THE GROWTH OF LABORATORY POPULATIONS OF *SITOPHILUS, RHYZOPERTHA* AND *SITOTROGA* ON SORGHUM SEEDS UNDER AMBIENT AND HUMIDITY-CONTROLLED CONDITIONS IN NORTHERN NIGERIA

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Abstract

Results obtained from a number of field investigations carried out in Nigeria have suggested that the major insect pests of stored sorghum and maize, are distributed according to a pattern that follows the availability of atmosperic moisture in the country. To confirm this observation, a laboratory investigation was conducted, in which populations of the most important sorghum pests in northern Nigeria, Sitophilus oryzae (L.), Rhyzopertha dominica (Fab.) and Sitotroga cerealella (Oliv.) were separately cultured on sorghum seeds under ambient and humidity-controlled conditions, for a period of nine months. During the period of observation, significant increases were recorded in the growth of populations of Sitophilus oryzae, Rhyzopertha dominica and Sitotroga cerealella cultured in the humidity controlled environment (76.3 - 91.4% r.h) while the populations of these pests decreased and in some cases died out completely from cultures maintained under ambient laboratory conditions (26.4 - 48.6% r.h.). The results of this investigation have demonstrated that high relative humidity, and consequently adequate grain moisture, favour continuous breeding in populations of Sitophilus oryzae, Rhyzopertha dominica and Sitotroga cerealella on sorghum, and confirm that the incidence and distribution of these major pest species on grains in Nigeria, are dependent on the availability of adequate moisture in the grains on which these insects develop.

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Introduction

It has been suggested that moisture is the most important factor determining insect infestation of, and damage to stored grains in Nigeria (Caswell, 1979). In a number of field investigations carried out on the incidence and distribution of various insect pests on stored products at different geographical locations in Nigeria, a close association has been observed between insect incidence and moisture availability (Cornes and Riley, 1962; Giles, 1964; Halliday, 1966; Caswell, 1979). The amount of moisture in the air is expressed as relative humidity and it is known that the relative humidity of an environment affects grain moisture to which it is closely related. Because grains are hygroscopic, they absorb moisture from or give up moisture to the environment, until the grain moisture content is in equilibrium with the relative humidity of the environment (Pixton, 1967; Hunt and Pixton, 1974). Thus at high relative humidities high grain moistures are recorded while low relative humidities result in low grain moistures. In a survey of insect infestation and damage to maize and sorghum seeds in three climatic zones of Nigeria, Ayertey and Ibitoye (1986) reported that *Rhyzopertha dominica* (Fab.), *Sitotroga cerealella* (Oliv.) and *Sitophilus* species, the most important insect pests of stored sorghum and maize, were distributed according to a pattern that corresponded with the pattern of moisture availability in the different climatic zones. Because of the status and importance of these pests on cereals in storage in Nigeria, it became desirable to confirm this observation through laboratory experimentation.

Materials and Methods

This investigation was carried out by comparing the development of populations of the major insect pests of stored grains in Nigeria, cultured on grains maintained in a high humidity environment with those maintained in a low humidity environment in the laboratory.

Stock cultures and culture medium. The three major insect pests of stored sorghum in northern Nigeria, *Sitophilus oryzae* (L.), *Rhyzopertha dominica* (Fab.) and *Sitotroga cerealella* (Oliv.) were used in this investigation. They were initially obtained from stock cultures maintained on sorghum at the Institute for Agricultural Research, Zaria in Nigeria. These were used to start fresh monocultures which provided a source of supply of insects for the population growth experiments. All insect culturing was done using sorghum taken from a 20kg grain lot stored in the laboratory. Three months before insect culturing in the laboratory began, a 20kg grain lot from a freshly-harvested consignment of sorghum was obtained and fumigated with phosphine gas released from phostoxin. Preliminary tests confirmed that the fumigation was effective and the treatment had no adverse effects on insects subsequently cultured on it. The fumigated grain lot was kept in a drum and, as and when required, portions of this grain were taken and transferred to a dessicator for a month for the grain to be conditioned to the laboratory environment and its moisture content determined before it was used to set up cultures of the pest insects.

The fresh stock of monocultures which provided the source of insects for these experiments were set up as follows: For Sitophilus oryzae and Rhyzopertha dominica, one hundred adults of each pest species were randomly selected from the laboratory stock cultures and placed separately on 300g of conditioned sorghum in 750cc Kilner glass jars with screw tops. Each jar was covered with muslin and wire mesh held in position by the screw top. Five such culture jars were set up for each pest species. At the same time a similar set of cultures were set up with Sitotroga cerealella except that in the case of the moth, the 100 adults were placed on 100g grain placed in 500cc jars and the number of jars doubled to ten. Offspring emerging from these culture jars were used to set up the experimental cultures.

Experimental cultures. The insect cultures that were used to compare the growth of the pest populations in this experiment were set up as follows: For each of the three pest species, 25g of the laboratory-conditioned sorghum was put into each of six 60cc screw-topped glass jars and 20 adult insects from the stock monocultures were introduced into each jar. The jars were covered with muslin before the screw tops were replaced. Each screw top jar cover bore three 1cm-diameter holes for ventilation. Three of the set of six culture jars of each pest species were randomly selected and placed on benches in the laboratory while the other three jars of each set were placed in a humidity-controlled cabinet in the laboratory.

Humidity controlled cabinet. A humidity cabinet capable of maintaining high relative humidity was used for storing half of the culture jars containing the experimental insects. The cabinet, measuring 53cm high, 40cm wide and 28cm deep was made of fibre glass and had two glass shelves and a glass door. It was manufactured by Towson and Mercer Limited of Croydon. A dessicant tray in the bottom chamber of the cabinet could hold beakers containing saturated salt solutions responsible for maintaining the required relative humidity. For this experiment, saturated sodium chloride solution, desired to provide a relative humidity of about 76% was used (Peterson, 1934). A small fan circulated air in the humidity chamber.

The culture jars placed in the cabinet were arranged on the glass shelves to which were added a thermometer and a portable hygrometer to record daily changes in temperature and humidity. Similar records were taken of the ambient temperature and relative humidity of the laboratory, using a thermohygrograph. The equipments used in the humidity cabinet and on the laboratory bench were standardised with those used by the Meteorological Section of the Institute for Agricultural Research in Zaria.

Assessment of population growth. One month after the experimental jars were set up, the culture jars were emptied, the grains sieved and any insects found were counted and recorded. The grain contained in each jar was then weighed and the weight topped up to the original 25g weight. After this, the live insects were returned to their respective jars which were in turn returned to their appropriate locations. This procedure was repeated monthly for nine months. To monitor changes in grain moisture content, additional samples of sorghum, with or without insects, were also maintained separately under the two experimental conditions and the moisture content of the grains determined at intervals during the culturing period.

Results and Discussion

Growth of Rhyzopertha dominica populations under ambient or humidity controlled conditions. A comparison of the populations of the lesser grain borer Rhyzopertha dominica cultured under ambient laboratory and humidity-controlled conditions over the period of observation showed that more beetles developed in the cultures placed in the humidity-controlled cabinet than those kept on the laboratory bench under ambient conditions. However, significant differences in the monthly records of R. dominica in the two culture environments could only be detected after March, five months following the start of insect culturing (Fig.1). After this period, a rapid increase in the R. dominica population in the humidity-controlled environment was recorded, an increase that continued until observations were terminated at the end of June. On the other hand the insect population under ambient laboratory conditions declined until June when an increase was recorded. No adult beetles emerged from either culture medium until two months after the cultures were set up, suggesting that the development period of R. dominica was prolonged under the conditions prevailing at the start of the experiment.

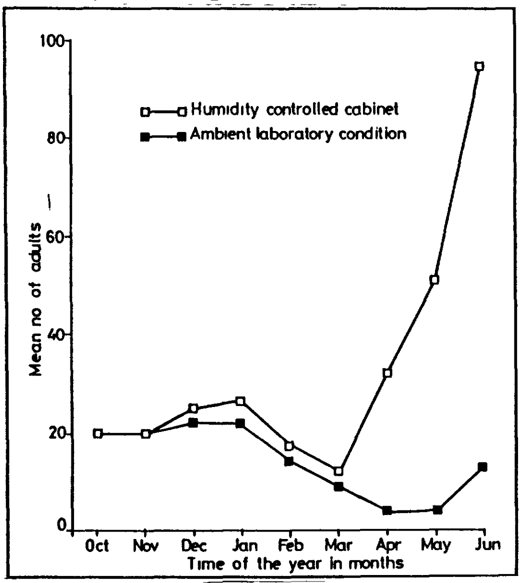

Fig. 1 **The growth of populations of** Rhizopertha dominica **started with 20 adults on 25g sorghum, under humidity-controlled or ambient laboratory conditions.**

Of the two environmental factors monitored in the two breeding environments, no major temperature differences could be detected between the two environments during the period but mean relative humidity in the cabinets was about double that recorded under ambient conditions (Table I). Under the two breeding conditions, ambient relative humidity was less than 45% from December to April and the resultant grain moisture content was low during the period, reaching 5.9% in February (Table II). Substantial increases in relative humidity were recorded from May, resulting in a grain moisture content of 11.1% in June. In this culturing environment, the period of low population growth coincided with the period of low relative humidity and grain moisture content while the period of rapid population growth also coincided with the period of increased relative humidity and grain moisture content. In the humidity-controlled cabinet, the minimum relative humidity recorded during the period of observation was 76.3% rising to 90.3% in June when grain moisture content reached 13.2%. The significant increases in population recorded for *R. dominica* were from this environment. The higher population levels obtained under the humidity-controlled conditions must therefore be due to the higher relative humidity in this culturing environment.

Table I Mean monthly relative humidity and temperature recordings obtained from the humidity cabinet or ambient laboratory conditions at Zaria.

MONTHS	CABINET		AMBIENT CONDITION	
	R.H.%	TEMP. °C	R.H.%	TEMP. °C
OCTOBER	75.4	27.0	65.3	27.0
NOVEMBER	76.3	26.2	48.6	26.0
DECEMBER	80.6	22.1	35.8	22.5
JANUARY	82.2	23.4	29.4	23.3
FEBRUARY	83.9	24.8	26.4	25.5
MARCH	84.7	28.3	35.2	29.0
APRIL	84.5	29.6	44.3	29.8
MAY	88.0	27.6	76.1	28.1
JUNE	90.3	27.2	83.1	27.3
JULY	91.4	25.7	85.1	25.8

Table II Per cent grain moisture content determined at intervals on sorghum kept in a humidity-controlled cabinet or under ambient laboratory conditions.

	NOVEMBER	FEBRUARY	JUNE
Cabinet	12.2	12.4	13.2
Ambient	9.2	5.9	11.1

Khare and Agrawal (1962) reported that the optimum relative humidity range for the development of R. dominica was 60 - 75% r.h. and Prevett (1971) found that 25% r.h. was the minimum this beetle could tolerate for its development. Thomson (1966) and Pingale and Girish (1967) also reported that R. dominica could breed in grain with 8% moisture content but Thomson (1966) found that newly hatched larvae of R. dominica could not enter grain of less than 8% moisture content. Birch (1945b) also reported that the minimum moisture content of grain in which R. dominica could develop varied with temperature and decreased with an increase in temperature from 18.2°C to 34°C. For most of the period of investigation therefore, grain moisture under the ambient laboratory conditions was inadequate for rapid population growth in R. dominica. Only when this increased, following an increase in relative humidity, did the R. dominica population begin to rise under the ambient laboratory conditions.

Temperature, and probably grain moisture also, may have been responsible for the initial delay in the development of the R. dominica population and the slow rate of population growth under both breeding conditions between November and March. According to Birch (1945a), Khare and Agrawal (1962) the optimum temperature for R. dominica development was 34°C and Prevett (1971) observed that at this temperature development was completed in 28-30 days. These authors further reported that developmental period in R. dominica increased with a decrease in temperature from the optimum level towards a minimum of 18°C. Thomson (1966) also reported that the development period of R. dominica lasted 30-35 days on sorghum of 12% moisture content at 29°C and 75% r.h. At the start of this experiment, grain moisture averaged 11%, relative humidity ranged from 65-75% and temperature averaged 27°C. During the period December to February, temperatures under the two breeding conditions were comparatively low (22.1 - 25.5°C). It would appear therefore that the slow initial development was due to the temperatures prevailing under both breeding conditions at the time. As soon as temperatures began to rise in March, the Rhizopertha populations which were not limited by moisture deficiency began to rise (Fig. 1).

Growth of Sitotroga cerealella populations under ambient or humidity-controlled conditions. Four months after separate cultures of the Angoumois grain moth Sitotroga cerealella were started under ambient and humidity-controlled conditions in the laboratory, significantly more moth adults began to emerge from the cultures maintained under the controlled conditions than from those maintained under ambient laboratory conditions. While the moth population under the controlled conditions continued to rise, the population under ambient conditions decreased until it died out completely by May (Fig. 2). During the period when differences were detected in the moth populations bred under the two conditions and the death of S. cerealella from the cultures maintained under ambient conditions (February to April), ambient relative humidity ranged from 26.4 to 44.3% r.h., resulting in grain moisture of 5.9% in February (see Tables I and II). During the same period, relative humidity in the humidity-controlled cabinet ranged from 83.9 to 84.7% r.h, resulting in 12.4% grain moisture content in February. Since no significant differences in temperature could be detected in the two culturing environments, it may be inferred that the only detectable major difference, relative humidity, and consequently grain moisture, is responsible for the low moth productivity under the ambient laboratory conditions. Indeed the highest population levels reached in both breeding environments were obtained during the periods of low temperature (December - February). Between October and February, the growth of the S. cerealella populations under the two breeding conditions were similar and characterised by the more or less regular fluctuations (generation peaks) associated with S. cerealella populations (Ayertey, 1979).

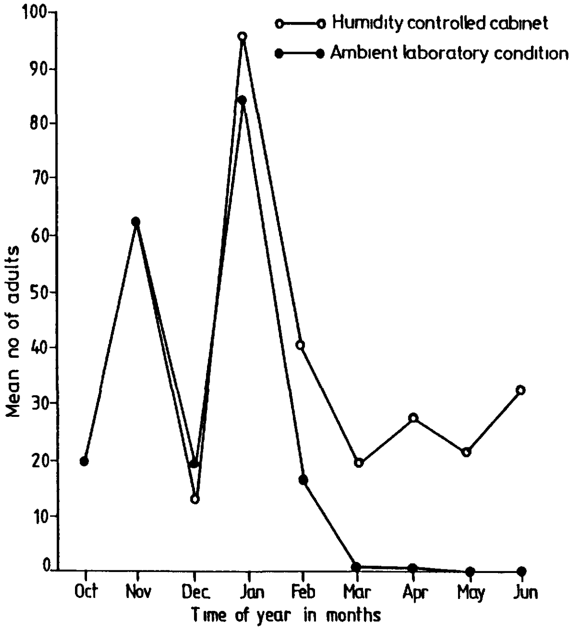

Fig. 2 The growth of populations of Sitotroga cerealella started with 20 adults on 25g sorghum, under humidity-controlled or ambient laboratory conditions.

According to Grewal and Atwal (1969) and Prevett (1971) the development of S. cerealella was more favoured at relative humidities of 70 - 80% and Howe (1965) and Pingale and Girish (1967) reported that the minimum relative humidity for the development of S. cerealella was 30% r.h. The low moth productivity and its eventual death from the cultures maintained under ambient conditions was therefore due to the subnormal relative humidity levels recorded in January and February. Although S. cerealella is known to develop more favourably at temperatures between 25°C and 30°C (Grewal and Atwal, 1969; Prevett, 1971) the S. cerealella populations did not appear to have been affected by the low temperatures of December and January, characteristic of northern Nigeria and recorded in this investigation, because even these were in excess of its recorded minimum tolerable temperature of 16°C (Howe, 1965).

Growth of Sitophilus oryzae populations under ambient or humidity-controlled conditions. Two months after setting up separate cultures of the rice weevil Sitophilus oryzae under humidity-controlled and ambient laboratory conditions, significantly more weevils were recorded in the humidity-controlled cultures than in the cultures maintained under ambient laboratory conditions. Although the weevil population in the humidity-controlled environment fluctuated from month to month, it remained higher than the level recorded on the cultures maintained on the laboratory bench, from which S. oryzae died out completely by April, six months of the start of the cultures (Fig. 3). The disappearance of S. oryzae from the cultures maintained under ambient conditions in April was preceded by a drastic population reduction between January and February. During these two months relative humidity ranged from 26.4 to 29.4%, producing a grain moisture content of 5.9% (Tables I and II). During the same period the relative humidity in the humidity-controlled cabinet ranged from 82.2 to 83.9% r.h., with grain moisture content of 12.4%. Temperature recordings of the two breeding environments during the period were similar, ranging from 23.3 to 25.5°C. Low relative humidity, and therefore low grain moisture content, must be responsible for the death of S. oryzae from the cultures under ambient laboratory conditions.

According to Howe (1965) S. oryzae would not develop at humidities below 60% r.h. and Birch (1945b) and Reddy (1950) found that a minimum grain moisture content of 10% was necessary for S. oryzae to complete development. Reddy (1950) reported optimum temperature and relative humidity conditions for the development of S. oryzae as 28 - 30°C and 75 - 90% r.h. These conditions prevailed during most of the breeding period in the humidity cabinets and explains the high weevil productivity in these cultures. The rather slow rate of population increase observed between December and January under the two culturing conditions (Fig. 3) may be due to the low temperatures prevailing at the time.

Conclusion

A well defined relationship exists between the moisture content of grain and the relative humidity of the air surrounding it. Consequently the effect of relative humidity on insect development appears to operate indirectly through grain moisture content. Increased insect activity and development are usually associated with relative humidities above 75% and moisture contents of 14 - 15% (Pingale and Girish, 1967). For the majority of storage insects, lower relative humidities and grain moisture contents may be tolerated, but moisture contents below 10% are not adequate for normal activity and development. Moisture is also closely related to temperature as the amount of water retained in the air may depend on the prevailing temperature conditions.

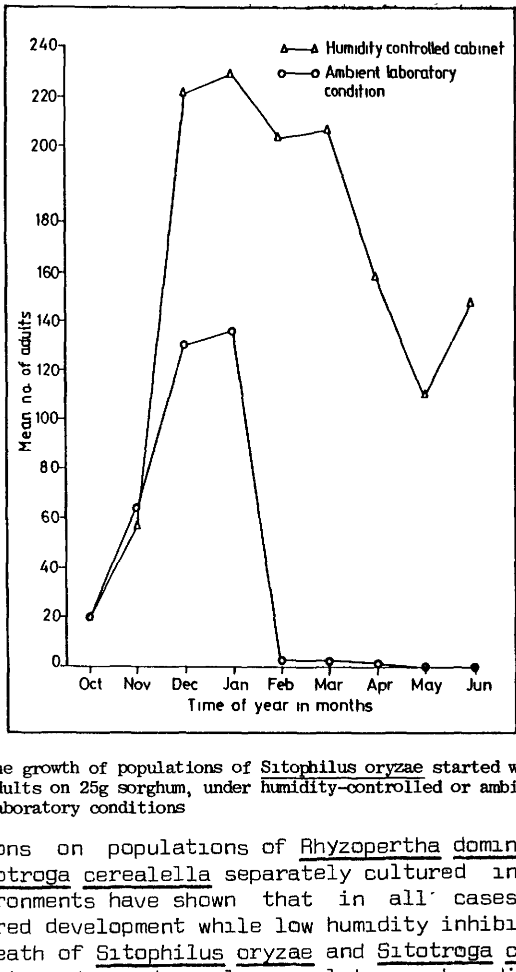

Fig. 3 The growth of populations of Sitophilus oryzae started with 20 adults on 25g sorghum, under humidity-controlled or ambient laboratory conditions

Observations on populations of Rhyzopertha dominica, Sitophilus oryzae and Sitotroga cerealella separately cultured in high and low humidity environments have shown that in all cases, high relative humidity favoured development while low humidity inhibited growth and led to the death of Sitophilus oryzae and Sitotroga cerealella from cultures maintained under low relative humidity conditions. Populations of Rhyzopertha dominica cultured under low humidity conditions in the laboratory survived because the insect could tolerate low temperature and relative humidity conditions. According to Prevett (1971) the minimum relative humidity for development in Rhyzopertha dominica was 25% r.h. and Birch (1945a) recorded the minimum temperature for its development as 22°C. Although this pest can tolerate low temperature and relative humidity, such conditions inhibited rapid population development. The slow growth recorded between December and March under the two breeding conditions in the investigations described here, must therefore be due to the low temperatures prevailing at the time. Sitotroga cerealella and Sitophilus oryzae died out of the cultures maintained under ambient conditions because they could not tolerate the low relative humidities that prevailed between December and March under the culturing conditions. Howe (1965) reported that Sitophilus oryzae would not develop at humidities less than 60% r.h. and Birch (1945b), Reddy (1950) and Pingale and Girish (1967) recorded that Sitophilus oryzae did not develop in grains with 8 - 10% moisture content. Howe (1965) has given the minimum relative humidity required for development in Sitotroga cerealella as 30% r.h. Between December and March, relative humidity ranged from 26.4 to 35.8% with moistures reaching 5.9% in February. Temperatures during the same period ranged from 22.5 to 29.0°C. Such conditions did not encourage satisfactory development in these insects.

Sitophilus oryzae died out of the cultures in April, that is within four months of the onset of unfavourable temperature and relative humidity conditions while Sitotroga cerealella survived until May. It appears Sitotroga cerealella survived longer because, in addition to its tolerance of low relative humidity, it could also tolerate very low temperature conditions. Howe (1965) recorded that Sitotroga cerealella could tolerate temperatures of 16°C. It is probably this tolerance of low temperatures that enabled it to attain population peaks in January and so made it possible for it to survive longer than Sitophilus oryzae in the cultures maintained under ambient laboratory conditions. Inspite of this tolerance of low temperatures, the moth died out from the cultures probably because of increased moisture stress, following the onset of higher temperatures in March.

In an earlier report (Ayertey and Ibitoye, 1986) the incidence of insect pests infesting maize and sorghum grains in three climatic zones of northern Nigeria was found to decline from December to April, when grain moisture was low, and increased from May, following an increase in grain moisture content. More insect pests were also found on grains obtained from the southern guinea savannah zone, characterised by higher relative humidity and consequently higher grain moisture, than from the more northern zones, characterised by low relative humidity. Also, the development of the insect pest populations was found to begin from the southern zone and moved northwards with the movement of the rains. The results of the laboratory investigations reported here have confirmed the role of moisture in these observations. Thus the occurrence and distribution of storage insect pests in different climatic zones in Nigeria as reported by Giles (1964), Halliday (1966), Caswell (1979) and Ayertey and Ibitoye (1986) are regulated by moisture availability, which is dependent on rainfall. Consequently damage to grains caused by insect pests also depended on moisture availability, with increasing damage with an increase in grain moisture. From the stand point of long term storage of grain, these findings suggest that in Nigeria, more strategic grain reserve stores should be cited in the drier north, where there are fewer storage pests and where the rigours of the environment between December and March will reduce the populations of the major insect pest species when these develop.

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