THE EFFECTS OF CROP DIVERSITY ON INSECT PESTS AND YIELD OF CABBAGE

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SUMMARY

An experiment was carried out to examine the effect of crop structure and spatial diversity on the three main insect pests of cabbage present in New Zealand and to give a detailed analysis of crop yield. Fewer white butterfly eggs were laid on more densely planted cabbages, although larval survival was apparently higher. Lower numbers of winged cabbage aphids were recorded on cabbages amongst the dill. No differences between treatments occurred with diamondback moth larvae. *Bacillus thuringiensis* applications led to improved cabbage quality but not significantly higher yield. Yield differences appeared to be largely due to plant competition effects, rather than insect feeding.

INTRODUCTION

Three main insect pests of cabbage are present in New Zealand. These are white butterfly (*Artogeia rapae* (L.)), diamondback moth (*Plutella xylostella* (L.)) and cabbage aphid (*Brevicoryne brassicae* (L.)). Control of these pests normally involves regular application of mainly organophosphate, carbamate or pyrethroid insecticides.

Other possible control tactics have been examined overseas. An example of this has recently included examining the effects of crop structural and spatial diversity on insect pests of brassicas. Such practices have been considered desirable, but with some qualification, by reviewers such as van Emden and Williams (1974).

A recent review by Risch *et al* (1983) collated results from 150 published studies on intercropping. Altogether, 53% of the insect species were less abundant in more diverse crop systems, 18% showed greater herbivore abundance while 9% showed no difference between uniform and diverse plantings. The remaining 20% showed a variable response. While most reports of these experiments have documented insect responses well, few have given detailed analyses of crop yield.

An experiment was carried out at Lincoln College in the 1984/85 growing season, the main objective of which was to examine the effect of an intercrop on the three main insect pests of cabbage present in New Zealand and to give a detailed analysis of yield. The crop used was dill (*Anethum graveolens*), which is considered amongst other umbelliferous plants to increase the efficiency of tachinid and ichneumonid parasites (Chumakova 1960). It was also quoted by Riotte (1975) to be "a good companion to cabbage, improving its growth and health". Neither author has indicated the structural and spatial array that led to such beneficial effects.

METHODS

The following is a summary of the methods as presented by Kenny (1985). Four treatments were chosen to examine the stated objectives. These were:

Treatment 1: cabbages grown at a spacing of 50 cm within rows by 100 cm between rows.

Treatment 2: cabbages grown at same spacing as Treatment 1, with fortnightly application of *Bacillus thuringiensis* (B.t.) (Thuricide HP).

Treatment 3: cabbages grown at same spacing as Treatment 1 with dill grown between the cabbage rows and on the outside rows of the plots.

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Treatment 4: cabbages grown at a spacing of 50 cm within rows by 50 cm between rows.

Plot size was 5 m x 5 m and each treatment was replicated five times in a randomised block design.

Crop establishment and management: Dill was sown on 17/10/84, and was well established by January 1985. Cabbages were transplanted into the field on 23/1/85. Rye-corn straw was spread through all plots to assist with weed management. Crops were irrigated as required. B.t. was applied to appropriate plots fortnightly from 2/2/85 at a rate of 1.23 kg/ha in 600 litres of water/ha.

Insects were sampled, weekly for the first six weeks and subsequently every two weeks by randomly choosing four plants per plot from which were made direct counts of white butterfly eggs and larvae, cabbage aphid alatae and diamondback moth larvae.

On 17/4/85 six cabbages per plot were harvested for measurement of fresh weights and quality assessment. Marketable fresh weights (head only), whole plant and head dry weights were each measured from two plants per plot.

RESULTS

Insect responses

The results presented in Table 1 give the overall mean values for the estimates of insect pest numbers. While representing the general trends, they do not necessarily reflect results as measured on all sampling dates (Kenny 1985).

TABLE 1: Overall mean numbers of insect pests per cabbage plant.

Treatment	White butterfly eggs	White butterfly larvae	Cabbage aphid alates	Diamondback moth larvae
1	6.4	2.2	14.1	1.0
2	5.6	1.4	13.3	0.7
3	5.4	2.0	4.4	0.7
4	3.7	1.7	11.0	0.9
LSD (5%)	1.0	0.4	3.9	0.4
LSD (1%)	1.4	0.6	5.4	0.5

One of the most significant results ($P < 0.01$) was the lower number of white butterfly eggs laid per plant in Treatment 4, the higher cabbage density. This result was consistent for all but one sampling date. Interestingly, a much greater proportion of eggs from this treatment survived to the larval stage than any other treatment (Kenny 1985). Numbers of eggs per plant were similar for the other three treatments.

As might be expected, survival of white butterfly larvae was lowest with the B.t. treatment particularly on the sampling dates directly following B.t. applications.

Treatment 3, using dill, resulted in significantly ($P < 0.01$) lower numbers of cabbage aphid alatae. This was the case on most sampling dates, especially when flight activity was greatest. Treatment 4 (higher density cabbage) usually gave counts intermediate between Treatments 1 and 2.

Numbers of diamondback moth were low for the entire experiment, with sufficient numbers for statistical analysis being present on only two dates. No overall differences were apparent but on one sampling date there were significantly lower numbers in the B.t. treatment. This count was made 5 days after a spray date.

Crop yield and quality

Table 2 presents mean values of whole plant and marketable fresh weights per plant and per plot. Only fresh weights are given because these gave the same trends as dry weights.

Plant yields in Treatments 1 and 2 were similar as were yields in the dill and higher density cabbage plots. Plot yield of whole plants was significantly greater ($P < 0.01$) in the higher density cabbages. Plot yields of the marketable portion of the plant (head) were similar for Treatment 1 and the B.t. and higher cabbage density treatments.

TABLE 2: Mean plant and plot fresh weights of cabbage (kg) and damage score.

Treatment	Mean plant yield		Mean plot yield		Mean damage score*
	Whole	Head	Whole	Head	
1	2.8	1.5	112	59	3.9
2	3.2	1.8	128	73	3.0
3	2.4	1.1	95	42	4.1
4	2.2	0.9	194	77	4.1
LSD (5%)	0.5	0.5	20	23	0.4
LSD (1%)	0.7	0.7	28	32	0.6

*Mean damage score: 1-5 scale where 1 indicates no damage and 5, severe damage.

Damage scores are also given in Table 2, following a system originally devised by Greene *et al* (1969). B.t. treated cabbages were of a consistently higher quality (lower damage score) compared to cabbages from the other three treatments which showed similar levels of quality.

DISCUSSION AND CONCLUSIONS

The dill suffered an infestation of carrot aphid in November, 1984. It was suspected that this resulted in the appearance of carrot motley dwarf virus in the dill crop. Most of the dill was showing signs of die-back by the time the cabbages were transplanted, some plots being quite severely affected. It is not known how this may have affected the results.

Insect responses to diversity

The estimates of white butterfly egg numbers suggest that ovipositing females generally responded to the spatial array of the brassica crop rather than vegetational diversity. Although such inferences were cautioned against by Ives (1978) his, amongst other work, generally supports this conclusion.

The higher white butterfly larval survival amongst the higher density cabbages also suggests that conditions were more favourable in this treatment. This may have been related to a lower density of natural enemies, a more favourable microclimate, or a combination of these factors. Numbers of larvae were higher than expected in the B.t. treatment. This was probably due to larvae emerging between spray dates and perhaps poor spray penetration into some plants.

Lower numbers of cabbage aphid *alatae* amongst the dill treatment may have had two possible causes. The dill may have visually masked the cabbages and physically interfered with landing of the *alatae*. The lack of significant differences between different cabbage spacings was contrary to the results A'Brook (1973) recorded with other aphid species. In his work the aphids were more frequently caught over widely spaced crops. This he attributed to the contrast between plants and soil with wider spacings giving greater electromagnetic emissions from bare earth. The straw mulch used as a weed preventative in this experiment would not have provided such a contrast.

Crop yield and quality

The failure of the B.t. treatment to give significantly better yields than the untreated cabbages has two possible reasons:

1. The spray was not entirely effective, either through poor penetration and coverage, insufficient concentration or its slower action compared to synthetic insecticides.
2. Insufficient insect herbivores were present to result in significant yield differences.

The lower per plant yield of cabbages amongst the dill was not complemented by significantly higher insect herbivore numbers. It is therefore suggested that plant competition effects were more responsible for yield loss than was insect herbivore feeding. Lower relative per plot head yield in Treatment 4 also suggests that increased competition in the denser plots led to poorer head formation.

The application of B.t., although not sufficiently effective to give a significantly higher yield than the untreated cabbages, did result in plants with less feeding damage. This supports the overall conclusion that insect herbivores affected plant quality, but that yield differences were mainly due to plant competition effects.

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