Biomass and nutrient dynamics of mistletoe (*Dendrophthoe falcata*) and neem (*Azadirachta indica*) seedlings

K. S. T. K. Karunaichamy, K. Paliwal*,† and P. A. Arp**

Exploitation Studies, Rubber Research Institute of India, Kottayam 686 009, India
*Department of Plant Sciences, School of Biological Sciences, Madurai Kamaraj University, Madurai 625 021, India
**Faculty of Forestry and Environmental Management, University of New Brunswick, Fredericton, NB, Canada E3B 6C2

Growth and tissue concentration of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sodium (Na) were measured for *Dendrophthoe falcata* (L.F.) Ettingsh., which is a hemiparasitic mistletoe growing on its host *Azadirachta indica* A. Juss. seedlings, or neem seedlings. The shoot length and root length of the host seedlings were significantly reduced ($P < 0.05$) after mistletoe infection. Biomass of the infected *A. indica* seedling components (leaves, stem and root) was also significantly ($P < 0.05$) reduced. Mineral nutrient concentrations of N, P, K, Mg and Na were significantly higher ($P < 0.05$) in mistletoe leaves than in the leaves of both uninfected and infected host, whereas Ca concentration in mistletoe leaves was significantly higher ($P < 0.05$) than in the leaves of its host. Continued mistletoe growth kills the host, and the mistletoe as well.

HEMIPARASITIC mistletoes of the Loranthaceae tap the xylem vessels of their hosts to obtain water and minerals but produce, to at least a certain extent, their own supply of assimilate[1]. Many types of mistletoes are found in tropical regions, spread from one host tree to another by frugivorous birds. For example, a single taxon (*Dicaeum erythrohynchos*, Latham.), also known as Tickel's flower pecker is responsible for the seed dispersal of *D. falcata* (L.F.) Ettingsh. (Loranthaceae) among *A. indica* A. Juss. (Meliaceae) in southern India. This bird feeds on *D. falcata* and *A. indica* fruits alike and seeds are placed on host plants by excretion or regurgitation[2].

Trees that carried a greater number of mistletoe plants in the branch showed a reduction in diameter and growth. The development of mistletoe plants on the host tree is a dynamic process which necessarily leads to the death of the host tree. The whole process may last for a decade or so. Mistletoes, considered to be hemiparasites, infect trees by tapping into the host xylem to gain access to water and nutrients[3]. Often, mistletoes have higher nutrient concentrations than their host[4,5]. The objective of this study was to document growth performance and nutrient concentrations (N, P, K, Ca, Mg, Na) of *D. falcata* and *D. falcata* infected *A. indica* seedlings.

The experiment was done at the Biomass Research Centre, Madurai (9°58'N latitude; 78°10'E longitude). Neem seeds were soaked for 24 h and then placed into polythene bags. After seed germination, seedlings were thinned to one seedling per bag, and were allowed to grow for 45 days. Seeds of the hemiparasitic angiosperm (*D. falcata*) were collected from host tree branches after the birds swallowed the fruit and excreted or regurgitated. These seeds were separated and kept on the stem of host seedlings, one seed per stem.

After 30 days of mistletoe growth, ten seedlings of uninfected and infected plants were harvested. The root collar diameter of uninfected and infected host seedlings was measured using a vernier calliper. The biomass of host seedlings and mistletoes was determined after separation. Samples were oven-dried and milled in preparation for mineral analysis of N, P, K, Ca, Mg and Na. Concentrations of the elements N and P were determined after Kjeldahl digestion with a continuous flow autoanalyser (Gradko International Ltd., Winchester, Hampshire, UK). Concentrations of K, Ca, Mg and Na were determined with an acidic plant digest (10:4:1 ratio of HNO_3, $HClO_3$ and H_2SO_4). The digest was filtered (Whatman no. 42), and analysed with an atomic absorption spectrophotometer (Perkin-Elmer 5000, Norwalk, Connecticut, USA). The Student–Newman–Keuls test was used to compute the least significant difference (LSD) at 95% level for multiple range test. Differences were considered significant at a level below $P < 0.05$.

Mean growth values of uninfected seedlings, infected seedlings, and mistletoe are shown in Table 1. As indicated, the host shoot length, root length and root collar diameter, and biomass of infected seedlings were all significantly reduced ($P < 0.05$). Shoot length in the infected host seedlings was generally lower than in the uninfected host seedlings (up to three times). This clearly indicates that xylem-tapping mistletoe have greater influence after infecting the host seedlings. Parasitic plants tap into the xylem of the host plants following attachment, and the haustorium penetrates the

Table 1. Growth performance of mistletoe (*D. falcata*) growing on its host (*A. indica*) seedlings

Parameter	Uninfected host (*A. indica*)	Infected host (*A. indica*)	Parasite (*D. falcata*)
Shoot length (cm)	53.8 ± 1.88^c	17.7 ± 0.87 (3.0 X)^a	25.4 ± 1.61^b
Root length (cm)	31.0 ± 2.18^b	18.8 ± 0.92 (1.6 X)^a	–
Root collar diameter (mm)	6.2 ± 0.20^b	4.9 ± 0.3 (1.3 X)^a	–

Values are the mean ± SE of ten replicates. Brackets give ratios of uninfected versus infected host seedlings. Mean values in rows with different letter(s) differ significantly at $P < 0.05$.

†For correspondence. (e-mail: ecd@pronet.rdweb.com)

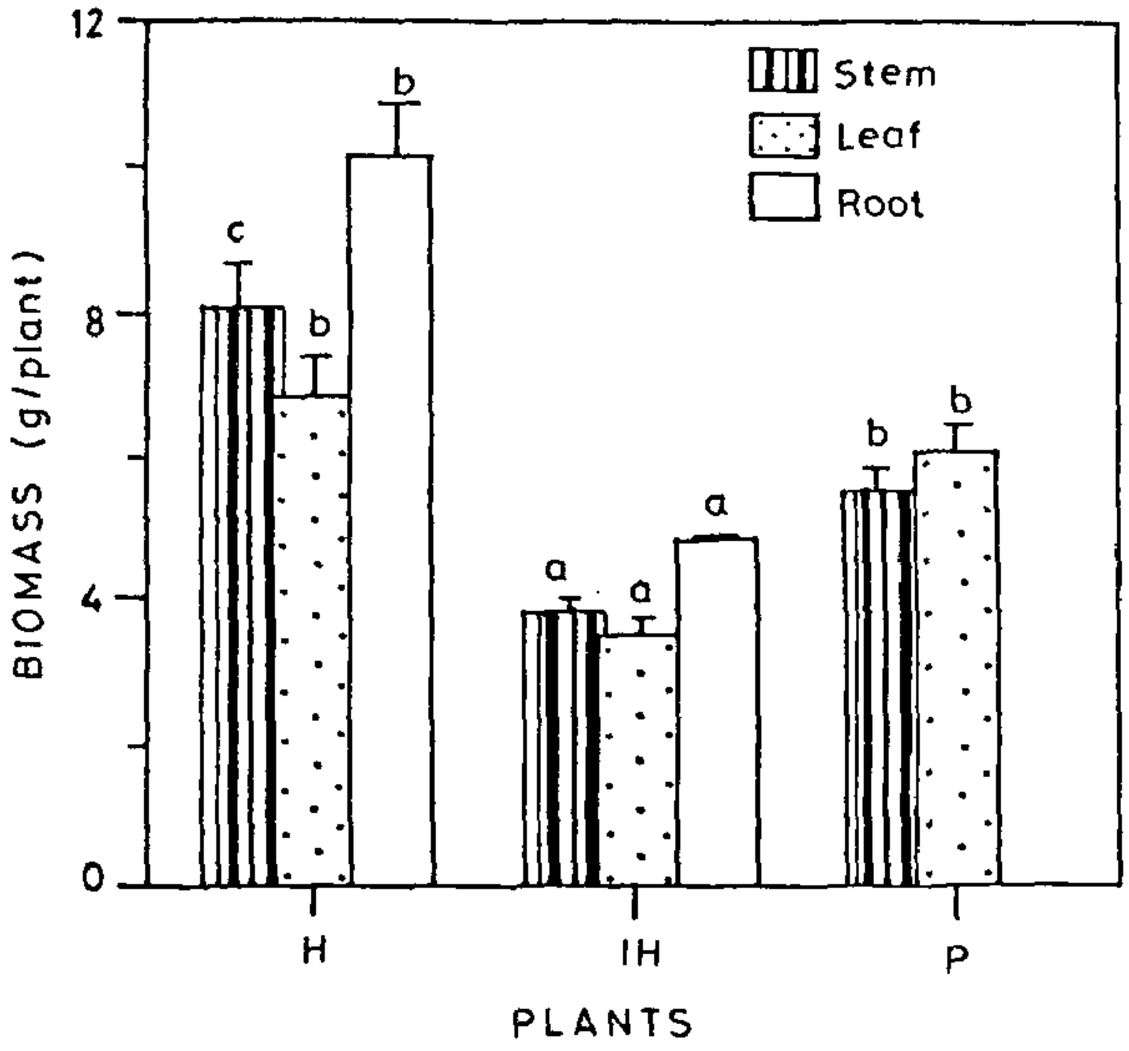

Figure 1. Changes in the biomass of plant components of mistletoe (*Dendrophthoe falcata*) growing on its host (*Azadirachta indica*) seedlings. H, uninfected host seedlings; IH, infected host seedlings, P, parasite. Vertical lines indicate the SE of means ($n = 10$). Bars sharing the common letter(s) do not vary significantly at $P < 0.05$.

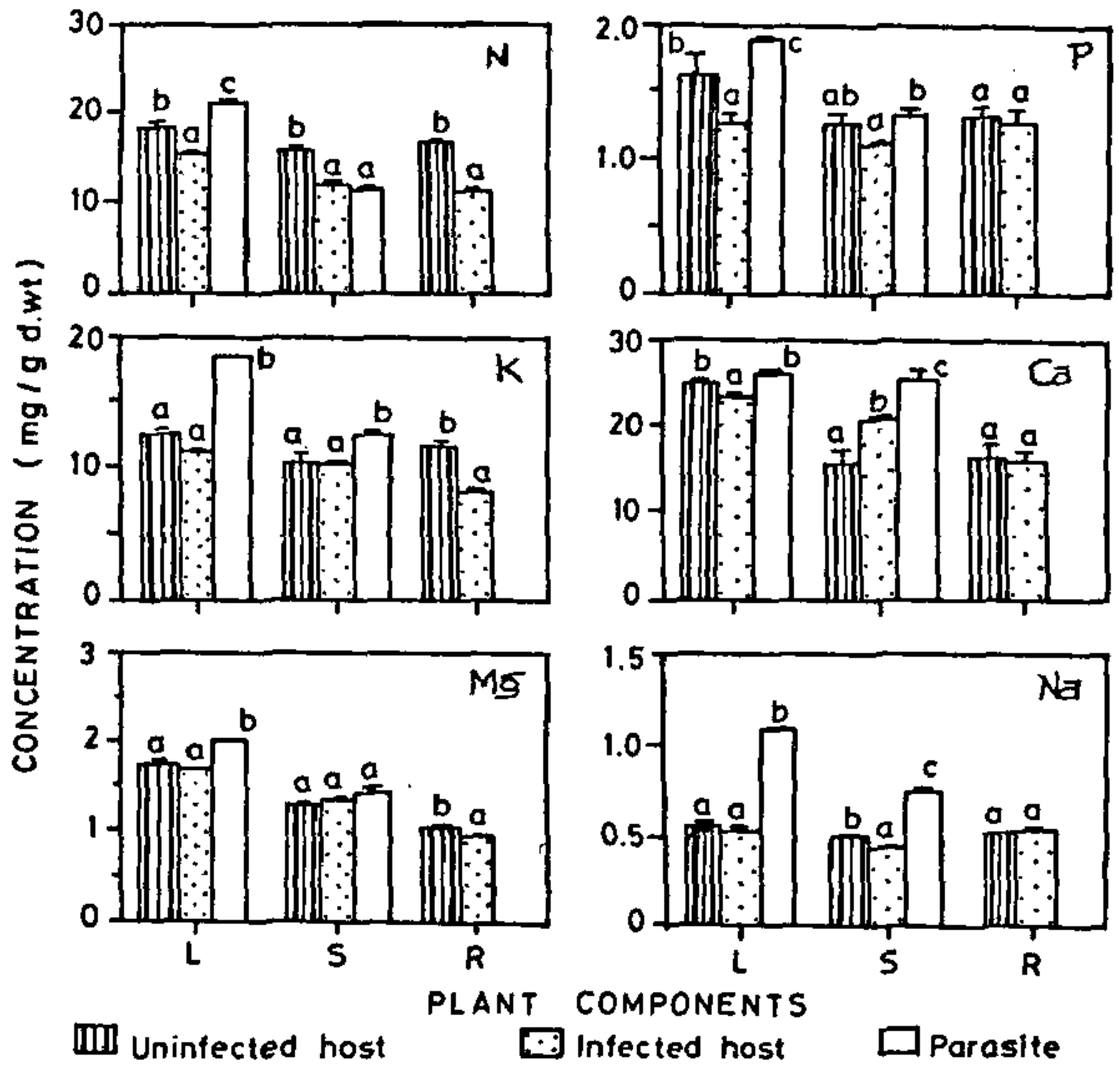

Figure 2. Changes in the nutrient concentration of plant components of mistletoe (*Dendrophthoe falcata*) growing on its host (*Azadirachta indica*) seedlings. L, leaves; S, stem; R, root. Vertical lines indicate the SE of means ($n = 5$). Bars sharing the common letter(s) do not vary significantly at $P < 0.05$.

Table 2. Leaf nutrient concentrations (mg g^{-1}) in leaves of mistletoe and leaves of infected and uninfected *A. indica* seedlings

Element	Uninfected host (*A. indica*)	Infected host (*A. indica*)	Parasite (*D. falcata*)
N	18.4 ± 0.51	15.5 ± 0.17 (1.2 ×)	20.9 ± 0.47 (1.3 ×)
P	1.62 ± 0.14	1.26 ± 0.06 (1.3 ×)	1.88 ± 0.02 (1.5 ×)
K	12.4 ± 0.38	11.1 ± 0.15 (1.1 ×)	18.4 ± 0.09 (1.7 ×)
Ca	25.0 ± 0.27	23.2 ± 0.43 (1.1 ×)	26.0 ± 0.48 (1.1 ×)
Mg	1.76 ± 0.03	1.70 ± 0.02 (1.0 ×)	2.01 ± 0.02 (1.2 ×)
Na	0.57 ± 0.02	0.53 ± 0.03 (1.1 ×)	1.09 ± 0.01 (2.1 ×)

$n = 5$, ± SE. Brackets give uninfected/infected and mistletoe/infected host concentration ratios.

host primarily to obtain water and nutrients from it[3]. The biomass of infected host seedlings are significantly decreased ($P < 0.05$) after 30 days of infection (Figure 1). The biomass of hemiparasitic mistletoe plant components are significantly higher ($P < 0.05$) than the infected host seedlings. Biomass reductions amounted to 48% in shoot, 51% in leaves and 47% in roots of infected *A. indica* seedlings. The mistletoe biomass exceeded infected host biomass by 43% for shoot, and 73% for leaves. The mistletoe does not have a root system and could be dependent on the host for water and minerals. After the mistletoe infects host seedlings, the changes in host leaf area, leaf number, reduction in growth performance and biomass reflect the physiological and metabolic perturbation induced by the parasite. Competition for water, inorganic ions and metabolites is the simplest explanation for loss in host production[6].

Concentration of certain minerals (N, P, K, Ca, Mg and Na) in plant components of uninfected seedlings, infected seedlings and mistletoe is shown in Figure 2. The haustorium of mistletoe plants penetrates the host primarily to obtain minerals and water from it. The nutrient concentration of N, P, K, Mg and Na in the leaves of mistletoe was significantly higher ($P < 0.05$) than the leaves of uninfected and infected *A. indica* seedlings. Similarly, the nutrient concentration of N, P and Ca in the leaves of uninfected seedlings was significantly higher ($P < 0.05$) than in the leaves of infected seedlings. Elemental concentration decreased in the following order: Ca > N > K > Mg > P > Na. Elemental concentrations were generally higher in mistletoe stems than in infected *A. indica* stems, except for N and Mg. Leaf nutrient concentrations were generally higher ($P < 0.05$) in uninfected *A. indica* seedlings than in infected *A. indica* seedlings (Table 2). For K, Mg and Na, there were no significant differences between the leaves of infected and uninfected *A. indica* seedlings. No significant difference in the leaf Ca concentration was found between mistletoe and uninfected seedlings of *A. indica*.

Differences between elemental concentrations for mistletoe and its host are thought to result from differential translocation of elements within the host phloem[7]. The concentrations of some elements, notably K are

particularly elevated in mistletoe leaves[5]. Higher K concentration in the leaves is a consequence of high transpiration rates and the lack of a retranslocation system[8]. Major cations have lowered concentrations in mistletoe infected branches, but it has not been established that this causes any ion-deficiency disease[9]. Mistletoe infection may lead to N deficiency in host plants[10]. Nutrient acquisition may play a vital role in the regulation of assimilate transport in mistletoes.

An extraordinary phenomenon is seen in the fruits of the mistletoe, which strongly resemble those of the host fruit. Therefore, specialization would attract the frugivorous that disperse the seeds more efficiently. Seeds of *D. falcata* were defecated in slimy masses by birds on particular substrates like branches in order to survive and grow. The results of this study indicate that the mistletoe affects *A. indica* seedling growth by reducing the nutrient concentrations within the host plants. This reduction is accompanied by a reduction in seedling growth. The growth of the mistletoe on *A. indica* seedlings, causes little apparent changes in the initial stages but after a month of infection gradually the host and parasite can be devastated. Further studies need to devise strategies to control the mistletoe which poses a menance to this important woody species.

1. Kuijt, J., *The Biology of Parasitic Flowering Plants*, Unive of California Press, Berkeley, 1969, p. 246.
2. Davidar, P., *Oecologia*, 1983, **60**, 271–273.
3. Calder, M., in *The Biology of Mistletoes* (eds Calder, M. Bernhardt, P.), Academic Press, New York, 1983, pp. 1–7.
4. Lamont, B. B., in *The Biology of Mistletoes* (eds Calder, M. Bernhardt, P.), Academic Press, New York, 1983, pp. 185–2
5. Karunaichamy, K. S. T. K., Paliwal, K. and Natarajan, K., *I Indian Natl. Sci. Acad. Part B.*, 1993, **59**, 505–510.
6. Stewart, G. R. and Press, M. C., *Annu. Rev. Plant Physiol. I Mol. Biol.*, 1990, **41**, 121–151.
7. Ehleringer, J. R. and Schulze, E. D., *Am. J. Bot.*, 1985, **72**, 568–.
8. Smith, S. and Stewart, G. R., *Plant Physiol.*, 1990, **94**, 1· 1476.
9. Glatzel, G., in Proceedings of the 4th International Sympo on Parasitic Flowering Plants (eds Weber, H. C. and Forstre W.), Marburg, Philips Universitat, FRG, 1987, pp. 253–262.
10. Knutson, D. M., in *Plant Disease: An Advanced Treatise* Horsfall, J. G. and Cowling, E. B.), Academic Press, New Y 1979, pp. 293–312.

ACKNOWLEDGEMENTS. Financial support from the Depart of Non-conventional Energy Sources to K. P. is gratefully ackn edged. K. S. T. K. K. thanks the Department of Science and T nology, Govt. of India for the BOYSCAST fellowship.

Received 22 June 1998; revised accepted 31 February 1999