Fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae), larval development and moth fecundity on sorghum at various stages of maturity

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Abstract. The fall armyworm (FAW) can be a significant pest of many crops in the United States and is a principal constraint to sorghum and corn production in some regions in Central America. This insect can cause economic damage to these grain crops at various stages of plant development. Larvae were fed sorghum at four stages of maturity to measure the influence of plant growth stage on insect growth, survival, and reproduction. Insects fed on early whorl stage leaves, mid-whorl stage leaves, boot stage leaves plus seed, or blooms plus seed of sorghum in the laboratory had significant (P=0.05) weight gain reduction with increasing maturity of the host plants. Larvae fed for 11d on blooms plus seed weighed less than larvae fed on other growth stages. Larval developmental time increased with increased plant maturity. Larvae fed blooms plus seed weighed less as pupae than larvae fed on early whorl stage leaves. Pupal mortality was lower when larvae were fed blooms plus seed than when larvae were fed leaf material from early whorl, mid-whorl, or boot stages. Larval mortality, number of egg masses deposited, egg mass weight, and adult female longevity were not significantly different when larvae were fed sorghum at the various stages of maturity. The stage of maturity of sorghum when attacked by FAW larvae can influence the level of plant damage but appears to have had no effect on reproductive potential of this lepidopterous defoliator when fed the four plant growth stages included in this study.

Keywords: Maicillo, pest, *sorghum bicolor*.

Resumen. El gusano cogollero puede ser una plaga importante en varios cultivos en los Estados Unidos y es una de las restricciones principales en la producción de sorgo y maíz en algunas de las regiones de América Central. Este insecto puede causar daños económicos a estos cultivos en varios estados de desarrollo de la planta. La larva se alimentó de sorgo en cuatro estados de madurez para medir la influencia de la planta en el crecimiento, sobreviviencia y reproducción del insecto. En el laboratorio los insectos alimentados con hojas de plántulas, hojas de plantas maduras, hojas más semillas de plantas en embuchamiento y hojas de plantas en floración más semillas de sorgo tuvieron una reducción significativa (P=0.05) en el aumento de peso al aumentar la madurez de la planta. Las larvas alimentadas por 11 días con flores más semillas pesaron menos que las alimentadas con otros estados de crecimientos. El tiempo de desarrollo de las larvas aumentó con el aumento en madurez de la planta. Las larvas alimentadas con flores más semillas pesaron menos como pupas que las larvas alimentadas con hojas de plántulas. La mortalidad de las pupas fue menor cuando las larvas se alimentaron con flores más semillas, que cuando se alimentaron con hojas de plántulas, hojas de plantas maduras u hojas más semillas de plantas en embuchamiento. La mortalidad de las larvas, el número de masas de huevos depositadas, el peso de la masa de huevos, y la longevidad de la hembra no fueron significativamente diferentes cuando la larva se alimentó con sorgo en varios estados de madurez. El estado de madurez del sorgo en el momento de ser atacado por la larva de cogollero puede influir en el nivel de daño de la planta, pero parece no haber tenido efecto en el potencial reproductivo de este defoliador lepidóptero cuando se alimentó con las cuatro fases de crecimiento incluidas en este estudio.

Palabras claves: Maicillo, plaga, *Sorghum bicolor*.

INTRODUCTION

The fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith), is an important defoliator of sorghum, *Sorghum bicolor* (L.) Moench, corn, *Zea mays* (L.), and other grass species (Luginbill, 1928). The larvae damage these crops from early whorl through reproductive stages. Damaging infestations usually require chemical control (Pitre 1984). While this pest is given much attention on corn, it receives much less attention on sorghum. Larval development on and damage to sorghum at various stages of maturity need to be determined. This information is important in determining economic injury levels at specific stages of plant development (Garner and Lynch, 1981).

FAW larvae fed corn varieties in early whorl, mid-whorl, and late whorl stages had similar weights 7 days after initiating feeding (Videla *et al.* 1992). Larvae were reported to survive better on mid-whorl stage corn than on the early whorl or late whorl stages (Morrill and Greene, 1973). Fewer FAW larvae survived on early tassel stage corn than on early whorl, mid-whorl, or late whorl stages.

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Garner and Lynch (1981) reported that FAW larvae selected younger (2- to 10-day-old) and intermediate (10-to 20-day-old) aged peanut leaves for feeding and had little acceptance for older leaves (20-to 40-day-old). Consumption and pupal weight decreased, whereas developmental time increased with peanut leaf age. Information on the effects of plant phenology on consumption, growth, development, survival, and oviposition of FAW on sorghum is needed for developing or refining insect control tactics. The objective of this study was to determine the influence of sorghum growth stages on aspects of the biology and behavior of the FAW.

MATERIALS AND METHODS

Sorghum seed, variety 'Funks DR 522', was planted in 7.6 L pots filled with a 50:50 mixture of Promix B® soil and Black Kow® top soil on four dates at 14-day intervals in a greenhouse at Mississippi State University. Seedlings were thinned to two per pot. Plants were watered daily and fertilized weekly for 4 weeks with Peter's® (20: 20: 20 N: P: K) nutrient solution at the recommended rate of 134 kg N/ha. No insecticides were applied to the plants. The larval feeding study was started when plants in the four plantings were at early whorl (33.02 ± 4.01 cm), mid-whorl (48.26 ± 2.69 cm), boot (64.52 ± 9.77 cm), and mid-bloom (75.44 ± 6.93 cm) (mean ± SD) stages. The study was completed when plants in the early whorl, mid-whorl, boot, and bloom stages at the start of the study had reached mid-whorl (47.63 ± 5.63 cm), late whorl (69.85 ± 7.89 cm), mid-bloom (78.11± 2.43 cm), and dough (83.82 ± 2.93 cm) stages, respectively.

Neonate FAW larvae [corn strain (Pashley *et al.*, 1992)] were obtained from a colony maintained at the USDA ARS Crop Science Research Laboratory, Starkville, Mississippi (Davis, 1989). The colony had developed through seven generations after it was infused with wild males collected as larvae on corn plants. The neonates were placed individually in 30 ml plastic cups with 2% non-nutritional agar and the cups were capped to maintain leaf freshness (Ng *et al.*, 1985). Larvae were fed *ad libitum* on leaf material from the top two leaves or seed from whole panicles of the greenhouse-grown plants and food was replaced daily. The treatments included diets of early whorl stage leaves, mid-whorl stage leaves, boot stage leaves plus developing seed, or blooms plus seed in successive stages of development. Each treatment was initiated with 60 neonate larvae. Treatments were arranged at random on 10 plastic trays, each holding 24 cups, using six larvae per treatment per tray (=block) in a randomized complete block design. The larvae were held at 26.7° C, 50-60% RH, and 14:10 L:D photoperiod. The leaf material and seed were washed with 10% chlorine bleach (Clorox®) solution, rinsed with running tap water for 20 minutes, and dried with paper towel before being fed to the larvae.

Larvae were weighed at ages 7 and 11 days using an electronic balance. Pupae were sexed, and female pupae were placed individually in 3.75 L jars covered with cotton cloth and with moist paper towel at the bottom. Larval and pupal mortality were recorded. Eclosing females and males for each treatment (n = 5, 5, 4 and 11 for females fed as larvae on early whorl stage leaves, mid-whorl stage leaves, boot stage leaves plus developing seed, or blooms plus seed, respectively), were paired on day 2 for three nights and the females were allowed to lay eggs on the cotton cloth in the jars. Egg masses were removed from the cloth and weighed to estimate the number of eggs per egg mass (Lynch *et al.*, 1983). Larval developmental time (days), pupal weights (mg) at 48 hours post pupation, and female longevity (days) were

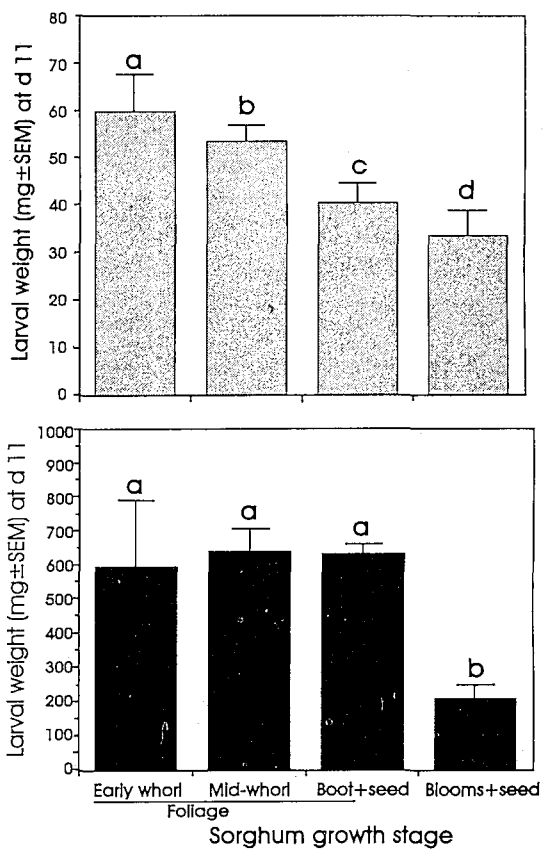

Figure 1. Mean weight of 7- and 11-day-old fall armyworm *(Spodoptera frugiperda)* larvae fed in the laboratory on early whorl stage sorghum foliage, mid-whorl stage foliage, boot stage foliage plus seed, and blooms plus seed. Bars with the same letter are not significantly different (P=0.05, LSD).

recorded. Data were analyzed using GLM and treatment means were separated using Fisher's Protected LSD (P = 0.05; SAS Institute 1985). The larval and pupal mortality data were subjected to square root transformation prior to analysis (Steel and Torrie, 1980).

RESULTS

FAW larval weights at day 7 for insects fed the four sorghum diets varied significantly (F = 53.05; df = 3, 27; P = 0.0001) depending upon the growth stage of the sorghum plant serving as diet (Figuire 1). Larval weights were significantly lower with each increase in age of the sorghum plant tissues. Weights were 45, 33 and 10% lower for larvae fed blooms plus seed, boot stage leaves plus seed, and mid-whorl stage leaves, respectively, compared to larvae fed early whorl stage leaves through day 7. However, by day 11, only larvae that were fed blooms plus seed had significantly (F = 33.78; df = 3, 27; P = 0.0001) lower weight than larvae fed the other diets (Figure 1).

Larval developmental times varied significantly (F = 71.33; df = 3, 27; P = 0.0001) among sorghum diets (Figure 2). Larvae fed the more mature plant diets had longer developmental times (19 to 22% longer) than larvae fed the younger plant tissues, and pupae generally weighed 19 to 47% less (F = 3.60; df = 3, 27; P = 0.0261) when larvae were fed the older plant parts (Figure 2).

Larval mortality did not differ significantly (F = 0.08; df = 3, 27; P = 0.970) as a function of sorghum plant growth stage (Figure 3), whereas pupal mortality was significantly

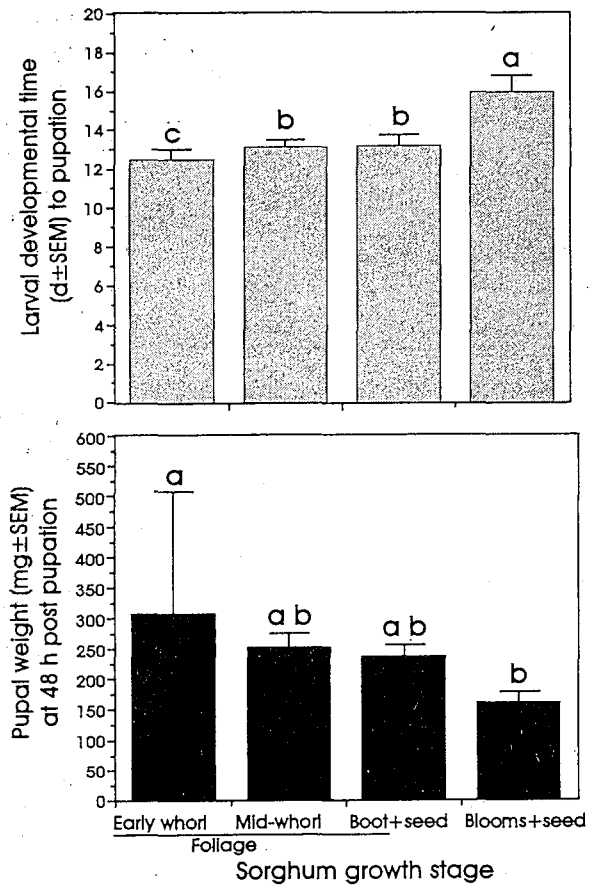

Figure 2. Mean fall armyworm *Spodoptera frugiperda* (larval developmental times neonate to pupae) and pupal weights at 48h after pupation by insects fed in the laboratory on early whorl stage sorghum foliage, mid-whorl stage foliage, boot stage foliage plus seed, and blooms plus seed. Bars with the same letter are not significantly different (P=0.05, LSD).

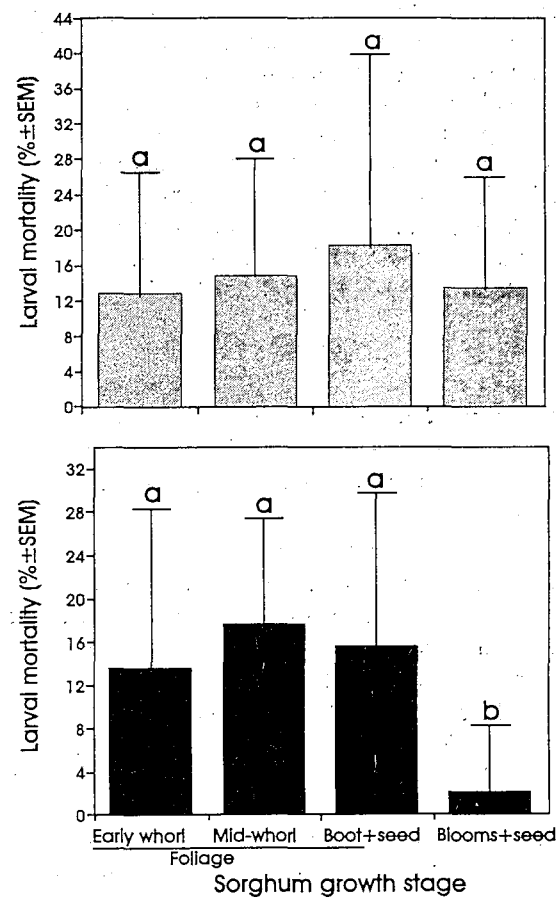

Figure 3. Mean percentage mortality of fall armyworm *(Spodoptera frugiperda)* larvae and pupae fed in the laboratory on early whorl stage sorghum foliage, mid-whorl stage foliage, boot stage foliage plus seed, and blooms plus seed. Bars with the same letter are not significantly different (P=0.05, LSD).

less (2% mortality) (F = 5.41; df = 3.27; P = 0.0048) for insects having developed on the bloom plus seed diet compared to the other three sorghum diets (13.5 to 18% mortality) (Figure 3). No explanation is offered for the observed lower pupal mortality of insects fed blooms plus seed.

The number of eggs, or at least the total weight of eggs produced by the female, is the most relevant measure of reproduction output. This measure of reproduction, observed as number of egg masses deposited per female, was not influenced significantly (F = 1.95; df = 3, 22; P = 0.1503) as a result of larval feeding and developing on the four sorghum diets. Similarly, egg mass weights were not significantly different (F = 0.62; df = 3,20; P = 0.6129) for females fed the various diets. Female longevity was not influenced (F = 0.63; df = 3,21; P = 0.6058) by larvae feeding on sorghum at the four growth stages tested. Relative measures of total performance of the insects fed on the four sorghum diets were determined by calculating, larval survival x pupal survival x reproduction output = total performance rating [1] (egg mass weight).

These calculations revealed similar relative performance ratings for the insects fed the four sorghum diets (0.0053, 0.0049, 0.0061 and 0.0078 ratings for insects fed early whorl foliage, mid-whorl foliage, boot stage foliage plus seed, or bloom plus seed, respectively).

DISCUSSION

As sorghum matures from the early vegetative to late vegetative stages, there is a decline in nitrogen and an increase in lignin in plant tissues (Joo, 1965). Price (1984) reported that nitrogen, in the form of amino acids, can be found in higher concentrations in the younger foliage of plants. Nitrogen is recognized as an important constituent of protein, and thus it is needed for larval development and adult fecundity (Price, 198; Horn, 1988).

FAW larvae in third to last instars feed in the whorl of sorghum (Luginbill, 1928), a region of the plant which could have a higher concentration of nutrients. The differences in FAW larval weights for insects fed 7 and 11 days on vegetative or reproductive stages of sorghum could be associated with declines in nitrogen level and increased toughness of plant tissues as the crop matures. The nutritional value of the foliage alone or foliage plus seed appeared to be superior diets for FAW development compared to the reproductive stages alone.

FAW larvae are known to either increase consumption rates, lengthen their developmental periods, or both to compensate for a reduction in nutrient availability (Barfield, *et al.*, 1980). The lower weight of larvae fed blooms plus seed for 7 and 11 days could be due to food toughness and lower food palatability that could result in reduced food intake. This may result in longer developmental times to pupation by larvae fed on seed compared with those fed on the succulent leaves. McMillan *et al.*, (1967) reported that FAW larvae consumed more filter paper treated with leaf extract than when treated with kernel extract of corn. Morrill and Greene (1973) reported no differences in FAW larval preference for stalks, tassels, leaves, furls, silks, or ears of corn.

Although the nutritional quality of sorghum may be only fair to poor during larval development, female oviposition may not be limited if the adult diet is nutritionally acceptable. This might be suggested for FAW fed the four diets in this study, since the relative performance ratings for insects fed the different diets were similar. Furthermore, a longer larval developmental period may allow larvae to compensate, by additional feeding, for the poor nutritional quality of the host plant. However, the longer the larval development time to pupation, the longer the insect is exposed to mortality factors (eg., environment, predators, parasitoids, and pathogens), hence reducing population growth (Price, 1984).

The damage potential of FAW larvae on sorghum would appear to vary with the stage of maturity of the crop when infested. Therefore, there is a need for having variable economic thresholds for FAW on sorghum with respect to stages of crop maturity. Additional research is needed on consumption rates and nutritional indices for FAW larvae on sorghum, as larval growth and development are influenced by the nutritional value of the crop in various stages of plant maturation.

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