Population Growth Potentials of the Mexican Bean Beetle, *Epilachna varivestis* (Coleoptera: Coccinellidae), on Soybean and Lima Bean Cultivars

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ABSTRACT Laboratory studies were conducted to determine effects of three soybean and one lima bean cultivars on the population growth potential of the Mexican bean beetle (MBB), *Epilachna varivestis* Mulsant. The cultivars were 'Bonus', 'Williams', and 'Cutler 71' soybean and 'Henderson Bush' lima bean. Greenhouse-grown plants were subjected to both immatures and adults. Data on development time, survival, and fecundity were used to construct MBB life tables for each cultivar. The lowest rate of population growth occurred on 'Cutler 71', where MBB immature development time, immature mortality, and preoviposition period were highest, and egg production was lowest. The highest rate occurred on lima bean. Adult longevity was not significantly affected by soybean cultivar, but was significantly longer on lima bean. Intrinsic rates of increase for MBB on 'Williams', 'Bonus', and 'Cutler 71' were 0.053, 0.043, and 0.012, respectively, compared to 0.100 on 'Henderson Bush'.

THE MEXICAN BEAN BEETLE (MBB), *Epilachna varivestis* Mulsant, is a pest of snap beans, *Phaseolus vulgaris* L., and lima beans, *P. lunutus* L., throughout the midwestern and eastern United States, but is a pest of soybean, *Glycine max* Merrill, only in certain areas of this region. Soybean yield is reduced by the foliage-feeding activity of MBB larvae and adults. The degree of defoliation is proportional to the past and present field densities of these stages.

Certain soybean cultivars adversely affect the population growth of MBB in the field. On some cultivars, MBB larvae exhibit lower survival (Van Duyn et al. 1972, Barney and Rock 1975) despite increased food consumption, which is due to a lower conversion efficiency of ingested food (Barney and Rock 1975). The resulting pupae weigh less (Barney and Rock 1975, Hallman et al. 1977) and suffer higher mortality (Van Duyn et al. 1972). MBB adults exhibit decreased longevity and fecundity (Van Duyn et al. 1972). Consequently, such cultivars sustain relatively lower percent defoliations (Elden and Paz 1977, Hallman et al. 1977) and higher yields (Elden and Paz 1977).

In the eastern Midwest, resistant soybean cultivars appear to have high potential for the management of MBB populations. The extensive planting of such cultivars could temporally and spatially retard the adaptational shift of MBB from *Phascolus* spp. to soybeans. However, the abundance and proximity of cultivated snap beans and lima beans could alter the dynamics of such phenomena. The objective of this research was to compare longevity, survival, and fecundity of MBB on three soybean cultivars of varying field resistances to each other and to a preferred *Phaseolus* cultivar.

Materials and Methods

The MBB culture was initiated in 1979 from adults and larvae collected from soybean fields in southern Indiana. Culture techniques were similar to those described by Stevens et al. (1975) and Flanders (1984).

Based on relative differences in field defoliation by the MBB (C.R.E., unpublished data), 'Williams', 'Cutler 71', and 'Bonus' soybeans were selected for study. 'Henderson Bush' lima bean was selected for comparison with soybean. Plants were grown in a greenhouse at 22–35°C, 30–80% RH, and a 14:10 (L:D) photoperiod. Seeds were treated with thiram and planted in vermiculite (ca. 2.5 liters) in plastic pots. The plants were thinned to eight per pot, and were fertilized weekly with 14N: 31P:14K liquid fertilizer. Only pots containing lima bean and soybean plants that had reached the V1–V2 and V3–V5 growth stages (Fehr et al. 1971), respectively, were used in the studies. Vegetative plants were chosen due to similarity in size and texture of leaves and ease of growing in the greenhouse.

All studies were conducted in environmental chambers at 25 ± 1°C, 55–75% RH, and a 14:10 (L:D) photoperiod (eight 40-W, cool-white fluorescent tubes per chamber). Immature and adult MBB were confined to test plants in clear plastic containers (20 cm diam by 39 cm high). Each container had three holes (7 cm diam), covered with cotton organdy, in the sides and six holes (2.5 cm

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Table 1. Mean durations of immature MBB stages on lima bean and soybean cultivars in the laboratory at 25 ± 1°C, 70–100% RH, and a 14:10 (L:D) photoperiod

Cultivar	$\bar{x}$ ± SE (days)						
	First instar	Second instar	Third instar	Fourth instar	Prepupa	Pupa	Total
Lima Bean							
'Henderson Bush'	3.4 ± 0.1b	3.1 ± 0.2a	3.5 ± 0.2c	4.5 ± 0.2b	2.3 ± 0.2ab	5.5 ± 0.3a	22.3 ± 0.4c
Soybean							
'Bonus'	4.3 ± 0.2a	3.5 ± 0.1a	4.5 ± 0.3b	5.5 ± 0.2a	2.0 ± 0.2ab	5.7 ± 0.2a	24.9 ± 0.2b
'Williams'	4.3 ± 0.2a	3.3 ± 0.1a	5.1 ± 0.3ab	5.4 ± 0.4ab	1.7 ± 0.2b	5.4 ± 0.1a	25.1 ± 0.5b
'Cutler 71'	4.2 ± 0.2a	3.2 ± 0.1a	5.8 ± 0.6a	5.7 ± 0.4a	2.7 ± 0.4a	5.2 ± 0.5a	26.3 ± 0.6a

Means followed by the same letter within a column are not significantly different ($P \leq 0.05$; Duncan's [1955] multiple range test).

diam) in the lid for ventilation. A foam ring surrounded the enclosed pot and confined MBB larvae and adults to the upper volume of the test container. The relative humidity inside the containers was 70–95%. To study the effects of cultivars on immature MBB, hatching egg masses were obtained from the culture. Fifty newly emerged first instars were transferred with a small brush to the intact plants in each container. Each treatment (cultivar) was replicated 20 times. The foliage in each unit was replaced as necessary. The number of MBB in each developmental stage was recorded daily. The data were used to calculate mean duration and survival of each stage. The mean duration of a stage was defined as the time required for at least 50% of the individuals to pass from the previous to the next stage. New adults were counted by sex daily.

Newly eclosed male and female MBB adults from the preceding studies of immature MBB were randomly paired, and each pair was then placed in a container with the intact foliage of the same cultivar on which they had developed. Each treatment (cultivar) was replicated 20 times. Adult survival, and egg mass and egg production were recorded daily. Preoviposition and oviposition periods were calculated from these data for fecund females. In any container, any male that died before the female was replaced. All adults in the studies were assumed to be capable of successfully mating.

To determine the duration and mortality of the egg stage, 20 newly laid egg masses were randomly selected from the culture. The number of eggs per egg mass was recorded and the eggs were then placed in an environmental chamber. The egg masses were examined at 8-h intervals and the time to hatch was recorded. The number of eggs producing larvae was recorded for each mass to determine egg survival. The duration of the egg stage was calculated as the time to 50% egg hatch. Plant cultivar was assumed not to affect egg survival and duration.

Life tables were constructed for each cultivar from the results of the immature and adult studies. The tables were constructed and statistics calculated by methods described by Southwood (1978). An iterative method was used to calculate the intrinsic rate of increase for each cultivar (Andrewartha and Birch 1954).

Results

Development from egg hatch to adult eclosion was significantly different among cultivars ($P < 0.05$; analysis of variance [ANOVA]), requiring 22.3, 24.9, 25.1, and 26.3 days on 'Henderson Bush' lima bean, 'Bonus', 'Williams', and 'Cutler 71', respectively (Table 1). These differences were the result of significant differences ($P \leq 0.05$; ANOVA) in the durations of first, third, and fourth instars, and prepupae (i.e., fourth instars that had attached to surfaces, but whose larval integuments were still intact).

Immature survival from egg hatch to adult eclosion was significantly higher ($P \leq 0.05$; ANOVA) on 'Williams' and lima bean compared to 'Bonus' and 'Cutler 71' (Table 2). The low survival on 'Bo-

Table 2. Percent survival of immature MBB stages on lima bean and soybean cultivars in the laboratory at 25 ± 1°C, 70–100% RH, and 14:10 (L:D) photoperiod

Cultivar	$\bar{x}$ ± SE (days)						
	First instar	Second instar	Third instar	Fourth instar	Prepupa	Pupa	Total
Lima Bean							
'Henderson Bush'	60.6 ± 3.8b	77.4 ± 3.4b	83.2 ± 3.8a	88.7 ± 2.4a	84.3 ± 3.5a	92.3 ± 1.6a	29.6 ± 4.2a
Soybean							
'Bonus'	42.0 ± 3.8c	74.6 ± 3.0b	65.2 ± 4.7b	73.9 ± 6.5ab	87.9 ± 3.6a	88.4 ± 3.4a	15.9 ± 2.3b
'Williams'	72.8 ± 3.0a	89.5 ± 1.5a	68.3 ± 5.0b	78.5 ± 4.4a	88.0 ± 5.4a	83.3 ± 2.5ab	30.5 ± 4.3a
'Cutler 71'	72.7 ± 2.0a	87.0 ± 1.7a	55.9 ± 5.1b	64.6 ± 4.7b	63.6 ± 6.7b	74.3 ± 5.6b	15.9 ± 2.8b

Means followed by the same letter within a column are not significantly different ($P \leq 0.05$; Duncan's [1955] multiple range test).

Table 3. Mean reproductive potentials and durations of adult MBB females on lima bean and soybean cultivars in the laboratory at 25 ± 1°C, 70–100% RH, and a 14:10 (L:D) photoperiod

Cultivar	$\bar{x}$ ± SE					
	Adult longevity (days)	Preoviposition period (days)	Oviposition period (days)	Egg masses/♀	Eggs/♀	Eggs/ egg mass
Lima Bean						
'Henderson Bush'	30.8 ± 1.6a	7.3 ± 0.2c	20.7 ± 1.6a	14.9 ± 1.2a	621.4 ± 52.9a	42.1 ± 2.5ab
Soybean						
'Bonus'	24.3 ± 2.2b	10.7 ± 1.0b	11.5 ± 1.9b	3.2 ± 0.7b	110.7 ± 24.8b	34.7 ± 3.1b
'Williams'	22.7 ± 2.3b	11.3 ± 0.6b	10.0 ± 2.2b	2.4 ± 0.5bc	99.8 ± 22.7b	44.9 ± 3.9a
'Cutler 71'	22.2 ± 2.0b	14.9 ± 0.8a	5.8 ± 1.4b	1.3 ± 0.3c	27.8 ± 7.6c	22.4 ± 3.7c

Means followed by the same letter within a column are not significantly different ($P \leq 0.05$; Duncan's [1955] multiple range test). Preoviposition and oviposition period means were based only on females that produced eggs: 20 on 'Henderson Bush', 14 on 'Bonus' and 'Williams', and 11 on 'Cutler 71'. All other means are based on 20 replications per cultivar.

nus' was due to relatively higher mortalities in the first three instars, whereas on 'Cutler 71' it was due to higher mortalities in the last larval instar, including prepupae, and in pupae.

The longevity of MBB females was significantly longer ($P \leq 0.05$; ANOVA) on lima bean than on the soybean cultivars, but it was not significantly different among the soybean cultivars (Table 3). It was observed that the females that had developed on the soybean cultivars were smaller than those that developed on lima beans.

Of the 20 females per cultivar, 100, 70, 70, and 55% produced eggs on lima bean, 'Bonus', 'Williams', and 'Cutler 71', respectively. Fecund females began laying eggs earlier and continued laying longer on lima bean than on the soybean cultivars (Table 3). Females on 'Cutler 71' exhibited a significantly longer ($P \leq 0.05$; ANOVA) preoviposition period than on the other cultivars, but oviposition periods among MBB on the soybean cultivars were not significantly different.

Cultivar significantly affected the egg production of MBB. Daily egg production peaked 10 to 15 days after adult eclosion on all cultivars. However, egg production on lima bean did not begin to decline until 25 to 30 days after adult eclosion, whereas on the soybean cultivars it began declining 15–20 days after eclosion. Mean numbers of egg masses and eggs per female were highest ($P \leq 0.05$; ANOVA) on lima bean, and lowest on 'Cutler 71' (Table 3). Eggs per egg mass were lowest ($P \leq 0.05$; ANOVA) on 'Cutler 71'.

The mean survival of eggs in a mass was 82.1 ± 2.5% ($n = 1,079$, $P = 0.05$) and the mean duration of the egg stage was 5.0 ± 0.1 days. Linear regression analysis of eggs per egg mass on egg survival and on duration of the egg stage indicated no significant relationships ($P > 0.05$; ANOVA).

Statistics calculated from the life tables that were constructed for each cultivar indicated that the major difference in population growth potential was due to net reproductive rates (Table 4). Net reproductive rates on lima bean, 'Williams', and 'Bonus' were 42.4-, 7.1-, and 4.1-fold higher, respectively, than on 'Cutler 71'. The generation time of MBB on lima bean was the shortest at 43.6 days, and that on 'Cutler 71' was the longest at 50.5 days. The intrinsic rates of increase on lima bean, 'Williams', and 'Bonus' were 8.3-, 4.4-, and 3.6-fold greater, respectively, than on 'Cutler 71'. The high intrinsic rate of increase of MBB on lima bean was due to its relatively higher net reproductive rate and shorter generation time compared to the soybean cultivars.

Discussion

The results indicated that the cultivars that were studied significantly affected the population growth potential of MBB. These effects were a result of differences in 1) duration of immature development, 2) survival of immature stages, 3) duration of female preoviposition period, and 4) production of eggs. Our observations on female size concur with those of Campbell and Brett (1966), who also found that females reared on resistant *Phaseolus* cultivars were smaller than those on more susceptible cultivars. Under the experimental conditions, the greatest difference in resistance was between 'Henderson Bush' lima bean and the soybean cultivars, confirming Kogan's (1972) conclusion that MBB is better adapted to *Phaseolus* spp., its presumed evolutionary host, than to *Glycine max*, its recently adopted host. However, there also were

Table 4. Life table statistics of MBB on lima bean and soybean cultivars in the laboratory at 25 ± 1°C, 70–100% RH, and a 14:10 (L:D) photoperiod

Cultivar	Net reproductive rate (♀♀ progeny/ ♀ parent)	Generation time (days)	Intrinsic rate of increase (per ♀/day)
Lima Bean			
'Henderson Bush'	76.4	43.6	0.100
Soybean			
'Bonus'	7.3	46.5	0.043
'Williams'	12.7	47.8	0.053
'Cutler 71'	1.8	50.5	0.012

significant differences in resistance to MBB population growth among the soybean cultivars. Thus, the planting of resistant soybean cultivars could be an effective tactic for the suppression of MBB populations.

The present differences in resistance among soybean cultivars and between soybean and *Phaseolus* spp. may diminish as MBB continues to adapt to soybean. Soybean has been attractive to MBB adults for a considerable length of time (Davis 1925), but populations have only recently reached damaging levels in apparent response to post-World War II increase in soybean acreage and the more frequent double cropping of soybean with small grains. Currently, damage to soybean occurs in relatively isolated geographic areas, despite widespread cultivation of soybean and broad distribution of MBB populations on *Phaseolus* spp. In the Midwest, high populations of MBB on soybean presently develop only in southern and central Indiana, eastern Ohio, northern Kentucky, and southeastern Illinois, but the problem appears to be expanding. The geographic expansion of the MBB on soybean may be due to a combination of factors, including higher survival of overwintering adults, the presence of abundant early-season host plants that allow rapid early season population increases, and the planting of susceptible soybean cultivars. Increased colonization of soybean by MBB also may be a presently incomplete but still occurring adaptational shift of local populations to a new food source (Kogan 1981), which may not only be affected by levels of resistance in currently planted soybean cultivars but also affect the potential for future MBB control by resistance mechanisms.

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