Survival of diapause larvae of the stem borer, *Coniesta ignefusalis* (Hampson) (Lepidoptera: Pyralidae), in northern Ghana as affected by the method of storage of millet stalks

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ABSTRACT

Studies were conducted in the Sudan savanna zone of Ghana on the effect of method of storage of millet stalks on mortality of diapause *Coniesta ignefusalis* larvae residing in such stalks. Internal stalk temperatures were generally higher than the corresponding ambient temperatures and peaked between 12.00 and 14.00 h GMT. During these periods of the day, temperature within the stalks stored in the sun usually exceeded 40 °C, the critical threshold for survival of diapausing *C. ignefusalis* larvae. Larval mortality was positively correlated with internal stalk temperature, and was highest in stalks spread out in the sun. Subjecting stalks to this treatment resulted in 80 per cent larval mortality within 6 weeks compared with 20 per cent mortality in stalks stored in the shade. The results indicate that high temperature resulting in the generation of excessive heat within the millet stalks is a key mortality factor in the population ecology of this insect. The implications of these findings for the integrated management of the insect are discussed.

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RÉSUMÉ

TANZUBIL, P. B., MENSAH, G. W. K., ANSOBA, E., ZAKARIA, M. & ALEM, A.: *Survie des larves de diapause de l' insecte térébrant* Coniesta ignefusalis *(Hampson) (Lepidoptera Pyralidae) au nord du Ghana comme affecté par la méthode de stockage des tiges de millet.* Des études se sont déroulées dans la zone savane-soudanalse du Ghana sur l'effet de la méthode de stockage des tiges de millet sur la mortalité des larves de diapause *C. ignefusalis* qui vivent dans telles tiges. Les températures internes étaient généralement plus élevées que les températures ambiantes correspondantes et pointues entre 12.00 et 14.00 h GMT. Pendant ces périodes de la journée, la température des tiges stockées sous le soleil excédait d' habitude 40 °C, le seuil critique pour la survie des larves de *C. ignefusalis* en diapause. La mortalité larvaire était positivement correlée avec la température interne de tige et était la plus élevée dans les tiges dispersées sous le soleil. Exposant les tiges à ce traitement aboutissait à 80 pour cent de mortalité larvaire dans un délai de 6 semaines par comparaison avec 20 pour cent de mortalité en tiges stockées à l'ombre. Les résultats indiquent que la température élevée menant à la production de chaleur excessive dans les tiges est un facteur clef de mortalité dans l'écologie de la population de cet insecte. Les implications de ces conclusions pour le contrôle intégré de l'insecte sont discutées.

Introduction

The stem borer, *Coniesta ignefusalis* (Hampson) (Lepidoptera : Pyralidae), is an important pest of pearl millet in Ghana. It can cause up to 23 per cent yield reduction in unprotected millet fields (Tanzubil & Yakubu, 1997). The insect survives the long dry season as diapause larvae residing within millet stalks and stubble. Larvae that undergo dry season diapause in the tropics usually face very harsh environmental conditions that can make survival uncertain (Denlinger, 1986). In northern Ghana, the dry season is characterized by high ambient temperatures and low relative humidity (Kasei, 1991), factors that can create stressful conditions for insects in diapause. In the tropics, the critical factors determining survival of insects in diapause in the field are temperature and the activities of biocontrol agents (Usua, 1970; Kfir, 1993).

The levels and causes of mortality in diapausing *C. ignefusalis* larvae during the dry season in Ghana have not yet been studied. A good knowledge of these would, however, be useful for developing cultural practices that could lead to reduced infestation and crop damage by the insect. Since diapause is the sole survival tactic used by this insect (Tanzubil, 1998), the size of the pest population at the beginning of each year will depend on the number of diapause larvae that survive long enough to emerge as adults during the season. Monitoring the survival and development of the population of diapausing larvae can thus contribute to effective management of the insect. To do this effectively, it is essential to establish the key mortality factors in the environment and to examine how these can be manipulated to the disadvantage of the insect.

Weather records for Manga in the Sudan savanna zone of Ghana show that temperatures are generally higher in the dry season than in the rainy season. This suggests that diapausing larvae are exposed to higher environmental temperatures, and excessive heat could be suggested as an important cause of mortality in such larvae.

Experiments were, therefore, designed to determine if, and for what periods, internal stalk temperatures exceeded the critical level of 40 °C established for diapause (Tanzubil, 1998). Results from these studies could prove useful in formulating integrated pest management (IPM) strategies for the insect based on improved handling of cereal stalks and stubble during the dry season.

Materials and methods

The studies were designed to determine the internal temperature of millet stalks stored under different conditions and to estimate *C. ignefusalis* larval mortality in such stalks. Dry millet stalks showing signs of borer infestation (exit/entry holes) were collected from the field in January 1998 and stored under shade in a fenced area. The field from which stalks were collected was one known to have been heavily infested with larvae during the growing season. In March 1998, the stalks were divided into groups of about 1000 stalks. Each group was stored in the sun in one of the following ways:

(a) Stalks were spread out thinly to ensure maximum contact with the ground.
(b) Stalks were stored in heaps on the ground.
(c) Stalks were stored in heaps on wooden platforms.
(d) Stalks were maintained in a standing position and leaning on wooden supports.
(e) Stalks were kept in heaps in the shade (control).

There were four replications of each storage method. Thermister probes were inserted deep into the cavities of 15 stalks selected randomly in each treatment to measure internal temperature hourly. Temperatures were measured from different sets of stalks daily to minimize positional effects. Larval mortality was estimated from 50 stalks per replicate, sampled randomly at the end of March, in mid-April, and again at the end of April to study the relationship between mortality and stalk temperature. These sampling periods represented 2, 4 and 6 weeks after placement in the sun, respectively. The maximum temperatures generated inside millet stalks were of special interest in explaining larval mortality, and these were recorded between 12.00 and 14.00 h GMT. Temperatures recorded during these hours were thus used to evaluate and compare the various storage methods. Air temperatures were collected from the Manga Research Station (weather station) for comparison.

Results

Temperatures recorded inside millet stalks varied with time of day from a low of about 26 °C to a high of 48 °C (Fig. 1). For most storage methods, temperatures were highest between 12.00 and 14.00 h, and lowest at 06.00 h GMT. This followed the trend for air temperatures recorded at the local weather station close to the experimental site.

Internal temperatures were highest in stalks spread out in the sun, followed by those maintained in a standing position, those heaped, and those kept on wooden platforms in that order (P<0.001, $F_{4, 15}$ = 23.58) (Fig. 2). Stalk cavity temperatures were generally higher than the corresponding ambient temperatures for the same time period, and for most parts of the study period the maximum temperatures generated within the stalks were always above 40 °C. Correlation analyses showed significant positive relationships between air and stalk temperatures in most treatments. The correlation coefficients, r, were 0.783, 0.893, 0.780 and 0.876 (df = 6), respectively, for stalks heaped, stored on platform, spread, and standing.

Mortality figures (Fig. 3) followed a similar trend as stalk temperatures, being highest in stalks that were spread out and lowest in those stored in the shade or on wooden platforms (P<0.001, $F_{4, 15}$ = 32.6). There was a significant positive correlation between larval mortality and internal stalk

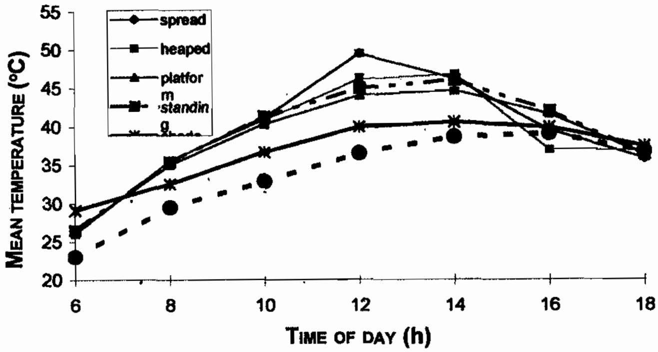

Fig. 1. Temperature profile inside millet stalks stored by various methods.

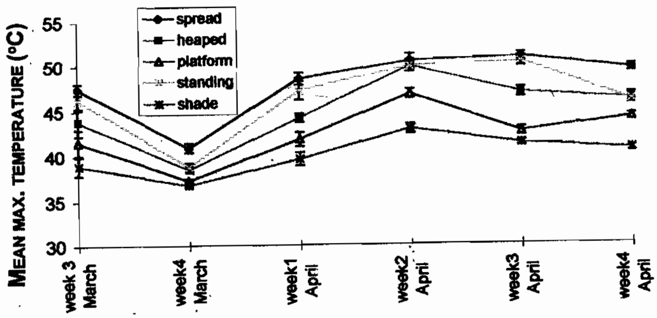

Fig. 2. Maximum internal temperature of millet stalks stored by various methods.

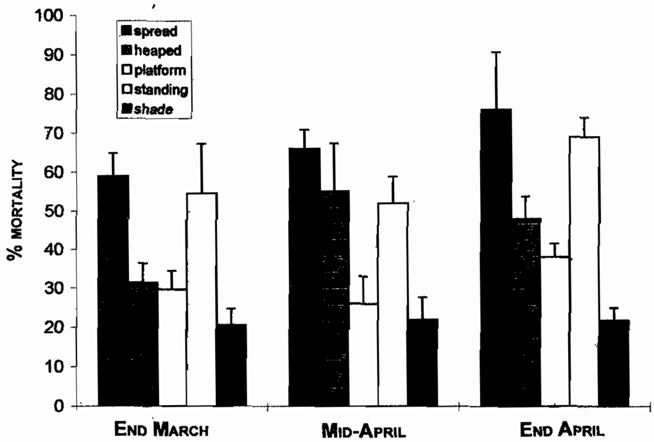

Fig. 3. Effect of storage method on mortality in diapause *C. ignefusalis* larvae in millet stalks.

temperature (r = 0.98), and regression analysis confirmed a very strong relationship between both variables (R^2=0.97, P= 0.0014). Mortality levels measured during the preparatory period of the studies (when all stalks were stored in the shade) averaged 15.45 ± 2.8 per cent. Larval mortality increased sharply from this figure during the first few weeks of storage in the sun, but it remained fairly constant throughout the study period in the shade (Fig. 3).

Discussion

Results for the studies in this paper confirm the hypothesis that heat is mainly responsible for the high, natural mortality suffered by diapausing larvae of *C. ignefusalis* in dry millet stalks. It has recently been established from studies in northern Ghana that 40 °C is the critical temperature above which mortality in *C. ignefusalis* larvae increases very significantly (Tanzubil, 1998). Long periods of exposure to this, and to higher temperatures would ultimately annihilate carry-over populations of the insect.

In studies conducted in Nigeria, Usua (1973) observed that the critical temperature for diapause larvae of the sorghum stem borer, *Busseola fusca*, was about 35 °C, far below that recorded for *C. ignefusalis*. The results for the studies in this paper suggest that *C. ignefusalis* has higher heat tolerance than *B. fusca*, though both may diapause in the same stalks. This probably explains the position of *C. ignefusalis* as the predominant cereal stem borer in the Sahel zone, where temperatures are generally higher than those recorded in the savanna ecosystems. In *C. ignefusalis*, therefore, temperatures above 40 °C would be required over a long period for appreciable population decline.

Correlation and regression analyses confirmed the positive relationship between internal stalk temperature and larval mortality. These results, therefore, provide evidence that high stalk cavity temperature is the key mortality factor in the population ecology of *C. ignefusalis* during the diapause period. In field studies conducted over two dry seasons (1997 and 1998), Tanzubil (1998) observed that peak larval mortality coincided with periods of highest ambient temperature.

The method of storage of the millet stalks clearly influenced the survival of diapause larvae. Storing stalks in the shade resulted in only 20 per cent mortality compared with about 80 per cent mortality in stalks spread out in the sun for the 6-week period. Absorption of heat radiating from the ground was probably responsible for the higher temperature and subsequent larval mortality recorded from the stalks spread out to ensure maximum contact with the ground. In other tropical stem borers, it has been reported that larval mortality is often higher in stalks buried in the ground than in those stored otherwise (Lawani, 1982; Lukefahr, Mamalo & Klaij, 1988). In Ethiopia, Gebre-Amlak (1988) similarly observed that horizontal placement of maize and sorghum stalks in the sun resulted in 97 per cent mortality in diapausing larvae of *B. fusca* within 4 weeks. The bases for these observations were, however, not fully established. The results reported in this paper indicate that it is the higher temperature generated in stalks maintained in contact with the ground that caused the higher larval mortality reported by these authors.

From an IPM perspective, the inference is that it is possible to reduce population carry-over of *C. ignefusalis* by manipulating the method of handling and storing millet stalks and stubble. Earlier workers had reached similar conclusions for other stem borers (especially *B. fusca*) and variously recommended burning/partial burning of stalks (Adesiyun & Ajayi, 1980; Sagnia, 1989; Gahukar, 1990), deep burying of stalks (Lukefahr *et al.*, 1988), and ploughing in of stalks and stubble after harvest (Lawani, 1982) as ways of controlling such insects. Harris (1962) recommended complete burning of the stalks after harvest to kill *B. fusca* larvae in Nigeria, but these recommendations are seldom followed by farmers (Adesiyun & Ajayi, 1980), probably because of their sociological implications for the farm family.

Cereal stalks have other very important uses such as domestic fuel, roofing, animal feed, and fencing. Any recommendations that probably interfere with their availability and quality would most certainly be ignored. It is, therefore, not surprising that such recommendations have seldom been adopted. The treatment studies here involved only modifications to the method of storing the stalks already used by farmers and should be more appealing to them. Farmers in the study area store millet stalks on the branches of shade trees around their compounds or on the roofs of their homes.

A major recommendation from this study would be that farmers store their millet stalks in the sun and in as much contact with the ground as possible. This should lead to high larval mortality and thus contribute to reducing subsequent insect populations. The results also show that although increases in larval mortality can be substantial within 2 weeks of such treatment, some larvae can tolerate the high temperatures and survive for longer periods. Ideally, therefore, stalks in the sun should continue for as long as possible. The sociological implications of such a change need, however, to be critically assessed to ensure mass adoption by farmers.

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