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Influence of Initial Pest Density on the Survival and Development of *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) in Broken grains of Three Physiological types of Pearl Millet and Nine Cultivars of Wet Season Sorghum

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ABSTRACT

The effects of three pest densities (5, 10 and 15 pairs of adult beetles/5 g of broken grains) on the survival and development of rust-red flour beetle (*Tribolium castaneum*) using cereal diets processed from three physiologically different millets and nine sorghum cultivars were assessed under tropical storage conditions. The maiwa millet diet was the most preferred both for survival and progeny development of *T. castaneum* in comparison with dauro and gero millets. The proportion of adult beetles that died and the mean number of larval and adult progeny that developed on a maiwa diet were 30.8% and 52.3, respectively. Comparable figures for dauro and gero millets were 37.4% and 49.0, and 48.1% and 25.7, respectively. The initial pest density of 30 adult beetles/5 g of broken grains significantly suppressed progeny development in millet in comparison with development at pest density of 10 or 20 adult beetles/5 g of broken grains. The mean numbers of *T. castaneum* progeny that developed at the pest densities of 10, 20 and 30 adult beetles/5 g of broken millet grains were 44.4, 44.3 and 38.4, respectively. In sorghum, the proportion of *T. castaneum* adults that died (46.5%) was significantly higher in broken grains of Chakalari-red than in those of any of the other cultivars except Jarma-jos. Mortality of adult flour beetles was lowest (15.9%) in broken grains of Jigari-red. Mean number of *T. castaneum* progeny that developed in broken sorghum grains ranged, on average, from 34.0 in Tumbuna-fadama to 43.7 in Chakalari-red. In contrast, progeny development in sorghum increased significantly with increasing initial pest density being 29.3, 39.4 and 48.5 at pest densities of 10, 20 and 30 adult beetles/5 g of broken grains, respectively.

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INTRODUCTION

Pearl millet, *Pennisetum glaucum* (L.) R. Br., and sorghum, *Sorghum bicolor* (L.) Moench are two of the world's most important cereals. Africa produces a third of the world's total output of millet on a land area of 15 million hectares (FAO, 1985). These cereals constitute the staple food in the drier parts of tropical Africa, India and China (Purseglove, 1988). Their merit is that they thrive on poor sandy soils in low rainfall areas in the West African savanna. In Nigeria, over 5 million hectares are planted to millet annually (Agboola, 1979).

Millet and sorghum grains are used as feed for poultry and other livestock (Purseglove, 1988). They are also used to produce malt and in Africa the malted seed is an important source of beer. Sorghum grains are, however, more valuable for brewing beer and so are widely used for this purpose particularly in Africa. In recent times, sorghum has become especially important as a source of malt for beer in Nigeria because of import restrictions on barley. This has encouraged many farmers to increase the land area under sorghum cultivation and this has, in turn, led to the storage of large quantities of sorghum grain by grain merchants to meet the demands of brewing companies in the country. Dark-coloured bitter grains are usually preferred for brewing (Purseglove, 1988). Of the 4.6 million tonnes of millet grains produced annually in Nigeria from 1992 to 1994, for instance, ICRISAT/FAO (1996) reported that 3.3 million tonnes were used as food for humans, 1.2 million tonnes were used for seed and brewing beer, and only 0.1 million tonnes were used as feed for livestock.

Different types of pearl millet are cultivated in West Africa. Pearl millet cultivars are often classified into three main physiological types based on photosensitivity and time taken from sowing to maturity (Cobley and Steele, 1976; Purseglove, 1988), and include photosensitive, short-day; photosensitive, long-day; and non-photosensitive, day-neutral cultivars. In Nigeria, three types of pearl millet known locally as gero, maiwa and dauro, belonging to two physiological groups, are commonly grown, and their agronomic characteristics have been enunciated by Ikwelle (1998). Gero is day-neutral and early-maturing, taking only 70-100 days from sowing to harvest. It is cultivated mostly in the Sahel savanna where the wet season is shortest, although it is grown on a much smaller scale in the Sudan and northern Guinea savanna areas. Maiwa is photosensitive, long-day and late-maturing (120-280 days). It is mostly grown in the southern and northern Guinea savanna areas. Dauro, like maiwa, is photosensitive, long-day and late-maturing. Unlike maiwa, however, it is a transplanted millet cultivated in restricted areas of the southern Guinea savanna. Many cultivars of sorghum are also available in Africa, India, the United States of America, and elsewhere

(Purseglove, 1988) and new cultivars are being produced all the time. Local cultivars have usually developed adaptation to their environment, often with resistance or tolerance to local diseases and pests especially in the field, and will survive and give some yield every season even when grown under infertile conditions (Purseglove, 1988). Many local sorghum cultivars of wet season sorghum are available in Nigeria.

Both crops are usually threshed before the grains are stored, and threshing consists of pounding harvested millet heads or sorghum panicles with a pestle in a mortar and then winnowing. The seed coat is usually removed by soaking or damping the grain and pounding it gently, with frequent winnowing to remove the bran (the process known as polishing) before milling into flour. These processes cause varying degrees of grain breakage and this predisposes grains to infestation by the rust-red flour beetle, *Tribolium castaneum* (Herbst) and other secondary insect pests (Lale and Yusuf, 2001). Recently, the influence of grain breakage and processing method on the relative susceptibility of cultivars of gero millet or different cultivars of dry season (Masakwa) sorghum was investigated (Lale and Yusuf, 2001; Lale *et al.*, 2002). In this study, the influence of pest density at commencement of infestation on the survival and development of *T. castaneum* in broken grains of three physiological types of pearl millet or nine cultivars of wet season sorghum, was investigated.

MATERIALS AND METHODS

Insect rearing and sources of seeds

The colony of *T. castaneum* used for the study was established from a batch of millet obtained from Maiduguri, northeastern Nigeria and was subsequently reared on broken grains of a locally available cultivar of gero millet (cv. Ex-borno) and whole flour derived from the same cultivar under prevailing storage conditions (32-35°C and 60-65% r. h.). The experiment was also conducted under these conditions. The three pearl millet types used for the study were obtained from different sources: gero millet (cv. Ex-borno) was obtained from Lake Chad Research Institute, Maiduguri, Nigeria; maiwa (cv. Potiskum local) and dauro (Kafanchan local) millets were obtained from Institute for Agricultural Research, Samaru, Nigeria. The nine wet season cultivars of sorghum were obtained from Borno State Agricultural Development Programme, Maiduguri, Nigeria.

Experimental procedure

Broken grains were produced from a batch of each millet type and sorghum cultivar by pounding gently with a pestle in a mortar. Five grammes of broken grains of

each millet type and sorghum cultivar were then weighed into a 100-ml glass jar and infested with 5, 10 or 15 pairs of 3 to 5-day old *T. castaneum* adults. Adult flour beetles were sexed by relying entirely on the relative sizes of the sexes: females are larger than males (Haines, 1991). The experiment was set up as a randomized complete block design with initial pest density and millet type and sorghum cultivar as factors. Treatments were replicated three times. Female beetles were allowed to lay eggs for 20 days after which all insects were removed. On day 20, the number of beetles that died in each replicate was counted and expressed as a percentage of the number introduced in each glass jar. On day 40, the larval and adult progeny that developed in each jar were counted together.

Statistical analysis

Data obtained were subjected to two-way analysis of variance and differences between means were determined using the least significant difference (LSD) statistic at appropriate levels of probability ($P \leq 0.05$).

RESULTS

Survival of adult flour beetles

Different levels of mortality occurred in adult flour beetles that fed on the cereal diets obtained from the different types of millet and cultivars of wet season sorghum. In pearl millet, a significantly higher percentage of adult *T. castaneum* died in broken grains derived from gero millet than in those derived from maiwa or dauro millet, and a considerably higher percentage of adult flour beetles died in broken grains derived from dauro millet than in those derived from maiwa millet (Table 1). Table 1 also shows that a lower percentage of the beetles died in broken millet grains initially infested with 10 adult beetles than in those infested with 20 or 30 adult beetles but the difference was not significant ($P > 0.05$). There was no significant interaction between initial density of the beetle and cereal diet.

Table 2 shows that a significantly higher percentage of the beetles died in broken grains derived from sorghum cultivar Chakalari-red, Jarma-jos or Kilburi than in broken sorghum grains derived from Tumbuna-fadama, Kafimoro, Jigari-white, Jigari-red or Chakalari-white. A significantly higher proportion of the beetles died in broken grains derived from Chakalari-red than in broken grains derived from any of the other sorghum cultivars except Jarma-jos. Percentage mortality was lowest in broken grains of Jigari-red.

Table 1. Mean percentage of *Tribolium castaneum* adults that died in broken grains obtained from three pearl millets after 20 days

	Initial pest density (no. of adult beetles/5 g of grain)			
Millet type	10	20	30	Mean
Maiwa	26.0	33.0	33.3	30.8
Dauro	34.0	39.0	39.3	37.4
Gero	44.0	49.0	51.3	48.1
Mean	34.7	40.3	41.3	

SED = 4.2, LSD (P = 0.05) = 8.7 (Millet type); SED = 4.2, LSD ($P > 0.05$) (Initial density); SED = 7.2, LSD ($P > 0.05$) (Interaction)

Table 2. Mean percentage of *Tribolium castaneum* adults that died in broken grains obtained from nine cultivars of wet season sorghum after 20 days

	Initial pest density (no. of adult beetles/5 g of grain)			
Sorghum cultivar	10	20	30	Mean
Tumbuna-fadama	33.3	21.7	15.6	23.5
BES	36.7	36.7	20.0	31.1
Kilburi	50.0	31.7	31.1	37.6
Farma-jos	56.7	41.7	36.7	45.0
Kafimoro	40.0	12.2	22.2	24.8
Igari-white	23.3	16.7	23.3	21.1
Igari-red	16.7	16.7	14.4	15.9
Chakalari-white	36.7	26.7	15.6	26.3
Chakalari-red	53.3	45.0	41.1	46.5
Mean	38.5	27.7	24.4	

SED = 5.3, LSD (P = 0.05) = 10.7 (Sorghum cultivar); SED = 3.1, LSD (P = 0.01) = 8.2 (Initial density); SED = 9.2, LSD (P = 0.05) = 18.5 (Interaction)

Progeny development

Gero millet, on average, supported significantly fewer larval and adult *T. castaneum* progenies than Maiwa or Dauro; and significantly fewer *T. castaneum* larvae and adults developed in dauro grains than in maiwa grains (Table 3). Millet grains which were infested initially with 30 adult flour beetles, on average, supported significantly fewer larval and adult progenies than millet grains that were infested initially with 10 or 20 adult beetles. There was no significant interaction between pest density and cereal diet (Table 3).

Table 4 shows that sorghum cultivar Tumbuna-fadama supported a lower number of *T. castaneum* progenies than any of the other cultivars ex

Kafimoro and Jigari-white. Mean number of *T. castaneum* progenies that developed in broken sorghum grains was highest in Chakalri-red. Progeny development in sorghum, on average, increased significantly with increasing initial pest density. With the exceptions of Jigari-white and Chakalari-white, each of the sorghum cultivars interacted significantly with pest density: *T. castaneum* progeny development in each of these cultivars increased significantly with increasing pest density (Table 4).

Table 3. Mean number of *Tribolium castaneum* adult and larval progenies that developed in broken grains obtained from three pearl millets

	Initial pest density (no. of adult beetles/5 g of grain)			
Millet type	10	20	30	Mean
Maiwa	56.8	54.8	45.4	52.3
Dauro	49.0	52.2	45.8	49.0
Gero	27.4	25.8	24.0	25.7
Mean	44.4	44.3	38.4	

SED = 1.7, LSD (P = 0.05) = 3.4 (Millet type); SED = 1.7, LSD (P = 0.05) = 3.4 (Initial density); SED = 2.9, LSD (P = 0.05) = 5.8 (Interaction)

Table 4. Mean number of *Tribolium castaneum* adult and larval progenies that developed in broken grains obtained from nine cultivars of wet season sorghum

	Initial pest density (no. of adult beetles/5 g of grain)			
Sorghum cultivar	10	20	30	Mean
Tumbuna-fadama	25.0	31.0	46.0	34.0
BES	32.7	42.3	53.3	42.8
Kilburi	26.3	41.0	49.7	39.0
Jarma-jos	28.0	40.3	50.3	39.6
Kafimoro	25.7	35.3	45.7	35.6
Jigari-white	26.3	38.3	43.0	35.9
Jigari-red	28.7	41.3	51.0	40.3
Chakalari-white	34.7	42.3	45.3	40.8
Chakalari-red	36.0	43.0	52.0	43.7
Mean	29.3	39.4	48.5	

SED = 2.0, LSD (P = 0.05) = 4.0 (Sorghum cultivar); SED = 1.2, LSD (P = 0.01) = 3.1 (Initial density); SED = 3.5, LSD (P = 0.05) = 6.9 (Interaction)

DISCUSSION

The results of the present study have shown that maiwa millet is a more suitable medium for the development and survival of *T. castaneum* than dauro and gero millets as the levels of mortality of adult flour beetles and mean numbers of progeny that developed in the different diets indicate. The study has also shown that increasing the initial pest density from 10 or 20 to 30 adult beetles/5 g of broken grains significantly suppressed development of *T. castaneum* in pearl millet. It is already well established that different substrates support differential levels of development of *T. castaneum*. In an earlier study, Lale and Yusuf (2001), for instance, reported that broken grains of gero millet cultivar Zimbabwean dwarf supported a significantly higher number of *T. castaneum* progenies than ICMV-N89305 after a 40-day storage period. Intraspecific competition is also known to adversely affect progeny development and this and cannibalism are often responsible for high mortalities especially in populations of flour beetles (Haines, 1991).

These results are of particular significance in Nigerian agriculture because of the varying agroecologies in which the three pearl millet types are cultivated and the fact that their produce is stored for varying lengths of time across the country. Gero millet which is cultivated mostly in the Sahel savanna where the environmental conditions are harsh for the optimum development and survival of *T. castaneum*, has been shown to be more resistant to infestation by this beetle. The implication is that maiwa and dauro millets which are cultivated in the Guinea savanna where the temperature and humidity are generally more favourable than they are in the Sahel savanna would be at a greater risk of infestation by *T. castaneum* in storage. The extent of the risk of infestation will, however, depend on the level of grain breakage accompanying threshing and polishing (Haines, 1991; Throne, 1993; Dudu *et al.*, 1996; Lale and Yusuf, 2001; Lale *et al.*, 2002). The results for pearl millet should, however, be interpreted with caution since single cultivars of the three millet types were used for the present investigation. Different cultivars of each millet type are likely to exhibit different levels of susceptibility to infestation by *T. castaneum*.

The study has also revealed that wet season sorghum cultivars have different levels of susceptibility to *T. castaneum* infestation. The mean number of progenies that developed in Chakalari-red was 43.7 whereas Tumbuna-fadama supported a mean number of 34.0 progenies during the 40-day storage period. Lale *et al.* (2002) screened 10 cultivars of dry season sorghum for susceptibility to *T. castaneum* infestation and also observed differences in susceptibility between the sorghum cultivars. It is known that damaged cereal grains release some volatile compounds and these facilitate the

attraction of secondary pests by broken grains (Thanedaru *et al.*, [illegible] *et al.*, 2000). It is not known, however, whether sorghum cultivars Chadi and millet cultivars have higher levels of these attractant chemicals than the [illegible] season sorghum or the other physiological types of millet. Sorghum [illegible] has been found to contain phenolic compounds which confer on them some degree [illegible] to infestation by stored-product pest beetles (Gwinner *et al.*, 1996). [illegible] uncertain whether sorghum cultivars such as Tandoumafiama, Kaffimoro and [illegible] while millet cultivars which supported the lowest number of *T. castaneum* progeny contain higher levels of these soluble phenolic compounds than the other cultivars.

The overall effect of pest density at the commencement of infestation on the development of *T. castaneum* differed amongst the cereal types. In millet, progeny development was suppressed significantly at the density of 30 adult beetles per 100 g of broken grains. In contrast, progeny development in sorghum cultivars increased as the pest density increased. The reason for the observed difference in the effect of pest density of *T. castaneum* in the different cereals is not known. It is perhaps possible that millet which is nutritionally of a lower status than sorghum (Dobley and Brue, 1943; Purseglove, 1988) may have been depleted of its nutrients faster than sorghum at the high density of infestation. This, coupled with intraspecific competition and accumulation of toxic metabolic products and benzoquinones may have resulted in the low level of progeny number. Intraspecific competition in *T. castaneum* is known to decimate populations of this beetle through the cannibalism of smaller larvae by larger larvae and adults (Haines, 1991).

The findings of this study have serious implications for the storage of these cereals in tropical Africa and Asia where these cereals constitute the staple food of the people. First, there is an urgent need for the modification of current threshing and polishing practices and the adoption of modern methods in order to reduce grain breakage. *T. castaneum* being a secondary pest will find sound grains more difficult to infest in storage. Undamaged cereal grains are relatively resistant to infestation by secondary storage pests (Haines, 1991). However, millet and sorghum grains are normally milled into whole flour or after the bran has been removed, into polished flour and stored for differing lengths of time. This practice is likely to aggravate the problem of infestation by secondary storage pests. Gueye and Delobel (1999) reported that food products prepared from flour derived from pearl millet were infested more than whole millet kernels by four secondary pests comprising *T. castaneum*, *Tribolium confusum* J. du Val, *Corcyra cephalonica* (Stainton) and *Ephestia cautella* (Walker). Lale and Yusuf (2001) reported that the susceptibility of flour derived from gero millet cultivars was

higher than that of whole or broken grains. Similar observations were made by Lale *et al.* (1992) in a study involving cultivars of dry season sorghum. It may therefore be necessary to discourage farmers and food handlers in tropical Africa and Asia from the preparation and storage of ready-to-use cereal products for prolonged periods. Alternatively, measures should be taken to protect such products in storage. The application of *Piper guineense* Schum. and Thonn. seed oil to broken grains of gero millet or whole gero millet seeds before milling into flour has been shown to significantly reduce infestation of these products by *T. castaneum* compared to the level of infestation in products obtained from untreated seeds (Lale and Yusuf, 2001).

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