Sustainable Vegetable Production: Effects of Cropping Systems on Weed and Insect Population Dynamics

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Abstract

Sustainable agriculture continues to attract the attention of policy makers, researchers, and growers. While a lot of research and extension activities have been devoted to sustainable production systems in agronomic crops, there have been few studies on vegetables. This study was conducted in 1999 and 2000 to evaluate the effect of cover crops and management systems on weed and insect populations in lettuce (*Lactuca sativa*). Cover crops treatments included cowpea (*Vigna unguiculata*), sudangrass (*Sorghum bicolor*), and the traditional summer dry fallow. Management systems included Conventional (CNV), Integrated (ICM), and Organic (ORG) systems. Cover crops were grown in the summer, followed by fall lettuce. Over the two years, cover crops had no effect on insect populations in lettuce, as neither cover crop is an alternate hosts for lettuce insect pests. However, the population of cabbage loopers [*Trichoplusia ni* (Hubner)] increased at the end of each growing season in cowpea mulch plots. The increase in loopers was greater in 2000 than in 1999. The cowpea cover crop suppressed weeds and increased yield. Lettuce yield was reduced when sudangrass was the previous crop. Soil analyses strongly suggest a possible allelopathic interaction between sudangrass residues and lettuce. The ICM system reduced production inputs. For example, the number of insecticide applications was reduced from four to one without an increase in insect damage. After two years, the ORG system produced lettuce yield equivalent to that obtained in the CNV system. Cowpea cover crop offers many advantages in vegetable based cropping systems. Cowpea and sudangrass are compatible with CNV, ICM, and ORG management systems.

INTRODUCTION

Long-term studies have shown that although crop yields are high under intensive agriculture, this farming system creates important environmental problems, including reduced soil fertility and reduced biodiversity (Drinkwater et al., 1995; Mader et al., 2002). In order to mitigate these negative effects, policy makers, researchers, and vegetable growers are become increasingly interested in sustainable production systems (Hutchinson and McGiffen, 2000). Among the sustainable practices now being embraced by vegetable growers are the inclusion of cover crops into the production system and the transition to organic farming (McGiffen et al., 2000; Ngouajio and McGiffen, 2002; Mader et al., 2002). In addition to changes in soil fertility, the transition to organic agriculture and use of cover crop affect weed and insect population dynamics (Roe et al., 1993; Teasdale, 1998; Hald, 1999; Hutchinson and McGiffen, 2000; Liebman and Davis, 2000; Norris and Kogan, 2000; Van Elsen, 2000; Herrero et al., 2001; Ngouajio and McGiffen, 2002, Ngouajio et al., 2002; Shrestha et al., 2002). The objective of this work was to study the effect of a prior cover crop and in-season management practice on weed and insect populations as well as on crop yield.

MATERIALS AND METHODS

Field trials were conducted in 1999 and 2000 at the University of California

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Coachella Valley Agricultural Research Station in Thermal, CA. Cover crops were grown in the summer (from July to September) followed by lettuce 'Shining Star' in the fall (from October to December) and cantaloupe (*Cucumis melo* L.) in the spring (from February to June).

The experiment was a factorial arranged in a split-plot design with four replications. The main-plot factor was summer cover crop type and the subplot factor was management system. Cover crop treatments included (i) summer cowpea (*Vigna unguiculata*) incorporated into the soil in the fall (CWPI), (ii) summer cowpea used as surface mulch in the fall (CWPM), (iii) summer sudangrass (*Sorghum vulgare*) incorporated into the soil in the fall (SDNG), and (iv) summer dry fallow (DFLW). Management practices included the organic (ORG), the integrated (ICM), and the conventional (CNV) systems. The main-plot treatments were subdivided into three subplots of equal size each with six beds. The three subplots were then managed as the CNV, ICM, and ORG management treatments during the lettuce and cantaloupe cash crops. The CNV and ICM treatments received synthetic fertilizers, and the ORG treatments received compost. For insect control, a formulation of *Bacillus thuringiensis* subsp. aizawai (XenTari) was used in the ORG plots, and bifenthrin (Capture) was used in the CNV and ICM plots. In the ORG and ICM plots, insecticide applications were initiated only when a threshold of two cabbage loopers per ten plants was reached. In the CNV system however, there was a pre-established schedule of four applications. All treatments were kept in the same plots throughout the duration of the study.

Weed density was measured in the lettuce crop using two 1 by 0.5-m quadrats placed randomly on the bed top. Weed counts were conducted at 9 and 21 days after lettuce transplanting in 1999 and 2000, respectively. Cabbage loopers were assessed three times during each growing season. At each date, 10 plants were harvested in each plot and the number of larvae counted. Lettuce was harvested in the four middle beds of each plot and heads 200 g or higher and without defects put into 24-count boxes according to market standards. Data were analyzed by ANOVA for a split-plot design and means separated using Fisher's Protected LSD at the 0.05 probability level.

RESULTS AND DISCUSSION

In general, there was no interaction between cover crop and crop management system for weed density, insect number, and lettuce yield. All data were therefore presented separately for cover crop and management system.

Weed Population

In both 1999 and 2000, cover crops affected weed density (Table 1). Plots previously grown with cowpea and residue kept as surface mulch (CWPM) showed fewer weeds compared with other cover crop treatments. During the two growing seasons, weed counts in the cowpea mulch plots showed less than 30 seedlings m^{-2} compared with over 125 seedlings in all other cover crop treatments. The greatest weed density was observed in plots grown with sudangrass in 1999 (336 plants m^{-2}) and in the bareground fallow plots in 2000 (246 plants m^{-2}). The bareground summer fallow is the common practice used by many vegetable growers in the Coachella Valley in California. The fact that weed density became the greatest in those plots the second year suggests that summer fallow is a poor cropping system for weed management.

The effect of crop management practice on weed populations was assessed only in 2000 (Table 1). Plots managed conventionally resulted in higher weed pressure than organic plots or those managed in an integrated system. An average of 202, 134, and 131 weeds m^{-2} were recorded in the conventional, integrated, and organic systems, respectively. The difference between the conventional system and the integrated system was the fewer number of insecticides applied in the latter system (Table 2). The reduced weed population in the integrated system was probably due to a reduced effect of insecticides in the integrated system. Insecticide applications can have an indirect effect on weed populations by killing phytophagus arthropods that feed on weeds (Norris and Kogan, 2000).

Insect Population

Cabbage loopers are one of the most important lettuce pests in the Coachella Valley. They were therefore the focus of our study. Cabbage looper populations were not affected by the previous cover crop (Fig. 1). Insect populations were generally higher in 2000 than in 1999. For both years, the cabbage looper population increased sharply following lettuce transplanting. After the first insecticide treatment two weeks after lettuce planting, cabbage loopers populations dropped and stayed low for the remainder of the growing season. At lettuce harvest however, more loopers were recorded in the cowpea mulch plots. This observation was consistent in both years and was amplified in 2000 (Fig. 1). Although there is no report of cabbage loopers being a pest in cowpea, increased populations in plots where cowpea residue was used as surface mulch is an indication that additional observations should be made.

Lettuce management system significantly affected cabbage looper populations (Fig. 1). Although the initial population increase following lettuce transplanting was similar for all systems, the efficacy of insect control depended upon the method used. The organic system had high insect populations throughout the growing season. This indicates a reduced efficacy of the insecticide used in this system. The insecticide Xentari used in the organic plots is a formulation of the bacterium *Bacillus thuringiensis*. The action of the bacterium is slow and thus the slow reduction in insect population. Both synthetic and biological insecticides were initiated at the same time, therefore favoring the conventional and integrated systems. Initiation of the treatments earlier or at a lower insect threshold may have improved efficacy in the organic system.

Crop Yield

Lettuce marketable yield was affected by the cover crop treatment (Table 3). Plots where cowpea was grown in the summer and residue incorporated into the soil prior to lettuce planting resulted in the highest yield in both years. 1226 and 1466 boxes ha^{-1} of lettuce were harvested in those plots during the 1999 and the 2000 seasons, respectively. Similar results were observed for lettuce weight (Ngouajio et al., 2002). Yield was very low and unacceptable to most growers when sudangrass was used as the cover crop in 1999. Lettuce growth was severely retarded in those plots, suggesting possible nutrient immobilization or allelopathy of sudangrass residue. Soil analyses (data not presented) showed no difference in soil fertility between these plots and other treatments. In 2000 when sudangrass was killed at a younger stage, lettuce yield was equivalent to that in other cover crops. Killing sudangrass earlier probably enhanced the degradation of possible allelochemicals from its residue.

Yield from plots with no prior cover crop was low in both years. 990 boxes ha^{-1} were harvested in 1999 and 813 ha^{-1} in 2000.

Yield in the organic system was significantly lower than any other system in 1999; but by 2000, yield for organic lettuce was equivalent to that in the conventional and integrated systems in 2000. Other investigators have reported reduced yield in the organic system during the first years (Warman, 1997). In a 21-year study however, Mader et al. (2002) found crop yield to be 20% lower in the organic system. The same study indicates a 97 % reduction in pesticide input and 34 to 53 % reduction in fertilizer and energy inputs in the organic system compared with the conventional system. This is an indication that even with slightly low yield, the organic system is possibly both more sustainable and profitable.

Our results indicate that cover crops can be included into vegetable cropping systems to improve weed management and increase crop yield with no associated detrimental effect on insect infestation. During the growing seasons, cabbage loopers infestations were not affected by the cover crops. Both cowpea and sudangrass cover crops are compatible with the conventional, the integrated, and the organic system. In 1999 lettuce yield was lower when it was planted after sudangrass. Additional studies need to be conducted on the effect of sudangrass on rotational crops.

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Tables

Table 1. Weed density in "Shining Star" lettuce as affected by prior cover crop and in-season management system. [1]

Factor	Level	Weed density 1999	Weed density 2000
		number m^{-2}	
Cover Crop (cc)	CWPM	26 d	18 c
	CWPI	128 c	180 b
	SDNG	336 a	179 b
	DFLW	167 b	246 a
Management system (ms)	CNV	-	202 a
	ICM	-	134 b
	ORG	-	131 b
Statistics	cc	***	***
	ms	n/a	**
	cc*ms	n/a	NS

[1] Weed evaluation was conducted 9 and 21 days after lettuce transplanting in 1999 and 2000, respectively. Cover crop is the main-plot factor and includes summer cowpea (*Vigna unguiculata*) incorporated into the soil in the fall (CWPI), summer cowpea used as surface mulch in the fall (CWPM), summer sudangrass (*Sorghum vulgare*) incorporated into the soil in the fall (SDNG), and summer dry fallow (DFLW). Management system is the subplot factor and includes organic (ORG), integrated crop management (ICM), and conventional system (CNV). Within each year, cover crop type, and management system, means followed by the same letter are not significantly different (LSD test, P < 0.05).

Table 2. Insecticides used for cabbage loopers control in lettuce and number of applications made during the growing season for different management systems.

Insecticide Used	Number of applications					
	Conventional system		Integrated system		Organic system	
	1999	2000	1999	2000	1999	2000
Capture[1]	4	4	1	2	0	0
Xentari[2]	0	0	0	0	2	3

[1] The active ingredient of Capture is bifenthrin.
[2] Xentari is a bioinsecticide containing the bacterium *Bacillus thuringiensis*.

Table 3. Lettuce "Shining Star" marketable yield as affected by prior cover crop and in-season management system. [1]

Factor	Level	Number of boxes ha^{-1} 1999	2000
Cover Crop (cc)	CWPM	948 b	1137 b
	CWPI	1226 a	1466 a
	SDNG	522 c	1137 b
	DFLW	990 b	813 c
Management system (ms)	CNV	1132 a	1091
	ICM	1029 a	1144
	ORG	603 b	1179
Statistics	cc	***	***
	ms	***	NS
	cc*ms	NS	NS

[1] Yield was recorded in boxes of 24 heads each. Cover crop is the main-plot factor and includes summer cowpea (*Vigna unguiculata*) incorporated into the soil in the fall (CWPI), summer cowpea used as surface mulch in the fall (CWPM), summer sudangrass (*Sorghum vulgare*) incorporated into the soil in the fall (SDNG), and summer dry fallow (DFLW). Management system is the subplot factor and includes organic (ORG), integrated crop management (ICM), and conventional system (CNV). Within each year, cover crop type, and management system, means followed by the same letter are not significantly different (LSD test, P < 0.05).

Figures

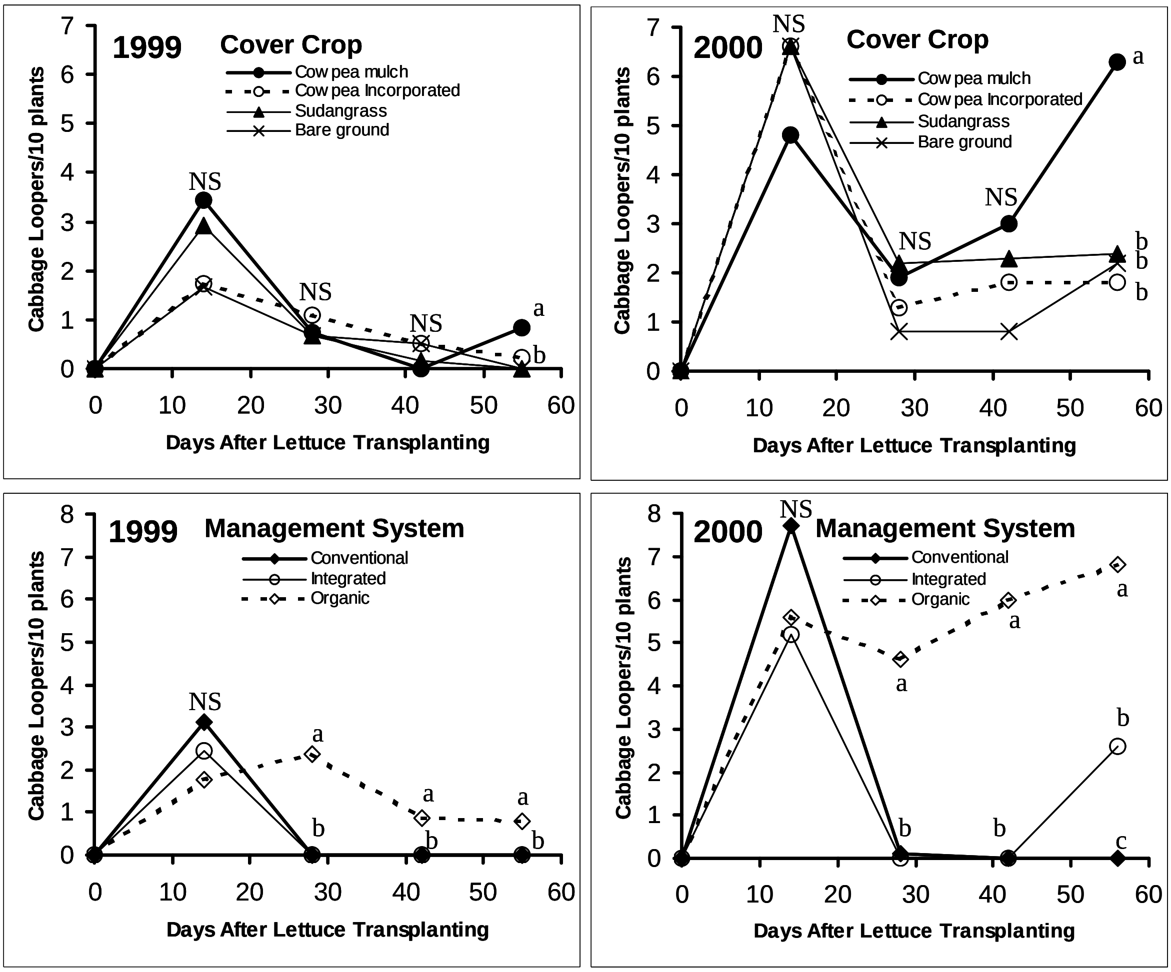

Fig. 1. Number of cabbage loopers in “Shining Star” lettuce as affected by prior cover crop and in-season management system. Within the same date, means with different letters are significantly different (LSD test, $P < 0.05$). NS indicates that means are not statistically different