

Growth and Development of the Beet Armyworm Spodoptera exigua on Carbon Dioxide Enriched Cotton

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ABSTRACT

Growth and development was studied in the beet armyworm (BAW), Spodoptera exigua, reared on cotton seedlings at high (650 ppm) or ambient (325 ppm) carbon dioxide (CO₂) levels and at 2 fertilizer levels. Under high fertilization, female BAW reared on CO₂-enriched seedlings weighed significantly less (87.3 mg) than controls (101.0 mg) and had a significantly longer developmental time (14.2 vs. 12.4 days for controls). Male BAW followed the same pattern but the data were not statistically significant. Combined (male & female) survival rates for BAW reared on CO₂-enriched cotton seedlings on a high fertilizer level were 19.1 compared to 41.6 % for controls; more females survived than males by a significant ratio of 2:1.

INTRODUCTION

Present atmospheric levels of carbon dioxide (CO₂) are about 350 ul/liter. However, ambient levels are rising yearly and may double in the next century (Trabalka et al. 1985). Increased availability of CO₂ permits many plants to increase leaf area, photosynthesis, and yield (Kimball 1986). Cotton is especially responsive to CO₂ with a plus 95% yield increase compared to a plus 31% for the average of many plant species (Kimball 1986). The enhanced carbohydrate under CO₂ enrichment decreases nitrogen : carbon ratios in some plant tissues (Oechel & Strain 1985). This tends to decrease the nutritive quality of those tissues. Such CO₂-related changes may alter the damage done by herbivorous insects. Data are needed to assess this problem and plan for future insect control under these conditions.

To date, studies of insect development on CO₂ enriched plants have been conducted on two leaf-feeding caterpillars: the soybean looper, Pseudoplusia includens (Walker), on soybeans and the cabbage looper, Trichoplusia ni (Hubner), on lima beans (Lincoln et al. 1986, Osbrink et al. 1987). In general, these studies showed that the caterpillars did not do as well on CO₂-enriched plants as they did on the ambient CO₂-control plants. Since similar developmental data have not been gathered on leaf-feeding caterpillars on cotton, I initiated a study on the growth, developmental time, and survival of the beet armyworm (BAW), Spodoptera exigua (Hubner) reared on CO₂ enriched cotton.

MATERIALS AND METHODS

Deltapine 61 cotton seedlings were grown in two green houses (30°C day; 24°C night). One greenhouse was maintained at an CO₂ level of 650 ppm and the other at an ambient CO₂ level of 325 ppm. Hoagland solution was used to fertilize the seedlings after the first two true leaves appeared. Two fertilizer levels were used: low, a 75-ml treatment applied once; and high, 75-ml treatments applied every other day.

The tests were conducted in four incubators held at 30°C with an 18:6 light:dark photoperiod. Two of the incubators received atmosphere from the CO₂-enriched greenhouse and the other two received atmosphere from the ambient greenhouse. Eight seedlings were kept in each incubator.

One to three newborn BAW larvae were placed on each cotton seedling (at first two true leaves). Containment was by clear plastic cages that enclosed each seedling from the stem upward. Seedlings were

replaced as needed as the growing larvae defoliated them. BAW were collected when mature larvae entered the "wandering" (prepupal) stage or pupated. Pupae were weighed and sexed. Data were summarized and analyzed by analysis of variance to determine BAW growth, developmental time, and survival.

RESULTS

BAW reared on CO₂-enriched cotton seedlings weighed significantly less (87.8 mg) than controls (98.6 mg) (Table 1). The growth of female BAW reared on CO₂-enriched seedlings on the high fertilizer level was most affected (87.3 mg versus 101.0 for controls, Table 2). A developmental time of 14.6 days was a significant two-day increase for BAW reared on CO₂-enriched seedlings compared to the control group (Table 3). As with growth, the development of female BAW reared on CO₂-enriched seedlings on the high fertilizer level was most affected (14.2 versus 12.4 days, Table 4.). The significant difference between the survival rate of 19.1 % for BAW reared on CO₂-enriched seedlings on the high fertilizer level compared to the 41.6 % survival rate of the controls was striking (Table 5); more females survived than males by a significant 2:1 ratio (Table 6.).

DISCUSSION

The results presented here support the concept that the foliage of CO₂ enriched plants does not meet the needs of insect herbivores as well as foliage from plants grown at present ambient levels of CO₂. The significant decrease in survival will likely alter the population dynamics of BAW. Additional studies will be needed to assess the overall effect of CO₂-enriched plants on insect populations.

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Table 1. Beet Armyworm Growth

Fertilizer	Carbon dioxide			Ambient			Total		
	No.	Mg	± SEM	No.	Mg	± SEM	No.	Mg	± SEM
High	30	89.0	2.5 *	51	98.6	3.0	81	95.0	2.1
Low	6	81.9	12.6	8	85.5	6.1	14	84.0	6.1
Group	36	87.8	2.9 *	59	96.8	2.7			

* $P \leq 0.05$; # $P = 0.058$

Table 2. Beet Armyworm Growth, Females and Males

Sex	High Fertilizer						Low Fertilizer					
	Carbon dioxide			Ambient			Carbon dioxide			Ambient		
	No.	Mg	± SEM	No.	Mg	± SEM	No.	Mg	± SEM	No.	Mg	± SEM
Female	20	87.3	3.2 *	27	101.0	4.3	3	95.7	21.5	5	93.4	5.5
Male	10	92.3	4.3	24	95.8	4.0	3	68.1	11.8	3	72.5	10.4
Group	30	89.0	2.5 *	51	98.6	3.0	6	81.9	12.6	8	85.5	6.1

* $P \leq 0.05$

Table 3. Beet Armyworm Development Time

Fertilizer	Carbon dioxide			Ambient			Total		
	No.	Days	± SEM	No.	Days	± SEM	No.	Days	± SEM
High	30	13.7	0.5 **	56	12.3	0.3	86	12.8	0.3
Low	7	18.3	1.7	7	15.1	1.6	14	16.7	1.2
Group	37	14.59	0.6 **	63	12.6	0.3			

** $P \leq 0.01$; *** $P \leq 0.001$

Table 4. Beet Armyworm Development Time, Females and Males

Sex	High Fertilizer						Low Fertilizer					
	Carbon dioxide			Ambient			Carbon dioxide			Ambient		
	No.	Days	± SEM	No.	Days	± SEM	No.	Days	± SEM	No.	Days	± SEM
Female	20	14.2	0.7 *	27	12.4	0.5	4	16.5	1.7	5	16.2	2.2
Male	10	12.8	0.4	29	12.1	0.3	3	20.7	3.2	2	12.5	0.5
Group	30	13.7	0.5 **	56	12.3	0.3	7	18.3	1.7	7	15.1	1.6

* $P \leq 0.05$; ** $P \leq 0.01$

Table 5. Beet Armyworm Survival

Fertilizer	Carbon Dioxide		Ambient
High	19.1 (30/157)	***	41.6 (57/137)
	**		***
Low	4.9 (7/143)		5.4 (7/129)

** $P \leq 0.01$; *** $P \leq 0.001$

Table 6. Beet Armyworm Survival, High Fertilizer

Sex	Carbon Dioxide		Ambient	
	%	No.	%	No.
Female	66.7	(20/30)	48.2	(27/56)
	*			
Male	33.3	(10/30)	51.8	(29/56)

* $P \leq 0.05$