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TABLE OF CONTENTS

INTRODUCTION

One of the major pests which threaten commercial potato production in the northeastern United States is the Colorado potato beetle, *Leptinotarsa decemlineata* (Say), (CPB). Insecticides have traditionally been the sole means for controlling the beetle. As a result of the extensive use of chemicals, the beetle has developed resistance to insecticides (Forgash 1981) and the environment has been contaminated by insecticide residues. CPB populations with resistance to some insecticides are highest in southern Maine and decrease as latitude increases (Forgash 1985). Consequently, alternative methods to control the beetle are needed.

Beauveria bassiana (Balsamo) Vuill. (*Bb*), a fungal pathogen of the beetle has been used to control CPB in eastern Europe and the Soviet Union (Lappa 1978) and in France (Farques, Cugier, and van de Weghe 1980). Preliminary studies in the United States gave promising results for CPB control by using the fungus (Campbell, Anderson, Semel, and Roberts 1985; Roberts, LeBrun, and Semel 1981; Watt and LeBrun 1984). Based on these studies, a three-year pilot test program was initiated to evaluate the potential for using *Bb* to control the Colorado potato beetle in the United States. An overview of the results of the pilot test program in the United States is available (Hajek, Soper, Roberts, Anderson, Biever, Ferro, LeBrun, and Storch 1987). We report herein on the results obtained in southern Maine from using this mycoinsecticide to control the beetle.

MATERIALS AND METHODS

The experiments were conducted at the Maine Agricultural Experiment Station located in Monmouth, Maine from 1983 through 1985. In 1983 and 1984, 0.2 ha, unreplicated plots surrounded by bare soil were used. CPB population and yield data for each treatment were taken from each of two areas that were 4 rows by 30.5 m (0.01 ha) located near the center of each plot. In 1985, the experiment was changed to a randomized complete block design with 4 replicates of each treatment. Each plot was 16 rows by 21.3 m (0.03 ha) and the sample area in each plot was 4 rows by 14.6 m (0.005 ha). The non-sample areas of each plot were treated with aldicarb to reduce movement of adult beetles into the sample area. In all years, sample areas were set up to exclude "wheel-rows" because yields in "wheel-rows" are usually lower than in "non-wheel-rows" due to compacting of the soil by tractors and spray equipment. Each year healthy Katahdin seed pieces, ca. 75 g each, were planted with a picker planter. Fertilization, cultivation, and hilling practices normal to the area were used. Late blight was controlled by applications of chlorothalonil. A chronological list of major events is presented in Table 1.

B. bassiana was applied at rates of 5 x 10^{13} colony forming units (cfu) per hectare (high *Bb*) and 5 x 10^{12} cfu's/ha (low *Bb*). A Century boom sprayer

Table 1
Chronological Table of Events

Event	Julian Date		
	1983	1984	1985
Plant	138	129	134
Cultivate	172	163	162
1st *Bb* Application	192	173	170
2nd *Bb* Application	196	181	174
3rd *Bb* Application	200	185	181
4th *Bb* Application	208	191	186
1st Standard Insecticide Application	193	174	181
2nd Standard Insecticide Application	—	198	202
3rd Standard Insecticide Application	—	208	211
1st Vine Desiccant Application	235	—	232
2nd Vine Desiccant Application	242	—	238
Harvest	255	—	254

(—) = activity not performed

equipped with 3 drop nozzles/row applied the mycoinsecticide at a pressure of 7.0 kg/sq cm and 935.4 l/ha of water. Formulations of the isolate ARSEF 252 used in the experiments were provided by Abbott Laboratories. Applications of the mycoinsecticide were begun when the composition of the larval population was 70:30 small larvae to large larvae (1983) or after hatched egg masses were counted on two successive sampling dates (1984 and 1985). In all years, applications were continued at 4-day intervals for a total of 4 sprays. The standard insecticide (fenvalerate in 1983 and permethrin in 1984 and 1985) was applied with the boom sprayer at a rate of 224 g active ingredient per hectare whenever the CPB action threshold for Maine was reached (4 larvae and/or adults per plant based on a count of 100 plants).

Population data were taken twice weekly on 0.3 m of stem as follows. The categories recorded were a) number of unhatched egg masses, b) number of egg masses with newly emerged larvae on the mass, c) number of small larvae (1st and 2nd larval stages), d) number of large larvae (3rd and 4th larval stages), and e) number of adults. Counts were made on fifty stems in each of the two sample areas in each plot in 1983 and 1984. In 1985 counts were made on twenty-five stems in each sample area of each plot (100 stems/treatment).

Defoliation ratings were made near the end of the growing season using the visual rating system presented in Table 2. Statistical analyses were not performed because of the subjective nature of the data.

Data on yield of tubers were taken from the sample areas of each plot. The tubers were harvested and sorted into three grades: undersize = tubers 3.2 to 5.7 cm diameter, U.S. No. 1's = tubers 5.7 to 10.2 cm diameter, and oversize

= tubers greater than 10.2 cm diameter. Tubers in each grade were weighed and analyses of variance were calculated following transformation of the data using $\log_{10}(x+1)$.

Table 2
Visual Defoliation Rating System

0 = No feeding damage
1 = A few leaflets with feeding holes
2 = Some leaflets consumed, a few bare petioles
3 = Several stems mostly defoliated
4 = Most stems defoliated, only a few lower leaves remaining
5 = All stems defoliated

RESULTS AND DISCUSSION

The most effective foliage protection, indicated by the defoliation index, was provided by the standard insecticide treatment (Table 3). Some foliage protection was observed in fields treated with the high dosage of *Bb*, but defoliation in fields treated with the low dosage of *Bb* was similar to defoliation in fields where no CPB control measures were undertaken.

Table 3
Effect of CPB Control Measures on Defoliation

Treatment	Defoliation Rating	
	1983	1985
	(229)	(231)
High *B. bassiana*	1.5	3.1
Low *B. bassiana*	3.5	3.6
Standard Insecticide	0.5	1.8
No Insecticide	3.5	3.8

Numbers in parentheses are Julian dates when readings were taken.

The yields of tubers by grade and the total yields are given in Table 4. Total yield and yield of U.S. No. 1 tubers were significantly higher from fields treated with the standard insecticide in 1983. The reason(s) for differences in yields of undersize and oversize tubers is not known. The extremely low yield in the low *Bb* plot in 1983 was probably due to high weed populations in two of the sample rows. Results of the 1984 test are not presented because excessive rain prevented the application of materials according to schedule. Late application of *Bb* did not provide CPB control and all foliage in the fields was consumed prior to maturation of the tubers. In 1985, the total yield and yield of U.S. No. 1 tubers in the fields treated with the standard insecticide and high rate of *Bb* did not differ significantly. In all years the total yield and yield of U.S. No. 1 tubers from control fields and fields treated with the low rate of *Bb* were significantly lower than yields from other fields treated with the standard insecticide.

Table 4
Average Yield (in kg) of Tubers per 30.5 meters of Row
in Monmouth, Maine

Treatment	Yield and Standard Deviation			
	Undersize	US No. 1	Oversize	Total
1983				
High *B. bassiana*	7.2 b	63.8b	2.4a	73.3b
	(2.0)	(7.2)	(1.9)	(8.9)
Low *B. bassiana*	9.0a	47.4c	0.2 b	56.6c
	(1.4)	(6.7)	(1.9)	(7.3)
Standard Insecticide	8.5ab	86.5a	2.9a	98.0a
	(1.0)	(6.1)	(2.0)	(6.2)
No Insecticide	9.3a	66.1b	1.4ab	76.7b
	(1.6)	(8.7)	(1.2)	(10.0)
1985				
High *B. bassiana*	3.0a	69.1ab	0.3a	72.3ab
	(0.4)	(10.2)	(0.3)	(10.2)
Low *B. bassiana*	2.5a	61.9 b	0.2a	64.6 b
	(0.7)	(6.0)	(0.4)	(6.3)
Standard Insecticide	2.9a	84.0a	0.5a	87.5a
	(0.4)	(16.2)	(0.5)	(15.9)
No Insecticide	2.2a	61.7 b	0.1a	64.0 b
	(0.4)	(8.6)	(0.1)	(8.9)

For each year, any two means in a column sharing a common letter are not significantly different ($p < 0.05$)

Numbers in parentheses are the standard deviation of the mean.

Population data on numbers of CPB stages can be summarized as follows. Numbers of egg masses in fields treated with the standard insecticide were higher than egg masses in other fields late in the growing season (Figure 1).

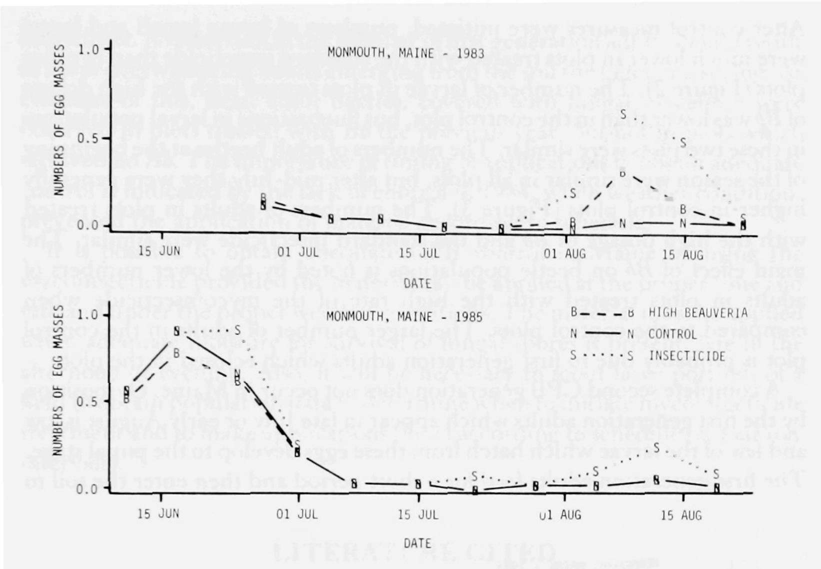

Figure 1. The mean number of Colorado potato beetle egg masses on 0.3 m of potato stem in plots treated with a high rate of *B. bassiana*, a standard insecticide, and a plot not treated with insecticide in 1983 and 1985.

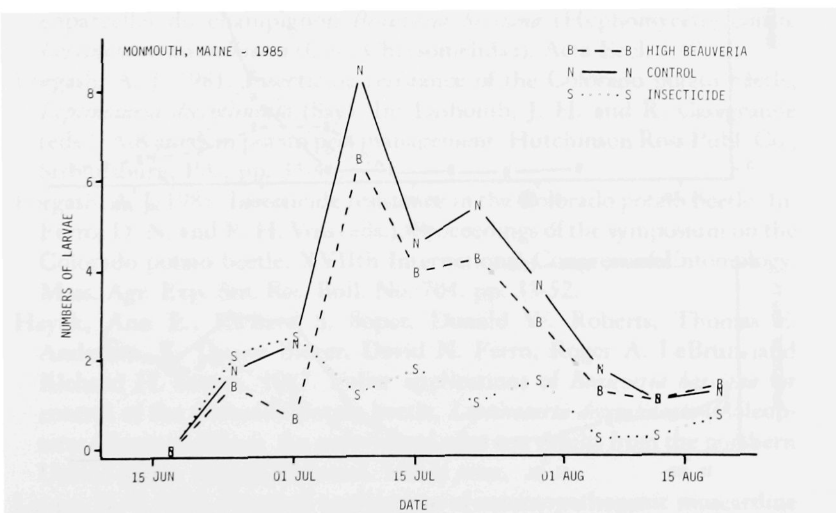

Figure 2. The mean number of larval Colorado potato beetles on 0.3 m of potato stem in plots treated with a high rate of *B. bassiana*, a standard insecticide, and a plot not treated with insecticide in 1985.

After control measures were initiated, numbers of larvae (small and large) were much lower in plots treated with the standard insecticide than in other plots (Figure 2). The number of larvae in plots treated with the high dosage of *Bb* was lower than in the control plot, but fluctuations in larval populations in these two plots were similar. The numbers of adult beetles at the beginning of the season were similar in all plots, but after mid-July they were generally higher in control plots (Figure 3). The numbers of adults in plots treated with the high dosage of *Bb* and the standard insecticide were similar. The main effect of *Bb* on beetle populations is noted by the lower numbers of adults in plots treated with the high rate of the mycoinsecticide when compared to the control plots. The larger number of adults in the control plot is probably due to first generation adults which eclosed in the plot.

A complete second CPB generation does not occur in Maine. Oviposition by the first generation adults which appear in late July or early August is low and few of the larvae which hatch from these eggs develop to the pupal stage. The first generation adults feed for a short period and then enter the soil to

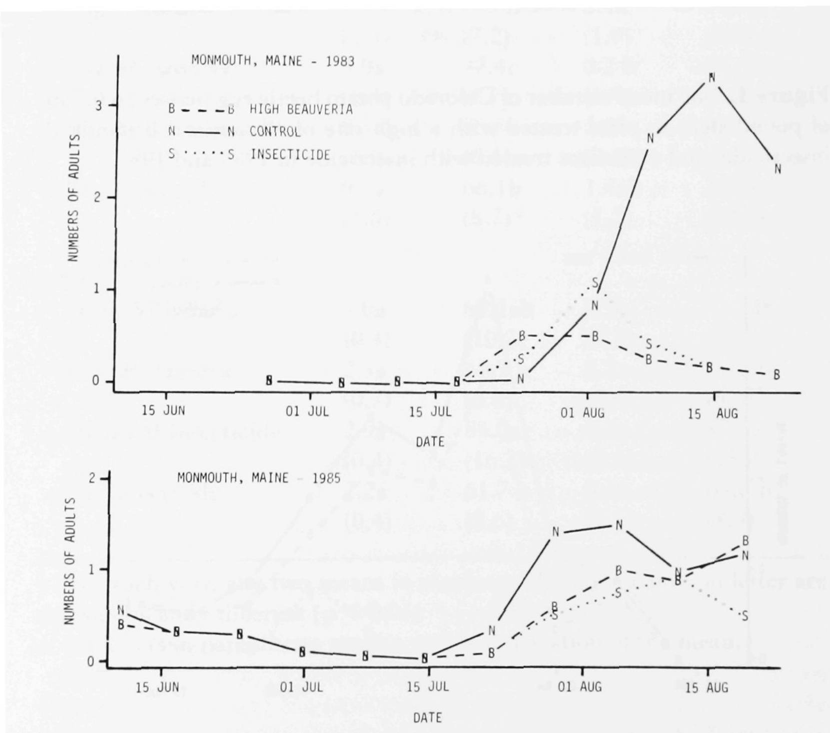

Figure 3. The mean number of adult Colorado potato beetles on 0.3 m of potato stem in plots treated with a high rate of *B. bassiana*, a standard insecticide, and a plot not treated with insecticide in 1983 and 1985.

overwinter. A reduction in the number of first generation adults should result in fewer overwintering adults emerging from the soil the following spring. As evidence of this, dead adult beetles, covered with fungal mycelium were observed in plots treated with *Bb* the previous year, but not in plots which received no *Bb*. The importance of timing of applications to obtain adequate control is indicated by the lack of control in 1984, when weather conditions prevented the application of material according to schedule.

It is possible to obtain adequate CPB control in Maine by using the mycoinsecticide provided the material can be applied at the proper time and rate and under the proper weather conditions. The material must be applied when adequate moisture for survival of fungal spores is present, late in the afternoon or evening. Also, it will be necessary to scout large portions of a field to obtain population data to determine when to initiate mycoinsecticide treatment and to make applications (four) according to schedule (at four day intervals).

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