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[Garcerá, C., Moltó, E., Zarzo, M., Chueca, P. (2012). Modelling the spray deposition and efficacy of two mineral oil-based products for the control of California red scale, *Aonidiella aurantii* (Maskell). *Crop Protection*, 31(1), 78-84.]

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Institut Valencià
d'Investigacions Agràries

The final publication is available at

[\[http://dx.doi.org/10.1016/j.cropro.2011.10.004\]](http://dx.doi.org/10.1016/j.cropro.2011.10.004)

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Garcera et al.: Efficacy model of PDSO on

Aonidiella aurantii

Crop Protection

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1 **Modeling the Spray Deposition and Efficacy of Two Mineral Oil-based Products for the**

2 **Control of California Red Scale *Aonidiella aurantii* (Maskell)**

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8 Abstract

9 In this study we evaluated under laboratory conditions the efficacy of two petroleum-derived
10 spray oils (PDSO) (Laincoil[®], ~~Oil A~~, and Sunspray Ultrafine[®], ~~Oil B~~) applied at 1.5%
11 concentration at five water volumes (0.5, 1, 2, 3 and 4 ml) against different stages of *Aonidiella*
12 *aurantii* Maskell (Homoptera: Diaspididae). In parallel, we characterized the deposition pattern
13 of treatments resulting of these five volumes and two PDSO. The objective was to model the
14 characteristics of deposition and ~~the~~ efficacy as a function of the deposited volume in order to
15 determine the optimum volume that should be applied in PDSO treatments against this pest.
16 Different models that relate ~~the~~ efficacy as a function of the deposited volume have been
17 obtained for ~~both two~~ PDSO and for the tested stages of *A.aurantii*. Results ~~reflected the~~
18 ~~optimum deposited volume for each oil and each stage, showing~~ showed that Sunspray
19 Ultrafine[®] ~~Oil B~~ had higher efficacy and produced more but smaller impacts that Laincoil[®] ~~Oil~~
20 A, which may indicate the influence of formulation on the efficacy of PDSO. We propose a
21 methodology to evaluate the effect of PDSO on the spray deposition pattern and efficacy against
22 various California red scale stages, thus providing a scientific basis for product comparison.

23 **Key words:** PDSO, coverage, spray volume, formulation

24 1. Introduction

25 Petroleum-derived spray oils (PDSO) have been used as crop protection products for over a
26 hundred years; they were first applied in the 1920s (Ackerman, 1923; De Ong, 1926). Indeed,
27 they have a good ecotoxicological profile and pests do not develop resistance. Furthermore,
28 populations of beneficial arthropods are not severely affected because of the short-term residual
29 activity of PDSO (Childers, 2002; Davidson, 1991; Nguyen et al., 2002; Riehl, 1981; Urbaneja et
30 al., 2008).

31 California red scale *Aonidiella aurantii* (Maskell) (Homoptera: Diaspididae) (CRS), one of the
32 pests with greater economic impact in worldwide citrus growing, has traditionally been
33 controlled by organophosphate insecticides. However, the extensive and continuous use of these
34 pesticides has caused **environmental impact as well as** resistance development in this pest
35 (Bedford, 1998a, b; Grafton-Cardwell and Vehrs, 1995; Levitin and Cohen, 1988; Smith et al.,
36 1997) ~~as well as environmental impact~~. PDSO show good efficacy against CRS and they are
37 currently registered worldwide to control CRS in citrus and are commonly used in integrated pest
38 management programs. In Spain, recommendations for PDSO application are based on a
39 prescribed concentration, specifically 1.0 to 1.5% (MARM, 2010). However, information about
40 volumes of water required depending on the quantity of plant canopy is not provided and is not
41 regulated. This fact may lead to waste through overuse or ineffective control as a result of
42 inadequate application.

43 The primary cause of mortality produced by PDSO is anoxia, i.e. suffocation by directly
44 blocking the spiracles of scales (Kallianpur et al., 2002; Taverner, 2002). For this reason, high
45 water volumes are presumed to be very important in order to completely cover the target insect
46 (Gaskin et al., 2002).

47 Mineral oils are characterized by some parameters that might affect their efficacy such as

48 viscosity, gravity, unsulfonated residue, pour point, distillation temperature and n-paraffin
49 carbon number (nC) (Agnello, 2002). PDSO normally contain a specific mineral oil as active
50 ingredient (a.i.) mixed with a wide range of emulsifiers and surfactants. Although these
51 coadjuvants probably do not directly affect the inherent oil toxicity, they have a great influence
52 on the physico-chemical properties of the solution. It is widely known that these properties affect
53 their droplet size spectrum (Bouse et al., 1990; Fraser and Eisenklam, 1956; Haq et al., 1983;
54 Yates et al., 1983) and their deposition pattern (Salyani, 1988; Spillman, 1984; Zabkiewicz,
55 2007), affecting thereafter the PDSO wetting capacity, and consequently the plant-pest
56 interaction and the efficacy (Agnello, 2002; Zabkiewicz, 2002).

57 Several researchers have attempted to determine how much volume should be applied in PDSO
58 treatments against CRS, but the results were not conclusive and sometimes they were
59 contradictory. Jeppson and Carman (1974) stated that a low volume field treatment (935 l/ha) did
60 not successfully control CRS, probably due to a bad deposition in the canopy center. Riehl
61 (1981) improved the efficacy of low volume treatments by adjusting the application equipment
62 to reach this area in the **tree** center of the tree, even decreasing concentration. This research also
63 stated that efficacy depends on the **pest** stage of the pest, in such a way that to control adult
64 females, higher deposits ($\mu\text{g oil}/\text{cm}^2$) than those needed for young stages were necessary. Other
65 authors also found differences in efficacy under field conditions related to oil deposit, depending
66 more on volume than on concentration (Beattie et al., 2002; Grout and Stephen, 1993). In
67 contrast, Grafton-Cardwell and Reagan (2005, 2006) found no difference in efficacy in several
68 field trials **conducted** ~~made~~ with very high volumes (8000 and 15000 l/ha) varying
69 simultaneously the concentration of oil. The lack of conclusive results is probably due to the
70 existence of many factors under field conditions that can affect the efficacy of mineral oils
71 treatments against CRS. **These factors** ~~which~~ are difficult to take into account altogether: the oil

72 formulation, the population level, the stage of scales, the size and shape of trees, the density of
73 canopy, the type of sprayer used and its setup parameters, etc. Furthermore, each of these studies
74 had different goals and authors provide data of different nature, depending on the factor of
75 interest, and therefore results cannot be compared.

76 The objectives of this study were: (i) to characterize the deposition pattern of two PDSO applied
77 in different volumes with constant concentration, (ii) to study the efficacy of these treatments on
78 the different stages of CRS under laboratory conditions, and (iii) to model the efficacy as a
79 function of the deposited volume. ~~Moreover,~~ We investigated if the two PSDO produced the
80 same deposition and efficacy or if they followed different models, which would highlight the
81 importance of the commercial product formulation on the pesticide distribution and pest control.

82

Material and Methods

83 Two experiments were carried out under laboratory conditions to test the effect of volume on (i)
84 ↪ deposition characteristics, and (ii) ↪ efficacy of mineral oils-based treatments against
85 different stages of CRS. In both experiments two of the most common PDSO in Spain were
86 used: Laincoil[®], an *n*C21 oil with a content of 83% w/v (Lainco, S.A., Barcelona, Spain),
87 hereafter Oil A, and Sunspray Ultrafine[®], an *n*C21 with a content of 85% w/v (Sun Oil Co.,
88 Antwerp, Belgium), hereafter Oil B. Both PDSO have an unsulfonated residue of 92%. They
89 were used at the most common concentration in Spanish field applications against CRS, which is
90 the maximum prescribed concentration of 1.5%. The spray volumes used for both experiments
91 were 0.5, 1, 2, 3 and 4 ml. The maximum spray volume tested was 4 ml because the droplets
92 coalesced at higher volumes, producing a surface of liquid that run-off from the target surface.

93 Applications were ~~carried out made~~ with a Potter Spray Tower fitted with its finest nozzle
94 (internal diameter: 0.762 mm) (Burkard Scientific, Uxbridge, United Kingdom) (Potter, 1952).
95 Pressure was fixed at 0.1 MPa.

96 The Potter Spray Tower was calibrated before each experiment. The volume of solution
97 deposited per unit area ($\mu\text{l}/\text{cm}^2$) on the **tower** base ~~of the tower~~ for each spray volume was
98 estimated by a series of tests. Different volumes of water were sprayed over Petri dishes of
99 known area (63 cm^2). Petri dishes were weighed before and after the application using an
100 analytical balance (XR 205 SM-DR, Precisa Instruments Ltd., Dietikon, Switzerland). Five
101 replicates were used per volume tested. The average increase of weight produced by the
102 deposition of droplets per unit area was measured. From these data, the amount of a.i. per unit
103 area was estimated for each PDSO (Table 1).

104 **Deposition Pattern**

105 In order to study the deposition pattern, the five volumes were tested with two PDSO solutions
106 (Oil A and Oil B), with 3 replicates per treatment.

107 White PVC-sheet 4.5×4.5 cm pieces were used as artificial collectors of the spray solution.

108 PVC drop retention behavior is similar to that of citrus leaves (Mercader et al., 1995). Collectors
109 were sprayed with the corresponding solution (water + PDSO), plus 2% of chelated iron
110 (Sequestrene 138 Fe G-100, Syngenta Agro S.A., Madrid, Spain) as a dye to produce sufficient
111 drop/background contrast for subsequent image analysis.

112 Collectors were then photographed and the images analyzed using the methodology described by
113 Chueca et al., (2010). Three parameters were measured from each collector to describe the
114 deposition: (i) coverage, expressed as percentage of area occupied by impinging droplets
115 (henceforth impacts) against the total area (%); (ii) area of impacts, estimated by the mean of the
116 sizes of all the impacts on the collector (mm^2); and (iii) number of impacts per unit area (No. of
117 impacts/ cm^2).

118 **Efficacy Against CRS Stages.**

119 Five volumes of both solutions (Oil A and Oil B) were tested as well as a control with just water.
120 Experimental trials were conducted on lemons infested with CRS populations in different stages.
121 CRS-infested lemons were obtained from the rearing colonies of our institution (Centro de
122 Agroingeniería, Instituto Valenciano de Investigaciones Agrarias). Rearing takes place in
123 chambers with a temperature of 26 ± 3 °C, $50 \pm 5\%$ relative humidity (RH) and continuous light,
124 following the protocol developed by Pina (2006).

125 The insect's life cycle was divided into four groups of stages, in a way that each group comprised
126 various stages of development. These groups of stages were labelled as follows (each one
127 included the growth stages shown in brackets): N1 (nipple stage and first molt), N2 (second
128 instar and second molt), N3 (third instar and gravid females) and PP (prepupal and pupa males).

129 To infest the target lemons, clean lemons were partially covered by wax, leaving a clean surface
130 (arena) of about 16 cm^2 where CRS developed. Lemons were big enough relative to the size of
131 these arenas so that the arenas could be considered flat. These arenas were kept horizontal during
132 and after spraying. ~~In the base of a box~~ A series of lemons infested with crawler-producing
133 females from the colony was put **in the base of a box** with the area upward. ~~Over the arena of~~
134 ~~each lemon~~ A black paperboard **tube tubes** (10 cm high and 3 cm base diameter) ~~was were~~ put
135 **over the arena of each lemon**. On the top of black paperboard tubes the waxed clean lemons were
136 put with the areas upward. Fluorescent lights were placed over this set up to attract crawlers from
137 the infested lemons to the clean lemons for 24 hours. After crawlers reached the “whitecap”
138 stage, lemons with more than 50 fixed scales were removed and placed in a tray during a period
139 long enough to allow the majority of individuals to reach one of the desired stages in which CRS
140 life cycle had been divided for the trial. This period was of about 5 days for N1, 9 days for N2
141 and 15 days for N3 and PP, checking before the applications whether they had really reached the
142 required stage.

143 Before the PDSO treatment, about 50 living individuals per lemon were circled with a permanent
144 marker (Staedtler permanent Lumocolor, Staedtler, Germany). Ten days after treatment the
145 circled individuals were turned over and the number of dead scales was recorded. N1, N2 and PP
146 scales that had not matured to the next stage were considered as dead. N3 scales were considered
147 dead when the body under the shield had a dry, thin and flat appearance. Percentage of mortality
148 was calculated from these data.

149 The experimental design consisted of 48 treatments: six volumes x four stages x two PDSO.
150 Each treatment was replicated 5 times, and one lemon was used for each replicate. Hence, 240
151 lemons were used. In each replicate, treatments were applied in a random order.

152 **Data Analysis.**

153 Multiple linear regression (MLR) was used to model the relationship between the volume
154 deposited on the target, which will be referred to hereafter as variable D (deposited volume, μl
155 solution/ cm^2), and the parameters that characterize the deposition pattern (coverage, mean
156 impact area and number of impacts per unit area). One MLR model was obtained for each
157 parameter. Quadratic and cubic terms of the independent variable D were also taken into
158 account. In order to study if both tested PDSO differ in their deposition pattern, an indicator
159 variable called $I_{\text{OIL_A}}$ was also considered. It takes the value one for the experimental data
160 corresponding to Oil A and zero otherwise. Residues of the model were calculated and then
161 Analysis of Variance (ANOVA) was performed on them using PDSO as the factor, in order to
162 study the inclusion of the indicator variable in the regression model.

163 Regarding the mortality data obtained with infested lemons, Dunnett's test (Dunnett, 1985) was
164 used to compare for each CRS stage and each spray volume the percentage of mortality in the
165 control treatment (only water) versus the mortality of PDSO treatments. When significant

166 differences were found, efficacies were calculated using the Schneider-Orelli formula (Püntener,
167 1981). MLR was also applied to study the effect of D , PDSO and stage on efficacy. The above
168 explained methodology was followed to study the inclusion of the quadratic term D^2 as well as
169 the interaction between I_{OIL_A} , D and D^2 . In order to assess whether there was a different
170 response exhibited by any stage, the inclusion of three additional indicator variables were
171 studied: I_{PP} , I_{N3} and I_{N2} , as well as their interactions with the rest of variables. Given that the
172 number of variables was quite high in this case, stepwise MLR was used to identify those with a
173 statistically significant effect on the efficacy. When the indicator variables were found
174 significant, the model could be expressed as a set of equations that depended on the PDSO and
175 the stage.

176 In all fitted models it was checked by means of a normal probability plot and a Shapiro-Wilks
177 test (Shapiro-Wilk, 1965) that residuals followed approximately a normal distribution, and no
178 outliers were identified. All MLR models were carried out with the software Statgraphics® Plus
179 version 5.1 (StatPoint Technologies Inc., Warrenton, Virginia, USA).

180 Results

181 Deposition Pattern.

182 Equation 1 describes the effect of D on coverage. The coefficients of both independent variables,
183 ~~D or D^2 , in the model~~ were statistically significant (Table 2). **The coefficient of the indicator**
184 **variable I_{OIL_A} was not statistically significant ($p=0.082$) and it was not included in Equation 1.**
185 ~~When the inclusion of the dummy variable, I_{OIL_A} , was studied, factor “oil” did not significantly~~
186 ~~affect the residues of the model ($F = 3.25$; d.f. = 1, 29; p -value = 0.0822), so it was not included.~~
187 These results indicated that equation 1 was valid for both PDSO assessed, with a coefficient of
188 determination $R^2 = 0.864$.

$$189 \quad \text{Coverage (\%)} = -0.410 + 22.722 \cdot D - 2.712 \cdot D^2 \quad (1)$$

190 The fitted equation is depicted in Figure 1A. It shows that in the tested range of volumes, the
 191 increase of coverage is very low for $D > 3.5 \mu\text{l}/\text{cm}^2$, reaching a maximum value of
 192 approximately 50%.

193 Although there was no evidence of difference in the coverage produced by the two PDSO, they
 194 differed in the way that this coverage was achieved because the indicator variable $I_{\text{OIL_A}}$ was
 195 statistically significant in the models obtained for the mean impact area and number of impacts
 196 per unit area (Tables 3 and 4). The coefficients of determination for these models were 0.823 and
 197 0.750, respectively.

198 In the mean impact area model it was found that the relationship between deposited volume and
 199 mean impact area was linear, ~~and that residues differed significantly between PDSO, so the~~
 200 ~~inclusion of the dummy variable in the model was studied.~~ The regression coefficient of the
 201 variable $D \cdot I_{\text{OIL_A}}$ was **statistically** significant (Table 3), which means that these responses could
 202 be described by two equations (2 and 3), one for each PDSO.

$$203 \quad \text{mean area}_{\text{OIL_A}} (\text{mm}^2) = 0.0046 + 0.026 \cdot D \quad (2)$$

$$204 \quad \text{mean area}_{\text{OIL_B}} (\text{mm}^2) = 0.0046 + 0.016 \cdot D \quad (3)$$

205 These models are depicted in Fig. 1B, showing that the slope for Oil A was significantly higher
 206 than for Oil B. This result suggests that increases of D resulted in a greater size of impacts for the
 207 Oil A applications.

208 Regarding the number of impacts per unit area, both PDSO showed an increasing trend between
 209 $D = 0.46$ and $D = 1 \mu\text{l}/\text{cm}^2$. However, the number of impacts decreased between $D = 2$ and $D =$
 210 $3.4 \mu\text{l}/\text{cm}^2$. This was probably due to coalescence of droplets since the nozzle is static with
 211 respect to the target. In this case, the variable $I_{\text{OIL_A}}$ was also **statistically** significant (Table 4),

212 which implies differences between the two PDSO. As a result, the fitted model can be described
 213 by a different equation (4 and 5) for each PDSO. Oil B produced a higher number of impacts for
 214 all volumes assessed. Taking together the results of both impact size and number, Oil B
 215 generated smaller impacts but more numerous.

$$216 \quad (\text{impacts/cm}^2)_{\text{OIL}_A} = 310.633 + 647.683 \cdot D - 302.665 \cdot D^2 + 34.654 \cdot D^3 \quad (4)$$

$$217 \quad (\text{impacts/cm}^2)_{\text{OIL}_B} = 570.102 + 647.683 \cdot D - 302.665 \cdot D^2 + 34.654 \cdot D^3 \quad (5)$$

218 **Efficacy Against CRS Stages.**

219 N1, N2, N3 and PP mortalities resulting from both PDSO were significantly different from the
 220 water control (Dunnett test, $P < 0.05$), except in the lowest treatment with $0.46 \mu\text{l solution/cm}^2$ of
 221 Oil A. This resulted in negative values of efficacy (%) for this treatment when using the
 222 Schneider-Orelli formula, as reflected in Fig. 2. The mortality percentages for water controls
 223 were 12.00% (SE=2.00%) for N1, 11.33% (SE=2.40%) for N2, 7.42% (SE=2.63%) for N3 and
 224 19.09% (SE=1.57%) for PP.

225 By means of stepwise MLR and after checking different alternative models, the best goodness-
 226 of-fit was achieved with the model reflected in Table 5, resulting $R^2 = 0.826$. The quadratic term
 227 D^2 was statistically significant as well as its interaction with several indicator variables
 228 ($P < 0.011$). This model can be expressed as five different equations (6-10), depending on the
 229 PDSO and the stage (fitted curves in Fig. 2). ~~When the same model is used for different stages,~~
 230 ~~it's because no differences in the residues were found.~~

231 a) OIL A

$$232 \quad \% \text{ Efficacy}_{N1/N2} = -10.099 + 41.613 \cdot D - 4.349 \cdot D^2 \quad (6)$$

$$233 \quad \% \text{ Efficacy}_{N3} = -10.099 + 41.613 \cdot D - 5.288 \cdot D^2 \quad (7)$$

$$234 \quad \% \text{ Efficacy}_{PP} = 11.886 + 17.047 \cdot D - 0.634 \cdot D^2 \quad (8)$$

235 b) OIL B

$$236 \quad \% \text{ Efficacy}_{N1/N2/N3} = -10.099 + 49.816 \cdot D - 6.087 \cdot D^2 \quad (9)$$

$$237 \quad \% \text{ Efficacy}_{PP} = 11.886 + 25.250 \cdot D - 2.373 \cdot D^2 \quad (10)$$

238 The efficacy of both PDSO against N1 and N2 was close to 90% for the highest tested volumes,
 239 and no significant differences were observed between those stages. The difference between the
 240 two PDSO depended on the amount of deposited volume required to reach the maximum
 241 efficacy. Oil A required a deposit close to 4 μl solution/ cm^2 to reach 90% efficacy while Oil B
 242 needed a lower one, close to 3.5 μl solution/ cm^2 , and consequently, a lower coverage, to reach
 243 92% efficacy.

244 In the case of stage N3, it followed the same regression model as N1 and N2 in the experiments
 245 with Oil B. However, Oil A reached a lower efficacy against N3 for the higher volumes, with a
 246 maximum efficacy close to 70%. This result suggests that Oil B was more effective than Oil A
 247 against stage N3, since it reached a similar efficacy to that obtained for younger stages.

248 For both PDSO, efficacy against stage PP followed a different model and no relative maximum
 249 was reached. Thus, higher deposited volumes would become more effective against this stage.

250 Generally, the efficacy on PP was lower than for the other stages at higher deposit levels.

251 Discussion

252 Various authors (Herron et al., 1995; Riehl and LaDue, 1952; Riehl et al., 1958; Riehl, 1981;)
 253 established that LD 95 for mineral oils ranges from 55 to 115 μg oil/ cm^2 for CRS. The lowest
 254 value is similar to that obtained with the maximum deposited volume of 4.9 $\mu\text{l}/\text{cm}^2$ at
 255 concentration of 1.5% in our experiments (Table 1). Taking into account that collectors used in

256 this experiment behave similar to citrus leaves (Mercader et al., 1995) and higher volume
257 applications will produce run-off, ~~we would expect that~~ the highest value of 115 $\mu\text{g oil/cm}^2$
258 reported in the literature ~~would~~ ~~could~~ only be attained in the field, under Spanish conditions, by
259 increasing the oil concentration to more than 2.8 % which could potentially cause phytotoxicity,
260 thus rendering it an unrealistic application. Because this work describes both the total deposition
261 volume and the distribution of deposits, it also opens the possibility to relate the results obtained
262 in laboratory to other reported studies, even with those conducted in field conditions.

263 Consequently, one of the outcomes of our experiments is a more precise recommendation to
264 Spanish citrus growers that is based on scientific evidence and has practical applications.

265 This study shows that younger stages of CRS were more susceptible than adult stages, ~~which is~~
266 ~~consistent~~ ~~according~~ with the literature (Riehl, 1981), however it proposes a new method to
267 model the relationships between efficacy, developmental stage and deposited spray volume.
268 Hence, this methodology could be used to determine the coverage necessary to be reached in
269 field conditions to obtain the maximum efficacy. The maximum efficacy obtained under field
270 conditions may differ from the maximum efficacy obtained under laboratory conditions because
271 in laboratory it has not been taken into account the influence of ~~uncontrolled~~ ~~out-of-control~~
272 factors in real applications such as meteorological conditions, ~~the resistance of the pest to the~~
273 ~~applied product~~, the lack of coverage uniformity on the tree canopy, etc.

274 Significant differences were found in deposition parameters and efficacy depending on the two
275 particular PDSO employed in these experiments. The methodology proposed here can be useful
276 to compare the efficacy of several commercial PDSO under laboratory conditions. This
277 information, as well as their price could be of interest for citrus growers in order to choose the
278 most convenient PDSO as well as for the manufacturers to improve product quality.

279 In our experiments, Oil A was somewhat less effective than Oil B in controlling CRS. However,

280 it is important to remark that mineral oils which are the base of both PDSO have similar
281 unsulfonated residue and n-paraffin carbon number (nC), so the results may suggest that
282 differences in deposition and efficacy could be due to other factors. We speculate that
283 coadjuvants might play a significant role in these differences, since although total coverage was
284 not significantly different, the resulting distribution of impacts was not the same: Oil B produced
285 smaller but more numerous impacts than Oil A. Thus, more studies of commercial PDSO are
286 needed because both spray distribution and efficacy are dependent on the commercial
287 formulations, not only on the mineral oil on which they are based.

288 **Acknowledgements**

289 This research was partially funded by the Ministerio de Ciencia e Innovación de España (project
290 AGL2007-66093-C04) and Fondo Europeo de Desarrollo Regional (FEDER). C.G. was recipient
291 of a grant from IVIA.

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404 **Table 1. Estimated amount of active material deposited per unit area ($\mu\text{g}/\text{cm}^2$) (Mean and**
405 **SEM*) for the five volumes of solution and for each PDSO sprayed with the Potter tower**
406 **onto Petri dishes.**

407

408 **Table 2. Regression coefficients of the MLR equation for coverage as a function of D**
409 **(deposited volume, $\mu\text{l solution}/\text{cm}^2$)**

410

411 **Table 3. Regression coefficients of the MLR equation for mean impact area as a function of**
412 **D (deposited volume, $\mu\text{l solution}/\text{cm}^2$)**

413

414 **Table 4. Regression coefficients of the MLR equation for number of impacts per unit area**
415 **as a function of D (deposited volume, $\mu\text{l solution}/\text{cm}^2$)**

416

417 **Table 5. Regression coefficients of the MLR equation for efficacy as a function of D**
418 **(deposited volume, $\mu\text{l solution}/\text{cm}^2$)**

419

420 **Fig. 1. Experimental data and regression curves for coverage (A), mean impact area (B)**
421 **and number of impacts per unit area (C) as a function of D ($\mu\text{l solution}/\text{cm}^2$) for each**
422 **PDSO**

423

424 **Fig. 2. Experimental data and regression curves for efficacy (%) as a function of D (μl**
425 **solution/ cm^2) for Oil A (A) and Oil B (B)**