

APPENDICES

ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่
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APPENDIX A

Plant species descriptions

Descriptions of each plant species in this study base on Gardner *et al.* (2007), The Botanical Garden Organization (2011), Pakkad (1997) and FORRU (2006). Plant scientific names, family names and local name follow The Plant List (2013) and Gardner *et al.* (2007). Seed volumes (width x long x thickness of seed) were measuring in this study.

***Hovenia dulcis* Thunb**

Mawn Hin(หมอนหิน)

(RHAMNACEAE)

A large, pioneer, briefly deciduous tree, growing up to 30 m tall. This species were record as rare species in evergreen forest often along stream, seasonal, hardwood forestand open disturbed roadside, at elevation of 1,025 to 1,325 m above sea level.

Bark: thick bark with broad, longitudinal, grey or brown ridges, separated by narrow brick-red fissures (Figure 7.1A).

Leaf: spirally arranged, simple blade with ovate to elliptic (Figure 7.1B)

Flower: in cymes, numerous, light green and cream, small (March to May)

Fruit and seed: septicidal capsule, fruit stalks very thin and curving for 2-3 mm above each fruit, swollen and fleshy, green when fruit are unripe (Figure 7.1C), turning red-brown or black as fruit ripen(August to February), glossy, black seed per locule (4.60 x 4.84 x 2.13 m³ of seed volume), birds-dispersed particularly by pigeons (Kopachon *et al.*, 1996).

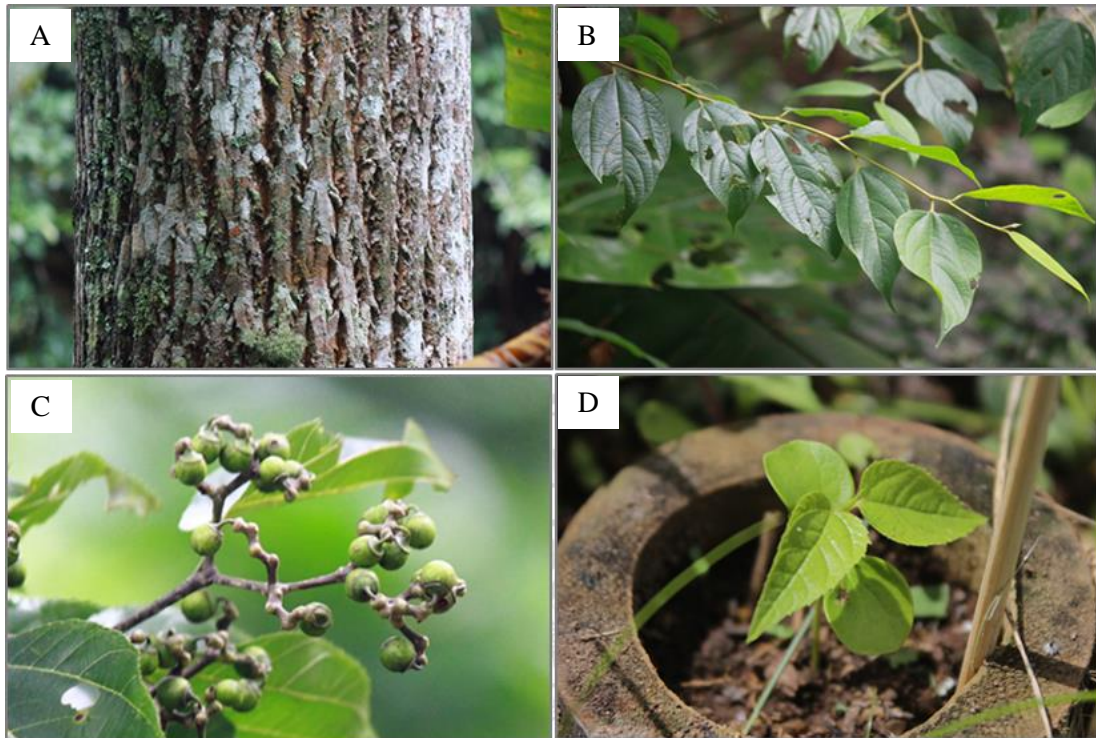


Figure 7.1 Bark (A), leaves (B), fruits (C) and small seedling (D) of *Hovenia dulcis* species.

***Alangium kurzii* Craib**

Sa Leek Dong (สะเล็ดคอง)

(CORNACEAE)

Pioneer tree, growing up to 28 m tall. Common in evergreen forest at elevation 600-1,400 m above sea level.

Bark: smooth, dark grey, lenticellate; inner bark orange and cream mottled (Figure 7.2A).

Leaf: broadly ovate with tapering tip and heart-shaped base, obviously asymmetric; mature leaves densely covered with soft golden hair below and on veins only above (Figure 7.2B).

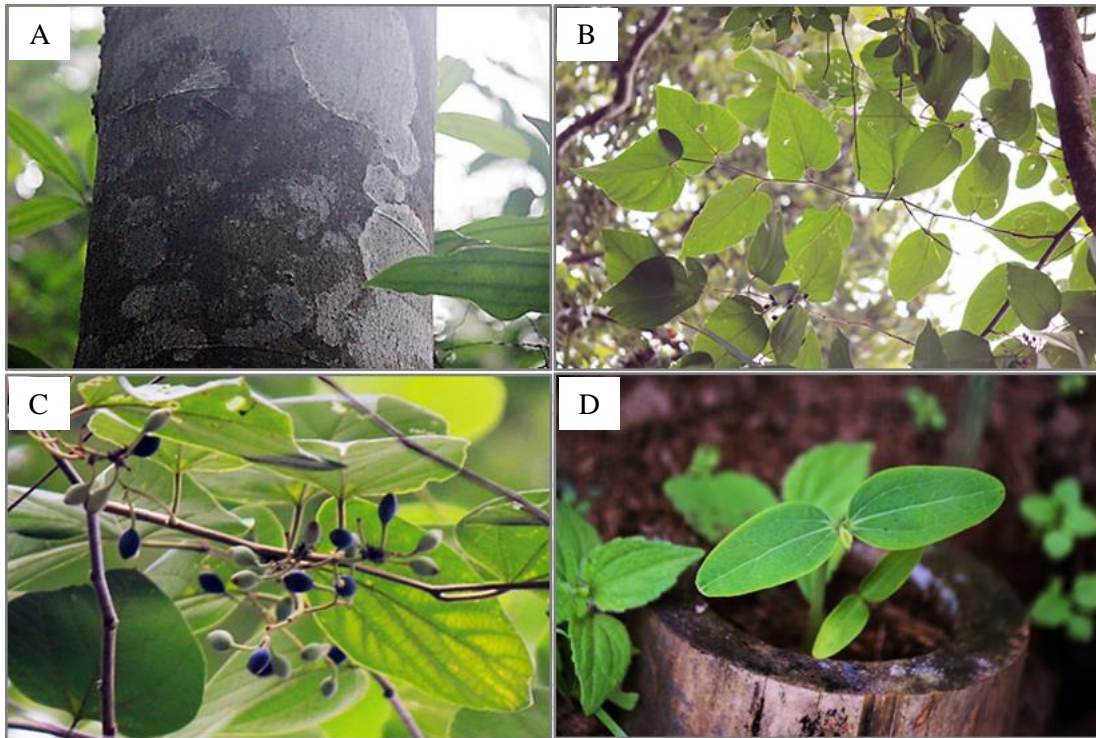


Figure 7.2 Bark (A), leaves (B), fruits (C) and small seedling (D) of *Alangium kurzii* species.

Flower: very fragrant, main stalks to 7-9 petals, dense silvery hairs, connectives also hairy (March to May).

Fruit and seed: 1.2-1.5 cm, ellipsoid with blunt tip, smooth to thinly hairy, sometime slightly grooved, crowned by distinct disc, ripening dark purple to black (June to September), contains one black seed (7.08 x 11.83 x 4.67 m³ of seed volume), oval with pointed ends (Figure 7.2C), bird-dispersed

***Prunus cerasoides* D. Don** **Nang Paya Sua Krong** (นางพญาเสือโคร่ง)

(ROSACEAE)

A medium-sized, pioneer, deciduous tree, growing up to 16-18m tall. It's fairly common in evergreen forest, mixed-forest and evergreen forest-pine, often in disturbed areas, at elevations of 1,040 to 2,400 m above sea level.

Bark: shiny, red-brown, with large, raised, brown lenticels; outer layer peeling horizontally (Figure 7.3A).

Leaf: spirally arranged, simple, blades; margin finely serrate; dark red, stalked, glands where petiole meets blade (Figure 7.3B).

Flower: in axillary clusters, petals, pink; on leafless trees (December to January).

Fruit and seed: drupes (small cherries), ovoid, red when ripe, 10 -15 mm(March to May), each containing a single-seeded pyrene(7.31 x 9.67 x 6.01 m³of seed volume); dispersed by birds, squirrels and other small mammals ((Figure 7.1C).

Birds such as, Sunbirds, Spider-hunters and White-eyes feed on the nectar, whilst bulbuls eat the fruits.

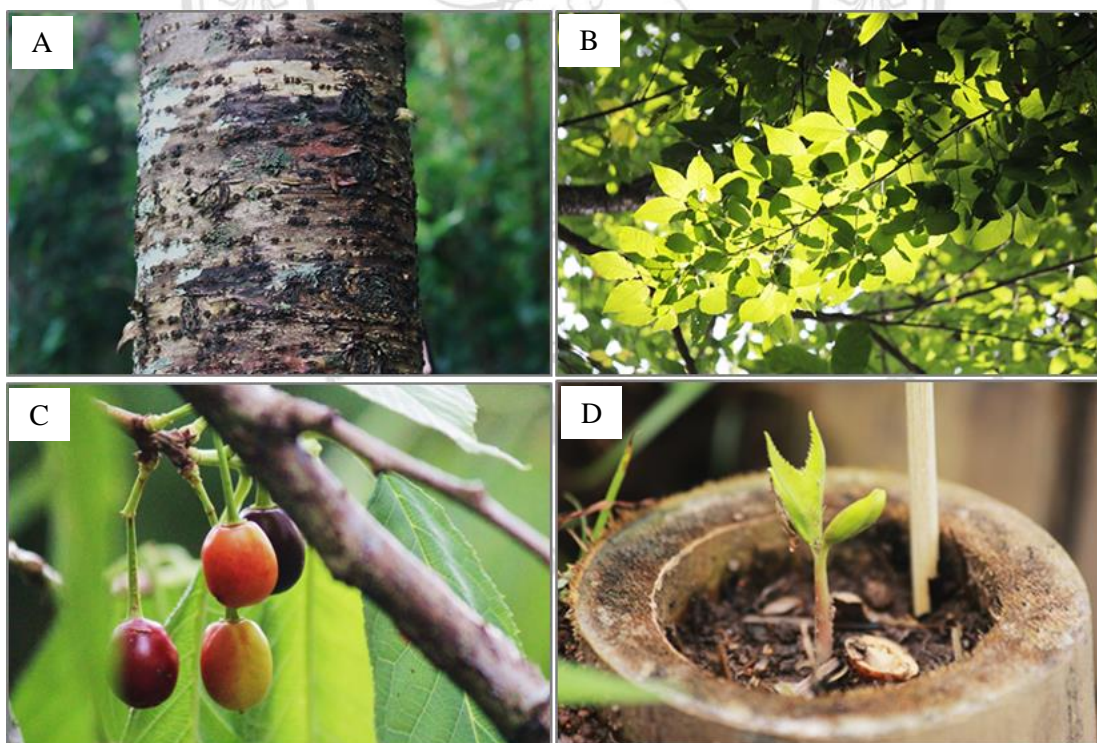


Figure 7.3 Bark (A), leaves (B), fruits (C) and small seedling (D) of *Prunus cerasoides* species.

***Choerospondias axillaris* Roxb.**

Ma Kak (มะกัก), Ma Mue (มะมือ)

(ANACARDIACEAE)

A medium-sized, pioneer, deciduous tree, growing up to 25 to 30 m tall. The common plant species, widespread in evergreen forest, evergreen forest-pine and mixed forest at elevations of 700 to 1,600 m above sea level. Planted saplings achieve very high survival and growth rates. The tree support nesting birds from the 5th year after planting.

Bark: grey-brown, thin, vertically cracked (Figure 7.4A).

Leaf: spirally arranged, compound, once pinnate, leaflet blades opposite or sub-opposite, ovate to ovate-lanceolate, apex acuminate (Figure 7.4B).

Flower: male inflorescences 4-10 cm long; male corollas dark reddish purple, 0.4-0.5 cm; females solitary in upper leaf axils; January to March.



Figure 7.4 Bark (A), leaves (B), fruits (C) and small seedling (D) of *Choerospondias axillaris* species.

Fruit and seed: drupes, oval-shaped, with yellow leathery exocarp when ripe (June to August), 25-30 x 20mm across, each containing a single pyrene with 5 locules (13.81 x 18.83 x 13.67 m³ of seed volume); animal-dispersed (fruits are eaten by deer, wild pigs and bears) (Figure 7.4C).

***Horsfieldia glabra* (Reinw. ex Blume) Warb.**

Luead Ma (เลือดม้า)

(MYRISTICACEAE)

Evergreen, climax, small to medium tree to 10 to 25 m. This species distributed or locally common in less-disturbed forest, seasonal, hardwood forest, granite bedrock, at elevation 200 to 1,060 m above sea level.



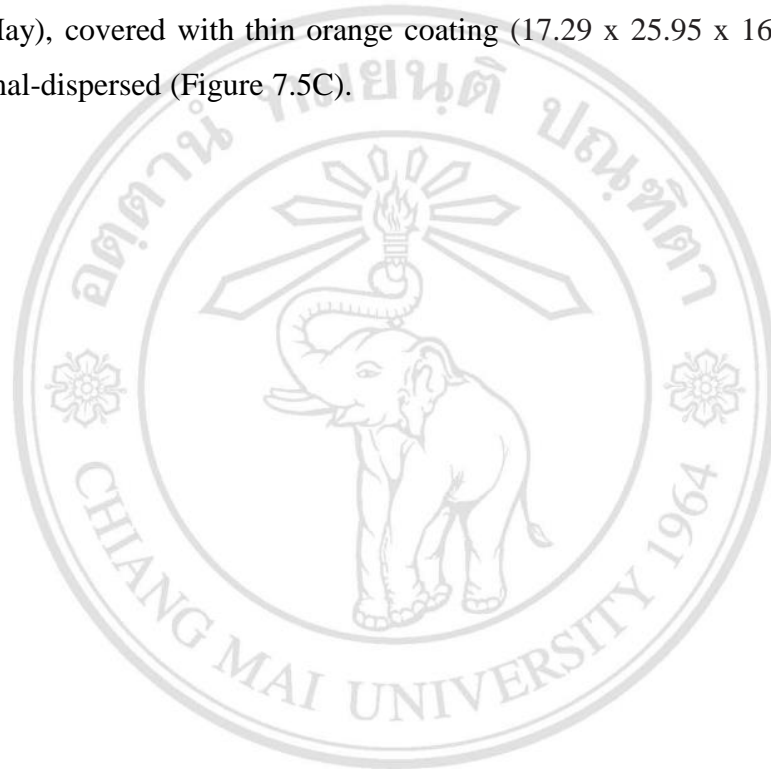
Figure 7.5 Bark (A), leaves (B), fruits (C) and small seedling (D) of *Horsfieldia glabra* species.

Bark: grey-brown, outer bark hard and brittle, inner bark yellow (Figure 7.5A).

Leaf: narrowly elliptic or obovate with blunt or pointed tip, smooth, dark green and glossy above (Figure 7.5B).

Flower: unisexual, pale yellow, in much-branched clusters at leaf axis or behind leaves; calyx globose or oval, often slightly triangular at base (September to October).

Fruit and seed: capsule fruit, yellow, smooth, firmly fleshy with single oblong seed (January to May), covered with thin orange coating (17.29 x 25.95 x 16.61m³ of seed volume); animal-dispersed (Figure 7.5C).



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APPENDIX B

Vertebrate and Invertebrate species

Photos from camera trap

Seed predators



Figure 7.6 *Rattus* sp. (Rat: หนูบ้านหรือหนูท้องขาว).



Figure 7.7 *Turnix suscitator* (Barred buttonquail: นกคู้มอกลาย).
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Non-Seed predators

Tree shrew species



Figure 7.8 *Tupaia belangeri* (Northern treeshrew: กระแตเหนือ).

Carnivore species



Figure 7.9 *Canis aureus cruesemanni* (Siamese jackal: หมาจิ้งจอกทอง).



Figure 7.10 *Prionailurus bengalensis* (Leopard cat: แมวดาว).



Figure 7.11 *Herpestes javanicus* (Small asian mongoose: พอนเล็ก หรือ ฟังพอนธรรมดา).



Figure 7.12 *Arctonyx collaris* (Hog badger: หมูหริ่ง).



Figure 7.13 *Viverra zibetha* (Large indian civet: ชะมดแดงหางปลีอง).

Bird species



Figure 7.14 *Anthus cervinus* (Red-throated Pipit: นกเค้าดินอกแดง).



Figure 7.15 *Centropus sinensis* (Greater coucal: นกกระปูดใหญ่).



Figure 7.16 *Lanius schach* (Long-tailed Shrike: นกอีเสือหัวดำ).



Figure 7.17 *Lonchura punctulata* (Scaly-breasted Munia: นกกระต๊อขี้หนุ).



Figure 7.18 *Phylloscopus trochiloides* (Greenish Warbler: นกกระจิดเขียวคล้ำ).



Figure 7.19 *Pycnonotus aurigaster* (Sooty-headed bulbul: นกปรอดหัวสีเขม่า).



Figure 7.20 *Saxicola caprata* (Pied Bushchat: นกขอดหญ้าสีดำ).

Photos of Invertebrates species

A) Family Formicidae



B) Family Apidae

C) Family Braconidae

D) Family Ceraphronidae



E) Family Ichneumonidae

Mouthpart: Chewing

Feeder type: Herbivore, Carnivore and Omnivore

Figure 7.21 Example of insect in Order Hymenoptera (9 families, 3255 individuals).

A) Family Acrididae



B) Family Tetrigidae



C) Family Gryllotalpa



D) Family Gryllidae



Mouthpart: Chewing

Feeder type: Herbivore

Figure 7.22 Example of insect in Order Orthoptera (4 families, 62 individuals).

A) Family Chloropidae



B) Family Dolichopodidae



C) Family Muscidae



Mouthpart: Lapping

Feeder type: Scavenger

Figure 7.23 Example of insect in Order Diptera (12 families, 301 individuals).



Family Oligomuchinae

Mouthpart: Chewing
Feeder type: Predator

Figure 7.24 Example of insect in Order Mantodea (1 family, 1 individual).



Family Heteronemiidae

Mouthpart: Chewing
Feeder type: Herbivore

Figure 7.25 Example of insect in Order Phasmida (2 families, 2 individuals).

A) Family Aphididae

B) Family Cicadellidae



Mouthpart:Sucking
Feeder type: Plant feeder

Figure 7.26 Example of insect in Order Homoptera (5 families, 36 individuals).

A) Larva of family Geometridae

B) Larva of family Noctuidae



C) Larva of family Erebidae



Mouthpart: Chewing

Feeder type: Plant feeder

Figure 7.27 Example of insect in Order Lepidoptera (3 families, 49 individuals).

A) Family Pentatomidae

B) Family Reduviidae

C) Family Rhopalidae



D) Family Cyxiidae

E) Family Miridae



Mouthpart: Sucking

Feeder type: Herbivore, Predator

Figure 7.28 Example of insect in Order Hemiptera (6 families, 14 individuals).

A) Family Carabidae



B) Family Chrysomelidae



C) Family Curculionidae



D) Family Scarabaeidae

Mouthpart: Chewing

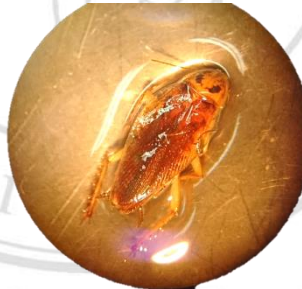
Feeder type: Predator, Herbivore

Figure 7.29 Example of insect in Order Coleoptera (9 families, 105 individuals).

A) Family Blatellidae



B) Family Blaberidae



Mouthpart: Chewing

Feeder type: Scavenger

Figure 7.30 Example of insect in order Blattodea (2 families, 8 individuals).



Family Forficulidae

Mouthpart: Chewing

Feeder type: Scavenger

Figure 7.31 Example of insect in Order Dermaptera (1 family, 2 individuals).



Family Termitidae

Mouthpart: Chewing

Feeder type: Scavenger

Figure 7.32 Example of insect in Order Isoptera (1 family, 3 individuals).

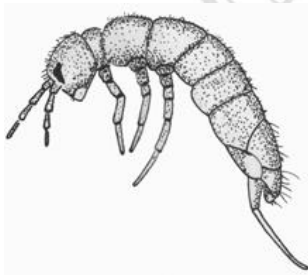


Family Corioxenidae

Mouthpart: Chewing

Feeder type: Parasitoids

Figure 7.33 Example of insect in Order Strepsiptera (1 family, 1 individual).



Springtail

Family Entomobryidae

Mouthpart: Chewing

Feeder type: Scavenger

Image from: <https://extension.entm.purdue.edu/401Book/default.php?page=collembola>

Figure 3.34 Example of insect in Order Collembola (1 family, 21 individuals).



Mouthpart: Chewing
Feeder type: Predator

Figure 3.35 Example of insect in Order Araneae (3 families, 3 individuals).



Mouthpart: Chewing
Habit: Herbivore

Figure 3.36 Example of insect in Order Gastropoda (1 family, 1 individual).

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APPENDIX C

Statistic test

Seed removal model from GLM result

Call: glm(formula = cbind(Removed, (Sowing - Removed)) ~ Species + Treatment, family = binomial, data = Removal, weights = disp.weights)

Deviance Residuals: Min 1Q Median 3Q Max
 -2.8261 -0.4561 -0.0707 0.2234 4.7994

Coefficients:	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	-5.3404	1.1474	-4.654	3.25e-06 ***
SpeciesChoerospondias	1.3370	1.0023	1.334	0.182220
SpeciesHorsfieldia	10.5630	1.7850	5.918	3.26e-09 ***
SpeciesHovenia	0.5202	1.1212	0.464	0.642681
SpeciesPrunus	0.5202	1.1212	0.464	0.642681
TreatmentCage	-5.5826	1.6183	-3.450	0.000561 ***
TreatmentInsecticide	1.3612	0.8976	1.516	0.129408
TreatmentInsecticide+Cage	-3.1599	1.6424	-1.924	0.054358 .
TreatmentOpenCage	0.7438	0.9643	0.771	0.440510

--- Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

Null deviance: 801.287 on 74 degrees of freedom

Residual deviance: 58.748 on 66 degrees of freedom

AIC: 96.854 Number of Fisher Scoring iterations: 8

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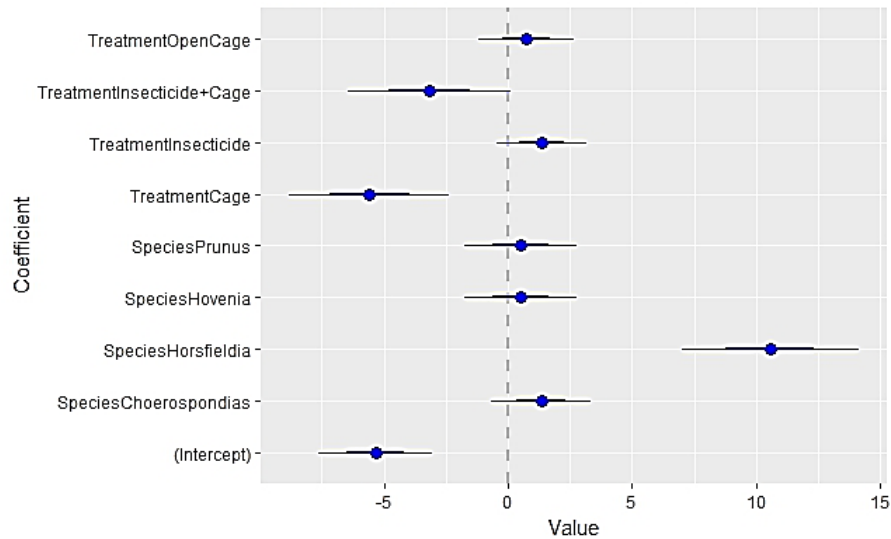


Figure 3.37 Coefficient plot of seed removal model from GLM.

Table 7.1 Probability of seed removal predicted by GLM.

	<i>H. dulcis</i>	<i>A. kurzii</i>	<i>P. cerasoides</i>	<i>C. axillaris</i>	<i>H. glabra</i>
Cage	0.00003	0.00002	0.00003	0.00007	0.41096
Insecticide	0.03050	0.01836	0.03050	0.06647	0.99862
Insecticide plus cage	0.00034	0.00020	0.00034	0.00077	0.88723
Open cage	0.01668	0.00998	0.01668	0.03698	0.99744
Control	0.00800	0.00477	0.00800	0.01793	0.99464

Relationship between seed removal and seed mass

Nonlinear regression model

Formula: Removal ~ exp(Mass * a) + 0

Parameters: Estimate Std. Error t value Pr(>|t|)

a 1.08079 0.01736 62.25 3.99e-07 ***

---Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 7.302 on 4 degrees of freedom

Number of iterations to convergence: 4

Achieved convergence tolerance: 6.178e-07

Seed germination model from GLM result

Call: glm(formula = cbind(Germination, (Sowing - Germination)) ~ Species, family = binomial, data = Germ, weights = disp.weights)

Deviance Residuals:	Min	1Q	Median	3Q	Max
	-3.2582	-0.6117	0.1900	0.6280	1.8579
Coefficients:	Estimate	Std. Error	z value	Pr(> z)	
(Intercept)	1.01160	0.21243	4.762	1.92e-06	***
SpeciesChoerospondias	-1.74502	0.29221	-5.972	2.35e-09	***
SpeciesHovenia	-2.57379	0.32666	-7.879	3.30e-15	***
SpeciesPrunus	-0.06714	0.29816	-0.225	0.822	

---Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

Null deviance: 176.472 on 59 degrees of freedom

Residual deviance: 61.514 on 56 degrees of freedom

AIC: 118.93

Number of Fisher Scoring iterations: 5

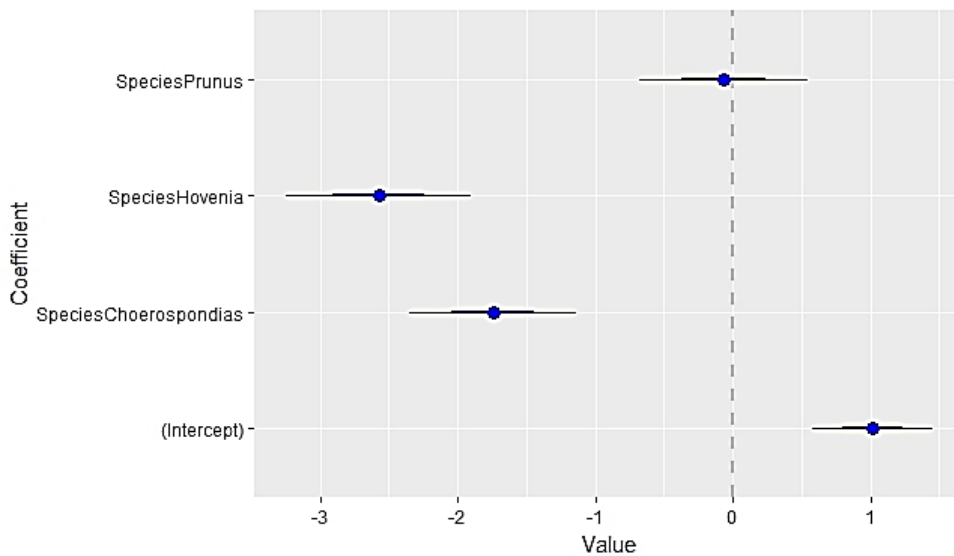


Figure 3.38 Coefficient plot of seed germination model from GLM.

When relevant and use Hovenia as a reference speciesChoerospondias has higher germination than Hovenia.

Call: glm(formula = cbind(Germination, (Sowing - Germination)) ~ Species, family = binomial, data = Germ2, weights = disp.weights)

Deviance Residuals: Min 1Q Median 3Q Max
 -3.1642 -0.5941 0.1845 0.6099 1.8043

Coefficients:	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	-1.5622	0.2555	-6.113	9.75e-10 ***
SpeciesAlangium	2.5738	0.3364	7.652	1.98e-14 ***
SpeciesChoerospondias	0.8288	0.3286	2.522	0.0117 *
SpeciesPrunus	2.5066	0.3342	7.500	6.39e-14 ***

---Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

Null deviance: 166.440 on 59 degrees of freedom

Residual deviance: 58.017 on 56 degrees of freedom

AIC: 112.62

Number of Fisher Scoring iterations: 5

Table 7.2 Percent probability of seed germination predicted from GLM model.

<i>H. dulcis</i>	<i>A. kurzii</i>	<i>P. cerasoides</i>	<i>C. axillaris</i>
17.33	73.33	72.00	32.44

Cotyledonous-seedling mortality from GLM result

Call: glm(formula = cbind(Mortality\$Cmortality, (Mortality\$Germination - Mortality\$Cmortality)) ~ Species + Treatment, family = binomial, data = Mortality)

Deviance Residuals: Min 1Q Median 3Q Max
 -1.7905 -0.7019 -0.3748 0.4017 2.0005

Coefficients:	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	-2.3953	0.3536	-6.774	1.26e-11 ***
SpeciesChoerospondias	-0.9762	0.5673	-1.721	0.08529 .
SpeciesHovenia	-1.7945	1.0408	-1.724	0.08468 .
SpeciesPrunus	0.2251	0.3272	0.688	0.49138
TreatmentCage	-1.7292	0.6565	-2.634	0.00844 **
TreatmentInsecticide	0.6387	0.3917	1.631	0.10293
TreatmentInsecticide+Cage	-1.3592	0.5897	-2.305	0.02116 *
TreatmentOpenCage	-0.4584	0.4583	-1.000	0.31719

---Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

Null deviance: 75.667 on 56 degrees of freedom

Residual deviance: 39.472 on 49 degrees of freedom

AIC: 114.47 Number of Fisher Scoring iterations: 6

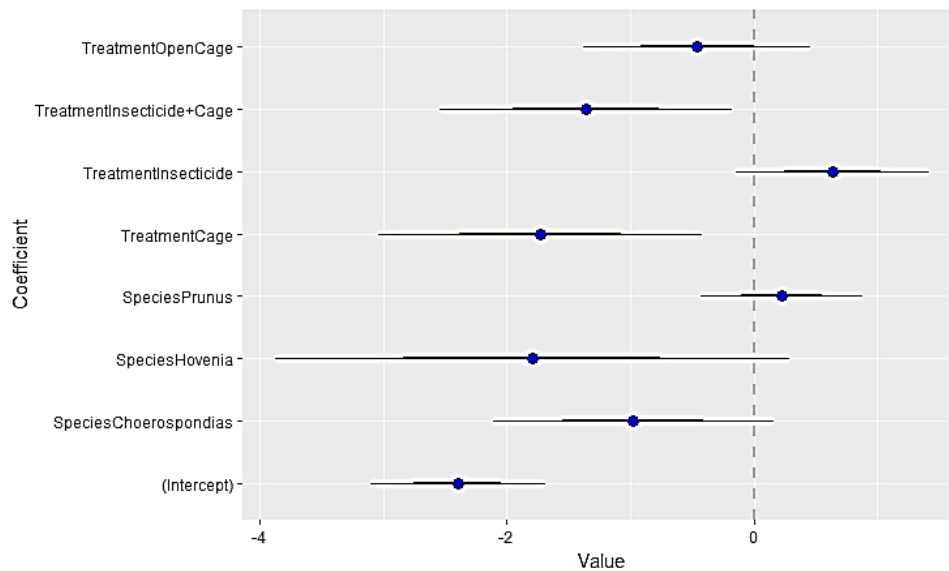


Figure 3.39 Coefficient plot of Cotyledonous-seedling mortality model from GLM.

Table 7.3 Probability of Cotyledonous-seedling mortality from GLM prediction model.

	<i>H.dulcis</i>	<i>A. kurzii</i>	<i>P. cerasoides</i>	<i>C. axillris</i>
Control	0.015	0.084	0.102	0.033
Cage	0.003	0.016	0.020	0.006
Insecticide	0.028	0.147	0.178	0.061
Insecticide plus cage	0.004	0.023	0.028	0.009
Open cage	0.009	0.054	0.067	0.021

Leafy-seedling mortality

Call: glm(formula = cbind(Lmortality\$Dead, (Lmortality\$Germination - Lmortality\$Dead)) ~

Species + Treatment, family = binomial, data = Lmortality, weights = disp.weights)

Deviance Residuals: Min 1Q Median 3Q Max

 -2.2678 -0.7980 -0.1651 0.7246 2.6816

Coefficients:

 Estimate Std. Error z value Pr(>|z|)

(Intercept) -1.32295 0.36302 -3.644 0.000268 ***

SpeciesChaerospondias -0.28853 0.40518 -0.712 0.476392

SpeciesHovenia	1.09053	0.38276	2.849	0.004384 **
SpeciesPrunus	0.02046	0.34468	0.059	0.952662
TreatmentCages	-0.85329	0.45187	-1.888	0.058979.
TreatmentInsecticide	0.11985	0.39119	0.306	0.759314
TreatmentInsecticide+Cages	-0.32137	0.40467	-0.794	0.427096
TreatmentOpen	-0.63058	0.43571	-1.447	0.147823

---Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

Null deviance: 79.263 on 56 degrees of freedom

Residual deviance: 58.554 on 49 degrees of freedom

AIC: 128.3 Number of Fisher Scoring iterations: 4

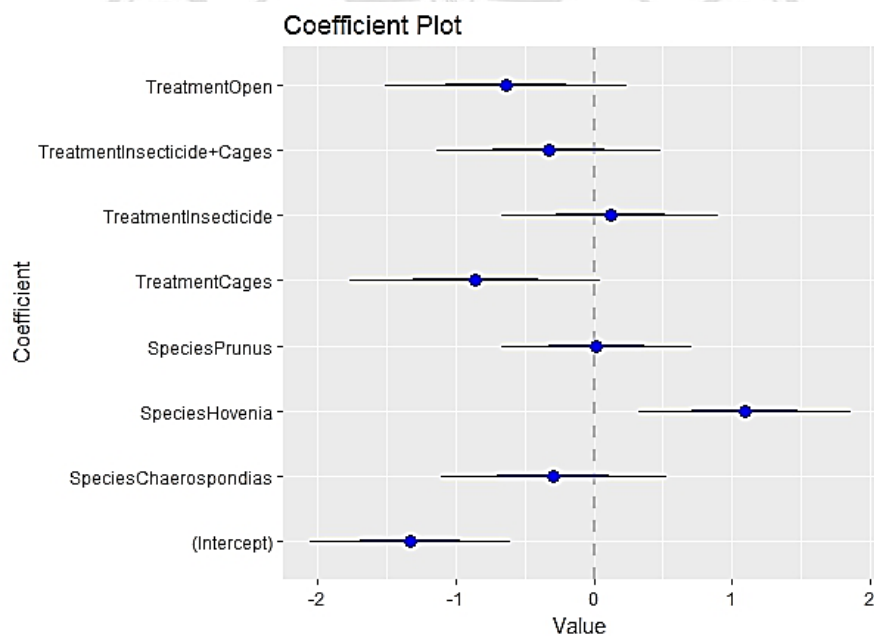


Figure 3.40 Coefficient plot of leafy-seedling mortality model from GLM.

Table 7.4 Probability of leafy-seedling mortality from GLM prediction model.

	<i>H.dulcis</i>	<i>A. kurzii</i>	<i>P. cerasoides</i>	<i>C. axillris</i>
Control	0.442	0.210	0.214	0.166
Cage	0.252	0.102	0.104	0.078
Insecticide	0.472	0.231	0.235	0.184
Insecticide plus cage	0.365	0.162	0.165	0.126
Open cage	0.297	0.124	0.126	0.096

T-test -> test between mortality per day of cotyledonous-seedling and leafy-seedling

Alternative hypothesis: true difference in means is not equal to 0

H. dulcis: $t = -2.4004$, $df = 4$, $p\text{-value} = 0.07432$

95 percent confidence interval: -0.85403771 0.06203771

sample estimates: mean of x mean of y

0.000 0.396

A.kurzii: $t = 2.6743$, $df = 5.1757$, $p\text{-value} = 0.04261^*$

95 percent confidence interval: 0.0444665 1.7888668

sample estimates: mean of x mean of y

1.0383333 0.1216667

P. cerasoides: $t = 2.9783$, $df = 5.0153$, $p\text{-value} = 0.03074^*$

95 percent confidence interval: 0.1638399 2.2161601

sample estimates: mean of x mean of y

1.3033333 0.1133333

C. axillaris: $t = 0.6839$, $df = 5.2471$, $p\text{-value} = 0.5231$

95 percent confidence interval: -0.4465007 0.7765007

sample estimates: mean of x mean of y

0.2383333 0.0733333

Seedling survival

glm(formula = cbind(Survive, (Germinated - Survive)) ~ Species, family = binomial, data = Survival, weights = disp.weights)

Deviance Residuals: Min 1Q Median 3Q Max
-1.44052 -0.62329 -0.09298 0.56284 1.73860

Coefficients:	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	0.3645	0.3314	1.100	0.27151
SpeciesAlangium	-1.5924	0.5111	-3.116	0.00184 **
SpeciesChoerospondias	-0.2404	0.4813	-0.500	0.61742
SpeciesHovenia	-1.6331	0.5734	-2.848	0.00440 **

---Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

Null deviance: 24.9167 on 11 degrees of freedom

Residual deviance: 8.0787 on 8 degrees of freedom

AIC: 25.58

Number of Fisher Scoring iterations: 4

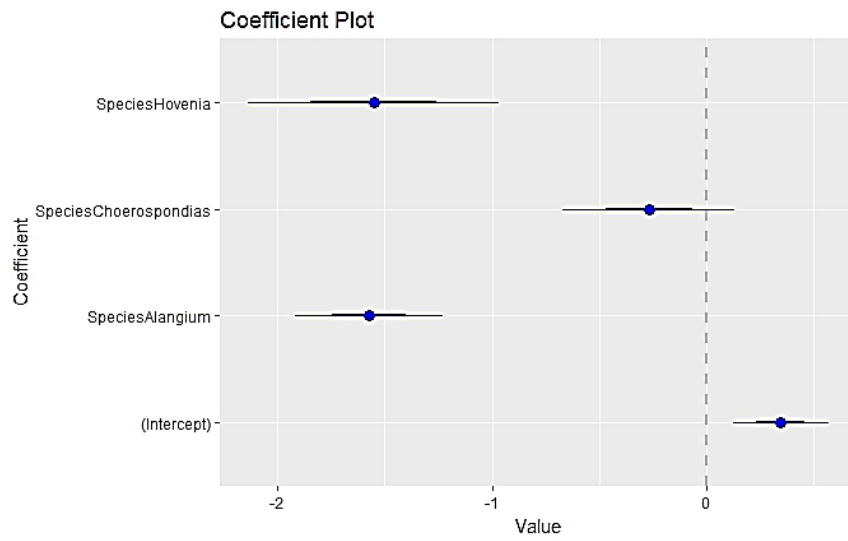


Figure 3.41 Coefficient plot of seedling survival model from GLM.

Table 7.5 Percent probability of seedling survival predicted from GLM model.

<i>H. dulcis</i>	<i>A. kurzii</i>	<i>P. cerasoides</i>	<i>C. axillaris</i>
22.0	23.0	58.0	52.0

APPENDIX D

Insecticide application



Trade name:	Kino505
Common name:	Chlorpyrifos and Cypermethrin
Chemical:	Organophosphate compound and Pyrethroid compound
Targets:	Insect such as aphids, caterpillar, ants and termites

Cypermethrin kills insects that eat or come into contact with it. This chemical works by quickly affecting the insect's central nervous system. The typical half-life of cypermethrin in the soil is 30 days and it can be rapidly broken down by soil microbes. Cypermethrin is highly toxic to fish, birds, bees and other insects. People handling or working with cypermethrin sometimes developed tingling, burning, dizziness and itching (NPIC, 1998).

Chlorpyrifos works by blocking an enzyme which controls messages that travel between nerve cells. Chlorpyrifos affects the nervous system of people, pets, and other animals the same way it affects the target pest. When chlorpyrifos released into the soil, it can take weeks to years for all of the chlorpyrifos to break down by ultraviolet light and chemicals in the soil (NPIC, 2010)

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