Locally produced toxic baits for leaf-cutting ants for Latin America; Paraguay, a case study*1/

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COMPENDIO

Los principios de la fabricación de cebos tóxicos para controlar hormigas cortadoras indican que pueden utilizarse materiales locales y baratos. Como ejemplo, se traza el desarrollo de un programa para el control de las hormigas cortadoras en el Paraguay. Se describen los constituyentes de cebos tóxicos fabricados localmente, y se dan a conocer los resultados de ensayos llevados a cabo con los mismos. Se estima que los costos de producción local de cebos tóxicos para hormigas cortadoras pueden ser de 50 a 90 por ciento de los gastos de importación de cebos tóxicos comerciales. Se subraya que los materiales disponibles para la producción de cebos tóxicos variarán de país a país, pero los principios indicados pueden aplicarse a cualquier condición.

Introduction

MANY developments in toxic baits for leaf-cutting ant control have been reported since the early 1960's, when initial trials were performed. A brief history of toxic bait development has been given by Cherrett and Lewis (2). Phillips and Lewis (9) have discussed current trends in bait development, based largely on laboratory studies, and have also listed the requiriments of a good bait. A more comprehensive reference list can be found in Cherrett and Lewis (2). A series of papers by Lewis and his co-workers (5, 6, 7) have described experimental results of general broadcasting of locally developed and manufactured baits.

Many commercial baits are now available for leaf-cutting ant control. Of the 39 reported commercial baits, 21 have aldrin as the toxicant, 10 have heptachlor, 4 have mirex, 2 have nonachlor and 2 are not given (3, and unpublished personal observations). Of the commercial baits available, 'Mirex' (previously produced by Allied Chemical International, although continued production is now in doubt) is generally thought to be the most widely used (3).

Phillips and Lewis (9) list eight characteristics as being necessary for a good bait, and although they mention cost, it is not included as one of these characters. For countries where agriculture is still developing, cost is one of the prime factors. In Paraguay, cost of commercial baits tend to be high enough to prevent effective use by small farmers. In countries with a still developing agriculture, we believe that the immediate future for leaf-cutting ant baits lies in the utilization of locally available materials at a low cost. Small units formed under the general umbrella of the various Ministeries of Agriculture where leaf-cutting ants are pests could produce cheap baits that are then made available to farmers at cost of production.

This paper describes the development of locally produced baits in Paraguay. We believe that the principle discussed here will prove ueful elsewhere where leaf-cutting, and possibly other ants, are pests.

Previous Schemes and the Development of a Scheme for Paraguay

Four previous schemes to control leaf-cuttings have been proposed for Paraguay. So far, none of these has

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had any lasting success. An "erradication" scheme run by the USAID in the early 1960's, using powdered insecticides pumped down nests, killed many nests in a few areas throughout the country, but when massive USAID financing was withdrawn, the scheme collapsed and leaf-cutters rapidly reinfested the areas from which they had been 'erradicated'. Indeed, in just 12 years, no evidence can be seen of this scheme in the areas that were treated.

In 1968, in an unpublished report, Oviedo and Fleitas* estimated the annual loss to Paraguayan agriculture due to these ants was between 6.3×10^6 and $7.9 \times 10_6$ $US/ year, a figure we believe to be high. They suggested a scheme of 10 years of duration with the aim of killing 1.5 million nests per year at a total cost of 4.7×10^6 $US, of which $ 3,000,000 was to be spent on pesticides. No action was taken on their proposal. Amante* proposed a third scheme to the Paraguayan Ministry of Agriculture in 1971, but again no action was undertaken and no costs were estimated.

In 1972, Jonkman* proposed yet another scheme based on the massive purchase of commercial baits. Although he discounted the 'erradication' of leaf-cutters from Paraguay, he suggested a five year campaign and the purchase of 6.4×10^6 $ US of "Mirex" (although Jonkman wrongly estimated the cost of "Mirex", and quoted a total cost of only 1.92×10^6 $US) as the amounts he suggested would be needed, plus other expenses amounting to 3.5×10^6 $US.

None of the above mentioned schemes were effective in Paraguay, and indeed none could have been put into operation due to the high costs that would be involved, and the general shortage of funds within the Paraguayan Ministry of Agriculture. If a control scheme is to have a realistic chance of operation in a country with a still developing agriculture, such as Paraguay, then certain principles should be followed:

1. Baits must be of local manufacture from locally available materials, in so far as possible, as clearly most countries will have to import toxicants.
2. Manufacture should be by Ministry of Agriculture extension service personnel or other non-profit bodies, with charges for the baits being made only to cover costs.
3. The scheme need only be a small scale operation to produce cheap baits for farmers who feel the need to purchase them and to protect specific crops. Attempts at complete erradication are unpractical as well as possibly undesirable.
4. The scheme should not be considered as having a specific duration, but should be thought of as a permanent part of the agricultural extension service, and may be terminated when it no longer becomes useful.
5. The baits should be distributed through, and as part of, the normal agricultural extension services that are present.

* Unpublished report, 1972

The present control scheme in Paraguay

A leaf-cutting ant control scheme based, as far as possible, on the principles outlined above, was started in Paraguay in 1974. Locally formulated toxic baits were developed and tested, and a small scale scheme has begun using these baits. As these or similar baits, or the principles on which they were developed, may be useful in other countries where leaf-cutting ants are pests, their development and manufacture is given below as an example of what can be done.

Availability of commercial baits in Paraguay

The only commercial bait available in Paraguay in any quantity is "Mirex", produced by Allied Chemicals do Brasil. This is imported and sells for 400 Guaranies/kilogram (US$ 3.17). Using about 250 grams (US$ 0.79) of this bait, good kill rates can be obtained for all the pest species of *Atta* that occur in Paraguay. However, because of the high cost of the baits, farmers generally tend to underdose the nests giving less than the suggested 5-10 g/m² of nest surface. This results in low kill rates, wastage of money, and the reluctance to reuse the product. A reversion to poison dusts or an acceptance of ant produced crop losses results from these practices.

Development of locally produced alternative baits presently in use

Although commercial "Mirex" bait is efective for both leaf and grass-cutters, we were not able to develop a local bait suitable for both types of ants. The two separate baits developed will be discussed separately below.

Baits for use against grass-cutting ants

A range of products and formulations were tested for their suitability as a matrix for a grass-cutter bait. Suitable bait acceptance and pickup was eventually obtained with shredded and dried grass which had sugar cane molasses added to it. An effective bait for the control of grass-cutting ants was made as follows:

Ingredients	Approximate composition
5 kg of dry chopped elephant grass	83%
500 ml of soy bean oil	8%
500 ml of sugar cane molasses	8%
0.05 kg of technical "Aldrin"	1%

The dry grass is used as a matrix with the sugar cane molasses acting as an arrestant and pickup inducer. The soy bean oil is used to dissolve and ensure an even distribution of the toxicant "Aldrin" throughout the bait.

Method of manufacture

The elephant grass is cut and shredded using a rotary chopper. This grass is then dried to remove excess moisture, either in a hot air tray dryer that we have locally built especially for this job, or, if the weather permits, it can also be sun dried

The dry elephant grass is then placed in a cement mixer and is mixed with the 500 ml of sugar cane molasses. It is convenient to dilute the molasses with an equal volume of water to ensure a thorough mixing

Once mixed, the grass is once again dried. At this stage an extremely thorough drying is essential. Once dry, the grass is again returned to the mixer where the aldrin, dissolved in the soy oil, is added. Once the oil is thoroughly mixed, the bait can be placed into bags, sealed, and stored until needed.

The cost of the grass-cutter bait described above can be kept very low. If all the materials are bought locally, the bait can be produced for less than 20 Guaranies/kilogram (excluding labour and capital expenditure) Thus, the cost in materials of killing a large *Atta* nest becomes less than 1 5 Guaranies (US$ 0.01) The cost of materials and insecticides, traditionally the most expensive part of any control scheme, become small compared to labour costs, which in any case, tend to be low in developing countries.

Baits for use against leaf-cutting ants

As with grass-cutting ants, a range of products and formulations were tested as a suitable bait matrix for a leaf-cutting ant bait. It was found that an effective bait for use against leaf-cutting ants could be made from the following:

Ingredients	Approximate composition
25 kg of dry soy bean pellets	96%
900 ml of soy beans oil	3 5%
0.1 kg of technical "Aldrin"	0.4%
25 ml of propionic acid	0.1%

The soy bean pellers are used as the basic arrestant and matrix for the bait, the soy bean oil is used to dissolve the "Aldrin", and to ensure an even distribution of the toxicant, and the propionic acid is added to prevent fungal growth on the bait during storage (8).

Method of manufacture

Broken pieces of soy bean meal can be bought from a company that commercially processes soy bean products (CAPSA - Compañía Algodonera Paraguaya Sociedad Anónima) at Capiata. These pieces are already sieved between 3 and 8 mm, and this size was found to be suitable.

A 25 kg sample of soy bean pellets is placed in the cement mixer. 900 ml of soy bean oil is heated gently, and the 100 g of "Aldrin' 'and 25 ml of propionic acid is added to this This solution is then poured directly into the 25 kg sample of pellets whilst the mixer is in operation Previous trials with dyed soy bean oil indicated a complete and even mixing is obtained in this way.

When thoroughly mixed, the 25 kg sample can be removed from the mixer and initially stored in large samples in sealed polythene bags until it is required for final packaging in smaller bags for distribution to farmers

It is perhaps interesting to note that the smaller dust particles that we can sieve from the bait has also proved to be an efective bait for the control of *Solenopsis wasmanni,* which is a nuisance pest in Paraguay, and is closely related to the imported fire ant of the southern USA.

At the present prices, 84% of the cost of this bait is the price of the soy bean meal. Since the start of the control scheme, the price we have had to pay for soy bean meal has gone from 16 to 34 Guaranies/kg The price of soy bean meal is likely to increase again in the future Thus, it is important that the staff of the scheme should continue to search for products that can be used as a bait matrix in the future. At present, we can produce this bait for about 40 Guaranies/kg, which is about 10% of the cost of the commercial alternatives

Field Trials Using the Locally Produced Baits

1 *Grass-cutter baits with Atta vollenweideri*

Mature nests (122) of *Atta vollenweideri* were marked with numbered stakes Bait was prepared as previously described and was sealed in polythene bags in lots of approximately 60 g. To treat the nests, the contents of a 60 g bag of bait was spread aruond each nest by walking around the nest mound and putting bait on each of the foraging trails radiating from the nest The amount of bait placed on each trail was roughly in proportion to its size. Nests were treated with either freshly made bait, or with bait that had been produced and stored in sealed polythene bags for six months A further set of nests were left untreated to serve as controls All 122 nests were treated on the same day After treatment, the nests were examined six weeks later Nests were recorded as alive if any evidence of ant activity could be seen (i.e, fresh digging or foraging) or if ants could be provoked to emerge by banging the nest surface. The results of this trial are given in Table 1.

A similar field trial was run in which three bags of bait, each sufficient to treat 10 nests, together with a plastic glove for each bag, were given to farmers. The farmers were asked to treat nests without supervision by spreading a handful of bait (approximately 60 g) around each nest. From a total of 33 nests treated, 28 (85%) were killed outright, with 5 (15%) still showing signs of activity after three weeks Although a 2 x 2 Chi squared test (1) gave no significance difference in kill rate between 'expert' and farmer applied baits ($X_c^2 = 0\ 58$, with 1 d.f., $P<0\ 3$), the

Table 1.—The effect of treating *Atta vollenweideri* nests with 60 g of a locally produced bait.

	Nests treated with		control	Total
	fresh bait	old bait		
Number of nests treated on 16/11/77	57	48	17	122
Number of nests dead on 28/3/77	52	44	1	97
Number of nests alive on 28/3/77	5	4	16	12
% Kill rate	91.2	91.6	5.9	

A 2 x 2 chi squared test of the kill rates between old and new baits gave a $X^2 = 0.073$ with 1 d.f. $P < 0.7$ (1)

farmers did report that the last few nests treated with each packet were the ones that were not killed, as the remaining bait was neither sufficient in quantity nor quality to treat these nests properly. The first few nests treated were overtreated, and the final nests were treated with bait that consisted of a large proportion of fine powder that the ants will not carry back to the nest.

A second trial was planned giving the farmers baits packaged in lots of 60 g, or one bag for each nest to be treated. In this case, 36 seperate packets of bait were given together with 36 small stakes so that the treated nests could be marked. The nests were again treated by ranch personel without supervision. Examination of the treated nests by us 20 days after bait application showed that all treated nests were dead. Three untreated nests in the same area that were used as controls were still actively foraging.

2. *Grass-cutter baits with Acromyrmex landolti*

On previous small trials, we had shown that when treated individually, 1g of the grass-cutter bait placed around a *Acromyrmex landolti* nest was sufficient to obtain nest kill rates in excess of 95%. However, as infestation of this species can be up to 6000 nests/ha (unpublished data), treament for individual nests in any large scale control effort is not practical. A fertilizer spreading apparatus driven from a power take off attachment when towed behind a suitable vehicle was used to test the possibility of general broadcasting of the bait to control *A. landolti*.

The outflow control of the bait spreading machine could be set at various openings, arbitrarily labelled from 0 to 30, with 30 being the most open. The spreader was charged with bait and driven once through a field with a proportion of the nests marked with small wooden stakes. The spreader was set to spread at either 10, 20 or 30. Previous tests had shown than these settings corresponded to bait distribution patterns of 1.54, 7.77 and 17.98 g/m² respectively. All of these amounts were uniformly spread over a strip of approximately 1.2 m wide. After a period of 2 weeks, the marked nests within 8 m of the path taken by the bait spreader were examined. Nests were recorded as dead or alive, and in each case, the distance from the path taken by the spreader was noted. The results of this trial are given in Table 2.

A second trial was designed to give a more complete cover, the opening on the bait spreader was set to 10. A series of 400 nests were marked in an open field to be tested, and 50 were marked in a similar field nearby to be used as controls. Both sets were traversed with the bait spreader, with each path taken 4 m from the preceeding one. This would give a bait distribution at a rate of approximately 3.8 kg/ha. After two weeks, the nests were examined. Unfortunately, the majority of the stakes marking the nests had been removed or scattered around the field. Although many dead nests were seen, only nests which still had stakes in them were recorded. The results of this trial are given in Table 3.

Table 2.—The effectiveness of elephant grass/"Aldrin" bait in killing nests of *Acromyrmex landolti* when spread evenly in a strip 1.2 m wide at three different release rates.

Distance (m) from path of bait spreader	Spreader setting*					
	10			20		30		
	Number of nests	present	% kill	Number of nests	present	% kill	Number of nests	present	% kill
0 - 1	5	100		3	66		5	100	
1 - 2	6	100		2	100		4	100	
2 - 3	5	80		5	80		8	100	
3 - 4	5	80		10	70		6	100	
4 - 5	8	75		8	25		6	50	
5 - 6	6	50		5	0		8	75	
6 - 7	1	0		5	0		5	40	
7 - 8	3	0		3	0		4	0	

* Rates of release of bait for each setting are 10 = 1.54 g/m, 20 = 7.77 g/m, and 30 = 17.98 g/m

Table 3.—The effect of grass bait on nests of *Acromyrmex landolti* when spread automatically from a bait spreading machine in strips 4 m apart at an outflow rate of 1.54 g of bait per meter (3.5 kg/ha).

	Treated area		Untreated (control) area	
	Dead nests	Living nests	Dead nests	Living nests
Number	99	13	3	33
% of total	88.4	11.6	8.3	91.7

A 2 x 2 chi squared test of living and dead nests between test and control areas gave $X^2 = 77.82$ with 1 d.f. $P < 0.001$ (1).

3. *Leaf-cutter baits with Atta sexdens rubropilosa*

The attempted large scale field trials with soy bean bait to control *Atta sexdens* have been disappointing. Large mature nests have proved difficult to kill. Good kill rates can be obtained, but the baits must be applied carefully and at the correct time. This is probaly due to the size and structure of the nests (they are extremely large and probably well spread out under the ground), and to the fact that "Aldrin" is not a very suitable toxicant. It is probably not posible to bait effectively more than 3 nests at any one time. This is adequate for the farmer, but makes large scale testing a difficult and time consuming process.

The recent trials with the final bait had to be done in winter, not a suitable time for baiting as foraging is reduced to a minimum. Attempts to bait large numbers of nests in one day by either spreading bait around or on the nest mound or by baiting trails as found produced only very poor kill rates. Bait spread on or around the nest mound was not collected, and bait placed on trails when the ants were not foraging was not necessarily collected as particular trails are not used every day or for even several days in winter.

In a series of trials in which individuals nests were carefully treated, rather as a farmer would treat them, 11 of 14 nests treated were killed. Two of the remaining three had an activity that was so reduced that either they were dying, or had stopped activity to the point where they were no longer pestiferous. The remaining nest was reduced to about half its original size and activilty. This could be probably have been killed with another dose of bait.

In areas with heavy populations of older nests, it is often not possible to determine which trail serves which particular nest, thus further complicating field trials. However, in field trials when trails' rather than nests have been baited, activity on the treated trails has always ended, even if the nest itself has not been totally killed.

An encouraging response was obtained in a trial when bait was sent to various extension officers for testing. Approximately 450 packets of bait, of about 350 g each, were sent to 7 officers in the field. All seven officers distributed the bait to farmers, and then reporter, without exception, that the bait has given excellent results.

Discussion

Trials with locally produced baits described above were highly encouraging. Both *Atta vollenweideri* and *Acromyrmex landolti* can be easily and cheaply controlled with the chopped grass/aldrin baits. Contrary to the results with *Atta sexdens*, nests of *Atta vollenweideri* were easily killed. If a total of 60 g of bait, approximately one handful, is placed on the trails leading out from a nest, excellent kill rates can be obtained. No fall off in efficiency with bait stored up to 6 months before use was observed. Bait stored for one year was readily accepted by *Atta vollenweideri*, and, although kill rates were not tested, there is no reason to suppose that the kill rates should be reduced.

Kill rates on several previous large scale trials with the soy bean/"Aldrin" baits for *Atta sexdens rubropilosa* were poor (unpublished data), and was probably due to a low pickup of bait in these trails. The initial samples of soy bean pellets were extremely variable in quality. Old, badly stored soy bean pellets were not attractive to the ants, and also tended to develop a slow growing fungal cover. Fungus growth of this type seems common in stored soy beans in Paraguay. However, if the soy bean is bought fresh from the factory, and 0.1% propionic acid is added, baits made with this fresh material can be stored without problems of fungal degradation.

Throughout the range where grass and leaf-cutting ants are a problem, similar baits could easily be made locally. It is likely that any dried grass would be sufficient for the grass-cutter bait, and this could conceivably be cut and collected by standard domestic lawn mowers. Molasses or sugar solution should easily be available, or any suitable vegetable oil could be used as a solvent for the toxicant. To produce a leaf-cutter bait, various agricultural and industrial waste products could be tried, depending upon what is locally available and cheap. Also, it has been demonstrated that material such as sugars, orange juice and citrus pulp extract can be added to inert materials and thus cause to be picked up by the ants in both laboratory (4) and in the field (10).

Nests of the leaf-cutter *Atta sexdens* have, in general, proven difficult to kill. Using the baits produced a good kill rate when care was taken when the baits were applied. The existence of any trails that are causing problems are generally known to farmers. The nests need not be found in order to treat the trails. It is important, however, that the trails are treated when the ants are foraging. This implies that summer is generally better than winter treatments. Also, cold or wet days should be avoided when treating nests.

These restrictions place undesirable constraints on farmers. Robinson *et al.* (unpublished) have shown that with other species of *Atta,* "Mirex" is a far better toxicant than either "Aldrin" or one of the better alternatives tested by Phillips and Etheridge (8) Therefore, for large nests of *Atta,* when baits are not critically placed, it would seem that, especially for *Atta sexdens rubropilosa,* it would be advantageous to change the toxicant from "Aldrin", with its unsuitable rapid contact action, to "Mirex".

The possibility of producing a 'one pack' of sugars, or other suitable arrestants, attractants or pickup inducers, with an insecticide emulsion that can be produced and mixed with any locally available suitable matrix is already being tested (Phillips and Etheridge, personal communication) Ideally, this 'one pack' should be manufactured locally again as part of a local small bait production scheme in areas where leaf-cutters are pests

When control is carried out by baits, environmental problems should be minimized due to the small amounts of toxicants spread into the enviroment. For example, Jonkman* gives the average density of *Atta tollenweideri* at 0 4 nests/ha, which would mean spreading "Aldrin" into the enviroment at a rate of 240 mg of toxicant/ha With *Acromyrmex landolti,* this rate would be equivalent to 38 g of toxicant/ha With *Atta sexdens rubropilosa,* nest density is highly variable, but approximately 1.5 g of toxicant are used to kill each nest. In all cases, the toxicant is quickly carried underground, thus minimizing unwanted side effects in the areas treated

Conclusions

By the publication of details of locally produced baits suitable for Paraguay, we do not want to suggest that identical baits would be suitable for all areas where leaf-cutting ants are a problem. Rather, we believe that the principle of toxic bait manufacture from locally available products can be most suitable for countries with a developing agriculture and economy Secondly, we suggest that if funds for research into methods of control of leaf-cutting ants are limited, then emphasis should be placed on the development of novel toxicants or 'one pack' attractant toxicant formulations rather than novel matrices that may have only a more limited application.

Summary

Principles for the production of toxic baits for leaf-cutting ants are discussed. Emphasis is placed on the utilization of locally available and cheap matrix material As an example, the development of a control program for leaf-cutting in Paraguay is illustrated. The production and constituents of locally fabricated toxic baits used in Paraguay are discussed. The usage of locally produced baits can reduce the cost to the farmer to 50 to 90% that of what he must pay for an imported commercial bait Special attention should be focused on country by country needs and the availability of suitable bait matrices, but the principles that have been developed in Paraguay can be applied to any Latin American country where leaf—cutting ants are a problem, even if the specific baits developed in Paraguay may not, due to the presence of cheaper alternatives in other countries

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