# FEASABILITY AND RESULTS OF POPULATION DYNAMICS STUDIES ON STORED GRAIN INSECTS IN SMALL SCALE BINS WITH SIMULATED CLIMATIC CONDITIONS

by
Francis FLEURAT LESSARD
Laboratoire de Recherches sur les Insectes des Denrées
I.N.R.A. - Centre de Recherches de Bordeaux, BP 131
F 33140 - Pont de la Maye, France

The grain bulk ecosystem requires analysis in relation to the extent of preventing losses in grain. Insects are common inhabitants of grain bulks, particularly major pests with hidden forms. When the grain is at a low water content during the storage period, the insect population monitoring is essential. Each of the primary species has its specific environmental requirements for its development. For long term storage, it is necessary to know the dynamics of an insect population produced in a grain bulk and sampling methods are used.

Nevertheless, in large scale bins where the grain cannot be removed the number of insects which is detected is of limited value for population dynamics purposes in relation with :

- the practical impossibility of sampling the wholeness of the bulk of grain,
- the insects tendancy to aggregate in some parts of static bulks where insects distribution is never random during the storage period,
- the necessity to use the sampling results in comparizon with others obtained at other periods of time for testing the evolution tendancy of the insects population.

Small laboratory studies on insect dispersal in grain are impossible. It is necessary to have a mass of grain of some importance for this study (critical size). Furthermore, population dynamics and dispersal of insects are inseparable in grain bulks studies. In addition when there are two or more species in the same bulk, the competition becomes active only in a small number of cases. In general the natural population densities are sufficiently low compared to the laboratory infestation densities and the cases of competition are restricted to the primary insect species with hidden immature stages.

We have selected three species for our studies, two weevils and the lesser grain borer. The lesser grain borer and the rice weevil can enter in a fight for the same place in the grain and the competition was studied in this instance.

A storage equipment, especially designed for controlled population dynamics studies of insects in grain bulks, is used that allowed the possibility of a seasonal regulated temperature in the warehouse and the choice of initial conditions of storage.

## MATERIAL AND METHODS

Storage experiments were made in several batches of small bins of 420 liters capacity each and partially filled with 250 to 300 kg of grain according to the types of grain. The bins were located in a store equiped with an air-conditioning system. The bins are insect proof and supplied with ducts for natural or forced ventilation.

The storage in simulated tropical, mediterranean or temperate climatic conditions was conducted with different insect species :

- the granary weevil, *Sitophilus granarius* (L.) on soft wheat,
- the rice weevil, *S.oryzae* (L.) on durum wheat,
- the lesser grain borer, *Rhyzopertha dominica* (F.) on sorghum and on durum wheat and in this last case, in competition with *S.oryzae*.

The initial insect infestation was realized always with young adults during the loading of the bins.

The modification of the grain water content was artificially done in some cases using a water spray on grain in a concrete mixer.

Different initial conditions in grain-insect complex were set in relation of a specific situation :

- In France, the granary weevil is the major pest on wheat especially in the north part of the country on wet grain (between 15 to 17 p.cent of water content). This is a warehouse pest and the re-infestation takes place during the storage at different density levels.

- In North Africa, two major pests breed on durum wheat, *S.oryzae* and *R.dominica* on dry grain and there is sometimes an interspecific competition.

- In Ivory Coast, on sorghum, the major pest is *R.dominica* with a large infestation level before the harvest.

There was in these three simulated climatic conditions that the storage experiments were conducted during variable period of time.

The sampling of each bulk was made vertically at three levels of depth at nine points per level with a compartmentalized probe (fig. 1) and at regular intervals of time. Adult insects were obtained by sieving and hidden stages by the I.S.O. reference method e.g. by incubation at 25°C and 70 p.cent R.H. Elementary samples were analysed separately for obtaining a three dimensional picture of the population dispersal inside the grain bulk. (FARJAN, 1983).

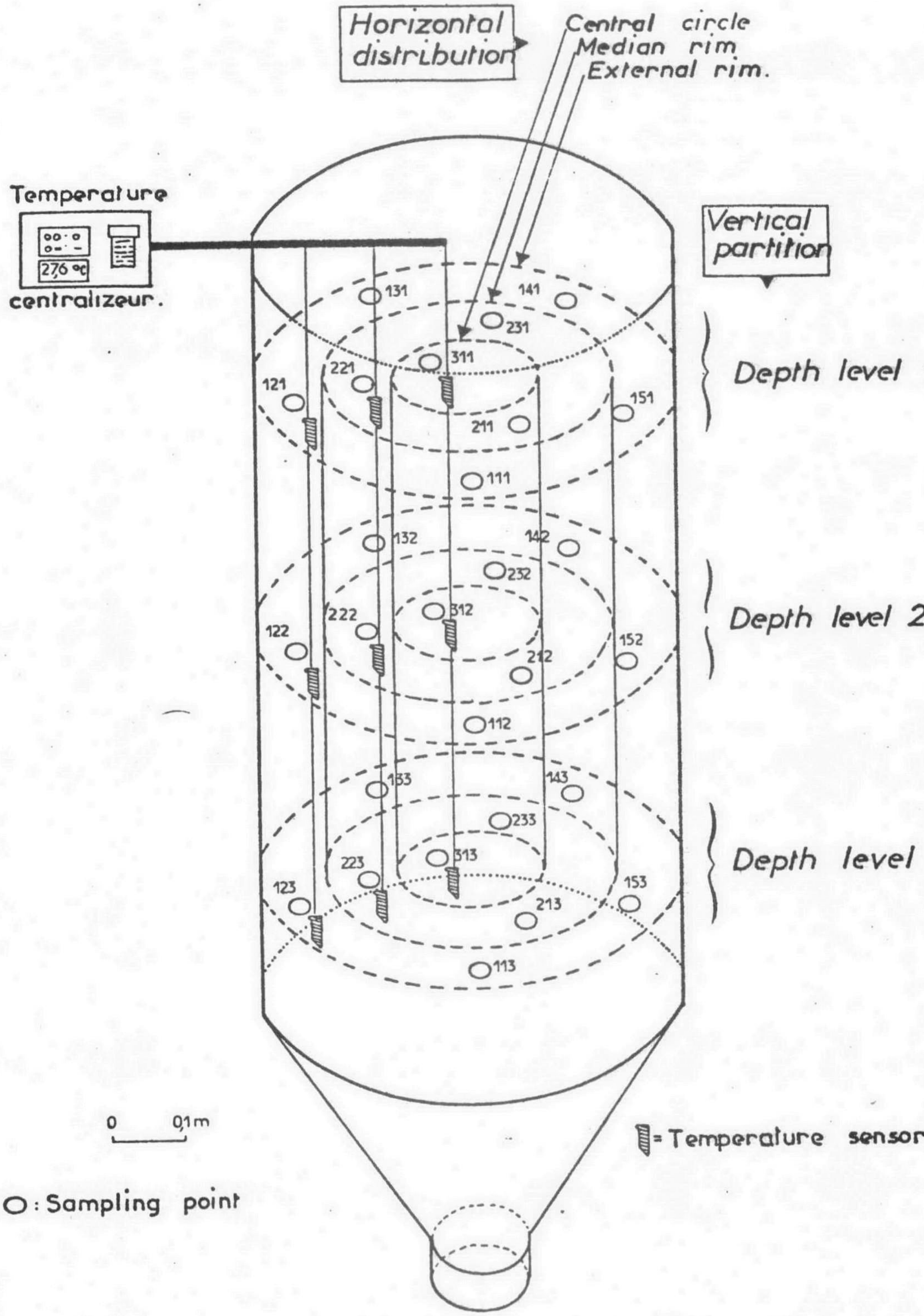


Fig. 1 - Location of elementar samples taken in each bin during insect survey.

## RESULTS AND DISCUSSION

### I - INITIAL INFESTATION LEVEL IMPORTANCE

Example : *Sitophilus granarius* on soft wheat in temperate climatic conditions : 24-26°C during summer, 18-20°C in spring and 13-14°C during winter.

Wheat grain of a french variety with an initial moisture content of 14 p.cent was stored during about two years with three different levels of infestation by the granary weevil adults : 1 adult/kg, 1 ad./5kg and 1 ad/25kg of grain with three replicates in each case. Sampling was made in relation with the time required for a mean development cycle (fig. 2).

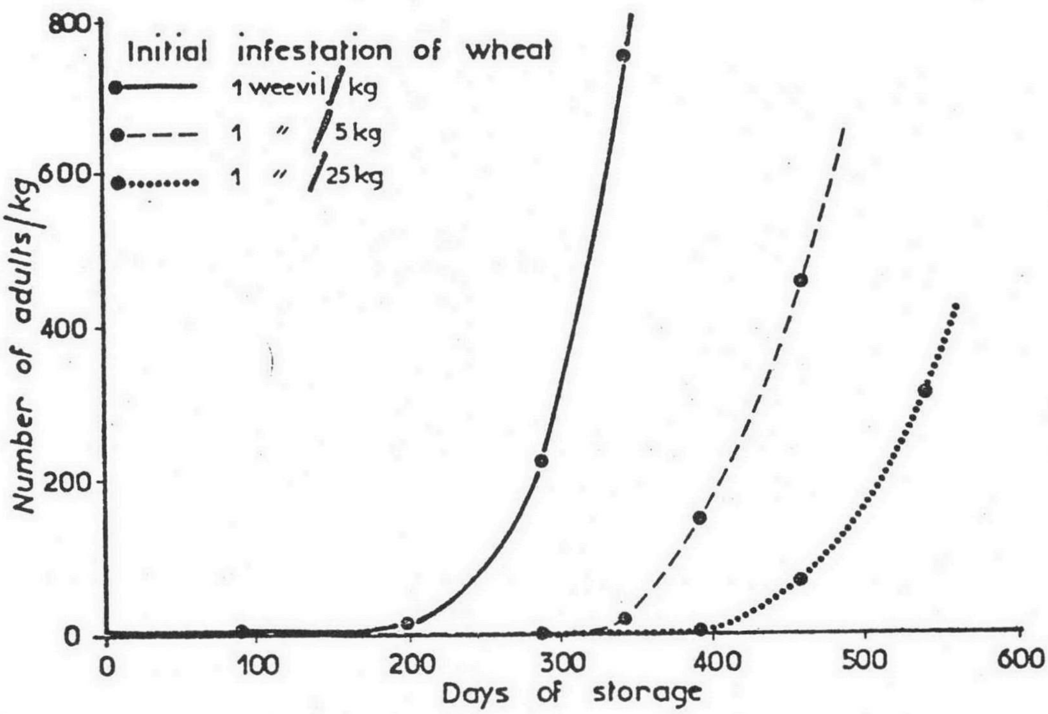


Fig. 2 - Population increase of populations of the granary weevil *Sitophilus granarius* in bulks of wheat at different levels of initial infestation in temperate conditions of storage.

An algebric ajustment of the estimated number of adults during the storage period was obtained by an exponential curve of general equation $y = b.e^{mx}$ for the three levels of infestation where :

$y$ = adults number per kg
$x$ = storage time in days

The coefficient m had a small variation from 0.023 to 0.039 and seemed related to be physical characteristics of the grain.

The coefficient b was decreasing from $27.10^{-2}$ to $43.10^{-8}$ when the initial infestation level decreased from 1 ad./kg to 1 ad/25kg. It was related to the long cryptic period of development during which the population density was below the minimum population detection level of 1 weevil per kg (table 1).

Table 1 - Exponential adjustments of adult population growth during storage of wheat bulks infested by the granary weevil at different infestation levels.

| initial infestation level in weevil number/ kg of wheat | Equation | Number of weevils after 100 days of storage | Storage period for reaching 100 weevils/kg |
|---|---|---|---|
| 1/kg | $y = 0.27\ e^{0.023x}$ | 3 | 255 d |
| 1/5kg | $y = 0.70 \times 10^{-4}\ e^{0.030x}$ | 0 | 400 d |
| 1/25kg | $y = 0.40 \times 10^{-6}\ e^{0.039x}$ | 0 | 494 d |

In our conditions, the critical period which started at the begining of the exponential phase of multiplication was reached after 200, 350 and 420 days of storage for the levels of initial infestation respectively 1/kg ; 1/5kg and 1/25kg (fig. 2).

## II - INITIAL MOISTURE CONTENT INFLUENCE

Example : *Sitophilus granarius* on soft wheat in temperate climatic conditions ; moisture contents of the grain : 13 and 15 p.cent. Infestation level of 1 weevil per 5kg of wheat.

After a nine months storage period, the mean density of adults in wheat was observed at 9 weevils/kg and 552 weevils/kg in the bins with grain respectively at 13 and 15 p.cent of water content. The exponential equation of the growth curve indicated that the critical level of detection of 1 weevil/kg was reached after 140 days with the dry grain (13% W.C.) and only after 112 days of storage with the humid grain (15% W.C.). (table II). The difference increased at the end of the storage period (fig. 3).

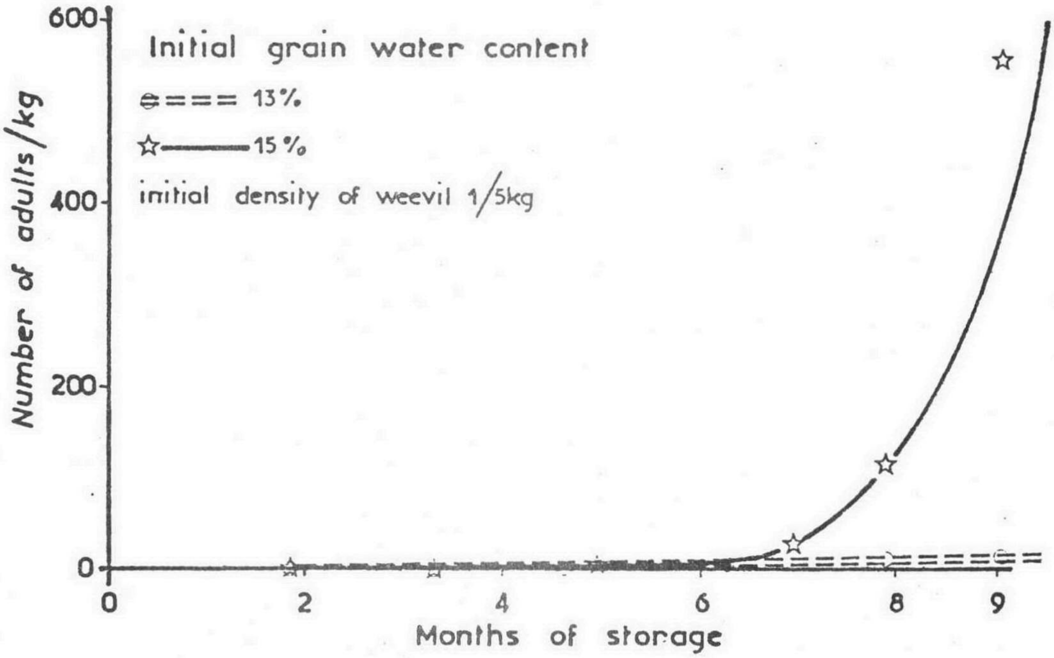


Fig. 3 - Population increase of the granary weevil, *S. granarius*, in two bulks of wheat at different water content in temperate climatic conditions.

Table II - Exponential adjustements of adults population growth during storage of wheat bulks infested by the granary weevil at two levels of grain water content (infestation level 1 weevil/5kg).

| Grain water content | Equation | Storage period to reach 1 weevil/kg | Storage period to reach 20 weevils/kg |
|---|---|---|---|
| 13% | $y = 0.008\ e^{0.018\ x}$ | 140 | 357 d |
| 15% | $y = 0.016\ e^{0.037\ x}$ | 112 | 216d |

The light difference of water content at the beginning of the experimental storage resulted in a large difference of level of damage by the weevils. The geometric rate of increase of the population related to the coefficient of the exponential exponent m is twice higher with humid grain than with dry grain.

## III - SIMULATION OF TROPICAL STORAGE

Example : *R. dominica* on sorghum grain at 13,5 p.cent of water content at a temperature range of 30-34°C. High initial level of infestation of 10 adults per kg.

With the high level of the initial infestation the storage period was very short and dit not exceed hundred days in simulated tropical conditions. The incubation of the samples was realized at the same temperature than inside the store and the estimations of the insects population allowed to plot a new type of adjustment curve : a simple quadratic equation gave a good model with a stagnation period of time near the origin (table 3 and fig. 4).

Table 3 - Polynomial adjustment of adult insect population growth during storage in tropical conditions of sorghum grain infested by the lesser grain borer (10 ad./kg).

| Equation | Population density /kg after 100 days | Storage period for reaching 100 ad/kg |
|---|---|---|
| $y = 9.63 \times 10^{-6} \quad x^{4.09}$ | 1439 | 52 days |

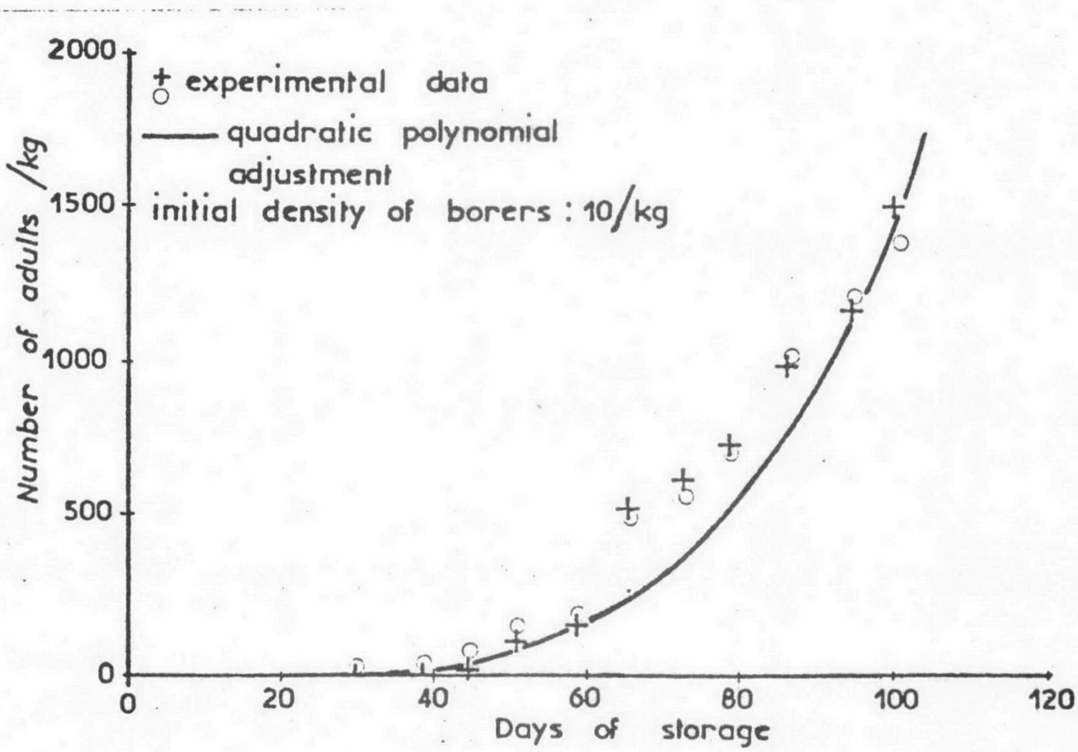


Fig. 4 - Multiplication model of the lesser grain borer *R. dominica* in sorghum bulks in simulated wet tropical conditions of storage.

This slope was in relation with a longer period of development of the lesser grain borer than the granary weevil and a high percentage of mortality of the first larval instar before the penetration inside the kernel. (TIADE, 1982).

## IV - GROWTH OF MEDITERRANEAN INSECT SPECIES ON DURUM WHEAT AND INTERSPECIFIC COMPETITION

Examples : *S.oryzae* and *R.dominica* on durum wheat, simulated mediterranean climate with a temperature range of 28-32°C during 3 months and 24-26°C after; grain water content 11,5 p.cent. Initial density of 4 ad./kg with monospecific and mixed populations.

With monospecific infestations of the grain, the increase of adult populations are similar in rate than with other initial conditions previously described. The highly simplified models, exponential for the rice weevil and quadratic for the lesser grain borer gave a adjustment with a good correlation (table IV, fig. 5).

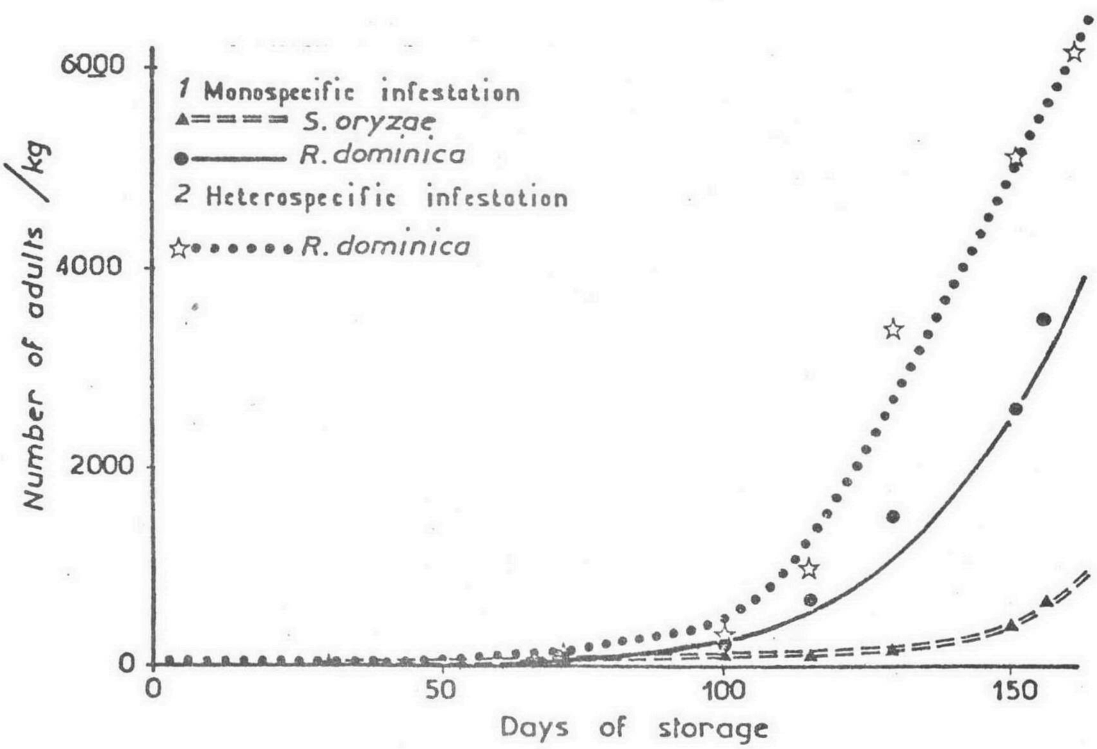


Fig. 5 - Population growth of the rice weevil, *S.oryzae* and the lesser grain borer *R.dominica*, in durum wheat bulks in simulated dry mediterranean climate : monospeficific infestation ●——— *R.dominica*

▲=== *S.oryzae*

or mixed infestation ☆●●●● *R.dominica*

in each bin.

Table IV - Exponential and quadratic adjustments of adult population increase of *S.oryzae* and *R.dominica* on dry durum wheat in mediterranean conditions of storage.

| Insect species | Equation | Number of adults after 100 days |
|---|---|---|
| *S. oryzae* | $y = 1.398\ e^{0.036x}$ | 50 |
| *R.dominica* (1) | $y = 7.4 \times 10^{-7}\ x^{4.37}$ | 413 |
| *R.dominica* (2) | $y = 4{,}9 \times 10^{-8}\ x^{5.07}$ | 669 |

(1) monospecific infestation (2) with *S.oryzae* in the same bin

The grain was very dry and in the bins where the two species had been introduced together, *R.dominica* was the dominant one. With the same infestation density, the polynomial adjustment showed that the population reached the density of 669 beetles per kg in this last case compared to 413 when the lesser grain borer is the single species in the grain bulk.

The hardness of the grain was unfavourable for the rice weevil development but the borings made in the kernel seemed favourable to the setting of the lesser grain borer larvae. In the same time, the population of the rice weevil was maintained at a very low level during all the storage period.

## CONCLUSION

We are now looking for the meaning and the influence of the environmental parameters on the coefficients of the highly simplified models used for the population growth description. Our work was not done for the substitution of traditional population dynamics studies. We only think that the results of these long studies might be of practical use in the future with very simplified calculation methods for prevision of the "insect risk" during a long term storage period using a few number of data.

The characteristics of the grain and the physical measurements are indispensable for the diagnosis. The detection of the insect presence is the second part of the project. Lower is the density of insects detected, better is the prevision of the storage duration. In this way, we are developping "in bin detection" systems with acoustic sensors set inside the grain bins ; insect presence might be recorded without sampling the grain.

In practice, this approach of centralized monitoring of grain storage without tedious human work inside the bins will result in minimizing insecticide use and insect damage with an improvement of the grain qualities knowledge.

AKNOWLEDGEMENTS

I thank Lama TIADE and Amin FARJAN, graduate students of Ivory Coast and Morocco, for providing a part of the experiments data presented in the paper. Thanks are due also to Pierre TURTAUT for his technical assistance and to Bernard FUZEAU for preparing the illustrations.

## REFERENCES

FARJAN, M.A., (1983) Biodynamique en laboratoire de deux insectes ravageurs du blé dur : le Charançon du riz *Sitophilus oryzae* (L.) (*Coleoptera:Curculionidae*) et le Capucin des grains *Rhizopertha dominica* (F.) (*Coleoptera Bostrychidae)* avec application aux conditions de conservation en Afrique du Nord. *Mem. I.A.V. Hassan II*, Rabat, 109p.

TIADE, L.S., (1982) Biodynamique d'une population de Capucins des grains *Rhizopertha dominica* Fabricius *(Coleoptera:Bostrychidae)*, dans une masse de sorgho, en conditions tropicales simulées. *Mem. D.A.A.*, ENSA Montpellier, 38p.