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THE NATURAL ENVIRONMENT AS A RESERVOIR FOR THE LARGER GRAIN BORER *PROSTEPHANUS TRUNCATUS* (HORN) (COLEOPTERA: BOSTRICHIDAE) IN KENYA

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ABSTRACT

The Larger Grain Borer (LGB), *Prostephanus truncatus* (Horn), is an exotic pest of stored maize and cassava which first appeared in Kenya in 1983. Studies using pheromone traps show that LGB is widespread in the natural vegetation in Tsavo National Park. Experiments to determine alternative hosts of the LGB have shown it capable of feeding and breeding in 16 tree species in the families Leguminoseae, Burseraceae and Anacardiaceae. Some of these species are of significance to agroforestry. Within a tree, breeding success of LGB is dependent upon the wood's age, and its moisture content. The possible role of alternative host plants in influencing LGB infestations in stored maize is discussed.

Key Words: **Bostrichidae, maize, stored products pest, agroforestry.**

INTRODUCTION

The Larger Grain Borer (LGB), *Prostephanus truncatus* (Horn) (Bostrichidae: Coleoptera) is a small beetle that attacks stored maize and cassava. It is indigenous in Central America where it is a sporadic pest of minor importance on stored maize. In Africa, LGB was accidentally introduced into Tanzania in 1980 (8) and Togo in 1984 (12), and was first reported in Kenya in 1983 (16). The pest is now spreading widely in both East and West Africa, and has become a major problem on stored maize. Its present distribution in West Africa is Benin, Ghana, Nigeria, Niger, Guinea and Togo, while in East Africa it has spread to Burundi, Kenya, Malawi, and Tanzania (7; 15). The eventual spread of LGB to all maize growing areas of Africa can be anticipated.

Losses of stored maize following the introduction of LGB have been severe. Dry weight losses of 17.4%, after six months of storage, and 41.2%, after 8 months of storage, were recorded in Tanzania (11). Recent studies in Kenya (P.H. Giles pers. comm.) report dry weight losses ranging from 22% to 48%, after 24 weeks storage. In Togo, dry weight losses after six months' storage rose from an average of 7.1%, caused by traditional maize storage pests such as the weevils *Sitophilus* spp. and the moth *Sitotroga cerealella* (Olivier), before the invasion by LGB, to 30.2% afterwards (17). Losses of this magnitude can render long-storage maize unfit for human consumption, even in Africa where people have become accustomed to insect damaged produce.

While LGB is a devastating pest of maize, recent studies of its biology in Central America have shown that it occurs in natural wooded habitats remote from maize or cassava cultivation (15). LGB is a member of the family Bostrichidae, the false powder-post beetles, which contains about 500 species and are mainly tropical in distribution. They are wood-boring in habit, and are traditionally pests of forest trees and dressed timber (1; 2; 14; 20). Thus, LGB may be primarily a wood borer and secondarily a pest of maize and cassava. For this reason, it is important to develop an understanding firstly, of the ecology of this new pest in the natural environment, and secondly, of the interaction between the natural ecology of LGB and its ecology within maize and cassava stores.

In the present study, the occurrence of LGB in a natural habitat remote from maize or cassava cultivation was investigated. The range of woody plants, which may be potential hosts of LGB in the natural environment and within the farming environment, as well as the optimal conditions for LGB breeding in wood were also assessed.

MATERIALS AND METHODS

Occurrence of LGB in the natural vegetation. The occurrence of LGB in the natural environment remote from agricultural land was investigated using aggregation pheromone traps placed on a transect along a road in Tsavo East National Park, Kenya. Tsavo Park is found along the route from the sea post of Mombasa and is close to the Tanzania border. This area experiences an average annual rainfall of 554 mm, distributed bimodally, with wet seasons from November to December and February to April. The rainfall is characteristically erratic and unreliable for arable farming.

The transect commenced at the Voi entrance to the park, approximately 340 km south east of Nairobi, at an altitude of 500 m. It ran west for 12 km through natural vegetation consisting of an open woodland dominated by *Acacia* spp. and *Delonix elata*. At 2-kilometre intervals along the transect, AgriSense® delta-flight trap baited with the pheromone *trunc-call* 1 and 2 (4), was placed in a tree at a height of approximately 1.5 metres. Records of adult LGB catches were taken and the traps and pheromone lures replaced every two weeks. Meteorological data was recorded by the Kenya Meteorological Service station at Voi, approximately 5 km from the first trap.

Testing of potential hosts of LGB: Initial observations to discover the range of LGB tree hosts in the study area were carried out in a field laboratory. Samples of woody material (mainly fresh shoots) from 60 species were collected and air-dried for one month. These samples were then exposed to 50 unsexed adult LGB, from a stock rearing culture (note: sexing of adult LGB is difficult and only about 80% accurate (21), in 2 litre ventilated glass jars in a field laboratory (ambient temperatures 18°C–29°C; 50–80% R.H.), to test their suitability as breeding media for the beetle. After two months, stem samples were dissected under a microscope to count and record all stages of LGB in each jar. The wood dust produced by the beetles was weighed to index their activity.

Following initial observations made in the field laboratory, further experiments were carried out under controlled laboratory conditions to test the ability of LGB to feed and breed on wood from some native and agroforestry tree species. Stem material (average thickness about 5 cm, probably 2–3 years old) from 19 agroforestry tree species and six indigenous tree species was cut to 15 cm lengths and dried to a constant weight in controlled environment room with temperature set at 27°C, and a diurnally-fluctuating relative humidity which averaged about 70%. Each wood sample was exposed to 50 unsexed adult LGB. After two months exposure, the stems were dissected and the numbers of all active stages of LGB recorded, along with the weight of dust produced by the boring and feeding activity of the beetles. Samples cut from the pieces of test wood were oven dried to constant weight and % moisture content of the wood calculated.

Relative suitability of different parts of identified hosts for LGB breeding. Seven tree species namely: *Commiphora africana*, *Commiphora riparia*, *Commiphora* sp., *Cassia siamea*, *Commiphora campestris*, *Cassia abbreviata* and *Acacia mellifera*, were used in the test. These included the four species which supported breeding in the original field laboratory experiment plus three others in the genus *Commiphora*. For each species, three different types of wood were chosen; twigs (measuring 5–12 mm in diameter and about 7 cm long), stems (measuring 70–110 mm in diameter) and heartwood (from the middle of stems which were at least 20-mm thick). Each type of wood was presented in three stages: freshly picked, air-dried or long-dead. The air-dried material was dried by exposure to the sun for one month, while the long-dead pieces were picked directly from trees.

Wood samples from stems and heartwood were split to increase the surface area of wood

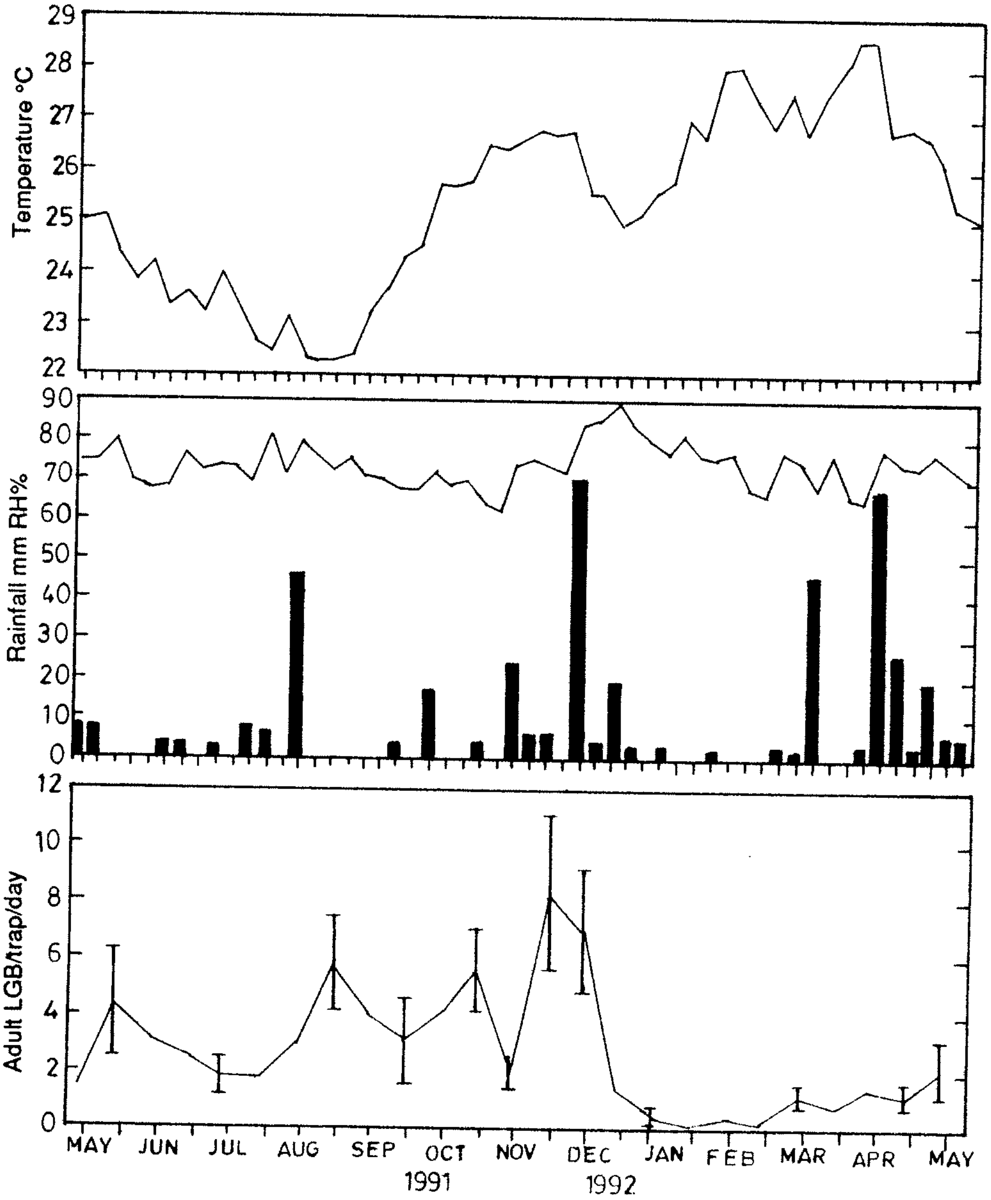

Fig. 1. Mean number of Larger Grain Borer adults trapped per day (with selected 95% confidence intervals) at two-weekly intervals in six pheromone traps placed in Tsavo East National Park, compared with total rainfall, mean relative humidity and mean temperatures.

exposed to LGB. The samples were then placed in ventilated glass jars with 50 adult LGB in the field laboratory. Each jar contained three wood pieces, and the treatments were replicated three times. After 2 months, the wood was dissected to record the number of LGB in all life stages, and the dust produced by LGB activity weighed.

All botanical names used in this paper were verified using Dale and Greenway (3) and Rocheleau *et al.* (20).

RESULTS

Occurrence of LGB in the natural vegetation. The mean adult LGB catch per trap per day per two-week sampling interval varied from a peak of 8.3 in December 1991 to 0.01 in February 1992 (Fig. 1). Peaks of LGB adult activity occurred during the "short rains", between September and December, when the weather was relatively warm and wet (average monthly temperatures 23.6, 25.7, 26.5 and 25.4°C). By contrast, there was a much lower adult flight activity during the "long rains" in April and May (average temperature 27.1 and 25.1°C). The intervening period from January to March was hot and dry (average monthly temperatures were 26.1, 27.4 and 27.4°C). Very few LGB adults were trapped during this period (Fig. 1). It is possible that the period was not conducive to LGB breeding, which would explain the lack of response of adults to the pheromone traps set at the onset of the long rains. There was no obvious correlation between relative humidity and LGB catches.

Potential alternative hosts of LGB. Of 60 woody host plants tested in the field laboratory, four (*Acacia mellifera, Commiphora campestris, Cassia abbreviata* and *Cassia siamea*) supported breeding of LGB (Table 1). The remaining 56 species showed no evidence of LGB breeding, although two species (*Commiphora* sp. and *Commiphora africana*) had live adult LGB at

TABLE 1. Results from a preliminary trial to test the suitability of 60 species of woody plant as breeding hosts of LGB in a field laboratory at Kiboko, Eastern Province, Kenya

Species		Live LGB		
	Wt. dust (g)	larvae	pupae	adults
A. Species (4) showing evidence of breeding by LGB				
1. *Acacia mellifera*	1.39	5	0	9
2. *Commiphora campestris*	1.36	12	3	3
3. *Cassia abbreviata*	1.79	18	5	4
4. *Cassia siamea*	2.15	24	0	5

B. Species (56) showing no signs of LGB breeding

Acacia brevispica
Acacia nilotica
Acacia senegal
Acacia tortilis
Acacia xanthophloea
Albizia amara
Albizia anthelmintica
Albizia sp.
Balanites aegyptiaca
Bauhinia taitensis
Boscia sp.
Cassia longiracemosa
Cassia spectabilis
Caucanthus sp.
Cesamosaminus villae
Combretum aculeatum
Combretum sp.
Commiphora africana
Commiphora baluensis
Commiphora shimperi
Commiphora sp.
Cordia gharaf
Cordia ovalis
Debra sp.
Delonix elata
Delonix regia
Entada leptostachya
Euphorbia candelabrum
Euphorbia sp.
Grewia bicolor
Grewia lilacius
Grewia nematopus
Grewia similis
Grewia sp.
Grewia villosa
Hoslundia opposita
Lantana virburnoides
Lannea sp.
Leucaena sp.
Lawsonia sp.
Maerua sp.
Melia sp.
Melia volkensii
Ormocarpum kirki
Platycelyphium sp.
Premna holstii
Premna oligotricha
Premna resinosa
Salvadora persica
Sericomopsis pallidae
Solanum incanum
Sterculia africana
Tamarindus indica
Thevetia peruviana
Thylachium thomasii
Xeromphis keniensis

TABLE 2. Mean numbers of live adults, pupae and larvae of the Larger Grain Borer, weight of dust produced, number of holes and moisture content of wood after two months exposure to 50 adult beetles under controlled laboratory conditions

	Live LGB at the end of the experiment											
	Adults		Larvae		Pupae		Wt. dust (g)		No. holes		% moisture content	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
Agroforestry and introduced spp.												
1. *Acacia holosericea*	3.0	0.5	0.0	0.0	0.0	0.0	0.33	0.03	42.3	29.5	10.5	0.2
2. *Acacia polyacantha*	425.0	15.5	22.3	9.3	50.7	14.2	20.19	1.26	333.3	85.0	11.6	0.2
3. *Acacia stuhmannii*	0.3	0.3	0.0	0.0	0.0	0.0	0.13	0.01	8.3	4.8	10.9	0.2
4. *Calliandra calothyrus*	4.7	2.4	0.0	0.0	0.3	0.3	0.18	0.04	31.0	1.4	10.7	0.4
5. *Cassia spectabilis*	2.4	0.0	0.0	0.0	0.0	0.0	0.29	0.10	12.8	4.5	9.3	0.0
6. *Cordia abyssinica*	2.3	0.3	0.0	0.0	0.0	0.0	0.03	0.01	13.3	6.1	11.2	0.1
7. *Croton megalocarpus*	1.7	0.3	0.0	0.0	0.0	0.0	0.04	0.01	7.0	0.8	10.7	0.3
8. *Erythrina abysinica*	3.7	1.9	0.0	0.0	0.0	0.0	0.29	0.07	27.7	13.2	10.9	0.2
9. *Grevillea robusta*	0.7	0.3	0.0	0.0	0.0	0.0	0.05	0.02	9.3	2.1	11.1	0.1
10. *Leucaena diversifolia*	33.0	10.1	14.3	10.9	24.7	3.5	3.24	0.30	149.0	40.8	11.3	0.2
11. *Leucaena leucocephala*	4.0	1.2	0.0	0.0	0.3	0.3	1.33	0.09	68.7	22.2	9.9	0.9
12. *Leucaena shamonii*	11.7	5.0	0.0	0.0	1.3	0.7	2.40	0.18	170.0	28.3	11.5	0.1
13. *Markhamia platycalyx*	0.7	0.3	0.0	0.0	0.0	0.0	0.06	0.02	13.0	5.4	11.2	0.2
14. *Melia azedarach*	1.0	0.5	0.0	0.0	0.0	0.0	0.14	0.05	30.0	7.0	11.9	0.5
15. *Parkinsonia aculeata*	1.3	0.5	0.0	0.0	0.0	0.0	0.06	0.01	10.0	2.4	9.9	0.9
16. *Prosopis chilensis*	2.3	1.5	0.0	0.0	0.7	0.5	0.25	0.12	12.0	6.7	11.4	0.1
17. *Samanea samani*	4.0	2.9	0.0	0.0	0.0	0.0	0.12	0.04	18.0	4.3	10.4	0.2
18. *Terminalia brownii*	2.7	1.1	0.0	0.0	0.0	0.0	0.00	0.00	3.0	1.6	10.7	0.3
19. *Ziziphus mauritiana*	2.3	0.7	0.0	0.0	0.0	0.0	0.01	0.01	2.0	1.4	11.1	0.4
Native species												
20. *Combretum apiculatum*	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.01	0.6	0.2	11.1	0.1
21. *Commiphora baluensis*	74.8	48.9	5.0	3.8	8.6	4.0	8.89	4.77	207.2	63.7	12.3	0.1
22. *Commiphora rostrata*	23.0	10.2	3.0	2.4	2.0	1.5	1.95	0.95	56.6	16.6	12.0	0.3
23. *Dalbergia melanoxylon*	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.02	0.6	0.5	10.8	0.1
24. *Delonixe lata*	48.8	18.2	8.4	4.7	18.8	6.0	5.63	1.72	65.0	18.8	10.8	0.1
25. *Lannea* sp.	4.0	2.9	1.0	0.9	2.0	1.5	0.29	0.21	11.8	5.5	12.3	0.2

the end of the experiment.

Under controlled chamber conditions, however, six of 19 species of agroforestry trees and four of six species from the natural environment showed evidence of supporting breeding of LGB (Table 2). All species of wood showed evidence of boring by LGB adults, but only those species which supported breeding had a large number of holes. The mean weight of wood dust produced by beetle boring was strongly correlated with numbers of live adult LGB at the end of the experiment (Spearman R_s = 0.81; n =25; P < 0.01; Table 2). The number of holes was also correlated with the number of live adults present at the end of the experiment (Spearman R_s = 0.7; P < 0.01).

Relative suitability of tree parts for LGB breeding. Analysis of variance on untransformed and log-transformed data showed highly significant differences in main treatment and interaction terms. However, the data were not strictly suitable for parametric analysis of variance as they did not satisfy necessary criteria of homogeneity and independence of variance after various transformations.

A visual inspection of the means for the nine treatment categories for each species of plant (Table 3) supports the general conclusion that air-dried wood is preferred to fresh and long-dead wood, and that stems are preferred over twigs and heartwood. However, as suggested by the preliminary analysis of variance, there was a

TABLE 3. Mean (and S.E.) numbers of live LGB on wood of three different ages and states of dryness from seven different species of tree after 2 months exposure to 50 adult LGB

		Twig			Stem			Heart		
		Fresh	Dried	Old	Fresh	Dried	Old	Fresh	Dried	Old
Larvae *										
Commiphora campestris	Mean	–	–	–	0.33	4.70	–	–	–	–
	S.E.	–	–	–	0.33	2.73	–	–	–	–
Cassia mellifera	Mean	9.00	20.30	–	–	–	–	–	–	–
	S.E.	2.08	7.83	–	–	–	–	–	–	–
Commiphora riparia	Mean	–	–	–	0.33	5.33	–	–	–	–
	S.E.	–	–	–	0.33	3.85	–	–	–	–
Cassia siamea	Mean	–	1.00	0.33	14.30	4.33	0.33	5.33	–	–
	S.E.	–	0.58	0.33	4.70	2.85	0.33	2.03	–	–
Pupae **										
Commiphora campestris	Mean	–	–	–	0.33	2.67	–	–	–	–
	S.E.	–	–	–	0.33	0.67	–	–	–	–
Commiphora riparia	Mean	–	–	–	–	4.00	–	–	–	–
	S.E.	–	–	–	–	1.00	–	–	–	–
Cassia siamea	Mean	–	1.00	–	–	–	–	–	–	–
	S.E.	–	1.00	–	–	–	–	–	–	–
Adults										
Commiphora campestris	Mean	–	–	–	7.00	29.67	0.67	0.67	1.00	–
	S.E.	–	–	–	0.58	4.26	0.67	0.33	–	–
Commiphora sp.	Mean	–	0.67	–	–	0.67	–	–	0.33	–
	S.E.	–	0.33	–	–	–	0.89	–	0.33	–
Commiphora africana	Mean	0.33	1.67	–	1.00	0.67	–	2.00	1.00	–
	S.E.	0.33	1.20	–	1.00	0.33	–	1.15	1.00	–
Cassia abbreviata	Mean	–	1.33	–	0.33	–	0.67	–	0.33	–
	S.E.	–	0.88	–	0.33	–	0.67	–	0.33	–
Acacia mellifera	Mean	5.00	3.00	–	–	0.33	0.33	0.67	0.33	–
	S.E.	1.53	0.58	–	–	0.33	0.33	0.33	0.33	–
Commiphora riparia	Mean	–	–	–	6.33	74.00	0.33	0.67	0.67	0.33
	S.E.	–	–	–	1.67	37.70	0.33	0.66	0.66	0.33
Cassia siamea	Mean	–	3.67	–	17.30	36.67	–	0.67	42.67	–
	S.E.	–	2.03	–	1.85	3.85	–	0.33	1.20	–

*: not found on *Commiphora* sp.; *C. abbreviata*.
**: not found on *Commiphora* sp.; *C. africana* and *A. mellifera*.

more complex variation in choice of host. For example, fresh stems of *Cassia siamea* supported more larvae and pupae than dried stems. Fresh and dried twigs of *Acacia mellifera* appeared to support more larvae and pupae than fresh or dried stems and, while heartwood was generally a poor substrate, dried *Cassia siamea* heartwood seemed to be an acceptable feeding and breeding site.

These differences were tested by one-way non-parametric analysis of variance carried out on individual tree species by treating the nine age-by-dryness combinations of wood as treatments in a Kruskal-Wallis test. Numbers of live adults on *Commiphora campestris* and *Commiphora riparia* were significantly greater on freshly-dried stems than other treatments (Kruskal-Wallis H = 19.76 and 19.65 respectively; n=27; 8 df; $P < 0.01$). Numbers of live adults also differed significantly between treatments for *Cassia siamea* (Kruskal-Wallis H = 20.97; 8 df; n =27, $P < 0.01$) with dried heartwood and dried stems being equally preferred. Finally, *Acacia mellifera*, while not a particularly good host, was significantly preferred as fresh or dried twigs (Kruskal-Wallis H = 19.77, 8 df; n = 27, $P < 0.01$). The recording of successful breeding of LGB on *Commiphora riparia* brought to 15 the number of confirmed hosts of LGB in this study.

DISCUSSION

The data in Fig. 1 suggest strongly that the Larger Grain Borer is a resident of the scattered-woodland habitat within Tsavo East National Park. The observations of the insect breeding in the wood of several common native tree species under laboratory conditions support this contention. The occurrence of adult LGB in pheromone traps in non-maize or cassava habitats has also been reported in Central America (18, 19 quoted in [15]).

The LGB successfully bred on tree species from two of the three main super-families of the Leguminoseae, namely Mimosoidea (*Acacia* (2 species); *Calliandra* (1 species); *Leucaena* (3 species); and *Prosopis* (1 species)) and Caesalpinioidea (genera *Cassia* (2 species); and *Delonix* (1 species)) was also recorded. Breeding from representatives of the Anacardiaceae (genus *Lannea* (1 species)), and the Burseraceae (genus *Commiphora* (4 species)). This result implies that LGB has potentially a very wide host range, including several commonly used agroforestry tree species (Table 2). Ramirez *et al.* (18) have recorded LGB larvae from *Bursera fagaroides* (Burseraceae) and *Spondias purpurea* (Anacardiaceae) in dry deciduous woodland in Mexico (quoted in 15). Detmers *et al.* (6) also recorded *Delonix regina* as host of LGB, and two other unidentified tree species have been recorded as supporting LGB breeding in Togo (13).

Results obtained also showed that breeding was a rare occurrence, with only four out of 64 tree species supporting breeding. Detmers (5) tested 25 species in the laboratory without succeeding in showing breeding by LGB. Ongoing investigations of LGB in Benin have also failed to show breeding in wood under laboratory conditions (R.H. Markham pers. comm.). It is suggested that moisture content of the wood is a critical factor in establishing breeding, and failure of many attempts to breed LGB in captivity may be due to the wood being too dry. Observations in the field laboratory (Table 1) were carried out under very dry conditions although wood moisture content was not accurately recorded. Under these conditions, *Delonix elata*, *Lannea* sp. and *Commiphora baluensis* did not support LGB breeding whereas later tests in the constant environment room showed that all three are suitable hosts with moisture contents of 10.8 to 12.3% (Table 2).

Additional set of tests carried out in the constant environment room but not reported here in detail failed to show breeding of LGB on 9 species, including *Commiphora riparia*, *Acacia mellifera*, *Commiphora campestris* and *Cassia siamea*, all of which had been shown to be suitable breeding hosts in earlier trials (Tables 1 and 3). The average moisture content for the nine species was 8.6% (95% confidence interval = 0.31) compared with an average of 11.0% (95% confidence interval = 0.28) for the 25 species recorded in Table 2. This is considered a strong circumstantial evidence that breeding of LGB in wood is possible only when the moisture content is at least 10%.

LGB appears to prefer younger, softer wood rather than old heartwood. This result is supported by observations in forest entomology literature that Bostrichidae bore mainly in sap wood rather than heartwood. This is generally attributed to the insect's need for starch (10). Ramirez *et al.* (18) have speculated that, in its area of origin in Mexico, LGB occupies a transient niche created as a branch dies and dries out. While more information is needed, the present observations that breeding is restricted below a certain wood moisture content would support this conclusion. Ongoing studies will focus on establishing optimal conditions for LGB breeding in a range of wood species, and the prevalence of those conditions in the natural environment.

The successful breeding of LGB on 15 tree species has important implications for the control of this pest in East Africa. Firstly, it is clear that quarantine restriction on the movement of maize can at best only slow the rate of spread of the pest in the region. The LGB will inevitably spread through infestation of naturally occurring woody hosts. However, because populations of this pest increase slowly, and spread through natural vegetation is probably relatively slow, restrictions on the movement of maize out of infested areas would be expected to slow the rate of spread and is still a worthwhile activity. Secondly, in areas where the pest was established, farmers may wish to remove susceptible tree species growing in or near maize fields and replace them with non-susceptible ones. They should also be made aware of the dangers of stored firewood as a reservoir of LGB, and should ensure that the structure of stores is made from LGB-resistant species or is suitably treated. However, general recommendations regarding agroforestry and local tree species in the environs of maize fields and stores need to be based upon a sound understanding of the real risks associated with their presence, and should be set against the benefits which they bring to the farmer and the farm environment.

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