Development and non-preference of *Sitophilus zeamais* on 'stackburnt' maize

D P Giga and J Canhao[1]

Abstract

Maize stackburn has emerged as a significant threat to food security in sub-Saharan Africa in the last decade resulting in significant losses commercially stored maize Stackburnt maize is characterised by a moderate to severe reddish-brown discoloration of the kernel and germ of maize resulting from heat build-up in the interior of polypropylene bag stacks Stackburn causes a reduction in the nutritional value of the grain

A comparative study of the development of the maize weevil, *Sitophilus zeamais*, on normal and stack burnt maize showed significant differences in progeny emergence, mean duration of development and indices of susceptibility between the two maize types An index of susceptibility of 12 34 ± 0 14 was recorded for normal maize while that for stackburnt maize was 9 29 ± 0 10

In free-choice tests weevils strongly selected normal maize, including adults which had been conditioned on stackburnt maize

Introduction

In Zimbabwe, large quantities of white maize (more than 1 2 million tonnes, annually) are successfully stored outdoors in modular 5000 tonne stacks These are built on a dunnage of poles and are covered with tarpaulins Woven polypropylene sacks have replaced jute sacks (in the late 1980s) and are now used for maize storage

During recent years, coinciding with the introduction of woven polypropylene sacks, maize throughout the centre of some bagstacks have been found to be discoloured from a light tan through to a dark red-brown colour after storage (Tyler, 1992) The discoloration, termed stackburn, results in the affected maize being downgraded with attendant financial losses Stackburn has also occurred frequently in food aid maize in several countries including Angola, Mozambique, Swaziland and Zambia (Phillips and Donaldson, 1994)

The characteristic discoloration of the germ and pericarp represents a form of heat damage and is recognised as a feature of 'dry grain heating' as distinct from the well known 'damp grain heating' (Tyler, 1992) Experimental data from the Natural Resources Institute (NRI) has shown that the discoloration results from moisture and temperature dependent chemical reactions, part of which may be non-enzymic browning (Phillips and Donaldson, 1994) Increased discoloration is characterised by a reduction in lysine and a conversion of sucrose to reducing sugars which may subsequently act as reactants in further chemical complexes Stackburning of maize causes a reduction in the nutritive value for all classes of livestock and can be predicted to do so for humans as well Panigrahi et al (1996) In the case of insects, *Sitophilus zeamais* and *Tribolium castaneum* development times, survival of F1 progeny and multiplication rates were adversely affected on stackburnt maize when compared to normal maize (Giga, 1995, Tanyongana and Nyanongo 1995)

Experimental stack data from Zimbabwe has shown that stackburn progression is characterised by rapid internal heating of polypropylene bagstacks to a maximum of 40℃ and maintenance of temperatures at this level, with only minor fluctuations, throughout storage (Conway, 1996) The causes of the rapid built up of internal stack temperatures are unclear, though insects have been implicated (Kennedy and Devereau, 1994, Conway, 1996) Kennedy and Devereau (1994) also observed a temperature limit of 40℃ in stacks followed by cooling after fumigations to varying degrees in experimental stacks The lethal temperature for *Sitophilus* spp and *Tribolium* spp , the insects which were found in greatest numbers in the samples, are reported by various authors (Howe, 1962a, Reddy, 1950) as 35 – 40℃

Howe (1962b) proposed a process by which insect heating in grain may progress An insect infestation in the grain respires and produces heat, causing a rise in temperature which in turn increases the reproductive rate and metabolic rate of the insects The infestation thus grows at an accelerating rate, releasing heat at an accelerating rate and resulting in greater temperature rises This process continues until the temperature becomes unfavourable for the insects and they either migrate or die

Whether the insects migrate back into stackburnt grain

[1] Department of Crop Science, University of Zimbabwe

once cooled is not known The objectives of this study were i) to determine whether *S zeamais* adults, in laboratory choice tests, showed any preference for stackburnt maize and ii) to compare the development of the insect on stackburnt and normal maize

Materials and Methods

Samples of stackburnt and normal maize were collected from the Grain Marketing Board Depot in Mvurwi for the experiments The maize was stored in a cold room and prior to the start of the experiments, subsamples were withdrawn and frozen for two weeks to disinfest the grain Thereafter, the grain was equilibrated to 70% r h and 28℃ Experiments were conducted in sealed plastic boxes placed in an incubator set at the experimental temperature The humidity was maintained using sodium chloride solutions

Development and indices of susceptibility

Fifty grams of maize were placed in small glass jars for each maize type and infested with 15 pairs (15 males and 15 females) of newly emerged (approximately 1-week old) adults The insects were left to oviposit on the grain for one week under the experimental conditions and after three weeks daily observations were made noting the daily emergences By recording the daily emergences the mean development times of the emerged insects from the time of infestation were calculated An index of susceptibility for the two maize types was calculated using the formula (Dobie, 1974)

Index = {ln no progeny}/mean development time × 100

The experiment was replicated ten times

Choice experiments: Preference/non-preference tests

A series of choice tests were conducted to determine whether there are any differences in the selection of normal and stackburnt maize by weevils that had received different conditioning treatments The following tests were performed

i) white vs stackburn maize using unconditioned weevils,
ii) yellow vs stackburn maize using unconditioned weevils,
iii) white vs stackburn maize using weevils conditioned on white maize,
iv) white vs stackburn maize using weevils conditioned on stackburn maize,
iv) white vs stackburn maize using a mixture (1 1 ratio) of weevils conditioned on white and stackburn maize

All tests were conducted at 28℃ in sealed plastic boxes (35cm × 14cm × 13cm) using maize equilibrated at 70% r h and 28℃ The weevils were conditioned on the appropriate maize types under the experimental conditions for three days before use in the tests

In each case, one petridish (9cm diameter) filled with normal maize and another with stackburnt maize were placed at opposite ends of the plastic boxes to which fifty weevils were introduced in the centre The boxes were then sealed and immediately placed in darkness in an incubator The numbers of weevils inside the petridishes containing the two types of maize and outside the dishes were counted 1, 2, 4, 8 and 24 hours after introduction Five replicates of each treatment were set up with the experiment being repeated twice Thus there were ten replicates for each treatment

Results and Discussion

Development and Indices of Susceptibility

The mean development period (days), mean number of adults emerged and the mean susceptibility indices are shown in Table 1 Comparisons of data using Student t-tests showed significant differences ($p < 0\ 01$) between the two maize types for all the parameters measured Development times of weevils were significantly longer on stackburnt maize with significantly fewer insects developing on this maize Similarly the index of susceptibility of stackburn maize (9 29) was significantly lower than normal maize (12 34) These data indicate that stackburnt maize is nutritionally 'inferior' for weevil development and survival Other workers (Tanyongana and Nyanongo, 1996, Allotey and Odamtten, 1996) have shown multiplication rates of several species of storage insects to be significantly lower on stackburnt maize compared to normal maize Whether this difference was due to increased development times on stackburn maize or reduced oviposition in the more 'brittle' stackburn maize is not known Since the stackburnt maize was equilibrated to the same moisture content as the normal maize in the current study, the lower emergence rate, delayed development and lower susceptibility index may be attributed to some other factor(s) besides the moisture content

Table 1. Mean development period, emergence and indices of susceptibility of *Sitophilus zeamais* on normal and stackburnt maize

Maize Type	Devpt period (days)	No adults emerged	Susceptibility index
Normal	36 3±0 33	89 0±3 4	12 34±0 14
Stackburnt	39 9±0 28	38 6±1 1	9 29±0 10
t-values	4 02	14 08	17 73
DF	18	18	18

Preference/non-preference tests

Figures 1 – 5 shows the numbers of weevils found on stackburnt and normal maize with time The figures clearly show a preference by the weevils for the normal undamaged

maize Chi-square tests for all the experiments, irrespective of the conditioning of the insects showed significant deviations from the 1 1 ratio Initially there was a small difference in the number of insects recorded on both maize types but with time significantly more weevils were recorded on the normal maize compared to the stackburnt maize Conditioning adults on stackburnt maize did not significantly affect their behaviour when given a choice of the two types of maize All insects showed a strong preference for the normal, undamaged maize

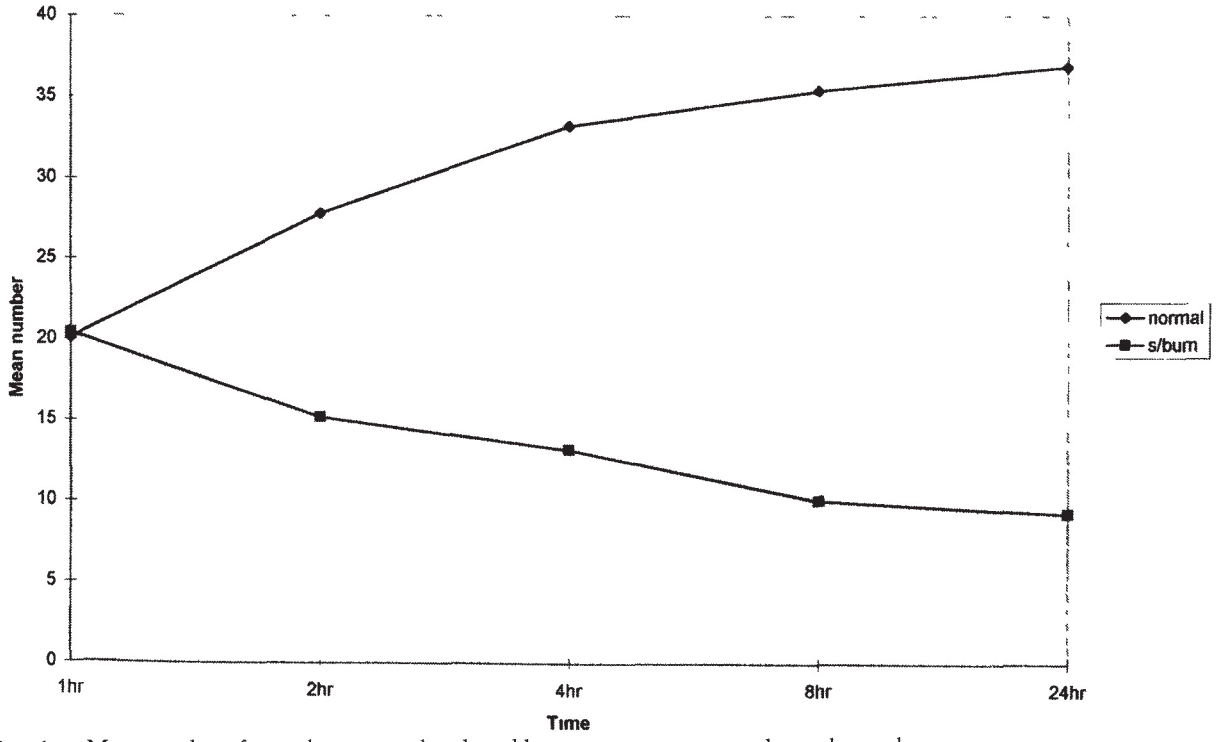

Fig. 1. Mean number of weevils on normal and stackburnt maize using unconditioned weevils

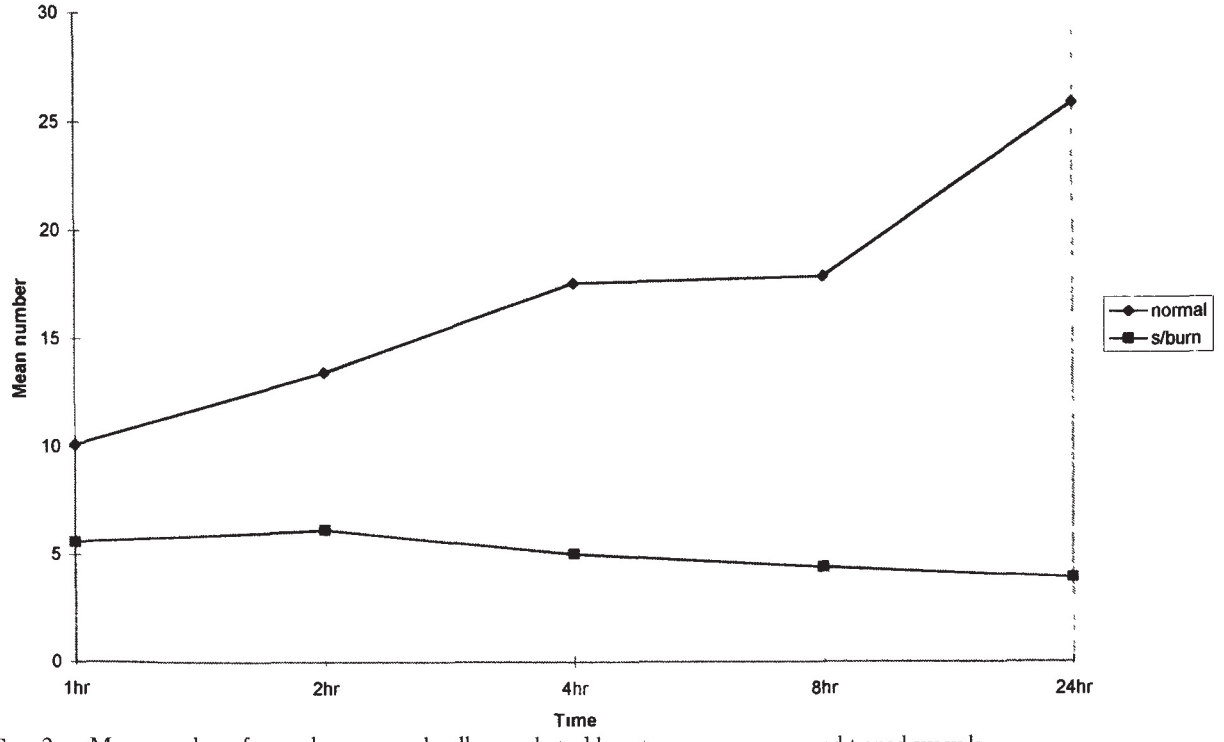

Fig. 2. Mean number of weevils on normal yellow and stackburnt maize using unconditioned weevils

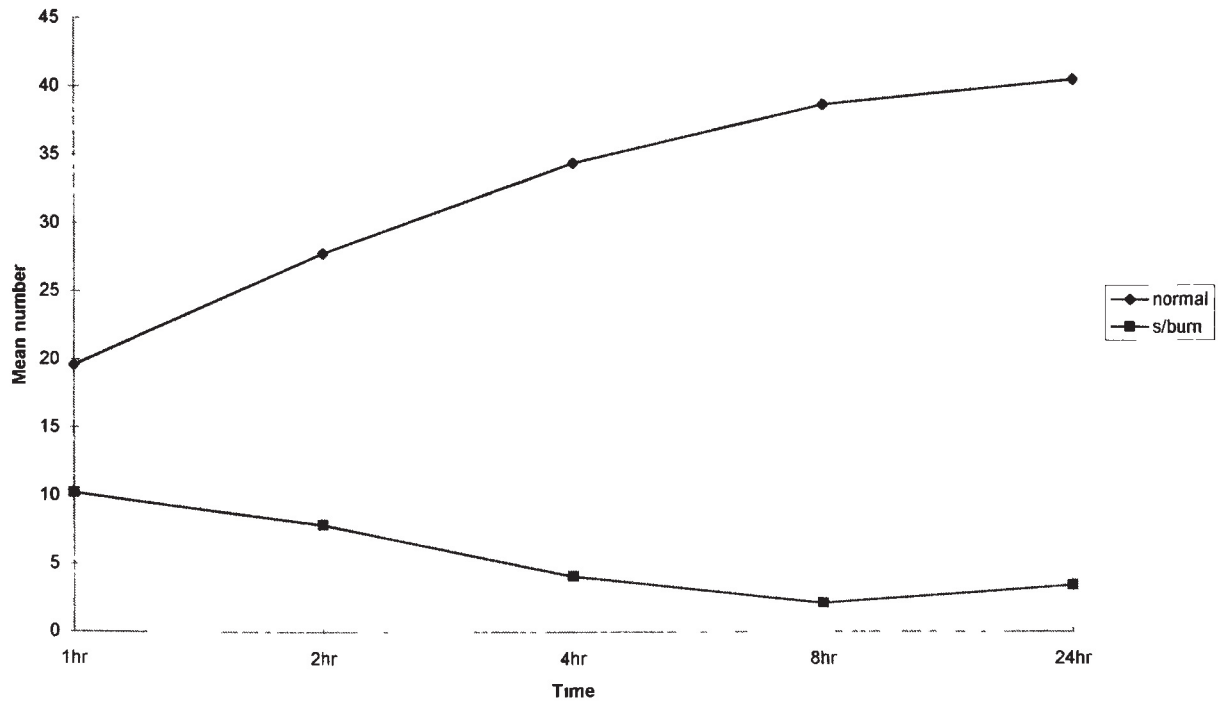

Fig. 3. Mean number of weevils on normal and stackburnt maize conditioned on stackburnt maize

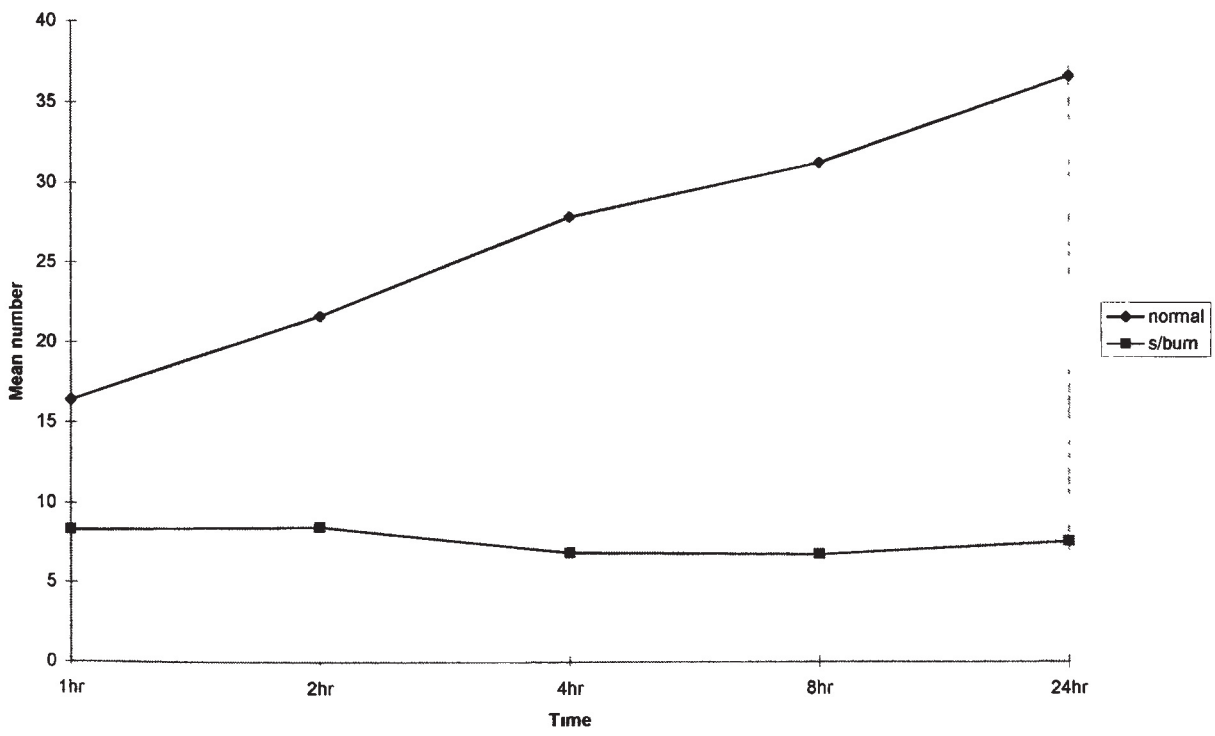

Fig. 4. Mean number of weevils on normal and stackburnt maize conditioned on normal maize

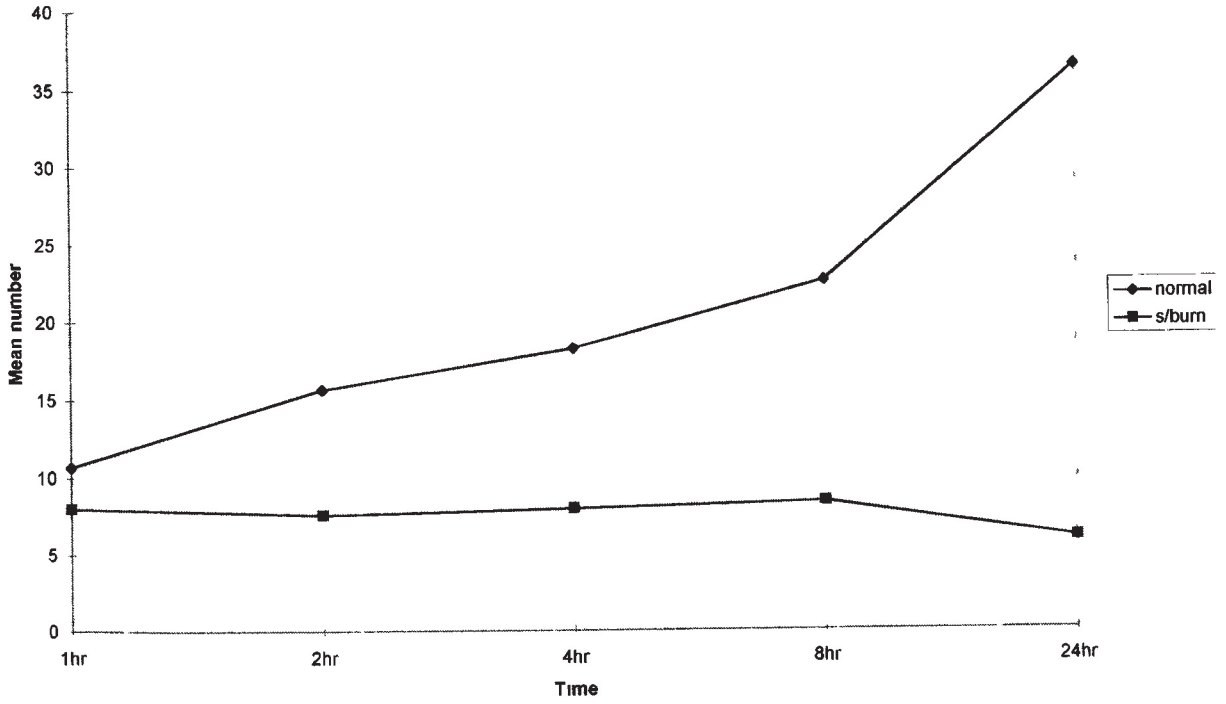

Fig. 5. Mean number of weevils on normal and stackburnt maize conditioned on both types of maize

References

Allotey, J and Odamtten, G T 1995 Insect multiplication, food preference, contaminant *Aspergillus* species and damage caused by *Cryptolestes ferrugineus*, *Rhyzopertha dominica*, and *Sitophilus zeamais* to normal and stackburnt maize in Ghana In Odamtten G T and Clerk G C (eds) Investigation on maize stackburn maize in sub-Saharan Africa Proceedings of a workshop 30 October – 3 November, 1995, University of Ghana

Conway, J A (ed) 1996 Third Annual Report on ECDGXII project P 156

Dobie, P 1974 The laboratory assessment of the inherent susceptibility of maize varieties to post-harvest infestation by *Sitophilus zeamais* Journal of stored Products Research, 10, 183 – 197

Giga, D P 1995 Development of *Sitophilus zeamais* on stackburnt and normal maize In Odamtten G T and Clerk G C (eds) Investigation on maize stackburn maize in sub-Saharan Africa Proceedings of a workshop 30 October – 3 November, 1995, University of Ghana, 53 – 57

Howe, R W 1962a Observations on the rate of growth and disruption of moulting in the larvae and pupae of *Tribolium castaneum* (Herbst) (Coleoptera Tenebrionidae) at sub-optimal temperatures Entomologia Experimentalis et Applicata, 5, 211 – 222

Howe, R W 1962b A study of the heating of stored grain caused by insects Annals of Applied Biology, 50, 137 – 157

Kennedy, L and Devereau, A D 1994 Observations on large-scale outdoor maize storage in jute and woven polypropylene sacks in Zimbabwe In Highley, E, Wright, E J, Banks, H J and Champ, B R (eds) Proceedings of the 6th International Working Conference on Stored-product Protection 290 – 295

Panigrahi, S, Bestwick, L A, Davies, R and Wood, C D 1996 The nutritive value of stackburned yellow maize for livestock tests in *in vitro* and in broiler chicks British Journal of Nutrition, 76, 97 – 108

Phillips, S I and Donaldson, T J 1994 Report No 5· ECDGXII Research Project Workshop, Harare, Zimbabwe, NRI Report R2140 (S) Chatham, UK Natural Resources Institute

Reddy, D B 1950 Ecological studies of the rice weevil Journal of Economic Entomology, 42, 203 – 206

Tanyongana, R and Nyanongo, R C 1995 A comparison of insect development on normal and stackburnt maize In Odamtten G T and Clerk G C (eds), Investigation on maize stackburn maize in sub-Saharan Africa Proceedings of a workshop 30 October – 3 November, 1995, University of Ghana, 24 – 26

Tyler, P S 1992 Heat and discoloration of bagged maize World Grain, September, 14 – 16