What mechanisms are involved in cabbage-clover intercropping and a further proof of the 'host plant quality' hypothesis

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Summary: Over 10 years of field trials show reductions of most of the pests in Brassicas undersown by clover. The pest-reducing effects are due to the 'appropriate / inappropriate landings' hypothesis *(Finch,* 1996), and the 'host plant quality' hypothesis *(Theunissen,* 1994). To find out the mechanisms within the 'host plant quality' hypothesis in the most promising intercropping (collards undersown by clover) glasshouse experiments were conducted to see whether intercropping influences the mean relative growth rate, fecundity and time of maturity of *Myzus persicae* (Sulzer) (Homoptera: Aphididae) a common pest of Brassicas.
The treatment modelling intercropping showed the smallest mean relative growth rate, delayed the maturity and slowed down the growth of cabbages. The treatment modelling monocropping showed the highest mean relative growth rate and the maturity was reached earlier. These results may indicate that intercropping delays the growth of settled aphid populations, giving another proof that in the case of clover undersown cabbages the 'host plant quality' hypothesis is likely to be acting. The differences between treatments where the roots of clover and cabbages were separated and allowed to grow together suggest that the effect is via the roots by competition.

Introduction

Intercropping systems (where two or more crops are grown together) tend to suffer less damage by pests than monoculture (where one crop is grown at one time), although not always *(Vandermeer,* 1989; *Andow,* 1991; *Altieri,* 1994).

The paper discusses that in the case of clover undersown intercroppings which mechanism is likely to cause the pest population reducing effect and describes an experiment which supported the 'host plant quality' hypothesis by measuring the performance of the aphid *Myzus persicae* on undersown and not-undersown cabbages in glasshouse experiments.

Review of literature

Intercropping is the dominant mean of food production in the tropics, which has been sustained for a long time. In temperate zones wheat undersown by clover was used to control weeds and to benefit from the nitrogen fixing capacity of these leguminous plants *(Theunissen,* 1997). Nowadays clover undersown vegetable cultures (collards and leek) became a good possibility for growing chemical-free crops.

The most researched intercropping in temperate zones is collards undersown by clover *(Fig. 1.).* Over 10 years of field trials show reductions of most of the pests of Brassicas (e.g. *Brevicoryne brassicae, Mamestra brassicae, Delia brassicae* and *Thrips tabaci) (Wiech & Wnuk,* 1991; *Theunissen* et al., 1992; *Finch & Edmonds,* 1994; *Lehmhus* et al., 1996). The competition between the species results in lower yields compared to insecticide-treated monocultures.

Another candidate for short-term implementation is the leek undersown by clover *(Theunissen & Schelling,* 1996; *Theunissen & Schelling,* 1997). Five years of experimental work demonstrate of considerably smaller damages by thrips *(Thrips tabaci).* This requires attention because *Thrips tabaci* cannot be controlled with the range of insecticides now available in the Netherlands *(Van de Steene,* 1996). This intercropping also reduced leek rust *(Puccinia allii)* incidence. The obstacle before using it on commercial farms is also the differences between the yields.

Perrin & Phillips (1978) gives an excellent summary on the possible effects of intercroppings: (1) disruption of olfactory / visual responses, (2) physical barriers to colonists, (3) diversion to tolerant / less important hosts, (4) limited dispersal between plants, (5) disruption of feeding and reproduction, (6) changes in mortality due to natural enemies.

Figure 1 Cabbage undersown by clovers

The pest-reducing effects in the case of clover undersown vegetable cultures are described by the (1) 'appropriate / inappropriate landings' hypothesis *(Finch,* 1996), and the (2) 'host plant quality' hypothesis *(Theunissen,* 1994).

1. 'appropriate / inappropriate landings' hypothesis

A number of cases showed that significantly more pests (e.g. aphids, whitefly, cabbage root fly and certain Lepidoptera) colonise on clean weeding than on plants with green background, like weedy culture or undersown cover *(Smith,* 1976; *Ryan* et al., 1980; *Hofsvang,* 1991; *Theunissen* et al., 1992; *Finch & Edmonds,* 1994; *Vidal & Bohlsen,* 1994; *Lehmhus* et al., 1996).

A good explanation of the above observation is given by *Finch* (1996) by his 'appropriate / inappropriate landings' hypothesis. It states that the close proximity of host and non-host plants affects colonisation. Pest species are attracted by volatiles of hosts, the colour of vegetation *(Moericke,* 1952) and the optomotor reaction in which landing is provoked by plants "looming up" along the path of the flying insect *(Kennedy* et al., 1961). In clean weeding the pests can easily locate their hosts because only the host plants are green and pest insects of the Brassica crops avoid landing on bare soil *(Kostal & Finch,* 1994). So most of the landings will be 'appropriate'.

Now the situation is different in covered backgrounds. As pest species do not discriminate between green colours (even green paper) *(Kostal & Finch,* 1994), the insects will land in proportion to the relative areas occupied by the host and the non-host plants, so many landings will be inappropriate.

The insects landed on non-host plants will fly off again and will repeat host landing with the above probability or leave the area.

This hypothesis was supported with same-size plants in laboratory *(Kienegger & Finch,* 1996)

2. 'host plant quality' hypothesis

Theunissen & Schelling (1996) report that in leeks undersown with clover the population of *Thrips tabaci* does not develop as fast as in leek monocrops. After initial, simultaneous low level colonisation in both treatment, in monocropping the adults and larvae become abundant, while in intercropping adult population remain low, small number of eggs are deposited, and larval populations remain low except at high immigration rates.

Theunissen & Schelling (1997) follow that as growing season passes feeding on intercropped leeks may become less or cease, but the first damage is done. A second element in the total intercropping effect is that a given number of thrips larvae per plant cause less injury on intercropped leek plants than on monocropped plants. In these cases the working mechanism of intercropping seems to be that the quality of intercropped host plants becomes less suitable for the pests.

There are some evidences that different fertilisation (mineral versus organic) affected few vitamin and mineral contents of carrot and celeriac *(Leclerc* et al., 1991).

According to this, it would be useful to examine the nutrient content and the physiological changes (e.g. width of epidermis) in laboratory, analysing the plants from different growing systems. Theunissen (pers. comm.) did not find any difference between monocropped and intercropped cabbages during the analysis of the nutrients. But he found the number of endophytes higher in intercropped cabbages.

To find out the mechanisms within the 'host plant quality' hypothesis in the most promising intercropping (collards undersown by clover) glasshouse experiments were conducted to see whether intercropping influences the mean relative growth rate, fecundity and time of maturity of *Myzus persicae*, a common pest of Brassicas. Certain field experiments say that there were no differences in the rate of increase in aphid numbers between the monocropped and undersown treatments *(Vidal & Bohlsen, 1994)*. But it was still interesting to see whether there will be differences between intercropped and monocropped plants when the roots of clover and cabbages are allowed to grow together or the roots are separated.

Material and methods

Glasshouse grown white cabbages (Minicole F_1) with white clover *(Trifolium repens ssp. sylvestre "Rivendel")* plants were arranged and / or transplanted in a glasshouse according to the following treatments *(Fig. 2.)*:

1. intercropping, roots allowed to grow together: 3 cabbage plants and 14 x 10 clover plants transplanted to a seedling tray
2. monocropping, roots allowed to grow together: 3 cabbage plants transplanted to a seedling tray
3. intercropping, roots separated: 3 pots of cabbage and 8 pots of clover (10 plants in each pot)
4. monocropping, roots separated: 3 pots of cabbage and 8 pots of peat

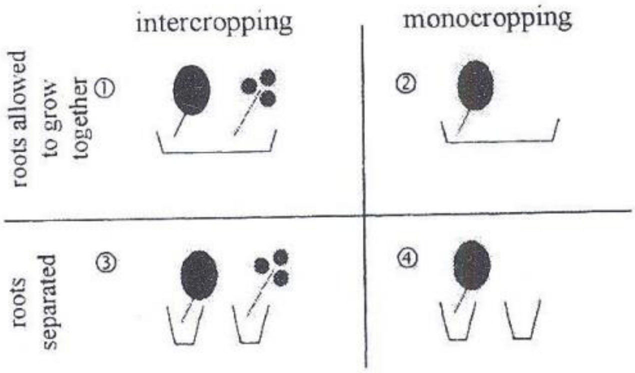

Figure 2 Treatments

M. persicae nymphs and pre-reproducing adults were raised in clip-cages placed on the same position of the same leaf considering the level above the ground, on the middle cabbage plants of each treatment.

The aphid performance was evaluated using three methods:

a) mean relative growth rate (van Emden, 1972) (4 nymphs in each replicate)
b) fecundity (3 pre-reproducing adults in each replicate)
c) delay in maturity (no. of adults / no. of all forms were counted every 5 hours) (from a) and b) methods, averaged)

The plants were arranged and / or transplanted 1 day before the experiment started, then the measurements took 9 days, and repeated again for 9 days on the same plants. Four replicates were used in each test. The aphids were derived from a genetic clone. The experiment was conducted in the glasshouse of the Scottish Agricultural College, Edinburgh, Scotland. The temperature was kept around 20°C by automatic heating and ventillation.

Results

On the 18th day of the experiment the cabbages in the treatment 'intercropping, roots together' had significantly ($p<0.01$) less leaves compared to all the other treatments *(Fig. 3.)*. The slower growth was probably caused by the competition between the cabbage and the clover. The shoot was the highest ($p<0.05$) in the treatment 'intercropping, roots separated' compared to all the other treatments *(Fig. 3.)*. This elongation could have been caused by the competition for light compared to monocropped cabbages, and better growth compared to the treatment 'intercropping, roots together'.

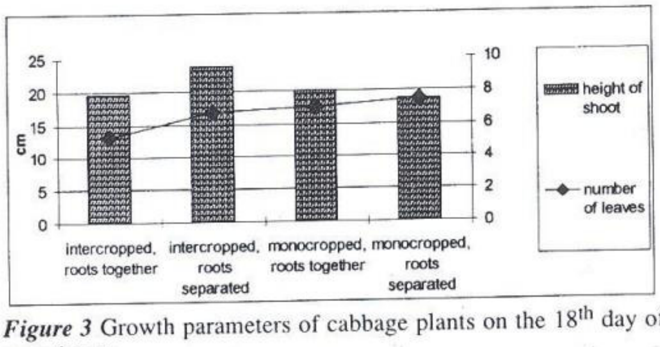

Figure 3 Growth parameters of cabbage plants on the 18th day of experiment

On the second 9 days of the experiment (by the time the roots grew together) the mean relative growth rate became the smallest in the treatment 'intercropping, roots together'. The fastest weight increase was measured in the treatment 'monocropping, roots separated'. The treatments with medium competition (intercropping, roots separated; monocropping roots together) gave intermediate results *(Fig. 4.)*. These results were not significant.The fecundity did not show differences.

The maturity was reached last always in the treatment 'intercropping, roots together', however, this became

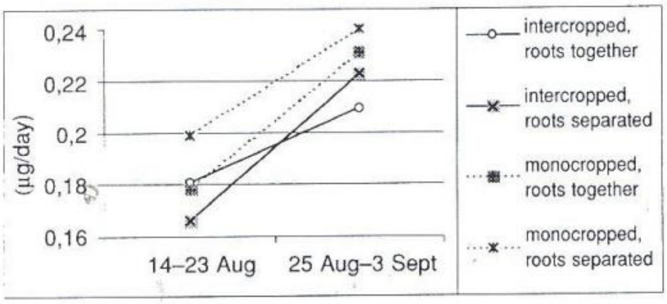

Figure 4 Mean relative growth rate of *M. persicae*

significant ($p<0.05$) from the treatment 'monocropping, roots separated' only in the second 9 days of the experiment. The maturity was reached first always in the treatment 'monocropping, roots separated'. The treatments with medium competition (intercropping, roots separated; monocropping roots together) gave intermediate results *(Fig. 5.)*.

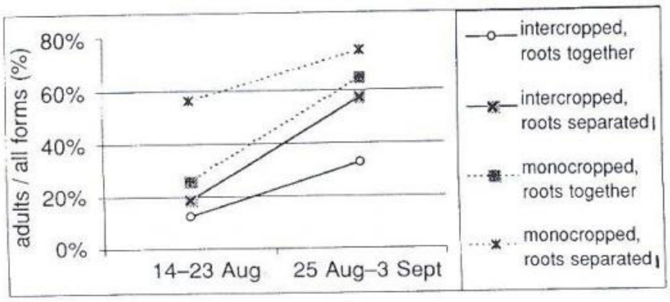

Figure 5 Delay in maturity of *M. persicae*

Discussion

Theunissen (pers. comm.) noticed that if the competition is reduced between the plants by planting clover only between every second cabbage row than the positive plant protection effect is also reduced. Therefore we expected that the model of the observed pest-population reducing growing method, the 'intercropping, roots together' treatment will differ from the other treatments.

The data supported our expectations. The 'intercropping, roots together' treatment showed the smallest mean relative growth rate, delayed the maturity and slowed down the growth of cabbages. The 'monocropping, roots separated' treatment showed the highest the mean relative growth rate and the maturity was reached earlier. The treatments with medium competition (intercropping, roots separated; monocropping roots together) gave intermediate results.

These results may indicate that intercropping delays the growth of settled aphid populations, giving another proof that in case of clover undersown cabbages the 'host plant quality' hypothesis is likely to be acting. The differences between the 'roots separated' and 'roots allowed to grow together' treatments suggest that the effect is via the roots by competition.

Theunissen and *Schelling* (1998) followed their investigations in leek-clover intercropping and found the right level of competition: where yield loss was acceptably low, but pest reducing effect was sufficient. (This was achieved by drilling only 2 rows of clover 12 cm apart between the 55 cm wide leek rows). Considering this, it is probable that also in the cabbage-clover intercropping the right level of competition will be found, and therefore commercial growers will be able to use this pesticide-free growing method.

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