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Abstract

A chemical exclusion trial was done in the field to determine the effect of the gall midge, *Zeuxidiplosis giardi*, on 200 paired St. John's wort seedlings. One member of each pair was protected against attack from the gall midge by regular, alternate applications of fenthion and monocrotophos. By the end of the trial the growth rate of the sprayed seedlings was almost four times that of the unsprayed seedlings. Survival of the unsprayed seedlings was 15% lower than that for the sprayed seedlings. *Z. giardi* therefore suppressed growth and reduced survival of St. John's wort seedlings in the field.

Effets du Moucheron Provoquant la Gale (*Zeuxidiplosis giardi*) (Diptère: Cecidomyiidae) sur les Jeunes Plantes de *Hypericum perforatum* (Clusiaceae) en Afrique du Sud

Le taux de survie, la croissance et le développement des jeunes plantes de *Hypericum perforatum* ont fait l'objet d'une surveillance pendant une période de 70 semaines afin de déterminer les effets des gales provoquées par *Zeuxidiplosis giardi*. Un membre de chaque 200 paires de jeunes plants combinés a été protégé contre la gale par des applications régulières d'insecticide. Quarante pour cent des plantes protégées et 25% des plants non vaporisés ont survécu. À la fin de l'essai, le taux quotidien de croissance de nouvelles feuilles était presque quatre fois plus élevé sur les plantes protégées (en l'absence de gale) et la masse moyenne finale en poids sec des jeunes plants vaporisés était environ deux fois plus élevée que celle des jeunes plants non protégés qui ont survécu. Seules huit inflorescences ont été produites par les 49 plantes non vaporisées qui ont survécu tandis que 43 inflorescences ont été relevées parmi les 79 jeunes plants vaporisés qui ont survécu. Les conclusions établissent donc que l'insecte réduit de façon marquée le taux de survie, de croissance et de floraison de *Hypericum perforatum*.

Introduction

St. John's wort, *Hypericum perforatum* L. (Clusiaceae), is an herbaceous perennial of Eurasian origin that has become an important weed in different parts of the world (Goeden 1978). It was first found in South Africa in 1942, and despite subsequent attempts to eradicate it chemically, it still occurs in localized patches in the South-Western Cape Province of South Africa (Gordon 1978).

Biological control of St. John's wort was initiated in South Africa with the introduction of *Chrysolina quadrigemina* (Suffrian) (Coleoptera: Chrysomelidae) between 1960 and 1962 (Annecke and Neser 1977); this beetle has since successfully controlled St. John's wort growing in dense stands. The gall midge, *Zeuxidiplosis giardi* Kieffer (Diptera: Cecidomyiidae), was introduced in 1972 to supplement *C. quadrigemina* (Annecke and Neser 1977). *Z. giardi* has not been particularly successful in biological control programs in other parts of the world (Andres et al. 1973; Huffaker in Given
1967), except in Hawaii where it was thought to have contributed to the control of St. John's wort (Davis and Chong 1968).

Many workers have speculated about the effect of galling by Z. giardi larvae on St. John's wort (Wilson 1943; Holloway and Huffaker 1953; Given 1967; Currie and Garthside 1932), but none of the possible effects, which include suppressed growth of the plants, reduced competitive ability, increased mortality and reduced seeding, have ever been evaluated experimentally.

In this study, the effects of the gall midge on growth and survival of St. John's wort seedlings in the field were quantitatively determined. From observations in the field, it appeared that Z. giardi attack was most destructive on this stage.

Materials and Methods

Experimental Site

The trial was set up in disturbed vegetation on a southeast facing slope above Ida's Valley dam near Stellenbosch (33°54'S, 18°54'E). This site is in a winter rainfall area that has a mean annual rainfall of 990 mm. Rainfall and temperature data (Fig. 1C) collected during the trial were recorded at a weather station in Stellenbosch, about 4 km away.

Two hundred St. John's wort seedling pairs, each with 2–6 leaf pairs, were selected over a distance of 150 m and matched with regard to their size and situation. The positions of each of these seedlings was marked with a metal stake. From the number of galls on plants in the vicinity, it was evident that Z. giardi was abundant at the experimental site. During the course of the trial, midge activity was monitored by making regular counts of galls that appeared to contain larvae or pupae on marked seedlings. Any other damage on above-ground parts of the plants was also noted.

Exclusion of Z. giardi by Insecticides

One seedling in each pair was randomly assigned to be sprayed to run-off with the insecticides fenthion (O-O-dimethyl O-[3-methyl-4-(methylthio) phenyl] phosphorothioate; Lebaycid® emulsifiable concentrate at 0.5 mg AI/litre) and monocrotophos (O-O-dimethyl-O-(2-methylcarbamoyl-1-methyl-vinyl)-phosphate; Azodrin® emulsifiable concentrate at 0.4 mg AI/litre). Fenthion was included because it has both a contact and a systemic effect. Except for the effect of monocrotophos on sorghum, neither of these two insecticides are considered widely phytotoxic at the given dosages (Thomson 1982). The chemicals were sprayed alternatively at approximately 10-day intervals (depending on the weather) with a hand atomizer. The control seedlings were sprayed in the same way with comparable amounts of distilled water. Precautions were taken to avoid spray drift.

Measurement of Seedling Growth and Survival

Plant growth was monitored by counting the number of leaf pairs along the stems. Twelve counts were made at 4–7-wk intervals between 18 September 1979 and 20 January 1981 (70 wks). Growth rates of sprayed and unsprayed plants were then compared by means of a straight line estimate of the growth rate (Fig. 1B) using the formula (Pianka 1974):

\[
\text{Growth rate} = \frac{N_{t_1} - N_{t_0}}{t_1 - t_0}
\]

where \(N_{t_0}\) = number of leaf pairs at the start of a period of time \((t_0)\), and \(N_{t_1}\) = number of leaf pairs after a period of time \((t)\).
Fig. 1. A diagrammatic representation of the interaction between the gall midge, Zeuxidiplosis giardi Kieffer, its host, St. John's wort, Hypericum perforatum L., and climatic factors during a chemical exclusion trial showing: (A) the seasonal activity of the gall midge; (B) the survival and growth rate of the sprayed and unsprayed St. John's wort seedlings; and (C) the temperature and rainfall over this period.

Overall growth of the two groups was compared by determining the dry mass of the surviving plants at the end of the trial. After these plants had been carefully lifted, and the soil had been washed from their roots, they were placed separately in paper bags, dried in an oven at 20°C for 36 h and weighed. The number of upright flowering stems on each plant was also noted. Survival was followed by recording the mortality of plants at each count.
Results and Discussion

Effects of Z. giardi on Growth

The growth rate of unsprayed plants, that were subject to Z. giardi attack, was always less than that of sprayed plants (Fig. 1B). The cumulative effect of Z. giardi on the growth rate is shown towards the end of the trial where, while the growth rate of sprayed seedlings increased markedly from 0.47 leaf pairs/seedling/day in September 1980 to 1.75 leaf pairs/seedling/day in January 1981, the growth rate of unsprayed seedlings remained below 0.38 leaf pairs/seedling/day over the corresponding period. The marked increase in the growth rate of all seedlings during July may be due to increasing temperatures over this period (Fig. 1C). Unsprayed seedlings reached their maximum growth rate during the same period which coincided with hibernation of the gall midge larvae (Fig. 1B).

Table 1. Comparison of the dry mass of the seedlings of St. John’s wort, Hypericum perforatum L., at the end of the chemical exclusion trial.1

<table>
<thead>
<tr>
<th>Treatment</th>
<th>n</th>
<th>x</th>
<th>range</th>
<th>s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprayed</td>
<td>76</td>
<td>1.69</td>
<td>0.01-14.99</td>
<td>2.96</td>
</tr>
<tr>
<td>Unsprayed</td>
<td>46</td>
<td>0.59</td>
<td>0.01-5.89</td>
<td>1.06</td>
</tr>
<tr>
<td>Galled</td>
<td>38</td>
<td>0.60</td>
<td>0.01-5.89</td>
<td>1.06</td>
</tr>
<tr>
<td>Ungalled</td>
<td>8</td>
<td>0.56</td>
<td>0.01-3.10</td>
<td>1.09</td>
</tr>
</tbody>
</table>

1a,b = Different consonants denote significant differences at P = 0.05.

The mean dry mass of surviving unsprayed plants was only 34.9% of the mean dry mass of surviving sprayed plants (P = 0.01) (Table 1). Although Z. giardi activity was recorded during the whole trial, not all unsprayed seedlings were galled at any one time. This raises the question as to whether unsprayed seedlings were in fact all attacked by Z. giardi. The mean dry weight of the eight surviving unsprayed, ungalled seedlings was 0.56 g compared with 0.59 g of the unsprayed group as a whole (Table 1). The growth of the former was therefore apparently suppressed despite the absence of galling. It can be assumed that these relatively small, almost stunted seedlings were also attacked by Z. giardi, but that the young larvae failed to induce ceidogenesis, very likely because these particular plants were generally stressed by the adverse conditions, and because galls only develop in actively growing shoot tips and buds.

The midge prevented normal development of upright flowering stems. A total of eight uprights were produced by the surviving 49 unsprayed plants, compared with 43 uprights on 79 sprayed plants. In the latter instance up to four uprights were counted on a single plant. By suppressing growth of seedlings, Z. giardi prevented flowering in the first year and delayed maturation of the plant.

Effects of Z. giardi on Survival

Seedling mortality in both groups was high; this is a common phenomenon in St. John’s wort seedlings (Clark and Clark 1952; Clark 1953; Smith 1958). The pattern of survival in both groups was similar with approximately 80% of mortality occurring within the first 190 days (Fig. 1B). This initial mortality coincided with the hot, dry
summer (22.8% of total rainfall measured during the course of the trial fell over this period). With the onset of winter rains and drop in temperatures, seedling mortality levelled off. This trend agrees with the findings of Clark and Clark (1951), Clark (1953) and Smith (1958), who concluded that temperature and rainfall (especially distribution of rainfall) are the most important causes of seedling mortality in St. John’s wort populations.

The survival of unsprayed seedlings was, however, still reduced by 15% compared to that of sprayed seedlings. In view of the importance of climate, it is concluded that *Z. giardi* only contributed to mortality by modifying the shape of the survivorship curve. The shape of the curve was primarily determined by climatic factors. The effect of the midge on young seedlings was accentuated by the dry summer following their establishment.

No noteworthy feeding damage of the beetle *C. quadrigemina* or any other organism was recorded.

This study has shown that *Z. giardi* reduces overall growth of St. John’s wort seedlings, thereby reducing seedling survival. While this trial demonstrates the effect of *Z. giardi* on seedlings, another study that includes plants of all age groups within the population would be required to determine the overall value of *Z. giardi* as a biological control agent for St. John’s wort. The fact that the growth rate of unsprayed seedlings was consistently reduced towards the end of the trial (Fig. 1B) suggests that *Z. giardi* is able to influence the growth rate of older plants. Nevertheless, *Z. giardi* is probably helping to increase the effectiveness of the other biological control agent, *C. quadrigemina*, by delaying recovery of St. John’s wort after periodic population crashes which are caused by *C. quadrigemina* (Clark 1953).

Acknowledgments

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References


