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— *Short Communication* —

Effects of Two Army Ant Species, *Dorylus laevigatus* and *Pheidologeton affinis*, on Seed Survival and Germination in Bird-dispersed Plant *Dysoxylum alliaceum*

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ABSTRACT Interaction between seeds of bird-dispersed plant, *Dysoxylum alliaceum* and two army ant species, *Dorylus laevigatus* and *Pheidologeton affinis* was observed in Bogor Botanic Garden of West Java. Especially the effects of ant species on the seed survival and germination were investigated by field observation and experiment. In the observation of 100 *D. allianceum* seeds placed on ground, 71 (71.0%) of them were buried under soil and monopolized by two ant species. All buried seeds were alive though their arils were completely devoured. When ant effects were excluded by covering the seeds with a plastic mesh, 32 (80.0%) of 40 placed seeds were dead by fungus infection. In the seed plantation experiment, the germination rate in seed groups where the arils were removed by hand and by ants was higher than that in intact group. Seed burial and aril removal by ants appear to enhance the survival and germination rate of *D. alliaceum* seeds.

Key words: seed / army ant / aril / germination / bird-dispersal

Ant-seed interaction is one of various types of ant-plant mutualism. Most studies on this topic have focused on seed dispersal of ant-dispersed plants whose elaiosome-bearing seeds are attractive to ants (Beattie, 1985). In many cases, seed dispersal behavior of ants enhances the rate of seed germination and seedling establishment. In the tropics where most shrub and tree plants depend on vertebrate frugivores for seed dispersal, ants frequently interact with fruits and seeds of non-ant-dispersed plants. Fresh fruits on the forest floor are often monopolized by many ant workers and the seeds are removed which have fallen (Kaufman *et al.*, 1991; Oliveila *et al.*, 1995). In the Atlantic forest of southeast Brazil, a total of 26 ant species removed seeds of a non-ant-dispersed tree, *Cabralea canjerana* (Pizo & Oliveila, 1998).

In many fruits adapted to frugivorous animals, the seeds are so large that ants cannot remove them. In such cases, ants devour only pulp and fruit matters without removing seeds. Therefore such ants are not always beneficial to seeds and plants. However Oliveila *et al.* (1995) found the germination rate of *Hymenaea courbaril* seeds was enhanced by ant's devouring and cleaning fruit matters because it reduced the frequency of fungus infection to seeds. Thus the interaction between ants and seeds with fruits seems more complex in the tropics and it is unclear how ants affect on the seed and plant. In the present study, the interaction between seeds of a bird-dispersed tree, *Dysoxylum alliaceum* and two army ant species was observed in a secondary forest in West Java, Southeast Asia. Particularly the effects of ants on seed survival and germination were investigated by field observation and experiment.

MATERIALS AND METHODS

Dysoxylum alliaceum is distributed from India to Australia (Hotta *et al*., 1989). The height of a tree is about 10-20 m and the fruits are produced from October to March in West Java. The fruit is 3-4 cm in diameter and includes 2-5 seeds. The seed measures 1-1.5 cm in maximum diameter, and is covered with very large fresh aril. The diaspore is very colorful with black seed and white and orange aril, exhibiting a typical bicolorous pattern for bird-dispersal (Willson & Thompson, 1982).

Dorylus laevigatus F. Smith (Dorylinae, Formicidae) is distributed widely on Java Island. The genus *Dorylus* is one of army ant groups having a nomadic life style and group raiding (Hölldobler & Wilson, 1990). Generally the colony size in *Dorylus* species is more than a million workers. The colony of *D. laevigatus* is also composed of a huge number of workers with a sequence of size classes. This ant is subterranean, foraging under ground and hunting other ants, insects and arthropods.

Pheidologeton affinis Jerdon (Myrmicinae, Formicidae) is one of dominant species in openlands of Java Island. A few species of the genus in tropical Asia are army ants with group raiding (Moffett, 1984, 1988). Since the workers were foraging in group with column and trail and the colony often moved, *P. affinis* also seems an army ant species. The colony is composed of a huge number of workers exhibiting a remarkable subcaste system. Most *Pheidologeton* species are omnivorous feeding on insects, arthropods and seeds.

From December 1999 to February 2000, field observations and experiments were conducted in the Bogor Botanic Garden of West Java, Indonesia. In the garden, 4-5 trees of *D. alliaceum* were found in the secondary forest. First, the seeds that were fallen on the ground were collected in areas of a 3 m radius from the trunks of these trees. Also the seeds buried underground were collected by digging the surface soil. After the number was counted, the collected seeds were classified by their conditions.

Second, the effects of ants on fallen seeds were observed. On the ground under *D. alliaceum* trees, 10 intact seeds were placed and covered with a plastic mesh to protect them from disturbance by other animals. After 48 hours, the number of survived and dead seeds was counted. Ten replicates of this procedure were conducted. Moreover ant effects were examined by excluding ants from the seeds. Since *D. alliaceum* seeds were devoured from underground, 10 seeds were put in a plastic mesh case (20 cm x 15 cm x 5 cm in size) which was placed on the ground under *D. alliaceum* trees, so that they were not directly placed on the ground. As a control additional 10 seeds were directly placed on the ground, and covered with a plastic mesh. After 10 days, the number of survived and dead seeds was counted. This procedure was repeatedly conducted four times.

Third, the effects of ants on seed germination were measured by planting seeds. The following four groups of *D. alliaceum* seeds were used: (1) intact seeds; (2) seeds of which arils were removed by hand; (3) seeds which had been buried by ants; (4) seeds of which arils were devoured by ants but not buried. In each group, 20 seeds were planted in the garden and the germination rate was compared among groups after 2 weeks. And the length of cotyledon in each germinated seed was also measured and compared.

RESULTS AND DISCUSSION

A total of 78 seeds was collected under *D. alliaceum* trees to see their conditions. Of them, 38 seeds

(48.7%) were on the ground and 40 (51.3%) were buried underground around 1 cm in depth. In 34 (89.5%) of 38 seeds on the ground, the arils were completely devoured and 4 (10.5%) were intact. Fourteen (35%) of the 40 buried seeds had already germinated, while the remaining 26 (76%) had not yet germinated though they were alive. In many buried seeds, it was observed that ant workers monopolized them and devoured their arils under the ground. *Dorylus laevigatus and P. affinis* workers monopolized 22 (55%) and 3 (7.5%) seeds, respectively, and 15 (37.5%) were buried by unknown species. Furthermore, a large number of dead seeds were found on the ground but they were almost decayed and could not be counted.

Out of the 100 seeds placed on the ground, 71 (71%) were buried by ants (in average 7.1 ± SD 2.6 seeds, N=10). Of the 29 unburied seeds, 18 (62.1%) were intact and 11 (37.9%) died from fungus infection. Of the 71 buried seeds, 45 (63.4%) and 25 (35.2%) were monopolized by *D. laevigatus* and *P. affinis* respectively (in average 4.5 ± 4.3 seeds in *D. laevigatus*, 2.5 ± 3.2 seeds in *P. affinis*). Though the arils were completely devoured in all buried seeds, they were still alive.

In the seed groups where ant effects were excluded using mesh cases, 32 (80%) of the 40 seeds placed were infected by fungus (in average 8.0 ± 2.4 seeds, N=4) and 8 (20%) were intact. On the other hand, 17 (42.5%) of the 40 seeds in the control group were buried by ants (average for 4

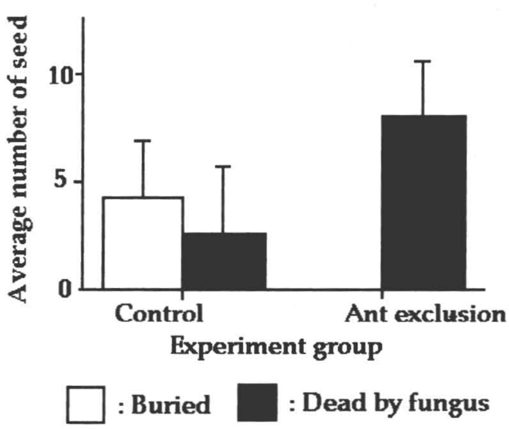

Fig. 1. Average number of buried and dead seeds in control and ant exclusion group. In ant exclusion group, none of the seeds was buried. Average number of infected seeds was significantly different between two groups (P<0.05, t=2.8, t-test).

Table 1. Effects of aril removal and seed burial on germination and survival of *D. alliaceum* seeds. The rate of seed germination was significantly different among experiment groups (P<0.001, χ^2 = 33.9, χ^2- test). Average length of cotyledon was also significantly different among them.

Experiment groups of seeds	N	Germinated	Survived	Died	Length of * cotyledon (mm) Average ± SD
Intact	20	5 (25%)	5 (25%)	10 (50%)	1.4 ± 0.5
Aril removed by hand	20	15 (75%)	4 (20%)	1 (5%)	1.0 ± 0.6
Aril devoured by ants	20	12 (60%)	6 (30%)	2 (10%)	1.4 ± 0.7
Buried by ants	20	20 (100%)	0	0	1.7 ± 0.8

* : P<0.05, One-way ANOVA test

replications: 4.3 ± 2.6 seeds) and 10 (25%) were infected (2.5 ± 3.1 seeds). In the remaining 13 seeds, arils were devoured. As shown in Figure 1, the average number of infected seeds was significantly different between ant exclusion and control groups ($P<0.05$, $t=2.8$, t-test), suggesting that the survival rate of fallen *D. alliaceum* seeds is enhanced by burial.

Among the 20 intact seeds planted, 10 (50%) died from fungus infection and 5 (25%) germinated (Table 1). On the other hand, in the seed group (2 replications) where the arils were removed and devoured, more than 50% of planted seeds survived and germinated. Furthermore, all seeds germinated in the group where they had been buried by ants. The rate of seed germination was significantly different among these experiment groups ($P<0.001$, $\chi^2=33.9$, χ^2-test). Average length of cotyledon was also significantly different among them ($P<0.05$, $F_{3,45}=2.9$, One-way ANOVA test; Table 1). In the group of seeds buried by ants, the length of cotyledon was longest probably because the growth had already begun when they were planted.

This is the first report that army ant species have mutualistic interaction with seeds and plants. A few *Pheidologeton* species gather plant seeds as foods (Moffett, 1988). In this study, *D. alliaceum* seeds were not eaten by *D. laevigatus and P. affinis,* with the result that they were able to survive and germinate. Furthermore, these two ants monopolized seeds by burying them completely. This behavior appears to be effective against seed predation by other insects, arthropods and mammals. However, it is unclear whether this effect is always beneficial to *D. alliaceum* because the seeds were not dispersed far from parent trees. It is needed to examine the frequency of seedling establishment and survivorship after burial of seeds.

In some tropical ant-dispersed plants, seed germination was facilitated by elaiosome or aril removal. In *Calathea* species distributed in the Neotropics, aril removal from seeds enhanced the seed germination rate (Horvitz & Beattie, 1980; Horvitz, 1981). In addition, the seed germination rate was enhanced by aril removal even in a non ant-dispersed plant, *Cabralea canjerana* (Pizo & Oliveira, 1998). In these cases, aril removal by ants functions as a cue to seed germination. Though it was not examined whether it functions as a seed germination cue, aril removal in *D. alliaceum* seed was mainly effective in avoidance of seed mortality caused by fungus infection, and burial of seeds appears to increase the effects. This observation indicates one aspect of the relationships between ant-dispersed and bird-dispersed plants in the evolution of seed dispersal mode.

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REFERENCES

Beattie, A. J. 1985. *The evolutionary ecology of ant-plant mutualisms*, 182 pp. Cambridge University

Press.

Hotta, M., Ogata, K., Nitta, A., Hosikawa, K., Yanagi, M. & Yamazaki, K. 1989. *Useful Plant of the World,* 1500 pp. Heibonsha LTD.

Horvitz, C. C. 1981. Analysis of how ant behaviors affect germination in a tropical myrmecochore, *Calathea microcephala* (P. & E.) Koernicke (Marantaceae): microsite selection and aril removal by neotropical ants: *Odontomachus, Pachycondyla* and *Solenopsis* (Formicidae). *Oecologia* **51**: 47-52.

——— & Beattie, A. J. 1980. Ant dispersal of *Calathea* (Marantaceae) seeds by carnivorous ponerines (Formicidae) in a tropical rain forest. *American Journal of Botany* **67**: 321-326.

Hölldobler, B. & Wilson, E. O. 1990. *The Ants*. 732 pp. Belknap Press of Harvard Univ. Press, Cambridge, MA.

Kaufman, S., Mckey, D. B., Mckey, M. H. & Horvitz, C. C. 1991. Adaptations for a two-phase seed dispersal system involving vertebrates and ants in a hemiepiphytic fig (*Ficus microcappa*: Moraceae). *American Journal of Botany* **78**: 971-977.

Moffett, M. F. 1984. Swam raiding in a myrmicinae ant. *Naturwissenschaften* **71**: 588-589.

——— 1988. Foraging behavior in the Malayan swam-raiding ant *Pheidologeton silenus* (Hymenoptera: Formicidae: Myrmicinae). *Annals of Entomological Society of America* **81**: 356-361.

Oliveila, P. S., Galetti, M., Pedroni, F. & Morellato, L. P. C. 1995. Seed cleaning by *Mycocepurus goeldii* ants (Attini) facilitates germination in *Hymenaea courbaril* (Caesalpiniaceae). *Biotropica* **27**: 518-522.

Pizo, M. A. & Oliveila, P. S. 1998. Interaction between ants and seeds of a nonmyrmecochorous neotropical tree, *Cabralea canjerana* (Meliaceae), in the Atlantic forest of southeast Brazil. *American Journal of Botany* **85**: 669-674.

Willson, M. F. & Thompson, J. N. 1982. Phenology and ecology of color in bird-dispersed fruits, or why some fruits are red when they are 'green'. *Canadian Journal of Botany* **60**: 701-713.

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西ジャワに分布する２種の軍隊アリ *Dorylus laevigatus* と *Pheidologeton affinis* が鳥散布植物 *Dysoxylum alliaceum* の種子生存と発芽に与える影響

熱帯域に分布する木本植物の多くは哺乳類や鳥類を種子散布者として利用し，報酬として種子に栄養価の高い果実を備えている。しかしそれら果実を伴った種子は高密度に分布するアリともまた複雑な関係を持っている。西ジャワ州のボゴール植物園において鳥散布種であるシマセンダン属の１種 *Dysoxylum alliaceum* の種子とその近隣に生息している２種の軍隊アリ，サスライアリの１種 *Dorylus laevigatus* とヨコヅナアリの１種 *Pheidologeton affinis* との関係を野外観察と実験によって調べた。特にこれらのアリ種が種子の生存率と発芽率に及ぼす影響に着目した。地表に種子を置いた観察では種子100個の内，71個（71.0%）が２種のアリによって地面に埋められ，その果肉（aril）が食べられていた。しかしその種子のほとんどは生存していた。プラスチックの網を使って実験的にアリの埋土を妨げると，配置した全ての種子は果肉部分からカビに感染して死亡した。また果肉をつけたままの種子群と除去した種子群を地面に植えて発芽率を比較したところ，果肉を除去した種子はしなかった種子よりも高い生存率と発芽率を示した。これらのことから２種の軍隊アリは埋土と果肉の除去によって *D. alliaceum* の種子の生存，発芽率を上げているものと思われる。