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Controlled release of naphthalene: a repellent against oviposition of the cabbage root fly, Delia brassicae

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Abstract

In the years between 1890 and 1950 the use of tarred felt discs and naphthalene flakes enabled cabbage growers to control *D. brassicae* in a for that time satisfactory way. Resistance- and residue problems with insecticides and the recent development of controlled release compounds resulted in a new approach of the use of insecticides and particularly of volatiles influencing behaviour. In field experiments dispersions of polymers loaded with the repellents tar and naphthalene were sprayed around the stem base of cauliflower plants and the effect of clay slurry discs mixed with these repellents was also studied. The degree of control was assessed by weekly stand scoring and by estimation of the root damage index.

In a second series of field trials the results of the polymer dispersion discs mentioned were compared to those obtained by applying three component granules (a polymer, a copolymer and 30% naphthalene) or sprayed discs of a similar composition. Untreated and trichloronatetreated plants were used as a standard.

Some of the naphthalene compounds almost equalled the effect of trichloronate on the development and size of the plants. The root damage indices, however, showed less favourable figures although their level was far below that of the untreated plants.

Adaptation of the controlled release polymer compositions to particular field situations (pH, soil type) in the future may lead to a further improvement of the results.

Additional keywords: cabbage root fly, repellent, controlled release.

Introduction

For cabbage and carrot growers, resistance to conventional insecticide treatments and residue problems are becoming a threat to production and marketing. Thus influencing the behaviour of the pest might lead to a new approach as introduced already in e.g. fruitculture.

Already in the 1930s Bungenberg de Jong applied encapsulation of biologically active agents. In the 1960s, new designs for dissolution and diffusion from elastomeric and other polymeric matrices loaded with antifouling and other molluscicide and herbicide agents led to a balanced application of these substances in aquatic environments (Cardarelli, 1975). According to a study of the systems available (Allan et al., 1976) different ways of encapsulation may be considered. In addition to the conventional low energy bonds by the van der Waals attraction between biologically active agents and substances like clays and silica gels, there is a chemical pesticide-polymer bond which can be synthesized by normal chemical procedures with or without the use of a chemical bridge which is susceptible to hydrolytic cleavage.

Controlled release from polymeric matrices can take place from solid solutions, solid suspensions and erodible systems. Solid solutions are easily manufactured, for example by extrusion. Size and loading of the polymer granules or material of another shape can be tested easily. However, mathematical approach to the release from this system often shows an exponential decrease in release with time. Solid suspensions have a more constant concentration of the agent in the matrix but there is a set of prerequisites in the relation between the active component and the polymer which makes realization of the device sometimes doubtful or expensive and only acceptable for medical purposes for example.

Erodible matrices are produced by mixing polymers and copolymers with various degrees of hydrophily and degradability. Their character often can be adapted to the requirements of the environment where they have to be applied and to the active components of the mixture to be released as the matrix erodes.

Thus modern formulation techniques might enable the reïntroduction of e.g. naphthalene as an agent influencing the behaviour of insect pests like cabbage root fly (*Delia brassicae*) which was controlled in the past by tarred felt discs used as a repellent and a mechanical barrier against oviposition and larval penetration of this fly (Slingerland, 1894). The continued release of tar vapour from the disc may have been the cause of its reasonable efficacity. An appropriately slow, if possible, controlled release of naphthalene, a component of coal tar, might be a useful alternative for insecticide treatment of cabbage and possibly of carrot. Naphthalene flakes, if applied repeatedly, had a reasonable effect against carrot rust fly, *Psila rosae* (Van 't Sant, 1961). Trials with the cabbage root fly are described below.

A report of the Entomological Society of America on integrated pest management (Glass, 1975) stated that no practicable repellent had been found for protecting agricultural crops from insect attack, because volatile materials must be applied too frequently. The necessity of proper application techniques for the use of biologically active substances was also emphasized.

In preliminary laboratory experiments data from literature about the repellent character of naphthalene were confirmed.

Materials and methods

Materials. For field trials in 1977 'Swedish tar' was mixed with Curasol in a volume ratio of 1 : 3. Curasol is a copolymeric plastic dispersion, readily miscible with water, 200% of which was added. The same ingredients, tar and Curasol, mixed in a 1 : 1 ratio were introduced into a slurry of clay powder to which some shortened polymer fibre was added for reinforcement of the 'disc'. The ratio mixture : water : powder was 1 : 6 : 2, v/v.

In 1978 the trials were done with Curasol-naphthalene mixtures prepared by adding 400 g of naphthalene powder in 100 ml of Teepol to 1000 ml of Curasol, adding water to a total volume of 3000 ml.

A new two-component polymer mixture, called Aqualith was also tested as a matrix for naphthalene. Aqualith is a plastic mixture of a styrene-maleïc anhydride copolymer and polyvinyl acetate which is prone to pH adjustable degradation by chemical and physical factors (Heslinga e.a., 1979). It was used in granular form and as a dispersion, both with 30% naphthalene.

The Curasol dispersions were sprayed in various doses (15, 30 and 60 ml per plant) in a disc of 12 cm diameter around the stem base of cauliflower plants; the clay slurry and the Aqualith dispersion were spread on the same surface through a 5 mm tube from a polyethylene flask, in doses of 20, 40 and 80 ml and 35 ml per plant, respectively. A dose of 25 ml (17 g) Aqualith granules was deposited around the stem base.

The plants were treated one or two days after planting, depending on the weather.

Layout of the experiments. In 1977 the first experiment was laid out in four 100 m^2 blocks, each placed in a corner of a 2 ha field of sandy soil. One block was untreated, on a second block the plots with two replicates of 40 cauliflower plants each were treated with 30 ml Curasol-tar dispersion or 40 ml clay slurry-tar mixture. These plots had 5 untreated plants in the centre, creating a preference situation for the flies. The third and fourth block consisted of non-preference plots treated with the above single and with double doses, respectively. In the second experiment in 1977 one block had untreated plants only, three others received low, medium and high doses of Curasol dispersion or clay slurry, both with or without tar.

In the two experiments of 1978 the plots of 5 × 8 plants were placed in two rows, each row presenting one replicate with randomized treatments mentioned in Fig. 3 and Table 1 and 2. So for each treatment two replicates of 40 plants could be observed.

Observations. Stand scores ranging from 1 to 5 were recorded periodically and the root damage index ranging from 1 to 4 was estimated mostly at the end of the trials. These data were determined according to a standard of the IOBC/WPRS Brassica Working Group (1976). In 1977 numbers of pupae were counted which, as was expected, did not correlate satisfactorily with the stand of the crop; the untreated plants were overcrowded with maggots and showed very low numbers of pupae. The number of pupae is an unreliable criterion for damage to the crop.

Pest populations. In 1977 severe infestation by two generations of *D. brassicae* occurred. In 1978 only the first generation appeared to damage cauliflower severely, the second one had a low density because of the cold weather, so the weekly stand scores of the second experiment showed optimal growth even of untreated plants. However, an adapted standard for root damage index estimation showed reliable differences between the treatments.

Results and discussion

Experiments in 1977. The results of the first 1977 trial planted on 2 May are shown in Fig. 1. The differences between untreated and treated plants are clear. In the second month of the experiment an increase in root damage was observed in the treated plants showing that protection by the treatment did not last. Root damage indices on 10 June were not higher in the non-preference plots, dose 1, than under preference conditions. There were no significant differences between the two types of protective discs around the stem base nor between the various doses which correlate to the thickness of these discs.

Fig. 1. Stand scores and root damage indices of the first experiment with Curasol or clay slurry discs around the stem base of cauliflower.

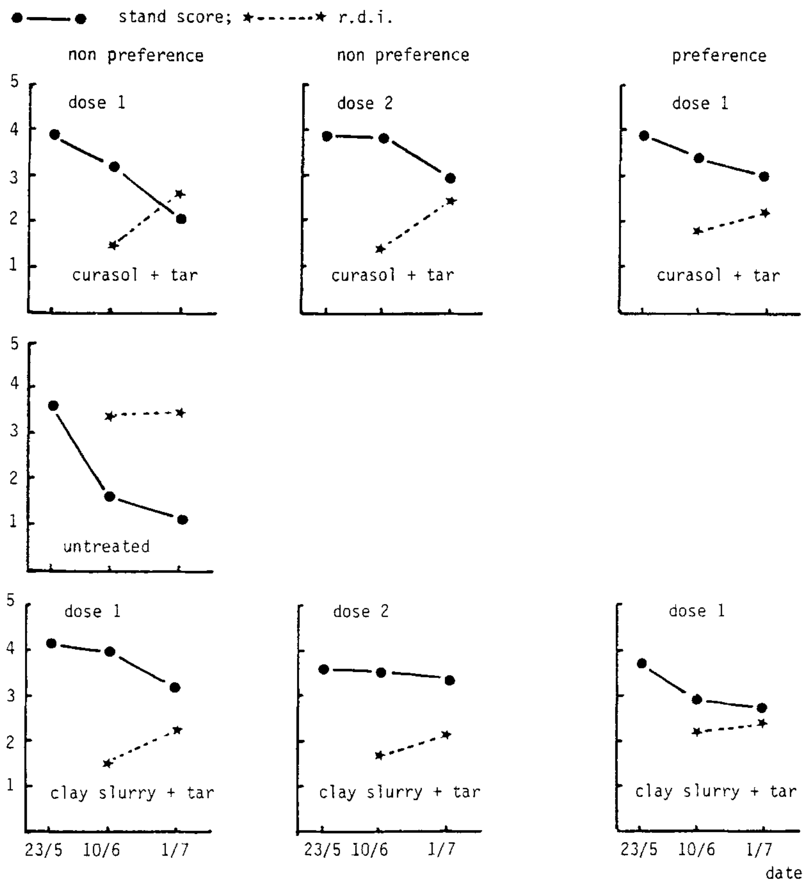

Fig. 1. Standcijfers en wortelschade-indices van de eerste proef met Curasol of dikke kleisuspensie als bodemafdekking om de stengelbasis van bloemkool.

The second 1977 experiment (Fig. 2) planted on 7 July again showed a significant difference between the development of the plants on untreated and treated plots and again an increase in initially very low root damage was observed. When the clay discs were hardening after their deposition, movement of the stems by wind often caused gaps between the stem and the central hole of the disc. These provided oviposition sites for the flies. Moreover, strong winds caused many stems to break on the sharp edges of the clay discs, especially on those of the thickest ones. Neither the tar vapour, nor the mechanical barrier worked satisfactorily during the second half of the growing period. There were no differences between plots treated with discs with or without tar. Clay discs (that did not show cracks owing to the presence of reinforcing fibres) were at least as effective as the Curasol discs. The lowest doses generally were the least effective, particularly where initial root damage was concerned.

General conclusions with respect to the continuation of this field work in 1978 were that a better repellent should be introduced, that the use of clay discs was too laborious

Fig. 2. Stand scores and root damage indices of the second 1977 trial with discs of Curasol AK, a felatively hard polymer, or of clay slurry with and without tar as a repellen around the stem base of cauliflower.

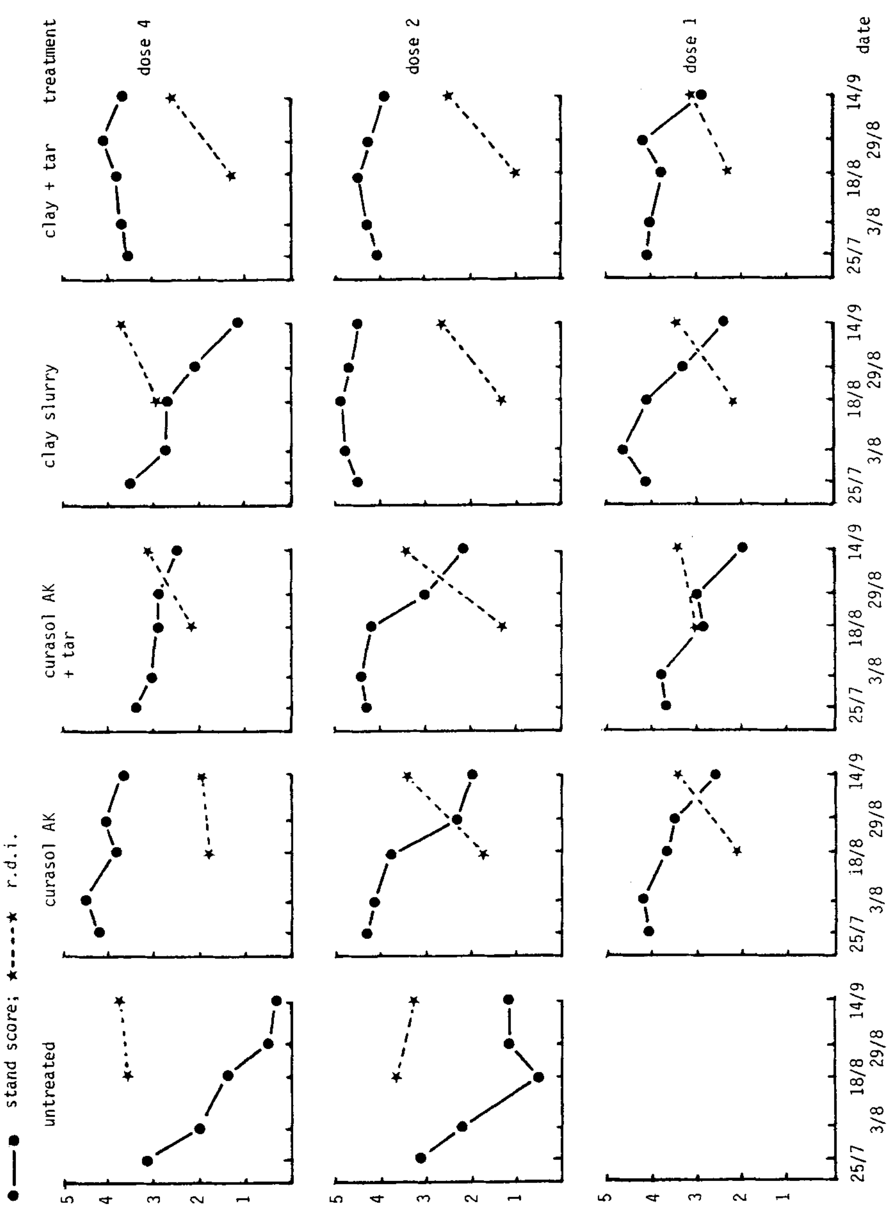

Fig. 2. Standcijfers en wortelschade-indices van de tweede proef in 1977. De bodem om de stengelbasis van bloemkool werd bedekt met Curasol AK, een relatief harde plastic, of met een dikke kleisuspensie al of niet met teer als repellent.

for practice and that the function of Curasol AK as a mechanical barrier needed improvement, for example by application of a more elastic substance around the stem base of the plants. Finally the treatments should be compared with the effect of a conventional insecticide.

Experiments in 1978. During the first trial the calculation of the weekly stand scores was based on the initial score on 26 April (Fig. 3) because initially the size of the planting material varied. The development of the crop that after planting flourished well showed marked differences between both treated and untreated plants and between the various treatments. Instead of the rather hard Curasol AK, the more flexible Curasol AH was applied but the effect of this polymer was not better than that of Curasol AK in 1977. However, addition of naphthalene showed a considerable improvement and the result equalled the effect of trichloronate (0.1% Phytosol, 100 ml per plant). Carbon black as a special component of the Curasol-naphthalene mixture did not improve the result. For the two Curasol-naphthalene mixtures the root damage index at the end of the experiment had an average of 2, whereas all plants treated with trichloronate, could be indexed under 1, while Curasol AH without addition had an average index of 3 which differed significantly from the other three (Table 1). The Aqualith HN and SN

Fig. 3. Relative stand scores of an experiment with naphthalene loaded Curasol discs and idem Aqualith granules around the stem base of cauliflower; HN granules are relatively hydrophilic, SN granules are relatively hydrophobic.

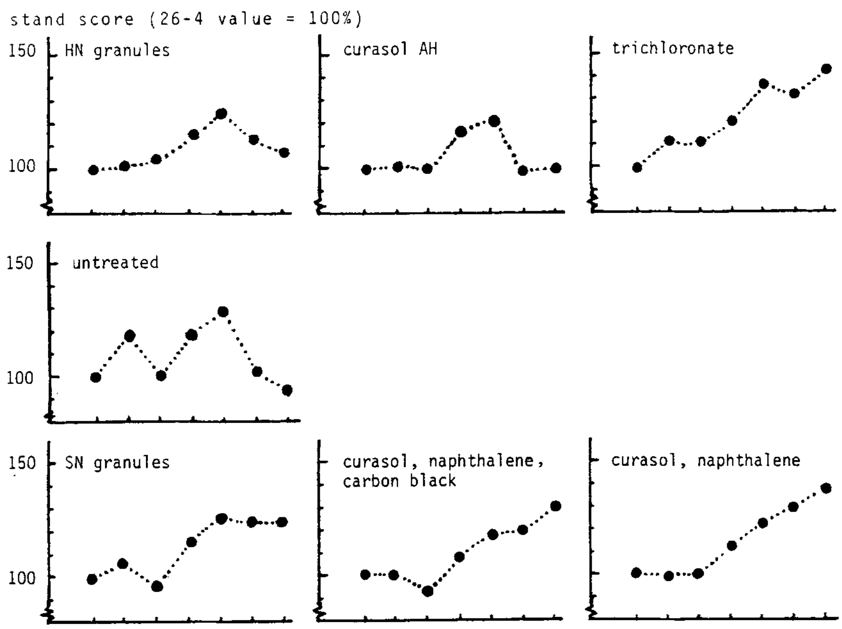

Fig. 3. Relatieve standcijfers van een proef met 'vaste suspensie' van naftaline in Curasol of Aqualithkorrels op de bodem om de stengelbasis van bloemkool. HN en SN korrels zijn relatief hydrophiel resp. hydrophoob.

Table 1. Final stand scores and root damage indices of the experiment shown in Fig. 3. Treatments have been compared pairwise and linked if they differed significantly. Two dots on top of line: P = 0.01, one dot: P = 0.05.

Treatment	Stand score 13/6: percentage plants with score 0, 1, 2 and 3	R.D.I. 13/6: percentage plants with R.D.I. 3 and 4
Untreated	45	89
HN granules	22	72
SN granules	22	73
Curasol AH	35	68
Cur., naphthalene, carbon black	10	25
Cur., naphthalene	12	32
Trichloronate	7	5

Tabel 1. Standcijfers en wortelschade-indices aan het eind van de proef weergegeven in Fig. 3. De behandelingen zijn paarsgewijs vergeleken en met een lijn verbonden bij significantie van het verschil. Twee stippen op de lijn: P = 0,01; één stip: P = 0,05.

granules were not very effective, though the chi square test showed significant differences with the untreated plants even for root damage index (Table 1). In this experiment treatments with Aqualith discs had a phytotoxic effect caused by the solvent. These treatments were discarded. In the second 1978 trial another dispersion of Aqualith PE was applied as sprayed discs. The root damage indices in this treatment were lowest of all except for those obtained by trichloronate (Table 2), those of a granular naphthalene Aqualith SN mixture being once more too high. The flexible Curasol failed, the stiff one was almost significantly better only, whereas addition of naphthalene improved the effect significantly. The data of Table 2 are the result of strict observation because maggots had infested the roots on a smaller scale than they usually do. The trichloronate-treated roots were undamaged. In this trial and in the first 1978 trial root damage indices show that the level of control as brought about by

Table 2. Final root damage indices of the second 1978 experiment with naphthalene loaded Curasol and Aqualith discs and Aqualith granules of a relatively hydrophobic character. Treatments have been compared pairwise and linked if they differed significantly. Two dots on top of line: P = 0.01, one dot: P = 0.05, broken line: difference almost significant at P = 0.05.

Treatment	R.D.I. 29/8: percentage plants with R.D.I. 3 and 4
Untreated	71
Trichloronate	0
SN granules	67
PE disc	29
Curasol AK	51
Curasol AH	64
AK + naphthalene	43
AH + naphthalene	45

Tabel 2. Wortelschade-indices aan het einde van de tweede proef in 1978 met 'vaste suspensies' van naftaline in Curasol of Aqualith (al of niet in korrelvorm) op de bodem om de stengelbasis van bloemkool. De behandelingen zijn paarsgewijs vergeleken en met een lijn verbonden bij significantie van het verschil. Twee stippen op de lijn: P = 0,01; één stip: P = 0,05; stippellijn: verschil bijna significant bij P = 0,05.

an insecticide treatment cannot be achieved by the formulations available. However, two to three weeks after planting the vulnerability of cauliflower and other *Brassicae* plants to cabbage root fly attack already begins to decrease. When the plants are well protected during this period they can stand relatively high numbers of maggots later during the growing season. Their tolerance is enhanced by favourable soil conditions and precipitation or irrigation (Coaker & Finch, 1965; Coaker, 1969).

A comparison of the use of insecticides and repellents shows that the selection pressure upon the pest population by the insecticide may lead to resistance whereas such a development seems less probable when using repellents. In spite of the repulsion a certain number of eggs will be deposited on the crop anyway and survive. Repelled females have a chance to reproduce on non-protected crops or wild crucifers. Therefore a genetic selection on the behaviour towards the repellent is virtually non-existent.

Protection of predators and parasites of other insect pests in the crop itself or in subsequent ones may contribute to maintaining a sound agro-ecosystem in the crop. Further development of resistance in fly populations particularly to organophosphorous insecticides as suggested by Brown (1971) may necessitate alternative control measures. Cross-resistance to carbofuran found by Harris & Svec (1976) in the onion fly in the United States and Canada as a result of a non-specific OP resistance is an ominous sign of increasing changes in resistance to the carbamate insecticides. Therefore it is necessary to develop the use of repellents as an element of integrated control of the cabbage root fly. Continued testing of various erodible systems as a matrix and experiments with other matrices combined with various doses of naphthalene and other possible repellents may, together with further study of the behaviour of the flies and larvae contribute to this development.

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Samenvatting

Gedoseerde afgifte van naftaline: een afweermiddel tegen eiafzetting van de koolvlieg

Voor de bestrijding van de koolvlieg (*Delia brassicae*) werden in de periode van 1890 tot 1950 koolkragen gebruikt. Het in teer gedrenkte karton of vilt fungeerde als mechanische barrière en als afstotend middel tegen de eileggende koolvlieg en zijn larve. Als zodanig werden sinds 1918 ook naftalineschilfers toegepast.

Resistentie- en residuproblemen bij het gebruik van insekticiden en de ontwikkeling van kunststofverbindingen geschikt voor langzame afgifte van daarmee gemengde vluchtige verbindingen leidden tot hernieuwd onderzoek naar de werking van naftaline als repellens.

In veldproeven werd de werking van polymeren beladen met de repellentia teer en naftaline tegen koolvlieg onderzocht aan de hand van gewasontwikkeling en wortelschade-indices. Enkele van de systemen met vertraagde afgifte evenaarden bijna het effect van het insekticide trichloronate op ontwikkeling en grootte der planten bovengronds. De wortelschade aan het einde van de proeven was echter niet minimaal, zoals na insekticidebehandeling, doch aanzienlijk minder dan bij onbehandelde planten. Combinatie van deze twee gegevens wijst op het ontstaan van een aanzienlijke tolerantie van de bloemkoolplanten in de eerste periode van de groei.

Aanpassing van genoemde kunststofverbindingen aan speciale veldsituaties als pH en bodemtype kan in de toekomst leiden tot verbetering der resultaten.

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