NITROGEN FERTILIZATION OF HEMLOCK INCREASES SUSCEPTIBILITY TO HEMLOCK WOOLLY ADELGID

by Mark S. McClure

Abstract. Fertilizing eastern hemlock *(Tsuga canadensis)* with nitrogen stimulated population growth of the hemlock woolly adelgid *(Adelges tsugae)* in a forest plantation in Connecticut. Percent survival of nymphs and the number of eggs produced per adult of this adelgid were more than twice as high on fertilized hemlocks than on unfertilized ones. Fertilized hemlocks had five times more adelgids, had inferior color, and produced 25% less new growth than unfertilized trees after a single adelgid generation. These trends did not differ between hemlocks which had been fertilized 6 months prior to infestation by *A. tsugae* and those which were fertilized at the same time that trees were infested. Therefore nitrogen fertilization of hemlock neither increased host resistance to the adelgid nor repressed adelgid population growth following establishment. These results may be generally applicable to piercing and sucking insects which feed on trees and shrubs.

Feeding trees with nitrogen is a common practice among arborists and nurserymen to improve the growth and appearance of trees and, presumably, to increase their resistance to insects and other pests. The effects of fertilization on host resistance and herbivory, however, are little understood and inconsistent (13). A review of the literature on this subject revealed that herbivory is usually positively correlated with foliar nitrogen concentrations and that low nitrogen concentrations in foliage limit insect populations (11, 13, 14). Indeed there are numerous examples where nitrogen fertilization of trees enhanced the buildup of insect pests. For example, the survival and fecundity of elongate hemlock scale *(Fiorinia externa)*, an imported Japanese species, were significantly improved following a soil application of nitrogen fertilizer to eastern hemlock *(Tsuga canadensis)* (4). Greenhouse and field plot experiments demonstrated that the relative suitability of 14 host species for *F. externa* was positively related to concentrations of foliar nitrogen during the time when nymphs were feeding most actively (4).

Another introduced Asian species which has become an important pest of eastern hemlock is the hemlock woolly adelgid *(Adelges tsugae)* (Fig. 1). Discolored and desiccated needles and dead branches are early symptoms of adelgid attack (Fig. 2). Populations of *A. tsugae* build rapidly and usually kill trees of all sizes and ages within four years (10). Control of this insect has been achieved only with chemical pesticides and only where trees can be drenched thoroughly such as in nurseries and in ornamental plantings (5, 6, 8). As population management programs are being developed for this pest, the relative benefits and risks of fertlizing hemlocks with nitrogen remain very much in question. Specific objectives of the current study were to determine the impact of nitrogen fertilization prior to and at the same time when trees first became infested on the performance of hemlock woolly adelgid and on the growth and appearance of hemlock.

Methods

An experiment was conducted during 1988 and 1989 in a forest plantation of eastern hemlock at the Connecticut Agricultural Experiment Station, Lockwood Farm in Mount Carmel, Connecticut. The plantation consisted of 30, 10 year old trees 2 m tall obtained from a common stock and planted in 1986 in 6 rows of 5 trees each spaced 2 m apart. On 18 October 1988 10 randomly selected hemlocks were fertilized with nitrogen by spreading 0.25 kg of Homogenite[r] 41N on the soil in a circular band 0.5 m from the trunk. Ten

Figure 1. Egg masses of hemlock woolly adelgid on *Tsuga canadensis*.

other hemlocks were fertilized in the same manner on 19 April 1989 at which time all 20 fertilized trees and the remaining 10 unfertilized ones were intentionally infested with hemlock woolly adelgid. Four infested hemlock branches (0.5 m long) collected from a forest in East Hampton, Connecticut were placed at the four cardinal directions on each of the 30 trees in the plantation and left in place for 2 weeks so that an ample number of hatching nymphs could colonize the trees.

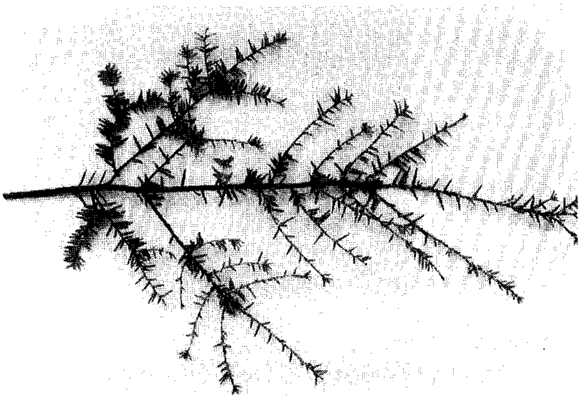

Fig. 2. Injury caused by *Adelges tsugae* to eastern hemlock after a single year of feeding.

On 28 June 1989 after most adelgids had completed their development and had laid eggs, each of the 30 trees were sampled by removing one branch from each of the four cardinal directions. Branches were examined and the number of living and dead adelgids present on 25, 2 mm wide by 10 mm long segments of the preferred youngest growth on each branch was counted. Fecundity was also determined by counting the number of eggs and chorions from hatched eggs in each of 10 ovisacs per branch (n = 40 per tree, 400 per treatment). Only ovisacs with dead adult females alongside were examined to ensure that oviposition had been completed. These methods have been described in more detail elsewhere (7, 9, 10).

The growth and foliage color of fertilized and unfertilized trees was appraised by removing 25 new leaders from each of the four branches sampled on 28 June, noting their color, and then drying them at 40°C for 3 days and then weighing them.

Analysis of variance and Duncan's (3) multiple range test were used to appraise differences in adelgid performance and hemlock growth on fertilized and unfertilized trees.

Results

Fertilizing hemlocks with nitrogen significantly improved the performance of resident adelgids for all three parameters measured (Table 1). After a single adelgid generation, population densities were more than five times higher on fertilized hemlocks than on unfertilized ones. In addition, percent survival of nymphs and numbers of eggs produced per adult were more than twice as high on fertilized hemlocks than on unfertilized trees. These trends did not differ between hemlocks that had been fertilized 6 months prior to infestation by *A. tsugae* and those that were fertilized at the same time that trees were infested (Table 1). These data indicate that nitrogen fertilization causes a swift and persistent improvement in the nutritional quality of hemlock for the adelgid.

Hemlock growth, measured as the biomass of each new leader was not significantly enhanced by nitrogen fertilization on either date (Table 1). Instead, the average biomass of new growth was significantly greater on unfertilized hemlocks than on fertilized ones. The foliage of fertilized hemlocks also had far inferior color than the unfer-

Table 1. Density, survival and fecundity of hemlock woolly adelgid and dry mass of new hemlock leaders in July on unfertilized hemlocks and on ones that had been fertilized with nitrogen 6 months before or at the time of infestation[1] on 19 April

Treatment	*number of adelgids per 20mm²*	*% adelgid survival*	*number of eggs per adult*	*biomass (mg) of new hemlock growth*
Fertilized				
before infestation	13.7 ± 4.1a	72.5 ± 17.6a	186.7 ± 28.7a	69.7 ± 9.5a
at infestation	14.1 ± 3.9a	79.7 ± 16.7a	198.2 ± 29.3a	66.1 ± 10.8a
Unfertilized	2.7 ± 1.1b	31.3 ± 8.6b	88.6 ± 14.3b	85.8 ± 11.3b

[1] Means (±SD) in each column followed by different letters differ significantly (p = 0.001) by ANOVA.

tilized trees; the characteristic gray-green foliage color of hemlocks under attack by this insect (10) was far more prevalent among branches from fertilized trees (88%) than among those from unfertilized hemlocks (12%). The higher adelgid densities (and feeding intensity) on fertilized hemlocks more than offset any potential advantage in hemlock growth and foliage color that otherwise might have been gained through nitrogen fertilization. This inverse relationship between adelgid density and hemlock growth and injury has been documented previously (10).

Discussion

Fertilizing with nitrogen produced no obvious advantages for hemlocks under seige by *A. tsugae.* Fertilization did not improve hemlock growth and appearance, and neither increased host resistance to adeglid attack nor repressed population growth once the adelgid had become established. The disadvantages of fertilization, however, were obvious. Tree feeding with nitrogen significantly enhanced adelgid performance and stimulated adeglid population growth, such that by the end of a single growing season, fertilized hemlocks were more heavily infested and were far less vigorous than unfertilized ones. Nitrogen fertilization may be of some value in helping hemlocks to recover once adelgids have been successfully controlled, but this was not examined in this study.

These findings may have widespread application to many other insect pests of trees and shrubs, especially those which feed on sap. Indeed, there is substantial evidence that piercing and sucking insects such as adelgids, aphids, leafhoppers and scales are generally favored by an increase in the soluble nitrogen component of their food (1, 2, 12). It is also well established that fertilization with nitrogen can significantly increase the concentration of soluble nitrogen in host sap where it can be readily intercepted by feeding nymphs. Consequently fertilizing trees with nitrogen may undermine programs for managing populations of piercing and sucking insects.

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Résumé. La fertilisation avec l'azote de la pruche du Canada ou pruche de l'Est (*Tsuga canadensis*) stimulait l'accroissement de la population de pucerons lanigères de la pruche (*Adelges tsugae*) dans une plantation forestière au Connecticut. Le pourcentage de survie des nymphes et le nombre d'oeufs pondus par adulte de ce puceron était de deux fois supérieur sur des pruches fertilisées que sur celles non fertilisées. Les pruches fertilisées poussédaient cinq fois plus de pucerons, présentaient une coloration inférieure et produisaient une croissance moindre de 25% que les arbres non fertilisés après une seule génération de pucerons. Ces tendances ne différaient pas entre pruches qui avaient été fertilisées six mois avant infestation par *A. tsugae* et celles qui étaient fertilisées au même moment qu'elles étaient infestées. Par conséquent, la fertilisation azotée de la pruche n'accroît, ni la résistance de l'hôte au puceron, ni la régression de l'accroissement de population du puceron après l'établissement. Ces résultats peuvent être applicables aux insectes perceurs et suceurs qui se nourrissent des arbres et des arbustes.

Zusammenfassung: Das Düngen von *Tsuga canadensis* mit Stickstoff in einer Forstplantage in Connecticut hat das Populationswachstum von *Adelges tsugae* angeregt. Der Prozentzahl von den überlebenden Nymphen und Eiproduktion unter den Erwachsenen *A. tsugae* war zweimal so groß bei den gedüngten *T. canadensis* als bei den ungedüngten. Gedüngte *T. canadensis* hatten fünfmal so viel *A. tsugae*, unterlegene Färbung und 25 Prozent weniger Neuwachstum nach der ersten *A. tsugae* Generation im Vergleich mit den ungedüngten Bäumen. Es gab keinen Unterschied zwischen Bäumen, die seit 6 Monaten vor der Verseuchung mit *A. tsugae* gedüngt worden waren, und Bäumen, die zur gleichen Zeit gedüngt und verseucht worden waren. Das Stickstoffdüngen von *T. canadensis* hat weder Wirtsresistenz gegenüber *A. tsugae* erhöht, noch die *A. tsugae* Population nach der Gründung unterdrückt. Diese Resultate darf man insgesamt auf steckenden und saugenden Insekten, die sich an Bäume und Büsche nähren, beziehen.

THE FUTURE OF ISA RESEARCH[1]

by Hyland R. Johns

Abstract. Research in arboriculture is taking new directions under ISA leadership. As a three billion dollar industry, we need to do much more for research and education—and get the results out to the users. We must increase our commitment, because we're investing in our own future. This is a challenge for every member of ISA, and will increase our professionalism in the field. We must identify and prioritize research and education needs, then find the money to support those needs.

Prospects for the future of arboriculture research are exciting! Of course, no one knows the future; but then the future never really comes. The future is now, and we're facing urgent research and education needs.

Early beginnings. Formal support of research by the ISA began in 1975, when the Trust was organized with O.J. Anderson, John Duling, Gene Himelick, Hyland Johns and Jack Rogers as Trustees. Five grants of $500 each were made that first year.

In just 15 years, we've awarded 162 grants totalling nearly a quarter of a million dollars throughout the United States, Canada and other countries. That's a good beginning, but it's not enough for today, or the future.

We're a three billion dollar industry, and we need to do much more for research and education. That's why the ISA has begun a million dollar campaign for the Trust. While the all-industry

1. Presented at the annual conference of the International Society of Arboriculture in Toronto in August 1990.

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