DIFFERENCES IN PENETRATION AND EFFICACY OF INSECTICIDE SPRAYS APPLIED BY AERIAL AND GROUND EQUIPMENT TO SOYBEAN[1]

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ABSTRACT

Insecticide sprays were applied to conventionally spaced (76.2 cm) soybean, *Glycine max* (L.) Merrill, by aerial and ground equipment. Drop penetration (no. drops/cm^2 and mean percent coverage) and drop size (number median diameter) were measured within and between the two treatments. Larval mortality was determined at each of three vertical strata of the canopy for the soybean looper, *Pseudoplusia includens* (Walker), in central Mississippi and for a pest complex of the soybean looper, green cloverworm, *Plathypena scabra* (F.), and velvetbean caterpillar, *Anticarsia gemmatalis* Hubner, in south Mississippi. At both locations aerial equipment deposited a drop size in successively decreasing numbers/unit area from the top down within the upper two-thirds of the canopy. Conversely, ground equipment generally delivered successively smaller and fewer drops to each lower level within the canopy at both locations. Significantly more spray droplets were deposited at each sample location in the soybean canopy by ground equipment than by aerial equipment. Mortality data indicated that permethrin (0.11 kg AI/ha) provided better control of the soybean looper when applied with ground equipment than with aerial equipment in central Mississippi, while methyl parathion (0.28 kg AI/ha) was equally effective when applied by air or ground in south Mississippi for control of the pest complex. Largest mortality was observed within the upper one-third of the soybean canopy for both methods of application at the two locations.

Key Words: Insecticides, application method, dosage, efficacy, lepidopterous pests, soybean.

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INTRODUCTION

The success or failure of a pest control technique is contigent on the accuracy of timing and the efficiency of implementation of the prescribed control measure. The type and dose (amount applied) of insecticide required to suppress most insect pests are generally well researched and available through public or private sources, but dosage (amount deposited) information is rather scarce. The proper method of application (aerial or ground) to employ, however, has been given less consideration even though it may affect the success of the management strategy.

Economic injury levels are based on break-even analysis and are intended to estimate the level of damage at which the cost of control is equivalent to the loss

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of expected yield (income) due to insect damage. Stone and Pedigo (1972) introduced the concept of a "gain threshold" which describes the minimum yield benefit (kg/ha) that must be achieved to justify the treatment where,

$$\text{gain threshold (kg/ha)} = \frac{\text{Management costs (\$/ha)}}{\text{market value of crop (\$/kg)}} .$$

As the cost of management (cost of insecticide plus cost of application) increases, the net benefit of control decreases. Hence, the actual economic injury level increases to accommodate the higher gain threshold which reflects the reduced profitability of production. Furthermore, an inefficiency of application may allow for rapid recolonization by pests which may require additional control applications. The point should be made, however, that special circumstances such as poor field conditions, spray drift, timing, scarcity of capital/labor, or grower preference may play an important and justifiable role in dictating the method of application for any given situation.

The purpose of this study is to characterize and evaluate aerial and ground methods of insecticide application on soybean, *Glycine max* (L.) Merrill, in Mississippi. Knowledge of the factors that influence efficacy of insecticides applied using these methods can be useful to growers and pest control applicators to make marginal decisions about the "proper" method of application for control of specific insect pests on specific crops with specific insecticides. Thus, we examined the relative efficiency of ground and aerial insecticide applications comparing spray penetration into the canopy and pest suppression on soybean.

MATERIALS AND METHODS

Field tests were conducted during 1982 at two locations in Mississippi.

Central Mississippi Field Test

'Centennial' soybean was planted within a 0.40 ha block on the Mississippi Brown Loam Branch Experiment Station near Raymond, MS. Plots consisted of 24 rows spaced 76.2 cm apart and 15.3 m long with 24 buffer rows (untreated) separating each treatment. Recommended crop management practices were employed in all plots. The experimental design was completely random with four replications per treatment (= method of application).

Permethrin (0.11 kg AI/ha) was applied by aerial and ground equipment to designated plots at conventional gallonages in order to evaluate currently accepted and commonly used application techniques. A fixed-wing Ag-CAT® aircraft was used to apply the insecticide in 28.06 liters of water/ha using D-10 disks and no. 45 cores over an 18.3 m spray swath. Airspeed was 177.02 km/h and the boom was ca. 2.44 m above the canopy. A tractor boom sprayer was utilized in applying the insecticide to ground-treated plots using 93.53 liters of water/ha with 8003 nozzles spaced 51 cm apart and at 2.25 kg/cm^2 of pressure. The plants were in the R-4 (full pod set, Fehr et al. 1971) stage of development at the time of application.

Prior to application of the insecticide, a series of four water sensitive cards[3] were attached to a pole with metal clips and the poles were positioned in an

[3] Water sensitive cards manufactured by Ciba-Geigy Corporation.

intermediate row of each treatment plot. Each card in the series was evenly spaced and positioned at a different vertical level (terminal ca. 123 cm, median ca. 83 cm, lower ca. 43 cm, and soil ca. 3 cm) within the canopy so that differences and degree of spray penetration could be assessed. The cards were preserved and later analyzed with an image analyzer.[4] The variables used to characterize spray penetration for this study were drops/cm^2, mean percent of area covered, and number median diameter (NMD, the diameter [microns] at which one-half of the drops are larger and one-half are smaller).

Soybean looper, *Pseudoplusia includens* (Walker), populations were sampled 1 day prior to and 2, 5, 10, and 25 days after application of the insecticide. A one m^2 sampling board, slotted and fitted with rubber gaskets, was placed around the sample plants. Soybean pods, stems, and foliage, with the larvae intact, were clipped at each card level (except terminal) and carefully placed on a ground cloth where the insects were identified and recorded. Data collected were subjected to an analysis of variance and Duncan's multiple range test ($P < 0.05$).

South Mississippi Field Test

'Coker 338' soybean was planted in a large field at Wiggins, MS. Plots consisted of 21 rows 15.3 m long and spaced 101.6 cm apart. Water sensitive cards were placed within the plots and the experimental design and analysis also were similar to the central Mississippi test.

Methyl parathion (0.28 kg AI/ha) was applied to a defoliating complex of the soybean looper (ca. 20%), velvetbean caterpillar, *Anticarsia gemmatalis* Hubner (ca. 40%), and green cloverworm, *Plathypena scabra* (Fabricius) (ca. 40%). Larvae of all species were in the intermediate stages of development (stages 3 and 4); however, a small percentage (ca. 15%) of the larvae were developed to a lesser or greater degree. Insecticide was applied to aerial plots with a fixed wing Cessna 188-B aircraft using D-8 orifice disks and no. 45 cores to apply 28.06 liters of water/ha over a 15.3 m spray swath. Airspeed was 177.02 km/h and the boom was ca. 2.44 m above the foliage canopy. A Hahn Hy-Boy applied the insecticide in 93.53 liters of water/ha using 8003 nozzles spaced 51 cm apart and 2.25 kg/cm^2 of pressure. The plants were in the R-4 stage of development at the time of application.

Sampling intervals and techniques were the same as in the central Mississippi test. All samples were obtained from the middle eight rows of each treatment plot and the data were analyzed as in the above test.

RESULTS AND DISCUSSION

Central Mississippi Field Test

A comparison of conventional application techniques indicated that permethrin applied with ground equipment reduced larval populations significantly more than permethrin applied by fixed wing aircraft (Table 1). Soybean loopers were collected in significantly lower numbers on days 2, 5, and 10 after application, in plots sprayed with ground equipment, but no difference was observed between the two treatments on day 25 post treatment. There was no difference in looper mortality at vertical positions within the canopy when aerial and ground application techniques were compared. However, when the data for both treatments were averaged differences were observed among the vertical levels (Figure 1). On

[4] Image analyzer manufactured by Optomax, Inc. of Hollis, New Hampshire.

Table 1. Effect of insecticides applied by air and ground; A — on the soybean looper at Raymond, MS; B — on the combined populations of the soybean looper, green cloverworm, and velvetbean caterpillar at Wiggins, MS. 1982.

Insecticide (rate)	Method of Application	Percent larval reduction compared to untreated check on days post application: day 2	day 5	day 10	day 25
A					
permethrin	aerial	69.23aA*	68.63aA	26.25aB	11.10aB
(0.11 kg/ha)	ground	92.88bA	93.13bA	63.47bB	20.33aC
B					
methyl para.	aerial	66.92aA	48.08aAB	55.62aAB	13.00aB
(0.28 kg/ha)	ground	77.10aA	65.63aA	39.90aAB	8.08aB

* Means followed by the same letter within columns (a-b) or rows (A-C) are not significantly different ($P < 0.05$) by Duncan's multiple range test.

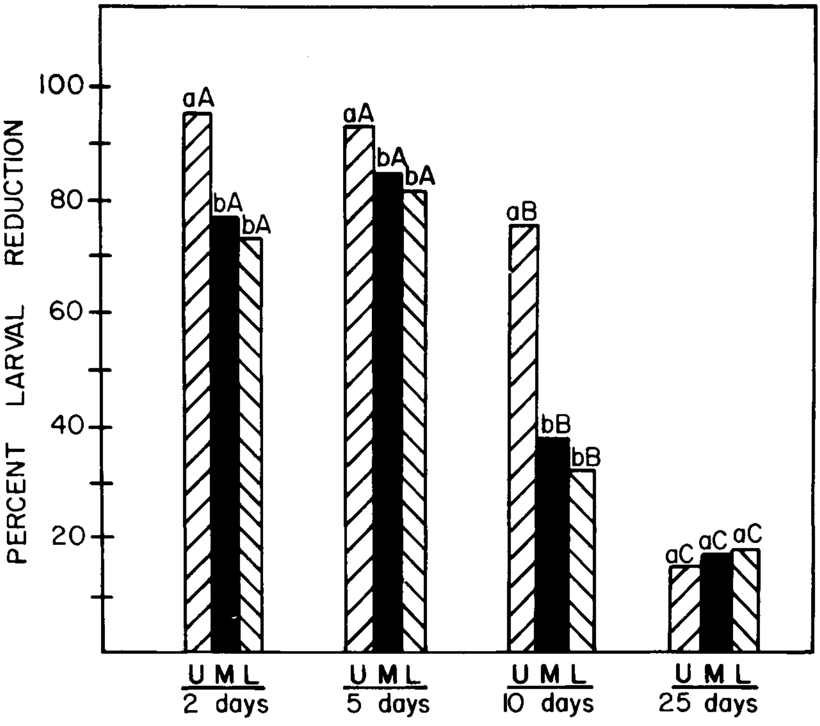

Fig. 1. Percent larval reductions of the soybean looper within three vertical strata (upper = U, median = M, lower = L) of soybean over four sample dates. Means followed by the same letters among levels within a date (a-b) or among dates (A-C) are not significantly different ($P < 0.05$) by Duncan's multiple range test. Raymond, MS 1982.

sampling days 2, 5, and 10 post application, larval mortality within the upper one-third of the canopy was significantly higher than larval mortality within the median and lower portions of the canopy. Apparently the soybean foliage in the uppermost portions of the canopy intercepted a disproportionate amount of insecticide spray, and this resulted in reduced mortality within the lower portions of the canopy.

Since different application criteria and spray volumes were used, caution should be exercised when comparing measurements of drop sizes and density between application methods; however, these data are useful when examining gross relationships between these modes of application. Drop penetration data within each treatment may explain the observed differences in larval mortality within the levels of the canopy.

Drop density (no. drops/cm^2) significantly decreased at each successively lower level in the soybean canopy when the insecticide was applied with aerial or ground equipment, with the former depositing about the same number of drops/cm^2 at the lowest two levels of the foliage canopy (Figure 2A). Similarly, there was less overall spray coverage (mean percent of area covered) in the plots sprayed with aerial than with ground equipment, with successively less coverage within both treatments as the spray entered and moved down into the canopy (Figure 2B). The greater drop density and coverage in plots sprayed with ground equipment are a function of the greater spray volume delivered by that system and complicates the separation of direct application efficiency effects between treatments. Density and coverage are probably also a function of evaporation and swath displacement and/or drift, parameters not measured in this study. Nevertheless, reduced drop density and coverage from the upper to the lower portions of the plant canopy within treatments may be attributed to spray interception by the uppermost portions of the soybean foliage. Smith and Burt (1970) observed similar effects with cotton foliage and noted that spray interception at a given level was a function of the number of drops deposited at each lower level.

The differences in spray volume, nozzle types and sizes, pressures, ground speeds and meteorological conditions when the insecticides were applied to the canopy by the two application techniques prevents any direct comparisions of NMD between these treatments. However, fluctuations in drop size within a given application treatment provide data necessary to characterize the particular mode of application. There were no differences in NMD at the vertical positions in the canopy in plots sprayed with aerial equipment, whereas the NMD within plots sprayed with ground equipment decreased as drops moved down into the canopy (Table 2). The reduction in the NMD within plots sprayed with ground equipment is due to interception of the largest drops at the highest levels of the canopy. The combined incidence of larger drops with greater drop deposition may explain the higher soybean looper mortality within the plots sprayed with ground equipment.

South Mississippi Field Test

Methyl parathion was equally effective in controlling the defoliating complex of green cloverworm, velvetbean caterpillar, and soybean looper when applied to soybean by either aerial or ground equipment (Table 1). The relatively low overall mortality within and between treatments may be explained by the comparable tolerance of the soybean looper to methyl parathion. Only the very small larvae of this species were observed to be adversely affected by the toxicant, whereas all stages of the remaining species were decimated. As in the central Mississippi test,

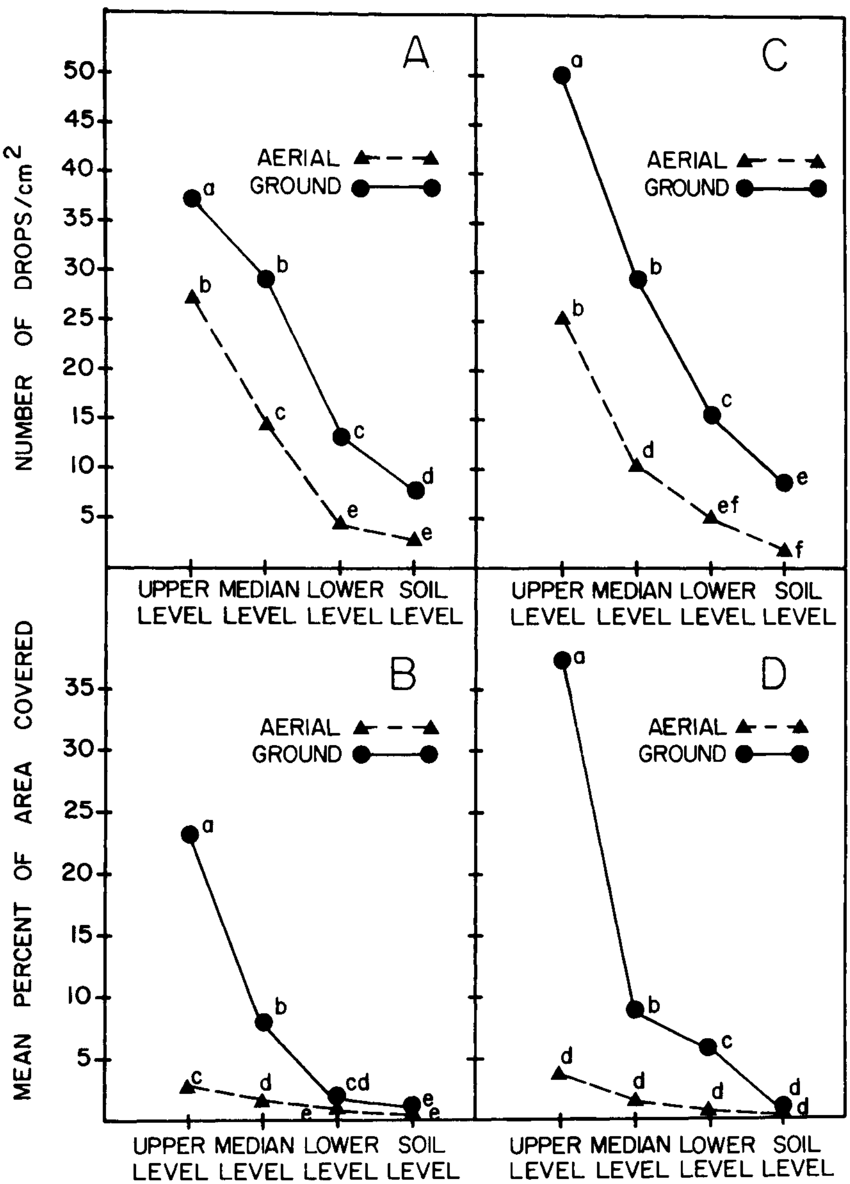

Fig. 2. A — Total number of drops/cm^2, and B — percent of area covered by insecticide deposited on water sensitive cards at four vertical levels within soybean at Raymond, MS. C — Total number of drops/cm^2, and D — percent of area covered by insecticide at Wiggins, MS. Means followed by the same letters are not significantly different ($P < 0.05$) by Duncan's multiple range test. 1982.

Table 2. Number median diameter (microns) of insecticide spray deposited on water sensitive cards at four vertical levels in soybean by aerial and ground equipment at Raymond and Wiggins, MS, 1982.

Card Position	Number median diameter at location			
	Raymond		Wiggins	
	aerial	ground	aerial	ground
Terminal level	275.0a*	495.0a	275.0a	545.0a
Median level	265.0a	365.0b	265.0a	435.0b
Lower level	255.0a	285.0c	265.0a	315.0c
Soil level	255.0a	275.0c	295.0a	255.0d

* Means within the same column followed by the same letter (a-d) are not significantly different ($P < 0.05$) by Duncan's multiple range test.

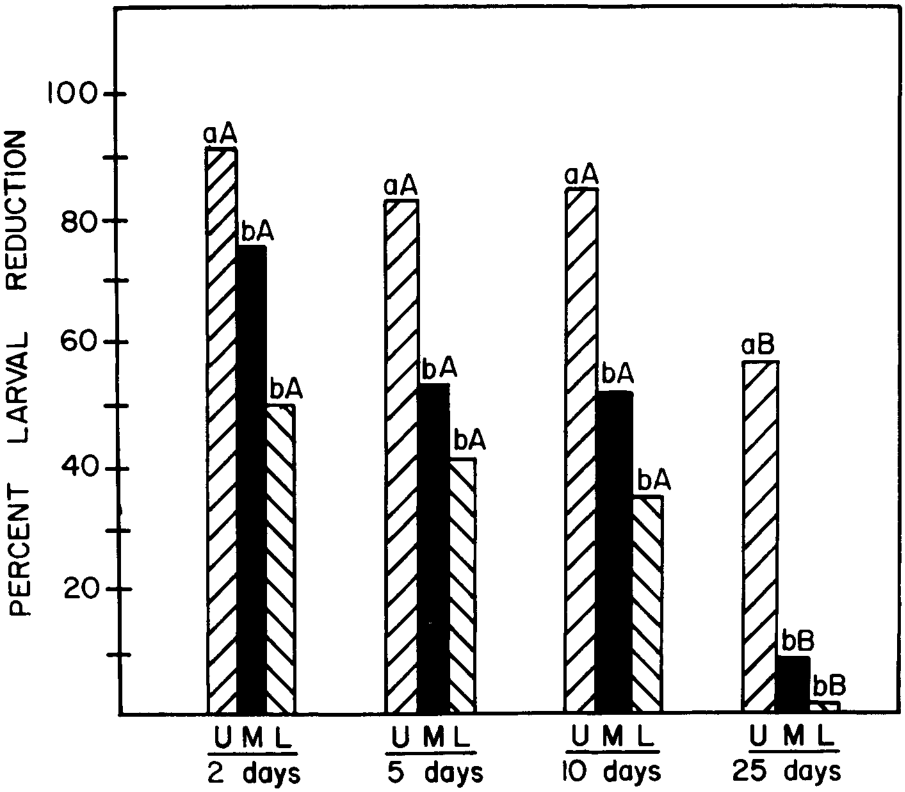

Fig. 3. Percent reduction of lepidopterous larvae (soybean looper, green cloverworm, and velvetbean caterpillar) within three vertical strata (upper = U, median = M, lower = L) of soybean over four sample dates. Means followed by the same letters among levels within a date (a-b) or among dates (A-B) are not significantly different ($P < 0.05$) by Duncan's multiple range test. 1982.

differences in larval mortality between vertical positions within the canopy were observed when treatments were combined (Figure 3). On all sample dates after application, larval mortality within the upper one-third of the canopy was greater than the mortality at all points lower in the canopy.

Criteria to evaluate spray deposition within the soybean canopy were similar to those used in the central Mississippi test. Measurements of spray deposition as drops/cm^2 were similar to data obtained in the previous test (Figure 2A and C). Likewise, trends for percent area covered by spray (Figure 2B and D) and NMD (Table 2) were similar for both locations with the aerial equipment applying relatively uniform median droplet sizes, while the ground equipment deposited successively smaller drops with less coverage at each descending vertical level within the canopy.

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