# Location of Beet Armyworm (Lepidoptera: Noctuidae) Egg Mass Deposition within Canopies of Cotton and Pigweed

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**ABSTRACT** The beet armyworm, *Spodoptera exigua* (Hübner), is a sporadic but devastating secondary pest of cotton. Scouting cotton for egg masses is commonly recommended for identifying potential outbreaks and for proper timing of insecticide applications. However, there is disagreement regarding where to look on the plant for beet armyworm eggs. We investigated and quantified placement of egg masses by laboratory colony females within cotton and pigweed (a preferred wild host plant) canopies of different heights. In cotton, almost all egg masses were deposited on the undersides of leaves, and ≈80% of the egg masses were consistently located in the upper 50% of the cotton canopy, and horizontally within the inner 50% of the canopy around the central axis. Although this trend was consistent among all categories of plant height tested, variation about the means decreased with increasing height. A smaller sample of wild females indicated similar vertical placement, but horizontal placement extending further distally in the canopy. Our results indicate that scouting for egg masses on the underside of leaves in the upper half of the canopy will recover ≈80% of the egg masses present on the plants. In pigweed, egg masses were commonly laid within the inner 50% of the canopy, but along the upper 80% of the vertical axis. As in cotton, variation about the means was less in taller plants. The number of eggs per egg mass was 29% less in cotton than in pigweed. This positional information will aid in further efforts to investigate, predict, and manage beet armyworm populations in cotton and noncotton hosts.

**KEY WORDS** *Spodoptera exigua*, beet armyworm, oviposition, egg mass, cotton, pigweed

BEET ARMYWORM, *Spodoptera exigua* (Hübner), outbreaks in cotton are sporadic, but can be very destructive (Smith 1989; Layton 1994; Huffman 1996; Summy et al. 1996; Mascarenhas et al. 1998, 1999), and the frequency of outbreaks in the United States has increased recently (Mascarenhas et al. 1998). It has been hypothesized that this increase may be due in part to adaptation of the beet armyworm to cotton as a primary host (Ruberson et al. 1994a, Smith 1994, Ruberson 1996). However, beet armyworm has been damaging cotton in the United States since 1904 (Campbell and Duran 1929, Ruberson 1996), and there is little evidence to support this hypothesis. Beet armyworm populations are normally held in check by a wide array of generalist predators and parasites (Howard 1907; Wilson 1933; Tingle et al. 1978; Ruberson et al. 1993, 1994a, 1994b; Summy et al. 1997). Outbreaks of this insect in cotton are often associated with multiple early-season treatments with broad-spectrum insecticides, especially organophosphates, which are intended to reduce populations of key pests like boll weevil, *Anthonomus grandis grandis* Boheman; pink bollworm, *Pectinophora gossypiella* (Saunders); or lygus bugs (*Lygus* spp.), but which severely reduce natural enemy numbers as well (Eveleens et al. 1973; Stolz and Stern 1978; Burris et al. 1994; Mascarenhas et al. 1996; Ruberson et al. 1994b, 1999).

Beet armyworms are particularly difficult to control with conventional insecticides (Brewer and Trumble 1991; Graves et al. 1995; Sparks et al. 1996; Mascarenhas et al. 1996, 1998), and older larvae are hard to kill. Thus, early warning of a high beet armyworm population is desirable for proper targeting of insecticides to young larvae. The beet armyworm infests a wide variety of plants (Jack 1915, Cherian and Kylasam 1939, Davidson and Lyon 1979, Ruberson et al. 1994b), which has been interpreted as evidence that the moth oviposits indiscriminately on any available plant species (Atkins 1960). However, it is clear that some hosts, especially pigweed (*Amaranthus* spp.) (Howard 1907, Wene and Sheets 1965, Tingle et al. 1978), are preferred. Consequently, populations may build up in alternate hosts with a rapid expansion into cotton if availability of those hosts becomes limiting. Sampling adult populations with pheromone traps can provide an indication of relative population changes in an area, but the specific relationship, if any, between numbers of moths captured in traps and infestation levels in local cotton fields is not known.

Most management guides for beet armyworm in cotton provide treatment thresholds based on the number of egg masses or groups of young larvae (which remain aggregated near the egg mass for a few

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[1] Deceased.

days through the third instar) per unit length of row (e.g., Huffman et al. 1996, Johnson et al. 1999, Sprenkel and Johnson 1999). If oviposition tended to occur in a certain region of the plant canopy, scouting could be restricted to that area, making the effort more efficient and estimates more accurate. Some management guides indicate that beet armyworm moths oviposit primarily on the lower half of the plant (e.g., Sprenkel and Johnson 1999), whereas others indicate that egg masses are found higher on the plant (e.g., Huffman et al. 1996). The purpose of the study reported herein was to quantify beet armyworm egg mass distribution on cotton, *Gossypium hirsutum*, plants of various sizes, and on its preferred native host, pigweed.

## Materials and Methods

Beet armyworm neonate larvae were obtained from a colony at the Kika de la Garza Subtropical Agriculture Research Center in Weslaco, TX, and reared on a soybean-wheat germ diet (Shaver and Raulston 1971). This colony was established from wild moths captured in the Lower Rio Grande Valley in 1997, and had therefore been in culture for 2 yr at the time the experiments were conducted. Beet armyworm pupae were separated by sex. Male pupae are distinguished by a pair of prominent protuberances on the ventral midline of the ninth sternite, which females lack. On the day of emergence, up to 20 males were placed together in 0.5-liter containers, and females were individually placed in 0.5-liter containers. Moths were provided with 5% sucrose and held overnight in an environmental chamber at 30°C, 85% RH, and a photoperiod of 13:11 (L:D) h. The following day one male was placed with each female. Females were allowed to oviposit for a single night before placement in field cages.

Eight rows of cotton ('Delta-Pine 50') or pigweed were treated with azinphos-methyl (Guthion 2 liter) at 0.28 kg (AI)/ha to kill natural enemies. After 48 h, one row of plants was selected from near the center of the treated area, and 1-$m^2$ plots, spaced at least 10 m apart, were delimited. For each plot, the number of plants, the height of each plant, and maximum width (radius) of the canopy of each plant was recorded. Over the course of the study, mean cotton canopy height ranged from 35 to 73 cm, and was categorized as short (<50 cm), medium (50–60 cm), or tall (>60 cm). Mean pigweed canopy height ranged from 74 to 121 cm, and was categorized as medium (plant height ≤95 cm) or tall (plant height >95 cm). The plots were covered with mesh cages (1 m long by 1 m wide by 1.05 m high), and four mated females were placed in each cage. After two nights, the cage was removed and plants were inspected for egg masses. The height above the soil surface and the distance from the center of the canopy was recorded for each egg mass.

It is possible that oviposition behavior of laboratory-colony beet armyworms differs from that of wild moths. To test this, young larvae were collected from a natural infestation of cotton in a field south of Lubbock, TX, in August 2000, and were reared to pupation on cotton leaves. Two larvae were placed on a cotton leaf in a plastic 10-cm-diameter petri dish, with a 2-cm-diameter screened hole in the lid for ventilation. The leaf petiole was wrapped in wet cotton to prevent desiccation, and the leaf was changed every 2 d. After pupation, the insects were handled as described above for colony insects. Because the date for mandatory crop destruction for the Lower Rio Grande Valley (1 September) had passed by the time adults emerged, tests were conducted on cotton (mean height 82 cm) inside large outdoor cages. Oviposition assays were conducted in 1-$m^2$ plots as described above.

Position of an egg mass within the canopy was described using two coordinates: the ratio of vertical displacement from the soil surface to mean canopy height, and the ratio of horizontal displacement from the central axis of the plant to mean maximum canopy width (radius). Square roots of the ratios were arcsine transformed for statistical tests and linear regressions (Analytical Software 1998), but untransformed data are presented for clarity. The nonparametric Kruskal–Wallis test (Kruskal and Wallis 1952) was used to separate multiple means after an initial Kruskal–Wallis test indicated a significant effect of height category. Differences among variances were tested using Bartlett's chi-square procedure (Sokal and Rohlf 1981).

## Results and Discussion

**Cotton.** Vertical placement of beet armyworm egg masses in cotton canopies did not depend on plant height ($F = 0.82$, total df = 22, $P = 0.38$). Similarly, regression of horizontal placement of egg masses on canopy width was not significant ($F = 0.02$, total df = 22, $P = 0.88$). Thus, height above the ground and absolute distance from the central axis of the cotton plant did not determine egg mass placement within the cotton canopy. In contrast, vertical egg placement increased linearly with increasing plant height (Fig. 1A). The slope of the regression line (0.90) is close to 1.0, suggesting that the relative vertical placement of egg masses remains constant regardless of plant height. This conclusion is supported by a Kruskal–Wallis one-way analysis of variance of percent vertical egg mass position, which indicated no significant differences among canopy height categories (short, medium, tall) (Kruskal–Wallis statistic = 4.03, $N = 23$, $P = 0.13$) (Fig. 2). Likewise, horizontal displacement of egg masses away from the central axis increased linearly with increasing plant width (Fig. 1B), but the slope of the regression line (0.42) was much <1.0, suggesting that relative placement of egg masses tended to be relatively closer to the central axis in taller than shorter plants. However, this tendency could not be demonstrated in comparisons of plant height categories (Kruskal–Wallis statistic = 0.09, $N = 23$, $P = 0.96$).

Standard deviation ellipses indicate that ≈80% of the egg masses deposited were consistently located in the upper 50% of the cotton canopy, and horizontally within the inner 50% of the canopy around the central axis (Fig. 2). Although mean relative placement of

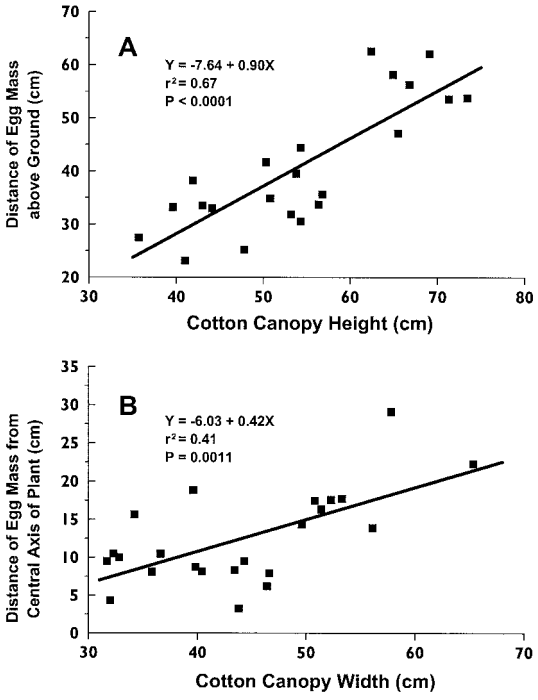


**Fig. 1.** Linear regression of (A) vertical distance of laboratory colony beet armyworm egg mass above ground on mean height of the cotton canopy, and (B) horizontal distance of egg masses from the central axis of the plant on mean maximum width (radius) of the cotton canopy. Each data point represents the mean of a replicate trial, with at least five egg masses per replicate.

eggs did not change with plant height category, the variation about the means appeared to decrease with increasing height (Fig. 2). Tests of equality of variances of relative vertical placement of egg masses was inconclusive (Bartlett's $\chi^2 = 4.78$, df = 2, $P = 0.09$), but the variance of relative horizontal placement was significantly less in tall cotton than in short (Bartlett's $\chi^2 = 17.00$, df = 1, $P < 0.0001$) or medium (Bartlett's $\chi^2 = 12.81$, df = 1, $P = 0.0003$) cotton. Of 267 egg masses deposited on cotton in this study, all were found on the underside of leaves except six on the top of leaves, one on a leaf petiole, one on a square, and one on a boll.

The number of eggs per egg mass oviposited on cotton did not differ among colony (62.5 ± 4.9 SE, $N$ = 97) and wild moths (82.5 ± 16.2 SE, $N$ = 23) (Kruskal–Wallis statistic = 0.68, $P$ = 0.41). Egg placement by wild moths in tall cotton was generally consistent with that by colony moths (Fig. 3). Average vertical placement of egg masses was high in the canopy, with >80% of total egg masses found in the upper 60% of the plant. Although most eggs were oviposited horizontally within the inner 60% of the plant, in two replicates the standard deviation ellipses extended out to 75–85% of the width of the canopy (Fig. 3). Thus, it seems clear that scouting for beet armyworm egg masses can be restricted to the undersides of leaves in the upper half of the cotton canopy, but until further data are collected from wild moths, it would be prudent to scout out to the horizontal extremes of the plant.

**Pigweed.** We were interested in characterizing egg mass placement on pigweed for several reasons. Areas of cotton undergoing heavy insecticide pressure are at increased risk for a secondary beet armyworm outbreak (Eveleens et al. 1973; Stolz and Stern 1978; Burris et al. 1994; Ruberson et al. 1994b, 1999; Mascarenhas et al. 1996). Because pigweed seems to be preferred over cotton by the beet armyworm as a host (Howard 1907, Wene and Sheets 1965, Tingle et al. 1978), pigweed stands within or near cotton may serve

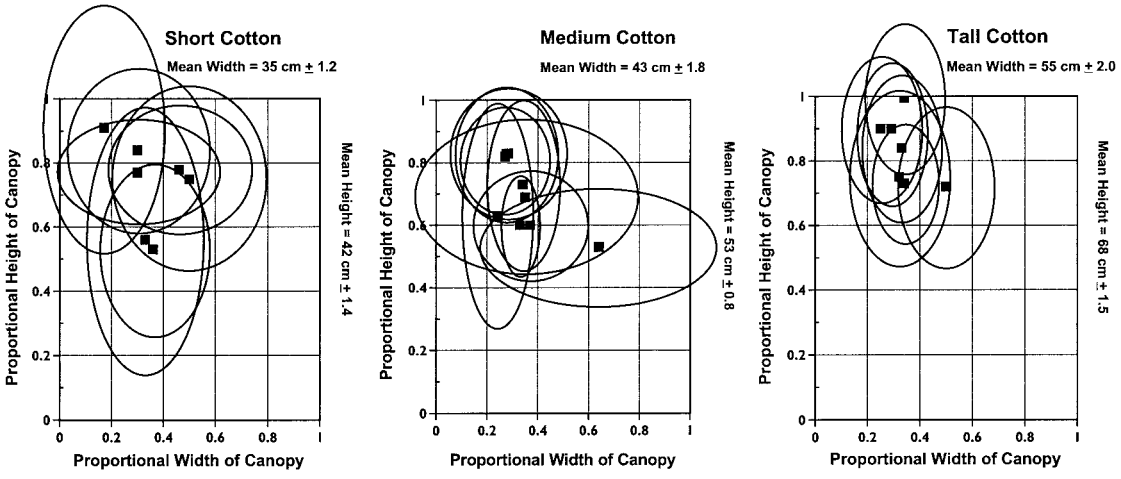


**Fig. 2.** Relative position of laboratory colony beet armyworm oviposition sites within cotton canopies of three different plant height categories (short, medium, and tall). Squares indicate replicate means of at least five egg masses. Each mean is surrounded by a standard deviation ellipse. To facilitate visual conceptualization, the X-axes are scaled to be 83% (short), 81% (medium and tall) the length of the y-axis, the average relationship of canopy widths to plant heights observed in this study for these plant-height categories.

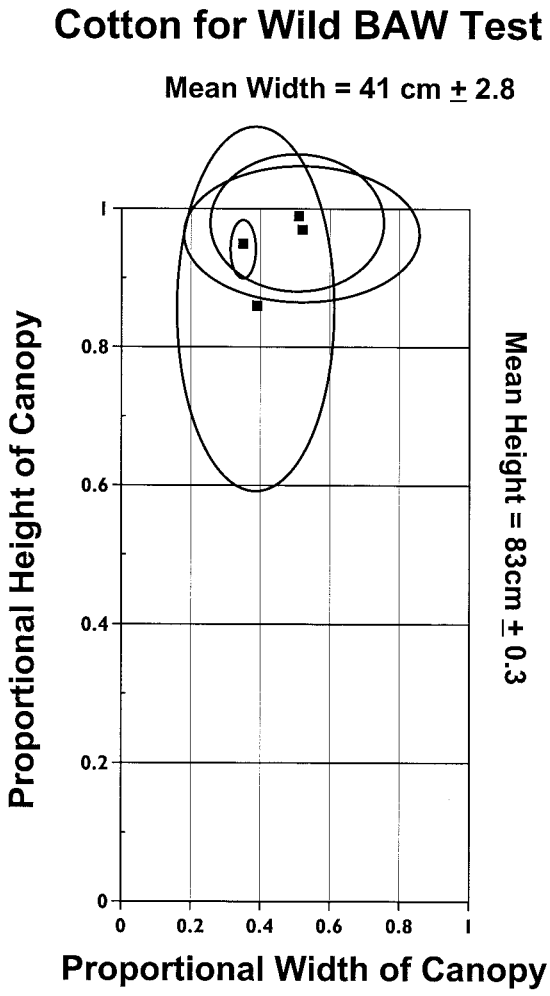


**Fig. 3.** Relative position of wild beet armyworm oviposition sites within the cotton canopy. Squares indicate replicate means of at least four egg masses. Each mean is surrounded by a standard deviation ellipse. To facilitate visual conceptualization, the x-axis is scaled to be 49% the length of the y-axis, the average relationship of canopy widths to plant heights observed in this experiment.

as a nursery for an early population buildup, and it could be of value to scout pigweed for egg masses under such high-risk circumstances, either for strictly predictive purposes, or for intervention through targeted insecticide treatment of pigweed stands. In addition, we reasoned that examining egg placement on a plant like pigweed with a markedly different canopy shape than cotton could provide insight into the spatial parameters important in egg placement.

As was the case with cotton, vertical placement of beet armyworm egg masses in pigweed canopies did not depend on plant height ($F = 0.68$, total df = 11, $P = 0.43$). Unlike cotton, however, regression of absolute vertical placement on plant height also was not significant ($F = 0.25$, total df = 11, $P = 0.63$). Differences in mean relative vertical placement of egg masses among height categories was not significant (Kruskal–Wallis statistic = 0.06, $N = 12$, $P = 0.81$). Thus, neither height above the ground nor relative vertical regions of the canopy seem to be important factors determining egg mass placement within the pigweed canopy. Schematic visualization of egg mass placement confirms this conclusion (Fig. 4), with 80% of the egg masses occurring anywhere in the upper 80% of the canopy.

Regression of relative horizontal placement of egg masses on pigweed canopy width (Fig. 5) was significant ($F = 18.35$, total df = 11, $P = 0.0016$). This indicates that, in contrast to egg placement on cotton, relative mean horizontal placement of beet armyworm egg masses on pigweed did not remain constant over all plant heights, as it tended to move closer to the main stem with increasing plant height. There was a tendency for absolute distance of egg masses from the central axis to decrease with increasing plant width, but this could not be demonstrated statistically with the sample size used in this study (linear regression, $F = 4.06$, total df = 11, $P = 0.07$). Mean relative horizontal placement did not differ with plant height category (Kruskal–Wallis statistic = 0.53, $N = 12$, $P = 0.46$)

Standard deviation ellipses indicate that ≈80% of the egg masses were consistently deposited horizontally within the inner 50–60% of the canopy around the central axis (Fig. 4). Variation about the means appeared to be less in tall pigweed than in plants of medium height (Fig. 4). Tests of equality of variances indicated that relative vertical placement of egg masses was significantly less variable in tall pigweed compared with pigweed <95 cm in height (Bartlett's $\chi^2 = 9.19$, df = 1, $P = 0.002$). There was a tendency for the variance of relative horizontal placement to be less in tall than in medium pigweed, but the difference was not statistically significant (Bartlett's $\chi^2 = 3.58$, df = 1, $P = 0.06$). Of the 137 egg masses oviposited on pigweed in this study, all were located on the underside of leaves except for three egg masses laid on the main stem of the plant.

Interestingly, the number of eggs per egg mass averaged 29% less on cotton (58.6 ± 2.75) than on pigweed (82.7 ± 5.48) (Kruskal–Wallis statistic = 12.47, $N = 403$, $P = 0.0004$). This may be related to the apparent oviposition preference of beet armyworm for pigweed over cotton (Wene and Sheets 1965; S.M.G., unpublished data). Although patterns of placement of egg masses within the canopies were observed (Figs. 2 and 4), and the number of eggs per egg mass varied widely (2–283), regression analyses and comparisons of means among height categories revealed no relationship between the number of eggs and their position within the canopies of either host plant (data not shown).

The pigweed in our study was taller, with a narrower, more open canopy than the cotton, and the spatial distribution of eggs laid by beet armyworms in the former was different in some respects (Figs. 2 and 4). In both host plants, most of the egg masses were found horizontally within the inner 50% of the canopy,

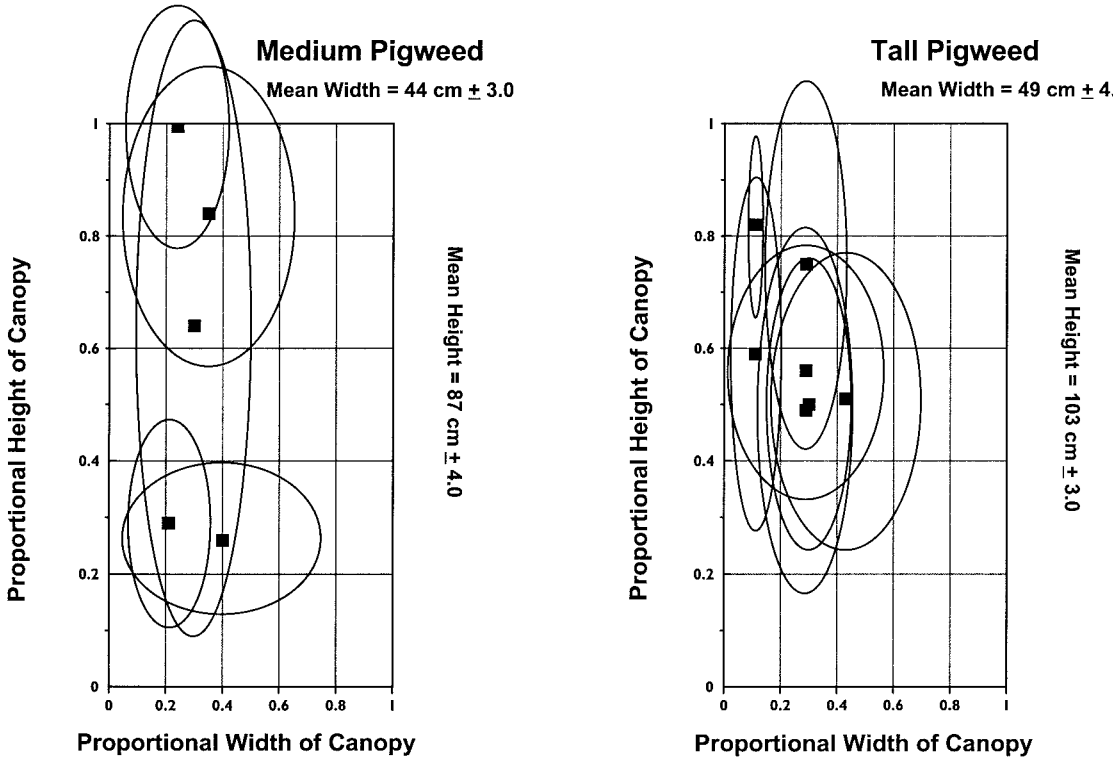


**Fig. 4.** Relative position of laboratory colony beet armyworm oviposition sites within the pigweed canopies of two different plant height categories (medium and tall). Squares indicate replicate means of at least five egg masses. Each mean is surrounded by a standard deviation ellipse. To facilitate visual conceptualization, the x-axis is scaled to be 51% (medium) or 48% (tall) the length of the y-axis, the average relationship of canopy widths to plant heights observed in this study for these plant-height categories.

but preference in the vertical dimension was less well defined in pigweed than in cotton. Diawara et al. (1992) reported that beet armyworm eggs are usually deposited in the upper half of celery plants, and the same seems to be true for tomato, *Lycopersicon esculentum,* plants (Zalom et al. 1983). Thus, Diawara et al. (1992) suggested that scouting for egg masses in celery may be preferable to scouting for young larvae, which tend to occur low in the celery canopy in relatively inaccessible positions. Our data suggest that spatial distribution of beet armyworm egg mass deposition within a plant canopy varies with the host plant species, and sometimes with developmental stage of the host. Our results should facilitate development of more effective and efficient egg scouting protocols in cotton, and provide a foundation for developing scouting protocols for pigweed stands as well.

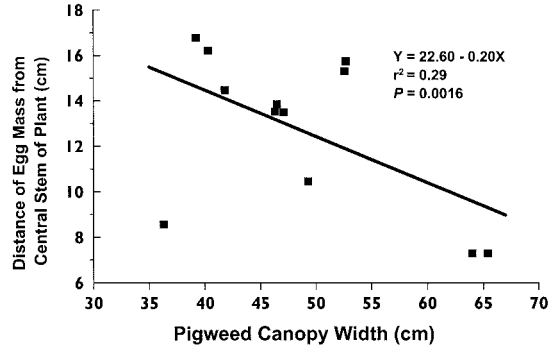


**Fig. 5.** Linear regression of horizontal distance of egg masses from the central axis of the plant on mean maximum width (radius) of the pigweed canopy. Each data point represents the mean of a replicate trial, with at least five egg masses per replicate.

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