LABORATORY AND ON-FARM ASSESSMENT OF RESISTANCE TO *Sitophilus zeamais* IN MAIZE GERMPLASM

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ABSTRACT

The relative susceptibility of maize germplasm from CIMMYT-Mexico, Malawi and Zimbabwe to attack by the maize weevil *Sitophilus zeamais* (Motsch.) was investigated under controlled temperature (28°C) and relative humidity (70-75%). An index of susceptibility derived from the numbers of F_1 progeny and the mean development period was used as the basis for the measurement of susceptibility. Significant differences in susceptibility between the maize germplasm was found with indices ranging from 9.3 for Rattray Arnold (1) 8149 (least susceptible) to 14.7 for PNR 6334 (most susceptible). In order to test whether the laboratory results were valid, 14 different maize genotypes were selected and evaluated under field conditions and natural infestation pressure. The maize was stored in small jute sacks in small farmers' stores over several months and percent damage and insect population growth monitored regularly. Generally, materials found to be the least susceptible in laboratory tests showed lowest damage in on-farm storage while the most susceptible varieties sustained the greatest damage.

INTRODUCTION

The maize weevil, *Sitophilus zeamais* is a serious pest of stored maize causing extensive damage in small farmer storage. Grain protectants such as malathion, pirimiphos-methyl and other organophosphates applied at dilute dusts are widely used by farmers. But because of their costs, hazards and insect resistance there is a need for alternative control strategies. Storing resistant varieties is one such strategy. Many workers have investigated resistance in maize against storage pests under laboratory conditions (e.g. van der Schaaf *et al*., 1969; Dobie, 1974; Schoonhoven *et al*., 1972, 1975, 1976) and found that maize differ greatly in their intrinsic susceptibility. Very few studies however, have examined whether the resistance under laboratory conditions do in fact hold under farmers' conditions.

It was long been known that resistance to insect attack is strongly correlated with physical factors such as tight husk covers, kernel hardness and low moisture content. Chemical factors such as amylose (Rhine and Staples, 1968) and sugar contents (Singh and McCain, 1963) are also important resistance factors. More recently, Serratos et al. (1987) demonstrated that resistance was related to the antifeedant properties of the phenolic acids, ferulic acid and p-coumaric acid located in the pericarp and aleurone layer. Studies on the role of the pericarp have shown that its thickness is not correlated with resistance (Eden, 1952; Gomez et al., 1983). Pericarp surface relief (smoothness) is considered to be significant component of maize resistance to the maize weevil by Tipping et al. (1988). The objectives of the study reported here were to screen a range of maize germplasm for resistance to damage by S. zeamais and to validate the laboratory findings in on-farm storage trials.

MATERIAL AND METHODS

Laboratory trials

A diverse range of maize germplasm (Table I) was screened for resistance to S. zeamais under controlled temperature (28°C) and relative humidity (70-75%). The maize materials were divided into three groups and susceptibility tests performed separately for each group. Cacahaucintle, a floury Mexican maize which is susceptible to S. zeamais, was included in each group as a susceptible check (control). The susceptibility of the maize germplasm was measured using the method described by Dobie (1974). Four 50 g samples of each maize variety were infested with 12 females and 6 males of S. zeamais adults (0-7 days old). The insects were allowed to oviposit for one week then removed. The maize was then left undisturbed under experimental conditions until F_1 adults started to emerge about 30 days later. The emerging adults were removed daily and counted until all the F_1 adults had emerged. The total number of F_1 emergents and the mean development period (time from mid-oviposition to 50% F_1 progeny) for the insects were derived from the data for each replicate of each maize type. The data were used to calculate on Index of Susceptibility using Dobies' (1974) formula:

$$\text{Index of Susceptibility (I)} = \frac{\log_e F}{D} \times 100$$

where D = mean development time
F = total number F_1 adults

The weight loss as a result of the feeding and development of the insects was also recorded.

On-farm Storage Trials

The following maize germplasm was stored in small farmers' granaries in the Chiweshe Communal Area and their performance evaluated against stored product insects: Poza Rica 7737, Ilonga 8032, Pool 23, Pool 34, Pool 32, Poza Rica 8121, Population 70, Population 68, Rattray Arnold, SR52, Kalahari Early Pearl (KEP), Kayile, Juyilele and Malawi local # 40(MLM#40). Thirty kilograms of each of the maize types contained in small jute sacks were placed in four farmers' granaries, together with the farmers' own grain and monitored monthly from December 1988 to July 1989. Each month a 0.5 kg sample of maize was withdrawn from each sack using a grain probe and the percent damage, percent weight loss

Table I. The maize germplasm screened for resistance against *Sitophilus zeamais*

Maize	Type	Source
Poza Rica 7737	Open-pollinated	CIMMYT-Mexico
Rattray Arnold (1)8149	"	"
Population 70	"	"
Ilonga 8032	"	"
Poza Rica 8121	"	"
Pool 32	"	"
Pool 34	"	"
Cacahaucintle	"	"
Malawi local accession 10	"	Malawi
Malawi local accession 6	"	"
Malawi local accession 40	"	"
Zimbabwe local accession 1	"	Zimbabwe
Zimbabwe local, Juyilele	"	"
Zimbabwe local, Kayile	"	"
Hickory King	" composite	"
Silver King	" composite	"
CCD	" composite	"
R215	Hybrid	"
R201	"	"
SC501	"	"
PNR 6549	"	"
PNR 695	"	"
PNR 6334	"	"
PNR 617	"	"
PNR 6557	"	"
PNR 482	"	"
SX5	"	"
SR 52	"	"

Table III. The rates of loss in weight, increase in damage and weevil numbers in different maize varieties

Maize	Slope (Rate)		Insect
	Percent damage	Percent weight loss	numbers
Kayile	0.121	0.032	0.593
SR 52	0.187	0.032	0.258
Ilonga 8032	0.093	0.026	0.523
Poza Rica 8121	0.153	0.033	0.562
Rattray Arnold	0.156	0.032	0.584
Population 70	0.154	0.033	0.491
Pool 23	0.111	0.026	0.491
Pool 32	0.157	0.038	0.590
Population 68	0.144	0.038	0.639
Pool 34	0.149	0.038	0.642
Kalahari E. Pearl	0.145	0.039	0.649
MLM #40	0.132	0.027	0.669
Poza Rica 7737	0.224	0.051	0.529
Juyilele	0.109	0.030	0.593
LDS (0.05)	0.060	0.009	0.215
Dunn (0.05)	0.090	0.013	0.320

Table II. Assessment of susceptibility of maize germplasm to *Sitophilus zeamais*

Maize	Weight loss (g)	Index of Susceptibility	Relative index of susceptibility
		Group 1	
R215	7.4	14.1	8.2
SC501	7.3	13.6	8.0
PNR6549	9.0	14.3	8.4
PNR695	5.1	12.7	7.4
PNR6334	7.8	14.7	8.6
PNR617	8.6	13.6	8.0
PNR6557	9.6	14.4	8.4
R201	9.0	14.6	8.5
SR52	6.5	13.7	8.0
Hicory King	7.5	13.3	7.8
SX5	9.0	14.4	8.4
Cacahaucintle	12.3	17.1	10.0
LSD (0.05)	1.5	0.7	-
		Group 2	
Malawi local (acc.10)	2.8	11.7	7.4
Malawi local (acc.6)	3.1	11.8	7.4
Malawi local (acc.40)	3.4	12.2	7.7
Zimbabwe local (acc.1)	4.0	12.5	7.9
Zimbabwe local (Juyilele)	5.9	13.6	8.6
Zimbabwe local (Kayile)	2.8	12.5	7.9
SR52	4.4	12.8	8.1
SR14	5.7	14.5	9.1
PNR482	3.1	11.0	6.9
Silver King	5.0	13.3	8.4
CCD	5.1	13.1	8.2
Cacahaucintle	6.3	15.9	10.0
LSD (0.05)	1.5	1.1	-
		Group 3	
Poza Rica 7737	5.3	14.5	12.1
Rattray Arnold	1.3	9.3	7.8
Population 70	1.6	10.3	8.6
SR52	2.7	11.0	9.2
Ilonga 8032	2.3	10.7	8.9
Poza Rica 8121	3.4	12.4	10.3
Pool 32	2.9	11.8	9.8
Pool 34	2.0	10.2	8.5
Cacahaucintle	3.3	12.0	10.0
LSD	0.8	1.1	-

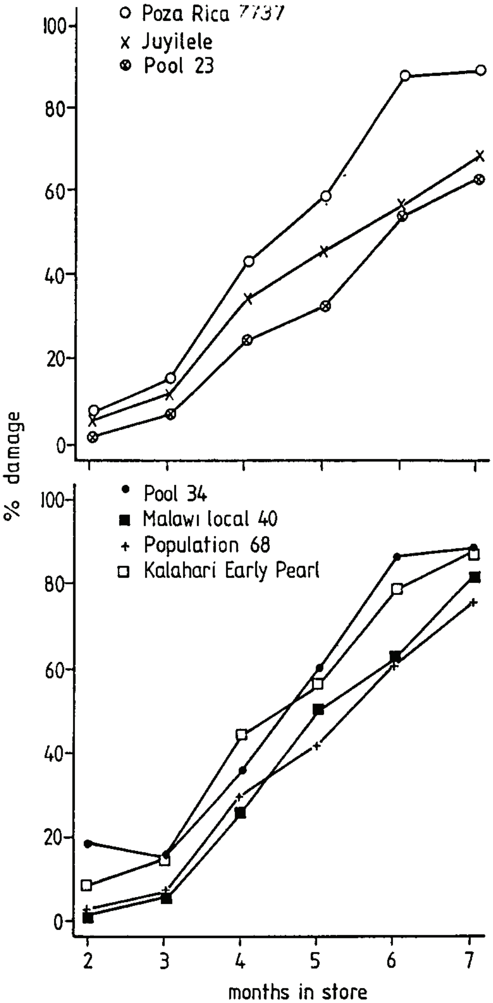
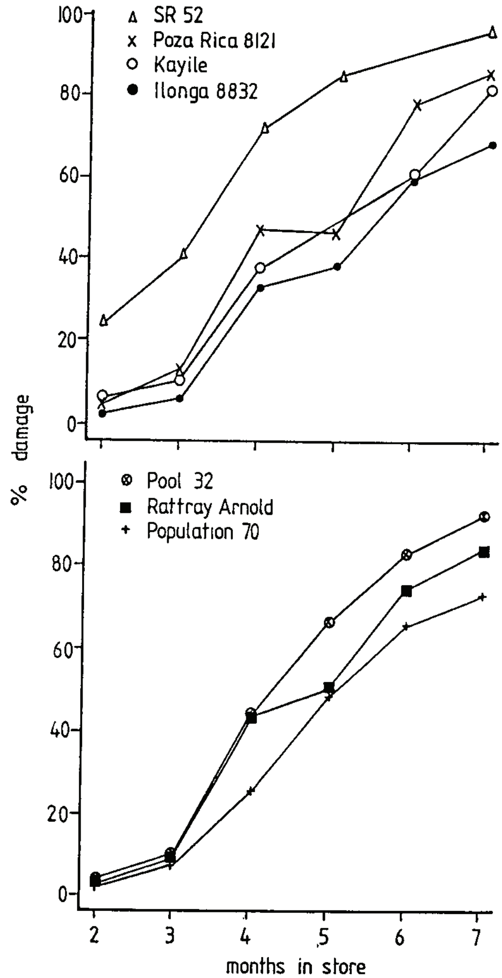


Fig. Ib Percent damage versus time in maize varieties stored on-farm



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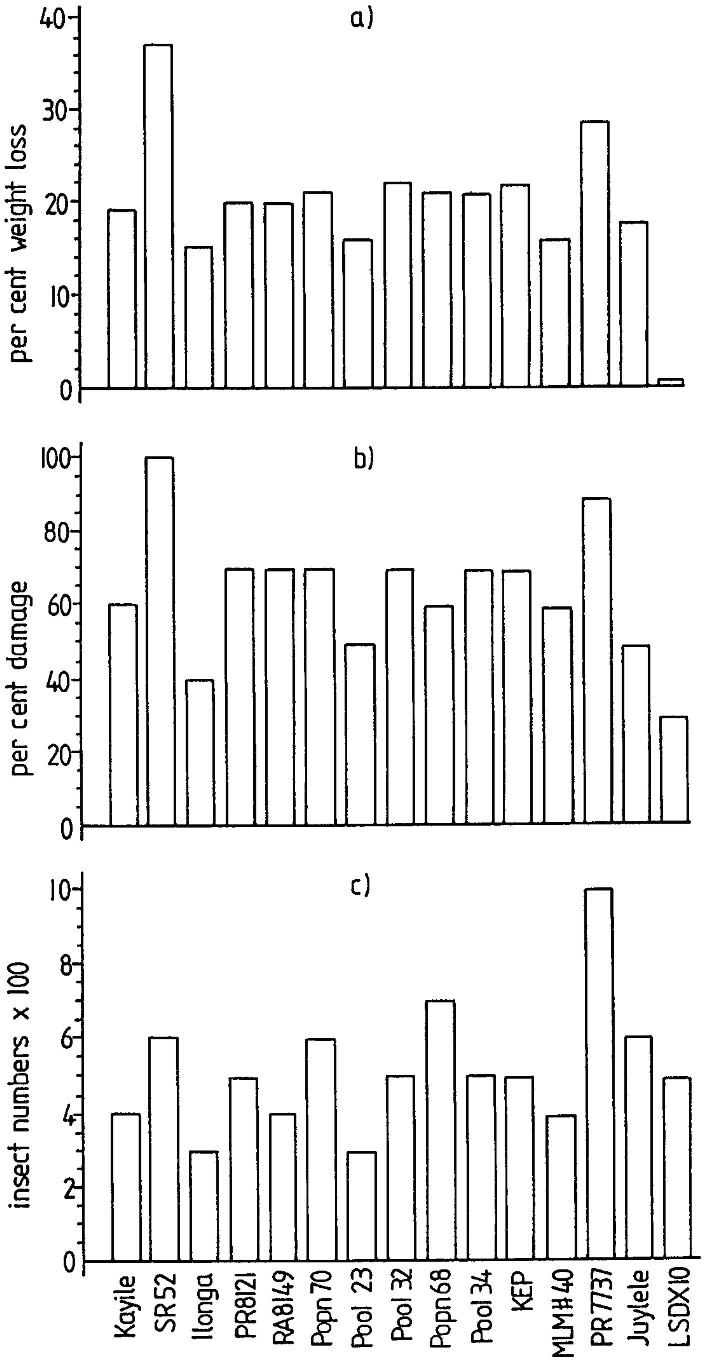

FIG.2 a) Percent weight loss, b) percent damage and c) *Sitophilus zeamais* numbers in different maize varieties after storage.

and maize weevil populations recorded. One thousand kernels were randomly selected from the samples and the percent damage determined. The weight loss was determined by the modified standard volume weight (SVW) method described by Boxall (1986). Linear regressions of percent damage and weight loss (arcsine transformations) and insect number ($\log_{10}$ transformation) with time were fitted for each farmer.

RESULTS

Laboratory trials

The weight loss, indices of susceptibility and relative indices of susceptibility of each of the maize types are given in Table II. The analyses of variance of these parameters showed significant differences between the maize materials. The numerical values of the indices of susceptibility were found to be affected by experimental conditions making comparisons between the data in the groups difficult. To overcome this problem the susceptible check variety Cacahuacintle which was included in each series of tests was used to express the Index of Susceptibility of any material as a proportion of the Index of Susceptibility of the control check. For convenience the ratio was multiplied by 10 and is referred to as the Relative Index of Susceptibility. Except for Poza Rica 7737 and Poza Rica 8121 all the maize materials were less suceptible than Cacahuacintle. The hybrid maize were generally more susceptible than the local, indigenous materials.

On-farm Storage Trials

The increase in percent damage with time in the maize varieties stored on-farm is shown in Figures 1a and b. The percent weight loss, percent damage and insect numbers estimated from linear regressions at the end of the storage season are shown as histograms in Figures 2a - c respectively. The analyses of variance of the slopes of the fitted lines for percent weight loss and damage revealed significant ($P < 0.5$) varietal differences and a comparison of the rates (i.e. slopes) of loss in weight and increase in damage showed that Pool 23, Rattray Arnold, Ilonga 8032, Poza Rica 8121, Kayile, Juyilele, MLM#40 and Population 68 stored better than all others (Table III). The hybrid SR52 and Poza Rica 7737 performed worst. Although the analysis of variance of the rate of insect population growth was not significantly different between the varieties, Dunnet's test indicated that Kayile, Ilonga 8032, Rattray Arnold, Pool 23 and MLM#40 supported significantly ($P < 0.05$) lower weevil populations than Poza Rica 7737 (Table III).

DISCUSSION AND CONCLUSIONS

The maize germplasm examined here showed significant variation in susceptibility to S. zeamais. In more extensive laboratory screening Dobie (1977) also showed that maize varieties differ greatly in their intrinsic susceptibility thus allowing the possibility of selecting resistant lines. It has long been known that indigenous maize varieties have better storage qualities and are less severely attacked by storage pests than improved varieties (Golob, 1984; Dobie, 1986; Fortier et al., 1982). The indigenous maize collections (Juyilele, Kayile and MLM#40) evaluated here were generally more resistant to S. zeamais than the hybrids in both laboratory and field trials. The Malawi local maize collections showed no variation as a group, the similarity in susceptibility probably due to a duplication of collections or contamination with a common maize source. Of the improved maize varieties from CIMMYT, Rattray Arnold, Pool 34 and Population 70 and Ilonga were least damaged while Poza Rica 7737 was the most susceptible under laboratory conditions. The work of Arnason et al. (1986, unpublished) using the same CIMMYT materials also confirm these results. Some of the improved maize such as Rattray Arnold, Ilonga and Population 70 have been selected for resistance at CIMMYT (Mihm pers. commun.) based on laboratory screening. The laboratory work would be of little use if it were not used to predict the actual behaviour of varieties under field conditions. Therefore on-farm trials were carried out to compare the laboratory results with the on-farm findings. Even in the on-farm trials, there was a wide variation in damage, weight loss and insect populations between the maize varieties. Except for a few discrepancies however, those varieties found to be less damaged under controlled laboratory conditions also showed better keeping qualities in field storage. Poza Rica 7737 and hybrid SR52 incurred greater damage than Rattray Arnold, Ilonga, Population 70 and Pool 23. These improved CIMMYT materials are available to national maize breeding programmes (Mihm, pers. commun.). An interesting feature is that the local collections (MLM#40, Kayile and Juyilele) were amongst the least susceptible entries. This coincides with the farmers observations that indigenous varieties through selection have good storage qualities. The work reported here confirms that maize varieties differ greatly in their intrinsic susceptibility, allowing the possibility of selecting resistant lines. Schoonhoven et al. (1975) in their studies on inheritance of resistance to S. zeamais demonstrated that resistance to the pest could be increased through selection in dent maize than in flints; this is because resistance was located in the pericarp which is maternal tissue. The pericarp and embryo are genetically similar in the nearly homozygous dents whereas in flints, with little inbreeding the two are different genotypically. As far as we are aware, no concerted attempt has been made to date to introduce resistance to storage pests by maize breeders.

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EVALUATION DE LA RESISTANCE DU GERMOPLASME DU MAIS A *SITOPHILUS ZEAMAIS* EN LABORATOIRE ET EN STOCKAGE PAYSAN.

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Résumé

La sensibilité relative du germoplasme du maïs de variétés provenant du CIMMYT–Mexique, du Malawi et du Zimbabwe aux attaques du charançon du maïs *Sitophilus zeamais* (Motsch.) a été étudiée à température (28° C) et humidité relative (70 à 75 %) constantes. Une échelle de sensibilité a été créée d'après le nombre de descendants en F1 et la durée de développement moyenne et a été utilisée comme base pour mesurer cette sensibilité. De nettes différences sont apparues entre les germoplasmes des différentes variétés de maïs, avec des indices allant de 9,3 pour le "Rattray Arnold (1) 8149" (le moins sensible) à 14,7 pour le "PNR 6334" (le plus sensible). Afin de savoir si les résultats de laboratoire étaient valables, 14 génotypes de maïs différents ont été choisis et évalués en milieu agricole et dans des conditions naturelles d'infestation. Le maïs a été stocké dans des petits sacs de jute dans de petits entrepôts fermiers pendant plusieurs mois et le pourcentage de détérioration ainsi que la croissance des populations d'insectes ont été surveillés régulièrement. En général, les variétés qui s'étaient avérées les moins sensibles en laboratoire étaient celles ayant présenté le moins de détérioration tandis que les plus sensibles ont été les plus atteintes.