Plant diversity in vegetable cropping systems

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Abstract

Concern about chemical resistance of pests in the field and about chemical residues by consumers in the market place is a growing problem in agriculture. Increasing the plant species diversity of vegetable cropping systems has been discussed as a possible management strategy to reduce reliance on chemical inputs. Field trials using potato (*Solanum tuberosum* cv. Russet Burbank) and broccoli (*Brassica oleracea* var. *italica* cv. Green Belt) strip crops and cereal rye (*Secale cereale*) as a cover crop were conducted at the Forthside Research and Development Station in Tasmania from 2004-2006. These trials demonstrated that substantial reductions in diamondback moth (*Plutella xylostella*) and cabbage aphids (*Brevicoryne brassicae*) could be achieved using cover crops due to interference with host plant location. The use of cover crops also suppressed weeds eliminating the need for mechanical inter-row cultivation and residual herbicides, but had no significant effect on cabbage white butterfly (*Pieris rapae*). Strip cropping as a diversification strategy had no significant effect on insect behaviour or yield in the crops studied and would be a difficult strategy to implement commercially. Therefore future research efforts should focus on increasing plant species diversity in the vertical plane (above and below) rather than the horizontal plane (side by side), and should include exploring the possibility of using cover crops in a no-till vegetable production system.

Key Words

Strip cropping, cover cropping, broccoli, potatoes, cereal rye, insect pests

Introduction

The initial success of DDT (dichlorodiphenyl-trichlorethane) in the 1930s shifted scientists away from fundamental research on insect biology, physiology and alternate methods of pest control, to developing synthetic organic insecticides to contain pests. The rapid expansion of insecticide research was also accompanied by development of chemicals to control pathogens and weeds. Along with yield gains from the green revolution came the economic incentive to chemically protect these yields from pests, pathogens and weed competition (Ruttan 1999). This was also the beginning of the "chemical treadmill". Ecological principles suggest that modern agricultural systems are relatively unstable and will continue to be prone to invasion by weeds, and to high incidences of pests and diseases (Tilman 1999), unless research effort is focused on blending ecology and agricultural science to design stable farming systems based on mimicking species diversity in natural systems (Lewis *et al.* 1997; Matson *et al.* 1997; Brummer 1998).

Two simple methods of increasing plant species diversity in vegetable cropping systems are strip cropping and the use of cover crops. Strip cropping increases plant species diversity on the horizontal plane (side by side) and involves growing two or more crops in repetitions of strips wide enough to facilitate separate mechanical management. Cover crops increase plant species diversity on the vertical plane (above and below) and consist of a sacrificial understorey mechanically and/or chemically suppressed in advance of the planting of the crop.

Methods

To explore the benefits, risks and challenges of strip cropping and cover cropping on insect pressures and crop production, the two systems were trialled at the Forthside Research and Development Station on Tasmania's northwest coast (E 438105, N 5438253) over the 2004/2005 and 2005/2006 growing seasons.

The 04/05 field trial consisted of three replications of a completely randomised block. Each plot was 10m x 10m with a 5m bare soil separation between plots. The 05/06 experiment consisted of six replications, in a latin square design. These design changes increased the statistical power of the experiment and removed possible site-specific sources of error in the 05/06 experimental area. Each plot was 9m x 9m with a 3m bare soil separation between plots. In both trials the four treatments were

1. Broccoli (*Brassica oleracea* var. *italica* cv. Green Belt) monoculture transplanted into a rye (*Secale cereale*) cover crop (Cover crop/Monoculture).

2. Broccoli and potato (*Solanum tuberosum* cv. Russet Burbank) strip crop transplanted into a rye cover crop (Cover crop/Potato strips).

3. Broccoli monoculture transplanted into tilled soil (Tilled/Monoculture).

4. Broccoli and potato strip crop transplanted into tilled soil (Tilled/Potato strips)

Rye for the cover cropping treatments was sown on 7 September in 04 and 21 September 05. Strip cropping treatments were based on multiple alternating tractor 1.65m widths of broccoli and potatoes. Potatoes for the two strip cropping treatments were planted on 4 November 04 and 2 November 05. The cover crop was desiccated approximately one week prior to transplanting of the broccoli on the 26 November 04 and 13 December 05 using glyphosate (720g ai/ha). For the 04/05 trial the cover crop was mechanically rolled and broccoli speedlings were transplanted by hand on 3 December as there is no commercially available transplanter in Australia capable of handling high levels of cereal residue. For the 05/06 experiment the cover crop was mechanically rolled and the broccoli speedlings were transplanted on 19 December in one pass using a prototype planter developed by Shane Broad. On both occasions the broccoli was planted in 80cm rows, 30cm apart and fertiliser (13N:15P:13K:1S) was applied at the rate of 500kg/ha.

For the 04/05 trial, commencing 12 days after planting (DAP), 60 randomly selected broccoli plants per plot were scouted each week for insect pest larvae and pupae of diamondback moth (*Plutella xylostella*), cabbage aphids (*Brevicoryne brassicae*) and cabbage white butterfly (*Pieris rapae*) until 41 DAP. A new randomisation was prepared before each sampling date. For the 05/06 trial, commencing 14 DAP, three broccoli plants from each plot were destructively sampled each week using a randomised sampling plan., The sampled plants were inspected under lights in a nearby work area, using jeweller's glasses for the presence of insect pest eggs, larvae and pupae. This strategy increased sampling precision and assisted in accurately counting the insect eggs. For both trials the insecticide spinosad was applied (0.128kg ai/ha) at 48 DAP (05) and 51 DAP (06) to prevent confounding yield data with insect damage. Broccoli inflorescences were sequentially harvested by hand when their diameter reached 12cm and their fresh weights were recorded. Potato plots were harvested using a twin row digger in 05 only and the total yields were recorded.

In both years the data were analysed using analysis of variance (ANOVA) (Proc GLM, SAS Institute, Cary, NC, USA), treatment means were separated using Fisher's least significant difference (LSD) and data were transformed when necessary to conform to the normality requirement of the ANOVA procedure. However, only non-transformed means are reported. In both years no weed control was performed on the cover cropping treatments, while the bare soil treatments were typically weeded three times during the period from transplanting until harvest.

Results

Insect pests

In both years the only insect pests encountered in significant numbers were diamondback moth (DBM), cabbage white butterfly (CWB) and cabbage aphid (CA). There were significant treatment differences in the incidence of DBM (Figure 1) and CA (data not shown) in both years, with the tilled treatments having higher pest numbers than the cover crop treatments, while the differences between strip cropping and monoculture treatments were not significant (except for 36 DAP in 05/06 season). The numbers of CWB were not significantly different across all treatments in both seasons (data not shown).

Yields

In the 04/05 trial there were no significant differences between the yields of the potato treatments or broccoli treatments (Table 1). The yields of broccoli in 05/06 were significantly different with the tilled treatments producing, on average, larger heads when compared to the cover cropping treatments. This could possibly be attributed to the use of the prototype planter resulting in some soil smearing in the planting slot during the transplanting process and the potential for cover crops to reduce soil temperatures. Contrasts of monoculture and strip cropping were once again not significant.

Table 1. Average treatment yields of potatoes and broccoli from the 2005 and 2006 harvests.

Treatment	2005 Av. Plot yield of potatoes (kg) ? SE	2005 Av. head weight of broccoli (g) ? SE	2006 Av. head weight of broccoli (g) ? SE
Cover Crop/Monoculture	386.9 ? 17.60	235.7 ? 20.01	302.7 ? 8.289 [b]
Cover Crop/Strip Crop	388.4 ? 12.56	256.5 ? 19.35	310.1 ? 5.365 [b]
Tilled/Monoculture	384.3 ? 3.56	266.4 ? 20.35	334.1 ? 2.309 [a]
Tilled/Strip Crop	394.5 ? 12.73	309.3 ? 15.32	339.9 ? 5.321 [a]
F	0.10	2.69	13.96
df	3	3	3
Probability	ns	ns	<0.0001
LSD (p=0.05)	-	-	15.22

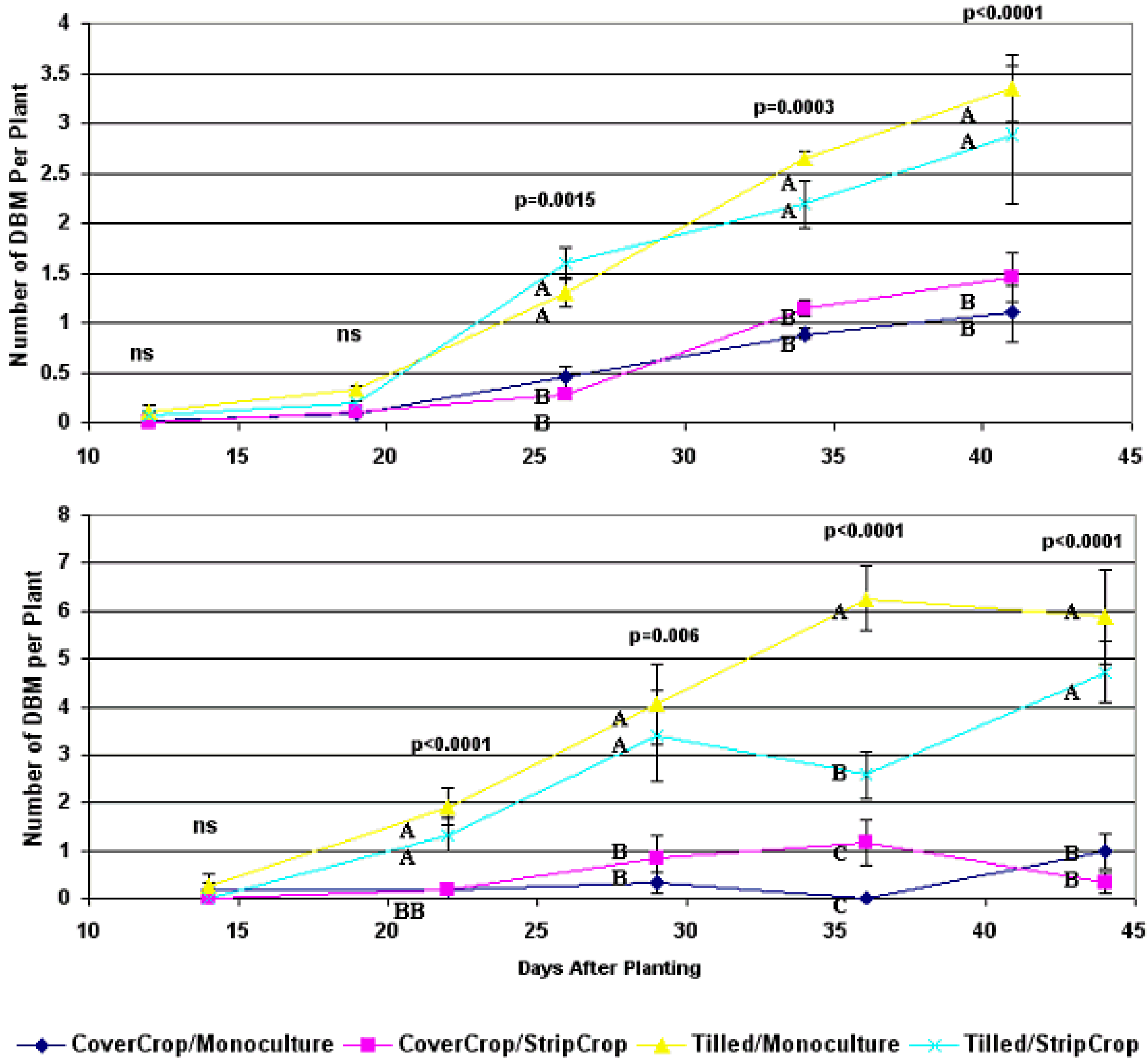

Figure 1. Graphs of the average number of diamondback moths (*Plutella xylostella*) per plant sampled ? SE in the 2004/2005 season (top) and the 2005/2006 Season (bottom).

Discussion

These trials demonstrated that substantial reductions in DBM and CA could be achieved using cover crops which has the potential to significantly reduce the amount of insecticide applied to broccoli crops. The strip cropping treatments did not significantly influence insect host plant location when compared to the monoculture treatments, apart from 36 DAP in 05/06. This support the assertion that the rates of colonisation of some insect pests are negatively impacted by the background vegetation (Finch and Kienegger 1997). A possible mechanism could be that the cover crop reduced the visual contrast between the broccoli and the soil, which caused more DBM and CA to land “inappropriately” on the rye (Finch and Collier 2000) rather than the broccoli host plant causing the insects to “lose’ the target plants (Bukovinszky *et al.* 2005). However, when discussing the impact of plant diversity on insect behaviour, or making recommendations, there is a need to clearly distinguish between different insects as CWB were not affected. This could be due to CWB exhibiting much more random “Markovian” flight patterns (Root and Kareiva 1984), when compared to DBM and CA and their very active egg spreading behaviour (Root and Kareiva 1984; Hern *et al.* 1996; Bukovinszky *et al.* 2005).

Strip cropping, as a diversification strategy, did not result in increased yields in the crops studied and would be a difficult strategy to implement commercially due to increased management complexity and the incompatible chemical management strategies required. These findings contradict notions that mixed species cropping, like the strip cropping system trialed, could be important pest management tools in sustainable cropping systems (R?mert 2002).

While the cover crops slightly reduced head weights when compared to the tilled soil treatments in the second experiment, further development of the prototype planter could reduce this difference by creating better planting slot tilth and less soil smearing. The use of cover crops also suppressed weeds eliminating the need for mechanical inter-row cultivation and residual herbicides. These factors combined with the reductions in two significant insect pests, indicate that future research efforts should focus on increasing plant species diversity in the vertical plane (above and below) rather than the horizontal plane (side by side), and should include exploring the possibility of using cover crops in a no-till vegetable production system.

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