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Competitiveness of fertilizers with proteinaceous baits applied in Mediterranean fruit fly, *Ceratitis capitata* Wied. (Diptera: Tephritidae) control

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ABSTRACT

The use of protein-based baits applied with insecticide or within several varieties of traps is still a widespread tool in fruit flies control. Fruit flies' proteinaceous baits, agricultural supplements and animal waste just as any decomposing biological matter share a common feature of production and emitting gaseous ammonia. This process is highly influenced by biotic and abiotic factors affecting the instability of ammonia release rate. Several common fertilizers were as attractive as several common commercial fruit fly baits to Mediterranean fruit fly females. Chicken litter served also as nutritional source of protein decreasing females' eagerness to baits. The potential of ammonia-emitting sources to interfere with fruit fly baits during control is discussed. The implications of using fertilizers during control procedure should be taken into account.

1. Introduction

Fruit flies (Diptera: Tephritidae) are amongst the largest families of Diptera and one of the most economically important. In 1994, White and Elson-Harris listed 4000 species arranged in 500 genera, within which 35% are soft-fruit attacking species including many commercial fruits. The Mediterranean fruit fly (medfly) is one of the most injurious members of this family since it is highly polyphagous and widely distributed. The most common procedure to control the medfly as well as other fruit flies is the low volume aerial or ground spraying of a blend containing insecticide and a protein-based bait (Steiner, 1955; Rössler, 1989). The need for external protein for sexual maturation leads fruit fly females to the proteinaceous bait. The role of the bait is to reduce environmental contamination as well as financial costs (Chambers et al., 1974). The bait may also be applied in variety of traps.

Gaseous ammonia is one of the most conspicuous end-products of decomposing processes and is the key component in attracting the flies to protein-based bait (McPhail, 1939; Bateman and Morton, 1981). Ammonia has been used as a fruit fly attractant since the early thirties of the 20th century (reviewed by Gow, 1954) but there are conflicting reports on its effectiveness in attracting fruit flies (reviewed by Bateman and Morton, 1981). The attraction of medfly females to ammonia is dose-dependent, meaning low attraction below the optimal rate of ammonia release and rejection above this value. The range of unattractiveness is very narrow while the range of rejection is much wider (Bateman and Morton, 1981; Mazor et al., 1987; Mazor et al., 2002).

Observations on the behavior of fruit flies in nature revealed that the flies are attracted by and feed on bird feces (Christenson and Foote, 1960; Bateman, 1972; Malavasi et al., 1983; Hendrichs and Hendrichs, 1990; Hendrichs and Prokopy, 1990; Hendrichs et al., 1991; Prokopy et al., 1992; Hendrichs et al., 1993a,b; Jacome et al., 1999). The competitiveness of bird droppings with proteinaceous bait spray droplets was studied by Prokopy et al. (1993a). Bird feces are natural ammonia-emitting sources. Additional ammonia-emitting sources present in an orchard are agricultural supplements such as organic and synthetic fertilizers. The aim of this study was to compare the attraction of several common fertilizers to several common commercial fruit fly baits and to correlate the attraction of these substances with the rate of ammonia release. The results may improve the coordination between the activities of fertilization and fruit fly control.

2. Materials and methods

2.1. Insects

Laboratory-reared flies from the 'Sade' strain were obtained as pupae from the Citrus Marketing Board of Israel. This colony was established about more than 30 years ago from infested citrus fruits

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collected from various orchards in Israel and was genetically strengthened every 2–3 years by field collected males. Pupae and emerging flies were kept in a room with windows, under natural photoperiod conditions and a controlled atmosphere of 26 ± 2 °C and $68 \pm 2\%$ relative humidity.

2.2. Comparison of the attraction of different ammonia-emitting sources in the laboratory

All the behavioral tests were conducted at the same conditions as described above. These tests were conducted with 200 protein-deprived and mostly unmated 3- to 10-day-old females in an olfactometer developed and described by Gothilf and Galun (1982). During the tests the flies were offered granulated sugar and water absorbed on cotton wool. The tested commercial baits were as follows: Entomela (Vioryl, Athens, Greece), Buminal (Bayer, Leverkusen, F.D.R.), NuLure (Miller Chemical & Fertilizer Co., USA) and Corn Steep Liquor (CSL) (Roquette, Lestrem, France), Nasiman (Tamogan, Tel-Aviv, Israel). Ammonium acetate (Merck, Germany) was included in this group since it is the main component of the dry bait Biolure. The tested manures were Guano (Lignotech, Norway), poultry litter, fresh cattle manure, fresh separated cattle manure, separated cattle manure, pelletized poultry manure, feather meal and grape rape (Shacham, Givat ada, Israel). The fertilizers urea prills and solution of ammonium nitrate (winter concentration) were supplied by Gat fertilizers, Israel. Manures are usually applied directly to the soil while the solution of the fertilizers urea and ammonium nitrate may also be applied as foliar spray. The liquidly commercial baits were tested in two concentrations, original and 10%-diluted. The original solution of most liquidly commercial is viscous and is usually diluted upon use. Most commercial baits are used as 10% solutions. A volume of about 1 ml of each material was pipetted into a 3-cm-long × 1.5-cm i.d. glass tube. A 10-cm metal wire was joined to the side of the glass tube allowing to insert the bait into the trap. 6 traps, 3 with bait and 3 empty ones as control were suspended alternately from the horizontally rotating wheel of the olfactometer at a rate of 1 complete turn/10 min for 1 h. At the end of the experiment, the entrance holes of each trap were plugged with a piece of cotton wool and the traps were transferred to the refrigerator for a few minutes to allow the counting of the captured flies. Flies trapped in all 3 baited traps in one olfactometer were considered as one replicate.

2.3. Ammonia trapping system

This system included a 100 ml round bottom flask containing 1–3, 3-cm-long × 1.5-cm i.d. glass tube(s), with the tested solution (depending on the rate of ammonia release) connected to two consecutive water traps, 16-ml-long × 2-cm i.d. glass tubes containing 10 ml double-distilled water. Each glass tube contained a volume of about 1 ml of the tested material. The whole system was sunk in a water bath at a temperature of 30 °C. Fresh air was pulled into the trapping system by a vacuum pump at a rate of 100 ml/min. The air was drawn into and through the round glass flask containing the tested material and then through sintered glass filters to the first and the second 10-ml water tubes. Most of the emitted ammonia was caught in the first water tube. The trapping of ammonia lasted 1–8 h (depending on the rate of release of ammonia). The amount of ammonium ion in the water was determined by a colorimetric phenol chlorite method (Solorzano, 1969) and was calculated as μg ammonia released from 1 ml experimental material per hour.

2.4. The effect of free access to poultry litter on the attraction of females to the most attractive pure ammonia solution of 0.1 N

The attraction of two groups, one with protein-deprived females and the other with females which had free access to poultry litter since emergence, was compared toward 0.01 N pure ammonia solution, the most attractive ammonia solution (Mazor et al., 1987; Mazor et al., 2002) in olfactometers. Both groups were served freely with granulated sucrose and water absorbed in cotton wool. The poultry litter was removed during the attraction tests to avoid interference with the ammonia solution. Each group included 200, 3- to 7-day-old females which were tested during 5 consecutive days. Dead flies were replaced with flies of the same group at the end and at the beginning of every experiment to avoid feeding on them. The experiment was conducted with 10 replicates.

2.5. Statistical analyses

All the data were analyzed by analyses of variance (ANOVA) and multiple comparisons of means by Tukey's HSD test using the GLM procedure available on SAS software.

3. Results

3.1. Attraction of the different sources releasing ammonia

The various sources of ammonia release, i.e., commercial protein-based baits and the fertilizers were divided into 4 groups according to their level attraction (Table 1). The excellent attractants, as shown by statistical analyses (a), were pelletized poultry manure and solution of ammonium nitrate which caught 44% and 45.9% of females/olfactometer/hour respectively. Less attractive but still good (b, c) were crystalline ammonium acetate, the key component of the dry bait Biolure which caught 38.57% females/olfactometer/hour, and both guano and poultry litter which caught 32.84 and 32.78 of females/olfactometer/hour respectively. The 3rd group is of moderate attraction (d–f and captures higher than 10% of females/olfactometer/hour) includes undiluted and 10%-diluted solutions of Entomela, undiluted solution of Buminal, fresh cattle manure, separated cattle manure and grape rape. The 4th group of poor attractants which caught less than 10% of females/olfactometer/hour included undiluted solutions of the commercial baits NuLure, CSL and Nasiman, 10%-diluted solutions of Buminal, NuLure, CSL and Nasiman and the fertilizers fresh separated cattle manure, feathers meal and urea belong to this group. Categories A and B, include only fertilizers, apart from the exceptional ammonium acetate, category C includes 3 fertilizers and 3 commercial baits while category D with the inferior attractants includes only 3 fertilizers and 7 commercial baits.

An interesting point appears while comparing the attraction between the original solutions of the commercial baits and 10%-diluted solutions. The attraction of the original solutions of Entomela, Buminal, CSL and Nasiman is higher than that of the 10%-diluted solution while in NuLure the situation is reversed, more females were attracted to the diluted solution. The explanation cannot be based on the rate of ammonia release since it is very low in both concentrations. The composition of commercial bait solutions is usually unknown. There is a possibility that the original solution of NuLure contains repulsive components that when diluted become less repulsive.

3.2. Ammonia trapping system

The rate of ammonia release of some of the ammonia-emitting materials was measured. The results are present in Table 1. The highest rates of ammonia release were demonstrated by ammonium acetate, Guano and poultry litter which were of 2 orders of magnitude higher than the others. The rate of ammonia released from pelletized poultry manure, fresh cattle and separated cattle