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D. P. LOCATELLI, P. GIRGENTI, I. PETRUZZELLIS

Evaluation of bait traps for *Tribolium confusum* J. du Val (Coleoptera Tenebrionidae)

Abstract - The efficacy of 7 traps currently on the market was evaluated on *Tribolium confusum* J. du Val. Three series of tests were carried out using a one way olfactometer to evaluate the attractiveness of foods and efficiency of commercial traps. The latter were also tested in an arena. The test was carried out in a thermostatically controlled room, at 27±1°C and 70±5% r.h.. Four replications were carried out for each test.
The results confirm that the efficiency of traps depend not only on the attractant used but also on the structure and means of capture. All the traps prove to be more efficient when they are baited with soft wheat flour previously infested by *T. confusum*, while the commercial attractants tested are shown to be of little efficacy, particularly when the traps are placed in poorly aired environments. The most suitable trap proved to be one rectangular in shape with both base and lid in black plastic, which allows the flour beetles to enter from the 4 sides. The adhesive cardboard, used in the tested sticky traps, didn't prove to be suitable for the capture of *T. confusum*. In fact fewer individuals were caught compared to those attracted by the same substrates placed on filter paper. Traps with seed oil in a plastic pitfall in the middle are attractive and efficient in aiding capture.
On the whole, this test shows the need to improve, by means of further research, the features of the traps currently on the market and to increase their ability to attract.

Riassunto - *Valutazione dell'efficacia di trappole adescanti per il monitoraggio di* Tribolium confusum *J. du Val (Coleoptera Tenebrionidae).*

E' stata valutata su *T. confusum* l'efficacia di 7 trappole attualmente presenti in commercio per il monitoraggio dei Triboli e, in alcuni casi, anche attrattive per altri insetti delle derrate. Si è utilizzato un olfattometro a 1 via per valutare l'attrattività di substrati alimentari e trappole commerciali; quest'ultime sono state saggiate anche in un'arena. La sperimentazione è stata effettuata a 27±1°C e 70±5% r.h.. Per ogni prova sono state effettuate quattro repliche.
Dai risultati si conferma che l'efficacia delle trappole è influenzata oltre che dalla sostanza attrattiva, dalla struttura delle stesse trappole e dalle modalità di cattura. Tutti i corpi-trappola risultano più efficienti quando sono attivati con farina in precedenza infestata da *T. confusum*, mentre gli attrattivi commerciali saggiati si

dimostrano poco efficaci, in particolare quando le trappole sono posizionate in ambiente poco aerato. Il corpo-trappola più adatto è risultato quello costituito da una base e un coperchio di plastica nera, di forma rettangolare, che consente l'accesso dei Triboli dai 4 lati. Il cartoncino collante, usato nelle trappole adesive saggiate, non si è rivelato idoneo alla cattura di *T. confusum*. Un'azione attrattiva e nel contempo invischiante si verifica per quelle trappole in cui è stato utilizzato olio di semi posto in un pozzetto al centro della trappola stessa.
Nel complesso, viene evidenziata la necessità di migliorare le caratteristiche delle trappole attualmente in commercio per *Tribolium confusum* per aumentarne la capacità attrattiva.

Key words: *Tribolium confusum*, commercial traps, activity, olfactometer, arena.

INTRODUCTION

Speedy and efficient monitoring of stored product pests is essential to know when control measures are to be used and verified (Wilkin, 1990; Campbell *et al.*, 2002). The visual control is particularly difficult as these insects tend to hide in crevices. The infestations caused by flour beetles remain unnoticed for a long time as the insects find many hiding places, mostly inside the machinery in the mill and in the food processing plants.

The first traps to monitor flour beetles were proposed by De Coursey (1931). They consisted of corrugated cardboard particulary suited to this species for nesting purposes, and were baited with food bait, mainly of different types of flour. The identification and the synthesis of sex and aggregation pheromones from different species allowed the baiting of traps with these substances, ideal for capturing certain Coleoptera of stored food products (Barak & Burkholder, 1976, 1985; Phillips & Burkholder, 1981; Williams *et al.*, 1981). As far as flour beetles are concerned, some researchers found a substance which was attractive to both sexes, identified as dimethyl decanal, produced by a gland present on the fore femurs of male adults (Suzuki & Sugawara, 1979; Suzuki, 1980). In laboratory tests this synthetic pheromone showed limited aggregation activity, compared to that of a natural pheromone; Suzuki and Mori (1983) obained better results synthesising one of its optical isomers (4R, 8R)-(-)-4,8-dimethyl decanal. Levinson and Mori (1983) assume that such pheromone in *Tribolium castanenum* (Herbst) and *T. confusum* J. du Val has an action as a sexual attractant towards females and acts as aggregation for males. Obeng-Ofori and Coaker (1990) think that this pheromone doesn't have any sexual function, as the response to this substance is similar both in the virgin individuals and in those which have just mated. A mixture of (4R, 8R)- and (4R, 8S)-4,8 dimethyl decanal, in the ratio 8:2, develops a strong attractiveness in *T. castaneum* up to 10 times superior to (4R, 8R)- used singly (Suzuki *et al.*, 1984).

At the beginning traps for Coleoptera of stored products had a rubber dispenser baited with specific pheromones and they were treated with pesticides. Barak and Burkholder (1985) suggested a trap in cardboard, without insecticide, with a plastic

pitfall full of seed oil which, besides permitting the capture of the insect, is synergic with the pheromone. For this reason the following oils were used: wheat germ oil (Nara *et al.*, 1981; Nara & Burkholder, 1983), oats oil (Freedman *et al.*, 1982; Mikolajczak *et al.*, 1983; Barak, 1989) and pumpkin oil and sesame oil (Barak, 1989). Currently most traps are made of plastic instead of adhesive cardboard which can easily deteriorate (Mullen, 1992).

Various kinds of traps are commercially available, baited with food and pheromones of different species. They capture individuals in different ways, mainly through the use of adhesive surfaces or pitfalls of oil. In this paper the efficacy of traps currently on the market in Italy and attractive also for other stored products insects, was evaluated on *T. confusum*.

MATERIALS AND METHODS

Three series of tests were carried out using a one way olfactometer (appendix A) to evaluate the attractiveness of foods and commercial traps. The latter were also tested in an arena (appendix B). The adults of *Tribolium confusum* were bred from the stock present in the Institute of Agricultural Entomology of University of Milan. Individuals from 30 to 60 days old were used.

The test was carried out in a thermostatically controlled room, at 27±1°C and 70±5% r.h.. Four replications were carried out for each test. The data were transformed into percentages, on which the mean values were calculated. The means were processed according to the arc-sin angular transformation and then variance analysis (ANOVA) and Duncan's *multiple range test* ($P<0.05$) (SPSS 11.0 for Windows) were used.

Attractiveness of various food substrates

The attractiveness of bran, corn flour, semolina, soft wheat flour, both uninfested and infested by adults of *T. confusum* was tested for 4 weeks. The attractiveness was also evaluated on soft wheat flour infested for 1, 2, 4, 6, 8 and 10 weeks. The infested substrates were obtained by adding 100 adults to 100 g of each food. Before using the substrates, they were sieved to remove eggs, larvae, pupae and adults. The tests were carried out by placing 20 adults at one end of the olfactometer and 6 g of food at the other end, placed on a filter paper disc (diameter 15 cm); after 48 h the food was sieved in order to count the adults. The attractiveness of corn flour and soft wheat flour, both infested for 4 weeks, was also evaluated by replacing the filter paper disc with an adhesive cardboard.

Attractiveness of commercial traps in one way olfactometer

The efficacy of 7 different kinds of commercially available traps currently on the market in Italy, identified by a capital letter from A to G was tested (Table1). One way olfactometers with a ventilation hole were used in order to simulate an enclosed

Table 1 - Traps for monitoring stored product Coleoptera used in the test on Tribolium confusum *J. du Val.*

Trap	Shape and dimensions	Material	Colour	Bait	Insect access from	Method of capture	Notes
A	Bottom and lid rectangular (17x13x2 cm) with joint lock (interspace between the 2 parts 1 cm)	rigid plastic	black	pheromone-treated rubber dispenser + oil based food attractant in cellulose disc (Ø 1cm)c	4 sides	adhesive cardboard	cardboard protected by a double antidust barrier
B	Rectangular (16x10x2 cm) book folded with joint lock	rigid plastic	black	pheromone-treated rubber dispenser + oil based food attractant in cellulose disc (Ø 1cm)c	3 sides	adhesive cardboard	–
C	Truncated cone bottom (Ø inferior 10.5 cm; Ø superior 4 cm; height 2.5 cm) with central pitfall; halfspheric lid (Ø 11.5 cm; height 3.5 cm) with joint lock (interspace between the 2 parts 0.5 cm)	rigid plastic	white	pheromone-treated dispenser + oil based food attractant in cellulose disc (Ø 3.5 cm) placed in the pitfall (depth 1.5 cm)	perimeter	fall in the pitfall	pheromone dispenser placed under the covering; base surface rough
D	Bottom and lid rectangular (15.5x8.5x1.7 cm) with joint lock (interspace between the 2 parts: 1 cm); bottom divided in 3 sectors	rigid plastic	white	oil based food attractant with pheromone	4 sides	fall in the oil	3 attractants placed at the same time in the 3 sectors
E	Adhesive square bottom (side 12 cm) covered at the top by a transparent plastic leaf which permits to count the captures; bottom perimeter in alveolar plastic	alveolar polypropilene (3 mm); semirigid plastic	white (bottom); transparent uncolour (covering)	pheromone-treated rubber dispenser + oil based food attractant in cellulose disc (Ø 1 cm)	4 sides	adhesive surface	derived from a corrugated cardboard trap
F	Trap truncated pyramid shaped with a triangular basis (catheti 11 cm; hypotenuse 15 cm; height 1.6 cm) with central pitfall, placed inside a covering of the same form	semirigid plastic (bottom); cardboard (covering)	white (bottom)	oil based food attractant with pheromone in the pitfall (depth 1 cm)	1 side	fall in the oil	step flight to facilitate the insects entrance
G	Rectangular (11x9x1.5 cm) book folded, with joint lock	semirigid plastic	transparent uncolour	pheromone-treated rubber dispenser + oil based food attractant in cellulose cylinder (Ø 0.5 cm; height 1.5 cm)	3 sides	adhesive surface	–

All the traps show oblique edges to increase the adherence to the floor and favour insects entry.
A, B, C, D, E and G: specific pheromone for flour beetles; F: mixture of pheromones for *Dermestes* spp., *Lasioderma serricorne, Tribolium* spp., *Trogoderma* spp. and *Plodia interpunctella.*
Traps A and B are activated with the same pheromone and food bait.

environment. At one end of the polypropylene tube 20 adults of *T. confusum*, were set free; at the other end a trap was set with food bait and the pheromone provided by the manufacturer.

To identify the most effective trap, tests were carried out in olfactometers without an air opening; the traps were baited with 6 g of soft wheat flour, which had been infested for 4 weeks by adults of *T. confusum*. The results were observed after 48 h. Records were made of the number of flour beetles trapped by the substance (oil or glue), the number of flour beetles present inside the trap but not trapped by the oil or glue (and so still able to move away) and the number of those hidden under the trap.

Attractiveness of commercial traps in arena

The efficiency of the 7 traps described in Table 1, was also tested in an open environment, by using arenas. All the tests were carried out by placing 20 adults in the arena (5 for each corner). The trap, baited with food bait and pheromone provided by the manufacturer, was placed in the middle of the arena. The identification of the best bait with pheromone was obtained by placing the commercial attractants in the middle of adhesive cardboard, without the presence of the respective traps. Soft wheat flour, infested for 4 weeks, was placed in the middle of a piece of adhesive cardboard or on filter paper (diameter 15 cm) as a control attractant.

The commercial attractants were further tested, by placing them in the middle of the trap A, which proved to be the most effective. The attractants used in traps D and F, composed of an oily substance mixed with the pheromone were poured into the pitfall of trap A, in order to catch any attracted flour beetles. In the tests with the attractants of traps A, B, C, E and G, the pitfall was filled with wheat germ oil and the dispenser of the pheromone was placed in the middle of the pitfall. Also in these tests, data were observed after 48 h. Records were made of the number of flour beetles trapped by the substance (oil or glue), the number of flour beetles present inside the trap, but not trapped by the oil or glue and the number of those hidden under the trap.

RESULTS

Attractiveness of different food substrates

The mean percentage of adults of *T. confusum* attracted by each of the 4 non-infested, tested foods (bran, corn flour, semolina and soft wheat flour) was not significantly different (Table 2). These substrates, particularly soft wheat flour are more attractive when infested.

A lower mean percentage of captures was observed when the food was placed on an adhesive cardboard rather than on a filter paper disc (Table 3).

The soft wheat flour, if infested for 4 weeks, can attract 81.3±4.3% of individuals (Table 4); this substrate, if used again after 4 weeks, only attracts 33.8±2.4% of individuals.

Table 2 - Mean (±SE) percentage of Tribolium confusum *J. du Val adults attracted with various food baits not infested or infested by flour beetle.*

Bait		Adults (%±SE)
Not infested	Bran	20.0±5.4a
	Corn meal	12.5±3.2a
	Semolina	15.0±2.0a
	Soft weath flour	11.3±5.2a
Infested	Bran	55.0±3.5b
	Corn meal	50.0±9.4b
	Semolina	56.3±3.1b
	Soft weath flour	81.3±4.3c

The bioassays were carried out in one way olfactometer (1 m).
The attractants were placed in filter paper discs.
The means followed by the same letters are not significantly different (Duncan's multiple range test, P>0.05).

Table 3 - Mean (±SE) percentage of Tribolium confusum *J. du Val adults attracted with food baits placed on filter paper disc or on adhesive cardboard.*

Bait		Adults (%±SE)
Filter paper	Corn meal	50.0±9.4b
	Soft weath flour	81.3±4.3c
Adhesive cardboard	Corn meal	17.5±4.3a
	Soft weath flour	20.0±2.0a

The bioassays were carried out in one way olfactometer (1 m).
The means followed by the same letters are not significantly different (Duncan's multiple range test, P>0.05).

Table 4 - Mean (±SE) percentage of Tribolium confusum *J. du Val adults attracted with soft weath flour infested by flour beetles for different time.*

Soft weath flour infested for n weeks[a]	Adults (%±SE)
1	16.3±2.4ab
2	25.0±3.5bc
4	81.3±4.3e
4 [b]	33.8±2.4c
6	51.3±2.4d
8	31.3±2.4c
10	26.3±3.1bc
Not infested soft weath flour 11.3±5.2	a

The bioassays were carried out in one way olfactometer (1 m).
The attractants were placed on filter paper discs.
[a]After n weeks of infestation the flour was sieved to remove larvae and adults, before being used in the tests.
[b]After sieving the flour was left to rest for further 4 weeks, before being used.
The means followed by the same letters are not significantly different (Duncan's multiple range test, P>0.05).

Table 5 - Mean (±SE) percentage of Tribolium confusum *J. du Val adults attracted with different commercial traps.*

Trap	Adults (%±SE)
A	1.3±1.3ab
B	2.5±1.4ab
C	7.5±3.2b
D	0.0±0.0a
E	3.8±2.4ab
F	1.3±1.3ab
G	1.3±1.3ab

The traps were discribed in table 1.
The bioassays were carried out in one way olfactometer (1 m).
The means followed by the same letters are not significantly different (Duncan's multiple range test, P>0.05).

Table 6 - Mean (±SE) percentage of Tribolium confusum *J. du Val adults captured with the trap with soft wheat flour infested by flour beetles*

Trap	Adults (%±SE)
A	85.0±7.4c
B	62.5±4.8b
C	51.3±8.3b
D	57.5±3.2b
E	16.3±2.4a
F	22.5±3.2a
G	30.0±4.6a

The traps were described in table 1.
The bioassays were carried out in one way olfactometer (1 m) with airing opening.
The means followed by the same letters are not significantly different (Duncan's multiple range test, P>0.05).

Attractiveness of commercial traps in one way olfactometer

All the commercial traps showed a poor attractive ability in the tests carried out in an enclosed environment. Trap C proved to be the best one (7.5±3.2% of captured adults of *T. confusum*) while trap D didn't capture any insects (Table 5).

In Table 6 trap A, baited with infested wheat flour, proved to be the most effective (85.0 ± 7.4% of captured individuals).

Attractiveness of commercial traps in arena

In the test carried out in an arena, the efficacy of commercial traps was significantly different. Traps B and F (Table 7) were the most attractive ones, respectively with 77.5±4.8 and 93.8 ± 3.8% of captured individuals; but only a small percentage of *T. confusum,* once attracted inside, fell into the oil or were trapped by the glue

Table 7 - Mean (±SE) percentage of Tribolium confusum *J. du Val adults attracted with different commercial traps.*

Trap	Adults (%±SE)			
	Inside		Outside	Total
	Captured	Not captured	Under the base	Attracted
A	1.3±1.3a	10.0±4.6b	6.3±3.8b	17.5±1.4ab
B	10.0±2.0b	67.5±5.2d	0.0±0.0a	77.5±4.8e
C	55.0±4.6d	0.0±0.0a	0.0±0.0a	55.0±4.6d
D	1.3±1.3a	0.0±0.0a	60.0±4.6c	61.3±5.2d
E	1.3±1.3a	35.0±4.6c	0.0±0.0a	36.3±5.2c
F	1.3±1.3a	92.5±3.2e	0.0±0.0a	93.8±3.8f
G	23.8±3.8c	0.0±0.0a	0.0±0.0a	23.8±3.8bc

The traps were described in table 1.
The bioassays were carried out in 1 m^2 arena.
The means followed by the same letters are not significantly different (Duncan's multiple range test, P>0.05).

Table 8 - Mean (±SE) percentage of Tribolium confusum *J. du Val adults captured with different commercial baits or with soft weath flour infested by flour beetles, placed on adhesive cardboard.*

Bait	Adults (%±SE)
A=B	1.3±1.3a
C	7.5±1.4bc
D	10.0±0.0bcd
E	5.0±2.0b
F	8.8±1.3bc
G	12.5±2.5cd
Infested soft weath flour[a]	20.0±5.4d

The baits were describe in table 1.
The bioassays were carried out in 1 m^2 arena.
[a] After 4 weeks of infestation the flour was sieved to remove larvae and adults, before being used in the tests.
The means followed by the same letters are not significantly different (Duncan's multiple range test, P>0.05).

(respectively 10.0±2.0% and 1.3±1.3%). In trap C the attracted individuals were found exclusively in the capture device (55.0±4.6%).

The single commercial baits, but also soft wheat flour, which have an attractive ability when placed on filter paper discs, as it is observed in Table 3, show a reduced attractiveness on adhesive cardboard (Table 8).

Placing the commercial baits in trap A, the most effective for capture, the attractant C is the most efficacious one, with a mean percentage of captures of 42.5±4.3 (Table 9). This trap, if baited with infested wheat flour, can attract 85.0±5.4% of individuals, which are found exclusively in the food bait.

Table 9 - Mean (±SE) percentage of Tribolium confusum *J. du Val adults captured in the trap A with different commercial baits or with infested soft weath flour.*[a]

Trap	Adults (%±SE)			
	Inside		Outside	Total
	Captured	Not captured	Under the base	Attracted
A=B	1.3±1.3a	10.0±4.6c	6.3±3.8ab	17.5±1.4ab
C	42.5±4.3c	1.3±1.3ab	5.0±3.5ab	48.8±3.1c
D	11.3±2.4b	2.5±1.4abc	8.8±3.1b	22.5±6.0b
E	5.0±0.0b	5.0±0.0bc	0.0±0.0a	10.0±0.0a
F	10.0±3.5b	3.8±2.4abc	5.0±3.5ab	18.8±1.3ab
G	10.0±2.0b	2.5±1.4abc	8.8±2.4b	21.3±3.1b
Infested soft weath flour[a]	85.0±5.4d	0.0±0.0a	0.0±0.0a	85.0±5.4d

The baits were describe in table 1.
The bioassays were carried out in 1 m^2 arena.
[a] After 4 weeks of infestation the meal was sewed to remove larvae and adults, before being used in the tests.
The means followed by the same letters are not significantly different (Duncan's multiple range test, P>0.05).

DISCUSSION

The results confirm that the efficiency of a trap depends not only on the attractant, but also on the structure and on the method of capture. All the traps proved to be more efficient when they were baited with flour previously infested by *T. confusum*, while the tested commercial attractants prove to be inefficient, particularly when the traps are placed in poorly ventilated environments; probably the synthetic pheromone aggregation 4,8-dimethyl decanal is in too high a quantity (Barak & Burkholder, 1985). Some authors state that the captures are affected by quantity and by the proportions of the different isomers (Suzuki & Mori, 1983; Suzuki *et al.*, 1984; Javer *et al.*, 1990).

The soft wheat flour infested for 4 weeks is more attractive than the ones infested for longer periods. In fact, the flour beetles placed in food, at first produce 4,8-dimethyl decanal, pheromone of aggregation for both sexes of *T. confusum* (Suzuki & Sugawara, 1979; Suzuki, 1980); afterwards they produce quinones, which negatively interfere with aggregation substances, diminishing the attractiveness (Burkholder, 1982).

The form of the trap also affects the capture; the most suitable trap was the black plastic rectangular shaped base and lid, which allows the flour beetles to enter from the 4 sides. Trematerra (1993) underlined the importance of improving the efficiency by using traps accessible for the insect from all sides of the trap itself. Also the material from which the trap is made can interfere; Obeng-Ofori (1993) noticed that metal traps repel these insects.

The adhesive cardboard, used in the tested sticky traps, didn't prove to be suitable for capturing *T. confusum*. In fact a lower number of individuals was caught compared to the number attracted by the same substrates placed on filter paper. On this subject, Obeng-Ofori (1993) observed that this insect tends to run away when it perceives the presence of a sticky surface.

Traps with oil placed in a pitfall in the middle both attracted and trapped the insects. Levinson and Levinson (1978) observed that *T. confusum* is attracted by triglycerids present in the wheat germ.

On the whole, this test shows the need to improve, through further research, the features of the traps currently on the market in order to increase the ability to attract. These traps, which attract only a small percentage of individuals compared to the real degree of infestation, will hardly have any effect on the numbers of *T. confusum* adults when there is only a slight infestation and so consequently a progressive and undisturbed increase in population can take place. Efficient methods of control are consequently delayed and the result of an eventual intervention will be less successful.

It is currently necessary to integrate this method of observation with that of visual monitoring which, undoubtedly, requires a lot of time and properly trained operators; however, in this way, if the observations are carried out regularly, the presence of *T. confusum* in the environment can be identified and an accurate evaluation of the real dimension of the infestation can be made (Süss & Cravedi, 1982).

Appendix A

The one way olfactometer consists of a cylinder (diameter 20 cm; length 1 m) obtained by thermowelding longitudinally the opposite ends of bioriented polypropylene leaves (thickness 30 μm). The material is flexible, transparent and permeable to gases such oxygen. To help the *T. confusum* adults walk along the tube a strip of white card was placed on the bottom of the tube from end to end. The cylinder is open at both ends to permit the introduction of the insects and of the substrate/trap under test. Suitable semi-rigid lids formed by a ring of acetate (length 45 cm; width 5 cm; thickness 1 mm), to which a finely meshed net was fixed with hot glue (120 mesh), permit the closure of the ends, whilst ensuring sufficient ventilation. A further one way olfactometer similar to the previous one was also used but this one additionally had a rectangular ventilation hole (length 80 cm; width 15 cm) in the upper part, which was similarly covered with a finely meshed net (120 mesh).

Appendix B

Tests were carried out in an arena, which was parallelepipedal shaped with a square base, in melamine laminated wood (thickness 2 cm; surface basis 1 m^2; sides height 20 cm); the internal surface was covered with white paper.

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PROF. DARIA PATRIZIA LOCATELLI, DR PAOLA GIRGENTI, DR IVAN PETRUZZELLIS - Istituto Entomologia agraria, Università degli Studi di Milano, Via Celoria 2, I-20133 Milano (Italy). E-mail: daria.locatelli@unimi.it paola.girgenti@unimi.it

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