INTEGRATED MANIPULATION OF STORAGE INSECTS BY PHEROMONES AND FOOD ATTRACTANTS

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The established and more recently devised methods (physical and chemical) for prevention and control of insect infestation in food stores have been critically reviewed by Howe (1). Cooling by air circulation is certainly a useful means of control. However, its considerable expense and risk of reintroducing moisture to the stored product limits the application of this technique (2). Airtight storage, another efficient control measure, depends on keeping the oxygen level of the atmosphere constantly below 3% and requires circulation of nitrogen or carbon dioxide through the storage bins (3). The availability of gasproof structures and fabrics, which are not cheap, is a prerequisite for this kind of control. The usefulness of inert dusts (e.g. chalk, kaolin, silica aerogels, tricalcium phosphate) as grain additives is restricted by possible adverse influence on human beings as well as by abrasive effects on machinery (4, 5). The rather effective technique of ionizing radiations from a gamma or accelerated electron beam source did not become customary in warehouses, probably due to its expensiveness.

The most common chemical methods for controlling stored product pests are either spraying of contact insecticides or fumigation by insecticidal gases. The pyrethrins, possibly synergized by piperonyl butoxide, as well as malathion (0,0-dimethyl S-1,2-di (ethoxycarbonyl) ethyl phosphorodithioate) are probably among the few contact insecticides which may be directly applied to stored food without subsequent risk to the consumer; however, the repellent action of the pyrethrins for various insect species warrants maximal covering of the grain surface to achieve complete protection (6). In spite of the high contact and vapour toxicity of DDVP (dimethyl dichlorovinylphosphate) for storage insects, the permanent use of this insecticide may be hazardous to human beings particularly due to accumulation of harmful concentrations in closed premises and extensive adsorption on stored grain (7).

Several insecticidal gases are rather effective storage fumigants, among which methyl bromide and phosphine are used widely. Desorption of the former from exposed products is relatively slow, while the latter is scarcely adsorbed at all. Hence, fumigation by phosphine does not result in adverse residual effects on seed germination and human health, and a single treatment is relatively inexpensive (approx. \$8.00 per m^2 of grain). However, a serious drawback resulting from the frequent use of such toxicants is the selection of resistant mutants, eventually leading to the necessity of increasing the insecticidal doses beyond the acceptable levels (8).

A new biotechnical approach to pest control recently suggested by Levinson (9, 10) depends on using insectistatics, i.e. agents decimating insect populations to a level that does not cause economic damage (insectistasis). Since most of the insect pheromones and feeding attractants comprise a relatively high signalizing value at exceedingly low activity thresholds, they can be readily employed for adverse modification of the normal behaviour of destructive species resulting in insectistasis (11). The pheromone composition of several species (mainly Coleoptera, Lepidoptera, and Orthoptera) being notorious pests of stored products has been studied in detail (9, 11, 12). Some of the more important components identified are listed in Figure 1. They are fairly volatile lipids of rather diversified structure such as unsaturated fatty acids and esters, branched olefinic aldehydes, a trienoate with two cumulative double bonds as well as hydrocarbons. The major components of certain sex and aggregation pheromones being integrated into sticky (Figure 2) or contact (Figure 3) traps are currently employed for the surveillance and detection of phycitid moths and dermestid beetles in warehouses (11, 13). Chemical feeding attractants for storage insects comprise components eliciting aggregation as well as feeding; e.g. oleopalmitin is known to act as a feeding aggregant and maltose as a feeding stimulant for *Tribolium confusum* (14, 15). The attractants released by a blend of seeds and fruits (enclosed in wire gauze bags, Figure 4) are also used for monitoring the presence of stored product pests (16, 17, 18). In both types of baits the attractants have to be adequately dosed in order to ensure quantitative predominance over the amounts of phagostimulants and sex pheromones occurring in the surroundings. Since food stores represent a rather closed system with fairly constant conditions and moderate levels of temperature, humidity, light intensity as well as rather slow air movement (about 0.1-0.5 m/sec) for the insects found in this environment, they are particularly suitable for the use of pheromone and food attractant traps.

On the background of the experience in chemical and biotechnical control measures we propose an integrated manipulation of the insect species infesting stored products. Figure 5 presents an outline of a feed-back system wherein a pest population is under continual supervision and control by traps baited with pheromones and food attractants in combination with insecticide treatments timed in accordance. There are up to three successive treatments involved. The first one serves to detect an infestation and to estimate its magnitude. For this purpose are a few traps permanently confronted with the pest biotope. In the

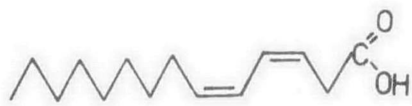
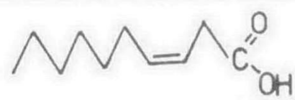
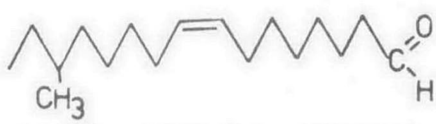
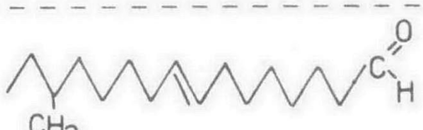
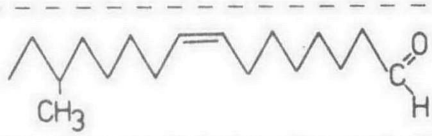
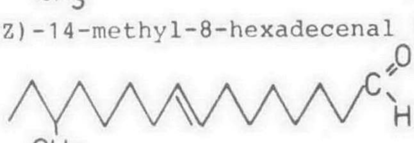
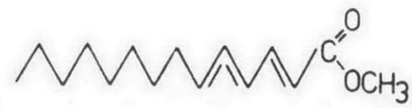
Family, Species and Sex	Formula	Reference
Dermestidae:		
Attagenus megatoma ♀	 (E,Z)-3,5-tetradecadienoic acid	(20)
Attagenus elongatulus ♀	 (Z,Z)-3,5-tetradecadienoic acid	(21)
Anthrenus flavipes ♀	 (Z)-3-decenoic acid	(22)
Trogoderma inclusum ♀ Trogoderma variabile ♀	 (Z)-14-methyl-8-hexadecenal	(23)
Trogoderma glabrum ♀	 (E)-14-methyl-8-hexadecenal	(23)
Trogoderma granarium ♀	 (Z)-14-methyl-8-hexadecenal (92%)  (E)-14-methyl-8-hexadecenal (8%)	(24)

FIGURE 1: Major pheromone components of some species of Coleoptera, Lepidoptera and Orthoptera infesting stored products.

Bruchidae:

Acanthoscelides obtectus

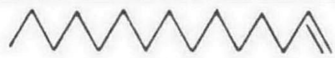
♂



methyl(-)-(E)-2,4,5-tetra-
decatrienoate

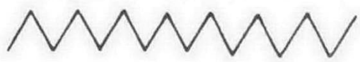
(25)

Tenebrionidae:



1-pentadecene

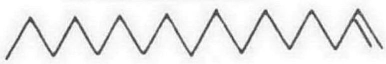
Tribolium confusum



♂, ♀

n-hexadecane

(26)

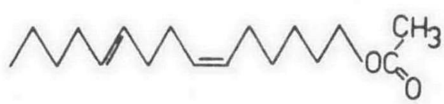


1-heptadecene

Gelechiidae:

Sitotroga cerealella

♀

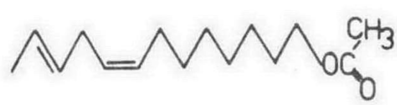


(Z,E)-7,11-hexadecadien-1-yl
acetate

(27)

Phycitidae:

Ephestia elutella
Plodia interpunctella ♀
Cadra cautella
Anagasta kuehniella
Cadra figulilella



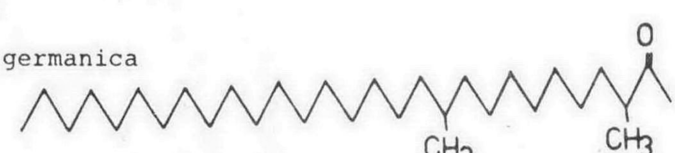
(Z,E)-9,12-tetradecadien-1-yl
acetate

(28)(29)

Blattidae:

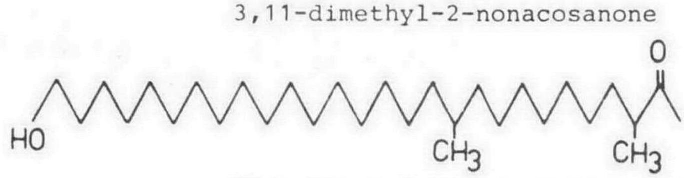
Blattella germanica

♀



3,11-dimethyl-2-nonacosanone

(30)



29-hydroxy-3,11-dimethyl-2-nona-
cosanone

(31)

FIGURE 1: Continued.

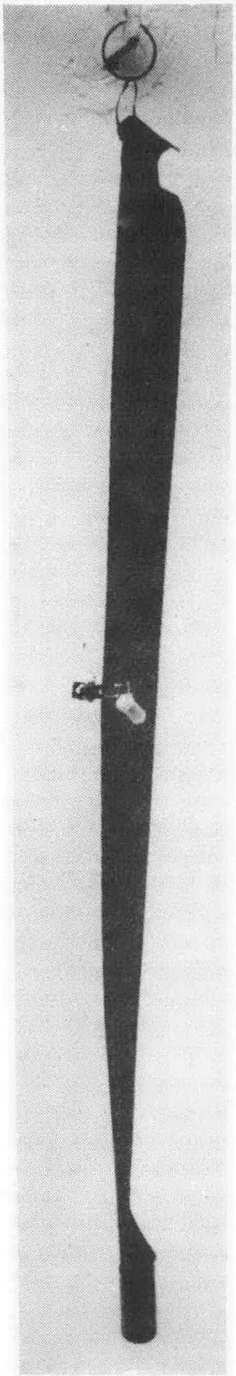
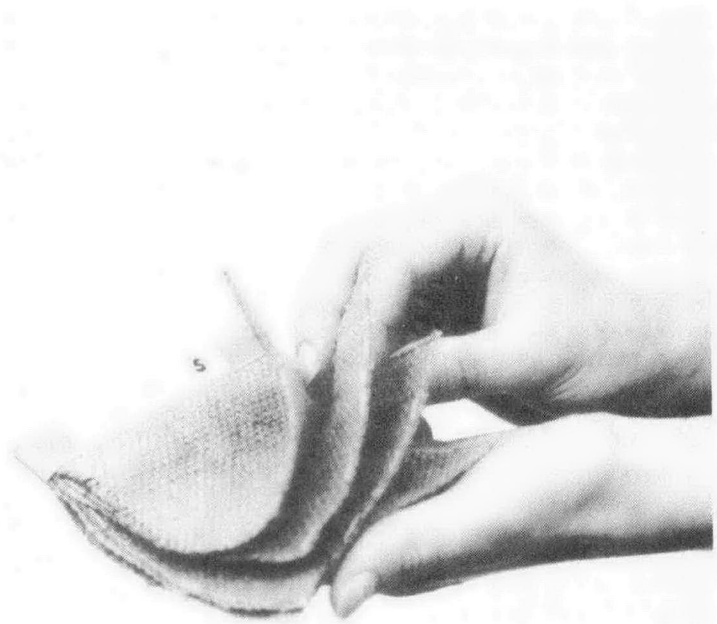


Fig. 2 (left). Trapping device for moths infesting stored products. It is a sticky paper strip (75x5 cm) provided with a polyethylene capsule (exchangeable) containing the mein pheromone component from the females of several phycitid species. An adequate amount of the attractive compound is adsorbed on the plastic capsule, which ensures slow vaporisation of the scent for several weeks.

Fig. 3 (below). Contact trap for dermestid beetles and larvae. It consists of four retangular sheets of gunny bag (11x9 cm) being stitched together on one side, and impregnated by the main pheromone component. The insects are first lured by the scent evaporating from the trap and then retained between its hairy sheets due to thigmotaxis.



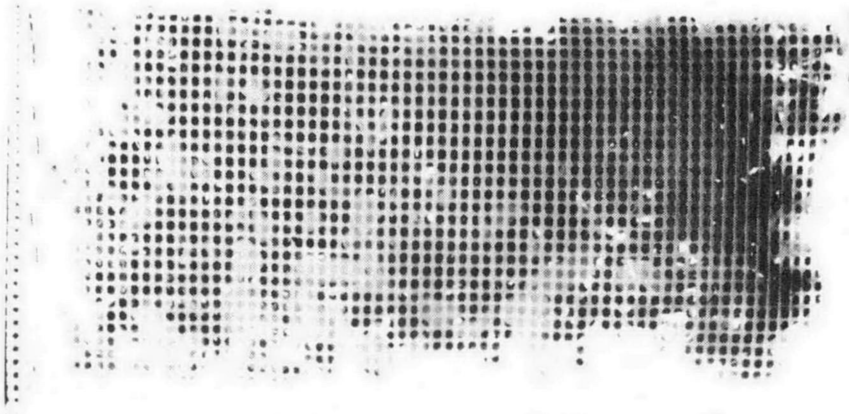


Fig. 4. PICL-Food bait trap for various stored product beetles. An envelope [20x10 cm] of plastic or metal mesh [apertures 1.5 mm] is filled with crushed carobs, groundnuts, wheat, raisins and possibly other food stuffs, and closed. Attracted insects enter the trap through the perforations and remain on the food mixture (Pinninger 1975).

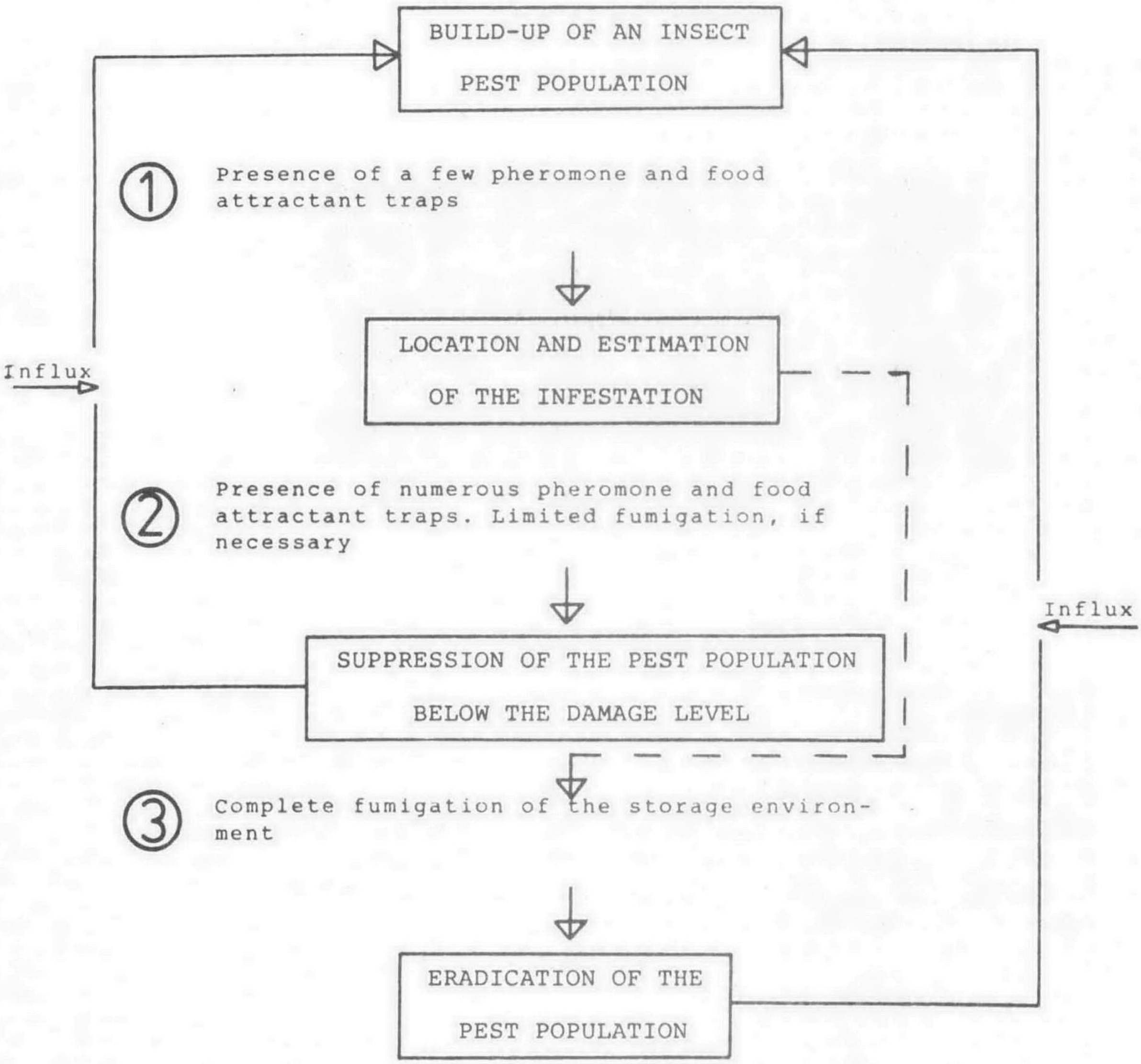


FIGURE 5. Flow sheet of insect manipulation in storage environment. The encircled numbers denote the successive measures to be undertaken under the conditions mentioned within the frames.

second one, suppression of the discovered population below the economic level is to be achieved. This step demands an adequate increase in the number of traps suspended so far. Control of regional infestations may also be supplemented by fumigation (e.g. with phosphine). The third treatment, complete fumigation of the storage environment, is carried out when a dense insect population has become evident. If rapid insect eradication in a commodity is necessary, one has to proceed directly from the detection of an infestation to complete fumigation. Integrated manipulation of storage insects by pheromones combined with insecticides is considerably cheaper than insecticidal control alone. It also meets the demand for methods of prevention rather than of control, as recently suggested by Burkholder (19).

Long term studies on the supervision and control of *Ephestia elutella* and *Plodia interpunctella* carried out in collaboration with Drs. R. Wohlgemuth and Ch. Reichmuth, Institut für Vorratsschutz, Berlin, support the possibility of introducing the above scheme to the practice of warehouse disinfestation.

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