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Antifeedant-treated Potato Plants as Egg-laying Traps for the Colorado Beetle *(Leptinotarsa decemlineata* Say, Col., *Chrysomelidae)*

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Following an antifeedant (2% Bordeaux mixture) treatment of a field plot, during two consecutive weeks, the number of eggs laid by Colorado beetle females on treated potato plants was significantly higher (P = 1%) compared with that on the untreated control ones. Laboratory choice and no-choice experiments have also strengthened the above. Substance(s) of insect-origin have induced a similar distribution of eggs in choice tests. It is thought that the phenomenon is primarily caused by the differential decrease in the surfaces of the two kinds of foliage and to a lesser extent, by substance(s) accumulated on untreated plants, because of the presence of various developmental stages. The unequal distribution of eggs might bear some effect on the decrease of a local Colorado potato beetle population.

The integrated pest control, besides conventional chemical means, incorporates methods selectively acting on organisms. Such procedures have the similar features in common, to wit, a high efficiency against target species and a low or neglectable harmfulness against beneficial organisms. There is no doubt that chemicals will still dominate in future plant protection practices, though purely biological control measures have already been taking their shares.

One of the selectively acting control procedures is the use of antifeedants (synonymes are: feeding inhibitors, feeding deterrents). It was demonstrated even before the 2nd World War that certain chemicals would inhibit feeding of some insect species (see WRIGHT, 1963, for references).

As it is the usual case in practically oriented research fields, antifeedants sooner became members of the protection arsenal than principles of their modes of action were understood in details. Even though our knowledge about feeding deterrents have developed more or less parallel to the domain of plant/insect relationships, to that of receptor physiology, and so on; and albeit it has also been repeatedly demonstrated by JERMY (1958, 1961, 1965, etc.) and by others, only recently it gains more and more appreciation that most phytophagous insect/host-plant relationships can temporarily be modified, at the behavioural level, by the application of substances rendering host recognition and acceptance depressed or impossible, even in the presence of optimal sensory input from the host.

The deterring effect of copper compounds to the feeding of the Colorado beetle *(Leptinotarsa decemlineata* Say) had long been known and demonstrated by

FEYTAUD (1922), RAUCOURT and BEUGE (1942) and JERMY (1961). Although, there are numerous other chemicals of natural and synthetic origin being potent antifeedants both in laboratory and field conditions, relatively few works discuss impacts of such compounds on pests' population dynamics. Among the sporadically occuring such studies MURBACH and CORBAZ (1963), MURBACH (1967) and ZHEMCHUZHINA (1976) present data about dispersion, damage, egg-laying, feeding ethology, locomotory activity of the Colorado beetle, under the influence of antifeedants containing copper.

For some years, in the Research Institute for Plant Protection, we have been screening chemicals (with or without copper) against the Colorado beetle in the laboratory, in order to develop potent antifeedants. In addition, field tests have also been conducted to study the population dynamics of the pest under antifeedant influence. Efforts are mostly focused on egg-laying responses in presence of antifeedants. Within the scope of the present study I am going to give a *preliminary* account on such field observations and laboratory experiments.

Material and Methods

For field works, the experimental plot was situated near Budapest, at an altitude of about 300 m above sea level, where the Colorado beetle had mostly one and a half or sometimes two generations per year. There was a single plot (0.12 ha) of Desirèe potato variety used, on which there were 6 rows marked in the middle of the plot, each being one hundred plants long. There were 20 plants chosen randomly in each of these rows. Regular population counts were made at approximately one week intervals. All stadia present, the damage done by them, and also the size of the plants were recorded. After the first population count 10 randomly selected plants of the 20 marked in each row received a treatment of 2% Bordeaux mixture (which is a complex chemical containing copper) while the remaining 10 served as control. The spray was renewed whenever it was necessary. The number of surveyed plants per population count ranged between 23 and 60.

In choice tests, under glass-house conditions, 25 to 35 cm long potato shoots were randomly arranged on the bottom of a wire screen (1 × 1 mm)-covered cage (50 × 50 × 100 cm). There was a sheet of black cardboard paper placed on the bottom of the cage having holes through which the stems of shoots were immersed into flasks of fresh water.

For no-choice tests, compound leaves of potato with 5 to 7 leaflets were placed into separate, 15 × 18 cm size glass jars (2 leaves per jar), then were covered with 1 × 1 mm mesh nylon screen. The two leaves in a jar received the same treatment.

Rinses of insect origin were prepared as follows: larvae and adults were collected in the field. They were either kept on paper towels, or were fed potato foliage in cages. After 1 to 2 days both the paper towels and the plant foliage on which the various instars had walked, fed, oviposited, defecated etc. were washed, or sprayed with destilled water until 100 to 150 ml solution was collected, respectively.

The solutions were sifted or centifuged at 6000 rpm for 5 min then sprayed onto fresh potato shoots and offered for gravid females to oviposit in choice tests. For controls either dist. water wash of paper towels or dist. water were sprayed on potato shoots.

In choice tests, depending on the number of choice possibilities and shoots applied, 22 to 250 gravid females were used. After 1 to 5 days the number of eggs laid and area of foliage consumed were recorded. In no-choice test, 4 ovipositing females were applied per jar.

Sprayings were carried out with a "Mistral Triumph N" electric spray machine, using No. 4 or 6 size nozzles. Plants were sprayed either until run-off or glass plates were also placed among shoots to be sprayed both for quantification and to measure uniformity of spray. In the latter case, a mean of 3.09 ($\pm$0.89 S. D.) mg dry material per cm^2 was found on sprayed leaves.

Results and Discussion

The results of population counts show that the number and distribution of eggs and damage (i.e. consumption) suffered by plants were disproportionate, to wit, there were significantly (P = 1 %) more eggs found on treated plants compared to untreated ones (Table 1). Also the damage on unsprayed plants gradually increased during subsequent population counts. A significant difference between eggs laid on sprayed and unsprayed plants did not appear until larval infestation

Table 1

Field oviposition response of a Colorado beetle population to antifeedant (Bordeaux mixture, 2%) spraying on potato plants. (June 13 till August 17, 1978; No. of data used: 23 to 60.)

Population count	Mean no. of eggs ($\pm$S. D.) per plant: sprayed		Mean no. of eggs ($\pm$S. D.) per plant: unsprayed	Mean no. of larvae ($\pm$S. D. of the mean) per unsprayed plant	Consumption ($\pm$S. D.) of foliage: sprayed	Consumption ($\pm$S. D.) of foliage: unsprayed
Before spraying	120$\pm$70			3$\pm$2	20$\pm$9	
After spraying						
1st	227$\pm$89	a	120$\pm$70	49$\pm$12	13$\pm$5	21$\pm$8
2nd	129$\pm$83	a	68$\pm$79	71$\pm$24	7$\pm$3	34$\pm$11
3rd	65$\pm$57	NSD	39$\pm$43	88$\pm$15	0	49$\pm$20
4th	22$\pm$29	NSD	22$\pm$36	44$\pm$10	0	74$\pm$17
5th	4$\pm$11	NSD	27$\pm$44	20$\pm$3	0	76$\pm$17
6th	5$\pm$13	NSD	6$\pm$15	14$\pm$3	0	85$\pm$14

Bordeaux mixture = $CaSO_4 \cdot Cu(OH)_2 \cdot 3\,Ca(OH)_2$ complex

a = Values in same row separated by this symbol significantly differ at 1 % level (Duncan's new multiple range test).

NSD = not significantly different

Table 2

Oviposition response of Colorado beetle females in a *choice* test, to potato shoots sprayed either with 1% Bordeaux mixture or distilled water. (No. or replicates: 9)

Spraying (= treatment)	Total no. of eggs laid/treatment	Consumption % (±S. D.) per shoot
	After 1 day	
Bordeaux mixture	210	0
Dist. water	224	14±11
	After 5 days	
Bordeaux mixture	651	0
Dist. water	374	45±10

Table 3

Oviposition response of Colorado beetle females in a *no-choice* test to potato leaves sprayed either with 1% Bordeaux mixture or distilled water (No. of replicates: 5)

Spraying (= treatment)	Mean (±S. D.) number of eggs laid/treatment	Consumption % (±S. D.) per compound leaf
Bordeaux mixture on the leaves'		
1. upper surface	198±43 a	0
2. lower surface	154±63 ab	0
3. both surfaces	140±59 ab	0
Dist. water	87±29 b	17±7

Means followed by the same letters are not significantly different at 5% probability level (DNMR-test).

level reached about 50 instars per unsprayed plant. The difference still remained, as the number of larvae increased on untreated plants then diminished, since the females of the overwintered generation slowed down and finally ceased laying eggs.

The same result was received in a glass house experiment. In a *choice* test, there were almost twice as many eggs laid on sprayed potato shoots than on the control ones (Table 2). However, the difference did not appear until after 5 days. By then consumption of unsprayed plants reached about 45%.

Treated (i.e. Bordeaux mixture-sprayed) leaf surfaces alone, in a *no-choice* test, received significantly more eggs (P = 5%) as compared with control ones, while consumption was about 17% on the latter (Table 3). The results indicate that even without any alternative choice possibility, treated foliage by itself can induce a biased egg-laying response.

MURBACH and CORBAZ (1963) did not find any unequal distribution of eggs in the presence of a copper oxychloride spray, in a field experiment. However, they also stated that this compound was repellent to the Colorado beetle, what could explain the lack of a similar response. We think that repellency is not a character of the Bordeaux mixture.

On the basis of field observations it has been supposed that the unequal distribution of eggs might have been caused, partly at least, by (1) the decrease of foliage surface, (2) the presence of various stadia, mostly larvae and/or by (3) the existence of substance(s) on unsprayed plants visited, chewed, defecated, oviposited also both by larvae and beetles.

On the other hand, however, Tables 2 and 3 indicated that the unproportional distribution of eggs could be elicited, in choice tests, (1) merely by the decrease of foliage on unsprayed shoots, (2) by excretions, impacts, as well as other substance(s) left behind by ovipositing females only since no larvae were present in the experiments, and in a no-choice situation, (3) by the Bordeaux mixture alone.

In order to elucidate the situation, various rinses (Table 4, rinses 1 to 4) were prepared and tested on field collected ovipositing females in *choice* experiments. The results obtained merely strengthened the field observations and data of Tables 2 and 3. Various rinses did not produce stronger alterations in egg distribution than that evoked by Bordeaux mixture.

Table 4

Oviposition responses of Colorado beetle females to potato shoots sprayed with freshly prepared solutions of insect origin. (Three choice experiments; No. of replicates: 5 to 6)

Spraying (= treatment)	Total no. of eggs laid/treatment			Consumption % (±S. D.) per shoot		
	I	II	III	I	II	III
Bordeaux mixture	1662	747	910	0	0	0
Rinse no. 1	1075	408	—	23±8	52±37	—
Rinse no. 2	1266	588	—	28±13	37±15	—
Rinse no. 3	—	—	882	—	—	25±17
Rinse no. 4	—	—	601	—	—	23±11
Dist. water	1109	194	699	28±26	77±20	22±17

Rinses: No. 1. Prepared by soaking paper towels in dist. water on which there were 258 gravid females walking for 1 day.

No. 2. Similar as no. 1, except that ca. 2300 larvae of mixed stadia were employed.

No. 3. Potato shoots chewed, defecated, oviposited, etc. by females then sprayed with dist. water.

No. 4. Similar to no. 3, however, gained by washing shoots packed with larvae of mixed stadia.

Explanations of the phenomenon can slightly differ according to the stimulus situations applied. The words "attracted" and "deterred" have not been used deliberately here, as it is thought that the ultimate reason of the unequal distribution of eggs between treated and untreated plants was the decrease of unsprayed foliage (because of consumption), of which degree might have somehow been estimated, together with the egg-load already present, by randomly walking gravid females. However, as some data showed, the influence of other insect-origin factors cannot also entirely be eliminated. Such factors resulted in a similarly distorted partitioning of ovipositing females.

In the field, there were substance(s) of insect-origin present on control plants acquiring a slight or medium level of inhibition on feeding and/or oviposition, and by this way they could produce a more clear cut difference in egg distribution. On the contrary, such substance(s) were absent on distilled water-sprayed control plants in the laboratory tests. Therefore, in the latter stimulus situation plants sprayed with rinses appeared in an intermediate position of preference between plain control and Bordeaux mixture-treated plants.

It can be concluded that Bordeaux mixture treated potato stands, while not being suitable for larval or imaginal consumptions, still can receive large number of eggs from ovipositing Colorado beetle females. This way, antifeedant-treated plants can function as *egg-traps*. Newborn larvae would eventually die on treated foliage (see also MURBACH and CORBAZ, 1963), therefore, a substantial decrease could be expected on a local potato beetle population. There is no doubt, however, that expected changes would considerably depend on actual population size, oviposition drive, dispersial ability, etc.

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