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Yield losses of white cabbage caused by competition with clovers grown as cover crop

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Abstract

To explore and develop intercropping as an integrated pest management tool to reduce population densities of pests in field grown vegetables, growth and yields of cabbage crops and clover cover crops were studied in four field experiments. In the first two experiments the clover crop had a clear pest reducing effect on fresh market cabbage. The associated yield losses by competition with the cover crop ranged between 15–24%. In the other experiments, designed to explore possibilities to reduce these yield losses in cabbage for storage, they ranged between 18 and 43%. The decrease in weight per head could be reduced by decreasing the row distance from 0.75 m to 0.50 m, but the yield losses were still high. Delay of sowing time of the clover crop or transplanting the cabbage into a rotary cultivated strip in the clover stand, instead of transplanting in the clover stand itself, did not reduce yield losses. Intercropping with clover as an IPM tool is presently not ready for inclusion in cropping systems of cabbage and more detailed research on interactions between cabbage, cover crops and pests is required.

Keywords: Integrated pest management, intercropping, cover crops, cabbage, *Trifolium repens*, *Trifolium subterraneum*

Introduction

In intercropping there are two or more crops cultivated in such a way that they interact agronomically (Vandermeer, 1989). If there is a primary crop intercropped with a secondary crop, covering the soil to replace another agricultural input, we call this latter crop *cover crop*. Extensive literature is available on effects of weeds and cover crops on insect infestations (Dempster & Coaker, 1974; Theunissen & Den Ouden, 1980; Andow, 1988; Kloen & Altieri, 1990; Trenbath, 1993; Theunissen *et al.*, 1995). The majority of these studies demonstrate that the presence of non-crop plants or cover crops may reduce population densities of a specialized herbivore (e.g. insects) in the main crop. Three hypotheses may explain these results (Trenbath, 1993). In the first, the cover crop reduces the suitability of the main crop as a host, for example, due to a changed morphology. In the second, the cover crop interferes directly with activities of the attacking insect, e.g. dispersal patterns of the insect might be affected because of the complex structure of the crop stand. In the third hypothesis, the cover crop changes the environment favouring natural enemies.

In spite of the extensive literature on possible contributions of intercropping to reduce yield losses by insects, so far little progress has been made towards intercropping in arable farming and field production of vegetables in temperate regions. In general, intercropping reduces biomass of each crop due to competition for light, nutrients or water. This yield reduction by competition should be compensated by increased product quality and reduced costs of pest control. This trade-off requires data about yields and effects on the population dynamics of the insects. Though the aforementioned literature extensively deals with effects of intercropping on insect infestations, data on yield reductions by competition between main crops and cover crops generally are lacking.

The present study is part of a multidisciplinary project to explore and develop intercropping in field grown vegetables as an integrated pest management tool to contribute to economically and ecologically acceptable systems of sustainable horticulture (Theunissen *et al.*, 1995). The aim of this paper is to present data on growth and yields of cabbage grown with cover crops of clovers, to quantify yield losses by competition with clover cover crops and to explore possibilities of reducing these yield losses by management practices. It was hypothesized that the yield losses can be reduced by decreasing the cabbage row distances, delaying the sowing time of the clover and by transplanting the cabbage into strips in which clover was removed by rotary cultivation.

Materials and methods

Four field experiments with white cabbage (*Brassica oleracea* L.) were carried out from 1990 to 1993. In the first two years, the main crop was fresh market white cabbage. In the third and fourth year the main crop was white cabbage for storage. In all experiments weeds were removed by hand.

Field experiments in 1990 and 1991

The fresh market white cabbage cv. Minicole was grown at the experimental station 'De Schuilenburg' near Lienden, the Netherlands. The soil type was a sandy loam and the preceding crop was winter wheat in both years. The experiments were of the same randomized complete block designs of four replicates with three treatments: 1. a cabbage monocrop, 2. cabbage with *Trifolium repens* (white clover) cv. Pertina, and 3. cabbage with T. *subterraneum* cv. Geraldton (subterraneum clover). Plot sizes were 23 m × 25 m. The clover seeds were inoculated with the appropriate strains of *Rhizobium* bacteria prior to sowing to ensure N-fixation. On 21 March 1990 and 26 March 1991 the clovers were machine drilled in rows 0.12 m apart at seed rates of 10 kg ha^{-1} for T. *repens* and 20 kg ha^{-1} for T. *subterraneum*. Cabbage plants in peat blocks were transplanted on 1 May 1990 and 7 May 1991 between the clover rows. Spacing of the cabbage plants was 0.50 m within the rows and 0.75 m between the rows. At transplanting the per plant above ground fresh biomass and leaf area for cabbage was 5.3 g and 75 cm^2, for *T. repens* 0.002 g and 0.3 cm^2, and for *T. subterraneum* 0.010 g and 1.4 cm^2 (average values of both years). *T. repens* covered the plots for about 50% and the *T. subterraneum* for about 60%. NPK 12–10–18 fertilizer was applied at a rate of 1000 kg ha^{-1} of which 500 kg ha^{-1} was applied before transplanting, 250 kg ha^{-1} two weeks after transplanting and 250 kg ha^{-1} in the third month after transplanting (cf. Everaarts, 1993). No pesticides were used.

Every 3–4 weeks during the growing season plant height and leaf area index (LAI) were determined for cabbage (from four neighbouring plants in one row) and clovers (0.5 m × 0.5 m) in each plot. Leaf area was measured with a LICOR area meter (model 3100, Lincoln, NE, USA). On 20 August 1990 and 3 September 1991, 25 cabbage plants per plot were sampled and above-ground fresh weight was assessed. Marketable heads were graded in two classes (1. no damage by pests, and 2. pest damage). For each class total weight of the marketable heads per sample of 25 cabbage plants was determined. In 1991 at harvest, the total nitrogen content of the cabbage plants and of the soil (layers 0–0.20 m, 0.20–0.40 m and 0.40–0.60 m) was determined with the Dumas extraction procedure, using a Macro-N analyser (Elementar Analysen-Systeme GmbH, Hanau, Germany).

Theunissen *et al.* (1995) have previously reported the populations of cabbage pests and the loss in quality related to injury by these pests in both experiments in detail.

Field experiment in 1992

White cabbage for storage, cv. Slawdena, was grown at the Regional Experimental Station Zwaagdijk, the Netherlands. The soil type was silty clay with 6% organic matter and the preceding crop was cabbage. Three experimental factors were studied in a split-split-plot design with four replicates. The first factor was 'intercropping', with either no cover crop (i.e. monocropped plots of cabbage) or a cover crop of *T. subterraneum*, cv. Trifoli. The second factor was 'row distance of the cabbage' spaced at 0.50 m or 0.75 m, and the third factor was 'pest control' with either control of cabbage root fly, caterpillars, aphids, and the fungal disease *Mycosphaerella brassicicola* or no control. During the growing season, these organisms were controlled with Dyfonate® (10 ml fonofos/tray) against cabbage root fly, Bactospeine® (*Bacillus thuringiensis*, dose 0.1%) against caterpillars, Hostaquick® (heptenofos, 0.5 l/ha) and Pirimor® (pirimicarb, 0.5 l/ha) against aphids, and Dorado® (pyrifenox, 0.75 kg/ha) against *M. brassicicola*. The factor 'row distance of the cabbage' was nested within the factor 'cover crop', and the factor 'pest control' was nested within the factor 'row distance of the cabbage', giving a total number of eight treatments. Plot size was 6 m × 13 m.

The amount of mineral nitrogen present in the soil in early spring was 40–50 kg N/ha. At the beginning of April 250 kg N/ha was applied as ammonium nitrate limestone before soil cultivation. The inoculated clover seeds were sown on 9 April at a rate of 15 kg/ha and the cabbage was transplanted on 20 and 21 May. Distance between cabbage plants in the row was 0.50 m.

Plant height, above ground dry weight and LAI were determined during the growing season as in 1990 and 1991. Final harvest of the cabbage was on 5 and 6 November. Twenty cabbage plants per plot were sampled and above-ground fresh weight assessed. Marketable heads were graded in the classes with and without pest damage, as in 1990 and 1991.

Field experiment in 1993

White cabbage for storage, cv. Slawdena, was grown at the experimental station as in 1992. Two experimental factors were studied in a split-plot design with four replicates to explore possibilities to reduce cabbage yield losses by clover cover crops. The first factor was 'intercropping', with either no cover crop (i.e. monocropped plots of cabbage) or a cover crop of *T. subterraneum*, cv. Geraldton, sown 3 weeks and 6 weeks before cabbage transplanting. The other factor was the preparation before transplanting with three variants. Cabbage was transplanted between the clover rows without rotary cultivation and in rotary cultivated strips of 0.15 and 0.30 m (creeping stems of clover removed). Plot size was 6 m × 6 m.

The mineral nitrogen present in the soil in early spring was about 50 kg N/ ha. In the beginning of April 300 kg N/ha was applied as ammonium nitrate limestone before soil cultivation. The inoculated clover seeds were sown on 5 or 27 April at a rate of 15 kg/ha and the cabbage was transplanted on 19 May. Distances between cabbage plants were 0.50 m × 0.75 m.

As in previous experiments, above ground dry weight and LAI were determined during the growing season. Final harvest of the cabbage was on 16 November. Marketable heads were graded in the classes with and without pest damage, as in the earlier years. Fourty-eight cabbage plants per plot were used to measure above-ground fresh weight. Fresh weights of a single cabbage head were determined from a sample of 12 cabbage plants.

Data analysis

The data were analysed by means of Analysis of Variance with the Genstat 5 programme where appropriate (Payne *et al.*, 1993).

Results

Field experiments in 1990 and 1991

T. repens emerged slowly and patchily. *T. subterraneum* emerged faster, within 10–14 days after sowing. Seven weeks after transplanting the cabbage, soil cover of *T. repens* was 30–50%, whereas *T. subterraneum* showed almost complete soil cover. At that time height of *T. repens* was about 0.10 m whereas height of *T. subterraneum* was 0.06–0.11 m. Ten weeks after transplanting the height of *T. repens* ranged between 0.20–0.25 m and height of *T. subterraneum* between 0.15–0.18 m. In the 13th week after cabbage transplanting, these ranges were 0.18–0.30 m and 0.09–0.16 m, respectively. The cabbage plants were taller than each clover species throughout the experiment. Maximum height of these fresh weight cabbage plants was ca. 0.28 m. Lower leaves of many cabbage plants were shaded by the clovers.

Both clover species started flowering nine to ten weeks after cabbage transplanting. *T. repens* flowered until the final harvest of the cabbage. Five to three weeks before this harvest, plants of *T. subterraneum* died off, leaving a dense 0.02 m layer of dried stems and leaves on the soil.

The above-ground dry matter and LAI of the cabbage monocrop tended to be higher than of cabbage with clovers in both years (Figure 1). Until about day number 200 (i.e. until flowering) above-ground dry matter of the clovers increased, after which it decreased considerably. This drop was also found in the LAI of both clover species. However, in contrast to that of *T. subterraneum* the LAI of *T. repens* increased between the last two harvests.

At final harvest in 1990, the average fresh weight of the cabbage plants and marketable yield was 24% lower in intercropped plots than in plots without clover (Table 1). No significant differences were found in per plant biomass and marketable yield between both clover treatments. Selecting only cabbage heads without pest damage, the marketable yield that remained from the 25 heads sample was considerably lower in the monocropped plots than in the clover plots. In 1990, the marketable yield of this quality class was significantly higher in the plots with *T. repens* than in those with *T. subterraneum*. The observed pest damage in the other class was mainly caused by caterpillar feeding, infestation by thrips (*Thrips tabaci*) and tunnelling in the underside of the head by larvae of the cabbage root fly (*Delia radicum*).

In 1991, at final harvest the average fresh weight of the cabbage plants and the marketable yield was 15% lower in intercropped plots than in plots without clover (Table 1). When considering only the quality class 'no pest damage' the monocropped plots again had a considerably lower marketable yield than the plots with both clover species. The differences between the treatments in the fresh weight of the 25 heads samples and the yield difference between the clover species in the quality class 'no pest damage' were not statistically significant in this second year.

No significant differences in total nitrogen content between the monocropped and the intercropped cabbage plants were found at harvest. The average nitrogen content over all treatments was 2.3%. Neither were there significant differences in total nitrogen content of the soil of plots with and without clovers at harvest (each $P>0.05$).

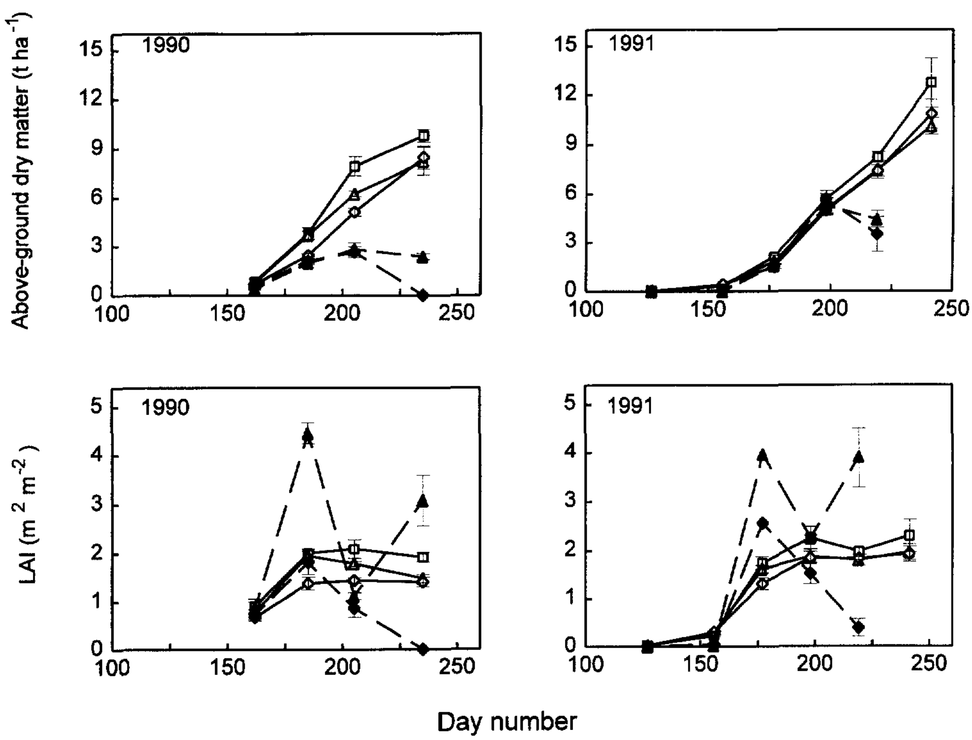

Figure 1. Above-ground dry matter and leaf area index (LAI) of fresh market cabbage, *T. repens* and *T. subterraneum*. Legend: –□– Cabbage monocrop, –△– Cabbage with *T. repens*, –◇– Cabbage with *T. subterraneum*, –▲– *T. repens*, –◆– *T. subterraneum*. Bars represent standard errors of the mean.

Field experiment in 1992

When the cabbage was transplanted the height of the clover was about 0.03 m and the soil cover was about 80%. The height of the *T. subterraneum* was lower than that of the cabbage until harvest. The maximum height that the clover reached was about 0.20 m. The clover started flowering on about day number 200 and completely died after day number 270.

During the experiment the above-ground dry matter and LAI of the cabbage monocrop was higher than that of the cabbage with clover (Figure 2). For both the monocropped and the intercropped cabbage these traits tended to be higher in plots with a row distance of 0.50 m than in plots with a row distance of 0.75 m (Figure 2). As in the previous experiments, the LAI of this clover dropped after about day number 200. The above-ground dry matter of the clover decreased after day 230. The clover above-ground dry weight tended to be higher in the plots with 0.75 m than in those with 0.50 m row distance.

No marketable heads were scored in the class without pest damage at harvest, because of an abundant infestation of the crop by thrips. The cabbage marketable

Table 1. Effect of *T. repens* en *T. subterraneum* used as cover crop on yield of fresh market cabbage, analysed with ANOVA[1]. Data refer to a sample of 25 cabbage plants at final harvest.

		Monocrop	*T. repens*	*T. subt.*	$F_{(2,6)}$	*A priori* contrasts Monocrop/ *Trifolium*	*T. repens*/ *T. subt*
1990	Above ground fresh weight (kg plant^{-1})	3.1	2.4	2.3	14.7 **	**	ns
	Fresh weight 25 heads (kg)	49.3	39.0	36.5	12.4 **	**	ns
	Fresh weight of the undamaged heads from the 25 head sample (kg)	0.5	12.9	4.2	23.5 ***	**	**
1991	Above ground fresh weight (kg plant^{-1})	3.1	2.6	2.7	6.3 *	**	ns
	Fresh weight 25 heads (kg)	49.8	42.0	42.8	4.7 ns	ns	ns
	Fresh weight of the undamaged heads from the 25 head sample (kg)	1.5	16.9	16.3	16.1 **	***	ns

[1] ns P>0.05, * P<0.05, ** P<0.01, *** P<0.001

yields (heads only) intercropped with clovers were 43% lower than those of the monocrop (P<0.05). The average marketable yield of the intercropped cabbage was 59 t ha^{-1} and of the monocrop cabbage 104 t ha^{-1}. Row distance had less effect on yield (marginally significant at P<0.10). At a plant distance of 0.50 m × 0.50 m the average marktable yield was 87.6 t ha^{-1} and at 0.50 m × 0.75 m it was 75.4 t ha^{-1}. The crop protection treatments had no effect (P>0.10).

The average weight of a single head of the monocropped cabbage was 3.4 kg whereas that of the intercropped cabbage was 2.0 kg (P<0.05). Row distance had a similar effect: 3.2 kg at 0.50 m × 0.75 m and 2.2 kg at 0.50 m × 0.50 m (P<0.001). Intercropping with clover reduced the weight of the cabbage more the larger the row distance (P<0.01). At a row distance of 0.50 m × 0.50 m this reduction was 34% and at 0.50 m × 0.75 m it was 43%.

Field experiment in 1993

When the cabbage was transplanted the soil cover of the clover sown 6 weeks before was 75% and that of the clover sown 3 weeks before 90%. At that time the height of the early sown clover was 0.08 m and that of the later sown clover 0.17 m. Though the later sown clover performed better than the early sown clover, both clovers started flowering on about day number 160.

The above-ground dry matter and LAI of the cabbage monocrop was higher than

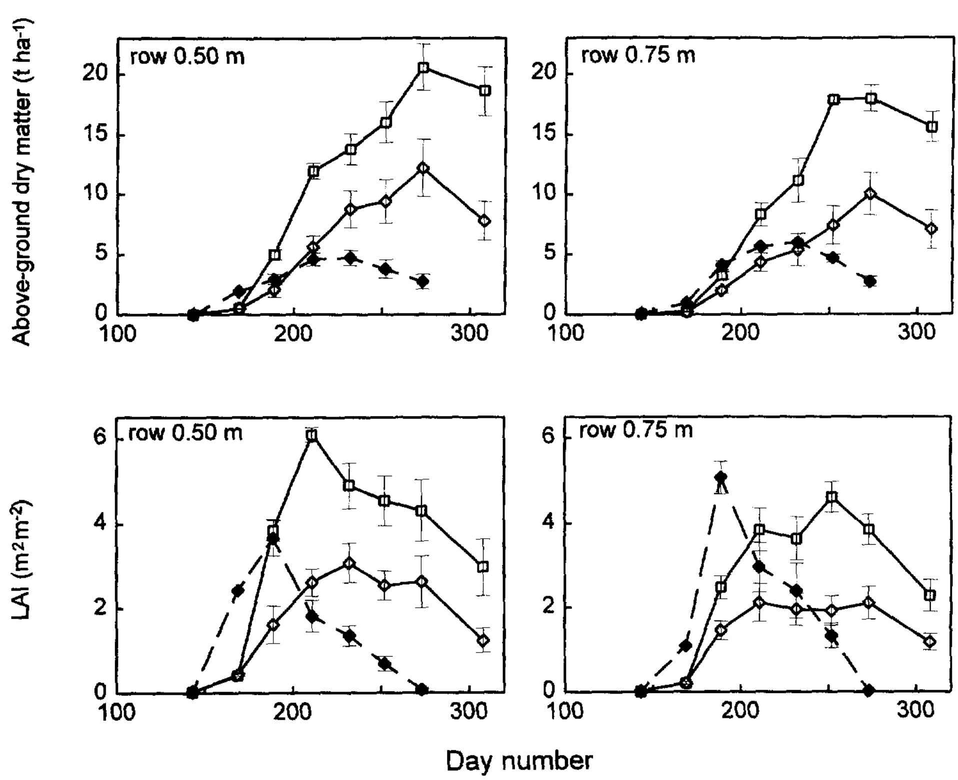

Figure 2. Above-ground dry matter and leaf area index (LAI) of white cabbage and *T. subterraneum* at different row distances in the 1992 experiment (only data included of the no-pest control treatments). Legend: –□– Cabbage monocrop, –◇– Cabbage with *T. subterraneum*, –◆– *T. subterraneum*. Bars represent standard errors of the mean.

that of the cabbage with clover (Figure 3). This difference was largest when the cabbage was transplanted into the rotary cultivated strip of 0.30 m. The above-ground dry weights of the cabbage intercropped with clover that was sown six weeks before transplanting was generally intermediate between the cabbage monocrop and the cabbage intercropped with the clover, sown three weeks before transplanting. This trend was also most clearly observed at the treatment with rotary cultivation to 0.30 m. The above-ground dry weight and the LAI of the clover in the beginning of the experiment was about three times higher when the clover was sown three weeks before than when it was sown six weeks before transplanting of the cabbage. After some weeks, biomasses of both clover crops were similar. After day number 200, the LAI, especially of the late sown clover, dropped sharply. After the first week of October (day number 280), hardly any clover plants were still alive.

No marketable heads were graded in the class 'without pest damage'. As in 1992, there was an abundant infestation by thrips. Subsequent analysis of the degree of thrips infestation per head did not reveal significant differences between clover treatments (data not presented). The average marketable yield of the monocropped

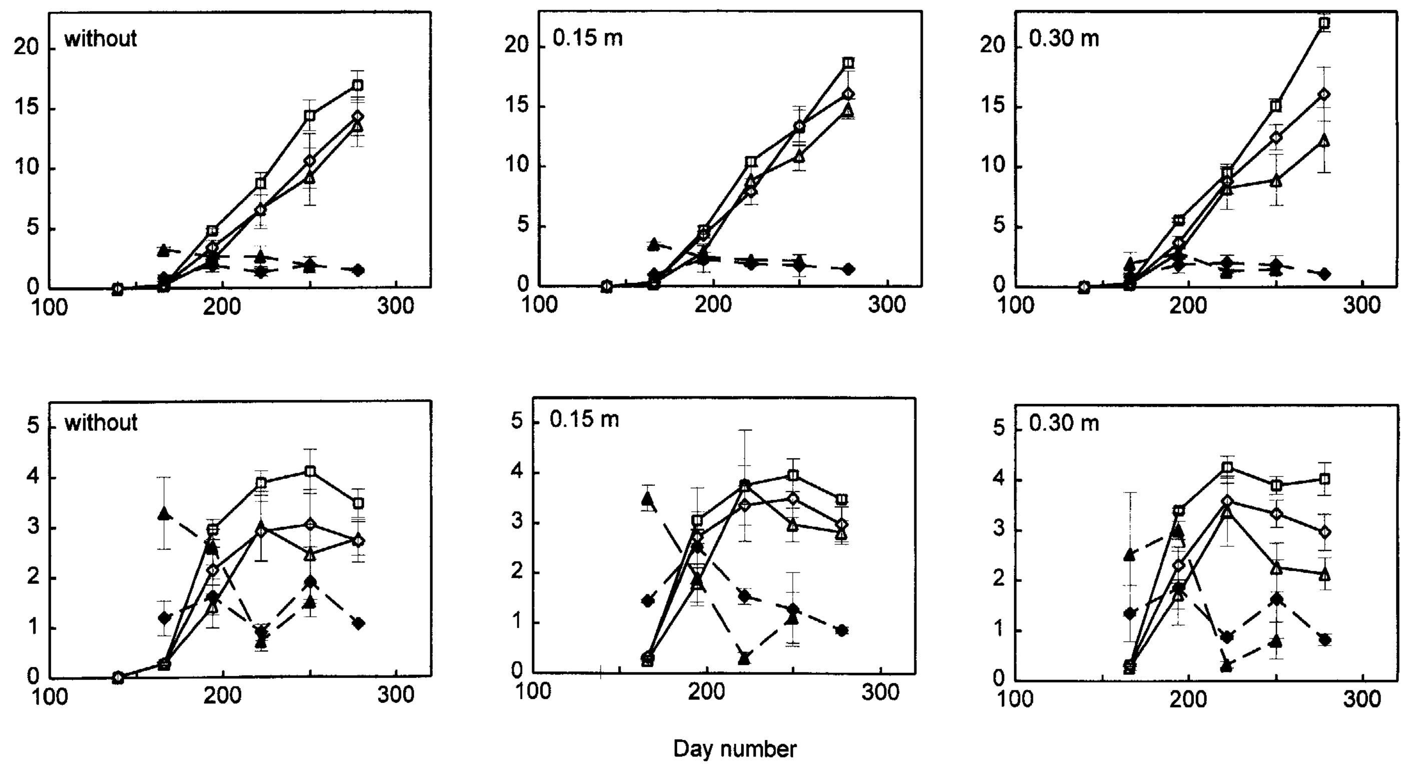

Figure 3. Above-ground dry matter and leaf area index of white cabbage and *T. subterraneum* in the 1993 experiment. Cabbage was planted in clover without rotary cultivation (without) and in rotary cultivated strips of 0.15 and 0.30 m. Clover was sown at 3 and 6 weeks before cabbage transplanting. Legend: –□– Cabbage monocrop, –△– Cabbage with *Trifolium* (3 w), –◇– Cabbage with *Trifolium* (6 w), –▲– *Trifolium* (3 w), –◆– *Trifolium* (6 w). Bars represent standard errors of the mean.

cabbage was 107 t ha^{-1} with a 4.0 kg average weight of a single head. As in the earlier experiments, the marketable yield and the weight of a head were both reduced by a clover cover crop ($P<0.05$). These reductions were similar for both clover crops (18% for yield and 21% for weight/head) and were not affected by rotary cultivation.

Discussion

Within-field diversity to reduce pest infestations in crops, can be enhanced by allowing non-crop plants within the field, either by sowing them or by tolerating naturally emerging weeds. Andow (1988) reviewed the possibilities that naturally occurring weeds have net positive effects on crop production. He showed that under some conditions weeds may have negative effects on arthropod communities. However, there are at least two serious disadvantages in tolerating naturally occurring weeds to incorporate these into pest control strategies. The first is that weed emergence might be variable and poorly predictable, which means that relying on naturally occurring weeds as a pest-reducing cover crop may cause problems in years with poor weed emergence. The second disadvantage is that, in other years, weeds may cause very high yield losses by competition. Bond (1991) summarized the effect of weed interference on the yield of vegetable crops in field trials made over a period of 20 years. He showed that in many occasions even low weed populations caused considerable crop losses. Moreover, seed production by weeds may cause serious problems in subsequent crops. Bond (1991) concluded that it is very difficult to define an economic level of weed control in vegetable crops. Naturally occurring weeds are therefore also difficult to rely on as cover crops. The reliability of emergence and the effectiveness of management practices to reduce yield losses might be much better when the cover crops are from crop cultivars that are sown. Such cover crops may even contribute to an effective weed management in field grown vegetables (e.g. Müller-Schärer & Potter, 1991). For these reasons, the present paper focuses on these sown cover crops.

In the 1990 and 1991 experiments the clover cover crop reduced pests in fresh market cabbage. Theunissen *et al.* (1995) showed that in both experiments the intercropped cabbage heads were less damaged by infestation by a range of pest organisms. Such pronounced effect of the cover crop on cabbage quality could not be demonstrated in the 1992 and 1993 experiments. These later experiments were designed principally to explore possibilities to reduce yield losses. For practical reasons the experimental plots were smaller than those in the first two years, which might be reason for the lack of a clear pest reducing effect of the cover crop (cf. Trenbath, 1993). Another reason might be that in 1992 and 1993 infestations of thrips were abundant and it was this pest that caused most damage. The white cabbage for storage, cv. Slawdena, which was grown in these experiments is generally susceptible to thrips. After the first week of October, the clover plants were dead, leaving the cabbage without a cover crop until the final harvest in the middle of November. Extending the cover crop period until harvest, e.g. by using another clover species or cultivar, might increase the pest reducing effect.

The fresh market cabbage with clover cover crops in 1990 showed an average yield reduction of 24%. In 1991 this yield loss was 15%. From the present results we cannot conclude whether these yield losses are related to competition for light, nutrients or water. The analysis of the nitrogen content in cabbage and soil at harvest in 1991 did not result in differences between monocropped cabbage and cabbage with clovers. Light competition will have, however, at least partly caused this yield reduction since the lower, expanded leaves of many cabbage plants were shaded by the clovers. Both clover species differed in development (e.g. time of flowering), LAI and plant height during the experiment. If light is the principal resource which cabbage and clover compete for, differences in these traits might cause differences in competitive ability between the clover species (Kropff *et al.*, 1993). Since LAI and plant height of *T. subterraneum* were generally lower than those of *T. repens*, it was expected that yield losses of cabbage were lower with a cover crop of *T. subterraneum*, but this was not found. In 1990, the quality of the cabbage intercropped with *T. repens* was better than that with *T. subterraneum*. The latter clover died early which might be the reason for this less pronounced reduction effect on pest damage. In 1991, however, no difference in cabbage quality between clover cover crops was found.

Yield reductions caused by the clover cover crops for the cabbage for storage were about 43% in 1992 and 18% in 1993. The smaller yield reduction in 1993 may be explained partly by the fact that then a clover cultivar was used with lower leaf area development and plant height than in 1992. In his review, Trenbath (1993) stressed that the inclusion of non-attacked series of plots are relevant to allow separation of the effects of pest attack and competition. Since no effect of the crop protection treatments was found in 1992, we conclude that crop biomass losses are mainly caused by competition with the clover cover crop and not caused by the pests. Pests particularly affected the quality of the marketable yield here.

In the 1992 and 1993 experiments three approaches were studied to reduce the cabbage yield losses by clover cover crops. The first approach was to decrease the row distance from 0.75 m to 0.50 m. This smaller row distance indeed caused that a lesser reduction in weight per head, however even at 0.50 m row distance the yield reduction still amounted to 35%. The second approach was to delay the clover sowing time. Growth of clover sown three weeks before cabbage transplanting, was better than that of clover sown six weeks before, in contrast to what might be expected. Therefore, the early sown clover cover crop reduced yields less than the later sown cover crop. The reason for the poor performance of the early sown clover might be abundant rainfall and relative low temperatures during germination and emergence. *T. subterraneum* is more susceptible to such weather conditions shortly after sowing than various other clover species (Theunissen, unpublished results). The third approach was to transplant the cabbage into strips in the clover stand, in which creeping stems of clover were removed by rotary cultivation. This rotary cultivation itself caused an increase in crop growth, especially in the monocropped cabbage. An improved soil aeration might be the reason for this increase. No significant effects of rotary cultivation could be demonstrated on final yields of cabbage that was intercropped with clovers.

From the present results we conclude that to develop intercropping as an IPM method in cabbage crops, more knowledge is required about the interactions between crop, cover crop and pests. The present results confirm, at least for the 1990 and 1991 experiments, that cover crops positively affect the quality of the marketable cabbage heads. However, the clover cover crop did not overcome pest problems completely and the associated yield losses due to competition with the cover crop were large (≥15%).

To be able to further decrease yield losses by competition between the cabbage crop and cover crop, while optimizing the beneficial pest reduction effect, a combination of two research strategies should be followed. The first is to study the competition between cabbage and clover into more detail to determine what resources (light, water, nutrients) are competed for during the season. If this is known for the competition between crop and cover crop, approaches to reduce the yield loss might be designed and tested more effectively than in the present study. For example, this may allow that critical periods for crop-cover crop competition (Kloen & Altieri, 1990; Müller-Schärer & Potter, 1991) can be determined depending on the availability of the particular resource. The second strategy is to derive from the ecology and population dynamics of the pest organism, at what specific stages during crop development beneficial cover crop effects are needed to reduce pest damage. Systems should be developed in which results of both strategies match. These systems should be tested in crop rotations in which also effects on the dynamics of nitrogen and of populations of weeds and soil-born pathogens in subsequent years are included (Dyck & Liebman, 1995).

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