THREE EXTRACTION DEVICES FOR RAPID SEPARATION OF LARGE NUMBERS OF LIVE TERMITES (INSECTA: ISOPTERA)

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Abstract *Proc. ent. Soc. Ont.* 132: 15–25

Three devices are described for separating subterranean termites, *Reticulitermes flavipes* (Kollar), from cardboard roll traps and soil. The first device, an extraction hopper, separates termites from cardboard roll traps as well as the removal of coarse debris. The extraction hopper is a large, legged funnel, constructed of galvanized sheet metal with a removable top screen; the bottom of the funnel connects to a stack of standard soil sieves. The second device, a baffle separator, provides for rapid separation of termites from soil after coarse sieving. When termites and soil are passed alternately at three-minute intervals between two baffle separators, 96.4% of the termites can be extracted from the soil within 15 minutes. The third device, a tray-in-box separator, has a similar function as the baffle separator, requires less manual processing time, but a longer waiting period to complete the separation. These three devices make it possible to efficiently obtain millions of debris-free, live termites which can then be used for various purposes such as experimentation, as vectors of control agents, or as animal feed for insectivores.

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Trois appareils sont décrites pour la séparation des termites à pattes jaunes, *Reticulitermes flavipes* (Kollar), de pièges en carton roulé et du sol. Le premier appareil est une trémie d'extraction en forme d'entonnoir sur des jambes et est construite de tôle galvanisé, surmonté d'un tamis détachable. Le fond de l'entonnoir est branché à une série de tamis. Cet appareil sépare les termites des pièges en carton roulé et enlève le débris grossier. Le deuxième appareil est un séparateur-déflecteur, qui sépare rapidement les termites du sol après avoir été passer au tamis. Quand les termites et sols sont passer alternativement à des intervalles de trois minutes entre deux séparateurs-déflecteurs, 96.4% des termites sont extraits du sol après 15 minutes. Le troisième appareil, qu'on appelle un séparateur-plateau-dans-boîte, demande moins de traitements manuels que le séparateur-déflecteur, mais il demande plus de temps pour la séparation complete. Ces appareils extraient efficacement un grand nombre de termites vivants sans debris, qui pourraient servir comme sujets d'experiences, vecteurs d'agents de lutte, ou même comme aliment pour les animaux insectivores.

Introduction

Methods for trapping and baiting subterranean termites (mainly Rhinotermitidae) have been developed and improved upon by various researchers. Trap substrates for termites have ranged from such items as bundles of wooden strips (Tamashiro et al. 1973), solid or rotten wooden blocks, (Beard 1974; Esenther and Beal 1979; Su et al. 1996), wood slats (Miller 1994), toilet paper rolls (La Fage et al. 1973; French and Robinson 1981), cardboard "sandwiches" (Esenther 1980) and cardboard rolls (La Fage et al. 1983; Grace 1989). Containers for these bait substances have included plastic containers and buckets (Su et al. 1993, 1995), wooden bait boxes (French 1994,) hollow stakes (Ewart et al. 1992), above-ground and below-ground perforated tubes and commercial bait stations (Grace et al. 1995; Su et al. 1995), 54 or 200 litre steel drums (Miller 1994), and polyvinyl chloride (PVC) pipes used as "sleeves" around the bait (French and Robinson 1981; La Fage et al. 1983, Lewis et al. 1998). Although numerous researchers have investigated and improved upon methods of trapping and aggregating subterranean termites, few accounts exist of methods to extract termites from substrate debris, and the methods that have been reported are either slow, labour intensive, or low yielding. Gay et al. (1955) described the classical method of "papering off", in which termites migrate from dry paper towels to moist paper towels after being manually removed from split logs or stumps; this method is still in widespread use. Becker (1969) noted that when small, debris-free groups of termites are needed, flexible forceps or hand aspirators could be used to manually collect the termites desired in the exact caste composition required. Tamashiro et al. (1973) proposed a method by which termites migrate from their substrate to a clean block of wood by crossing over damp wooden tongue depressors. Jones and Mauldin (1983) described a method of improved aspiration of large numbers of live termites by attachment of an aspirator to a small electric canister vacuum cleaner. Ewart (1985) gave a method for separating termites from nest debris involving the use of a fine-mesh sieve, to which the termites clung, while the debris was filtered away.

New approaches for termite control have required the collection of large numbers of termites to act as vectors of control agents (Tamashiro et al.1973; French 1991, 1994; Myles 1994, 1996; Myles et al. 1994). To use termites as vectors it is desirable to collect as many termites as possible and to extract them from their substrate as efficiently as possible with the least amount of termite injury. Tamashiro et al. (1973) devised methods for trapping substantial numbers of subterranean termites and separating them from debris with the intention of using the collected termites as vectors of pathogens. French (1991, 1994) developed the bait box technique in which a variety of bait containers are used to attract and aggregate termites prior to treatment with toxic dust. Myles (1994, 1996) developed a somewhat similar system called the Trap-Treat-Release technique, in which trapped termites are treated with a transmissible toxic coating before being released back into the colony. During the course of field trials of this method, conducted in Toronto, it became necessary on a daily basis to extract tens of thousands of termites from traps, debris, and soil. Three devices were developed to facilitate the process.

Materials and Methods

Extraction Hopper for Coarse Extraction of Termites

The first device, used in the separation of termites from coarse debris, is an extraction hopper (Fig. 1). It is constructed of galvanized sheet metal, measuring 115 cm in length by 75 cm in width by 95 cm in height. A removable screen of 12 mm mesh, 15 cm in depth, is fitted onto the upper part of the hopper to retain coarse debris such as large clods of soil and pieces of corrugated cardboard. Below the screen, the extraction hopper is tapered at an angle of 45°, forming a funnel 67.5 cm in length. At the bottom of the extraction hopper, is a circular opening, 20.5 cm in diameter, permitting a stack of standard soil sieves (W.S. Tyler, St. Catharines, Ontario, Canadian Standard sieve series) to fit snugly beneath. The termites and some debris are caught on the.No. 20 sieve and the coarser material on the Nos. 4, 5, 6 and 7 sieves. Fine material caught in the bottom pan is discarded. The termites and remaining debris in the No. 20 sieve may then be transferred to either the baffle separator or the tray-in-box separator for final separation of the termites from the remaining fine debris.

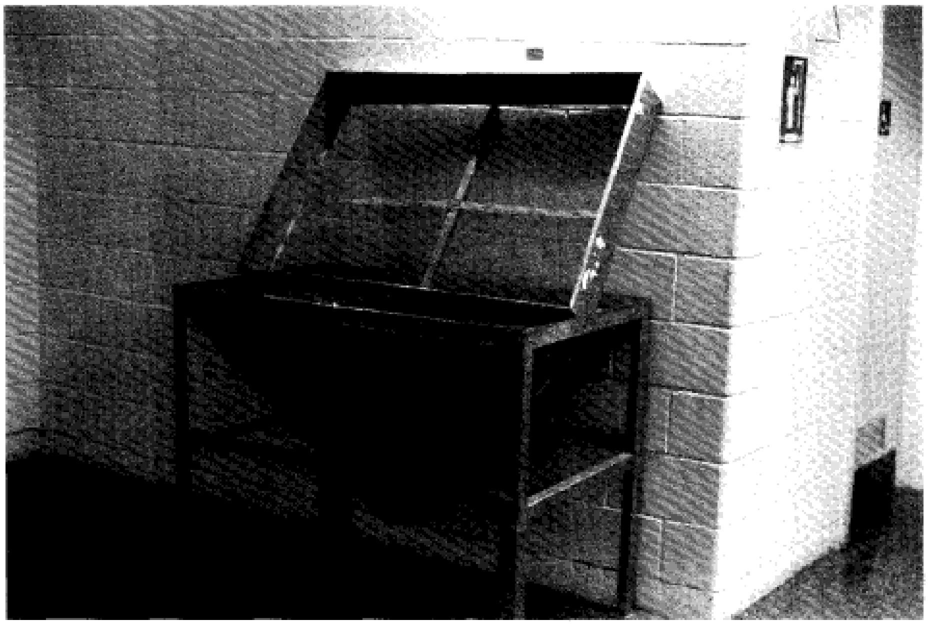

FIGURE 1. Extraction hopper with removable upper screen in raised position.

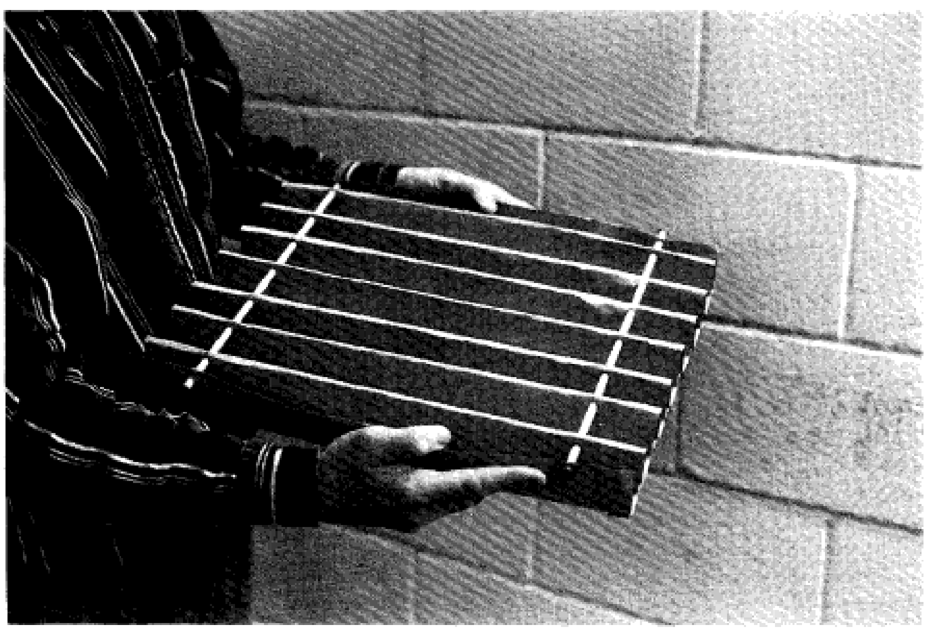

FIGURE 2. The baffle separator, top view, showing position of supporting wooden dowels.

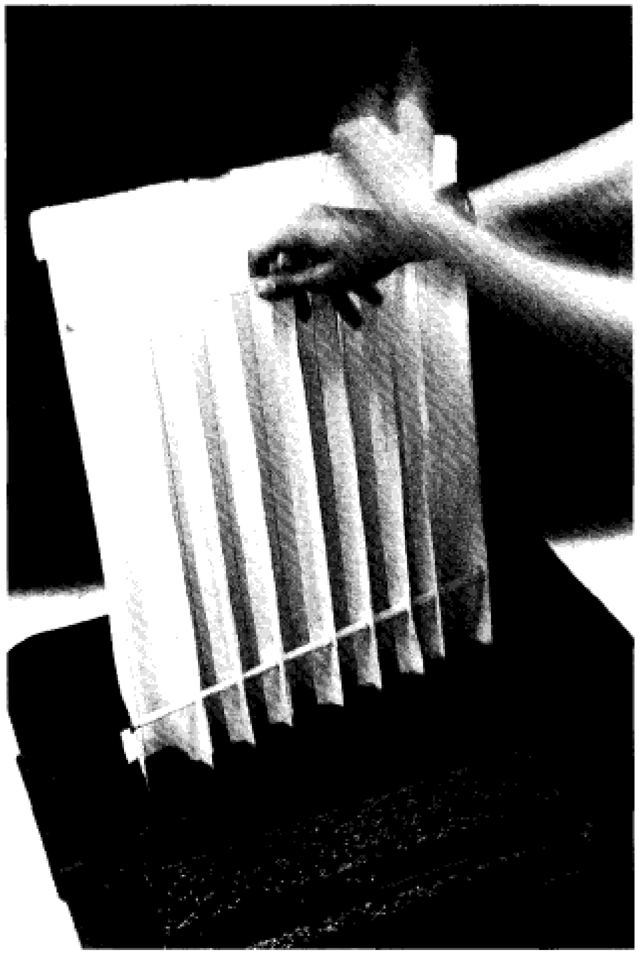

FIGURE 3. Method of dislodging termites clinging to the baffle separator.

Baffle Separator for Removal of Fine Debris and Soil

The baffle separator consists of a sheet of folded blotting paper secured with two dowels (Fig. 2). A sheet of blotting paper, 44 cm wide and 87 cm long, is folded to form ridges 3.5 cm high and 1.0 cm wide, with intervening spaces 3.0 cm wide. The wide floor space provides maximum settling area for the soil. Two wooden dowels, 5 mm in diameter and 36 cm long, are pierced through holes cut with a cork borer or a large hole punch in the upper third of the raised folds, and are placed 33 cm apart. To maintain the raised folds in position, two narrow strips of blotting paper, 36 cm by 2 cm, are stapled on the ventral surface, along the lateral edges and perpendicular to the folds, with the staples placed in between the ridges.

During the process of separation, the termites and debris are passed alternately, at intervals, between two baffle separators, as follows. The first baffle separator is placed inside a plastic box, 50 cm long by 42 cm wide by 12 cm deep. Termites and soil obtained from the extraction hopper and collected in sieve No. 20 are then spread evenly on top of this baffle. A waiting period of

FIGURE 4. A stack of tray-in-box separators.

several minutes is allowed to elapse, during which the termites crawl off the soil and onto the walls of the baffle extractor. When the number of termites walking off the soil and onto the baffle begins to reach an equilibrium with the number that are walking from the baffle back onto the soil, the soil needs to be passed to a second baffle separator. The first baffle extractor is lifted by the dowels from the tray and the soil is gently poured onto a second baffle extractor, placed in another tray. After the soil is transferred to the second baffle extractor, the termites still clinging to the first extractor are dislodged into a clean container by using one hand to rap the back of the other hand, which holds the upper dowel, held horizontal to the container (Fig. 3).

Tray-in-Box Separator for Soil Removal

In a third extraction device, a tray-in-box separator, the edges of a tray are covered with masking tape to provide a textured surface allowing termites to climb over the tray edges (Fig. 4). Two sheets of damp corrugated cardboard, cut to fit plastic boxes, 50 cm by 42 cm, and 12 cm deep, are placed on the bottom of the box, such that the corrugations on the lower sheet faced down, and those of the upper sheet faced up. Soil and nest debris containing termites are placed on the tray and spread out evenly. The tray is of such a size that it fits the box closely, but leaves at least a few millimeters of space around the edges or corners to enable the termites to crawl over the edges of the tray and into the damp cardboard below on the floor of the box. Under typical operation, a stack of tray-in-box separators are left overnight to allow time for the soil to dry out and for the termites to move off the trays and onto the damp layers of corrugated cardboard below. The following day, the soil is dumped off the trays and the clean termites are then shaken from the damp cardboard sheets.

Evaluation of Extraction Procedure

Termites were collected in cardboard roll traps from 14 different sites around Toronto. When termites were found to be present in the traps, the cardboard roll was removed with the termites and taken to the laboratory in a sealed plastic container. The roll traps were shaken into the hopper for coarse sieving. Termites and soil then were transferred to the baffle separator. After waiting periods of three minutes' duration, the baffle extractor was raised from the tray, and the soil with remaining termites was gently poured onto a second baffle separator and the clinging termites were dislodged from the first baffle separator and weighed. This procedure of transferring soil and termites was repeated at three-minute intervals five times, for the termites trapped from each of the 14 sites.

Results

The Devices

The dimensions of the extraction hopper are designed so that one to six individuals can stand at the sides of the hopper and work simultaneously to unravel and shake out the cardboard roll traps. The height is designed so individuals can work at a comfortable level while standing. The height of the hopper also facilitates a steep descent of the termites to the sieves below, without being so high as to cause termite injury. The removable screen facilitates dumping of debris and occasional cleaning of the hopper. This device was made to order within a week's time by a University of Toronto sheet metal fabricator for about $300.00 Cdn., including parts and labor.

The baffle separator is inexpensive and simple to construct from materials available at office and art supply stores. Construction of the baffle separator requires an hour or so of measuring, drawing lines, folding, punching holes, inserting dowels and stapling the reinforcement strips. The ease with which these devices are constructed improves with practice. These devices are fairly sturdy and can be used daily for several months before getting too dirty and worn. They have been used successfully in the lab and in the field for rapidly removing large numbers of termites from soil and nest debris.

The tray-in-box separator can be readily made from any combination of trays that fit in boxes. A suitable combination of trays and boxes are the standard plastic or fibreglass cafeteria trays and matching busboy boxes that can be purchased at restaurant supply companies at modest costs. Such boxes also have the advantage of being sturdy and having ridges that facilitate the space-saving, stable stacking arrangement (Fig. 4).

Experimental Assessment of Efficiency of Baffle Separator

Extractions of termites by the end of the first three-minute interval ranged from 39.8 to 86.5% (Table I). By the end of the second three-minute interval, extraction ranged from 8.3 to 30.6%. By the end of third three-minute interval, extraction ranged from 2.2 to 14.8%. By the end of the fourth three-minute interval, the additional percentage of termites extracted was below 10% in all cases. The average extracted at the end of three minutes was 56.8%, the cumulative average at six

TABLE I. Percentage of termites extracted from soil at three-minute intervals using baffle extractors from fourteen sites in Toronto, Ontario, Canada.

	Site	3-minute intervals 1	2	3	4	5	remainder
1	Blake 1	50.0	23.0	10.2	5.7	3.6	7.5
2	Blake 2	46.8	27.3	10.0	6.0	3.6	6.3
3	Blake 3	39.8	22.9	14.8	5.6	4.6	12.3
4	Borden	64.6	21.7	7.9	2.9	1.4	1.5
5	First	53.4	23.4	12.6	4.6	2.8	3.2
6	Fontainbleau	52.9	30.6	9.0	2.7	1.3	3.5
7	Gough 1	46.1	27.3	10.0	7.2	4.9	4.5
8	Gough 2	53.9	26.3	8.9	4.5	2.0	4.4
9	Logan	84.7	9.5	2.3	1.9	0.4	1.2
10	Montrose	86.5	8.3	2.2	1.2	0.5	1.3
11	Mould 1	45.9	25.9	13.2	6.7	3.7	4.6
12	Mould 2	47.3	17.9	12.0	7.9	5.5	9.4
13	Pritchard	53.5	24.4	8.6	5.5	3.3	4.7
14	Riverdale	69.8	15.5	8.1	3.5	1.4	1.7
Average		56.9	21.9	9.5	5.0	3.1	4.7
Cumulative Average		56.8	78.7	88.2	93.2	96.4	100.0

minutes was 78.7%, at nine minutes was 88.2%, at 12 minutes was 93.2% and at 15 minutes was 96.4%.

Discussion

Although numerous researchers have developed and refined various procedures and devices for trapping and baiting subterranean termites, few have examined how to efficiently extract large numbers of debris-free termites from their native substrate. The methods still widely used are labour intensive and time consuming. For example, the American Society for Testing and Materials, Standard D3345 (ASTM 1999), involves a standard technique termed "papering-off" (Gay et al. 1955). While this method has proved adequate for obtaining the few thousands of termites needed for typical bioassay tests, it is a slow, low-yield process. Tamashiro et al. (1973) proposed an extraction method in which termites were transferred from a tray with trap substrate to a tray with clean wood by migrating along damp wooden tongue depressors placed like bridges between the trays. Although this method has been used successfully for years, it is somewhat slow and requires the tedious process of setting up bridges. A further drawback of this method is that if a large amount of material is being processed, then a large amount of bench or floor space is needed.

With the start of Trap-Treat-Release field trials in Toronto in 1993, various methods were used in an attempt to separate collected termites from their substrate. These methods included "papering off", pump aspiration, paper and wood bridging mechanisms, and manual separation of termites from soil by placing them on an inclined tray and brushing them off the lower rim with a soft-hair paintbrush. Such methods required much time and tedious effort. In the first year of trials, the separation process was the rate-limiting step in the Trap-Treat-Release process. The three extraction devices that have been developed have significantly reduced the amount of time and effort spent in the separation process. Furthermore, these methods generate debris-free termites, permitting precise gravimetric quantification of the termites collected. Since the termites are completely separated from the soil it is a simple matter to weigh them, and, based on the weight of a counted sub-sample, determine the number of termites collected. This permits actual numbers of trapped termites to be recorded, which is simpler than inferring termite levels by calculating bait consumption (Su et al. 1993). In addition to rapidly separating large numbers of termites from their substrates, the extraction devices are simple to make and economical. Over 25 million termites have been processed by these methods since 1993.

More rapid and effective trapping, extraction and quantification of large numbers of live termites opens up many new possibilities for research, control, and ecological management using termites. For example, although baiting with toxic baits does not require trapping termites, it might be found that baiting could be promoted by trapping large numbers and then feeding them under no-choice feeding conditions for a day or more on baits before releasing them. Under such no-choice bait-feeding conditions, the trapped population could be made to consume larger amounts of bait and probably higher concentrations of bait toxicant. Such an approach remains to be tested.

More importantly, potential beneficial uses of termites can be explored. Termites possess unique digestive and nitrogen-fixing capabilities that are rare in animals (Martin 1991; Slaytor and Chappel 1994; Waller 2000; Lilburn et al. 2001). Termites can digest all classes of plant polymers including cellulose, hemicellulose and lignin, converting these otherwise indigestible, highly-abundant, renewable sources of organic carbon into animal protein, through the aid of symbiotic hindgut protozoans and bacteria (Abe and Higashi 1991; Kato et al. 1998). Thus, termites constitute a major ecological conduit through which plant cell wall polymers are converted into animal biomass (Higashi et al. 1992; Higashi and Abe 1996). Insectivores, which comprise large assemblages of some of the world's most diverse groups, including most reptiles, amphibians, birds and many mammals such as the edentates, pangolins, aardvarks, etc., utilize termites as an abundant and nutritious food-source (Redford and Dorea 1984). Furthermore, termites make up a significant portion of the diet in some human cultures in the tropics (Dufour 1987; Logan 1992). Through the bioconversion of lignocellulosic plant polymers to animal protein, and as superabundant prey items, termites aid in the maintenance of biodiversity. Termites function as keystone species in most tropical ecosystems in the degradation of cellulosic and humic matter, and in the pedoturbation of soils (Higashi and Abe 1996; Lavelle et al. 1997).

With their unique ability to convert plant fiber to animal biomass (lipids and proteins), and with their abundance in social colonies, termites can be exploited for agricultural purposes. Abasiekong (1997) describes termites being cultured on fibrous agricultural residues, which are then ground into animal feed with resulting greater protein content and reduced fiber content. Termite alates (winged forms) have been used as a source of feed for poultry and fish production in tropical countries (Logan 1992). In addition, termites can be used to decompose agricultural residues and, in the process, aid in revitalizing soil through increased nitrogen fixation. Termite tunneling also promotes soil aeration and water infiltration. In addition to agricultural uses, it might be possible to apply termites' unique digestive capabilities to manage urban wood and paper wastes.

The methods described here provide low-cost, low-tech tools which promote greater utilization of termites and termite biomass. For example, they could be used by small farmers in rural tropical areas for small-scale harvesting of termites as animal feed. Large numbers of collected termites could be used to assist in conservation projects for endangered termitivores such as the Australian echidna and numbat. Collected termites could be used as feed for certain termitivorous zoo animals or pets such as dendrobatid frogs.

In order for termites to be productively utilized (termiticulture, termite composting, environmental rehabilitation, conservation management, etc.), it will be necessary to have tools and procedures which permit the efficient harvesting, handling, and processing of termites from either natural or cultivated substrates. The devices discussed here may help to promote beneficial uses of an order of insects which have historically been viewed only as pests

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