Comparison of the Efficacy of Different Food Attractants and Their Concentration for Melon Fly (Diptera: Tephritidae)

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ABSTRACT The relative attractiveness of six commercially available protein hydrolysates and the influence of their concentration were evaluated in field cages by a release-capture method of lab-reared melon fly adults, *Bactrocera cucurbitae* (Coquillett). Buminal, Corn Steepwater, Hym-Lure, Pinnacle, Nulure, and SolBait were tested for both sexes of the melon fly. The tested products exhibited clear differences in attractiveness. SolBait was the most effective protein hydrolysate. Pinnacle and Corn Steepwater also gave promising results. A general tendency for an increase in effectiveness with increasing concentration within the range 0.5 to 10% was shown. This study will allow pest control practitioners to choose more effective attractants for use in bait sprays to control the melon fly thus reducing the intensive use of insecticides currently practiced in Reunion island and enabling the development of Integrated pest management (IPM) methods for cucurbit crops.

KEY WORDS *Bactrocera cucurbitae*, food attractants, protein hydrolysates, concentration.

THE MELON FLY, *Bactrocera cucurbitae* (Coquillett) (Diptera: Tephritidae), is an important pest on Cucurbitaceae within its large geographical range. *B. cucurbitae* is found in most countries in the new Guinea region of Asia, and has also reached Hawaii, Guam, Kenya, Tanzania, Egypt, Iran, Mauritius, Reunion island (White and Elson-Harris 1992), and recently the Seychelles (Stonehouse et al. 2000). Though recorded on >125 host plants belonging to various families (Weems 1964), this pest preferentially attacks Cucurbitaceae on which it may damage young fruits, flowers, stems, or petioles.

On Reunion island, *B. cucurbitae* can be considered the major fruit fly pest on cucurbit crops (Etienne 1982, Vayssières and Carel 1999). The pest is mostly found at low and medium altitudes on the island where it competes with the Ethiopian cucurbit fly *Dacus* (*Didacus*) *ciliatus* Loew. Both are in competition with the Indian ocean cucurbit fly *Dacus* (*Dacus*) *demmerezi* (Bezzi) in high altitude areas (above 500 m) (Etienne 1982, Vayssières 1999). On this island, *B. cucurbitae* is able to attack 12 species of cultivated cucurbits and four species of wild cucurbits (Etienne 1972, Vayssières and Carel 1999). Damage to cultivated crops may reach 100% without insecticide control (Vayssières and Carel 1999).

In most countries where *B. cucurbitae* is present, farmers frequently spray broad-spectrum insecticides to control this pest (Roessler 1989). For instance, in Reunion island, farmers apply synthetic pyrethroids, organophosphates or carbamates up to twice a week (P. Ryckewaert, personal communication). In the absence of more specific active ingredients for chemical control against tephritids, the improvement of bait spray techniques (Roessler 1989) remains a major step to developing integrated control methods against pests on cucurbits.

As with many tephritid species, females of melon fly need protein to mature sexually and for their eggs to develop (Hagen and Finney 1950). Thus, the available, effective food attractants are generally complex mixtures of protein hydrolysates derived from yeasts, corn bran or soy bran. Bait-sprays containing protein hydrolysates have been used extensively for a long time in various parts of the world against different tephritid species (Steiner 1952, Roessler 1989).

In some cases bait sprays have been used successfully to control the melon fly (Gupta 1960, Kavadia et al. 1977, Verma and Sinha 1977, Gupta and Verma 1982, Vijaysegaran 1985, Deshmukh and Patil 1996). For instance, Vijaysegaran (1985) mentions a significant reduction in damage to musk melon varieties (*Cucumis melo* L.) when using 0.2% (AI) Staley's Protein Insecticide Bait No seven (PIB-7) + 0.2% (AI) malathion EC. However, when applied at concentrations of 0.8% (AI) and above, PIB-7 was phytotoxic to plants (Vijaysegaran 1985).

In Taiwan, the comparison of various substances from yeasts, peptones and ammonium salts showed that a mixture of molasses and tryptone was most attractive for adults of *B. cucurbitae.* Moreover, the attractiveness could be improved by adding ethyl acetate to the mixture (Liu and Chang 1995). In another

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study with various commercial products, Liu and Chen (1995) obtained the best results with yeast hydrolysate and molasses. However, no detailed study has been conducted to assess the relative attractiveness of commercially available protein hydrolysates for both sexes of *B. cucurbitae.*

Very few studies are available on the optimal protein concentration to attract *B. cucurbitae* (Tamori and Iraha 1986, Liu and Chen 1995) though this was reported as major factor in an attractant's effectiveness (Matsumoto et al. 1985). Indeed, such studies are a prerequisite for the improvement of bait spray techniques against the melon fly.

In this study, we evaluated the influence of a range of concentrations of six commercially available protein hydrolysates on their attractiveness for both sexes of the melon fly. A method of release-capture of lab-reared adults in field cages was used. The relative attractiveness of these products in a choice situation was determined at two concentrations.

Materials and Methods

This study was conducted during the austral spring and summer, between September 2000 and February 2001, in the CIRAD (Center for International Cooperation in Agricultural Research for Development) experimental station of Saint-Pierre (Reunion Island, France).

Protein Hydrolysates. We used six commercially available protein hydrolysates: (1) Buminal (Bayer SA, Puteaux, France), the only protein hydrolysate registered in France, (2) Corn Steepwater (Corn Products, Summit Argo, U.S.A.), (3) Hym-Lure RTU (Robertsons [Pty] Limited, Durban, South Africa), (4) Pinnacle Protein Fruit Fly Bait (Mauri Yeast Products, Brisbane, Australia), (5) Nulure (Miller Chemical & Fertilizer Corporation, Hanover, U.S.A.), previously designated as Protein Insect Bait No seven (PIB-7) and (6) SolBait (U.S. Department of Agriculture, Weslaco, U.S.A.).

As the pH is known to have a marked influence on the efficiency of food attractants in some tephritids (Bateman and Morton 1981, Heath et al. 1994), the pH of the protein hydrolysates was measured just after preparing the solutions with a laboratory pH meter (Accumet model 25, OSI, France). Three replicates were made for each pH determination.

Field-Cages and Traps. This study was conducted in cylindrical mesh-screened field cages (2.5 m tall × 3 m diameter). Twenty potted plants of *Cucurbita moschata* Duchesne. (variety Martinica, Technisem) were placed in each field cage to create seminatural conditions and to homogenize the distribution of the flies. Protein hydrolysates were put in McPhail traps (Dome Trap, Agrisense, Pontypridd, U.K.) whose bottom surface had been painted black. In this way, flies responses to visual stimuli are minimized (F. F., P. R., P.F.D., F. C., and S. Q., unpublished data). Each trap contained 200 ml of solution. The components and concentration of the solutions varied with each experiment and are described below. Four traps per cage were hung on a H-shaped base, 50 cm above the plant canopy, and arranged along a 1-m radius imaginary circle centered in the field cage.

Flies. Wild pupae of *B. cucurbitae* were collected in June 2000 from infested pumpkins (*Cucurbita maxima* Duchesne) in three localities of Reunion Island (Petite Ile, Bassin Martin, and Piton Saint-Leu). Adult flies obtained from these samples were reared under controlled conditions of 25 ± 2°C, 70 ± 20% RH, and a photoperiod of 12:12 (L:D) h. They were given free access to granulated sugar complemented with enzymatic yeast hydrolysate (ICN Biomedicals, Aurora, OH, U.S.A.) and water. Experiments were conducted with the F2 laboratory reared-flies. Three times a week, for 1 h, zucchinis (*Cucurbita pepo* L.) were provided to mated F1 females as an oviposition substrate. Developing F2 larvae were fed with pumpkin fruits and dehydrated potatoes. Pupae were collected and adults were kept in 40 × 40 × 40 cm cages, from the beginning of emergence. So, we regularly obtained various cages with cohorts of flies of similar age. All flies used in our experiments were 15- to 25-d-old and were assumed to be sexually mature (Vargas et al. 1984). As the sexes were not separated until the day before each experiments, most flies were supposed to be mated. During all experiments, males and females were tested in different cages to prevent any sexual attraction (Kuba and Sokei 1988).

Influence of Dilution on Attractiveness. For each of the six protein hydrolysates, two ranges of concentration have been tested: (R1) 0.5, 1, and 2% and (R2) 1, 5, and 10% [vol/vol]. Each experiment (i.e., the combination between one protein hydrolysate and one range of concentration) was repeated eight times. A multiple choice test was proposed to the flies, using R1 in a first experiment and R2 in a second experiment. Each day of the experiment, 250 males were released in a one field cage and 250 females were released in a separate cage at 0700 hours local time to allow flies to disperse. At 0800 hours, four traps were placed in each field cage: one trap for each concentration studied and one trap with water as a control. The initial position of the traps was randomized at the beginning of first replicate. At 1000 hours, 1200 hours, 1400 hours, 1600 hours, and 1800 hours the flies collected in each trap were counted, killed and removed from the trap. Five counts were done daily to minimize a possible effect of the number of caught flies on the attractiveness of the traps. Moreover, after each observation, a circular permutation (quarter turn) of the position of the traps was carried out. Finally, for each subsequent replicate, the initial position of the traps (at 0800 hours) was modified according to a circular permutation. This method was used to lessen the consequences of a possible unequal distribution of the flies on the field cage walls, caused by exposure to natural light or wind.

Comparison of the Relative Attractiveness of Protein Hydrolysates at Two Concentrations. The comparison of all the protein hydrolysates was carried out at two selected concentrations (2 and 5%). These concentrations were chosen because of their com-

Table 1. *F* values and *P* values of the 12 three-way analysis of variance for influence of concentration of six protein hydrolysates on attractiveness

Experiment[a]	Replicate (V1)		Concentration (V2)		Sex (V3)		V1 × V2		V1 × V3		V2 × V3	
	F	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
SolBait												
R1	0.29	0.94	142	$<10^{-5}$	0.18	0.67	1.69	0.12	0.03	0.99	2.90	0.06
R2	0.17	0.98	91	$<10^{-5}$	0.05	0.82	1.03	0.47	0.03	0.99	0.45	0.72
Pinnacle												
R1	0.12	0.99	89	$<10^{-5}$	0.06	0.80	1.12	0.39	0.14	0.99	0.51	0.67
R2	0.11	0.99	98	$<10^{-5}$	0.12	0.72	1.45	0.20	0.04	0.99	2.75	0.07
Hym-Lure												
R1	0.06	0.99	46	$<10^{-5}$	0.09	0.77	0.47	0.95	0.01	0.99	0.46	0.71
R2	0.17	0.96	94	$<10^{-5}$	0.55	0.46	1.27	0.32	0.17	0.96	1.14	0.36
Nulure												
R1	0.08	0.99	49	$<10^{-5}$	0.01	0.91	1.03	0.46	0.12	0.99	2.80	0.06
R2	0.06	0.99	57	$<10^{-5}$	0.07	0.79	1.06	0.44	0.08	0.99	0.90	0.45
Corn Steepwater												
R1	0.09	0.99	63	$<10^{-5}$	0.04	0.94	0.86	0.63	0.06	0.99	0.09	0.96
R2	0.08	0.99	130	$<10^{-5}$	0.02	0.89	0.86	0.62	0.22	0.97	2.20	0.11
Buminal												
R1	0.07	0.99	64	$<10^{-5}$	0.36	0.55	1.99	0.06	0.02	0.99	3.54	0.03
R2	0.05	0.99	35	$<10^{-5}$	0.09	0.76	0.54	0.91	0.04	0.99	3.65	0.03

[a] V1, replicate (df 7); V2, concentration of the protein hydrolysates (df 3); V3, sex (df 1); V1 × V2, interaction between V1 and V2 (df 21); V1 × V3, interaction between V1 and V3 (df 7); V2 × V3, interaction between V2 and V3 (df 3), Residuals (df 56).

patibility with current agricultural practices (Roessler 1989). During every experiment, the relative attractiveness of four protein hydrolysates was determined by placing each protein hydrolysate in one of the four traps. A fifth trap containing water was placed as a control in the center of the field cage, its position being unchanged during the whole experiment. Except for this point, the procedure was similar to the one used in the previous series of experiments. For each of the two concentrations, three experiments have been conducted, so that finally each protein hydrolysate is compared at least once to the other five.

Statistical Analysis. As our purpose was a comparison of the relative effectiveness of the products, the data analyzed for each cage were the total number of flies caught in one trap during one day divided by the total number of flies caught in all the traps during the same day. Data were transformed by two arcsine (square root x) to stabilize the variance before analysis. Data were analyzed by a three way analysis of variance (ANOVA) with first order interactions (S-Plus 1999). For the first set of experiments, the three factors were "replicate" (controlled factor—eight levels), "concentration of protein hydrolysate" (studied factor—four levels) and "sex" (studied factor—two levels). In a single case, the comparison of Buminal concentrations, the interaction "concentration × sex" was significant and therefore a one way ANOVA was performed for each sex with the concentration as the single factor. For the second set of experiments, the three factors were "replicate" (controlled factor—eight levels), "type of protein hydrolysates" (studied factor—five levels), and "sex" (studied factor—two levels). When the *F* value was significant ($P < 0.05$), a Tukey's means separation test was used.

Results

Influence of Concentration on Attractiveness. A total of 12 experiments was carried out using six protein hydrolysates, each at two ranges of concentrations: (R1) 0.5, 1 and 2%; (R2) 1, 5, and 10%. For all of the 12 ANOVA realized (Table 1) neither replicate nor its interaction with concentration had any significant influence on the results, which meant that the relative attractiveness of each trap was the same for each replicate. In addition, the interaction "replicate × sex" was never significant, which meant that the rate of catches for both sexes and for each replicate was the same. Moreover, the factor "sex" also had no significant influence on the results. The interaction "concentration × sex" was also not significant, except in the case of Buminal. So, for all protein hydrolysates except for Buminal, both sexes showed a similar response whatever the tested concentrations were. Thus, all protein hydrolysates will be dealt with in pooling sexes, except for Buminal.

For all 10 experiments, the factor "concentration" always had a highly significant effect (df = 3, 56; $P < 10^{-5}$) (Table 1). Tukey's mean separation test showed that the control attracts significantly fewer flies than any of the other treatments. The percentage of flies caught in the control always remained very low, ranging from 1.6 to 4.2% of the total. In addition, it appears that the attractiveness of each protein hydrolysate increased with its concentration within the tested ranges.

Regarding the low range of concentration (R1) (Table 2), significant differences appeared between all tested concentrations only with SolBait. For Nulure and Hym-Lure significant differences were observed between 0.5 and 2% as well as between 1 and 2%. However, for these two protein hydrolysates, no sig-

Table 2. Mean (± SE) percentage of melon flies caught in traps with protein hydrolysate concentrations ranging between 0.5–2% (R1)

Protein hydrolysate	Concentration [vol:vol]			
	Control	0.5%	1%	2%
SolBait	2.5 ± 1.0a	15.6 ± 1.5b	29.4 ± 2.6c	55.5 ± 3.3d
Pinnacle	3.7 ± 1.1a	25.3 ± 1.6b	31.2 ± 2.1bc	39.8 ± 1.6c
Hym-Lure	2.1 ± 0.4a	22.9 ± 2.5b	30.3 ± 3.0b	44.8 ± 2.8c
Nulure	4.2 ± 1.1a	23.3 ± 3.1b	29.5 ± 2.2b	43.0 ± 2.5c
Corn Steepwater	2.9 ± 0.5a	18.2 ± 1.8b	36.5 ± 2.6c	42.4 ± 2.9c

Within line, means followed by the same letter are not significantly different (Tukey's mean separation test on 2 arcsin (sqrt x) transformed data; non transformed means presented).

Data for males and females combined, $n = 16$.

nificant differences existed between 0.5 and 1%, though the latter concentration showed the greatest catches. For Corn Steepwater, significant differences were observed between 0.5 and 1% as well as between 0.5 and 2%. However, one and 2% were not different, though the latter concentration captured more flies. Finally, for Pinnacle, the only significant difference appeared between 0.5 and 2%, though here again the catches increased with the concentration.

Regarding the high range of concentration (R2) (Table 3), significant differences appeared between all tested concentrations of four out of five products (SolBait, Pinnacle, Hym-Lure, and Corn Steepwater). The fifth product, Nulure, showed significant differences between 1 and 5% as well as 1 and 10% but not between 5 and 10% even though the latter concentration attracted more flies.

For Buminal, the interaction between concentration and sex was significant in the first set (R1) and second set (R2) of experiments ($P < 0.05$) (Table 1). So, the influence of concentration was analyzed for each sex using a one-way ANOVA. As for the other protein hydrolysates, the influence of concentration was highly significant ($P < 10^{-5}$) for both sexes and the control always attracted less flies than any concentration tested. Regarding the low range of concentration (R1) (Table 4), no significant differences in the catches of females were observed between the concentrations tested. As for the males, the concentration of 2% was significantly more attractive than 0.5 or 1%, and no significant difference was found between the two latter concentrations. Regarding the high range of concentration (R2) (Table 4), females were significantly more attracted to the concentration of 10% than to 1 or 5% that were not significantly different. Males were significantly more attracted by 5 and 10 than by 1%, and no significant difference was found between the two highest concentrations.

Table 3. Mean (± SE) percentage of melon flies caught in traps with protein hydrolysate concentrations ranging between 1 to 10% (R2)

Protein hydrolysate	Concentration [vol:vol]			
	Control	1%	5%	10%
SolBait	1.6 ± 0.5a	20.6 ± 1.8b	32.3 ± 2.4c	45.5 ± 2.9d
Pinnacle	2.6 ± 0.5a	23.3 ± 2.2b	32.2 ± 2.4c	42.0 ± 2.5d
Hym-Lure	3.2 ± 0.8a	15.9 ± 1.9b	31.6 ± 1.6c	49.2 ± 2.6d
Nulure	3.3 ± 0.7a	19.1 ± 2.4b	34.4 ± 3.0c	43.2 ± 2.9c
Corn Steepwater	2.2 ± 0.6a	14.0 ± 1.6b	34.7 ± 2.1c	49.1 ± 2.1d

Within line, means followed by the same letter are not significantly different (Tukey's mean separation test on 2 arcsin (sqrt x) transformed data; non transformed means presented).

Data for males and females combined, $n = 16$.

Table 4. Mean (± SE) percentage of flies caught in traps for high and low concentration ranges of Buminal ($n = 8$)

	Concentration [vol:vol]			
Low range	Control	0.5%	1%	2%
Males	2.1 ± 0.3a	19.2 ± 2.3b	25.4 ± 3.2b	53.3 ± 4.6c
Females	4.7 ± 0.6a	28.2 ± 2.9b	27.6 ± 3.0b	39.5 ± 2.4b
High range	Control	1%	5%	10%
Males	3.3 ± 0.9a	15.0 ± 1.9b	42.4 ± 4.3c	39.3 ± 3.5c
Females	3.4 ± 0.5a	26.1 ± 1.9b	23.1 ± 2.9b	47.5 ± 2.7c

Within line, means followed by the same letter are not significantly different (Tukey's mean separation test on 2 arcsin (sqrt x) transformed data; non transformed means presented).

Comparison of the Relative Attractiveness of Protein Hydrolysates at Two Concentrations. For all six ANOVA realized (Table 5), the factors "replicate" and "sex," as well as all first order interactions between the three factors, had no significant influence on the results. In particular, the relative attractiveness of different protein hydrolysates was similar for both male and female flies.

By contrast, for all six ANOVA, the factor "type of protein hydrolysate" had a highly significant influence on the results (df = 4, 28; $P < 10^{-5}$) (Table 5). Tukey's mean separation test confirmed that the control attracted significantly fewer flies than any of the other treatments. The percentage of flies caught in the control always ranged from 0.77 to 2.01%.

In the first experiment at the concentration of 2% (Fig. 1), Buminal, Nulure, Hym-Lure, and Corn Steepwater were compared. Buminal traps caught significantly fewer flies than the three other protein hydrolysates whereas Corn Steepwater caught significantly more flies than the other three ($F = 54$; df = 4, 28; $P < 10^{-5}$). No significant differences were observed between Nulure and Hym-Lure. In the second experiment at 2% with Buminal, Nulure, Pinnacle, and SolBait, significantly more flies were attracted to SolBait than to any of the other baits. Buminal appeared significantly less attractive than Pinnacle and SolBait but just as attractive as Nulure. In the last experiment at 2% with Pinnacle, SolBait, Hym-Lure, and Corn Steepwater, SolBait traps caught significantly more flies than Pinnacle, Hym-Lure, or Corn Steepwater, and there was no significant difference among the latter.

In the series of experiments at the concentration of 5% (Fig. 1), Hym-Lure, Nulure, Corn Steepwater, and SolBait were compared in the first experiment. SolBait caught significantly more flies than the three other protein hydrolysates that were not significantly different between them. The second experiment aimed at comparing Hym-Lure, Nulure, Pinnacle, and Buminal. The latter treatment attracted significantly fewer flies than the three others. The others were not

Table 5. *F* values and *P* values of the 6 three way-ANOVA for the comparison of relative attractiveness of six protein hydrolysates at two concentrations

Experiment[a]	V1		V2		V3		V1 × V2		V1 × V3		V2 × V3	
	F	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
Exp 1 2%	0.11	0.99	54	$<10^{-5}$	0.01	0.89	1.7	0.08	0.10	0.99	0.06	0.99
Exp 2 2%	0.08	0.99	76	$<10^{-5}$	$<10^{-3}$	0.97	1.34	0.22	0.12	0.99	1.51	0.22
Exp 3 2%	0.02	0.99	41	$<10^{-5}$	0.02	0.89	0.96	0.54	0.02	0.99	0.34	0.85
Exp 4 5%	0.04	0.99	50	$<10^{-5}$	0.04	0.85	1.14	0.35	0.04	0.99	0.57	0.68
Exp 5 5%	0.08	0.99	53	$<10^{-5}$	$<10^{-3}$	0.97	0.99	0.50	0.09	0.99	0.76	0.55
Exp 6 5%	0.79	0.60	192	$<10^{-5}$	0.16	0.69	1.74	0.08	0.17	0.98	1.41	0.25

Exp 1: comparison between Buminal, Nulure, Hym-Lure and Corn Steepwater at 2%; Exp 2: comparison between Buminal, Nulure, Pinnacle and SolBait at 2%; Exp 3: comparison between Pinnacle, SolBait, Hym-Lure, and Corn Steepwater at 2%; Exp 4: comparison between Hym-Lure, Nulure, Corn Steepwater, and SolBait at 5%; Exp 5: comparison of Hym-Lure, Nulure, Pinnacle, and Buminal at 5%; Exp 6: comparison between Pinnacle, Buminal, Corn Steepwater, and SolBait at 5%.

[a] V1, replicate (df 7); V2, protein hydrolysate (df 4); V3, sex (df 1); V1 × V2, interaction between V1 and V2 (df 28); V1 × V3, interaction between V1 and V3 (df 7); V2 × V3, interaction between V2 and V3 (df 4); Residuals (df 28).

significantly different although Pinnacle attracted more flies than Nulure or Hym-Lure (33.2, 27.1, and 25.7% for Pinnacle, Nulure, and Hym-Lure, respectively). In the last experiment, Pinnacle, Buminal, Corn Steepwater, and SolBait were compared. Again, Buminal attracted significantly fewer flies than the three others. SolBait caught more flies than Pinnacle (36.4 versus 29.9%) although they were not significantly different, both being significantly more attractive than Corn Steepwater.

pH values. Within the range of concentration tested, the pH of every solution showed a slight decrease as the concentration increased from 0.5 to 10%, which is logical for acid solutions of increasing concentration (Fig. 2). The different protein hydrolysate types could be divided into three groups according to their pH values. In the lowest pH group, Corn Steepwater and Nulure had a mean pH value of four at the concentration of 2% while in the highest pH group, Pinnacle, Buminal, and Hym-Lure showed a mean pH value near six at the same concentration. SolBait appeared to have an intermediate pH value of 5.2 at 2%.

Discussion

Generally, in this study, increase of attractiveness with increasing concentrations from 0.5 to 2% was observed (though for Corn Steepwater 1% is not different from 2%). Also, a clearer increase of attractiveness was recorded with increasing concentrations

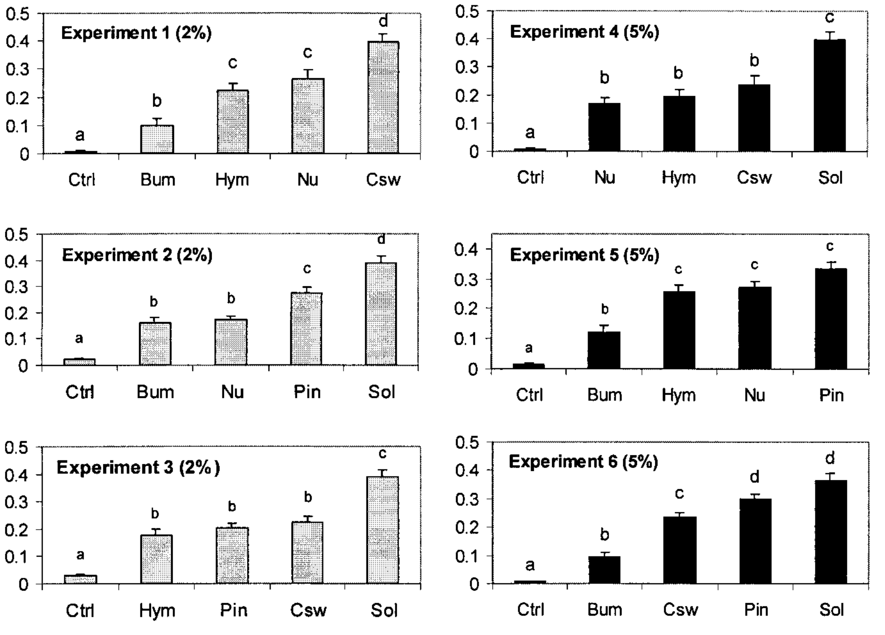

Fig. 1. Percentage of melon flies (mean of males and females [± SE]) captured in each Dome trap with water (Ctrl); Buminal (Bum); Nulure (Nu); Hym-Lure (Hym); Pinnacle (Pin); Corn Steepwater (Csw); and SolBait (Sol). Bars headed by the same letter within a graph are not significantly different (Tukey's test mean separation on two arcsine (sqrt x) transformed data; nontransformed means presented).

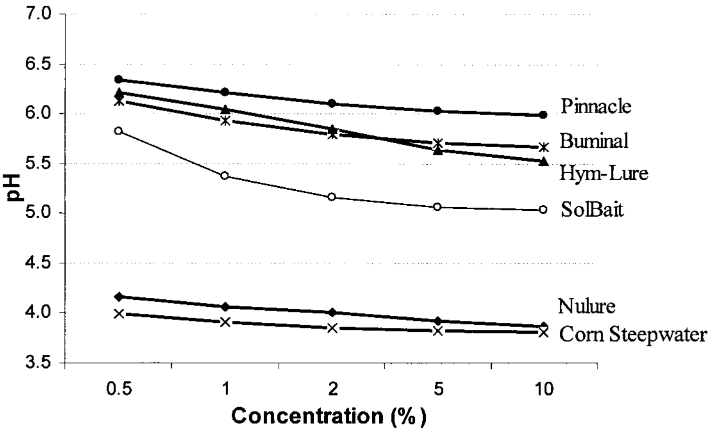

Fig. 2. Relationship between protein hydrolysates concentration and pH (means of three replicates).

from 1 to 10% (though for Nulure 5% is not different from 10%). This appears logical as the amplitude of the first range of concentration tested corresponds to a four-fold increase whereas that of the second range of concentration corresponds to a 10-fold increase. These two trends are valid for both sexes. These results may be because of the fact that more active compounds are present with increasing concentrations of the attractants (Matsumoto et al. 1985) or that a greater quantity of active compounds increases the attractiveness.

To determine an optimal concentration for attractiveness for each of the tested products, it would be worth testing the possibility of an increase in attractiveness for higher concentrations. In this case, it might be more interesting for bait-spraying to use more concentrated solutions, while applying a lower volume for each spot. Before implementing such a plan, we would have to take into account the possible phytotoxicity of concentrated solutions on cucurbits (Vijaysegaran 1985).

Most of the products compared in our study have been successfully tested in the field against various tephritids: Nulure (Wakabayashi and Cunningham 1991), Corn Steepwater (Epsky et al. 1994), Buminal (Mazor et al. 1987), and Hym-Lure (Buitendag and Naude 1994). All of them are commonly used in bait-sprays to control fruit flies.

At a concentration of 2%, Buminal appeared as one of the least effective hydrolysates (Fig. 1). Only Nulure was not significantly less effective than Buminal in experiment 2. A concentration of 2% is used for bait-sprays with Buminal against *Ceratitis* spp. in Reunion Island (Quilici 1993). Unfortunately, Buminal is currently the only registered product for use in bait-sprays against fruit flies in France. The results of this study clearly show that products like Corn Steepwater or SolBait would be more effective for use in bait sprays to control the melon fly. Pinnacle also gave promising results. At a concentration of 5% Buminal again is the least effective hydrolysate (Fig. 1). Corn Steepwater, Hym-Lure, and Nulure appear intermediate, while the best results are obtained with SolBait. Pinnacle may also be of interest as it is not different from SolBait in experiment 3, (though not different from Nulure and Hym-Lure in experiment 2). With Buminal, the highest concentration tested (10%) seems particularly attractive for females, whereas, for males, the increase in attractiveness with increasing concentration is only apparent up to 5%. It could be interesting to examine if this difference between sexes appears with other products, for higher concentrations.

Generally, the analysis on the distribution of percentages of catches among treatments showed no difference between sexes. This result is not surprising considering the fact that the attractants used were food based. Though significant differences between treatments were demonstrated in all our experiments, it is possible that the power of the test might have been insufficient to discriminate between treatments of low attractiveness when very attractive treatments were tested together with treatments of low attractiveness. For instance, in the fourth comparison experiment between protein hydrolysates, the high attractiveness of SolBait may have masked less important differences between the three other treatments.

Contrary to what is observed with some other tephritid species (Bateman and Morton 1981, Heath et al. 1994), pH does not seem to play a major role in the recorded attractiveness of the different products for the melon fly. Indeed, the best results were obtained with Corn Steepwater (which has a rather low pH), Pinnacle (neutral pH), and SolBait (intermediate pH) (Fig. 2). However, for a given product, it would be worth testing how a modification of pH affects attractiveness.

Further tests should be conducted to compare the most effective protein hydrolysates tested in this study with yeast products commonly used in fruit fly trapping experiments such as Torula yeast, which is very attractive to some *Anastrepha* spp. (Epsky et al. 1993). In the future, it will be necessary to confirm our results in field tests, using trapping systems or bait-sprays.

In particular, our study only shows the short term attractiveness of the hydrolysates without taking into account their persistency or their modification by natural fermentation processes in the field. In addition, such tests would enable us to assess the selectivity and eventual phytotoxicity of the most interesting products. As a further step, it will also be useful to look at the efficacy and eventual repulsiveness of the insecticides used in mixture with the protein hydrolysates in bait-sprays. Finally, for practical use at the grower level, it will be necessary to obtain a registration in Europe and France for the selected products.

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