* and 16.75 for

M. koratensis) for germination indicated that they are non-dormant seeds according to (Baskin, C. and Baskin, J. M., 2014), as same as *Capparis* sp. (Baskin, C. and Baskin, J. M., 2014), which is in the same family.

Considering the phenology of these 2 species, the fruits are ripened during May-June, the late dry season begins to the beginning of wet season in the upper part of thailand. It seems that these species have been adapted to the environment, met with moisture condition, for seedling survival. Thus, there is no dormancy to protect the embryo any more.

Table 4.7 showed that seed of *M. siamensis* can germinate at a rather high rate (84.44%) after being kept in the refrigerator with about 5°C in the plastic bag after drying in room condition. It indicated that it is an orthodox seed (Elliott, S., Navakitbumrung, P., Kuarak, C., Zangkum, S., Anusarnsunthorn, V., and Blakesley, D., 2003). Thus, species can conserve by means of the seed banking. However, it needs to do further long-term monitoring on survival rate after keeping in seed bank condition, low temperature and moisture content.

Table 4.5 Effect of treatment on various parameters related to germination of *M. siamensis*. [abcd] Means in the same column with significantly different letters are different at $p < 0.05$.

Treatment	Germination percentage (%)	Mean Daily Germination (%/day)	Germination Speed (seed/day)	Mean Germination Time (days)
Control	58.89±14.19[b]	2.10±0.50[b]	1.05±0.12[c]	17.52±1.92[ab]
Soaking in water 24 hours	75.56±6.76 [ab]	2.70±0.24[ab]	1.80±0.32[b]	14.78±1.58[bc]
Soaking in hot water 80°C for 5 mins	2.22±1.11[c]	0.08±0.04[c]	0.03±0.02[d]	22.00±4.00[a]
Soaking in 98% sulfuric acid for 5 mins	0.00±0.00[c]	0.00±0.00[c]	0.00±0.00[d]	Undefined
Mechanical scarification (nail clip)	96.67±1.92[a]	3.45±0.12[a]	3.13±0.40[a]	10.17±0.96[c]

Table 4.6 Effect of treatment on various parameters related to germination of *M. koratensis*. [abcd] Means in the same column with significantly different letters are different at $p < 0.05$.

Treatment	Germination percentage (%)	Mean Daily Germination (%/day)	Germination Speed (seed/day)	Mean Germination Time (days)
Control	70.00±15.28[a]	2.5±0.55[ab]	1.36±0.38[b]	16.75±1.22[a]
Soaking in water 24 hours	35.56±10.72[b]	1.27±0.22[b]	0.92±0.15[b]	12.28±0.54[b]
Mechanical scarification (nail clip)	92.22±8.39[a]	3.29±0.17[a]	5.27±0.28[a]	6.03±0.05[c]

Table 4.7 Germination percentage (GP), Mean Daily Germination (MDG), Germination Speed (GS) and Mean Germination Time (MGT) values of *M.siamensis* compare with *M. koratensis*.

Germination index	**Treatments**	***M. siamensis***	***M. koratensis***	**T- test**
Germination percentage	Control	58.89±14.19	70.00±15.27	-
(%)	Soaking in water 24 hours	75.56±6.76	35.56±6.19	*
	Scarification with nail clip	96.67±1.92	92.22±8.39	-
Mean Daily Germination	Control	2.10±0.50	2.5±0.55	-
(%/day)	Soaking in water 24 hours	2.70±0.24	1.27±0.22	-
	Scarification with nail clip	3.45a±0.12	3.29±0.17	-
Germination Speed	Control	1.05±0.12	1.36±0.38	-
(seed/day)	Soaking in water 24 hours	1.80±0.32	0.92±0.15	-
	Scarification with nail clip	3.13±0.40	5.27±0.28	*
Mean Germination Time	Control	17.52±1.93	16.75±1.22	-
(days)	Soaking in water 24 hours	14.78±1.58	12.28±0.54	-
	Scarification with nail clip	10.17±0.97	6.03±0.05	*

Table 4.8 Germination percentage (GP), Mean Daily Germination (MDG), Germination Speed (GS) and Mean Germination Time (MGT) values of *M. siamensis seeds* stored for one week compared with one year. * significant $p<0.05$

Treatments	Germination (%)	Mean Daily Germination (%/day)	Germination Speed (seed/day)	Mean Germination Time (days)
Control one week	58.89±14.19^{b}	2.10±0.50^{b}	1.05±0.12^{b}	17.52±1.93^{c}
Control one year	7.78±2.22^{c}	0.28±0.07^{c}	0.12±0.04^{c}	19.67±3.67^{ab}
Mechanical scarification one week	96.67±1.92^{a}	3.45±0.07^{a}	3.13±0.40^{a}	10.17±0.97^{ab}
Mechanical scarification one year	84.44±4.44^{a}	3.01±0.16^{a}	1.70±0.15^{b}	16.28±1.13^{a}
One way ANOVA test	*	*	*	-

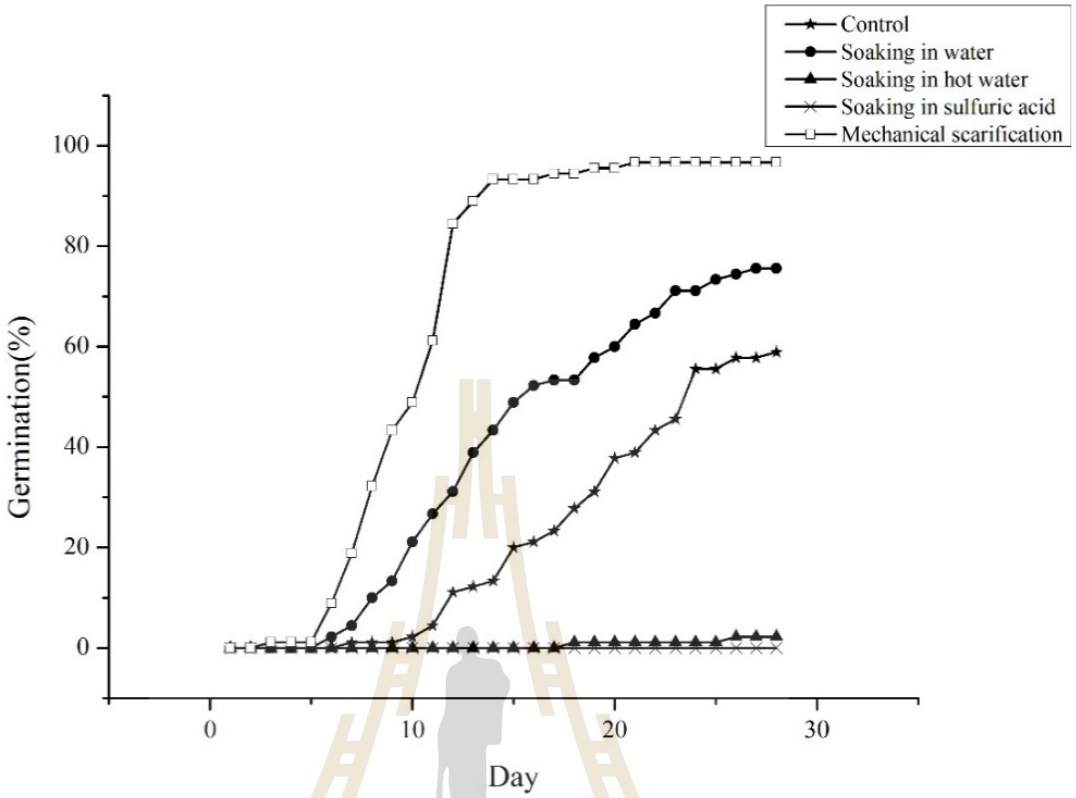

Figure 4.7 Seed germination of *M. siamensis* within 28 days.

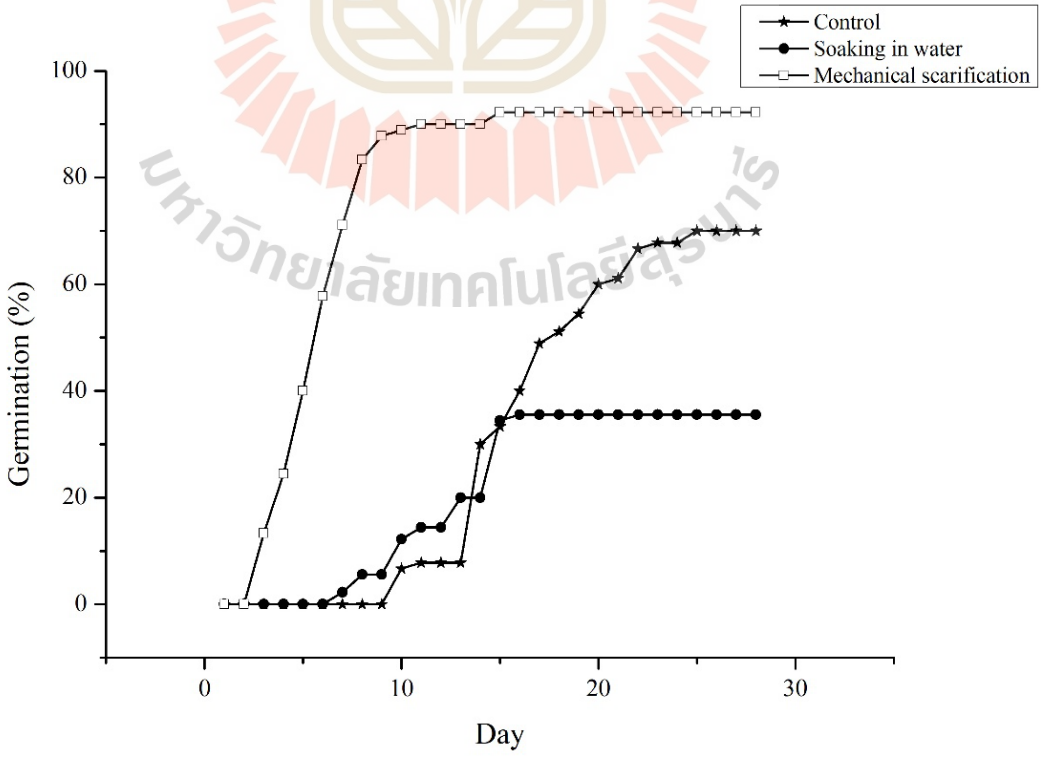

Figure 4.8 Seed germination of *M. koratensis* within 28 days.

Figure 4.9 Example of seed germination experiment in boxes. A—*M. siamensis*, B—*M. koratensis.*

Seed germination of seed storage in one week compared with seed storage in one year shown significantly MDG values with control treatment. GP, GS, and MGT values of seed storage in one week are higher than seed storage in one year. Mean Daily Germination of shortly after storage in one week compared in one year is that they may change their germination responses during long term dry storage at room temperatures (Baskin, C. and Baskin, J. M., 2014). From the results, *M. siamensis* categorized to non-dormancy seed as Capparis sp. in Capparaceae (Baskin, C. and Baskin, J. M., 2014).

CHAPTER V
CONCLUSIONS

5.1 Floral morphology and phenology

The floral traits in the genus *Maerua* are monotypic and polytypic depending on species. *Maerua siamensis* is firstly reported that it is a polytypic flower consisting of mainly hermaphrodite, few female and few male flowers in the same individual. While, *M. koratensis* is a monotypic flower. Although the monotypic flower is more common than mixtypic flowers, *Capparis herbacea* also has 2 floral types which are hermaphrodite and male flower.

From field observation, the flowers can be divided into 5 stages, floral buds, flower start to open, flowers fully open, flowers start to withered and flowers completely withered. It was found that *M. siamensis* has about 50% of fertile flowers from a total of flower production.

5.2 Breeding system and fruit set

Both species of *Maerua* in Thailand are not apomixis. They are self-compatible due to setting fruit in the same individual, geitonogamy. Natural fruit sets of both species are low, indicating that they are allogamy or xenogamy. The hand pollination experiment on cross and self pollination and other pollen ecology are needed for further study, as well as pollinators.

5.3 Seed germination and dormancy

Both species are non-dormant seeds. They seem to adapt to the environment. Time of seed fruit and seed ripened in the late of dry season in Thailand. Seeds are ready to germinate at the beginning of the rainy season. Thus, they do not need to be dormant waiting for moisture.

Comparative germination from this study revealed that mechanical scarification with nail clip gave the highest germination rate in both species. For *M. siamensis*, doing not any treatment is an option for producing seedlings due to cost saving. *M. siamensis* seems to be an orthodox seed because seeds which were kept for 1 year can germinate at a rather high rate. This species can apply to seed banking, but it needs to monitor long term survival rate after seed banking.

5.4 Conservation implementation

For conservation and reforestation of both species, the best treatment for germination is scarification by nail clip, but scarification process loses more time. The second choice of reforestation of *M. siamensis* and *M. koratensis* is soaking in water and untreated the seeds respectively. It saves more time than scarification by nail clip in each seed. Hot water and sulfuric acid can't be used for reforestation of both species.

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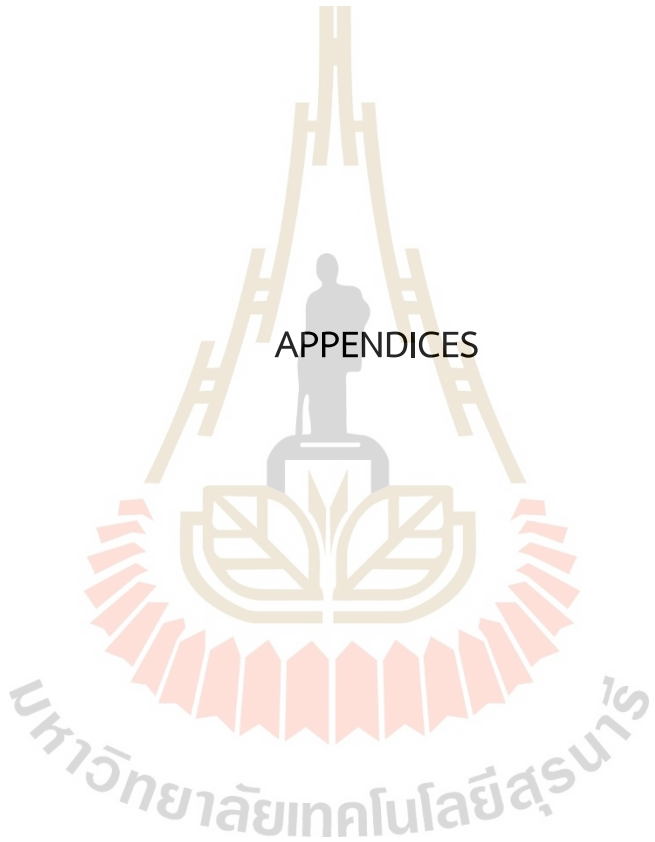
APPENDICES



APPENDIX A

DATASHEET OF SEED GERMINATION RESULTS

Table A.1 Seed germination percentage in 28 days of *M. siamensis* (Control).

Date	Day	Number of seed germinated/box/day			Cumulative number of seed germinated/box/day			Average cumulative number	Percent of germination
		Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3		
27/03/2020	1	0	0	0	0	0	0	0.00	0.00
28/03/2020	2	0	0	0	0	0	0	0.00	0.00
29/03/2020	3	0	0	0	0	0	0	0.00	0.00
30/03/2020	4	0	0	0	0	0	0	0.00	0.00
31/03/2020	5	0	0	0	0	0	0	0.00	0.00
01/04/2020	6	0	0	0	0	0	0	0.00	0.00
02/04/2020	7	0	1	0	0	1	0	0.33	1.11
03/04/2020	8	0	0	0	0	1	0	0.33	1.11
04/04/2020	9	0	0	0	0	1	0	0.33	1.11
05/04/2020	10	0	0	1	0	1	1	0.67	2.22
06/04/2020	11	1	0	1	1	1	2	1.33	4.44
07/04/2020	12	0	1	5	1	2	7	3.33	11.11
08/04/2020	13	0	1	0	1	3	7	3.67	12.22
09/04/2020	14	0	1	0	1	4	7	4.00	13.33
10/04/2020	15	3	2	1	4	6	8	6.00	20.00
11/04/2020	16	1	0	0	5	6	8	6.33	21.11
12/04/2020	17	0	2	0	5	8	8	7.00	23.33
13/04/2020	18	0	4	0	5	12	8	8.33	27.78
14/04/2020	19	1	2	0	6	14	8	9.33	31.11
15/04/2020	20	4	0	2	10	14	10	11.33	37.78
16/04/2020	21	0	1	0	10	15	10	11.67	38.89
17/04/2020	22	3	0	1	13	15	11	13.00	43.33
18/04/2020	23	2	0	0	15	15	11	13.67	45.56
19/04/2020	24	8	0	1	23	15	12	16.67	55.56
20/04/2020	25	0	0	0	23	15	12	16.67	55.56
21/04/2020	26	2	0	0	25	15	12	17.33	57.78
22/04/2020	27	0	0	0	25	15	12	17.33	57.78
23/04/2020	28	1	0	0	26	15	12	17.67	58.89

Table A.2 Seed germination percentage in 28 days of *M. siamensis* (Soaking in water for 24 h).

		Number of seed germinated/box/day			Cumulative number of seed germinated/box/day			Average cumulative	Percent of
	Day	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	number	germination
27/03/2020	1	0	0	0	0	0	0	0.00	0.00
28/03/2020	2	0	0	0	0	0	0	0.00	0.00
29/03/2020	3	0	0	0	0	0	0	0.00	0.00
30/03/2020	4	0	0	0	0	0	0	0.00	0.00
31/03/2020	5	0	0	0	0	0	0	0.00	0.00
01/04/2020	6	1	0	1	1	0	1	0.67	2.22
02/04/2020	7	1	0	1	2	0	2	1.33	4.44
03/04/2020	8	2	0	3	4	0	5	3.00	10.00
04/04/2020	9	3	0	0	7	0	5	4.00	13.33
05/04/2020	10	4	1	2	11	1	7	6.33	21.11
06/04/2020	11	2	1	2	13	2	9	8.00	26.67
07/04/2020	12	0	2	2	13	4	11	9.33	31.11
08/04/2020	13	3	1	3	16	5	14	11.67	38.89
09/04/2020	14	1	1	2	17	6	16	13.00	43.33
10/04/2020	15	2	1	2	19	7	18	14.67	48.89
11/04/2020	16	1	2	0	20	9	18	15.67	52.22
12/04/2020	17	0	0	1	20	9	19	16.00	53.33
13/04/2020	18	0	0	0	20	9	19	16.00	53.33
14/04/2020	19	0	2	2	20	11	21	17.33	57.78
15/04/2020	20	1	0	1	21	11	22	18.00	60.00
16/04/2020	21	0	4	0	21	15	22	19.33	64.44
17/04/2020	22	1	1	0	22	16	22	20.00	66.67
18/04/2020	23	1	2	1	23	18	23	21.33	71.11
19/04/2020	24	0	0	0	23	18	23	21.33	71.11
20/04/2020	25	0	0	2	23	18	25	22.00	73.33
21/04/2020	26	0	0	1	23	18	26	22.33	74.44
22/04/2020	27	0	1	0	23	19	26	22.67	75.56
23/04/2020	28	0	0	0	23	19	26	22.67	75.56

Table A. 3 Seed germination percentage in 28 days of *M. siamensis* (Soaking in hot water for 5 mins).

Date	Day	Number of seed germinated/box/day			Cumulative number of seed germinated/box/day			Average cumulative number	Percent of germination
		Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3		
27/03/2020	1	0	0	0	0	0	0	0.00	0.00
28/03/2020	2	0	0	0	0	0	0	0.00	0.00
29/03/2020	3	0	0	0	0	0	0	0.00	0.00
30/03/2020	4	0	0	0	0	0	0	0.00	0.00
31/03/2020	5	0	0	0	0	0	0	0.00	0.00
01/04/2020	6	0	0	0	0	0	0	0.00	0.00
02/04/2020	7	0	0	0	0	0	0	0.00	0.00
03/04/2020	8	0	0	0	0	0	0	0.00	0.00
04/04/2020	9	0	0	0	0	0	0	0.00	0.00
05/04/2020	10	0	0	0	0	0	0	0.00	0.00
06/04/2020	11	0	0	0	0	0	0	0.00	0.00
07/04/2020	12	0	0	0	0	0	0	0.00	0.00
08/04/2020	13	0	0	0	0	0	0	0.00	0.00
09/04/2020	14	0	0	0	0	0	0	0.00	0.00
10/04/2020	15	0	0	0	0	0	0	0.00	0.00
11/04/2020	16	0	0	0	0	0	0	0.00	0.00
12/04/2020	17	0	0	0	0	0	0	0.00	0.00
13/04/2020	18	0	1	0	0	1	0	0.33	1.11
14/04/2020	19	0	0	0	0	1	0	0.33	1.11
15/04/2020	20	0	0	0	0	1	0	0.33	1.11
16/04/2020	21	0	0	0	0	1	0	0.33	1.11
17/04/2020	22	0	0	0	0	1	0	0.33	1.11
18/04/2020	23	0	0	0	0	1	0	0.33	1.11
19/04/2020	24	0	0	0	0	1	0	0.33	1.11
20/04/2020	25	0	0	0	0	1	0	0.33	1.11
21/04/2020	26	1	0	0	1	1	0	0.67	2.22
22/04/2020	27	0	0	0	1	1	0	0.67	2.22
23/04/2020	28	0	0	0	1	1	0	0.67	2.22

Table A.4 Seed germination percentage in 28 days of *M. siamensis* (Soaking in Sulfuric acid for 5 mins).

Date	Day	Number of seed germinated/box/day			Cumulative number of seed germinated/box/day			Average cumulative number	Percent of germination
		Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3		
27/03/2020	1	0	0	0	0	0	0	0.00	0.00
28/03/2020	2	0	0	0	0	0	0	0.00	0.00
29/03/2020	3	0	0	0	0	0	0	0.00	0.00
30/03/2020	4	0	0	0	0	0	0	0.00	0.00
31/03/2020	5	0	0	0	0	0	0	0.00	0.00
01/04/2020	6	0	0	0	0	0	0	0.00	0.00
02/04/2020	7	0	0	0	0	0	0	0.00	0.00
03/04/2020	8	0	0	0	0	0	0	0.00	0.00
04/04/2020	9	0	0	0	0	0	0	0.00	0.00
05/04/2020	10	0	0	0	0	0	0	0.00	0.00
06/04/2020	11	0	0	0	0	0	0	0.00	0.00
07/04/2020	12	0	0	0	0	0	0	0.00	0.00
08/04/2020	13	0	0	0	0	0	0	0.00	0.00
09/04/2020	14	0	0	0	0	0	0	0.00	0.00
10/04/2020	15	0	0	0	0	0	0	0.00	0.00
11/04/2020	16	0	0	0	0	0	0	0.00	0.00
12/04/2020	17	0	0	0	0	0	0	0.00	0.00
13/04/2020	18	0	0	0	0	0	0	0.00	0.00
14/04/2020	19	0	0	0	0	0	0	0.00	0.00
15/04/2020	20	0	0	0	0	0	0	0.00	0.00
16/04/2020	21	0	0	0	0	0	0	0.00	0.00
17/04/2020	22	0	0	0	0	0	0	0.00	0.00
18/04/2020	23	0	0	0	0	0	0	0.00	0.00
19/04/2020	24	0	0	0	0	0	0	0.00	0.00
20/04/2020	25	0	0	0	0	0	0	0.00	0.00
21/04/2020	26	0	0	0	0	0	0	0.00	0.00
22/04/2020	27	0	0	0	0	0	0	0.00	0.00
23/04/2020	28	0	0	0	0	0	0	0.00	0.00

Table A.5 Seed germination percentage in 28 days of *M. siamensis* (Scarification by nail clip).

Date	Day	Number of seed germinated/box/day			Cumulative number of seed germinated/box/day			Average cumulative number	Percent of germination
		Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3		
01/04/2020	1	0	0	0	0	0	0	0.00	0.00
02/04/2020	2	0	0	0	0	0	0	0.00	0.00
03/04/2020	3	0	0	1	0	0	1	0.33	1.11
04/04/2020	4	0	0	0	0	0	1	0.33	1.11
05/04/2020	5	0	0	0	0	0	1	0.33	1.11
06/04/2020	6	0	4	3	0	4	4	2.67	8.89
07/04/2020	7	0	3	6	0	7	10	5.67	18.89
08/04/2020	8	0	7	5	0	14	15	9.67	32.22
09/04/2020	9	0	3	7	0	17	22	13.00	43.33
10/04/2020	10	5	0	0	5	17	22	14.67	48.89
11/04/2020	11	2	6	3	7	23	25	18.33	61.11
12/04/2020	12	15	5	1	22	28	26	25.33	84.44
13/04/2020	13	4	0	0	26	28	26	26.67	88.89
14/04/2020	14	1	1	2	27	29	28	28.00	93.33
15/04/2020	15	0	0	0	27	29	28	28.00	93.33
16/04/2020	16	0	0	0	27	29	28	28.00	93.33
17/04/2020	17	0	0	1	27	29	29	28.33	94.44
18/04/2020	18	0	0	0	27	29	29	28.33	94.44
19/04/2020	19	0	0	1	27	29	30	28.67	95.56
20/04/2020	20	0	0	0	27	29	30	28.67	95.56
21/04/2020	21	1	0	0	28	29	30	29.00	96.67
22/04/2020	22	0	0	0	28	29	30	29.00	96.67
23/04/2020	23	0	0	0	28	29	30	29.00	96.67
24/04/2020	24	0	0	0	28	29	30	29.00	96.67
25/04/2020	25	0	0	0	28	29	30	29.00	96.67
26/04/2020	26	0	0	0	28	29	30	29.00	96.67
27/04/2020	27	0	0	0	28	29	30	29.00	96.67
28/04/2020	28	0	0	0	28	29	30	29.00	96.67

Table A.6 Seed germination percentage in 28 days of *M. koratensis* (Control).

Date	Day	Number of seed germinated/box/day			Cumulative number of seed germinated/box/day			Average cumulative number	Percent of germination
		Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3		
15/05/2020	1	0	0	0	0	0	0	0.00	0.00
16/05/2020	2	0	0	0	0	0	0	0.00	0.00
17/05/2020	3	0	0	0	0	0	0	0.00	0.00
18/05/2020	4	0	0	0	0	0	0	0.00	0.00
19/05/2020	5	0	0	0	0	0	0	0.00	0.00
20/05/2020	6	0	0	0	0	0	0	0.00	0.00
21/05/2020	7	0	0	0	0	0	0	0.00	0.00
22/05/2020	8	0	0	0	0	0	0	0.00	0.00
23/05/2020	9	0	0	0	0	0	0	0.00	0.00
24/05/2020	10	6	0	0	6	0	0	2.00	6.67
25/05/2020	11	0	1	0	6	1	0	2.33	7.78
26/05/2020	12	0	0	0	6	1	0	2.33	7.78
27/05/2020	13	0	0	0	6	1	0	2.33	7.78
28/05/2020	14	12	7	1	18	8	1	9.00	30.00
29/05/2020	15	0	1	2	18	9	3	10.00	33.33
30/05/2020	16	2	4	0	20	13	3	12.00	40.00
31/05/2020	17	3	3	2	23	16	5	14.67	48.89
01/06/2020	18	0	0	2	23	16	7	15.33	51.11
02/06/2020	19	1	1	1	24	17	8	16.33	54.44
03/06/2020	20	1	3	1	25	20	9	18.00	60.00
04/06/2020	21	1	0	0	26	20	9	18.33	61.11
05/06/2020	22	1	3	1	27	23	10	20.00	66.67
06/06/2020	23	0	1	0	27	24	10	20.33	67.78
07/06/2020	24	0	0	0	27	24	10	20.33	67.78
08/06/2020	25	0	0	2	27	24	12	21.00	70.00
09/06/2020	26	0	0	0	27	24	12	21.00	70.00
10/06/2020	27	0	0	0	27	24	12	21.00	70.00
11/06/2020	28	0	0	0	27	24	12	21.00	70.00

Table A.7 Seed germination percentage in 28 days of *M. koratensis* (Soaking in water for 24 h).

Date	Day	Number of seed germinated/box/day			Cumulative number of seed germinated/box/day			Average cumulative number	Percent of germination
		Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3		
29/05/2020	1	0	0	0	0	0	0	0.00	0.00
30/05/2020	2	0	0	0	0	0	0	0.00	0.00
31/05/2020	3	0	0	0	0	0	0	0.00	0.00
01/06/2020	4	0	0	0	0	0	0	0.00	0.00
02/06/2020	5	0	0	0	0	0	0	0.00	0.00
03/06/2020	6	0	0	0	0	0	0	0.00	0.00
04/06/2020	7	1	1	0	1	1	0	0.67	2.22
05/06/2020	8	0	1	2	1	2	2	1.67	5.56
06/06/2020	9	0	0	0	1	2	2	1.67	5.56
07/06/2020	10	1	5	0	2	7	2	3.67	12.22
08/06/2020	11	0	0	2	2	7	4	4.33	14.44
09/06/2020	12	0	0	0	2	7	4	4.33	14.44
10/06/2020	13	4	0	1	6	7	5	6.00	20.00
11/06/2020	14	0	0	0	6	7	5	6.00	20.00
12/06/2020	15	5	6	2	11	13	7	10.33	34.44
13/06/2020	16	1	0	0	12	13	7	10.67	35.56
14/06/2020	17	0	0	0	12	13	7	10.67	35.56
15/06/2020	18	0	0	0	12	13	7	10.67	35.56
16/06/2020	19	0	0	0	12	13	7	10.67	35.56
17/06/2020	20	0	0	0	12	13	7	10.67	35.56
18/06/2020	21	0	0	0	12	13	7	10.67	35.56
19/06/2020	22	0	0	0	12	13	7	10.67	35.56
20/06/2020	23	0	0	0	12	13	7	10.67	35.56
21/06/2020	24	0	0	0	12	13	7	10.67	35.56
22/06/2020	25	0	0	0	12	13	7	10.67	35.56
23/06/2020	26	0	0	0	12	13	7	10.67	35.56
24/06/2020	27	0	0	0	12	13	7	10.67	35.56
25/06/2020	28	0	0	0	12	13	7	10.67	35.56

Table A.8 Seed germination percentage in 28 days of *M. koratensis* (Scarification by nail clip).

Date	Day	Number of seed germinated/box/day			Cumulative number of seed germinated/box/day			Average cumulative number	Percent of germination
		Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3		
29/05/2020	1	0	0	0	0	0	0	0.00	0.00
30/05/2020	2	0	0	0	0	0	0	0.00	0.00
31/05/2020	3	6	2	4	6	2	4	4.00	13.33
01/06/2020	4	3	6	1	9	8	5	7.33	24.44
02/06/2020	5	4	5	5	13	13	10	12.00	40.00
03/06/2020	6	4	5	7	17	18	17	17.33	57.78
04/06/2020	7	5	7	0	22	25	17	21.33	71.11
05/06/2020	8	2	3	6	24	28	23	25.00	83.33
06/06/2020	9	3	0	1	27	28	24	26.33	87.78
07/06/2020	10	0	0	1	27	28	25	26.67	88.89
08/06/2020	11	0	1	0	27	29	25	27.00	90.00
09/06/2020	12	0	0	0	27	29	25	27.00	90.00
10/06/2020	13	0	0	0	27	29	25	27.00	90.00
11/06/2020	14	0	0	0	27	29	25	27.00	90.00
12/06/2020	15	1	1	0	28	30	25	27.67	92.22
13/06/2020	16	0	0	0	28	30	25	27.67	92.22
14/06/2020	17	0	0	0	28	30	25	27.67	92.22
15/06/2020	18	0	0	0	28	30	25	27.67	92.22
16/06/2020	19	0	0	0	28	30	25	27.67	92.22
17/06/2020	20	0	0	0	28	30	25	27.67	92.22
18/06/2020	21	0	0	0	28	30	25	27.67	92.22
19/06/2020	22	0	0	0	28	30	25	27.67	92.22
20/06/2020	23	0	0	0	28	30	25	27.67	92.22
21/06/2020	24	0	0	0	28	30	25	27.67	92.22
22/06/2020	25	0	0	0	28	30	25	27.67	92.22
23/06/2020	26	0	0	0	28	30	25	27.67	92.22
24/06/2020	27	0	0	0	28	30	25	27.67	92.22
25/06/2020	28	0	0	0	28	30	25	27.67	92.22

Table A.2 Seed germination percentage in 28 days of *M. siamensis* (Soaking in water for 24 h).

Date	Day	Number of seed germinated/box/day			Cumulative number of seed germinated/box/day			Average cumulative number	Percent of germination
		Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3		
27/03/2020	1	0	0	0	0	0	0	0.00	0.00
28/03/2020	2	0	0	0	0	0	0	0.00	0.00
29/03/2020	3	0	0	0	0	0	0	0.00	0.00
30/03/2020	4	0	0	0	0	0	0	0.00	0.00
31/03/2020	5	0	0	0	0	0	0	0.00	0.00
01/04/2020	6	1	0	1	1	0	1	0.67	2.22
02/04/2020	7	1	0	1	2	0	2	1.33	4.44
03/04/2020	8	2	0	3	4	0	5	3.00	10.00
04/04/2020	9	3	0	0	7	0	5	4.00	13.33
05/04/2020	10	4	1	2	11	1	7	6.33	21.11
06/04/2020	11	2	1	2	13	2	9	8.00	26.67
07/04/2020	12	0	2	2	13	4	11	9.33	31.11
08/04/2020	13	3	1	3	16	5	14	11.67	38.89
09/04/2020	14	1	1	2	17	6	16	13.00	43.33
10/04/2020	15	2	1	2	19	7	18	14.67	48.89
11/04/2020	16	1	2	0	20	9	18	15.67	52.22
12/04/2020	17	0	0	1	20	9	19	16.00	53.33
13/04/2020	18	0	0	0	20	9	19	16.00	53.33
14/04/2020	19	0	2	2	20	11	21	17.33	57.78
15/04/2020	20	1	0	1	21	11	22	18.00	60.00
16/04/2020	21	0	4	0	21	15	22	19.33	64.44
17/04/2020	22	1	1	0	22	16	22	20.00	66.67
18/04/2020	23	1	2	1	23	18	23	21.33	71.11
19/04/2020	24	0	0	0	23	18	23	21.33	71.11
20/04/2020	25	0	0	2	23	18	25	22.00	73.33
21/04/2020	26	0	0	1	23	18	26	22.33	74.44
22/04/2020	27	0	1	0	23	19	26	22.67	75.56
23/04/2020	28	0	0	0	23	19	26	22.67	75.56

Table A.3 Seed germination percentage in 28 days of *M. siamensis* (Soaking in hot water for 5 mins).

Date	Day	Number of seed germinated/box/day			Cumulative number of seed germinated/box/day			Average cumulative number	Percent of germination
		Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3		
27/03/2020	1	0	0	0	0	0	0	0.00	0.00
28/03/2020	2	0	0	0	0	0	0	0.00	0.00
29/03/2020	3	0	0	0	0	0	0	0.00	0.00
30/03/2020	4	0	0	0	0	0	0	0.00	0.00
31/03/2020	5	0	0	0	0	0	0	0.00	0.00
01/04/2020	6	0	0	0	0	0	0	0.00	0.00
02/04/2020	7	0	0	0	0	0	0	0.00	0.00
03/04/2020	8	0	0	0	0	0	0	0.00	0.00
04/04/2020	9	0	0	0	0	0	0	0.00	0.00
05/04/2020	10	0	0	0	0	0	0	0.00	0.00
06/04/2020	11	0	0	0	0	0	0	0.00	0.00
07/04/2020	12	0	0	0	0	0	0	0.00	0.00
08/04/2020	13	0	0	0	0	0	0	0.00	0.00
09/04/2020	14	0	0	0	0	0	0	0.00	0.00
10/04/2020	15	0	0	0	0	0	0	0.00	0.00
11/04/2020	16	0	0	0	0	0	0	0.00	0.00
12/04/2020	17	0	0	0	0	0	0	0.00	0.00
13/04/2020	18	0	1	0	0	1	0	0.33	1.11
14/04/2020	19	0	0	0	0	1	0	0.33	1.11
15/04/2020	20	0	0	0	0	1	0	0.33	1.11
16/04/2020	21	0	0	0	0	1	0	0.33	1.11
17/04/2020	22	0	0	0	0	1	0	0.33	1.11
18/04/2020	23	0	0	0	0	1	0	0.33	1.11
19/04/2020	24	0	0	0	0	1	0	0.33	1.11
20/04/2020	25	0	0	0	0	1	0	0.33	1.11
21/04/2020	26	1	0	0	1	1	0	0.67	2.22
22/04/2020	27	0	0	0	1	1	0	0.67	2.22
23/04/2020	28	0	0	0	1	1	0	0.67	2.22

Table A.4 Seed germination percentage in 28 days of *M. siamensis* (Soaking in Sulfuric acid for 5 mins).

		Number of seed germinated/box/day			Cumulative number of seed germinated/box/day				
Date	Day	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Average cumulative number	Percent of germination
27/03/2020	1	0	0	0	0	0	0	0.00	0.00
28/03/2020	2	0	0	0	0	0	0	0.00	0.00
29/03/2020	3	0	0	0	0	0	0	0.00	0.00
30/03/2020	4	0	0	0	0	0	0	0.00	0.00
31/03/2020	5	0	0	0	0	0	0	0.00	0.00
01/04/2020	6	0	0	0	0	0	0	0.00	0.00
02/04/2020	7	0	0	0	0	0	0	0.00	0.00
03/04/2020	8	0	0	0	0	0	0	0.00	0.00
04/04/2020	9	0	0	0	0	0	0	0.00	0.00
05/04/2020	10	0	0	0	0	0	0	0.00	0.00
06/04/2020	11	0	0	0	0	0	0	0.00	0.00
07/04/2020	12	0	0	0	0	0	0	0.00	0.00
08/04/2020	13	0	0	0	0	0	0	0.00	0.00
09/04/2020	14	0	0	0	0	0	0	0.00	0.00
10/04/2020	15	0	0	0	0	0	0	0.00	0.00
11/04/2020	16	0	0	0	0	0	0	0.00	0.00
12/04/2020	17	0	0	0	0	0	0	0.00	0.00
13/04/2020	18	0	0	0	0	0	0	0.00	0.00
14/04/2020	19	0	0	0	0	0	0	0.00	0.00
15/04/2020	20	0	0	0	0	0	0	0.00	0.00
16/04/2020	21	0	0	0	0	0	0	0.00	0.00
17/04/2020	22	0	0	0	0	0	0	0.00	0.00
18/04/2020	23	0	0	0	0	0	0	0.00	0.00
19/04/2020	24	0	0	0	0	0	0	0.00	0.00
20/04/2020	25	0	0	0	0	0	0	0.00	0.00
21/04/2020	26	0	0	0	0	0	0	0.00	0.00
22/04/2020	27	0	0	0	0	0	0	0.00	0.00
23/04/2020	28	0	0	0	0	0	0	0.00	0.00

Table A.5 Seed germination percentage in 28 days of *M. siamensis* (Scarification by nail clip).

Date	Day	Number of seed germinated/box/day			Cumulative number of seed germinated/box/day			Average cumulative number	Percent of germination
		Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3		
01/04/2020	1	0	0	0	0	0	0	0.00	0.00
02/04/2020	2	0	0	0	0	0	0	0.00	0.00
03/04/2020	3	0	0	1	0	0	1	0.33	1.11
04/04/2020	4	0	0	0	0	0	1	0.33	1.11
05/04/2020	5	0	0	0	0	0	1	0.33	1.11
06/04/2020	6	0	4	3	0	4	4	2.67	8.89
07/04/2020	7	0	3	6	0	7	10	5.67	18.89
08/04/2020	8	0	7	5	0	14	15	9.67	32.22
09/04/2020	9	0	3	7	0	17	22	13.00	43.33
10/04/2020	10	5	0	0	5	17	22	14.67	48.89
11/04/2020	11	2	6	3	7	23	25	18.33	61.11
12/04/2020	12	15	5	1	22	28	26	25.33	84.44
13/04/2020	13	4	0	0	26	28	26	26.67	88.89
14/04/2020	14	1	1	2	27	29	28	28.00	93.33
15/04/2020	15	0	0	0	27	29	28	28.00	93.33
16/04/2020	16	0	0	0	27	29	28	28.00	93.33
17/04/2020	17	0	0	1	27	29	29	28.33	94.44
18/04/2020	18	0	0	0	27	29	29	28.33	94.44
19/04/2020	19	0	0	1	27	29	30	28.67	95.56
20/04/2020	20	0	0	0	27	29	30	28.67	95.56
21/04/2020	21	1	0	0	28	29	30	29.00	96.67
22/04/2020	22	0	0	0	28	29	30	29.00	96.67
23/04/2020	23	0	0	0	28	29	30	29.00	96.67
24/04/2020	24	0	0	0	28	29	30	29.00	96.67
25/04/2020	25	0	0	0	28	29	30	29.00	96.67
26/04/2020	26	0	0	0	28	29	30	29.00	96.67
27/04/2020	27	0	0	0	28	29	30	29.00	96.67
28/04/2020	28	0	0	0	28	29	30	29.00	96.67

Table A.6 Seed germination percentage in 28 days of *M. koratensis* (Control).

Date	Day	Number of seed germinated/box/day			Cumulative number of seed germinated/box/day			Average cumulative number	Percent of germination
		Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3		
15/05/2020	1	0	0	0	0	0	0	0.00	0.00
16/05/2020	2	0	0	0	0	0	0	0.00	0.00
17/05/2020	3	0	0	0	0	0	0	0.00	0.00
18/05/2020	4	0	0	0	0	0	0	0.00	0.00
19/05/2020	5	0	0	0	0	0	0	0.00	0.00
20/05/2020	6	0	0	0	0	0	0	0.00	0.00
21/05/2020	7	0	0	0	0	0	0	0.00	0.00
22/05/2020	8	0	0	0	0	0	0	0.00	0.00
23/05/2020	9	0	0	0	0	0	0	0.00	0.00
24/05/2020	10	6	0	0	6	0	0	2.00	6.67
25/05/2020	11	0	1	0	6	1	0	2.33	7.78
26/05/2020	12	0	0	0	6	1	0	2.33	7.78
27/05/2020	13	0	0	0	6	1	0	2.33	7.78
28/05/2020	14	12	7	1	18	8	1	9.00	30.00
29/05/2020	15	0	1	2	18	9	3	10.00	33.33
30/05/2020	16	2	4	0	20	13	3	12.00	40.00
31/05/2020	17	3	3	2	23	16	5	14.67	48.89
01/06/2020	18	0	0	2	23	16	7	15.33	51.11
02/06/2020	19	1	1	1	24	17	8	16.33	54.44
03/06/2020	20	1	3	1	25	20	9	18.00	60.00
04/06/2020	21	1	0	0	26	20	9	18.33	61.11
05/06/2020	22	1	3	1	27	23	10	20.00	66.67
06/06/2020	23	0	1	0	27	24	10	20.33	67.78
07/06/2020	24	0	0	0	27	24	10	20.33	67.78
08/06/2020	25	0	0	2	27	24	12	21.00	70.00
09/06/2020	26	0	0	0	27	24	12	21.00	70.00
10/06/2020	27	0	0	0	27	24	12	21.00	70.00
11/06/2020	28	0	0	0	27	24	12	21.00	70.00

Table A.7 Seed germination percentage in 28 days of *M. koratensis* (Soaking in water for 24 h).

Date	Day	Number of seed germinated/box/day			Cumulative number of seed germinated/box/day			Average cumulative number	Percent of germination
		Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3		
29/05/2020	1	0	0	0	0	0	0	0.00	0.00
30/05/2020	2	0	0	0	0	0	0	0.00	0.00
31/05/2020	3	0	0	0	0	0	0	0.00	0.00
01/06/2020	4	0	0	0	0	0	0	0.00	0.00
02/06/2020	5	0	0	0	0	0	0	0.00	0.00
03/06/2020	6	0	0	0	0	0	0	0.00	0.00
04/06/2020	7	1	1	0	1	1	0	0.67	2.22
05/06/2020	8	0	1	2	1	2	2	1.67	5.56
06/06/2020	9	0	0	0	1	2	2	1.67	5.56
07/06/2020	10	1	5	0	2	7	2	3.67	12.22
08/06/2020	11	0	0	2	2	7	4	4.33	14.44
09/06/2020	12	0	0	0	2	7	4	4.33	14.44
10/06/2020	13	4	0	1	6	7	5	6.00	20.00
11/06/2020	14	0	0	0	6	7	5	6.00	20.00
12/06/2020	15	5	6	2	11	13	7	10.33	34.44
13/06/2020	16	1	0	0	12	13	7	10.67	35.56
14/06/2020	17	0	0	0	12	13	7	10.67	35.56
15/06/2020	18	0	0	0	12	13	7	10.67	35.56
16/06/2020	19	0	0	0	12	13	7	10.67	35.56
17/06/2020	20	0	0	0	12	13	7	10.67	35.56
18/06/2020	21	0	0	0	12	13	7	10.67	35.56
19/06/2020	22	0	0	0	12	13	7	10.67	35.56
20/06/2020	23	0	0	0	12	13	7	10.67	35.56
21/06/2020	24	0	0	0	12	13	7	10.67	35.56
22/06/2020	25	0	0	0	12	13	7	10.67	35.56
23/06/2020	26	0	0	0	12	13	7	10.67	35.56
24/06/2020	27	0	0	0	12	13	7	10.67	35.56
25/06/2020	28	0	0	0	12	13	7	10.67	35.56

Table A.8 Seed germination percentage in 28 days of *M. koratensis* (Scarification by nail clip).

		Number of seed germinated/box/day			Cumulative number of seed germinated/box/day			Average cumulative	Percent of
Date	Day	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	number	germination
29/05/2020	1	0	0	0	0	0	0	0.00	0.00
30/05/2020	2	0	0	0	0	0	0	0.00	0.00
31/05/2020	3	6	2	4	6	2	4	4.00	13.33
01/06/2020	4	3	6	1	9	8	5	7.33	24.44
02/06/2020	5	4	5	5	13	13	10	12.00	40.00
03/06/2020	6	4	5	7	17	18	17	17.33	57.78
04/06/2020	7	5	7	0	22	25	17	21.33	71.11
05/06/2020	8	2	3	6	24	28	23	25.00	83.33
06/06/2020	9	3	0	1	27	28	24	26.33	87.78
07/06/2020	10	0	0	1	27	28	25	26.67	88.89
08/06/2020	11	0	1	0	27	29	25	27.00	90.00
09/06/2020	12	0	0	0	27	29	25	27.00	90.00
10/06/2020	13	0	0	0	27	29	25	27.00	90.00
11/06/2020	14	0	0	0	27	29	25	27.00	90.00
12/06/2020	15	1	1	0	28	30	25	27.67	92.22
13/06/2020	16	0	0	0	28	30	25	27.67	92.22
14/06/2020	17	0	0	0	28	30	25	27.67	92.22
15/06/2020	18	0	0	0	28	30	25	27.67	92.22
16/06/2020	19	0	0	0	28	30	25	27.67	92.22
17/06/2020	20	0	0	0	28	30	25	27.67	92.22
18/06/2020	21	0	0	0	28	30	25	27.67	92.22
19/06/2020	22	0	0	0	28	30	25	27.67	92.22
20/06/2020	23	0	0	0	28	30	25	27.67	92.22
21/06/2020	24	0	0	0	28	30	25	27.67	92.22
22/06/2020	25	0	0	0	28	30	25	27.67	92.22
23/06/2020	26	0	0	0	28	30	25	27.67	92.22
24/06/2020	27	0	0	0	28	30	25	27.67	92.22
25/06/2020	28	0	0	0	28	30	25	27.67	92.22

APPENDIX B

STATISTICS ANALYSIS OF SEED GERMINATION RESULTS

Table B.1 Seed germination percentage in 28 days of *M. siamensis*.

Descriptives

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	Upper Bound	Minimum	Maximum
Control	3	58.8889	24.57038	14.18572	-2.1473	119.9251	40.00	86.67
H_2O	3	75.5556	11.70628	6.75863	46.4755	104.6356	63.33	86.67
Scarification	3	96.6667	3.33333	1.92450	88.3862	104.9471	93.33	100.00
Hot water	3	2.2222	1.92450	1.11111	-2.5585	7.0029	.00	3.33
H_2SO_4	3	.0000	.00000	.00000	.0000	.0000	.00	.00
Total	15	46.6667	41.76655	10.78408	23.5371	69.7962	.00	100.00

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	22911.111	4	5727.778	37.904	.000
Within Groups	1511.111	10	151.111		
Total	24422.222	14			

Table B.1 Seed germination percentage in 28 days of *M. siamensis* (Continued).

Multiple Comparisons

Dependent Variable:result

	(I) treatment	(J) treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
LSD	Control	H_2O	-16.66667	10.03697	.128	-39.0304	5.6971
		Scarification	-37.77778*	10.03697	.004	-60.1415	-15.4140
		Hot water	56.66667*	10.03697	.000	34.3029	79.0304
		H_2SO_4	58.88889*	10.03697	.000	36.5251	81.2526
	H_2O	Control	16.66667	10.03697	.128	-5.6971	39.0304
		Scarification	-21.11111	10.03697	.062	-43.4749	1.2526
		Hot water	73.33333*	10.03697	.000	50.9696	95.6971
		H_2SO_4	75.55556*	10.03697	.000	53.1918	97.9193
	Scarification	Control	37.77778*	10.03697	.004	15.4140	60.1415
		H_2O	21.11111	10.03697	.062	-1.2526	43.4749
		Hot water	94.44444*	10.03697	.000	72.0807	116.8082
		H_2SO_4	96.66667*	10.03697	.000	74.3029	119.0304
	Hot water	Control	-56.66667*	10.03697	.000	-79.0304	-34.3029
		H_2O	-73.33333*	10.03697	.000	-95.6971	-50.9696
		Scarification	-94.44444*	10.03697	.000	-116.8082	-72.0807
		H_2SO_4	2.22222	10.03697	.829	-20.1415	24.5860
	H_2SO_4	Control	-58.88889*	10.03697	.000	-81.2526	-36.5251
		H_2O	-75.55556*	10.03697	.000	-97.9193	-53.1918
		Scarification	-96.66667*	10.03697	.000	-119.0304	-74.3029
		Hot water	-2.22222	10.03697	.829	-24.5860	20.1415

*. The mean difference is significant at the 0.05 level.

Table B.1 Seed germination percentage in 28 days of *M. siamensis* (Continued).

			Subset for alpha = 0.05		
	Treatment	N	1	2	3
Duncan[a]	H_2SO_4	3	.0000		
	Hot water	3	2.2222		
	Control	3		58.8889	
	H_2O	3		75.5556	75.5556
	Scarification	3			96.6667
	Sig.		.829	.128	.062

Table B.2 Mean daily germination (MDG) in 28 days of *M. siamensis.*

Descriptives

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Control	3	2.1032	.87751	.50663	-.0767	4.2830	1.43	3.10
H_2O	3	2.6984	.41808	.24138	1.6598	3.7370	2.26	3.10
Scarification	3	3.4524	.11905	.06873	3.1567	3.7481	3.33	3.57
Hot water	3	.0794	.06873	.03968	-.0914	.2501	.00	.12
H_2SO_4	3	.0000	.00000	.00000	.0000	.0000	.00	.00
Total	15	1.6667	1.49166	.38515	.8406	2.4927	.00	3.57

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	29.223	4	7.306	37.904	.000
Within Groups	1.927	10	.193		
Total	31.151	14			

Table B.2 Mean daily germination (MDG) in 28 days of *M. siamensis* (Continued).

Multiple Comparisons

Dependent Variable: result

	(I) treatment	(J) treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
LSD	Control	H2O	-.59524	.35846	.128	-1.3939	.2035
		Scarification	-1.34921*	.35846	.004	-2.1479	-.5505
		Hot water	2.02381*	.35846	.000	1.2251	2.8225
		Sulfuric acid	2.10317*	.35846	.000	1.3045	2.9019
	H_2O	control	.59524	.35846	.128	-.2035	1.3939
		Scarification	-.75397	.35846	.062	-1.5527	.0447
		Hot water	2.61905*	.35846	.000	1.8203	3.4178
		Sulfuric acid	2.69841*	.35846	.000	1.8997	3.4971
	Scarification	control	1.34921*	.35846	.004	.5505	2.1479
		H2O	.75397	.35846	.062	-.0447	1.5527
		Hot water	3.37302*	.35846	.000	2.5743	4.1717
		Sulfuric acid	3.45238*	.35846	.000	2.6537	4.2511
	Hot water	control	-2.02381*	.35846	.000	-2.8225	-1.2251
		H2O	-2.61905*	.35846	.000	-3.4178	-1.8203
		Scarification	-3.37302*	.35846	.000	-4.1717	-2.5743
		Sulfuric acid	.07937	.35846	.829	-.7193	.8781
	H_2SO_4	control	-2.10317*	.35846	.000	-2.9019	-1.3045
		H2O	-2.69841*	.35846	.000	-3.4971	-1.8997
		Scarification	-3.45238*	.35846	.000	-4.2511	-2.6537
		Hot water	-.07937	.35846	.829	-.8781	.7193

*. The mean difference is significant at the 0.05 level.

Table B.2 Mean daily germination (MDG) in 28 days of *M. siamensis* (Continued).

Homogeneous Subsets

			Subset for alpha = 0.05		
	treatment	N	1	2	3
Duncan[a]	H_2SO_4	3	.0000		
	Hot water	3	.0794		
	Control	3		2.1032	
	H_2O	3		2.6984	2.6984
	Scarification	3			3.4524
	Sig.		.829	.128	.062

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Table B.3 Germination speed (GS) in 28 days of *M. siamensis*.

Descriptives

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Control	3	1.0458	.21064	.12162	.5225	1.5690	.86	1.28
H_2O	3	1.7968	.54908	.31701	.4328	3.1608	1.16	2.12
Scarification	3	3.1331	.69536	.40146	1.4057	4.8605	2.36	3.70
Hot water	3	.0313	.02845	.01643	-.0393	.1020	.00	.06
H_2SO_4	3	.0000	.00000	.00000	.0000	.0000	.00	.00
Total	15	1.2014	1.26571	.32680	.5005	1.9023	.00	3.70

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	20.768	4	5.192	31.269	.000
Within Groups	1.660	10	.166		
Total	22.428	14			

Table B.3 Germination speed (GS) in 28 days of *M. siamensis* (Continued).

Multiple Comparisons

Dependent Variable:result

	(I) treatment	(J) treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
LSD	Control	H_2O	-.75103*	.33271	.048	-1.4923	-.0097
		Scarification	-2.08733*	.33271	.000	-2.8286	-1.3460
		Hot water	1.01444*	.33271	.012	.2731	1.7557
		H_2SO_4	1.04577*	.33271	.010	.3045	1.7871
	H2O	Control	.75103*	.33271	.048	.0097	1.4923
		Scarification	-1.33630*	.33271	.002	-2.0776	-.5950
		Hot water	1.76547*	.33271	.000	1.0242	2.5068
		H_2SO_4	1.79681*	.33271	.000	1.0555	2.5381
	Scarification	Control	2.08733*	.33271	.000	1.3460	2.8286
		H_2O	1.33630*	.33271	.002	.5950	2.0776
		Hot water	3.10176*	.33271	.000	2.3604	3.8431
		H_2SO_4	3.13310*	.33271	.000	2.3918	3.8744
	Hot water	Control	-1.01444*	.33271	.012	-1.7557	-.2731
		H_2O	-1.76547*	.33271	.000	-2.5068	-1.0242
		Scarification	-3.10176*	.33271	.000	-3.8431	-2.3604
		H_2SO_4	.03134	.33271	.927	-.7100	.7727
	H_2SO_4	Control	-1.04577*	.33271	.010	-1.7871	-.3045
		H_2O	-1.79681*	.33271	.000	-2.5381	-1.0555
		Scarification	-3.13310*	.33271	.000	-3.8744	-2.3918
		Hot water	-.03134	.33271	.927	-.7727	.7100

*. The mean difference is significant at the 0.05 level.

Table B.3 Germination speed (GS) in 28 days of *M. siamensis* (Continued).

			Subset for alpha = 0.05			
	treatment	N	1	2	3	4
Duncan[a]	H_2SO_4	3	.0000			
	Hot water	3	.0313			
	Control	3		1.0458		
	H_2O	3			1.7968	
	Scarification	3				3.1331
	Sig.		.927	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Table B.4 Mean germination time (MGT) in 28 days of *M. siamensis.*

Descriptives

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	Upper Bound	Minimum	Maximum
Control	3	17.5265	3.33839	1.92742	9.2335	25.8195	15.17	21.35
H_2O	3	14.7766	2.73283	1.57780	7.9878	21.5653	12.26	17.68
Scarification	3	10.1717	1.67653	.96795	6.0070	14.3365	9.17	12.11
Hot water	2	22.0000	5.65685	4.00000	-28.8248	72.8248	18.00	26.00
Total	11	15.5840	5.08264	1.53247	12.1695	18.9986	9.17	26.00

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	183.484	3	61.161	5.720	.027
Within Groups	74.848	7	10.693		
Total	258.332	10			

Table B.4 Mean germination time (MGT) in 28 days of *M. siamensis* (Continued).

Multiple Comparisons

Dependent Variable:result

	(I) treartment	(J) treartment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
LSD	Control	H2O	2.74993	2.66990	.337	-3.5634	9.0632
		Scarification	7.35477*	2.66990	.028	1.0415	13.6681
		Hot water	-4.47350	2.98504	.178	-11.5320	2.5850
	H_2O	Control	-2.74993	2.66990	.337	-9.0632	3.5634
		Scarification	4.60484	2.66990	.128	-1.7085	10.9182
		Hot water	-7.22343*	2.98504	.046	-14.2819	-.1649
	Scarification	Control	-7.35477*	2.66990	.028	-13.6681	-1.0415
		H2O	-4.60484	2.66990	.128	-10.9182	1.7085
		Hot water	-11.82827*	2.98504	.005	-18.8868	-4.7698
	Hot water	Control	4.47350	2.98504	.178	-2.5850	11.5320
		H2O	7.22343*	2.98504	.046	.1649	14.2819
		Scarification	11.82827*	2.98504	.005	4.7698	18.8868

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets

	treartment	N	Subset for alpha = 0.05 1	2	3
Duncan[a]	Scarification	3	10.1717		
	H_2O	3	14.7766	14.7766	
	Control	3		17.5265	17.5265
	Hot water	2			22.0000
	Sig.		.148	.364	.158

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.667.

Table B.5 Seed germination percentage in 28 days of *M. koratensis.*

Descriptive

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	Upper Bound	Minimum	Maximum
Control	3	70.0000	26.45751	15.27525	4.2759	135.7241	40.00	90.00
H_2O	3	35.5556	10.71517	6.18640	8.9376	62.1735	23.33	43.33
Scarification	3	92.2222	8.38870	4.84322	71.3835	113.0609	83.33	100.00
Total	9	65.9259	28.85682	9.61894	43.7446	88.1072	23.33	100.00

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4891.358	2	2445.679	8.289	.019
Within Groups	1770.370	6	295.062		
Total	6661.728	8			

Pos Hoc (Multiple Comparisons)

	(I) treatment	(J) treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
LSD	Control	H_2O	34.44444*	14.02526	.049	.1259	68.7630
		Scarification	-22.22222	14.02526	.164	-56.5408	12.0963
	H_2O	Control	-34.44444*	14.02526	.049	-68.7630	-.1259
		Scarification	-56.66667*	14.02526	.007	-90.9852	-22.3481
	Scarification	Control	22.22222	14.02526	.164	-12.0963	56.5408
		H_2O	56.66667*	14.02526	.007	22.3481	90.9852

*. The mean difference is significant at the 0.05 level.

Table B.5 Seed germination percentage in 28 days of *M. koratensis* (Continued).

Duncan

			Subset for alpha = 0.05	
	treatment	N	1	2
Duncan[a]	H_2O	3	35.5556	
	control	3		70.0000
	Scarification	3		92.2222
	Sig.		1.000	.164

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Table B.6 Mean daily germination (MDG) in 28 days of *M. koratensis.*

Descriptives

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Control	3	2.50	.945	.546	.15	4.85	1	3
H_2O	3	1.27	.383	.221	.32	2.22	1	2
Scarification	3	3.29	.300	.173	2.55	4.04	3	4
Total	9	2.35	1.031	.344	1.56	3.15	1	4

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	6.239	2	3.119	8.289	.019
Within Groups	2.258	6	.376		
Total	8.497	8			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: Result

	(I) treatment	(J) treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Tukey HSD	Control	H_2O	1.230	.501	.108	-.31	2.77
		Scarification	-.794	.501	.322	-2.33	.74
	H_2O	Control	-1.230	.501	.108	-2.77	.31
		Scarification	-2.024*	.501	.016	-3.56	-.49
	Scarification	Control	.794	.501	.322	-.74	2.33
		H_2O	2.024*	.501	.016	.49	3.56
LSD	Control	H_2O	1.230*	.501	.049	.00	2.46
		Scarification	-.794	.501	.164	-2.02	.43
	H_2O	Control	-1.230*	.501	.049	-2.46	.00
		Scarification	-2.024*	.501	.007	-3.25	-.80
	Scarification	Control	.794	.501	.164	-.43	2.02
		H_2O	2.024*	.501	.007	.80	3.25

*. The mean difference is significant at the 0.05 level.

Table B.6 Mean daily germination (MDG) in 28 days of *M. koratensis* (Continued).

Homogeneous Subsets

Result

			Subset for alpha = 0.05	
	treatment	N	1	2
Duncan[a]	H_2O	3	1.27	
	Control	3		2.50
	Scarification	3		3.29
	Sig.		1.000	.164

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Table B.7 Germination speed (GS) in 28 days of *M. koratensis*.

Descriptives

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Control	3	1.3608	.65281	.37690	-.2608	2.9825	.66	1.95
H_2O	3	.9188	.26398	.15241	.2630	1.5745	.64	1.17
Scarification	3	5.2749	.48884	.28223	4.0605	6.4892	4.71	5.58
Total	9	2.5182	2.12016	.70672	.8885	4.1479	.64	5.58

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	34.491	2	17.245	70.409	.000
Within Groups	1.470	6	.245		
Total	35.961	8			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: result

	(I) treatment	(J) treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
LSD	Control	H_2O	.44204	.40409	.316	-.5467	1.4308
		Scarification	-3.91406*	.40409	.000	-4.9028	-2.9253
	H_2O	Control	-.44204	.40409	.316	-1.4308	.5467
		Scarification	-4.35611*	.40409	.000	-5.3449	-3.3673
	Scarification	Control	3.91406*	.40409	.000	2.9253	4.9028
		H_2O	4.35611*	.40409	.000	3.3673	5.3449

*. The mean difference is significant at the 0.05 level.

Table B.7 Germination speed (GS) in 28 days of *M. koratensis* (Continued).

Homogeneous Subsets

			Subset for alpha = 0.05	
	treatment	N	1	2
Duncan[a]	H_2O	3	.9188	
	Control	3	1.3608	
	Scarification	3		5.2749
	Sig.		.316	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Table B.8 Mean germination time (MGT) in 28 days of *M. koratensis*.

Descriptives

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Control	3	16.7546	2.10463	1.21511	11.5264	21.9828	14.56	18.75
H_2O	3	12.2759	.93245	.53835	9.9596	14.5923	11.57	13.33
Scarification	3	6.0325	.08910	.05144	5.8112	6.2539	5.96	6.13
Total	9	11.6877	4.80385	1.60128	7.9951	15.3803	5.96	18.75

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	174.002	2	87.001	49.182	.000
Within Groups	10.614	6	1.769		
Total	184.616	8			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: result

	(I) treatment	(J) treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
LSD	Control	H_2O	4.47868*	1.08596	.006	1.8214	7.1359
		Scarification	10.72209*	1.08596	.000	8.0648	13.3793
	H_2O	Control	-4.47868*	1.08596	.006	-7.1359	-1.8214
		Scarification	6.24341*	1.08596	.001	3.5862	8.9006
	Scarification	Control	-10.72209*	1.08596	.000	-13.3793	-8.0648
		H_2O	-6.24341*	1.08596	.001	-8.9006	-3.5862

*. The mean difference is significant at the 0.05 level.

Table B.8 Mean germination time (MGT) in 28 days of *M. koratensis* (Continued).

Homogeneous Subsets

			Subset for alpha = 0.05		
	treatment	N	1	2	3
Duncan[a]	Scarification	3	6.0325		
	H_2O	3		12.2759	
	Control	3			16.7546
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

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