GROWTH AND DEVELOPMENT OF TOBACCO HORNWORM (LEPIDOPTERA: SPHINGIDAE) LARVAE REARED ON GREEN OR YELLOWING FLUE-CURED TOBACCO

TOBACCO SCIENCE

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Tobacco hornworm, *Manduca sexta* L., larval feeding studies were conducted on field-grown immature green or ripening yellow-green leaves of 'K 326' flue-cured tobacco, *Nicotiana tabacum* L., in 1994. The effects of leaf maturity on hornworm survival rate, days to complete each larval stage, pupal weight, and total consumed leaf area were measured. Tobacco hornworms fed yellow-green tobacco leaves required significantly more days to complete development to pupation and adult emergence (23.1 d and 39.3 d, respectively) than corresponding larvae reared on green leaves (19.8 d and 36.1 d). Larval survival and pupal weights were similar for individuals reared on both leaf types. The hornworm larvae reared on yellow-green leaves consumed significantly more total leaf area (1877 cm^2 vs. 1586 cm^2) than did larvae reared on green leaves. Results indicate that hornworms are capable of causing late-season economic losses to flue-cured tobacco. Thus, this pest must be monitored throughout the entire production season and control measures applied when necessary until harvesting is completed.

Additional key words: ***Nicotiana tabacum, Manduca sexta,* life cycle, foliage consumption.**

INTRODUCTION

The tobacco hornworm, *Manduca sexta* L., is an annual economic threat to flue-cured tobacco in Georgia, as well as throughout the tobacco belt in the southeastern and eastern United States (1,9,13). Although *M. sexta* is the predominant *Manduca* species in the southern states, the tomato hornworm, *M. quinquemaculata* (Haworth), is also present in the middle Atlantic states where both species commonly occur (3).

Tobacco hornworm larvae complete five larval stages and can reach a length of up to 10 cm just prior to pupating in the soil (2). These pests consume large quantities of green leaf tissue, particularly during the fifth stage. Severe plant damage usually occurs later in the growing season, during June and July in Georgia; however, hornworms can cause heavy defoliation on tobacco any time from transplanting to near harvest.

Host plant resistance studies have identified tobacco introductions that are resistant to insect defoliation. However, only CU 263 has been released as a tobacco variety with defoliator resistance, and this resistance is directed toward the tobacco budworm, *Heliothis virescens* F. (6). Stalk and root destruction also has been shown to be an effective management tool to reduce the food supply and overwintering sites for tobacco hornworms and other pests in tobacco (8). Reducing nitrogen fertilization rates also makes tobacco plants less desirable for ovipositing hornworms and budworm moths (5).

Tobacco is a high-value crop and must be protected throughout the entire growing season from insect-induced economic plant injury. Growers routinely monitor their tobacco fields for insect pests during the season, and treat with insecticides when necessary (7,9,13). However, producers often quit scouting for insect pests once the plants begin yellowing (ripening) and harvesting of the lower leaves begins. Hornworms are still present during this time and are capable of causing economic losses. There is, however, a paucity of information regarding the effect of tobacco leaf age on the growth and feeding characteristics of the tobacco hornworm. Such information is needed to develop effective and economical pest management decision guidelines. Therefore, this study was conducted to determine whether or not tobacco hornworm larval development, foliar consumption, and survival rate change as tobacco leaves begin to ripen.

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MATERIALS AND METHODS

K 326 flue-cured tobacco was transplanted on both 4 and 18 April 1994 at The University of Georgia Coastal Plain Experiment Station, Tifton, Georgia, in plots measuring 6 rows wide (1.1 m row spacing) by 15 m long. These plots were maintained according to recommended production practices of the Georgia Cooperative Extension Service (7). A preplant incorporated tank mix was applied in late March that included pebulate (Tillam®) and napropamide (Devrinol®) for weed control, metalaxyl (Ridomil®) for blue mold control, fenamiphos (Nemacur®) for nematode suppression, and chlorpyrifos (Lorsban®) for soil insect control. Fertilizer (6-6-18, N-P-K) was applied at a rate of 1122 kg/ha in a split application. Methomyl (Lannate®) was applied on 24 April and 3 May to keep tobacco budworm populations under control.

On 5 June, tobacco hornworm eggs were collected from the field plots. The foliage containing each egg was removed from the leaf and placed into a 3.8 L cylindrical cardboard container and returned to the laboratory. Flue-cured tobacco leaves can be classified according to the level of maturity using a relative scale of 1 to 5, where 1 represents an immature green leaf, 2 represents a light green leaf just beginning to senesce, 3 represents a yellow-green leaf (the stage commonly picked for curing), 4 represents a mature yellow leaf, and 5 represents a yellowish-gold cured ripe leaf. An individual egg was placed onto a freshly picked green (immature) or yellow-green (ripening) tobacco leaf that had been removed from the field plots. The green leaves were obtained from the upper portion of the late-planted tobacco plants and the yellow-green leaves were obtained from the middle portion of the early-planted tobacco plants. Twenty-eight eggs were randomly assigned to each treatment, either green leaves or yellow-green leaves.

Prior to placing a hornworm egg on the leaf surface, each leaf area was measured with an area meter (Li-Cor model Li-3000, Lincoln, NE), then placed onto a moistened paper towel in a 19 cm x 32 cm x 9 cm plastic container and sealed with a plastic lid. The containers were held in a rearing room set at 26.7°C and 14L:10D. Every day, between 0800 and 1000 hours, each yellow-green and green leaf was removed and the total remaining leaf area was measured. Then, all feeding holes were covered with masking tape and the leaves remeasured to determine the amount of foliage that had been removed by the hornworm feeding. Leaves were replaced daily. Since the initial leaf area measurement and the total area measurement (leaf with all feeding holes taped) one day later were nearly identical (<1% lower in the 1 d-old leaf), the remaining area was compared to the initial area to determine feeding from the tenth day until pupation. The foliage consumed was measured daily until each larva reached the prepupal stage and feeding ceased. Moistened paper towels were replaced weekly or more frequently if fungal or fecal contamination required.

The leaf, paper towel, and container were examined for exuviae during each daily removal of the immature or ripening leaf and each molt was recorded. Once the larva had pupated, the pupa was removed, weighed, and placed in a labeled and sealed 0.5 L plastic cup containing vermiculite. These cups were observed daily for moth emergence. On several dates throughout the entire life cycle, larvae were randomly selected from both green and yellow leaves and their length (tip of head capsule to tip of abdomen) and weight were measured. The days between each molt, days to pupation, and days to adult eclosion were analyzed with the nonparametric Mann-Whitney U test (12) at $P \leq 0.05$. Pupal weight and total leaf area consumed were analyzed with an analysis of variance (10). Only the larvae completing development to the pupal stage were utilized in the analyses.

Table 1. The duration (in days) of tobacco hornworm larvae to complete development through each larval stage when feeding on either green or yellow-green flue-cured tobacco, 1994.[1]

Tobacco leaves		1st stage		2nd stage	3rd stage	4th stage	5th stage
Green		3.6		3.6	2.9	3.1	3.0
Yellow-green		4.2		3.7	4.0	4.4	2.7
Z value	2.18	0.45	3.03	2.57	1.36		
P value	0.0146	0.326	0.001	0.005	0.086		

[1] Mann-Whitney U non-parametric test was used to analyze treatment differences (Siegel and Castellen, 1988).

RESULTS

Tobacco hornworm larvae fed yellow-green tobacco leaves required significantly longer to complete development through the first, third, and fourth stages than corresponding larvae feeding on green tobacco **(Table 1)**. Most of the extended feeding period occurred during the third and fourth stages. The length of the prepupal stage was similar for larvae feeding on green leaves (3.5 d) and those feeding on yellow-green leaves (3.8 d). Total days to pupation and days to adult eclosion were longer for larvae fed yellow-green leaves **(Table 2)**. The pupal weights were similar for both green and yellow-green leaves **(Table 2)**. Both green and yellow-green tobacco leaves provided an adequate source of nutrition for hornworm larvae, with over 82% and 89% pupation rates for yellow-green and green leaves, respectively. Larvae fed yellow-green leaves consumed over 290 cm^2 more leaf area during their larval development than did larvae fed on green leaves **(Table 2)**. This increased foliage consumption was due in part to the additional 2.5 d required to complete larval development on the yellow-green leaves.

DISCUSSION

The results of this study demonstrated that tobacco hornworm larvae were capable of defoliating yellow-green (ripening) flue-cured tobacco leaves at rates equal to or exceeding defoliation that occurred when larvae fed on immature green leaves. Larval development was extended about 2.5 d to complete the five larval stages when larvae fed on yellowing leaves. Survival on yellow-green leaves was also very good (82% compared with 89% on green leaves). The larvae fed on yellow-green leaves consumed over 290 cm^2 more leaf area before completing larval development. Pupal weights, however, were unaffected by the age of the leaf consumed.

The epicuticular and internal leaf chemistries of immature and ripening flue-cured tobacco (4,11) may affect *M. sexta* development. However, based on this study, the needed nutritional requirements were apparently available in both green and yellowing K 326 leaves. Preliminary surface chemistry of green and yellowing K 326 leaves indicates that there is a difference in total diols, 33.3 μg per cm^2 in green leaves and 8.8 μg per cm^2 in yellowing leaves, but no difference in docosanol, 0.4 μg per cm^2 in both leaf types (unpublished data). Further studies are needed on leaf chemistry comparisons and how they affect *M. sexta* development.

The plant growing condition, plant growth stage during insect feeding, and leaf position on the stalk are also variables that could influence the growth and development of hornworm larvae on flue-cured tobacco. The effects of these plant characteristics, plus results reported herein on leaf-ripening, would be very useful additional information to include in the hornworm management database.

It is apparent that tobacco producers must monitor their crop for the presence of hornworms until all leaves are harvested and curing begins. Otherwise, economic losses can occur late in the season due to hornworm feeding. This information on the effects of leaf ripening on tobacco hornworm development will be incorporated into the existing Georgia Tobacco Integrated Pest Management Program.

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Table 2. Days to pupation, adult eclosion, pupal weight, and total leaf area consumed for tobacco hornworm larvae feeding on either green or yellow-green flue-cured tobacco, 1994.[1]

Tobacco leaves	Days to pupation	Days to adult	Pupal wt (gm)	Total leaf area consumed (cm^2)
Green	19.8	36.1	387.7	1586.9
Yellow-green	23.1	39.3	378.2	1877.3
	Z = 3.11	Z = 2.82	F = 0.08	F = 5.67
	P = 0.001	P = 0.002	P = 0.78	P = 0.02

[1]Mann-Whitney U non-parametric test used to analyze days to pupation and adult emergence (Siegel and Castellen, 1988). ANOVA used to analyze pupal weight and leaf area consumed.

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