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Differences in some life history traits between triazine-resistant and susceptible *Solanum nigrum*

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Summary

Two major triazine resistant weeds are found in silage maize in the Netherlands. One way to reduce herbicide resistance in weed populations is the reduction of selection pressure by adjusting cropping practices. Crop management as a tool to control herbicide resistant weeds depends on knowledge of the biology of the target weed. In this study, emergence patterns, growth and establishment of triazine-resistant and susceptible *Solanum nigrum* L. in a maize crop were investigated. Resistant plants emerged sooner, their emergence rate was higher, and the total number of emerged seedlings was also much higher than that of susceptible plants. Resistant plants grown in a maize crop showed decreased growth compared to susceptible plants. This was reflected in small differences in seedling weights and a possible lower relative growth rate of resistant plants. These results suggested that a stale seedbed preparation that precedes a maize crop may specifically decrease the number of resistant plants in the field. Moreover, increasing competitiveness of the crop by cultivar choice may further repress growth of resistant plants.

Introduction

Two major weeds in maize (*Zea mays* L.), have become triazine-resistant in the Netherlands. These two species, *Solanum nigrum* L. and *Chenopodium album* L., have infested a large part of the area where silage maize is grown. Triazine-resistant weeds were not identified in the Netherlands until 1982 (Van Oorschot & Straathof, 1988). Triazine-resistant biotypes will survive the usual weed control practices in maize based on the use of triazine herbicides. Berries of *S. nigrum* may contaminate the harvested crop, and at high densities, the economic value of the crop will be severely reduced. Therefore, control of resistant biotypes of *S. nigrum* is necessary.

When herbicide-resistant weeds are present, different management strategies may be developed. One strategy is to reduce the selection intensity by rotating herbicides, use tank mixtures with herbicides with different modes of action, or avoid sequential applications of the same herbicide or herbicides with the same mode of action. Another strategy is to adjust cultural practices such as rotating crops if possible, using mechanical tillage and increase crop competition (Morrison & Bourgeois, 1995). Adjusting cultural practices affects weed communities in general. However, when there are differences in life history characteristics between herbicide-resistant and susceptible weeds, the effect of cultural practices can be used to improve the control of herbicide-resistant weeds.

In their review, Warwick and Black (1994) concluded that in general, when no triazines are used, triazine-resistant weeds have a reduced fitness compared to susceptible biotypes. Based on this conclusion a project has been started called: "Control of atrazine-resistant biotypes in populations of the arable weed black nightshade (*Solanum nigrum* L.)". This project focuses on the life history characteristics of triazine-resistant and susceptible *S. nigrum* in a maize crop with the aim of developing an integrated weed management system that reduces herbicide-resistant weed populations.

The life history stages of an annual weed are: germination, emergence, establishment and growth, seed production and seed survival in the soil. This paper will focus on only two stages in the life history of triazine-resistant and susceptible *S. nigrum*: emergence and establishment to seed production. Time of emergence is very important for weeds in competition with a crop (Kropff *et al.*, 1993). Bad timing of weed emergence can result in complete eradication of the seedlings during seedbed preparation. One other important stage where fitness differences might become clear is the growth of weeds in a crop when there is competition. Since triazine-resistant *S. nigrum* has a decreased photosynthetic efficiency (Ireland *et al.*, 1988), this might result in reduced growth under light limited conditions.

The aim of this study was to quantify differences between triazine-resistant and susceptible *S.nigrum* in terms of emergence pattern and growth in a crop. These differences may then be used to adjust cultural practices to improve the specific control of triazine-resistant *S. nigrum.*

Materials and Methods

Emergence

Seeds of triazine-resistant and susceptible *S. nigrum* were harvested from plants grown in a glasshouse in 1992. Originally both biotypes were found in one maize field near Wageningen. Batches of 4000 seeds were buried in bags in the field, during winter at a depth of 5 cm. Thousand kernel weight of the susceptible seeds was 0.906 g and of resistant seeds 0.814 g. In the spring of 1993, pvc cylinders with a diameter of 30 cm were dug in the soil to a depth of 10 cm. The soil was removed and X-ray radiated with 1 MRad to kill all seeds present. The 4000 seeds, that overwintered in the field, were then thoroughly mixed with soil from one pvc cylinder and put back in the cylinder in the field. From May until mid-August, the number of emerged seedlings of *S. nigrum* from a known biotype were counted in five replicates every 3 to 5 days. Every replicate consisted of one cylinder with susceptible seeds and one cylinder with resistant seeds. After counting, emerged seedlings were removed. Before the winter, soil from all cylinders was removed and stored at 5 °C. The soil was again laid out in the field in May 1994 and emergence of triazine-resistant and susceptible *S. nigrum* was observed for more than three months.

Establishment and growth

Triazine-resistant and susceptible seeds from the same origin as used in the emergence experiment were incubated in petri-dishes on filter paper with water to germinate. The weed seedlings were grown in a glasshouse without artificial lighting to the 3-4 leaf stage. Three days after emergence of the maize crop, the seedlings were transplanted into the field in four replicates. At the time of transplanting into the field, the average above-ground dry matter of triazine-susceptible transplants was 0.053 g, significantly higher than that of triazine-resistant transplants, which was 0.037 g (t-test, $p \leq 0.05$).

In every maize plot, 20 seedlings from one biotype were transplanted between the crop rows at a density of 5 plants/m². At this density, intraspecific competition was assumed to be of no importance. At 42, 69 and 128 days after transplanting, weeds from one plot per biotype per replicate were harvested and growth parameters per single plant were measured. In this paper, only data on total above-ground dry matter per plant will be discussed.

Results

In 1993, there was no difference between the emergence patterns of the resistant and susceptible biotypes (Fig. 1A). However, in 1994, after the soil had been stored at 5 °C during winter, emergence patterns of resistant and susceptible biotypes differed significantly (Fig. 1B). Resistant plants emerged sooner, their emergence rate was higher and the total number of emerged seedlings was also much higher than that of susceptible plants.

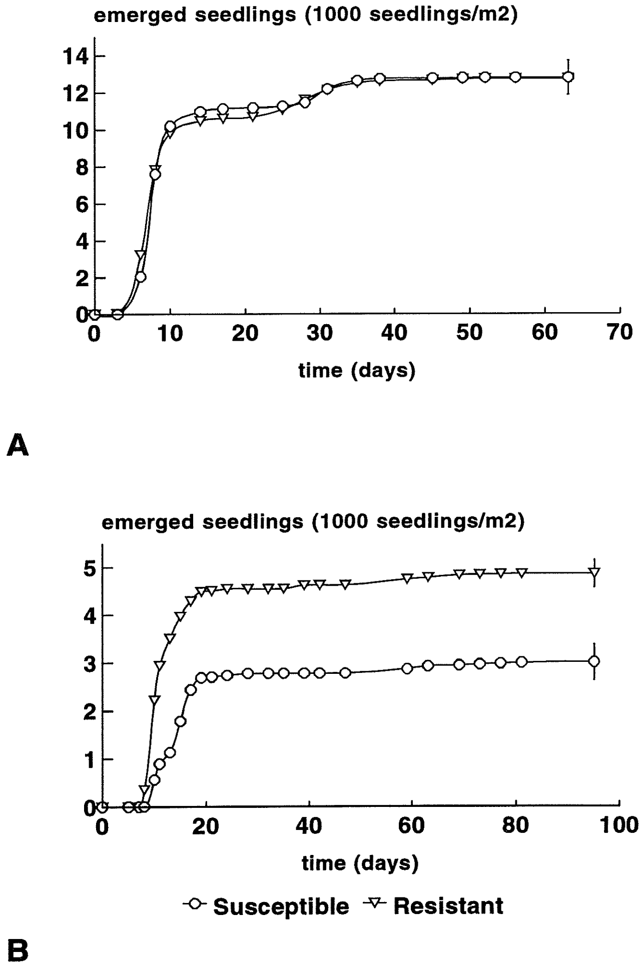

Fig. 1. Average number of emerged seedlings in 1993 (A) and in 1994 (B). Monitoring of seedling emergence started (day=0) on May 4, 1993 and May 6, 1994. Vertical bars indicate standard errors (5 replicates).

Individual plants were harvested at three different times during the season to measure the growth of the two biotypes in a maize crop. The first harvest (42 days after transplanting) showed no significant differences between total dry matter per plant of both biotypes (Fig. 2). At the second and third harvest, total biomass of susceptible *S. nigrum* plants was significantly higher than that of resistant *S. nigrum.*

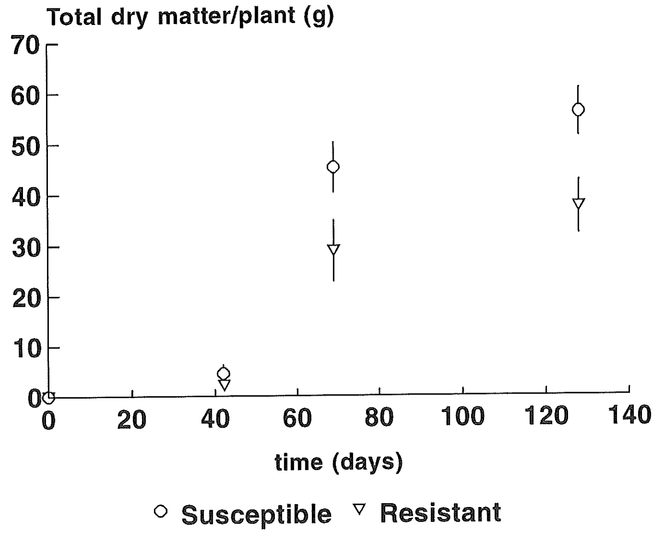

Fig. 2. Average total above-ground dry matter of triazine-resistant and susceptible plants transplanted in the field at 3-4 leaf stage, 3 days after emergence of the maize crop. Vertical bars indicate standard errors (4 replicates).

Discussion

In this study, seed weight of the susceptible biotype was higher than that of the resistant biotype. Bulcke et al., (1985) found no differences in seed weight between triazine-resistant and susceptible *S. nigrum*, while Dominguez et al., (1994) found a higher seed weight for resistant *S. nigrum*. Differences in seed weight can have major implications. From a review of natural populations, Cook (1980) concluded that selection for persistence in the soil favours decreasing seed size, whereas the seed coat thickness does not change. The relative increase in the thickness of the seed coat will probably require the embryo to develop enhanced structural strength in order to emerge. Therefore, smaller seeds may also have a higher degree of seed coat-imposed dormancy.

Despite the differences in seed weight, the observed emergence pattern and number of seedlings of resistant and susceptible plants did not show any differences during the first year of the experiment. In the second year, clear differences in emergence of resistant and susceptible plants developed. Resistant plants emerged earlier, their emergence rate was higher, and the total number of seedlings was also higher. This is in contrast with the aforementioned theory that lower seed weights have a higher level of coat-imposed dormancy. Differences in emergence were not observed until the second year of the experiment. A possible explanation could be a decreased survival rate of susceptible seeds in the seed bank, resulting in a reduced number of viable seeds in the second year. We could also surmise that the resistance trait is genetically linked with a life history strategy to recruit as many seedlings as possible in a very short time (2-3 years), whereas the strategy of the susceptible biotype is to persist in the soil to produce seedlings over a longer period of time.

Results of growth experiments with triazine-resistant and susceptible weeds are variable and this might be caused, for example, by biotype origin or growth conditions (Zanin & Lucchin, 1990; Dominguez *et al.*, 1994). In our study, transplants of both biotypes of *S. nigrum* were grown in a maize crop. Significant differences in total biomass were found at harvest 2 and 3. These differences might be caused by the different initial weights of the transplants. Analysis of relative growth rate (RGR) did not provide any evidence that susceptible plants had a higher RGR than resistant plants. Subsequent studies are in progress to investigate the growth of both biotypes from equally sized seeds in maize.

From this study on life history characteristics of triazine resistant and susceptible *S. nigrum*, two methods to control resistant biotypes might be suggested. Differences in emergence pattern between resistant and susceptible biotypes may offer opportunities to adjust cultural practices to reduce the proportion of resistant *S. nigrum* in a population. Removing resistant plants with stale seedbed preparation before applying a triazine or a herbicide with the same mode of action would be favourable. This combination of a stale seedbed with chemical weed control could result in a fairly good control of both biotypes of *S. nigrum*. The use of soil tillage to prevent or control herbicide-resistant weeds is well documented (Moss & Rubin, 1993). More knowledge of the life history of a weed population with herbicide-resistant biotypes will further increase the potential of soil tillage as a tool for the control of herbicide-resistant weeds.

Another method is to increase the relative competitiveness of the maize crop, which may further reduce the growth of the resistant biotype. A program for the maximization of crop competition has been termed "Weed Smart" in Canada (Morrison and Bourgeois, 1995). This program is based on optimal crop management which includes the ensurance of optimal crop emergence, optimal fertilization for a quick canopy closure, keeping records of cropping history and herbicide use history, and choosing competitive cultivars. With respect to our study, this means that the choice of a maize variety with a high level of weed suppression potential may reduce the total biomass of triazine-resistant weeds, resulting in a reduction of their seed production. This may contribute to an optimal maize cropping system that reduces the proportion of resistant plants in the *S. nigrum* population in the long term.

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