INFESTATION PROBLEMS IN FARM-STORED MAIZE IN NICARAGUA

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ABSTRACT: Maize, a most important staple crop in Nicaragua, is largely produced on small farms and stored as unhusked ears in wooden granaries, although sometimes small quantities of shelled grain are kept. Heavy damage, estimated nationally at 15 per cent each year, occurs due to attack by stored-product insects which are listed according to distribution and relative occurrence. Results of trials are presented on methods of reducing these losses by early harvesting, selection of less susceptible varieties, storing ears without the husk and treating with insecticide dusts (Lindane, malathion, pirimiphos-methyl, and tetrachlorvinphos) and the storage of shelled grain in plastic film bags and metal drums with or without fumigants (aluminium phosphide, carbon tetrachloride/ethylene dichloride).

INTRODUCTION: Maize is the most important staple crop in Nicaragua. It is mainly produced and stored on small holdings by farmers who are commonly living near the subsistence level. Modern bulk storage facilities exist at a hundred silo installations where quality control is possible but, as expected at this socio-economic level and in the hot, damp climate, considerable insect damage occurs in the grain stored on the farm for household needs or before sale.

After harvest most of the crop is stored as ears with the husk on in tight layers in a variety of structures made of local materials in or near the farmer's house. Smaller quantities of shelled grain are sometimes kept in earthenware, wooden or metal containers or in sacks. The maize is almost invariably infested by stored product insects in the field where it is left on the plant after maturity to allow natural drying, although it would appear that the moisture content at harvest is dangerously high[1] for long-term storage. Some farmers use insecticides which usually have a high mammalian toxicity and are often ineffective.

EARLY-HARVESTED EARS: Trials at two different sites, one at Managua (Hot and relatively dry), the other at Matagalpa (cooler and damper),

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[1] In the series of twenty trials described below the average M/C of the farmers' maize at the beginning of storage was about 20 per cent.

have shown that it is possible to dry maize early-harvested at a high M/C when it is stored without husks in a narrow crib. In these trials the time taken for the M/C to drop from the original 32 per cent to 12.5 per cent was only 32 days in Managua and 43 days in Matagalpa. This practice resulted in a lower overall level of stored product insect damage than in maize harvested, as normal, 6-8 weeks later if storage hygiene and chemical control were carefully carried out.

INSECT DISTRIBUTION: As a result of survey work and storage trials in the producing areas a check list of insects with their distribution and relative abundance has been prepared (Table I). The high incidence of new records largely reflects the scarcity of previous stored products entomological work in Nicaragua.

FIELD VARIETAL SUSCEPTIBILITY: Trials are being carried out on the varietal susceptibility to stored product insect attack before harvest. The results of a randomised block trial planted close to a heavy source of infestation have been presented in detail elsewhere [1] but a summary of the results are shown in Tables II and III. As is evident in Tàble II the varieties that are relatively susceptible to field infestation are Salco, NB1, X338, XB101 and Tuxpeno Crema, PB1. Varieties that are both tolerant to field infestation by storage insects and produce a high yield of undamaged grain are H5, Nicarillo, and to a lesser extent, NA2 Macho. Usually but not always, a higher infestation rate occurred in ears with poor husk cover. Studies of the inherent grain susceptibility of the different varieties are in progress. By far the most widely grown type of maize is Criollo. This "variety" usually has a very tight husk and suffers little insect damage in the field and therefore proportionately less subsequently than all the introduced higher-yielding varieties. This largely explains why farmers are reluctant to plant commercial varieties.

The pattern of infestation of the total number of adult beetles in all varieties 116 days after planting (59 - 76 days after 50 per cent anthesis) when the M/C varied from 16 to 31 per cent, is shown in Table III. Nearly 90 per cent of the beetles consisted of *Carpophilus* spp., *Cathartus quadricollis* and *Gnathocerus maxillosus*, all of which can cause serious damage during storage.

CRIB STORAGE OF EARS: In a trial in Managua, maize ears with or without husks at a low grain M/C of 10.6 per cent and stored without layering in small wood and wire netting cribs, were treated with four insecticides - two per cent dusts of malathion, tetrachlorvinphos, pirimiphos-methyl and lindane. The nominal rate of application was 12.5 p.p.m. in ears without husks and 27.4 p.p.m. in ears with husks. Results of one method of assessing quality of eight-weekly samples are shown in Table IV. A fuller report has been presented elsewhere [1]. In untreated maize ears with husks after 24 weeks, 94 per cent of the grains were damaged

TABLE I. Check List of Insects From Stored Maize

COLEOPTERA AND LEPIDOPTERA		
A. High populations, wide distribution		
Carpophilus dimidiatus (Fabricius)	*	
C. mutilatus Erichson	*	
C. pilosellus Motschulsky	*	
Cathartus quadricollis (Guerin-Meneville)		
Cryptolestes pusillus (Schonherr)	*	
Gnathocerus maxillosus (Fabricius)	*	
Sitophilus zeamais Motschulsky	*	
Tribolium castaneum (Herbst)		
B. High populations, narrow distribution		
Araecerus fasciculatus (Degeer)		
Prostephanus truncatus (Horn)	*	
Sitophilus oryzae (Linnaeus)		
C. Low populations, wide distribution		
Cryptolestes ferrugineus (Stephens)	*	
Ephestia calidella (Guenee)	*	
E. cautella (Walker)		
Plodia interpunctella (Hubner)		
Rhizopertha dominica (Fabricius)		
Sitotroga cerealella Olivier		
Typhaea stercorea (Linnaeus)	*	
D. Low populations, narrow distribution		
Carpophilus freemani (Dobson	Nitidulidae	*
Cathartosilvanus trivialis (Grouvelle)	Silvanidae	*
Catolethrus fallax Boheman	Curculionidae	*
? *Conotelus* sp.	Nitidulidae	*
Dinoderus minutus (Fabricius)	Bostrychidae	*
Ephestia kuhniella (Zeller)	Phycitidae	
Hapalips sp.	Languriidae	*
Oryzaephilus surinamensis (Linnaeus)	Silvanidae	
Stelidota ferruginea Reitter	Nitidulidae	*
Trogoderma sternale Jayne	Dermestidae	*
Xyleborus ferrugineus (Fabricius)	Scolytidae	
HYMENOPTERA		
Anisopteromalus calandrae (Howard)	Pteromalidae	
Brachymeria sp. nr *pedalis* (Cressen)	Chalcididae	
Choetospila elegans Westwood	Pteromalidae	
Protolaccus sp.	Pteromalidae	
Zeteticontus scutellaris (Howard)	Encyrtidae	
HEMIPTERA		
Lyctocoris sp.	Anthocoridae	
Peregrinator biannulipes (Moutrouzier)	Reduviidae	

* New record in Nicaraguan stored products

TABLE II. Varietal Susceptibility To Pre-Harvest Infestation 90 days after 50% anthesis (130-147 days after planting)

Variety	Adult Beetles Per Ear		Open Ears		Wt. of Undamaged Grain per plant	
	No.	Order*	%	Order*	g.	Order*
Salco	40	8	35	7	57	9
Nicarillo	25	3	31	6	92	4
Sint. Nic. 2	31	5	20	4	72	7
NB - 1	47	9	29	5	50	10
NA - 2 Macho	23	2	10	1 =	74	6
X 338	36	7	75	10	109	2
XB 101	56	10	40	8	80	5
Tus. Crem P.B.	34	6	42	9	98	3
H 5	29	4	11	3	119	1
Criollo	13	1	10	1 =	71	8

* The lower the number, the lower the damage, infestation or proportion of open ears.

TABLE III. Pattern of Pre-Harvest Infestation In All Varieties 116 days After Planting.

Insects	% of Total
Carpophilus spp.	36.5
Cathartus quadricollis	34.5
Gnathocerus maxillosus	17.4
Cryptolestes spp.	9.0
Tribolium castaneum	2.0
Sitophilus spp.	0.2
Others	0.4

externally by insects; a 40 per cent weight loss had occurred. In the same cribs 25 per cent (by weight) of the grain shelled from the ears consisted of insect dust.

Good results were obtained with some insecticides in ears stored without husks for 16 weeks but in the subsequent eight weeks the insect population increased dramatically in all treatments.

Whatever the insecticide employed, ears without husks were always less damaged than ears with husks. Malathion was always superior, followed closely by pirimiphos-methyl. Lindane and tetrachlorvinphos gave disappointing results.

The changing pattern of infestation can be seen in Table V. The most important pest became *Prostephanus truncatus* which appears not to be widely established in Nicaragua.

The stability of insecticide formulations used is shown in Table VI. Tetrachlorvinphos and pirimiphos-methyl were stable. Lindane and malathion were not.

TABLE IV. Percentage Grains With External Insect Damage in Managua.

Insecticides*	With Husk			Without Husk		
	8 wk	16 wk	24 wk	8 wk	16 wk	24 wk
M	9	33	78	5	5	51
T	16	54	83	9	11	51
L	14	45	85	10	18	70
P	11	34	82	6	8	64
C	13	52	94	9	22	69

* M = malathion, T = tetrachlorvinphos, L = lindane, P = pirimiphos-methyl, C = untreated control.

AT 0 weeks % damaged grains = 3

TABLE V. Pattern of Infestation Percentage of Total Live Insects In All Cribs.

Insect	Weeks' Storage			
	0	8	16	24
Prostephanus truncatus	2.2	46.7	53.1	56.5
Tenebrionidae	2.9	33.5	38.6	8.9
Rhizopertha dominica	0	1.7	2.9	1.6
Cathartus quadricollis	94.2	14.0	1.4	9.3
Sitophilus spp.	0.7	1.5	0.6	2.4
Carpophilus spp.	0	0.3	0.2	5.9
Lepidoptera	0	2.3	0.9	5.1
Hymenopterous parasites	0	0	2.3	10.3

TABLE VI. Shelf Tests - Concentration of Insecticide Dusts (%)

Date	T	P	L	M
20 May	1.85	2.85	1.68	1.58
Mid-July	1.98	2.70	--	--
Beginning Aug.	--	--	1.02	0.86

Date of application = 12 February.

As can be seen in Table VII very low insecticide contaminative levels were found after 16 weeks' storage. As expected, less insecticide was present on grain from those ears with husks on than those without.

Twenty trials were set up recently on small farms in the producing areas to study further the effect of husk cover on the control of infestation by two per cent dusts of either pirimiphos-methyl or malathion, applied at a nominal dosage rate of 12.5 p.p.m. on ears without husks and 27. p.p.m. on ears with husks. The ears were stored in layers in four cubical compartments on each farm.

The results of one of the many methods employed of assessing quality, mean percentage insect damaged grains in samples taken after 12 and 24 weeks of storage are shown in Table VIII.

TABLE VII. Grain Contamination in Treated Grain After 16 Weeks of Storage (p.p.m.)

	T	P	L	M
With husk	0.10	<0.1	0.04	<0.1
Without husk	0.18	<0.1	0.14	<0.1

TABLE VIII. Mean Percentage Grains With External Insect Damage In 20 Farm Trials.

		With Husk		Without Husk	
		Treated	Untreated	Treated	Untreated
	0 wk	1.6		2.7	
12 wk	M	12.4	23.5	11.6	39.4
	P	9.1	13.9	13.8	23.8
24 wk	M	21.9	25.9	29.3	41.1
	P	19.1	20.2	31.1	45.0

The 12 week data have been analyzed statistically. Dehusked ears were more damaged than those that have husks. Insecticide treatment is effective but not as much so as expected. Malathion would appear to be more effective than pirimiphos-methyl but this is because the untreated maize in the ten sites where malathion was used was more heavily damaged than in the other ten sites with pirimiphos-methyl. There is a significant interaction between husk cover and insecticide treatment. Of the covariates: initial level of infestation, maize variety stored, site altitude and site rainfall, only the last two have a significant effect. Under conditions of high rainfall and high altitude, where in fact much of the maize is grown, husk retention and insecticide treatment are highly beneficial and there is a high interaction.

The statistical analysis of all the other data is at the time of writing, incomplete but it would appear that at 24 weeks heavy damage has occurred in all treatments. At this time, husk removal would also appear to be disadvantageous and it would seem that after six months, storing treated dehusked maize ears is less effective than storing the ears with husks and without insecticide. Firm conclusions cannot be made without complete analysis.

These crib storage trials have shown that husk retention and treatment with pirimiphos-methyl or malathion is effective in maize stored for three months but not for six months. The level of infestation control could be improved for the shorter term.

Contamination studies (Table IX) have shown that after shelling treated ears, malathion levels in the grain are very low and rapidly fall with time. By extrapolation it would be expected that the increased dosage rates needed to further reduce insect damage would not cause hazard to consumers even allowing for overdosing and the availability of more stable formulations.

SHELLED GRAIN IN PLASTIC BAGS: Two trials have been organized with 100 lb capacity polyethylene film bags containing shelled grain with a M/C of either 12.0 or 14.5 per cent in an infested store in Managua. The bags were treated with aluminium phosphide tablets (producing 1 g of phosphine) at the rate of one tablet per bag, or pellets (producing 0.2 g of phosphine) at the rate of one pellet per bag, 15 ml of a 3 : 1 mixture of ethylene dichloride/carbon tetrachloride (EDCT) or without treatment (to see if hermetic storage is possible). The results of the two trials were essentially the same except that at the higher M/C rotting occurred more readily

TABLE IX. Grain Contamination In Ears Treated With 0.75% Malathion Dust (p.p.m.)

	Without Husks			With Husks		
Days	6.25*	9.4*	12.5*	12.5*	18.75*	25.0*
1	0.39	0.88	0.92	0.03	0.04	0.08
32	0.12	0.34	0.45	0.03	0.03	0.04

* Original nominal dosage rate.

particularly with high infestation levels. A summary of the results of the trial with the drier maize is given in Table X. Hermetic storage was not achieved in untreated bags and even after 22 days there were 15 insects per kg in the thinner bags. The lowest oxygen level was 7.5 per cent but normally it was 14 - 18 per cent. Phosphine (from 1 pellet per bag) and EDCT were effective but not always completely so at 22 days. After 66 days all the treatments contained a reasonably high infestation. The 700 gauge bags were not always better than the 500 gauge bags but this may be due to in-bag variation in thickness.

In the other trials the higher rate of phosphine gave a very satisfactory result. One major problem is that all the bags eventually became perforated by insects. Nevertheless less damage occurred in fumigated bags in these trials than in insecticide-treated maize ears.

SHELLED GRAIN IN METAL DRUMS: In a trial at Managua infested shelled grain at 12.7 per cent M/C was placed in metal drums of

TABLE X. Storage of Shelled Maize in Polyethylene Film Bags

	Days' Storage	No Fumigant		Ph_3		EDCT	
		500 g	700 g	500 g	700 g	500 g	700 g
Live adult	0	Mean 7.5					
insects	22	15.0	4.3	2.6	1.0	0	1.6
per Kg.	66	38.7	36.5	26.0	31.4	36.3	23.6
% D.G.	0	Mean 4.4					
external	22	5.5	3.0	3.0	0.7	3.0	3.7
	66	4.3	9.8	3.7	8.3	3.0	6.3

about 200 l capacity containing 330 lb of grain. Two types of drums were used; -

1. Open topped, covered with 2 layers of 500 gauge polyethylene film tied with string
2. Closed ones, having a metal top with two holes closed with screw-in plugs lined with polyethylene film.

Three sub-treatments were used: - 92 ml of EDCT (0.44 ml per l.), l aluminium phosphide tablet (48 mg phosphine per l) and no fumigant. Uncovered, untreated controls were set up.

The results of infestation levels after 16 weeks' storage are shown in Table XI. It can be seen that complete infestation

TABLE XI. Storage of Shelled Maize in Metal Drums

Treatment		Number of Insects Per Kg. of Grain	
Fumigant	Cover*	Live	Dead
EDCT	Pol.	0	13.1
	Met.	1.3	34.6
Ph_3	Pol.	4.7	61.3
	Met.	2.8	39.4
None	Pol.	24.3	29.8
	Met.	0	57.5
None	None	85.9	56.6

At filling the populations of live and dead insects were 76.5 and 56.2 per Kg. respectively.

* = Pol. = polyethylene film, Met. = metal tops.

control was achieved in two treatments -- the plastic covered drum treated with EDCT and the metal topped unfumigated drum. The oxygen level in the latter had dropped to 0.5 per cent after 14 weeks whereas in the plastic covered unfumigated drum the level was 6.0 per cent and an unsatisfactory high level of infestation was present. Good control was generally achieved with the fumigants, EDCT being marginally better than phosphine at the rates employed.

REFERENCE:

[1] Giles, P. H., Sequeira, A., Leon, O. Prevención de daños en productos agricolas despues de la cosecha en Nicaragua in Proceedings of the XX Reuñion Anual del Programa Cooperativa Centroamerica para el Mejoramiento de Cultivos Alimenticios - Maiz y Sorgo, San Pedro Sula, Honduras, (1974) 141-159.