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Host–plant resistance: A viable non – chemical and environmentally friendly strategy of controlling stored products pests-a review

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Abstract: Harvested grains suffer enormous damage from insect pests during storage. Their protection in storage has been the subject of many studies including the search for resistant varieties. Screening of many seed varieties had led to the successful isolation of strains that are resistant to insect pests in some African countries. Amongst grain legumes, three out of the 12,000 cowpea (*Vigna unguiculata* (L.) Walp.) varieties screened were found to be effectively resistant to two cowpea bruchids (*Callosobruchus maculatus* F.) and *C. subinnotatus* (Pic.). Out of 31 Bambara groundnut (*Vigna subterranea* Thou.) varieties screened, 6 were found to be resistant to these bruchids. Similarly, four varieties of groundnut (*Arachis hypogea* L.) were found to be resistant to both Indian meal moth (*Plodia interpunctella* Hubner) and rust red flour beetle (*Tribolium castaneum* Herbest). Among the cereal grains, 175 maize (*Zea mays* L.) varieties were investigated and 28 found resistant against both the larger grain borer (*Prostephanus truncatus* Horn.) and the maize weevil (*Sitophilus zeamais* Motschulsky). These studies revealed that host–plant resistance is a very good method of combating pest depredation in storage. It is perhaps the easiest, most economical and effective means of controlling insect pests on stored grains as there is no special technology which has to be adopted by farmers. The expenses to the farmer are limited because he only has to buy the seeds and no environmental hazards are involved. Furthermore the method is quite compatible with other methods of control.

Keywords: Host–plant resistance, resistant varieties, groundnut, cowpea.

العلاقة بين النبات والعائل : استراتيجية قيمة وطبيعية وصديقة للبيئة لمقاومة آفات المخازن- دراسة مرجعية

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تتحمل الحبوب بعد الحصاد أضراراً كبيرة من قبل الآفات الحشرية خلال فترة التخزين. وتعتبر حماية هذه الحبوب موضوع العديد من الدراسات، والتي تشتمل على أبحاث تتعلق بالأصناف المقاومة للآفات. وقد أدت عملية غربلة أو فصل العديد من أصناف الحبوب إلى عزل ناجح لسلالات تعتبر مقاومة للآفات الحشرية في بعض الدول الأفريقية. ومن بين الحبوب البقولية ثلاثة أصناف لوبياء، من أصل 12,000 صنفاً، تم غربلتها (*Vigna unguiculata* (L.) Walp.)، ووجدت بأنها مقاومة لحشرات براكيد (سوس) اللوبياء (*Callosobruchus maculates* F.) و *C. subinnotatus* (Pic.). وقد وجدت 6 أصناف مقاومة لحشرات البراكيد من بين 31 صنفاً من الفول السوداني "بامبارا". وبشكل مشابه، وجدت 4 أصناف من الفول السوداني (*Arachis hypogea* L.) مقاومة لفراشة الطحين الهندية (*Plodia interpunctella* Hubner) و خنفساء الطحين الحمراء الصدئية (*Tribolium castaneum* Hernest). ومن بين 175 صنفاً من حبوب الذرة، وجد 28 صنفاً مقاوماً ضد حفار الحبوب الكبير (Prostephanus trancatus Horn.) وسوسة الذرة (*Sitophilus zeamais* Motschulsky). وقد أظهرت الدراسات أن العلاقة بين النبات والعائل تعتبر طريقة جيدة جداً لمقاومة إصابات الآفة في المخازن. ومن مميزات هذه الطريقة كونها سهلة

واقتصادية وفعالة لمكافحة الآفات الحشرية على الحبوب المخزونة، حيث لا توجد هناك تقنية خاصة لكي يتم تبنيها من قبل المزارعين. وتعتبر هذه الطريقة محدودة على المزارع، حيث أنه يتطلب منه فقط شراء البذور ولا ينتج عنها أي أخطار بيئية. بالإضافة إلى ذلك، تعتبر هذه الطريقة ملائمة للتطبيق مع طرق المكافحة المختلفة.

الكلمات المفتاحية: العلاقة بين النبات والعائل، صنف مقاوم، الفستق، اللوبيا.

Introduction

Grain legumes such as cowpea, bambara groundnuts and various forms of beans are important protein sources in the tropics and sub – tropics while cereal grains such as maize and sorghum are important sources of carbohydrates. These crops also serve as sources of income to small–and large–scale farmers in developing countries. Following harvest, these crops are often infested by insect pests in store which cause considerable damage in form of loss of weight, loss and conversion of nutrient, reduction in germination capacity or loss of seed vigour, downgrading and lowering of market value, contamination and aesthetic violation of the grains leading to customer resistance, damage to storage structures and containers, distribution of pathogens and parasites to man and his domestic animals (Ahmed, 2005). Table 1 shows the status of some of the major insect pests of stored agricultural produce in Nigeria. Uncontrolled infestation by these insect pests could lead to total loss of the stored grains as Caswell (1973) reported a 100% loss in cowpea within 3 – 5 months of storage.

Table 2 shows the annual loss estimates in stored legumes for some African countries. These losses range from 8 – 100%. Caswell (1973) estimated that a 5% loss of cowpea due to insect infestation costs Nigeria 30 million US dollars per annum. This situation may also be found in some African countries. Similarly, Table 3 shows losses caused to major cereals by insect pests in some African countries. These range from 2 – 70%.

The search for viable non–chemical means of controlling stored product pests, especially beetles has been particularly vigorous and significant progress has already been made. This search was necessitated mainly by the harmful side effects and high costs of insecticides and their ability to leave harmful residue in stored produce and of course causing the emergence of resistant strains of pests (Agboola, 1992). For instance Joia et al. (1985) reported that the reduction of residues in flour through bread making with wheat treated with cypermethrin and fenvalerate was slow and that 79–84% of cypermethrin and 87–88% of fenvalerate were present in bread made from flour containing residue of both insecticides. This and many other data, which have resulted from the search for alternative pest management strategies, suggest the need for the use of plant varieties with host–resistant qualities in avoiding insect pest infestation in stored produce.

Background Information

In Africa, non–chemical control programmes have received little or no attention in the past. This may be partly due to a lack of information on the methods, coupled with the absence of trained personnel and research facilities. However, some work have been and are being done on the collection and identification of various predators, parasitoids, disease–causing micro-organisms and particularly the screening of insect pest–resistant varieties (Bamaiyi et al., 2000).

Use of resistant varieties is the most cheap, effective and ecologically safe method of protecting grains against insect pests since there is no special technology which has to be adopted by the farmer

(Helbig, 1997). The expenses to the farmer are limited because he only has to buy the seed and health risks associated with insecticide application are avoided. It is therefore, evident that breeding for resistance to post–harvest pests is important for small and large–scale farmers alike.

Resistance of stored plant materials to insect pests

Resistance of plant or plant materials to insects is defined as the relative amount of heritable qualities possessed by a plant or its materials (for example, its seeds) which influence the ultimate degree of damage done by the insects (Mbata, 1997). For stored grains, resistance represents the ability of a certain crop variety to produce grains that maintain better quality than commonly cultivated varieties following long storage under similar insect populations (Mbata, 1987).

Mechanism of protection in resistant varieties of grains

In stored grains several factors lead to the production of resistance against infestation by storage insect pests. These include the tightness of the glumes in unmilled rice (Cogburn and Bollich, 1986; Haryadi and Fleurat–Lassard, 1991) which serve as physical barrier working against penetration by insects; well–fitting and tight–sheating leaves of the husks covering a maize cob (Giles and Ashman, 1971; Kossou et al., 1993) may reduce infestation by *Sitophilus* spp in the field and in store; hardness of seeds (Jansen, 1977; Dick, 1988) is thought to make insect penetration more difficult thus providing protection; seed size (Nwanze et al., 1975; Dharmasena and Subasinghe, 1986) has also been shown to influence infestation by insect pests as large grain legumes provide more surface area for oviposition and larval development than small–size grains; the texture and hairiness of the coats of cowpea seed; Nwanze et al., 1975; (Nwanze and Horber, 1976; Ofuya and Awelewa, 1993) may have negative influence on the oviposition of the cowpea weevil; the quantity and quality of nutritional constituents (Jackai and Daoust, l986; Adetunji, 1991; Consoli and Amaral Filho, 1995) have been described to have influence on the fecundity of the females, on the development period of the pre – imaginal instars and on the rate of adult emergence; the presence of compounds which inhibit oviposition and the development of insects on seeds (Gatehouse et al., 1979; Singh et al., 1985; Dobie, 1986; Mbata, 1987; Desroches et al., 1995).

Methods of screening

Methods for screening resistant grain varieties involve infesting grains artificially with the storage insect under investigation and evaluating the suitability of the test variety for oviposition, duration of development of the insect on the varieties, adult emergence pattern and calculating the susceptibility indices from these observations (Dobie, 1974; Jackai et al., 1985). Losses sustained by the different varieties are compared. Occasionally, particular attention is given in these studies to assessing the effects of relative humidity and the associated variable grain moisture content on pest population dynamics. These parameters have helped in identifying resistant varieties (Mbata, 1986; Mbata et al., 1988; Vowotor et al., 1997).

Varietal resistance in storage grains against insect pests

The potential of resistant varieties of maize, cowpeas, groundnuts and bambara groundnuts against infestation by insect pests is examined and reviewed.

MaizeSome highly resistant maize varieties and some others with a moderate degree of resistance have been screened against *S. zeamais* which is the most important maize storage pest worldwide (Helbig, 1977). Other varieties were also screened for resistance to lepidopteran pests as shown in Table 4. These results show the potentials of some varieties to be adopted by the local farmers against storage insect pests.

Maize is normally stored in three ways: storage of the entire cob with husks intact in open ventilated stores or cribs (Vowotor et al., 1997), as dehusked cob and as shelled grains (Helbig, 1997). Resistance to storage pests in maize has been shown to be strongly affected by the storage form (Vowotor et al., 1994). Furthermore, husk has been shown to give a good protection not only in storage but in the field as well. The fitting of the husk cover, their thickness and hardness have been observed as important factors in protecting the grains against the penetration of insects (Helbig, 1997) and traditional local varieties are usually better protected than the new hybrid ones (Kossou et al., 1993; Helbig, 1997).

Vowotor et al. (1997) screened three maize varieties against population dynamics of *Prostephanus truncatus* Horn. (Coleoptera: Bostrichidae) and *S. zeamais* in maize stores. The study was divided into long and short season components. Two popular varieties (Abuita and Dzolokpuita) and an improved variety (Abeleechi) were used. Maize cobs were used with their husk intact. The results showed that *P. truncatus* numbers were lower in Dzokpuita than in either Abuita or Abeleechi (Table 5). No significant differences in *S. zeamais* numbers were found with respect to variety as shown in Table 6. Resistance to storage pests has also been observed in maize grains. Srinivas Acharyulus and Chaudhary (1992) screened 84 inbred lines for resistance to *S. cerealella*. They found 11 lines with a high degree of grain resistance to this pest. Cowpea

Many varieties of cowpea screened for resistance against the cowpea bruchid (*C. maculatus*) and other *Callosobruchus* species showed that some varieties posses a very high level of resistance (Table 7). Researchers at the International Institute of Tropical Agriculture (IITA) have screened the entire germplasm collection of cultivated *V. unguiculata* (12,000 accessions) and have identified only 3 varieties (TVu 2027, TVu 11952 and TVu 11953) exhibiting seed resistance to *C. maculatus* (Singh, 1977). Seck (1993) also reported 6 promising varieties with high resistance out of the 80 varieties screened. Furthermore, Ndolovu and Giga (1988) reported two promising varieties (IT 81D–1032 and IT 81D–1064) with high resistance against *C. rhodesianus* out of the 18 varieties screened (Tables 7 and 8).

Groundnuts

Groundnut is frequently infested with *T. castaneum* and *P. interpunctella*. Results from screening of 22 improved groundnut varieties against these two insect pests revealed 10 promising varieties with high resistance (Mbata, 1986; 1987). Details of which is shown in table 9. The testa, according to Mbata (1995) may have contributed to the resistance in most of the resistant varieties but further explained that the cotyledons may also possess some resistant characteristics due to antibiosis.

Bambara Groundnuts

Bambara groundnut is known to be infested by both *C. maculatus* and *C. subinnotatus* in storage. Results from screening 21 varieties cultivated in West Africa for resistance against *C. subinnotatus* revealed that three varieties (TVSu 1038, TVSu 346 and TVSu 688) were moderately resistant (Mbata, 1993). Mbata (1992) also reported 3 bambara groundnut varieties (TVSu 119, TVSu 9 and TVSu 11) that showed high resistance against *C. maculatus* out of the ten varieties screened (Table 10).

Table 1. Families, hosts and status of some major insect pests of stored agricultural produce in Nigeria*.

Family	Common name	Scientific name	Products attacked	Type of pest
Bostrychidae	Lesser grain borer	*Rhyzopertha dominica*	Cereals	Primary
	Larger grain borer	*Prostephanus truncatus*	Cereals	Primary
Bruchidae	Cowpea bruchid	*Callosobruchus maculatus*	Cowpea, bambaranut, soybean	Primary
	Bambara groundnut bruchid	*Callosobruchus subinmotatus*	Bambara groundnut	Primary
Curculionidae	Rice weevil	*Sitophilus oryzae*	Cereals	Primary
	Maize weevil	*Sitophilus zamais*	Cereals	Primary
Cleridae	Clerid	*Necrobia rufipes*	Dried fish & animal products	-
Dermestidae	Khapra beetle	*Trogoderma granarium*	Oilseeds, cereals	Primary
	Skin beetle	*Dermestes maculatus*	Dried fish & animal products	-
Gelechiidae	Angoumois grain moth	*Sitotroga cerealella*	Cereals	Primary
Pyralidae	Indian meal moth	*Plodia interpunctella*	Cereals,nuts, dried fruits, farinaceous products	Secondary
	Rice moth	*Corcyra cephalonica*	Cereals & products, groundnuts	Secondary
Tenebrionidae	Flour beetle	*Tribolium castaneum*	Cereals & products, dry plant material	Secondary

*Source: Lale (2001)

Table 2. Annual loss estimates of stored grain legumes in some African countries*.

Country	Percentage losses
Cameroun	10
Ghana	9- 10
Nigeria	30- 40
Sierra Leone	50
South Africa	5
Uganda	20- 30
Burkina Faso	50- 100

*Source: Taylor (1977)

Table 3. Losses caused to major cereal crops by insect pests in some African Counties.

Cereal Grain	Insect Species	Country	Percentage Weight loss estimate	Reference
Maize	*Sitophilus zeamais* (Mots.)	Ghana	20	Hall, 1970
	Tribolium castaneum (Herbst.)	Uganda	50	Hall, 1970
	Sitotroga cerealella (Oliv.)	Kenya	4 – 5	De Lima, 1979
	Ephestia cautella (W/K)	Nigeria	5 – 70	Anonymous, 1978
	Prostephanus truncatus (Horn.)	Tanzania	9 – 34	Hodges, et al., 1983
Wheat	*Sitophilus oryzae* (L.)	Kenya	2	Hall, 1970
	Rhizopertha dominica (F.)	Nigeria	34	Hall, 1970
Rice	*Sitophilus oryzae* (L.)	Sierra-	10	Anonymous, 1978
	Sitotroga cerealella (Oliv.)	Leone	2	Anonymous, 1978
Millet	*Sitophilus oryzae* (L.)	Egypt	2 – 5	Anonymous, 1978
	Sitotroga cerealella (Oliv.)	Mali	14	Anonymous, 1978
		Sudan		

Table 4. Varietal resistance of stored maize to insect pests.

Pest – Species	Number of Varieties Screened	Promising Varieties with high resistance	Reference
Sitophilus zeamais	9	4	IITA 1983
S. zeamais	16	3	Morah and Mbata, 1986
Sitotroga cerealella	84	11	Srinivas Acharyulu & Chaudhary, 1992
S. cerealella	5	1	Consoli and Amaral-Filho, 1995
Corcyra cephaconica	13	5	Mbata, et al., 1988
Plodia interpunctella	13	3	Mbata, 1990

Table 5. Numbers of *Prostephanus truncatus* recorded on cobs of three maize varieties stored in "cribs" during the long storage season in Ghana (October 1994 to May, 1995) [1].

Sampling	Mean number of *P. truncatus*[2]			F – ratio
	Abuita	**Abeleechi**	**Dzolokpuita**	
October, 1994	0.57	00.17	-	2.8
November, 1994	1.05	0.46	-	2.45
December, 1994	0.93a	-	-	7.23
January, 1995	3.93a	0.12	0.04	11.43
February, 1995	28.98a	4.64	0.16	7.11
March, 1995	24.62a	5.13	1.74	7.3
April, 1995	109.33a	15.38	6.48	5.89
May, 1995	131.14a	3.73	16.92	10.84

[1]After Vowotor et al. (1997)

[2]Means followed by a letter within a row are significantly different (p< 0.05) (Scheff test) after analysis of variance. Insect numbers determined from 3 pooled 26 – cob samples per crib. Each value is a mean of 4 cribs.

Table 6. Numbers of *Sitophilus zeamais* recorded on cobs of three maize varieties stored in "cribs" during the long storage season in Ghana (October 1994 to May, 1995) [1].

Sampling	Mean number of *S. zeamais*[2]			F – ratio
	Abuita	**Abeleechi**	**Dzolokpuita**	
October, 1994	169.30a	81.79	69.01	17.86
November, 1994	232.50	259.74	212.23	0.78
December, 1994	281.69	349.03	348.47	1.61
January, 1995	217.24	297.38	251.68	1.63
February, 1995	242.32	263.28	213.32	0.76
March, 1995	226.19	243.45	242.52	0.12
April, 1995	255.21	277.80	231.43	0.81
May, 1995	303.99	250.84	313.49	1.41

[1]After Vowotor et al. (1997).

[2]Means followed by a letter within a row are significantly different (p< 0.05) (Scheff test) after analysis of variance. Insect numbers determined from 3 pooled 26 – cob samples per crib. Each value is a mean of 4 cribs.

Table 7. Varietal resistance of stored cowpea to insect pests.

Pest species	Number of varieties screened	Promising varieties with high resistance	Reference
Callosobruchus maculatus	12000	3	Singh, 1977
C. maculatus	27	4	Mbata, 1993
C. maculatus	80	6	Seck, 1993
C. maculatus	25	3	Ofuya and Awelewa, 1993
C. maculatus	13	2	Ofuya and Credland, 1993
C. rhodesianus	18	2	Ndlovu and Giga, 1988
C. Subinnotatus	27	4	Mbata, 1993

Table 8. Summary of screening cowpea varieties for resistance to storage insect pests.

No. of varieties screened	Insect used in screening	Promising varieties with high resistance	Reference
12000	*Callosobruchus maculatus*	TVu 2027, TVu 11952, TVu 11953	Singh, 1977
18	*C. rhodesianus*	IT 81D – 1032, IT 81D – 1064	Ndlovu and Giga, 1988
29	*C. maculatus*	TVu 2027, IT87D – 1827, IT84S – 2246 -4, IT81D – 1007	Mbata, 1993
29	*C. subinnotatus*	IT 84S – 2264 – 4, IT 81D – 1157, TVu 2027 (AR), TVu 11952 (AR), TVu 11953 (AR) TVu 310 (AR)	Mbata, 1993

Table 9. Summary of screening groundnuts varieties for resistance to pests storage insect.

No. of varieties screened	Insect used in screening	Promising varieties with high resistance	Reference
13	*P. interpunctella*	M554 – 76, P1274/19, RMP – 12, RMP – 91, M 1204 – 781	Mbata, 1987
9	*T. castaneum*	P1274/191, F452.4, RMP – 12, 2479/79, RMP - 91	Mbata, 1986

Table 10. Summary of screening bambara groundnuts varieties for resistance to storage insect pests.

Number of varieties screened	Insect used in screening	Promising varieties with high resistance	Reference
21	*C. subinnotatus*	TVSu 1038 TVSu 346 TVSu 688	Mbata, 1993
10	*C. maculatus*	TVSu 119 TVSu 9 TVSu 11	Mbata, 1992

Conclusion

Insect control is essential for storing grains successfully. The control methods may be one of the following: hygienic, physical, chemical, biological or use of resistant crop varieties. Hygienic control measures require good and adequate drying, disinfection and storage practices which are combined with impeccable hygiene that satisfactory results can be achieved (Taylor, 1976). This is only achieved in small– scale farming system. Physical control measures involve modifying the pests' environment in order to make the grain stores more susceptible to control the pests. However, such an approach requires detailed knowledge of the biology of the pests and a clear understanding of the physical characteristics of grain bulks (Allotey, 1991). Chemical control measures is accompanied by inherent risks such as toxic residues contaminating the grains, poisoning of farmers, development of resistance by the insects and pollution of the environment. These chemicals are also beyond the reach of small–scale farmers. An effective chemical used against insect pests in stores must possess the correct blend of biological activity and either low mammalian traits or short residual life. On the other hand, biological control involves the use of natural enemies to suppress the stored grain insects (Benz, 1987). Nevertheless, natural enemies themselves in the grain store are still considered as one of the pollutants, which contaminate stored grains (Allotey, 1991). The use of resistant crop varieties for insect control is based on either antibiosis or antixenosis (Helbig, 1997). In many crops some varieties are less suitable than others for insect development. Such varieties are described as being resistant to insect attack. In small–scale farmers' stores the use of resistant varieties may extend the period during which the produce can be safely stored without the use of pesticides, whereas farmers who grow susceptible varieties may be forced to use expensive chemicals that are difficult to obtain (Dobie, 1984). On the other hand resistant varieties provide a cheep, effective and ecologically safe way of protection of grains against insect pests. The expenses to the farmer are limited because he only has to buy the seed and health risks associated with insecticide application are avoided. From this point of view, breeding for resistance to post–harvest pests is important for small–scale as well as large–scale farmers alike.

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