Arthropods Associated with Stored Maize and Farmers' Management Practices in the Bako Area, Western Ethiopia

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Abstract

Surveys conducted to assess arthropods on farm-stored maize revealed 24 species of Coleoptera, three Lepidoptera, one Diptera, one Thysanura, six Hymenoptera and two Pseudoscorpionida to be associated with the crop in the Bako area. Among those, the weevils *Sitophilus* spp, the Angoumois grain moth *Sitotroga cerealella* (Olivier), the flour beetles *Tribolium* spp and the sap beetles *Carpophilus* spp accounted for about 79, 11, 5 and 1 percent, respectively, of all arthropods counted. Other species that occurred commonly included *Cryptolestes* spp, the tropical warehouse moth *Ephestia cautella* (Walker) and the Indian meal moth *Plodia interpunctella* (Hubner). Average crop loss in storage in the Bako area was estimated at about 16%. Seventy five percent of farmers responded that weevil infestation starts in the field up to more than two months before harvest. Over 45% of the farmers responded that improved maize varieteis that are with large but poorly covered cobs were most attacked. In the Bako area farmers store maize as shelled, undehusked, dehusked or combinations of these in different traditional storage containers such as *gorbo*, *gotera* and *gumbi*. Jute or hessian sacks, clay jars, gourds, wooden boxes, suspending cobs under the eve of the roof or in trees, or in smoke over fire were also used with small quantity of maize. Farmers reported several traditional insect pest control methods, although most of those were not actually practiced. They showed a tendency towards depending on pesticides.

Introduction

Maize is the most important food crop grown and stored by farmers in the Bako area. The production and storage of maize is threatened by several constraints among which insect pests are considered to be the most important. In their survey on grain marketing and peasant production in Ethiopia, Franzel et al. (1989) reported that storage losses are substantial and are one of the reasons why farmers sell most of their maize soon after harvest and suffer food shortage in the later time of the year.

However, research information on stored products pests in general (Abate & Adhanom 1985) and thus on stored maize in particular is meager in Ethiopia. The only available published information on stored product pests in this country is the survey results of McFarlane (1969) and Walker and Boxall (1974).

The objectives of these studies were, therefore, to identify the arthropod species associated with stored maize and to develop an understanding of the storage and pest control practices of farmers in the Bako area so that planning for improved post-harvest pest management systems in ways compatible to farmers' practices are possible.

Materials and Methods

Surveys were conducted in 1989 and 1993 in the vicinity of Bako Research Centre (BRC) six to eight months after storage of maize. Bako is an area between the administrative regions of Shewa and Wellega and is located about 250 kilometers west of Addis Ababa. Survey sites were selected from both administrative regions within a radius of up to 120 kilometers from BRC (Table 1). Selection was made on a random basis or by choosing the first site and farmer at random and the rest at regular intervals as suggested by Adams (1976). Extremely inaccessible farmers were excluded. When a selected area did not produce maize or when a selected farmer did not store maize, the next area or farmer was taken as a substitute. Twenty sites, ten stores from each site and five maize grain samples from each store, were taken. The grain samples were taken by

Table 1. List of sites surveyed in seven *weredas*, their altitude (m), and distance (km) from Bako Research Centre, 1989 and 1993.

Name of site	Wereda	Altitude	Distance anddirection
Arjogudatu	Diga	1330	120 W
Wamakusay	Sibusire	1500	42 SW
Chakalegamare	Bakotibe	1650	20 E
Ongobodenbi	Gobussayo	1680	12 S
Gobuweldia	Bakotibe	1700	10 E
Ilalawereilu	Bakotibe	1700	37 E
Shaka	Bakotibe	1720	32 E
Cheri	Sibusire	1750	38 W
Gunjomariam	Sibusire	1770	32 S
Jatodirki	Bakotibe	1790	47 E
Babochekorssa	Sibusire	1800	28 S
Welgebigomisso	Sibusire	1810	28 W
Worago	Sibusire	1810	52 W
Annobekenissa	Gobussayo	1830	13 W
Gajo	Bakotibe	1880	15 N
Ago	Gobussayo	1930	13 NW
Guddanie	Jimageneti	2240	61 N
Gobanno	Jimageneti	2250	39 N
Jiresolle	Abaychomen	2300	112 N
Kistanasadeka	Horo	2350	87 N

scooping with a 100-gram capacity container. The samples were obtained from as many different parts—top, sides, centre, bottom—of the various storage facilities as possible. Each sample was put in a plastic-lined paper bag and sealed for inspection in the laboratory. Each bag of sample was labeled with the necessary information, including name and altitude of the site, date of sampling, and storage time. Five such samples obtained from the same store were placed in one cloth bag. In addition to grain samples, farmers were interviewed through interpreters using a semi-structured questionnaire developed for this purpose. Examination of the granaries also revealed information on other biotic and abiotic characteristics of farmers' storage practices.
In the laboratory, each sample of grain was separated into damaged and undamaged categories and all fractions were examined. The number and weight of grains in each category were recorded. The weight loss was estimated using the count and weigh method (Adams 1976).

Insects were removed, counted and grouped according to their order or genera and were preserved as dry pinned specimens or in 75% ethanol. The different fractions of grain samples were reconstituted and re-bagged and were kept at a room temperature to reveal internal infestation or parasitism. After about one month, these were re-examined and emerged insects were recorded as described earlier. Samples of arthropods obtained during both inspection periods were sent to CABI Institute of Entomology (CABIIE), England, for expert identification. The identified arthropod specimens were received as CABIIE List No. 10431 Africa, Collection No. A. 20992.

Results and Discussion

Arthropod species recorded

The species of arthropods recorded on stored maize are listed in Table 2. Twenty four species of Coleoptera, six Hymenoptera, three Lepidoptera, two Pseudoscorpionida, one Diptera and one Thysanura were identified. Among these, coleopterans and lepidopterans were the most common and widespread pests. *Sitophilus* spp, *Sitotroga cerealella, Tribolium* spp, *Carpophilus* spp and *Cryptolestes* spp accounted for 79, 11.2, 5.2, 1.1 and 0.6 percent, respectively. *Ephestia cautella* and *Plodia interpunctella* were also common in maize grain samples.

Although their numbers were low in the grain samples collected, *Rhizopertha dominica, Gnatocerus cornutus*, and *Oryzaephilus* spp were expected to be potential pests. Most of the pest species recorded were secondary pests attacking grains that have been broken or damaged by primary pests. Insects in the latter category include *Sitophilus* spp, *Sitotroga cerealella* and *Rhizopertha dominica* (TDRI 1984). *Sitophilus* spp were the commonest and perhaps the most destructive of all insect pests recorded. Both *S. zeamais* and *S. oryzae* were found attacking maize; however, *S. zeamais* was recorded from all of the samples while *S. oryzae* was found only in three out of five samples sent for identification. The ratio of *S. zeamais* to *S. oryzae* was 2.24: 1. Both species were recorded from samples obtained as a mixture of maize and sorghum or from samples of either maize or sorghum alone. However, samples of maize or sorghum obtained from BRC farm sto re did not contain *S. oryzae*. Similarly, Schmutterer (1971) did not indicate the occurrence of *S. oryzae* on either of these and other crops stored in the Bako area. He reported the severity of *S. zeamais* on both maize and sorghum in storage and showed a loss estimate of up to 80% in maize stored in unprotected silos. *Sitophilus granarius (L.)*, which was reported to be found at high elevations, was not recorded during this survey from altitudes higher than 2300 m. McFarlane (1969) recorded *S. granarius* from altitudes at or above 2100 m while Walker and Boxall (1974) reported that this species was commonly found in Addis Ababa and less common elsewhere.

Zabrotes subfasciatus was recorded from haricot bean (*Phaseolus vulgaris*) with which maize seeds were sparsely mixed and stored at BRC farm store. Walker and Boxall (1974) recorded *S. zeamais* on haricot bean in Ethiopia. *Zabrotes subfasciatus* is one of the important bruchids attacking haricot beans and other pulses in Africa. It has been recorded from west, north and central Africa and Madagascar but not from Ethiopia, Sudan or South Africa (Southgate 1978). Similarly, Abate et al. (1982) did not mention the presence of this species in Ethiopia. However, during the 1989 survey it was recorded as the only and most dominant bruchid attacking haricot bean (*cv* 'Mexican 142') grown and stored at BRC. Most of the species recorded are cosmopolitan pests in stored products. *Carpophilus freemani, Cryptolestes ugandae, Oryzaephilus gibbosus* and *Palorus laesicollis* are Afrotropical. According to CABIIE, *P. laesicollis* is especially common in Kenya and Ethiopia and *W. somalicus* is one of the most common Pseudoscorpions in eastern Africa. Some of the insects recorded did not appear to be of importance as direct pests. They seemed to be associated with the microfungi associated with stored produce. *Tenebroides mauritanicus* is known to be a cosmopolitan predator, and sometimes a minor pest in stored grain. *Typhaea stercorea, Mycetophagus* sp and *Drosophila* spp are likely to be mould feeders. *Carpophilus* sp and *Gonocephalum* sp are not usual pests of stored cereals and appeared to be new records. The root feeding larvae of *Gonocephalum* sp are sometimes field pests, and adults may scavenge dead plant or animal material. All species of insects recorded in the order Hymenoptera were natural enemies of pest species associated with stored products.

Anisopteromalus calandrae is a well known cosmopolitan parasite of Coleoptera (and perhaps some Lepidoptera) associated with grain in storage. *Theocolax elegans* (syn. *Choetospila elegans*) is a cosmopolitan parasite of small beetles in stored grains. Moreover, *Holepyris syvanidis* (syn. *Rhabdepyris zea*) is a primary ectoparasitoid of various Coleoptera, including *S. oryzae, T. confusum* and *O. surinamensis* (Evans 1978). *Pteromalus* and *Eupelmus* are large genera with cosmopolitan distribution and attack a variety of lepidopteran and coleopteran hosts. According to CABIIE, *Antrocephalus* spp attack mostly Lepidoptera and they are known from the warmer regions of the Old World.

Table 2. Arthropods recorded on farm-stored maize in the Bako area, 1989 and 1993

Species	Common name
Coleoptera	
Ahasverus advena (Waltl)	foreign grain beetle
Brachypeplus sp	a sap beetle
Carpophilus dimidiatus (F.)	corn sap beetle
C. freemani Dobson	a sap beetle
Carpophilus sp	a sap beetle
Cryptolestes pusillus (Schon.)	flat grain beetle
C. ugandae Steel & Howe	a flat bark beetle
Gnatocerus cornutus (F.)	broad horned flour beetle
Gonocephalum sp	dusty brown beetle
Mycetophagus sp	a fungus beetles
Oryzaephilus gibbosus Aitken	a flat dark beetle
O. mercator (Fauv.)	merchant grain beetle
O. surinamensis (L.)	saw-toothed grain beetle
Palorus laesicollis (Fair.)	a darkling beetle
P. subdepressus (Wollast.)	depressed flour beetle
Rhizopertha dominica (F.)	lesser grain borer
Sitophilus oryzae (L.)	rice weevil
S. zeamais Motsch.	maize weevil
Tenebroides mauritanicus (L.)	cadelle
Tribolium castaneum (Herbst)	red flour beetle
T. confusum J. de val	confused flour beetle
Tribolium sp	flour beetles
Typhaea stercorea (L.)	hairy fungus beetle
Zabrotes subfasciatus (Boh.)	Mexican bean weevil
Diptera	
Drosophila spp	small fruit flies
Hymenoptera	
Anisopteromalus calandrae (Howard)	a pteromalid wasp
Antrocephalus sp	a chalcid wasp
Eupelmus sp	a eupelmid wasp
Holepyris sylvanidis (Brethes)	a bethylid wasp
Pteromalus sp	a pteromalid wasp
Theocolax elegans (Westwood)	a pteromalid wasp
Lepidoptera	
Ephestia cautella (Walker)	tropical warehouse moth
Plodia interpunctella (Hubner)	Indian meal moth
Sitotroga cerealella (Oliver)	Angoumois grain moth
Thysanura	
Thermobia domestica Packard	fire brat
Pseudoscorpionida	
Stenowithius bayoni (Elligsen)	false scorpion
Withius somalicus (Beier)	false scorpion

Storage practices

Harvesting: Farmers harvest dried maize between mid-*Hidar* (November) and mid-*Tir* (January). Some farmers cut the plant, pile it and then pick the cobs while others harvest maize cobs from the standing maize plant. Maize cobs may be collected with or without the husk. These are taken to barn and kept for further drying on a raised bed. The drying period ranged between two weeks to four months, depending on the moisture content of the grain during harvesting and weather condition. The dried maize is then stored in the form the farmer preferred to, depending on the availability of storage space, time for shelling/threshing, and insecticides. During this time infestations may not be noticed but after one to two months from threshing infestations become conspicuous and after a period of two to four months damage was very serious in almost all farmers cases.

Seventy-five percent of the farmers interviewed indicated that infestations start in the field up to more than two months before the time of harvesting maize. Some farmers demonstrated green maize cobs in the field harboring a large number of weevils. Most of the infested cobs were found to be with bare tips which was either varietal characteristic or due to damage by birds. Farmers reported that the problem of weevils increased with the increase in growing improved maize varieties that are with large but poorly covered cobs. Moreover, field infestation was observed to be a problem in fields that were closer to storage facilities.

Separation of apparently damaged and infested grain from the rest of the harvest is a common practice of farmers in the area surveyed. The impact of selection at harvest on the subsequent infestation in storage is obvious. Damage to maize in storage caused by the maize weevil is directly related to the initial infestation which was present at the time of storage. Adams and Harman (1977) found fewer insects from stores of farmers who had selected cobs for storage than from untreated shelled grain. The whole content of a healthy store may be infested by introducing a batch of contaminated grain.

Storage forms: Farmers in the survey area stored their maize on cobs with or without the husk cover or shelled. In some stores mixtures of two or three forms of maize were observed. According to the questionnaire response, 61% of the farmers store their maize shelled, 20% store undehusked, 13% store dehusked maize, 4.5% store shelled maize mixed with undehusked maize, 1% store shelled maize mixed with dehusked cobs, and 0.5% store mixtures of the three maize forms. However, during sampling it was observed that 61% of farmers stored shelled maize, 20% undehusked maize, 13% dehusked maize and 6% stored mixtures of dehusked and undehusked maize. The reason why they stored maize in any one or mixture of the different forms was not understood. However, some farmers reported shelled maize to be less liable to damage by the Angoumois grain moth larvae than dehusked maize stored on the cob. Moreover, those who stored shelled maize reasoned out that storage space is a problem for storing maize on the cob while those who stored unshelled maize indicated that time shortage did not allow them to shell.

The difference between maize storage forms in weevil damage was insignificant, although the shelled form appeared to be less attacked. However, whether shelling or the possibility of shelled maize to be treated with insecticide protectants that has resulted in low infestation and damage levels is not clear. Damage by the Angoumois grain moth larvae appeared to be more common on dehusked cobs particularly placed in more accessible conditions: suspended cobs were more attacked than cobs in storage containers, cobs at the lower layer of storage containers were less liable than cobs at the uppermost layer. Cobs suspended in smoke over fire were least attacked by insect pests. Cobs with husks extending well beyond the tips of the ears and fitting closely about the silk restricted insect pests. Most farmers were aware of this fact and they select cobs with such husk cover or tie husks on cob tips together so that the complete husk coverage is retained.

Storage facilities: Farmers in the survey area store their maize in various types of traditional storage structures (Table 3). The major types are the *gorbo, gotera and gumbi*. *Gorbo* is made of vertical timber poles or twigs plus a thatched roof and resting on the ground or on cross-pole platforms. It may not be sealed to allow ventilation and is usually used for storing maize on the cob. *Gotera* is made of interwoven sticks or bamboo and resting on cross-pole platforms or on the ground and has conical grass roof. The indoor type which lacks grass roof and rests on the ground is also called *gotta*. *Gumbi* is made of a mixture of mud, tef straw and cow dung and is either made of a

Table 3. Storage container types/methods used and their occurrence (percentages) in the Bako area (n=200)

Storage container	Percent
Mud/straw/cow dung (*gumbi*)	23.5
Woven stick plastered (*gotera*)	15.5
Woven bamboo (*gotta*)	13.5
Woven stick unplastered (*gotera*)	9.0
Jute sack or hessian bag	7.5
Timber pole type unplastered (*gorbo*)	6.0
Suspended at home or in field	6.0
Timber pole type plastered (*gotera*)	6.0
Clay jar	5.5
On the floor inside home	4.5
Wooden box	3.0

single piece or rings stacked one above the other so that the vessel can be taken to pieces and reassembled elsewhere. It is used for storage of shelled maize. The storage containers may be located outside or inside, or just abutting to the outside wall of the hut. Whether they are plastered with mud and cow dung or not depended on the form of maize to be stored. Shelled maize is stored in containers plastered either internally or externally, or from both sides. The capacity of the stores ranged from about 100 to 1000 kg. Clay jars, gourds, jute or hessian bags, and wooden boxes were also used for storing maize in small quantities. Some cobs may be suspended in the smoke over fire, under the eve of the roof or in trees outside the house. Some farmers stored their maize in heaps on the floor at one corner of the room.

Suspended cobs in smoke over fire were least attacked while those suspended outside the house were more attacked by moth larvae than weevils. Maize in unplastered containers appeared to be the next most attacked. The presence of mud barrier in improving the protection level of treated grain has been reported by Golob and Muwalo (1984). The effect of pirimiphos-methyl was significantly influenced by the presence of the mud barrier. This may be due to the restriction of air flow through the store, improved by the mud barrier, which reduces the displacement or loss of the insecticide dust particle and may also reduce the rate of oxidation and degradation of the active ingredient. However, since maize was said to be transferred from one container to another just before a few days or several weeks from the time of survey, the comparison between store types in terms of pest infestation and grain damage levels may not be reliable.

Despite the variety of storage container types in use, conditions affecting storage and infestation were very uniform except for climatic differences in some localities. The general hygiene outside the stores was lacking in every store. All sorts of trash was piled up in the vicinity of the store making an attractive place for insects. Most of the stores were located inside or nearby maize fields facilitating cross-infestations by weevils and moths. It was observed in some farmers' fields during the survey that the proportion of ears infested was related to the distance from the crop edge and infested stores. During grain withdrawal the granaries are opened by lifting the conical grass roofs wholly or partly which gives ample opportunity for insects to fly into or out of the store to nearby maize fields. Moreover, the granaries were not raised well above the ground and thus it is likely that the grain absorbs moisture from the ground and this condition may facilitate the rapid prolification of insects as well as molds already present in small quantities. Molds in general did not appear to do much damage to the stored crops. However, the farming community should be aware of the health risks they take when eating mouldy grain or feeding it to their livestock.

An improved storage system has not only a significant impact on reducing the losses occurring during storage but also helps the farmer to keep his surplus so that he can sell it later when the commodity is scarce and highly priced. Minor improvements in the construction of storage containers can even give the produce greater protection against pests and damp. The problem of rodent damage, for example, was heard from different farmers in the different areas surveyed, but nowhere was the use of rat guards observed.

Loss estimates: Farmers' loss estimates ranged from 50 to 100%, the larger figure being in bad years. It was mentioned by some farmers that weevils have been their constant enemies since time immemorial. However, their threat to stored maize increased gradually and reached the present level in recent years. Some farmers related this situation with the cultivation of improved maize varieties. About 45.5% of the farmers interviewed responded that improved varieties are more susceptible to weevil damage than the local varieties. Some farmers reported that when they have grains of both local and improved varieties they mix them for storage.

The weight loss estimated from the samples obtained ranged between 5 to 30% with an overall mean of 16.3%, using the "count and weigh method". This figure appears to be low when viewed against the heavy pest population densities observed, farmers' estimates of grain loss reports and the high grain damage levels observed during the survey, particularly in some individual samples where grain damage levels of up to 100% were recorded. However, farmers over estimated losses. The problem was that it is difficult to differentiate clearly between grain damage percent and the probable percent weight loss. It is true that farm storage losses are liable to exaggeration if the pattern of grain withdrawal from the store is overlooked. Losses recorded at one period during the storage season will not give an indication of the overall loss throughout the year. If the objective is to know what losses farmers are suffering from, a study over the whole storage period is vital (Boxall 1986). It is always possible to identify the species responsible for damage and to quantify the number of grains attacked but interpreting this damage in terms of losses is a trickier matter (Appert 1987).

Pest control practices

Farmers mentioned several insect pest control methods on stored maize (Table 4). However, most of the methods reported by farmers did not appear to be currently practiced. Some farmers knew them theoretically or used them long ago when insecticides were not adopted. Despite the various traditional control practices, the reduction in insect infestations was insufficient probably due to incorrect timing or incorrect application techniques. High densities of dead insects present in grain reported as treated with chemical insecticides suggested that decisions to treat are often delayed until damaging levels of infestations have developed.

More than 70% of the farmers reported that they apply insecticides for the control of insects in their maize. However, farmers who had actually treated their grain of the survey season were less than 10%. They used insecticide dusts or tablets, possibly phostoxin, or a mixture of the two. However, no one storage container was observed to be suitable for the application of fumigants. Most farmers have used pirimiphos-methyl (Actellic 2%) dust which replaced lindane since 1988. Some used unknown (unlabelled) chemicals purchased from the open market. One farmer reported that he used an acaricide. The rate of insecticide used by the farmers was not according to the recommendation, but dependent upon the quantity of grain to be stored and the amount of chemical available to them. They often used a left-over chemical from the past season and saved a portion of the newly purchased one for the coming season. This suggests that obsolete chemicals may be used. They applied chemicals to shelled maize or to dehusked cobs layer by layer, after each of three to four baskets of maize. The majority of farmers applied to shelled maize and some farmers reported that they are reluctant to shell if insecticide protectants are not available. The application time reported was either just before storage or after they have observed weevils on their grain in the store.

Farmers are more than aware of pesticide use and consequently they appeared to have forgotten traditional pest control methods. What farmers lack is selection of insecticide, rate, method and time of application. They complained that pesticides were not available to them in the amount they required. The quantity packed was either too much to afford for some and too little for others. Some farmers reported that the chemical did not control pests which may be due to expired shelf life. Because of the sole dependence on pesticides most farmers reported that they did not use traditional pest control methods for they are less effective compared to insecticides. They seemed to think that insecticides are the only means to get effective control of insect pests. This trend should be discouraged.

Conclusion

Weevils, followed by grain moths, were the most serious pests of stored maize and sorghum in the Bako area. It appeared that storage of maize cobs with husks extending well beyond the tip results in lower infestation levels by weevils and the Angoumois grain moth while storing shelled maize appeared to result in low level of infestation by the moth. Therefore, investigations into these and other control strategies should be given priority as far as storage pests of maize are concerned. Moreover, nationwide surveys should be carried out in order to determine the species of pests associated with stored produce in general and with stored maize in particular. In addition, losses caused by the major pest species in the different types of stored produce should be determined experimentally.

The standards of on-farm storage were so low that farmers are forced to sell any surplus crop immediately after harvest at the time when the value is at its lowest. The applied control techniques were often insufficient due to lack of knowledge among farmers, and unsuitable insecticides were used or applications were made at incorrect dosage. With due consideration given to the problems the storage loss could be decreased substantially without the use of chemical insecticides. With subsistence farmers having limited resources and ability, only extremely modest measures for reducing losses are suitable. These may include encouraging the use of simple modifications to traditional storage structures, encouraging the use of effective traditional pest control methods, and improving storage hygiene thereby reducing cross infestation. Therefore, demonstrations and relevant training should be organized in selected villages on the appropriate construction, use and maintenance of traditional storage structures and the use of appropriate pesticides to protect stored maize.

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CAB International Institute of Entomology, England, identified the arthropod spp and Dr. J. Smith of the University of Reading, England, commented on the manuscript critically.

Table 4. Percentages of farmers responding to various methods of weevil control in the Bako area (n= 200), 1993

Control methods	Percentages
Consume and/or sell grain immediately	98.5
Dry sufficiently before storage	98.0
Clean and repair storage container	94.5
Treat with insecticides	73.5
Place in smoke over fire	70.0
Store grain in cold place (outside)	65.1
Re-plaster container with cow dung	63.5
Retain the husk	61.5
Select undamaged cobs at harvest	58.6
Aerate grain as much as possible	52.0
Store maize on the cob	43.0
Winnow and screen periodically	40.5
Mix maize with tef or finger millet	35.0
Transfer grain from container to container	22.0
Open container less frequently	17.5
Expose grain to sun to drive off insects	14.0
Heat (roast slightly) grain on clay pan	14.0
Hang up on trees in the field	10.5
Mix improved varieties with local cultivars	6.5
Seal in clay jar or gourd	6.5
Tie husk tip for complete coverage	5.5
Mix with hot pepper	2.0
Treat with cattle urine	1.0

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