EFFECTS OF POTASSIUM FERTILITY ON BEET ARMYWORMS

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Abstract

Cotton raised in soil with three different potassium levels and two moisture levels was used to study ovipositional preference and development of the beet armyworm. Moths preferred ovipositing on cotton reared in medium- and high-potassium soils. Larvae developed faster on the medium- and high-potassium treatments. Drought stress also decreased larval development time, yet did not affect pupal weight.

Introduction

The beet armyworm, *Spodoptera exigua* (Hubner), is a major pest of cotton in Alabama, especially in hot, dry weather (Smith 1989). Farmers in Alabama have indicated that armyworms appear to be more numerous in fields with a deficiency of potassium. Accumulated experimental evidence has made it clear that potassium ions (K^+) move from surrounding cells into guard cells when stomates open (Salisbury and Ross, 1985). Since the beet armyworm is known to be a dry weather pest and potassium is known to be involved in stomatal opening, we decided to include both potassium level and moisture level as treatments. Very little can be found in the literature on the nutritional requirements of beet armyworm. In this study, we examined the relationships between soil potassium levels and armyworm growth and oviposition and the effect of drought conditions on these relationships. We assayed nutrient levels in the different treatments in an attempt to explain the differences in growth and oviposition preference.

Methods and Materials

Soil low in potassium was collected from an established cotton fertility test at the Prattville Experiment Field. The soil was amended with potassium chloride to produce treatments of low-, medium- and high-potassium soil (51-101, 102-202, and 203-404 kg/ha respectively) as described by the Auburn University Soil Testing Laboratory (Adams, et al. 1994). DPL 90 cotton was planted in ≈8 L pots in the greenhouse (32:21°C D:N).

Twenty plants from each potassium level were maintained with adequate moisture and 20 were drought stressed. Moisture levels were maintained using a modification of the procedure described by Topp et al. (1984). At full bloom, five plants from each potassium level were removed from a moisture treatment. Three plants, one from each potassium level, were assigned a position in a screen cage. Five replicates of a single moisture treatment were run per day in a randomized complete block design. Fifty male and 50 female moths, two to four days post-eclosion, were placed in each cage late in the afternoon. Moths were removed early the next morning, and egg masses deposited on each plant were counted. This procedure was repeated four times for each moisture level. A similar experiment was conducted comparing oviposition preference by moisture level within a potassium level.

These plants were also used as the food source in a development study conducted in a growth chamber at a constant temperature of 29.5°C ($\pm$ 1°C) and a photoperiod of 14:10 (L:D). Ten neonate larvae were placed on leaf material from each moisture and potassium combination in petri dishes filled with 2% agar. Larvae were monitored every 8 h until pupation. Moults to successive instars were verified by the presence of a shed head capsule (Ali and Gaylor, 1992). Leaf samples were collected from each plant during the first week of the feeding trial. These samples were dried, ground and stored for analysis. Amino acid content was determined by reverse-phased HPLC after acid hydrolysis and derivatization using the PICO-TAG methodology of Millipore Corp (Millford, MA). Mineral content was determined by dry combustion using a LECO CHN-600 nitrogen analyzer (LECO Corp., St. Joseph, MI) and by ICP spectroscopy.

Seventy-eight plants were arranged in the greenhouse in a split-plot design with moisture level as the main plot and potassium level the subplot. Ten neonatal larvae per plant were held in cages on branch terminals to determine total developmental time. During the early stadia, larvae were examined several times per week. After reaching the last stadium, larvae were examined daily until the termination of the experiment.

Data for the study were analyzed using a PROC GLM and means were separated using LSD procedures ($P \leq 0.05$, unless noted in text) (SAS Institute, 1989).

Results

Within the adequate-moisture treatment, potassium level had no effect on the oviposition preference of the armyworm moths (Fig. 1). In the drought-stressed treatment, moths deposited more egg masses on the medium-potassium cotton than on the low. Neither treatment differed from the high-potassium treatment. When plants of the same potassium level and different moisture levels were placed in the cages, there was no difference in oviposition preference.

Larvae reared in the growth chamber developed faster on the medium- and high-potassium cotton than on the low-potassium cotton (Fig. 2). However, development time within stadia on the medium- and high-potassium cotton

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was faster for only the second and fourth instars (Fig 3). The cumulative effect of development differences during these two stadia decreased cumulative development time for the larvae in the medium- and high-potassium treatments. Moisture level had no effect on development time during the first three stadia (Fig. 4). Fourth instar larvae developed faster on the drought-stressed cotton. This difference resulted in faster cumulative development times for larvae on drought-stressed cotton during stadia five and six. Pupal weights were higher in the medium- and high-potassium treatments, but moisture had no effect on pupal weights (Fig. 5).

Larvae reared in cages in the greenhouse developed faster on the high- and medium-potassium cotton than on the low (Fig. 6). There were fewer days to 50% pupation on the medium- and high-potassium cotton than on the low and fewer days to 100% pupation on the high-potassium cotton than on the low (Fig. 7). Also, larvae reared on the drought-stressed cotton developed earlier than those reared on the cotton with adequate moisture (Fig. 8).

There were no potassium by moisture interactions for levels of Fe, Zn, B, Al, Cr, or Na (Table 1). Fe, B, and Al levels were higher in the low-potassium cotton than the high or medium. Zn and Na levels were higher in the high-potassium cotton than the medium. Ca, Mg, P, Cu, Mn, Mo, Ba, Si, and N levels in different potassium treatments were affected by moisture levels and were analyzed by moisture. In the adequate moisture treatment, levels of all elements but Cu, Mo and N were highest in the low-potassium cotton (Table 2). In the drought-stress treatment, levels of all elements but Cu, Mn and N were highest in the low-potassium cotton (Table 3). Ca, Mg, Cu, Mo, Ba, Si, and N were found in higher levels in the drought-stressed cotton than in the adequate-moisture cotton.

In cotton with adequate moisture, all amino acids except arginine, isoleusine, and serine were present in higher percentages in the medium-potassium cotton than in the other treatments (Table 4). In the drought-stressed cotton, all amino acids except arginine and methionine were present in higher percentages in the high-potassium cotton (Table 5). All amino acids were present in higher levels in the drought-stressed cotton than the adequate moisture.

Discussion

In both the greenhouse and the growth chamber, beet armyworms developed equally well on cotton grown in medium- or high-potassium soil and faster than larvae grown on cotton in low-potassium soil. Larvae in both of these treatments pupated faster in the growth chamber and reached 50% pupation faster in the greenhouse. Larval development was also faster on the drought-stressed cotton than on cotton grown with adequate moisture. Females showed no preference of oviposition site due to potassium level in the cotton reared with adequate moisture. However, on drought-stressed cotton, females showed a definite preference for medium-potassium cotton over low-potassium cotton. Females tended to oviposit more on the medium-potassium cotton than the high, but this difference was not significant.

Mineral and amino acid analyses were used to attempt to explain these differences. Although most minerals were found in higher levels in the low potassium treatments, these levels do not appear to be high enough to act as feeding deterrents. Larvae grew fastest on the medium- and high-potassium drought-stressed cotton. Yet, mineral levels in these treatments approached levels found in the low-potassium cotton grown with adequate moisture. Amino acid levels mirrored N levels found in the adequate-moisture and drought-stressed cotton. As with N levels, no pattern could be detected that correlated with the oviposition and development data.

Summary

The beet armyworm is a hot, dry weather pest. This fact is supported by faster growth of the larvae on drought-stressed cotton. From the poor performance of cotton in the greenhouse and in the original low-potassium plots in the field from which the soil was obtained, it must be assumed that farmers were referring to medium potassium levels in their fields when indicating that 'low-potassium' fields seemed to have more problems with beet armyworms. With larvae developing equally well on high- and medium-potassium cotton and females tending to prefer ovipositing on cotton reared in medium-potassium soil during drought conditions, fields with these conditions could become problems due to increased population size and rapid development of larvae. This experiment has not been validated in the field. Yet, if a farmer perceives this to be a problem, a simple and common sense preventative would be to fertilize all fields according to soil test to promote maximum cotton growth and possibly reduce attractiveness to beet armyworms.

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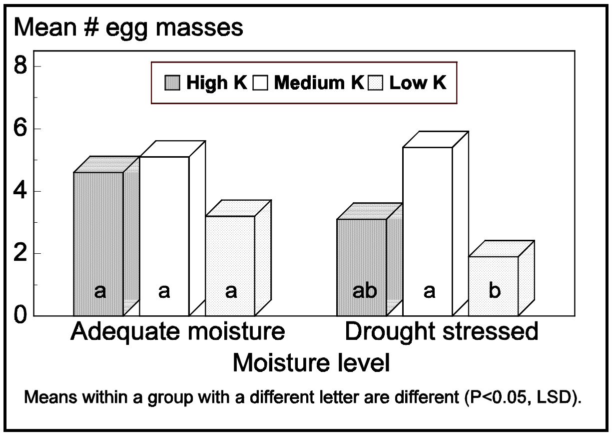

Figure 1. Beet armyworm oviposition preference on cotton plants grown in soils with different potassium levels and with different moisture levels

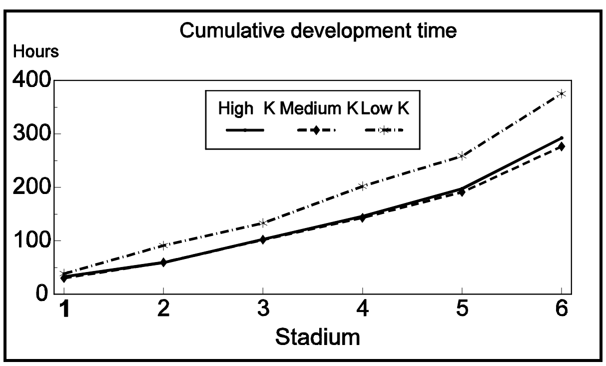

Figure 2. Beet armyworm development in a growth chamber when fed cotton leaves from plants grown in soils with different potassium levels.

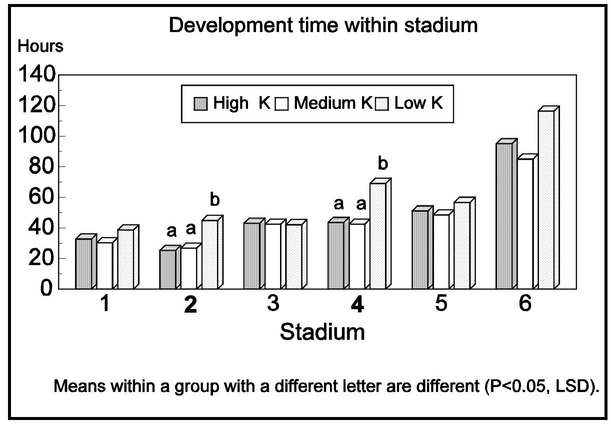

Figure 3. Beet armyworm development time within stadia in a growth chamber when fed cotton leaves from plants grown in soils with different potassium levels.

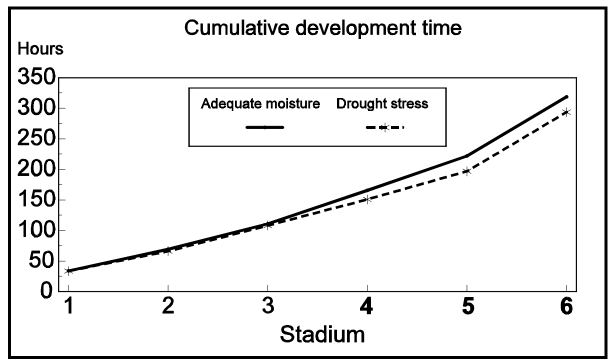

Figure 4. Beet armyworm larval development in a growth chamber when fed cotton leaves from plants grown at different moisture levels.

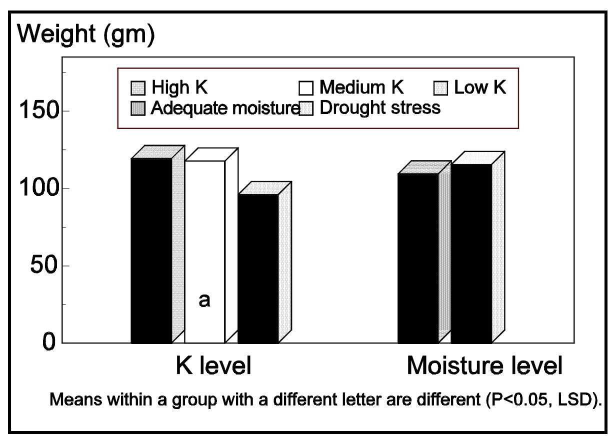

Figure 5. Beet armyworm pupal weights - growth chamber.

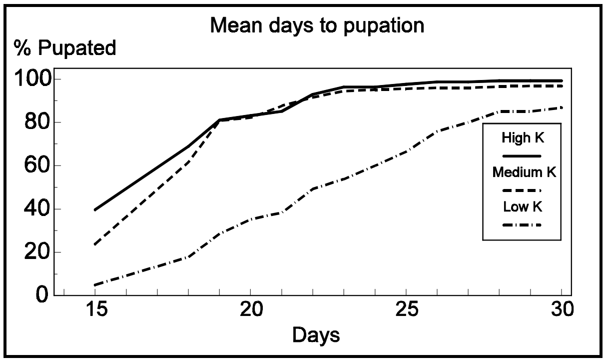

Figure 6. Beet armyworm larval development in the greenhouse when reared on cotton plants grown in different potassium levels.

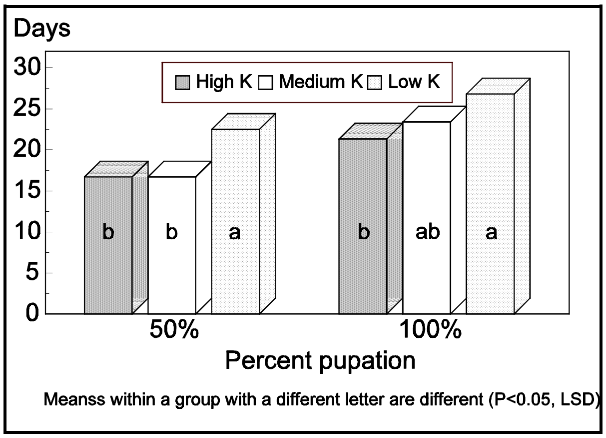

Figure 7. Beet armyworm pupation rate in the greenhouse.

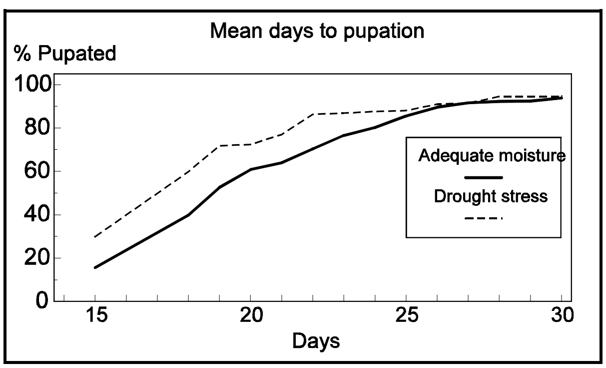

Figure 8. Beet armyworm larval development in the greenhouse on cotton grown at different moisture levels.

Table 1. Mineral analysis by K level - no K x moisture interaction

K Trt.	Mineral (ppm)[1]						
	K[2]	Fe	Zn	B	Al	Cr	Na
Hi	158 a	48 b	57 a	36 b	19 c	0.5 a	330 a
Med	100 b	98 a	34 b	33 b	26 b	2.0 a	189 b
Low	33 c	127 a	34 b	43 a	35 a	2.6 a	285 ab

[1]Means within columns followed by the same letter are not different
($P \leq 0.05$, LSD).

Table 2. Mineral analysis by K level - adequate moisture

K Trt.	Mineral (ppm)[1]								
	Ca[3]	Mg[2]	P[2]	Cu	Mn	Mo	Ba	Si	N
Hi	22 c	19 c	18 c	1.2 c	112 c	0.5 a	45 c	209 c	1.9 c
Med	34 b	43 b	28 b	5.3 a	176 b	0.5 a	73 b	337 b	2.5 a
Low	48 a	84 a	41 a	3.6 b	207 a	0.6 a	110 a	402 a	2.4 b

[1]Means within columns followed by the same letter are not different ($P \leq 0.05$, LSD).

Table 3. Mineral analysis by K level - drought stress

K Trt.	Mineral (ppm)[1]								
	Ca[3]	Mg[2]	P[2]	Cu	Mn	Mo	Ba	Si	N
Hi	27 b	63 b	24 c	5.3 a	188 a	0.5 b	62 b	356 b	3.8 a
Med	27 b	70 b	28 b	5.0 a	150 b	0.4 b	49 c	382 b	3.6 b
Low	41 a	115 a	33 a	4.7 a	177 a	1.1 a	85 a	484 a	2.9 c

[1]Means within columns followed by the same letter are not different ($P \leq 0.05$, LSD).
[2]Values x 100
[3]Values x 1000

Table 4. Amino acid analysis by K level - adequate moisture

K Trt.	% amino acid by wt.[1]							
	ala	arg	asp	glu	gly	his	ile	leu
Hi	0.8 c	0.9 b	1.2 b	1.4 c	0.6 b	0.2 a	0.5 b	1.0 c
Med	1.0 a	1.2 a	1.5 a	1.8 a	0.8 a	0.2 a	0.7 a	1.4 a
Low	0.9 b	1.1 a	1.3 b	1.6 b	0.8 a	0.2 a	0.6 a	1.2 b
	lys	met	phe	pro	ser	thr	tyr	val
Hi	0.7 b	0.06 c	0.7 c	0.61 c	0.6 b	0.6 c	0.4 c	0.7 c
Med	0.9 a	0.16 a	0.9 a	0.83 a	0.8 a	0.9 a	0.6 a	0.9 a
Low	0.8 b	0.11 b	0.8 b	0.76 b	0.7 a	0.7 b	0.5 b	0.8 b

[1]Means within columns followed by the same letter are not different ($P \leq 0.05$, LSD).

Table 5. Amino acid analysis by K level -drought stress

K Trt.	% amino acid by wt.[1]							
	ala	arg	asp	glu	gly	his	ile	leu
Hi	1.7 a	2.0 a	2.8 a	3.1 a	1.5 a	0.4 a	1.2 a	2.4 a
Med	1.5 b	1.9 a	2.3 b	2.7 b	1.2 b	0.3 b	1.1 b	2.1 b
Low	1.1 c	1.3 b	1.7 c	2.0 c	1.0 c	0.3 b	0.8 c	1.5 c
	lys	met	phe	pro	ser	thr	tyr	val
Hi	1.6 a	0.3 a	1.5 a	1.4 a	1.3 a	1.4 a	1.1 a	1.5 a
Med	1.4 b	0.3 a	1.3 b	1.2 b	1.1 b	1.2 b	1.0 b	1.3 b
Low	1.0 c	0.2 b	1.0 c	0.9 c	0.9 c	0.9 c	0.7 c	0.9 c

[1]Means within columns followed by the same letter are not different ($P \leq 0.05$, LSD).