

Attractiveness of some host plant and conspecific male semiochemicals to the banana weevil, *Cosmopolites sordidus* (Germar, 1824)

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ABSTRACT

The attractiveness of some chemicals derived from host plant and conspecific male sources in olfactometer bioassays was studied. The attractiveness of the chemicals was examined at two concentrations and, in some cases, in combination with banana rhizome. Pieces of banana rhizome on which male weevils (*Cosmopolites sordidus*) had fed were also compared with similar pieces of fresh rhizome. The attractiveness of the chemicals to the weevil varied with concentration. At 10 μ l, 3-methyl-butylaldehyde, 2-methyl-butylaldehyde and isobutylaldehyde proved to be very attractive to the weevil. At the same concentration, 4-mercaptophenol, valeraldehyde and methachrolein were also moderately attractive. At both 1 and 10 μ l, 2-methylbutylaldehyde was attractive. Ethyl acetate and 3-carene were attractive to the weevil at the lower concentration of 1 μ l. A combination of 4-mercaptophenol, 2-n-butylfuran, 3-methylbutylaldehyde and valeraldehyde with the banana rhizome were attractive, while 2-methylbutylaldehyde caused the rhizome to be repellent to the weevil. Rhizomes eaten by male weevils were more attractive than uneaten ones. The attractiveness of the combination of some of the chemicals with the rhizome and the additive or synergistic action of the rhizome for otherwise unattractive chemicals suggests that these chemicals can be used to improve on the trapping efficiency of split pseudostem and rhizome traps in the field.

RÉSUMÉ

BRAIMAH, H. & VAN EMDEN, H. F.: *Attraction de quelques substances médiateurs chimiques de plante hôte et de conspécifique mâle au charançon de banane (Cosmopolites sordidus (Germar, 1824)).* Une étude se déroulait pour évaluer l'attraction de quelques substances chimiques dérivés de plante hôte et de sources de conspécifique mâle dans les bio-essais d'olfactomètre. L'attraction de produits chimiques était évaluée à deux concentrations et en quelques cas en combinaison avec rhizome de banane. Les morceaux de rhizome de banane sur lesquels les charançons mâles se sont nourris étaient également comparés des morceaux semblables de rhizome frais. L'attraction de substances chimiques au charançon variait selon la concentration. 3-Methylbutylaldehyde, 2-methylbutylaldehyde et isobutylaldehyde faisaient preuve d'être très attirant au charançon à 10 μ l. 4-Mercaptophenol, valéraldehyde et méthachrolein étaient aussi modérément attirant à cette concentration. 2-Methylbutylaldehyde était attirant à 1 et 10 μ l. Ethyl acétate et 3-carène étaient seulement attirant au charançon aux plus faible concentration de 1 μ l. La combinaison de 4-mercaptophenol, 2-n-butylfuran, 3-methylbutylaldehyde et valeraldehyde avec le rhizome de banane étaient attirant alors que 2-methylbutylaldehyde provoquait le rhizome d'être repoussant au charançon. Les rhizomes qui ont été mangé par les charançons mâles étaient plus attirants que ceux qui n'ont pas été mangé. Le caractère d'attraction de la combinaison de quelques substances chimiques avec le rhizome et l'action additive ou synergique du rhizome pour les produits chimiques autrement non-attirant suggère que ces produits chimiques pourraient être utilisé pour améliorer l'efficacité de prendre au piège de pseudotige divisée et les pièges de rhizome aux champs.

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Introduction

About 400 million people in the humid tropical and subtropical regions of the world depend on bananas and plantains for carbohydrate, minerals and dietary fibre (McNicoll, 1989). Bananas and plantains are vital crops for the survival of the smallholder farmers in most cultivation areas of Africa, for whom they serve as commercial and subsistence crops. The banana crop is one of the 'cheapest' to cultivate and mixes well with industrial crops such as cocoa, coffee and rubber; and with food crops such as maize, yam, cocoyam and cassava (Johnston, 1958; Karikari, 1972; Jones, 1986). As a result, they fit well into the farming systems of the smallholder farmers of the humid tropics.

Banana and plantain production is constrained by several factors including pestilence by the banana weevil and a complex of nematodes (Bridge & Gowen, 1993). The banana weevil, *Cosmopolites sordidus* (Germar, 1824), is the most important insect pest of bananas worldwide (Ostmark, 1974; Waterhouse & Norris, 1987; Gold *et al.*, 1994). Through the mining feeding activities of its larvae, *C. sordidus* destroys the roots and stems of banana plants and causes the plants to topple over in the least wind (Froggatt, 1924; Mitchell, 1980; Bridge & Gowen, 1993). Yield losses of between 44 and 100 per cent have been reported, depending on the age at which the plant was attacked and the prevailing environmental conditions. Plants attacked at a younger growth stage suffered more damage and yield loss (Ostmark, 1974; Mitchell, 1980; Koppenhöfer & Schmutterer, 1993; Seshu-Reddy, Koppenhöfer & Uronu, 1993).

As a result of the economic importance of the weevil in banana production, several measures have been adopted for its control over the years. Chemical, biological, physical, and cultural methods have been used with little success (Edge, Wright & Goodyer, 1974; Swaine, Pinese & Corcoran, 1980; Waterhouse & Norris, 1987; Treverrow, 1993). The recent effort at finding effective pest management tools for controlling the weevil has tended to concentrate on the use of

combinations of pest management options (Kermarrec & Mauleon, 1989; Treverrow *et al.*, 1991; Kaaya *et al.*, 1993).

Unfortunately, however, it is difficult to reach the pest at any stage of its life cycle due to the mining behaviour of the larvae of *C. sordidus* during feeding, and the cryptic behaviour of the adults. Access to the weevil, therefore, can be improved by manipulating its behaviour. The use of semiochemicals, especially those with attractant and arresting properties to lure them out into split pseudostem and rhizome traps, provides such an opportunity. Host plant and conspecific-based semiochemicals are compatible with other conventional methods of pest control, and are environmentally friendly and ecologically sustainable.

This paper aimed at ascertaining the attractiveness of some identified chemicals of host plant and conspecific male origin to *C. sordidus*. The attractive ones can be used as lures for attracting weevils out of their hideouts into split pseudostem traps where they can be exposed to chemical or biological pesticides.

Materials and methods

Chemical identity and sources

The chemicals used in the study were identified from headspace analysis of host plant and weevil materials through standard coupled gas chromatography and mass spectrometry (GC-MS) methods (Braimah, 1997). The chemicals, as commercial industrial formulations, were selected for the study because they were either prevalent in the host plant materials analysed (Table 1), or were suspected to be possible components of a male-based attractant. Most chemicals were selected from the headspace analysis of dead banana leaves (Braimah & van Emden, 1999) and male weevils feeding on banana rhizome material. These materials had been found to be very attractive to the banana weevil in olfactometer studies (Braimah, 1997). Banana essence (isopropanol) was chosen as a test chemical because it is the main chemical component of the odour of ripening banana fruits.

TABLE 1

Origin in the Banana Plant or Weevil Materials Examined, Approximate Retention Times, CAS Numbers, Suppliers of the Commercial Products and the Purity of Some of the Compounds Tested for Attractiveness to the Banana Weevil, C. sordidus

<i>Chemical tested</i>	<i>Natural source</i>	<i>Retention time (min)</i>	<i>CAS number</i>	<i>Supplier/Purity (%)</i>
Methacolein	Dead leaf	9.93	78-85-3	Aldrich / 95
Isobutyraldehyde	"	7.71	78-84-2	Aldrich / 99'
2-methylbutyraldehyde	"	8.45	96-17-3	Aldrich / 95
3-methylbutyraldehyde	"	9.74	590-86-3	Aldrich / 97
Isopropanol	N/A	N/A	N/A	Langsdale / -
Propane-1,2-diol	General*	Varied	57-55-6	Fisher / -
2-n-butylfuran	Dead leaf	19.58	4466-24-4	Lancaster / -
Ethyl acetate	Dead leaf	8.77	141-78-6	BDH / 99
4-mercaptophenol	rhizome + weevils	35.46	637-89-8	Aldrich / 90
Phytol	General*	Varied	7541-49-3	Aldrich / 97
1, 2, 3-trimethylbenzol	rhizome + weevils	19.97	526-73-8	Aldrich / 90
(+)-3-carene	rhizome + weevils	21.55	0132466-78-9	Aldrich / 95
Valeraldehyde	dead leaf	10.78	110-62-3	Aldrich / 97

* = Available in several materials - = Not determined
+ = Purity is possibly above the percentage superscripted

N/A = Not applicable
Varied = retention time differed in the sources

Jones (1986) had reported that harvested banana stands harboured more weevils than younger ones.

All the chemicals, except isopropanol, were 90 per cent or higher pure and were not further analysed for purity. Isopropanol was purchased as a sealed food additive from a local food shop and its purity was not determined.

Dilution of chemicals

The chemicals were tested individually at two concentrations. For each concentration, the required amount of chemical was first dissolved in 1 ml of ethanol (100%) to ensure that it later mixed well with water. The higher concentration of the chemical was prepared by dissolving 10 μ l of the test chemical in 1 ml of ethanol and then in 99 ml of distilled water. For the low concentration of the chemical, only 1 μ l was used.

Bioassays

The chemical solutions were compared with

distilled water laced with only ethanol as a control in simple 'Y' olfactometer bioassays. Twenty millilitres of the diluted chemical was soaked in a 2-g ball of cotton wool in a small plastic box. A similar box of cotton wool was soaked with the control solution. To ascertain the possible effects that some of the chemicals would have on attractiveness of banana rhizome traps, they were tested in combination with the rhizomes at the lower concentration (1 μ l/100 ml). Due to shortage of rhizome material of the right physiological state, some of the chemicals could not be tested in combination with fresh banana rhizome. In another test, banana rhizome material on which the male weevils fed during the headspace analysis was compared with fresh material for attractiveness.

Each test was run by placing the test material in one arm of the olfactometer and a control material in the other. Twenty weevils were then placed in the response chamber and allowed 30 - 45 min to respond to the test materials. At the end of the

test period, the number of weevils in each chamber was counted and recorded. Weevils that remained in the response chamber were recorded as neutral. Each test was run three times with the test materials in the same arm of the olfactometer. The olfactometer was then wiped clean with cotton swabs soaked with ethanol, washed in distilled water, and allowed to dry in a glassware oven at 45° C for 30 min before it was re-used. In the second part of the test, the positions of the chemicals in the olfactometer were interchanged to eliminate the effects of position on the responses of the weevils.

Statistical analysis

The data collected were analysed using a χ^2 test that incorporates a test of heterogeneity (van Emden, 1993). Significant χ^2 tests that were followed by significant heterogeneity tests were considered to show inconsistency of replicates and were interpreted with caution. This was necessary to check the wrong interpretation of the data. Weevils that stayed neutral were left out of the analysis.

To evaluate the chemicals for their specific effects on the responses of the weevils at the tested concentrations, a coefficient of attraction (CA) was calculated. This supplemented the χ^2 test (which used only weevils that had responded to test materials). The calculation of the CA incorporated the neutral weevils as indicated in the following equation:

$$CA = \frac{WT - WC}{WN - WC}$$

WT = number of weevils attracted to test chemical

WC = number of weevils attracted to control material

WN = total number of weevils used in the test

The CA could take any value between -ve ∞ and 1. The closer the CA was to unity, the more attractive the test material was to the banana weevil.

Results and discussion

The responses elicited by the chemicals differed with the concentration of the test chemical (Tables 2 and 3). At the higher concentration of 10 μ l, 3-methylbutyraldehyde, 2-methylbutyraldehyde and isobutyraldehyde (the leaf aldehydes) proved to be very attractive ($P < 0.001$) to the weevil. They also showed significant heterogeneity ($P < 0.05$) of replicates. At the same concentration, 4-mercaptophenol, valeraldehyde and methacrolein were also attractive to the weevils. However, their χ^2 analysis showed significant heterogeneity ($P < 0.05$) of replicates (Table 2). Ethyl acetate, 3-carene, 2-n-butylfuran, 1, 2, 3-trimethylbenzol and isopropanol were not more attractive ($P > 0.05$) than the water control to the weevil at this concentration.

At the lower concentration of 1 μ l, only ethyl acetate, 3-carene, and 2-methylbutyraldehyde were found to be more attractive ($P < 0.05$) than the water control (Table 3). They did, however, show significant heterogeneity of replicates. The rest of the chemicals were unattractive at this concentration (Table 3). More weevils were attracted to the water control than to 3-methylbutyraldehyde, phytol, 4-mercaptophenol, and valeraldehyde at the lower concentration, though the differences were not statistically significant. Phytol, isopropanol, 1, 2, 3-trimethylbenzol and 2-n-butylfuran were less attractive than the control at both concentrations, but the differences were not statistically significant (Table 3 & 4).

The attractiveness of banana rhizome was enhanced by 4-mercaptophenol, 2-n-butylfuran, 3-methylbutyraldehyde, and valeraldehyde (Table 5). On the contrary, the combination of rhizome with methacrolein and isobutyraldehyde resulted in significantly reduced attractiveness, although with significant heterogeneity of replicates for the former (Table 4). Their combination with the banana rhizome resulted in the lowest of all the CA calculated (Table 5). Although neither 4-mercaptophenol nor 2-n-butylfuran was attractive

TABLE 2

Attractiveness to the Banana Weevil, C. sordidus, of Some Chemical Compounds Identified From the Headspace Analysis of Gases Trapped from Dead Banana Leaves and Pieces of Banana Rhizome While Male Banana Weevils Fed on Them

Chemical tested	Number of weevils attracted to		χ^2 1df	χ^2 n-1df
	Chemical	Distilled water		
3-carene	41	43	0.04 ns	10.76 ns
Ethyl acetate	43	53	1.04 ns	13.68*
2-n-butylfuran	53	36	3.43 ns	13.21*
4-mercaptophenol	44	22	7.33**	13.86*
Methacrolein	62	36	6.90*	12.78*
2-methylbutyraldehyde	77	19	35.04***	1.47 ns
3-methylbutyraldehyde	95	15	58.18***	3.92 ns
Isobutyraldehyde	73	22	27.38***	9.37 ns
Phytol	55	42	1.74 ns	29.86**
1,2,3,-trimethylbenzol	38	53	2.47 ns	18.29*
Valeraldehyde	66	44	4.40*	28.68**
Banana essence	36	40	0.21 ns	19.73*

ns = not significant ($P > 0.05$) * = ($P < 0.05$) ** = ($P < 0.01$) *** = ($P < 0.001$)

TABLE 3

Attractiveness to the Banana Weevil, C. sordidus, of Some Chemical Compounds Identified From the Headspace Analysis of Gases Trapped from Dead Banana Leaves and Pieces of Banana Rhizome While Male Banana Weevils Fed on Them

Chemical tested	Number of weevils attracted to		χ^2 1df	χ^2 n-1df
	Chemical	Distilled water		
3-carene	69	40	7.72**	11.21 ns
Ethyl acetate	66	37	8.17**	14.29*
2-n-butylfuran	40	29	1.75 ns	19.68*
4-mercaptophenol	33	42	1.08 ns	19.07*
Methacrolein	48	37	1.42 ns	8.10 ns
2-methylbutyraldehyde	66	34	10.24**	27.50**
3-methylbutyraldehyde	29	40	1.75 ns	44.10***
Isobutyraldehyde	54	37	3.18 ns	10.52 ns
Phytol	52	54	0.04 ns	14.52*
1,2,3,-trimethylbenzol	57	44	1.67 ns	14.89*
Valeraldehyde	49	57	0.60 ns	20.99**
Banana essence	50	33	3.48 ns	7.59 ns

ns = not significant ($P > 0.05$) * = ($P < 0.05$) ** = ($P < 0.01$) *** = ($P < 0.001$)

TABLE 4

Attractiveness to the Banana Weevil, C. sordidus, of the Combination of Some Chemicals Identified From the Headspace Analysis of Banana Plant Parts and Banana Weevil By-products with Fresh Banana Rhizome in an Olfactometer Bioassay

Chemical tested	Number of weevils attracted to		χ^2 1df	χ^2 n-1df
	Chemical	Distilled water		
3-methylbutyraldehyde	76	22	29.76***	19.76*
2-methylbutyraldehyde	36	75	13.70***	14.71*
2-n-butyrfuran	75	34	15.42***	13.02*
4-mercaptophenol	82	32	21.93***	5.14 ns
Isobutyraldehyde	40	62	4.76*	7.27 ns
Methacrolein	22	91	42.13***	16.21*
Valeraldehyde	67	42	5.73*	22.73**
Propylene glycol	27	85	30.04***	2.52 ns

ns = not significant ($P > 0.05$) * = ($P < 0.05$) ** = ($P < 0.01$) *** = ($P < 0.001$)

TABLE 5

Olfactory Attractiveness to the Banana Weevil, C. sordidus, of Some Host Plant and Conspecific-based Semiochemicals Tested at Two Concentrations and in Some Cases in Combination with Fresh Banana Rhizome Material

Chemical tested	Coefficients of attraction of weevils to chemicals and combinations with rhizome		
	10 μ l	1.0 μ l	+ rhizome
Isobutyraldehyde	0.52	0.20	-0.87
3-methylbutyraldehyde	0.76	0.14	0.55
2-methylbutyraldehyde	0.57	0.20	-0.38
Methacrolein	0.29	0.13	-2.38
Valeraldehyde	0.29	-0.13	0.32
2-n-butyrfuran	0.20	0.12	0.48
4-mercaptophenol	0.22	-0.12	0.57
3-carene	-0.03	0.36	0.36
Phytol	0.17	0.03	-
1,2,3-trimethylbenzol	-0.18	0.17	-
Ethyl acetate	-0.15	0.35	-
6-methyl-5-heptene-one	0.01	0.31	0.31
Banana essence	0.05	-0.24	-

to the banana weevil at the lower concentration (Table 3), their combination with the rhizome resulted in highly significant attractiveness ($P < 0.001$) (Table 4). However, heterogeneity between replicates for the combination of rhizome with 2-

n-butyrfuran was significant.

In contrast to this trend, the addition of 2-methylbutyraldehyde (which proved to be very attractive to the weevil on its own) (Tables 2 & 3) to banana rhizome showed repellent effects. How-

ever, the χ^2 analysis showed heterogeneity of replicates ($P < 0.05$), indicating inconsistencies between the replicates. Banana rhizome on which male weevils fed during headspace analysis was very attractive ($P < 0.001$) to banana weevil when compared with fresh rhizome without similar contact with male weevils (Fig. 1).

Some of the chemicals assayed singly were unattractive to the banana weevil at the concen-

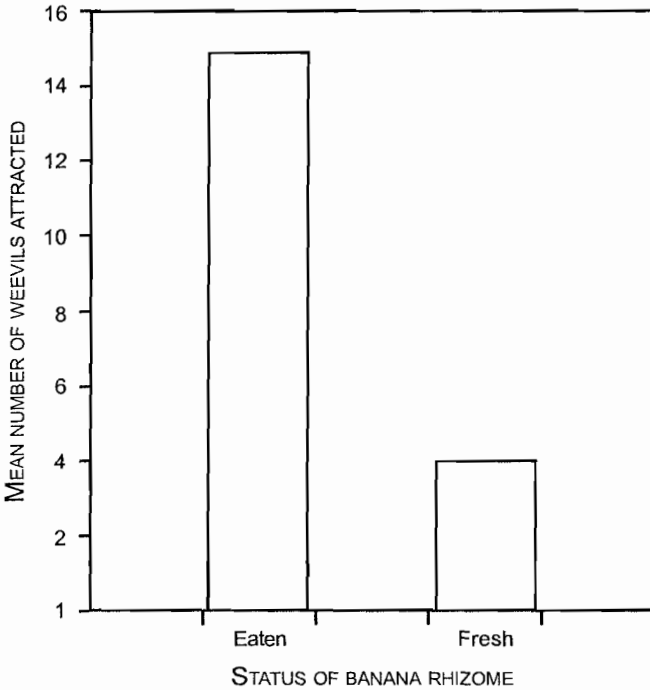


Fig. 1. Comparative attractiveness to the banana weevil, *C. sordidus*, of banana rhizome fed on by male weevils and freshly cut pieces of banana rhizome in an olfactometer.

trations at which they were tested (Tables 2 & 3). However, because the two concentrations spread over a 10-factor range (1-10 μ l), it is possible that the activity threshold of some compounds were missed out. On the contrary, Leal *et al.* (1994 b) in their study to identify the sex pheromone of the Oriental beetle, *Exomala orientalis* (Waterhouse), did not find any differences between the attractiveness of dosages of 1 and 10 mg when they tested the attraction of the insect to a 7:1 mixture

of the Z: E isomers of its pheromone at 0.1, 1.0 and 10 mg. They rather recorded a 2.9-fold increase in attractiveness between 0.1 and 1.0 mg and a significant increase in attractiveness between 1 and 100 mg. Essentially, they only found increasing attractiveness with increasing dosage of pheromone between the large range of 0.1 and 100 mg for *E. orientalis*.

In this study, only two concentrations were tested. Few compounds were found to be attractive to the insects at both concentrations. Three chemicals, including phytol, 2-n-butylfuran and 1,2,3-trimethylbutyraldehyde were less attractive to the weevil than the distilled water control at both concentrations ($P > 0.05$). Hayes *et al.* (1994) had reported that 4-allylannisol, a chemical of host plant origin, was repellent to the southern pine weevil.

The few chemicals that were unattractive at either of the two concentrations (Tables 2 & 3) and in combination with the banana rhizome (Table 4) may have been of the wrong isomeric configuration. Dickens (1978) found that *Ips typographus* (L.) discriminated between the enantiomers of its pheromone, cis-verbenol, while Bordon *et al.* (1980) reported that bark beetle *Gnathotricus retusus* (LeC.) responded to (S)-(+)-sulcatol but not to (\pm) sulcatol. The response elicited could also be affected by the absence of complementary chemicals. For example, Lin, Phelan & Barlett (1992) found that a three-component blend of acetaldehyde, ethyl acetate and 2-methylpropanol was significantly less effective in trapping the dried fruit beetle, *Carpophilus lugubris* Erichson, in the field than a seven-component blend. It is, therefore, possible that when mixed at the right proportions and concentrations, the chemicals identified from banana and banana

weevil by-products could be blended into attractive lures.

The volatile compound complex of most plants comprises mainly six-carbon aldehydes and primary alcohols formed from the oxidative degradation of plant lipids (Visser & Avé, 1978; Visser, 1986). Greater responsiveness to leaf alcohols relative to the aldehyde analogues has been reported for the Colorado potato beetle, *Leptinotarsa decemlineata* (Say) (Visser, van Straten & Maarse, 1979). The results here seem to contrast with the findings of Visser *et al.* (1979) for Colorado beetle. In this study, the aldehydes (isobutyraldehyde, 2-methylbutyraldehyde, 3-methylbutyraldehyde and methacrolein) proved to be attractive to the banana weevil while the other chemicals were either unattractive or were only marginally so when they were assayed individually (Tables 2 and 3). The results rather corroborate that of Guerin & Visser (1980) who found that the carrot fly *Psila rosae* (F.) responded more to leaf aldehydes than alcohols, and also that of Yan & Visser (1982) who reported that the aphid *Sitobion avenae* (F.) was attracted more to leaf aldehydes than alcohols.

Bioassays of 4-mercaptophenol and 2-n-butylfuran in combination with banana rhizome showed additive or synergistic interactions between the rhizome material for attractiveness to *C. sordidus* (Table 5), but heterogeneity between replicates was recorded for 2-n-butylfuran. Similar effects of a kairomone from dandelion, *Taraxacum officinale* Weber, on the sex pheromone of the scarab beetle, *Anomala octiescostata* (Waterhouse), were reported by Leal *et al.* (1994 a). Leal *et al.* (1994 a) also showed that the attraction of *A. octiescostata* to dandelion was stimulated by a mixture of cis-3-hexenyl acetate, benzaldehyde, phenylacetaldehyde, benzyl alcohol, phenethyl alcohol, phenylacetone nitrile, and benzyl benzoate in the ratio of 4:8:14:3:5:19:11.

Petroski, Bartelt & Vetter (1994) also found a synergistic action of a host plant chemical, propyl acetate, on the attractiveness of a male-produced aggregation pheromone of the dried fruit

beetle, *Carpophilus obsoletus* Erichson. It is probable that odours of the fresh banana rhizome synergised the attractiveness of 4-mercaptophenol and 2-n-butylfuran to *C. sordidus*. The synergistic actions of odours of the rhizome on pheromonal materials left on fresh banana rhizomes during the feeding of male weevils would explain the increased attractiveness of such rhizome materials over the fresh rhizome control to conspecific weevils (Fig. 1). The synergistic interactions between odours of the host plant material and conspecific-based semiochemicals indicate that their combination in traps would be more attractive than the host plant stands to *C. sordidus*. Adult *C. sordidus* would be attracted more to such traps and would be lured into them where they could be killed physically or with pesticides.

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