Damage of Rough and Brown Rice by Four Stored-product Insect Species

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Rough rice (175 g) and brown rice (145 g) of cv. Nankin 11, ca. 6,500 kernels, were artificially infested with *Ephesia cautella* (WALKER), *Tribolium castaneum* (HERBST), *Rhyzopertha dominica* (Fabricius), and *Sitophilus oryzae* (L.) at 30°C and 65% r.h. to assess losses over a 14 week period. Uninfested controls of each type of rice were also examined both at 30°C and 65% r.h. and at 10°C and 70% r.h. The variables measured were insect number, moisture content, weight of 100 kernels based on 14% moisture content, and germinability. Rough rice was not substantially affected by the presence of any insect species and largely maintained its initial quality. In brown rice, all insect species increased markedly and serious damage was detected in all variables. The brown rice lost 40, 19, 14, and 10% of initial kernel weight over the 14 weeks through infestation by *R. dominica*, *S. oryzae*, *T. castaneum* and *E. cautella*, respectively. Moisture content of brown rice in the infested treatments was higher than that of the control at 30°C and 65% r.h. in most cases. The germinabilities of the infested brown rice decreased abruptly after 4 weeks, and at the end of the experiment were almost nil. Loss assessment measures and the resistance of rough rice of this variety to insect infestation were discussed.

INTRODUCTION

Postharvest losses of grain are often caused by insect infestation. Losses of stored grains by insect feeding amount to at least 5% of the annual production (WHITE, 1953). This quantity may be substantially higher in developing countries (e.g. ADAMS, 1977; SAUNDERS et al., 1980; SCHULTEN, 1982) where in addition to the prevailing favorable climate for insect growth, proper postharvest loss prevention programs are often lacking.

The tropical warehouse moth *Ephesia cautella* (WALKER), the red flour beetle *Tribolium castaneum* (HERBST), the lesser grain borer *Rhyzopertha dominica* (FABRICIUS), and the rice weevil *Sitophilus oryzae* (L.) have been reported as major pests of stored rice and other cereals in many countries, especially tropical and sub-tropical countries (FEAKIN, 1971; GIRISH et al., 1974; SUKPRAKARN and TAUTHONG, 1981; PRAKASH et al., 1984; LIN, 1985). Although several investigations have been carried out to assess losses of rice and other grains caused by these 4 species (GIRISH et al., 1974; SCHULTEN, 1975; PRAKASH et al., 1981), no comparison of damage by the insects to rough and brown rice under identical laboratory experimental conditions has been made. This experiment

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was an attempt to assess losses of rough rice and brown rice, as stored seed or food, caused by the four insect species under a simulated tropical storage condition.

MATERIALS AND METHODS

Rice. The rice seed used was Indica type *Oryza sativa* (L.) (cv. Nankin 11, 1983 year crop) which was stored in a paper bag at room temperature (ca. 5–20°C) at Ibaraki Prefecture Agriculture Experimental Station for about 8 months. One-half of the seeds was shelled and transformed to brown rice; the other half was left intact as rough rice. Both types of rice were conditioned at the experimental condition of 30°C and 65% r.h. for 14 days before the experiment was initiated.

Insects. Stock cultures of *E. cautella*, *T. castaneum*, *R. dominica*, and *S. oryzae* had been maintained for many generations, the former two on wheat feed and the latter two on brown rice, at 25°C and 67% r.h. Newly hatched larvae of *E. cautella* were obtained by confining adult moths in a plastic container with a small quantity of wheat flour overnight, collecting eggs by passing the wheat flour through a 60-mesh sieve and incubating the eggs at 25°C for 5 days.

Experimental procedures. Rough rice weighing 175 g and brown rice weighing 145 g which corresponded to approximately 6,500 kernels, were separately placed in plastic containers (11 cm diameter and 6 cm deep). A 4-cm-diameter hole was made near the center of each container lid and covered with No. 5 Toyo filter paper. For the experiment with *S. oryzae*, the hole was first covered with 60-mesh brass screen before filter paper was placed over it. The experiments were replicated three times for each type of rice and each insect species; in total, 84 containers were used.

Twenty adults, less than 3 weeks old, of each insect species except *E. cautella* for which 20 newly hatched larvae were used, were introduced into each of the rice containers. The treated containers were kept in a growth chamber maintained at $30 \pm 0.5^\circ\text{C}$ and $65 \pm 0.5\%$ r.h. Identical insect-free sets, one of rough and the other brown rice, were kept in the same chamber as control. An additional set of similar control was kept in a cold room at $10 \pm 1^\circ\text{C}$ and 70% r.h.

Initially moisture content, percent germination and weight of 100 kernels of both rough and brown rice were determined. Thereafter, at each 2-week interval, a set of 3 containers from each treatment were taken out from the chamber for insect count, measurement of weight of 100 kernels, moisture content test, and germination test. Moisture content (wet weight basis) of rough and brown rice and germination of rough rice test by a paper towel method were determined by the procedures of the International Seed Testing Assoc. (ANON., 1966) except that only two replications of 100 seeds each and a constant 30°C were used for the germination test. Germination test of brown rice by the paper towel method was carried out at 25°C and only one seedling count was made on the 7th day. The rest of the procedures were the same as those for the rough rice test. Insects were counted by aspiration, sieving and hand sorting. Number of adults included both live and dead individuals and number of larvae included pupae. Generally, the number of pupae of each species was less than 5% of the number of larvae. Larval numbers were studied only for *E. cautella* and *T. castaneum*. For 100-kernel weight, 100 kernels were taken randomly and weighed with a Shimidzu analytical balance (Shimadzu Co., Kyoto, Japan); the weight was converted on a moisture basis of 14%. After evaluating the losses, the

Fig. 1. Mean number of adults of *Ephestia cautella*, *Tribolium castaneum*, *Rhyzopertha dominica* and *Sitophilus oryzae* in (a) rough rice and (b) brown rice. The ordinate has $\log_{10}(n+1)$ scale.

Fig. 2. Mean number of larvae of *Ephestia cautella* and *Tribolium castaneum* in (a) rough rice and (b) brown rice.

containers examined were discarded.

After week 12 the remaining unexamined containers were transferred from the growth chamber to a room at $30 \pm 0.5^\circ\text{C}$ and $70 \pm 12\%$ r.h. because of a malfunction in the humidifying unit of the chamber. Multiple comparisons of means were carried out by the protected LSD (JONES, 1984).

RESULTS AND DISCUSSION

Insect population

Increase in adult number in rough rice infested with all species was negligible, except in the *R. dominica* treatment (Fig. 1 a). Adults of *E. cautella* emerged after week 6 and at the end of the experiment the average number per container was less than 3, whereas comparable figures for *T. castaneum* and *S. oryzae* at that time were 32 and 30, respectively. Adults of *R. dominica* increased slightly after week 4 and sharply

after week 6 until week 12 when they peaked at 300. In contrast, the initial larval population number of *E. cautella* on rough rice had declined to zero at the end of the experiment (Fig. 2 a). In *T. castaneum* larvae appeared after week 2 and the peak of mean number was about 10 at week 6, then it generally decreased until the end of the experiment.

PRAKASH et al. (1984) ranked *E. cautella* as a minor pest of rough rice, although an earlier study concluded that it was a serious pest (Anon., 1977). On rough rice, the reproductive potential of *S. oryzae* is small (TAKAHASHI and MIZUNO, 1982), and the occurrence of *T. castaneum* usually follows infestation by the grain borer (PRAKASH et al., 1981). The slight increase of these two species on rough rice was probably due to the presence of broken grains in the containers, whereas *R. dominica* can exploit extremely narrow cracks and its larvae can penetrate the rice grains by boring along the center of the rachis (BRESE, 1960; FEAKIN, 1971). Nevertheless, the noticeably poor growth of the insect populations suggests that the rough rice of the variety used exhibited a strong resistance to these insect species.

In brown rice the adult population of the 3 beetles increased markedly after week 4 and by the end of the experiment the mean adult numbers of *R. dominica*, *S. oryzae* and *T. castaneum* were $4,561 \pm 134$ (S.E.), $1,631 \pm 245$, and 575 ± 66 per container, respectively (Fig. 1 b). Adults of *E. cautella* emerged after week 2; the number slightly fluctuated and the mean number at the end of the experiment was 70 ± 34 per container. The larval number of *E. cautella* in brown rice peaked twice at 525 ± 106 at week 6 and 443 ± 166 at week 10 (Fig. 2 b). In *T. castaneum* treatment the number of larvae increased markedly after the initial stage of the experiment and a maximum number of 529 ± 69 was attained at the end of the experiment.

Despite their higher rate of increase (HOWE, 1965), the adult numbers of *E. cautella* and *T. castaneum* were relatively lower than those of *S. oryzae* and *R. dominica* in brown rice. This phenomenon might have been caused by the difference of feeding habit of each species. Being germ- and bran-feeders, food might have been exhausted for *E. cautella* and *T. castaneum* at the later stage of the study, while *S. oryzae* and *R. dominica* could feed on the whole kernel during this period. The last drop in larval number of *E. cautella* in brown rice (Fig. 2 b) must have been due to exhaustion of food supply as in the case of adult insects.

Weight of 100 kernels

In rough rice, there was no decrease in the weight of 100 kernels in any of the treatments during the 14 weeks. There was no significant difference among treatments ($p > 0.05$) (Fig. 3).

In brown rice treatments, both controls more or less maintained their original weight throughout the experimental period. In all insect infested treatments, weight of 100 kernels began to decrease after week 4 and the reduction continued rather evenly until the end; *R. dominica* treatment alone caused an accelerated rate of decrease after week 8 (Fig. 3). At the end of the experiment the mean weights of 100 kernels of all insect-infested treatments were significantly lower than those of both controls ($p < 0.01$). Among the four insect-infested treatments, the weight of kernels from *R. dominica* was significantly lowest ($p < 0.01$), indicating that this species was the most injurious pest of brown rice in terms of loss in weight. The brown rice lost 40, 19, 14, and 10% of initial kernel weight over 14 weeks by the feeding of *R. dominica*, *S. oryzae*, *T. castaneum*, and

Fig. 3. Mean weight of 100 kernels of rough and brown rice based on 14% moisture content in controls, *Ephestia cautella*, *Tribolium castaneum*, *Rhyzopertha dominica* and *Sitophilus oryzae* treatments.

Fig. 4. Mean moisture content percentages (wet weight basis) of (a) rough rice and (b) brown rice in controls, *Ephestia cautella*, *Tribolium castaneum*, *Rhyzopertha dominica* and *Sitophilus oryzae* treatments.

E. cautella, respectively. Weight loss of grains may be dependent not only on the insect number but also on the amount of food consumption per individual of each species.

Moisture content

The results were assessed up to week 12, when the containers were transferred to the room at 30°C and 70% r.h.

In rough rice the pattern of moisture content changes in infested grains and controls generally followed a similar trend (Fig. 4 a). A drop in moisture content of all treatments including brown rice treatments at week 12 was assumed to be the result of the malfunction of the chamber which might have occurred at week 10 and gone unnoticed.

Fig. 5. Mean germination percentages of rough rice and brown rice in controls, *Ephesia cautella*, *Tribolium castaneum*, *Rhyzopertha dominica* and *Sitophilus oryzae* treatments.

The trend of moisture content of the cold-room-control was considerably higher than that of other treatments as was anticipated because of the higher relative humidity (70% r.h.). Despite such fluctuation, the results indicate that moisture content of rough rice was unaffected in all insect-infested treatments.

The moisture content of brown rice in the *R. dominica* treatment began to increase after week 2 and that in *T. castaneum* and *S. oryzae* treatments after week 6 (Fig. 4 b). In the control and *E. cautella* treatments, moisture content of brown rice gradually decreased up to week 12, indicating that the grain moisture content was not equilibrated at the beginning of the experiment with the relatively short conditioning period of 2 weeks. In cold-room-control, moisture content of the brown rice gradually increased until the end of the experiment. Statistical analysis attempted at week 12 indicates that the mean moisture content of brown rice of the control treatment in the growth chamber was significantly lower than that of any other treatment ($p < 0.01$). Among other treatments moisture content with *R. dominica* was significantly higher than the rest, and that with *S. oryzae* was significantly higher than with both *E. cautella* and *T. castaneum*.

The insect growth affected the moisture content of brown rice in varying degrees, depending on species. Brown rice infested with *R. dominica* was most affected followed by *S. oryzae*, *T. castaneum* and *E. cautella* in decreasing order. Metabolic activity of insects could possibly increase the moisture content of the rice. In other studies wheat seeds infested with *S. oryzae* (IMURA and SINHA, 1984; SINHA, 1984) and a combination of *R. dominica*, *S. oryzae* and *T. castaneum* (WHITE and SINHA, 1980) also increased moisture content significantly over the controls. However, *E. cautella* and another moth species, *Plodia interpunctella*, did not affect the moisture content of wheat grains which were stored at 30°C and 70% r.h. for 20 weeks (DEMIANYK and SINHA, 1981).

Germinability

There was a small variation of germination percentage of rough rice (Fig. 5). At the end of the experiment, germination of all treatments, except the cold room-control

which maintained its initial viability, decreased by about 5–6%. However, no significant difference occurred among the treatments of rough rice ($p > 0.05$).

In brown rice a drastic reduction in germinability was recorded (Fig. 5). The grains in all insect-infested treatments lost their germinability immediately after the initiation of the experiment, especially in *E. cautella* treatment. However, a sharp decrease was observed after weeks 4 and 6 and the rate of decrease was progressive until the end of the experiment when no germinability of more than 2% was recorded. Although the seeds in growth-chamber-control also lost their germinability, the rate of decline was not as rapid as those of other treatments under the same conditions, and their percentage at the end of the experiment was significantly higher than those of insect-infested treatments ($p < 0.01$). The cold-room-control maintained its initial viability throughout the study period.

E. cautella and *T. castaneum* normally feed on germ and bran, therefore, germinability of the brown rice infested with these species dropped more rapidly than that of the grains infested by *R. dominica* and *S. oryzae* which normally feed on endosperm. For the latter two species, however, the rates of decrease were accelerated after week 6 when more parts of the kernels were eaten. The results reveal a clear picture of the detrimental effect of insect feeding on brown rice viability. Increased moisture content may also have accelerated the loss of seed viability (ROBERTS, 1972). Similar results were observed in wheat infested with the same species; wheat infested with *T. castaneum* (LUSTIG et al., 1977) and with *S. oryzae* (SINHA, 1984) virtually lost germinability completely in 15 weeks. DEMIANYK and SINHA (1981) observed that wheat with dockage infested with *E. cautella* lost viability completely in 11 weeks.

Conclusions

Development of rational and widely acceptable methods for the loss assessment of stored grains is a pressing problem in postharvest loss reduction programs (HARRIS and LINDBLAD, 1978). In rough rice, no variable measured revealed substantial losses by all treatments, whereas in the insect-infested brown rice treatments, damage was detected in all variables. However, the losses assessed by the different variables varied with the insect species and density and the storage period. Among the variables, moisture content is not a sensitive indicator of grain damage when the insect densities are relatively low, while germinability is a sensitive measure for detecting grain damage, especially when the grain is infested with germ-feeders such as *E. cautella* and *T. castaneum*. The weight of 100 kernels reflected the insect numbers effectively. This measure is more important for the grains infested with *R. dominica* and *S. oryzae*. As BOXALL (1986) stated, there can be no single best method for assessing losses. It is important to understand the features of each assessment measure and to choose the most appropriate one(s) depending on objectives and situations.

The quality of rough rice was not substantially affected by the presence of any insect species used in the study, suggesting a high resistance of Nankin 11 rough rice to insect infestation. Resistance of rice seeds to attack by stored grain insects has been observed (BRESE, 1960; COHEN and RUSSELL, 1970; COGBURN, 1974; PENG et al., 1983; PRAKASH, 1982). Different cultivars, however, exhibit different degrees of resistance. The degree of resistance relates to the hardness of kernel, presence and nature of the hull, and nutritional value of the cereals (HORBER, 1983). It is apparent that physical properties of the hull were a main factor in the resistance of the seed to the insect species

because brown rice of the same cultivar was damaged severely by the same insects. Although no comparison among rice cultivars was made in this study, it is possible to conclude that Nankin 11, which has a tightly-closed lemma and palea, had a relatively high degree of resistance to most of the species investigated. Rough rice with a resistant cultivar such as Nankin 11 could be stored in good condition without specific control measures in tropical areas.

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REFERENCES

- ADAMS, J. M. (1977) Post-harvest losses in cereals and pulses—the results of a questionnaire survey, June 1976. *Trop. stored Prod. Inf.* **34**: 23–47.
- ANON. (1966) International rules for seed testing. *Proc. Inter. Seed Testing Assoc.* **31**: 1–152.
- ANON. (1977) *Stored Grain Insects*. Agriculture Handbook. No. 500, U.S.D.A., Washington, D.C., 57 pp.
- BOXALL, R. A. (1986) *A Critical Review of the Methodology for Assessing Farm-level Grain Losses after Harvest*. G191, Trop. Devel. Res. Inst., London, 139 pp.
- BREESE, M. H. (1960) The infestibility of stored paddy by *Sitophilus sasakii* (TAK.) and *Rhyzopertha dominica* (F.). *Bull. Ent. Res.* **51**: 599–630.
- COGBURN, R. R. (1974) Domestic rice varieties: apparent resistance to rice weevils, lesser grain borers, and Angoumois grain moths. *Environ. Entomol.* **3**: 681–685.
- COHEN, L. M. and M. P. RUSSELL (1970) Some effects of rice varieties on the biology of the Angoumois grain moth, *Sitotroga cerealella*. *Ann. Entomol. Soc. Am.* **63**: 930–931.
- DEMIANYK, C. J. and R. N. SINHA (1981) Effect of pyralid moth infestation on fat acidity, seed germination and microflora of stored wheat. *J. Econ. Entomol.* **74**: 526–531.
- FEAKIN, S. D. (1971) *Pest Control in Rice*. 2nd ed. Trop. Pest. Res. Headquarters and Information Unit, London.
- GIRISH, G. K., B. P. TRIPATHI, R. P. S. TOMER and K. KRISHNAMURTHY (1974) Studies on the assessment of losses IV. Conventional grain storage practices and losses in rural areas in Uttar Pradesh. *Bull. Grain Tech.* **12**: 199–210.
- HARRIS, K. L. and C. J. LINDBLAD (Compilers) (1978) *Post-harvest Grain Loss Assessment Methods*. American Association of Cereal Chemists, 193 pp.
- HORBER, E. (1983) Principles, problems, progress and potential in host resistance to stored-grain insects. *Proc. 3rd. Int. Work. Conf. Stored Prod. Ent.*, Manhattan, pp. 391–417.
- HOWE, R. W. (1965) A summary of estimates of optimal and minimal conditions for population increase of some stored product insects. *J. stored Prod. Res.* **1**: 177–184.
- IMURA, O. and R. N. SINHA (1984) Effect of infestation by *Sitotroga cerealella* (Lepidoptera: Gelechiidae) and *Sitophilus oryzae* (Coleoptera: Curculionidae) on the deterioration of bagged wheat. *Environ. Entomol.* **13**: 1471–1477.
- JONES, D. (1984) Use, misuse, and role of multiple-comparison procedures in ecological and agricultural entomology. *Environ. Entomol.* **13**: 635–649.
- LIN, T. (1985) Insect pests of granary. In *Ecology and Control of Stored-rice Pests in Taiwan, Republic of China* (W. K. PENG, ed.). Dept. Plant Pathol. Ent., Natn. Taiwan Univ., Taipei, pp. 2–18 (in Chinese).
- LUSTIG, K., N. D. G. WHITE and R. N. SINHA (1977) Effect of *Tribolium castaneum* infestation on fat acidity, seed germination, and microflora of stored wheat. *Environ. Entomol.* **6**: 827–832.

- PENG, W. K., S. J. HSU and K. K. HO (1983) Studies on the varietal resistance of rice to the rice weevil, *Sitophilus oryzae* (L.). *Phytopathologist and Entomologist, NTU* **10**: 27–38 (in Chinese with an English summary).
- PRAKASH, A. (1982) Varietal resistance of stored rice grains to *Phyzopertha dominica* FABR. (Coleoptera: Bostrychidae). *Uttar Pradesh J. Zool.* **2**: 89–92.
- PRAKASH, A., I. C. PASALU and K. C. MATHUR (1981) Population fluctuations of insect pests in stored paddy under natural and controlled conditions. *Oryza* **18**: 90–92.
- PRAKASH, A., I. C. PASALU and J. RAO (1984) The pest status of insects infesting rice stored in Orissa, India. *Trop. stored Prod. Inf.* **47**: 15–20.
- ROBERTS, E. H. (1972) Storage environment and control of viability. In *Viability of Seeds* (E. H. ROBERTS, ed.). Chapman and Hall, London, pp. 14–58.
- SAUNDERS, R. M., A. P. MOSSMAN, T. WASSERMAN and E. C. BEAGLE (1980) *Rice Post-harvest Losses in Developing Countries*. U.S.D.A. ARM-W-12, Oakland, 227 pp.
- SCHULTEN, G. G. M. (1975) Losses in stored maize in Malawi (C. Africa) and work undertaken to prevent them. *EPPO Bull.* **5**: 113–120.
- SCHULTEN, G. G. M. (1982) Post-harvest losses in tropical Africa and their prevention. *Food and Nutrition Bulletin* **4** (2): 2–9.
- SINHA, R. N. (1984) Effects of weevil (Coleoptella: Curculionidae) infestation on abiotic and biotic quality of stored wheat. *J. Econ. Entomol.* **77**: 1483–1488.
- SUKPRAKARN, C. and P. TAUTHONG (1981) Stored product insects research in Thailand. *Biotrop Spec. Publ.* No. 9: 77–86.
- TAKAHASHI, F. and H. MIZUNO (1982) Infestation of rice weevils in rice grain in relation to drying procedures after harvest and the form of the grain at different stages in the milling process. *Environ. Control in Biol.* **20**: 9–16.
- WHITE, G. D. (1953) Weight loss in stored wheat caused by insect feeding. *J. Econ. Entomol.* **46**: 609–610.
- WHITE, N. D. G. and R. N. SINHA (1980) Changes in stored-wheat ecosystems infested with two combinations of insect species. *Can. J. Zool.* **58**: 1524–1534.