A PESTICIDE CALIBRATION AND MIXING PROGRAM FOR HAND-HELD CALCULATORS

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Abstract: This paper reports on a software program written for a hand-held Hewlett-Packard HP-41 calculator that aids in pesticide mixing and sprayer calibration. Advantages offered by the calculator system over similar personal computer programs include reduced cost, field portability, and the ability to input spraying parameters in a combination of English and metric units. Furthermore, the calculator program is less rigid in input requirements and allows changes in individual sprayer parameters without reentry of unchanged parameters that personal computer programs require.

Key Words: Calculator, insecticide, mixing, software.

The recent increase in personal computer usage by agricultural experimental station personnel and pesticide industry representatives has led to the development of software that aids in small-plot pesticide studies. These programs provide such things as plot randomization schemes, plot layout maps, and reports; and may be used to determine the amounts of chemicals to add to the spray tanks (PDMP 1986). Although the benefits of these mixing programs, e.g. improved accuracy and reproducibility, are obvious, these programs also represent some disadvantages. Mixing programs must be run on relatively expensive personal computers which are seldom taken into the field. Thus changes in sprayer parameters made in the field cannot be easily incorporated into the program. The mixing programs currently available also lack a routine for sprayer calibration. The program user is simply prompted to input the sprayer output. Following this, the user is required to enter additional sprayer parameters by following a rigid menu. If only slight differences in spraying parameters are needed, e.g. two different rates of the same material, the user must reenter all spraying parameters. A final problem with current mixing programs arises because pesticide mixing is commonly performed with a combination of English and metric units. Spray boom width, length of sprayer travel, and rate of chemical, i.e., lb. AI per A, are commonly measured in English units while volume of spray per nozzle, volumes of liquid formulations and weights of solid formulations are often measured in metric units. Personal computer software allows for metric or English calculations but not combinations.

The objective of this report is to describe a software program written for a hand-held Hewlett-Packard HP-41 calculator which aids in sprayer calibration and allows the input of a combination of English and metric units. The program also utilizes the user-definable keys on the HP-41 in order to eliminate reentry of unchanged sprayer parameters.

The HP-41 system components required are the HP-41 calculator, overlay (Fig. 1) and the program. Magnetic program cards and a card reader are beneficial but not required. Program lines are listed in Fig. 2. These lines may be entered

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through keystrokes or by use of the optional card reader. Once entered, the non-volatile HP-41 memory will retain the program, provided memory is not overwritten, after calculator power is turned off.

Fig. 1. Calculator overlay with spraying parameters.

The program is initialized and executed by pressing the following keys: EXQ, ALPHA, S, P, R, A, Y, E, R, and ALPHA. These keystrokes result in the user being prompted for sprayer parameters. The first four parameters (spray volume in ml per nozzle per time unit, e.g. 30 sec; number of nozzles; spray width in ft; and length in ft of sprayer travel per time unit, e.g. 30 sec) are required for sprayer calibration and are listed on the overlay above keys A, B, C and D, respectively (Fig. 1). Each parameter is entered and the corresponding key (A, B, C or D) is pressed to store it. For example, to calibrate a backpack sprayer with three nozzles, the user would measure the amount of spray delivered by one nozzle in 30 sec, e.g. 54 ml. This value (54) is entered and key A is pressed. The values for the number of nozzles (3) is entered and key B is pressed. The width of the spray pattern in ft is measured, the value, e.g. 6, is entered and key C is pressed. Finally, the distance in ft that the sprayer travels in 30 sec is measured, the corresponding value, e.g. 80, is entered and key D is pressed. The sprayer output (gal per A) is next determined and displayed by pressing key E. In this example, 'GAL:A = 3.88' is displayed when key E is pressed. Additional parameters of chemical rate (lb AI per A), tank capacity (ml) and liquid formulation (lb AI per gal) are entered with keys F, G and H, respectively (Fig. 1). For example, if carbaryl (4 lb AI per gal) is to be applied with the aforementioned 3-nozzle backpack sprayer at a rate of 1.5 lb AI per A and the amount of spray required or tank capacity is 2000 ml, the following keystrokes are needed. The rate 1.5 is
entered and key F is pressed. The value of the tank capacity (2000) is entered and key G is pressed. The formulation value (4) is entered and key H is pressed. The amount (ml) of liquid formulation to add to the tank is then calculated and displayed when key I is pressed. In this example the display is ‘ML/TANK=193.1’. If a second carbaryl rate of 1 lb AI per A is needed, the rate value (1) is entered and key F is pressed. The amount of material to add to the tank is determined by simply pressing key I. For wettable powder (WP) formulations, when the percentage AI of the material is entered into key H, the amount of WP in g to be added to the spray tank is displayed.

The sprayer calibration and mixing program may appear complicated, however it offers a quick and functional method for sprayer calibration and mixing. Total time for program initialization, sprayer calibration and mixing determinations for a small plot study with 10 insecticide treatments, is generally less than two min. Furthermore, the calculator system is portable, less expensive and, under most field conditions, offers a practical alternative to the personal computer program.

```
Program Line Comment
01 LBL 'SPRAYER' labels program
02 SF 27 places calculator in user mode
03 'PARAMETERS' prompts program user for
04 PROMPT sprayer parameters
05 LBL A stores ml per nozzle in
06 STO 01 register 01
07 RTN stores number of nozzles
08 LBL B in register 02
09 STO 02 stores spray pattern width
10 RTN in register 03
11 LBL C stores distance of sprayer
12 STO 04 travel in register 04
13 RTN calculates sprayer output (GAL/A)
14 LBL D total GAL caught = (ml per nozzle *
15 STO 04 number nozzles)/3785
16 RTN area sprayed = (spray pattern width *
17 LBL E distance of sprayer travel)/43560
18 RCL 01 GPA = total GAL caught/area sprayed
19 RCL 02
20 *
21 3785
22 /
23 RCL 03
24 RCL 04
25 *
26 43560
27 /
28 /
29 STO 05
30 'GAL/A=' displays GPA
31 ARCL 05
32 AVIEW stores pesticide rate in
33 RTN register 06
34 LBL F stores sprayer tank capacity in
35 STO 06 register 07
36 RTN
37 LBL G
38 STO 07
Fig. 2. Sprayer calibration and mixing program lines.
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Program Line Comment
30  RTN stores liquid formulation in
40  LBL H register 08
41  STO 08 calculates amount of liquid formulation
42  RTN to add to spray tank
43  LBL I ml = (lb AI per A * ml per tank)/
44  RCL 06 (GPA * lb AI per GAL)
45  RCL 07
46  * displays ml per tank
47  RCL 05 calculates amount of WP
48  RCL 08 to add to tank
49  * g = (100 * lb AI per A * ml per tank
50  / * 454) / (WP% * GPA * 3785)
51  'ML/TANK=' displays grams per tank
52  ARCL X
53  AVIEW
54  RTN
55  LBL J
56  STO 09
57  100
58  RCL 06
59  *
60  RCL 07
61  *
62  454
63  *
64  RCL 09
65  RCL 05
66  *
67  3785
68  *
69  /
70  'G/TANK='
71  ARCL X
72  AVIEW
73  .END.

Fig. 2. Continued.

REFERENCES CITED

FUMIGANT ACTION OF VARIOUS INSECTICIDES 
ON THE EGG AND FIRST LARVAL STAGE 
OF HELOlOTHS ZEA

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Abstract: The fumigant effect of chlorpyrifos, methyl parathion, monocrotophos, methomyl, amitraz, chlordimefom, and fenvalerate was studied in the laboratory on Heliothis virescens (F.) eggs and young larvae. Chlordimefom and methyl parathion caused ca. 30% egg mortality while the other compounds caused ca. 20% mortality. Vapors of both chlorpyrifos and methyl parathion induced high mortality of first instar larvae, while mortality due to the vapor of the remaining compounds did not differ from the water control. Larval mortality was greatest when larvae were exposed to insecticide vapor during emergence.

Key Words: Fumigant effect, tobacco budworm, cotton, chlorpyrifos, methyl parathion, chlordimefom.

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The tobacco budworm (TBW), Heliothis virescens (F.), is a major pest of cotton in the United States. This pest and the cotton bollworm, H. zea (Boddie), are the primary causes of the loss of cotton production throughout the cotton belt (Head 1985; King et al. 1986). To reduce crop loss due to these Heliothis species, numerous pesticide treatments are applied to commercial cotton fields, primarily by aerial application. The main disadvantages of this application method are incomplete coverage and poor penetration into the cotton canopy (Uk and Courshee 1982). However, if insecticides are used which have an active vapor phase, control might be achieved through a fumigant effect.

In a previous paper we reported on the ovicidal activity of various insecticides on TBW (Horowitz et al. 1987). The purpose of this paper is to report on the fumigant effect on these insecticides on the egg and early larval stages of TBW.

MATERIALS AND METHODS

A colony of TBW was maintained for this study with the original material obtained from a laboratory colony at the ARS-USDA Western Cotton Research Lab, Phoenix, Arizona. Larvae were reared on a pinto bean diet at room temperature (21 to 24°C). Moths were allowed to mate in a cylindrical carton lined with paper towel which served as a substrate for oviposition.

Seven insecticides and a water control were tested in this study: monocrotophos (Azodrin 5M, Shell Corp.), chlorpyrifos (Lorsban 4E, Dow Chemical Corp.), methyl parathion (Methyl Parathion 5M, FMC Corp.), methomyl (Lannate 1.8W, DuPont Corp.), amitraz (Baam 1.5EC, Nor-Am Chemical Corp.), fenvalerate (Pydrin 2.4 EC, DuPont Corp.) and chlordimefom (Galecron 4E, Ciba-Geigy). In each case, an aqueous solution of the formulated material was used. The concentrations treated were extrapolated from field rates (see Table 1).

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The technique used for testing fumigant effect of each material was modified from Sun and Johnson (1963). Each test unit consisted of a plastic petri dish (10 cm diameter). The insecticide being tested was incorporated into a 4 cm² piece of filter paper; the filter paper was dipped into an aqueous solution of the formulated material for 3 s, then allowed to air dry for 1 h under a fume hood. In each test, a control using only water was also prepared. The paper was then placed onto a petri dish lid and covered with a 9-cm-diameter filter paper (Whatman #1) to provide a barrier against direct contact of insecticide by the insect.

Eggs used in each test were no more than 24 h old. A piece of paper towel containing ova was placed in the bottom of the petri dish and the dish closed with the lid containing the insecticide. Each dish was then sealed with masking tape. The units were maintained at 27 ± 0.5°C, 60 ± 5% RH, and continuous light. Under these conditions, the majority of larval emergence occurred after 43 to 48 h. For each test, one set of ova (15 to 25 eggs) was exposed to insecticide for 24 h second for 48 h. Eggs were then transferred into clean dishes and egg mortality recorded after 72 h.

A possible delayed fumigant effect of each insecticide on ova was evaluated by examining the mortality of larvae hatching from these eggs. Tests were conducted as previously described, with eggs exposed for a 42 h period after which ova were transferred to clean petri dishes containing artificial diet. In tests of chlorpyrifos and methyl parathion, larval mortality was determined after exposure periods of 24, 32, 42, and 72 h. In all tests, mortality of 1st stage larvae was determined at 32 h after larval emergence. Larvae were considered dead if they did not respond to a probe test.

A second test was conducted with chlorpyrifos and methyl parathion to determine whether death of newly emerged larvae resulted from fumigant penetration of the ova and delayed effect on the embryo (Smith and Salkeld 1965) or from larval exposure to insecticide absorbed by the substrate. Following the technique described previously, ova were exposed to the insecticide for 32 h, after which each ovum was taken from the paper and transferred to a clean dish containing a small amount of bean medium.

A third test was conducted to determine the relative insecticide absorption of cotton leaf and filter paper substrates and the resulting larval mortality. Circular sections (4.0 cm diameter) were exercised from cotton leaves and placed on a thin layer of agar (for maintaining leaf turgidity) in a small petri dish lid (4.0 cm diameter). Pieces of cotton and filter paper (of approximately the same dimensions) were exposed to the vapors of either chlorpyrifos or methyl parathion for 42 h. A small section of paper towel containing ova was then placed on each substrate.

Each test was replicated on at least three different days with ca. 20 eggs per replicate. Data were transformed using an arc-sin transformation and analyzed by two-way analysis of variance and Duncan’s Multiple Range Test (Duncan 1955).

RESULTS AND DISCUSSION

All materials tested affected TBW eggs through their vapor phase compared with the water control (Table 1). Chlordimeform and methyl parathion caused ca. 30% oval mortality; the other compounds caused ca. 20% mortality. No significant difference was found between the two exposure periods (24 and 48 h) tested. In
both exposure periods, the embryo continued to develop. Thus, the egg’s mortality was determined if the larvae did not hatch.

Table 1. Fumigant effect of various insecticides on tobacco budworm eggs.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Concentration (mg AI/ml)</th>
<th>n*</th>
<th>% Mortality†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlordimeform</td>
<td>0.8</td>
<td>175</td>
<td>33.9a</td>
</tr>
<tr>
<td>Methyl parathion</td>
<td>2.5</td>
<td>179</td>
<td>31.6ab</td>
</tr>
<tr>
<td>Chlorpyrifos</td>
<td>3.1</td>
<td>281</td>
<td>23.0bc</td>
</tr>
<tr>
<td>Amitraz</td>
<td>5.0</td>
<td>169</td>
<td>22.4bc</td>
</tr>
<tr>
<td>Methomyl</td>
<td>2.8</td>
<td>239</td>
<td>22.3bc</td>
</tr>
<tr>
<td>Monocrotophos</td>
<td>3.1</td>
<td>176</td>
<td>22.0bc</td>
</tr>
<tr>
<td>Fenvalerate</td>
<td>0.6</td>
<td>207</td>
<td>18.9c</td>
</tr>
<tr>
<td>Water Control</td>
<td></td>
<td>160</td>
<td>5.4d</td>
</tr>
</tbody>
</table>

* The data from two exposure periods (24 to 48 h) were pooled since no significant difference was found ($P > 0.05$).
† Means followed by the same letter are not significantly different ($P = 0.05$; Duncan’s [1955] multiple range test).

Eggs exposed to vapors of both chlorpyrifos and methyl parathion caused high mortality of 1st instar larvae, while mortality due to the remaining compounds did not differ significantly from the water control (Table 2).

Table 2. Effect of exposure of tobacco budworm eggs to insecticide vapors for 42 hours on 1st instar larvae.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>n</th>
<th>% Mortality*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorpyrifos</td>
<td>107</td>
<td>96.4a</td>
</tr>
<tr>
<td>Methyl parathion</td>
<td>105</td>
<td>84.7a</td>
</tr>
<tr>
<td>Monocrotophos</td>
<td>92</td>
<td>5.4b</td>
</tr>
<tr>
<td>Fenvalerate</td>
<td>64</td>
<td>4.5b</td>
</tr>
<tr>
<td>Amitraz</td>
<td>56</td>
<td>1.0b</td>
</tr>
<tr>
<td>Chlordimeform</td>
<td>61</td>
<td>1.0b</td>
</tr>
<tr>
<td>Methomyl</td>
<td>75</td>
<td>1.0b</td>
</tr>
<tr>
<td>Water Control</td>
<td>155</td>
<td>0.5b</td>
</tr>
</tbody>
</table>

* Means followed by the same letter are not significantly different ($P = 0.05$; Duncan’s [1955] multiple range test).

The removal of eggs from the poisoned substrate was found to substantially reduce subsequent larval mortality, particularly regarding exposure to methyl parathion (Table 3). The effect of the period of exposure to the substrate on larval mortality is shown in Table 4. Larval mortality was greatest when larvae were exposed to insecticide vapors during emergence (72-h exposure) with almost total mortality resulting. The level of mortality was generally correlated with the period of exposure.

Larval exposure to both substrates (cotton and filter paper) treated with methyl parathion or chlorpyrifos vapor showed no significant difference in larval mortality (Table 5). The larval mortality in this test was lower (especially with methyl parathion) than found when pieces of paper containing the eggs were directly exposed to insecticide vapor.
Table 3. Mortality in tobacco budworm larvae following transfer of eggs exposed to insecticides for 32 hours to an untreated substrate.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Type</th>
<th>Transfer</th>
<th>n</th>
<th>% Mortality†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorpyrifos</td>
<td>NT</td>
<td></td>
<td>192</td>
<td>61.3a</td>
</tr>
<tr>
<td>Methyl parathion</td>
<td>NT</td>
<td></td>
<td>171</td>
<td>59.0a</td>
</tr>
<tr>
<td>Chlorpyrifos</td>
<td>TS</td>
<td></td>
<td>89</td>
<td>17.7b</td>
</tr>
<tr>
<td>Methyl parathion</td>
<td>TS</td>
<td></td>
<td>60</td>
<td>2.7c</td>
</tr>
<tr>
<td>Water</td>
<td>NT</td>
<td></td>
<td>151</td>
<td>0.1e</td>
</tr>
<tr>
<td>Water</td>
<td>TS</td>
<td></td>
<td>38</td>
<td>0.0e</td>
</tr>
</tbody>
</table>

* TS, each egg was transferred to a clean dish after exposure for 32 h; NT, non-transfer.
† Means followed by the same letter are not significantly different (P = 0.05; Duncan's [1955] multiple range test).

Table 4. Ovicidal/larvicidal effect after different exposure time of eggs to various insecticidal vapors.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Period (h)</th>
<th>n</th>
<th>% Mortality*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorpyrifos</td>
<td>72</td>
<td>109</td>
<td>97.5a</td>
</tr>
<tr>
<td>Chlorpyrifos</td>
<td>42</td>
<td>107</td>
<td>96.3ab</td>
</tr>
<tr>
<td>Methyl parathion</td>
<td>72</td>
<td>82</td>
<td>91.0ab</td>
</tr>
<tr>
<td>Methyl parathion</td>
<td>42</td>
<td>105</td>
<td>84.7b</td>
</tr>
<tr>
<td>Chlorpyrifos</td>
<td>32</td>
<td>192</td>
<td>61.3c</td>
</tr>
<tr>
<td>Methyl parathion</td>
<td>32</td>
<td>171</td>
<td>59.0c</td>
</tr>
<tr>
<td>Methyl parathion</td>
<td>24</td>
<td>67</td>
<td>55.8cd</td>
</tr>
<tr>
<td>Chlorpyrifos</td>
<td>24</td>
<td>80</td>
<td>33.9d</td>
</tr>
<tr>
<td>Water</td>
<td>24</td>
<td>96</td>
<td>0.5e</td>
</tr>
<tr>
<td>&quot;</td>
<td>32</td>
<td>217</td>
<td>0.3e</td>
</tr>
<tr>
<td>&quot;</td>
<td>42</td>
<td>155</td>
<td>0.1e</td>
</tr>
<tr>
<td>&quot;</td>
<td>42</td>
<td>155</td>
<td>0.1e</td>
</tr>
<tr>
<td>&quot;</td>
<td>72</td>
<td>63</td>
<td>0.0e</td>
</tr>
</tbody>
</table>

* Means followed by the same letter are not significantly different (P = 0.05; Duncan's [1955] multiple range test).

Table 5. Ovicidal/larvicidal effect by leaf discs or filter paper after having been exposed to the vapor phase of chlorpyrifos or methyl parathion.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Substrate</th>
<th>n</th>
<th>% Mortality*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorpyrifos</td>
<td>cotton leaf</td>
<td>217</td>
<td>81.9a</td>
</tr>
<tr>
<td></td>
<td>filter paper</td>
<td>170</td>
<td>78.1a</td>
</tr>
<tr>
<td>Methyl parathion</td>
<td>cotton leaf</td>
<td>174</td>
<td>14.4b</td>
</tr>
<tr>
<td></td>
<td>filter paper</td>
<td>253</td>
<td>5.4b</td>
</tr>
<tr>
<td>Water</td>
<td>cotton leaf</td>
<td>163</td>
<td>0.0c</td>
</tr>
<tr>
<td></td>
<td>filter paper</td>
<td>96</td>
<td>0.0c</td>
</tr>
</tbody>
</table>

* Means followed by the same letter are not significantly different (P = 0.05; Duncan's [1955] multiple range test).
Previous studies have shown that the ovicide chlordimeform (CDF) affected eggs of various insects (including TBW) and spider mites through the vapor phase (Dittrich 1966, 1967; Phillips 1971; Streibert and Dittrich 1977). We also observed ca. 30% mortality of TBW eggs produced by the fumigant action of CDF. Methyl parathion demonstrated the same level of vapor activity (Table 1). The other two ovicides, methomyl and fenvalerate, that were found effective against TBW eggs (Horowitz et al. 1987) caused only ca. 20% egg mortality through their vapor phase. However, in a study by Chalfant et al. (1979), no fumigant effect was found for CDF, methomyl, or fenvalerate on eggs of the cabbage looper.

Streibert and Dittrich (1977) found that exposure of both young eggs (0 to 24 h old) and old eggs (24 to 28 h old) of four noctuid and one coccinellid to a saturated atmosphere of CDF induced a similar level of mortality. Similarly, our results with CDF, as well as other insecticides, show that short egg exposure (24 h) to the vapors caused the same level of mortality as longer exposures (48 h). Smith and Salkeld (1966) pointed out that early ovicidal treatment with organophosphates allowed continued development of the embryo to the stage when cholinesterase and acetyl-choline are found with mortality occurring at this stage. Apparently, poisoning of young TBW eggs occurred by a similar process.

Both chlorpyrifos and methyl parathion demonstrated high fumigant effect on young TBW larvae. Chlorpyrifos, which exhibited low ovicide activity (Horowitz et al. 1987), was found very effective against TBW young larvae with high larval mortality occurring soon after hatching (Table 2). Vapor of CDF showed a very low level of larvicidal activity on TBW. Streibert and Dittrich (1977) also reported TBW larvae to be less sensitive to vaporized CDF than the eggs.

Smith and Salkeld (1965) reported no oval mortality in the large milkweed bug from exposure to parathion vapor, but nymphs from treated eggs died soon after hatching. We found no such delay effect in our study, as egg treatment did not produce larval mortality (Table 3). We suggest that mortality resulted from larval contact with the contaminated substrate, cotton leaf or filter paper, which absorbed the insecticide vapors. In the case of chlorpyrifos, the small amount of vapor that apparently attached to the egg shell caused ca. 18% mortality of the young larvae.

Our findings demonstrate potential fumigant action of CDF, chlorpyrifos, and methyl parathion on TBW eggs and young larvae. This potential may be of importance in practical application, since the incomplete coverage and penetration associated with aerial applications could be accomplished by the fumigant activity of these insecticides.

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