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SEASONAL ABUNDANCE AND BIOLOGY OF *CROTONOTHRIPS POLYALTHIAE* (THYSANOPTERA: PHLAEOTHRIPIDAE) AND ITS DAMAGE TO A SHADE TREE, *POLYALTHIA LONGIFOLIA*

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Abstract

The population dynamics and biology of the gall-inducing insect, *Crotonothrips polyalthiae* Mound & Nasruddin, and its damage to *Polyalthia longifolia* Sonn. were studied in Makassar, South Sulawesi, Indonesia, from 15 Aug 2010 to 25 Jul 2011. The average number of thrips per gall, young leaves per plant, and bi-weekly rainfall peaked 3 times during the survey. The average number of living thrips per gall peaked about 4 wk after the peak in the number of young leaves per plant, and this occurred 2 to 4 wk after each rainfall peak. The thrips development time ranged from 17 to 25 d with an average of 20.8 d. Average adult longevity for female and male were 24.3 and 12.2 d, respectively. The number of eggs laid by a female ranged from 11 to 74 with an average of 41.5 eggs. An average of 94.9% of those eggs successfully hatched. One year after the initiation of the experiment, the thrips reduced the plant height and stem circumference by 49 and 37%, respectively, in comparison with the plants that were kept thrips-uninfested by using insecticides. This appears to be the first experimental account of a gall-inducing thrips impeding the growth of a tree or woody plant.

Key Words: *Crotonothrips polyalthiae*, leaf gall, Phlaeothripidae, shade tree

Resumen

Se estudió la dinámica poblacional y biología del insecto, *Crotonothrips polyalthiae* Mound & Nasrudin, que induce agallas y daño a *Polyalthia longifolia* Sonn. en Makassar, Sulawesi del Sur, Indonesia, desde el 15 de agosto del 2010 hasta el 25 de julio del 2011. El promedio del número de trips por agalla, el número de hojas tiernas por planta, y la cantidad de lluvia cada dos semanas se incrementó 3 veces durante el tiempo de estudio. El promedio del número de trips vivos por agalla alcanzó su punto máximo alrededor de 4 semanas después del incremento en el número de hojas tiernas por planta y esto ocurrió de 2 a 4 semanas después de cada aumento de la lluvia. El tiempo de desarrollo de los trips fue entre 17 y 25 días con un promedio de 20.8 dias. El promedio de la longevidad de los adultos hembras y machos fue 24.3 y 12.2 días, respectivamente. El número de huevos puestos por hembra fue de 11 a 74 con un promedio de 41.5 huevos. Un promedio de 94.9% de los huevos eclosionaron éxitosamente. Un año después del inicio del experimento, los trips redujeron la altura de la planta y la circunferencia del tronco en un 49 y un 37%, respectivamente, en comparación con las plantas que se mantuvieron sin trips mediante el uso de insecticidas. Este parece ser el primer relato experimental de un trips que induce agallas e impide el crecimiento de un árbol o una planta leñosa.

Palabras Clave: *Crotonothrips polyalthiae*, agallas de la hoja, Phlaeothripidae, árbol de sombra

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Polyalthia longifolia (Sonn.), which belongs to the family Annonaceae, is indigenous to Sri Lanka and currently widely planted in many tropical countries (Mughal 2009). In many cities of Indonesia, the plant is used as a border and shade tree in parks, universities, and city streets. The tree has been very popular because of its aesthetic and medicinal values. It is a small sized erect evergreen tree growing up to 15 m. The plant has straight trunk and weeping branches, longest at the base and gradually shorter towards the top of the trunk, giving a more or less triangularshaped canopy. Leaves are long and narrow with the edge wavy. Shoots are coppery brown color, soft, and delicate to touch; while older and mature leaves are light green and dark green, respectively. Cultivation of this tree is usually from cuttings, not from seeds. The tree is easy to grow with minimum care, and can be trimmed easily to the desired shape without affecting its growth.

The plant has also been used as traditional medicine for the treatment of fever, skin diseases, and hypertension (Kirtikar & Basu 1995). In addition, several studies have shown the tree potential for medicinal purposes, such as hepatoprotective and anti-inflammatory (Tanna et al. 2009), antimicrobial (Faizi et al. 2003), and antiulcer (Malairajan 2008) activities.

No serious pests have been known to be associated with the tree, until Feb 2010 when numerous leaf galls were noticed on many trees planted throughout Hasanuddin University campus, Makassar, Indonesia. The gall structure was simple, involving a leaf folding along the leaf mid-rib. Closer observation revealed the presence within the galls of black adult thrips, with white-banded red larvae, and red pupae. Samples were sent to Canberra, Australia, for taxonomic study, and the species was then formally described as *Crotonothrips polyalthiae* Mound and Nasruddin, in the Thysanoptera family Phlaeothripidae (Mound & Nasruddin 2012). This was the first report of a thrips species associated with this tree, despite extensive records of galling by thrips on a wide range of plants in the Asian region (Ananthakrishnan & Raman 1989).

Crotonothrips polyalthiae is now known to be widespread in Southeast Asia (Mound & Nasruddin 2012), and induces large numbers of galls on *P. longifolia* around Kuala Lumpur, Malaysia as well as in Makassar, and specimens collected by Dr Mark Hoddle have recently been studied from galls on this plant near Medan, Sumatra. The study reported here is a first investigation into its bioecology, potential damage to the plant, and control. The objective of this study was to determine the population dynamics and life history of the thrips, and to quantify the effects of its feeding on plant growth.

Materials and Methods

Population Dynamics of Thrips

Gall samples were collected from *P. longifolia* trees at Hasanuddin University campus and its vicinities in Makassar, South Sulawesi Province, Indonesia. Ten mature galls per tree were collected from 20 trees and placed in separate self-sealing plastic bags and then brought back to the laboratory for further processing. Because the 2 sides of leaf blades are closely folded together to form the gall, they usually needed to be broken apart in order to extract all life stages of the thrips. This was possible to do because the thrips are not very mobile, and neither are they active fliers. The thrips were washed off the galls by rinsing the leaves with 70% ethanol over a fine cloth filter placed on a Berlese funnel. The thrips retained on the cloth filter were rinsed with ethanol, collected onto a Petri dish, and then counted under a dissecting microscope. The numbers of adults and immatures were determined under a stereo microscope (50-100X). Sampling in this way was performed every 2 wk from 15 Aug 2010 to 1 Jul 2011, and samples were taken at the same location to examine the dynamics of the local population (number thrips per gall) through time. On each observation date, the number of young leaves (less than four weeks of fully expanded leaves) per tree was also recorded.

Life Cycle of *Crotonothrips polyalthiae*

The life history of the thrips was studied using ten 3-month old *P. longifolia* seedlings, individually planted in a 3-kg polybag. The plants were fertilized and watered as necessary. A couple of newly emerging adult thrips were transferred onto a young leaf (±21 d), and 2 leaves were used on each of the plants. The thrips-infested leaf was then caged using a cage made of a 400-ml plastic cup whose bottom had been removed and replaced with styrofoam. The styrofoam was sliced up to its midpoint to provide a gap for inserting the leaf petiole and the mouth of the cup was covered with a piece of fine cloth, which was held in place with a rubber band (Fig. 1). The main purpose of the caging was to protect thrips eggs from parasitoids and anthocorid predators. When about a half of the leaf blade had formed a gall (24-36 h after thrips infestation), the gall was checked for deposited eggs along the midrib inside the gall by using a magnifying lens. When eggs were present, the adults were removed from the gall, and each gall was observed every 24 h for emerging larvae.

As soon as first instar larvae were observed, the remaining eggs, if any, and all larvae except one were removed from each gall. The single remaining larva was then observed every 24 h until it became an adult. The number of instars and the length of each stadium were recorded. This experiment was conducted twice, during the rainy season from Dec 2010 to Jan 2011 and during the dry season from Jun 2011 to Jul 2011.

Adult Longevity, Egg Number, and Percent of Egg Hatch

A couple of newly emerging adults were transferred onto a young leaf (±21 days). The thrips-infested leaf was then caged using a cage

Fig. 1. Thrips cage used in studying the life cycle of *Crotonothrips polyalthiae* on *Polyalthia longifolia*.

as described above (Fig. 1). Ten 3-month old *P. longifolia* trees were used in this study and two cages were used on each tree. The cages were opened every 24 h to check the condition of the adults (alive or dead) and the presence of natural enemies and thrips larvae. Adult longevity was determined by counting the number of days from when the thrips were placed onto the leaves until they died. Dead adults were collected in a small vial with 70% ethanol for checking whether they were females or males under a microscope. Every newly formed larva was counted and recorded and then removed from the gall. Two weeks after both adults died, the number of unhatched eggs in each gall was counted under a dissecting microscope (50 to 100X). The percentage of hatching eggs was calculated using the following formula:

$$\text{Percentage of eggs that hatched} = \frac{\textit{Number of larvae per gall}}{\textit{Number of larvae and unhatched eggs per gall}} \times 100\%$$

Thrips Effects on Plant Height, Stem Circumference, and Number of Uninfested Young Leaves

Thirty 3-mo old plants (average height of 62.5 cm and stem circumference of 4.8 cm) were individually planted in 5-liter polybags on 5 Jul 2010, and fertilized and watered as necessary. Fifteen of the plants were randomly selected for insecticide application. Thirty grams of carbofuran (Furadan 3GR, PT, Bina Guna Kimia, Jakarta, Indonesia) per plant were applied to the soil at planting, and followed by deltamethrin (Decis 25 EC, PT. Bayer Indonesia, Jakarta) applications as thrips re-infestation occurred. The other 15 plants were left unsprayed to let thrips infestations occur throughout the course of the experiment. The plants were placed between rows of 2 yr old *P. longifolia* that were heavily infested by *C. polyalthiae.*

Plant height, stem circumference, and the number of uninfested young leaves (not forming galls) were recorded every 4 mo for 1 yr: 5 Jul 2010; 6 Nov 2011; 4 Mar 2011; and 10 Jul 2011. Plant height was measured from the soil surface to the top of the plant main stem using a metering tape. Stem circumference was measured using a metering tape on the largest part of the stem, close to the soil surface. In addition, the number of uninfested young leaves was also counted on every observation date. Plant height, stem circumference, and number of unifested leaves were compared between insecticide-treated and untreated plants on each date with t-test.

Results and Discussion

Population Dynamics of Thrips

There was a general trend that the thrips population in mature leaf galls increased following increase in young leaves available, which in turn was associated with the rainfall rate (Fig. 2). The average number of thrips per gall peaked 3 times, on 18 Dec 2010, 9 Mar 2011, and 17 May 2011 with thrips numbers of 96, 85, and 125.6, respectively. The first thrips population peak occurred 4 wk after the peak in the number of young leaves per plant on 21 Nov 2010, which was 3 wk after the rainfall peak that occurred on 24 Oct 2011. Similarly, the second and third population peaks occurred 2 wk after the peak in the number of young leaves per plant that was observed on 12 Feb 2011 and 20 Apr 2011 respectively; about 4 wk after the rainfall had peaked.

Populations of *C. polyalthiae* fluctuated throughout the year and peaked 3 times during the study, following the peaks in the number of young leaves that occurred 2 to 4 wk earlier. This was similar to the population dynamics of *Crotonothrips dantahasta* on *Memecylon edule* (Melastomataceae), and of *Teuchothrips longus* on *Pavetta hispidula* (Rubiaceae), both of which were influenced by the presence of young leaves (Ananthakrishnan & Raman 1989). Both hosts produce new leaves for a period of 7 mo and the populations of *C. dantahasta* and *T. longus* were also high during the same 7 mo. In addition, the

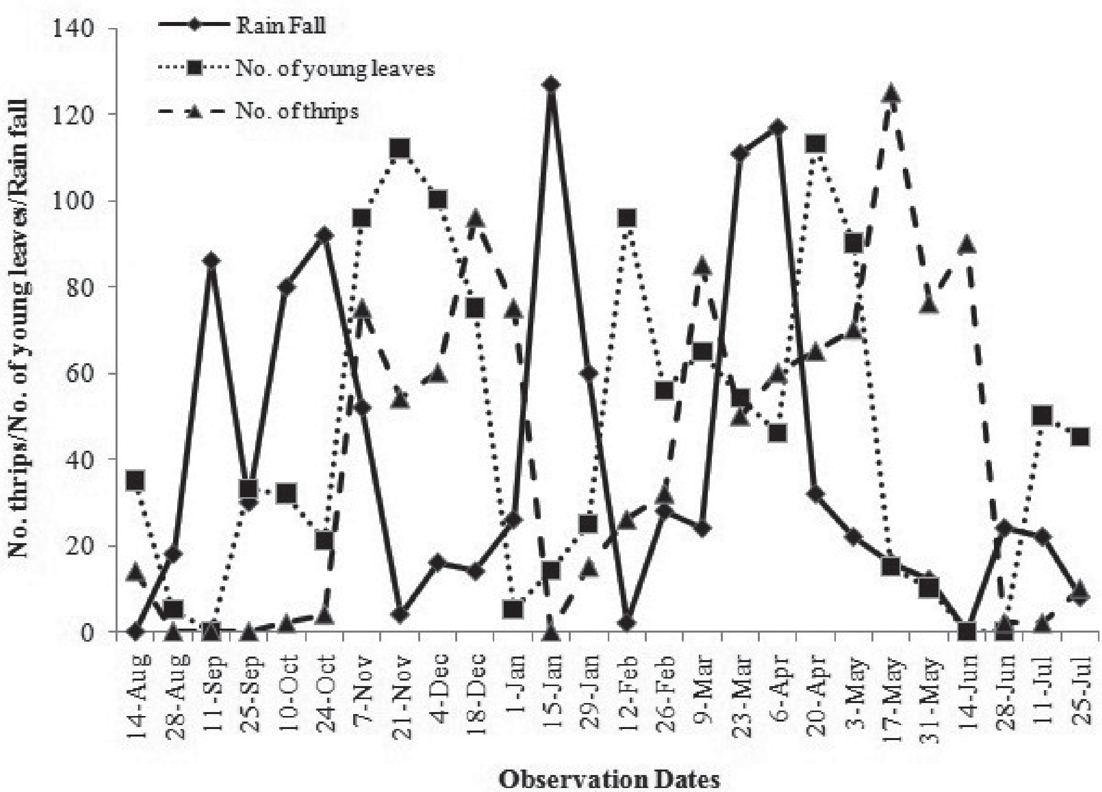

Fig. 2. Average number of *Crotonothrips polyalthiae* (mature and immature stages) found within each gall sample, rainfall rate, and the number of young leaves per *Polyalthia longifolia* tree (Makassar, 14 Aug 2010-25 Jul 2011). Thrips and young leaves expressed in numbers and rainfall accumulation in mm per 2 weeks.

emergence of adult thrips coincided with the availability of new leaf growth.

The number of young leaves produced was affected by the rainfall. The number of young leaves peaked 3 to 4 wk after the peaks in the rainfall. The thrips populations were generally higher during the rainy season than the dry season. This is probably because of the abundance of young leaves available for gall-induction. Besides that the leaves produced during the rainy season probably have better quality suitable for higher fecundity of the thrips. The thrips complete their life cycle inside the gall, therefore, they are not directly exposed to rain. This is contrary to those thrips that do not live in galls, such as *Frankliniella occidentalis* and species of the genus *Thrips*. Population growth in these thrips is hampered by rain, because many of the eggs, larvae, and pupae are washed off the plants or killed by raindrops (Boissot et al. 1998; Kirk 1997; Room & Wardhaugh 1977). During the dry season, however, the gall thrips populations remain relatively low, due to the low number of young leaves available. Other than the rainfall, thrips population fluctuation is also affected by biotic factors such as predators and parasitoids (Ananthakrishnan & Raman, 1989; Ramachandran et al. 2001). We observed the presence of anthocorids feeding on the eggs, larvae, and adults of *C. polyalthiae* within galls. Dry, galled leaves remained on *Polyalthia* plants long after they were abandoned by the thrips, in contrast to the leaves galled by *Gynaikothrips ficarum* on *Ficus* that commonly drop off prematurely (Buss 2003).

Thrips Life Cycle

The life cycle experiment was conducted twice, one each during the dry season and rainy season. However, the data from the two experiments were not significantly different in adult longevity, egg number per female, and percent of egg hatch per female ($p > 0.05$), and the data were therefore pooled, doubling the number of replicates (n = 30-40, depending on the number of missing or dead insects). The development time of *C. polyalthiae* from egg to adult took 17 to 25 d with an average of 20.8 d (Table 1). Soon after being placed onto a

TABLE 1. DURATION IN DAYS OF GROWTH STAGES OF *CROTONOTHRIPS POLYALTHIAE* UNDER FIELD CONDITIONS, 27.3 ± 3.3 °C (RAINY SEASON) AND 29 ± 2.9 °C (DRY SEASON) AND A PHOTOPERIOD OF ABOUT 12:12 H L:D.

Life Stage	Range (days)	Mean ± SE
Egg	5-10	6.62 ± 0.27
Larva		
First instar	2-4	3.21 ± 0.19
Second instar	2-5	2.62 ± 0.62
Pupa		
Prepupa	2-3	2.82 ± 0.14
First pupa	2-4	3.37 ± 0.16
Second pupa	2-5	3.07 ± 0.18
Egg to adult	17-25	20.82 ± 0.48

young leaf, the adults fed on the leaf midrib adjacent to the petiole. Twenty four hours after feeding commenced the leaf blade parts closest to the leaf petiole began moving upwards, and 24 h later they touched each other to initiate the formation of a leaf gall. At this point the female began laying eggs, scattered along the midrib. Eggs are elongate, somewhat cylindrical, rounded at both ends, shiny white turning gray as they mature. Egg incubation lasted five to 10 d. The first instar larva is a tiny, pale insect that soon turns dark pink with 2 solid white stripes across the abdomen, and lasts for 2 to 4 d. The antennae, head, nota, the tubular last segment of the abdomen, and legs are dark black. Second instar larvae lasted 2-4 d. They look similar to the first instar, apart from the larger size and slightly paler color with only the anterior part of the notum and head dark black. The prepupa lasted 2-3 d and is similar to the larvae but with the antennae short and pointed laterally; the antennae, head, and last abdominal segment are translucent, and the white stripes on the abdomen faded and less well defined than on the first and second instar larvae. The first pupa is similar to the prepupa but is larger and has wing buds, and the antennae are longer and directed backwards over the head. The abdominal white stripes are almost absent by this

TABLE 2. ADULT LONGEVITY (DAYS), EGG NUMBER, AND FEMALE FECUNDITY (%) OF *CROTONOTHRIPS POLYALTHIAE* UNDER FIELD CONDITIONS, 27.3 ± 3.3 °C AND A PHOTOPERIOD OF ABOUT 12:12 H L:D.

Parameter	Range	Mean ± SE
Adult Longevity (days)		
Female	16-29	24.3 ± 0.87
Male	4-18	12.2 ± 0.85
Eggs laid per female	11-74	41.5 ± 5.01
Percent of egg hatch	71-100	94.9 ± 1.55

TABLE 3. EFFECT OF *CROTONOTHRIPS POLYALTHIAE* DAMAGE ON PLANT HEIGHT, STEM CIRCUMFERENCE, AND THE NUMBER OF HEALTHY YOUNG LEAVES OF *POLYALTHIA LONGIFOLIA*.

	Plant height (cm)		Stem circumference (cm)		No. uninfested young leaves	
Date	Unsprayed	Sprayed	Unsprayed	Sprayed	Unsprayed	Sprayed
Jul 5, 2010	63.3 ± 1.7 (a)	62.1 ± 2.2 (a)	5.0 ± 0.1 (a)	4.8 ± 0.1 (a)	0.9 ± 0.4 (a)	1.1 ± 0.3 (a)
Nov 6, 2010	70.7 ± 1.4 (a)	77.1 ± 2.2 (a)	5.2 ± 0.1 (a)	6.6 ± 0.1 (b)	0.4 ± 0.2 (a)	7.1 ± 0.8(b)
Mar 4, 2011	84.7 ± 1.2 (a)	144.6 ± 1.7 (b)	5.7 ± 0.1 (a)	8.4 ± 0.2 (b)	0.3 ± 0.1 (a)	8.8 ± 0.9 (b)
Jul 10, 2011	85.3 ± 0.9 (a)	166.1 ± 5.8 (b)	6.5 ± 0.1 (a)	10.3 ± 0.4 (b)	1.9 ± 0.4 (a)	9.2 ± 0.9 (b)

Mean (± SE) followed by the same letter in the same row within the same parameter are not significantly different (t test, $n = 15$, $p = 0.05$).

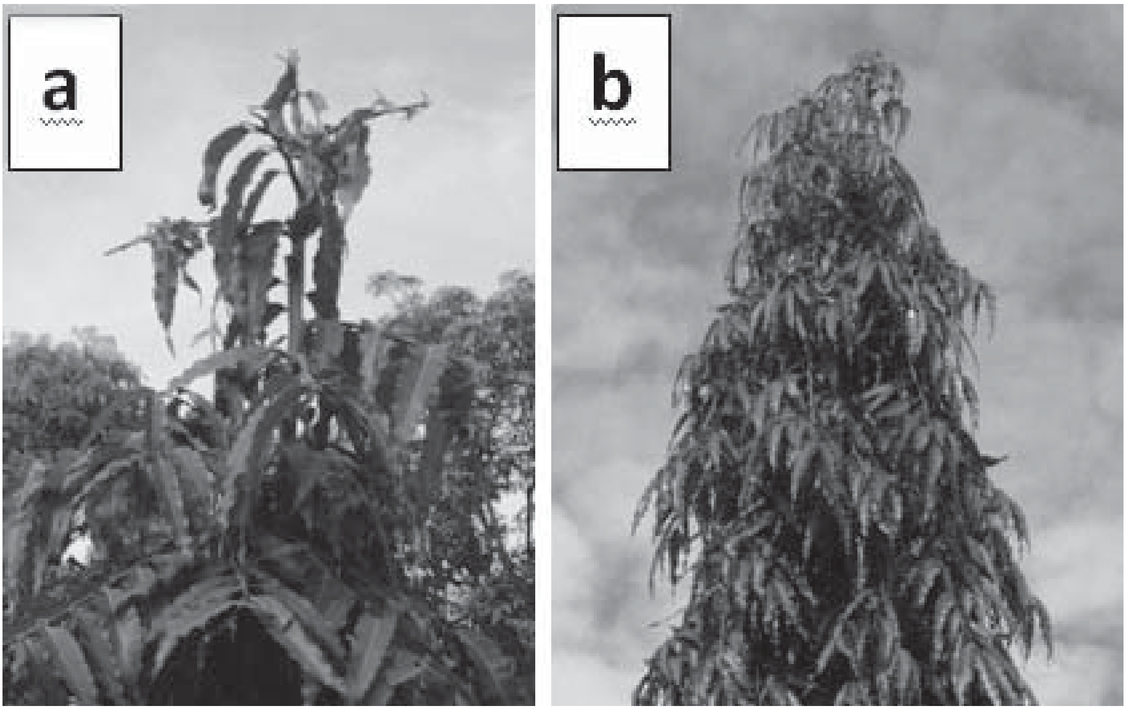

Fig. 3. (a) *Polyalthia longifolia* tree top damaged by *Crotonothrips polyalthiae*, (b) Normal tree top.

stage, and remain only on the lateral part of the terga. The second pupa is similar to the first pupa but with longer antennae, no white stripes, and the last abdominal segment darker.

Adult Longevity, Egg Number, and Percent of Egg Hatch

Adult female and male longevities, the number of eggs laid per female, and the number of hatching eggs, are listed in Table 2. These observations were made under field conditions, 27.3 ± 3.3 °C and a photoperiod of about 12:12 h (L:D). Adult females could live from 16 to 29 days, with an average of 24.3 d; adult males could live from 4 to 18 d with an average of 12.2 d. An adult female laid an average of 41.5 eggs, ranging from 11-74 eggs, during her life time. Seventy one to 100% of those eggs hatched successfully, with an average of 94.9%.

Thrips Effects on Plant Height, Stem Circumference, and Uninfested Young Leaf Number

The presence of this leaf-galling thrips significantly affected plant height, stem circumference, and the number of healthy young leaves produced by the experimental plants (Table 3). Pre-treatment observations showed that there were no significant differences in plant height, stem circumference, and the number of uninfested young

Fig. 4. A 6-month old *Polyalthia longifolia* plant severely damaged by *Crotonothrips polyalthiae*.

leaves between treated and untreated plants used in this experiment. However, in post-treatment observations, 4, 8, and 12 mo after the initiation of the study, there were significant differences in plant height, stem circumference, and the number of uninfested leaves between the sprayed and unsprayed plants.

The thrips reduced the plant height and stem circumference by 49 and 37%, respectively, 1 yr after the initiation of the experiment. To our knowledge this is the first record of any gall thrips hampering the growth rate of a host plant. Although we did not find any dead plants due to attack by this thrips, the damaged plants lost their aesthetic and economic values (Fig. 3). Young plants, up to six months old, could suffer such severe injury that damages young leaves and inhibits plant growth (Fig. 4), that the local nursery owners currently rely on insecticides to control *C. polyalthiae* on young plants.

Conclusion

This work elucidates the population dynamics of *C. polyalthiae* whose population fluctuation depends on the availability of young leaves. Young leaves were abundant 3 to 4 weeks after the peaks of the rainfall. The thrips life cycle was relatively short, an average of 20.8 d, but with a high reproductive capacity averaging 41.5 eggs per female and 94.9% of the eggs successfully hatched. This thrips has the potential to become an economically important pest by hampering the growth of this useful plant and by reducing its aesthetic value. The information presented in this paper is required to develop a population dynamics model for a pest forecasting system, as a component of the integrated pest management of the thrips. To achieve this, further studies are necessary, including the roles of natural enemies, safer and more effective insecticides, and investigations into the genetic variability of the host in order to increase the level of natural resistance. Cultivation of the tree from cuttings rather than seed presumably restricts the available genetic variation. Moreover, because the thrips species is not recorded from India, it is probably that it lives naturally on some other species of *Polyalthia* in Indonesia, and has transferred onto the inbred cultivar of the domesticated *P. longifolia*.

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