A STUDY OF POPULATION GROWTH OF *SITOPHILUS ORYZAE* L. AND *SITOPHILUS GRANARIUS* L. IN SINGLE AND MIXED CULTURE IN WHEAT AND RICE

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Dedicated to

My Mother and Father

SUMMARY

The oviposition rates, fecundity and lifespan of 100 0-7 day old adult S.oryzae and S.granarius were determined on wheat and rice at moisture levels of 12 and 16%. Oviposition rates for both species were low over a long period in rice and high over a shorter period in wheat (both 12 and 16% moisture levels). Overall S.oryzae was twice as fecund as S.granarius. Rice was the preferred seed species and 16% the most favourable moisture content. S.granarius lived longer than S.oryzae in rice but the reverse occurred in wheat.

In comparisons of developmental times from egg to adult the only significant differences were in 12% moisture content wheat where S.oryzae developed more rapidly than S.granarius and for S.granarius in wheat where development was more rapid at 16% than at 12% moisture content.

In single species cultures over three generations populations of both Sitophilus species reached greater levels in wheat than in rice. S.oryzae multiplied faster than S.granarius under all conditions. These results were consistent with data on oviposition rates and fecundity although S.granarius was slightly longer lived.

In mixed cultures populations of both Sitophilus species were reduced compared with single species cultures under the same conditions with the exception of S.granarius in 16% wheat where it performed better than in single species culture. Neither species was completely eliminated in mixed cultures but in 12% rice only very low numbers of S.granarius survived.

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TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE: GENERAL INTRODUCTION

Biological interactions between organisms which contend for the same resource, have been of interest to ecologists since the days of Darwin. Although this sort of association is evident for many animal-versus-animal and plant-versus-plant situations, one group which has received particular attention is the Class Insecta. Some insect species which attack stored grain and food products are especially convenient experimental animals for the investigation of some aspects of competition. Characteristics which enable insects inhabiting stored grain and grain products to become significant pests, include a short developmental period, resistance to dessication at all stages, a high reproductive rate and extended life span.

Of the many insects that have adapted themselves to a diet of dried vegetable material, a few are primary pests of grain in that they are able to bore into the sound kernels. Some major crops such as coconut, coffee and cotton, may be damaged by as many as 500-700 different species of insects but in general, the number of major insect pests of any crop is between 5 and 20.

The origin of insect pests of stored grain is uncertain. Undoubtedly, they formerly lived in the field, some of them breeding in supplies of seed that escaped the attention of birds and mammals, others feeding on the dried remains of plants, while still others perhaps bored into the roots, tubers and stems of plants (Cotton, 1941). Pest status is most commonly attained simply by an increase in numbers. The natural control of a population is upset by the practice of agriculture when the planted crop provides an unlimited food supply for a potential pest (Hill and Waller, 1982). The custom of storing seeds, roots, herbs and dried meats for food, adopted by man in early times, provided an easy living for the insects accidently brought in with these stores. Ideal conditions for breeding provided by such stores made it unnecessary for these insects to fly long distances in their search for suitable food. Evidence indicates that many of the insects that trouble grain stores today were prevalent in ancient times.

Cotton (1941) suggests that owing to the small size of many of the insects that attack stored grain and the ease with which they can conceal themselves in grain, many of them have been carried by commerce to all parts of the world and have become cosmopolitan in distribution. However, conditions in all parts of the world are not equally favourable for the development of all these insects, so that in some regions, where some species flourish, others are barely able to exist. Hill and Waller (1982) point out that seasonal increases in numbers usually result from changing climatic conditions (temperature, humidity and rainfall) and biological pressures (competition - both intra- and interspecific - parasitism and predation).

Many insect pests of stored grain are still to be found living in the field in regions where the climate is favourable. They breed in the seeds of many wild and cultivated plants and attack the growing grain as soon as it begins to ripen. In addition to rice weevil, other species particularly abundant in ripening corn are the Angoumois grain moth *Sitotroga cerealella* Oliv.; the pink corn worm *Pyroderces rileyi* Wals.; and the flour beetles of the genera *Tribolium* and *Gnathocerus*. In colder climatic conditions, a few species are able to survive the winter in the field. However, a certain number winter over in barns, granaries and elevators where they are protected from the cold. Additionally the congregation of large numbers of insects in stored grain or milled cereal products causes "heating" to occur, so that insects in these "hot spots" are not only protected from the cold but are able to remain actively breeding and feeding throughout the winter. Some of these overwintering insects later fly to the nearby fields and lay their eggs in or on the ripening grain.

Beetles classed as weevils are characterised by having the lower front part of the head prolonged into a more or less elongated beak or snout bearing the mouth parts at the tip. Several species of weevils attack stored grain, three of which are of primary importance as pests. The rice weevil, *Sitophilus oryzae* L. and *Sitophilus zeamais* Mots., which were originally found breeding in rice, prefer warm conditions and the granary weevil, *Sitophilus granarius* L., which can withstand lower temperatures. A fourth of the true-weevils is the broad-nosed grain weevil, Caulophilus latinasus Say. Unlike the rice and granary weevils, it is unable to feed on whole grain or seed that is dry and hard. It attacks cracked or damaged seed and grain before it is fully ripe and in addition may breed in acorns, avocado seed, sweet potatoes and roots of the dasheen.

Allied to the grain weevils are the grain borers and the most important of these is the lesser grain borer (Rhizopertha dominica F.). It is widespread in grain centres, attacking grain especially but also commonly found breeding in flour. Their larvae crawl actively, feeding on the flour produced by the boring of the beetles or boring directly into grains that have been slightly damaged.

One of the best known insect pests of stored grain in the United States is the cadelle, Tenebriodes mauritanicus L., which is thought to be a native of America. The large, fleshy larvae of this insect may burrow into woodwork of grain bins where they may remain until fresh grain is placed in the bins. The beetles feed upon grain, flour and milled products. Both larvae and beetles are found in accumulations of stock in elevator boots, flour conveyors and woodwork. This insect has a long life cycle of more than a year.

Several species of beetles that are not primary grain pests but feed on broken grain and grain dust, follow up the attack of the true grain beetles and complete the work of destruction. These include the flour beetles, Tribolium confusum J.du.V., and T.castaneum Hbst., each breeding in flour, foodstuffs and grain dust. Freeman (1960) in a survey of flour mills in many parts of the world has shown that in hot climates (both dry and damp), Tribolium confusum as well as T.castaneum occur but that in temperate climates T.castaneum is fairly uncommon.

Tribolium species are strong fliers which may account for their more frequent occurrence in farm stored grain. Developmental period from egg to adult may be short.

Other common beetles which are important pests of stored grain are Oryzaephilus surinamensis L. (saw-toothed grain beetle); the square-necked grain beetle (Cathartus quadricollis Guer); the foreign grain beetle (Ahasverus advena Waltl.); long-headed flour beetle

(Laetheticus oryzae Waterh.) and the broad-horned flour beetle (Gnathocerus cornutus Fab.). All attack stored grain and processed food in one way or another.

Moths which attack stored grain are usually encountered in hot, damp climates, e.g. Corcyra cephalonica Staint., but are usually absent from hot, dry climates. In temperate climates, only Ephestia kuehniella Zell. is important in unheated premises. The Indian meal moth (Plodia interpunctella Hbn.) also attacks stored grain and cereal products. This insect breeds freely in ear corn and flies to bins of shelled corn or other grains where larvae completely web over the surface by matting the grains together with silken threads.

Second only in importance to the rice and granary weevils as a pest of stored grain is the Angoumois grain moth, Sitotroga cerealella Oliv. It is known to lay eggs upon the ripening corn kernels and wheat heads in the field and spreads very rapidly while in storage.

Most other minor pests are scavengers, feeding upon the decaying grain and food products left behind by the other pests. They are rarely serious but are annoying and troublesome by their presence. Examples are the meal worms (larvae of comparatively large beetles belonging to the family Tenebrionidae).

Insects feeding or breeding in grains have an important advantage of being protected from adverse conditions such as very low or very high temperature, or humidity. They may also be protected from predators.

The behaviour and habits of stored grain insects are closely attuned to the moisture and temperature of their food media. For the most part the major stored grain pests are restricted to a narrow moisture band of between 11.5 and 14.5% grain moisture content. A moisture content of about 12.5% favours feeding and reproduction of most pests. Moistures above 14.5% permit the development of moulds and also of germination when temperatures are favourable. This results in heating, moulding and caking of the grain. A few insect species can utilise grain below 11.5% moisture, although their ability to do this varies with the species, the temperature and the physical condition of the food. Certain structural and physiological adaptations are essential for these storage insects to inhabit such a rigorous low-moisture environment. For example, their exoskeleton must largely prevent the loss of body moisture by evaporation.

The abundance of many insects in stored grain leads us to the question of how these pests live in the same niche and what happens if there are competitive interactions. From the literature, it is evident that many individual facets of the biology of the Sitophilus species (S.granarius and S.oryzae) have been well investigated. There is, however, a lack of information on the coexistence and competition between these species, although such work has been undertaken with species of other families and orders.

In Longstaff's review (1981) of the biology of Sitophilus species, it is apparent that only Birch (1953c) has attempted to investigate interactions between two Sitophilus species (S.oryzae and S.zeamais). He found that S.zeamais produced more progeny in maize but that on the other hand S.oryzae was more productive in wheat.

Coombs and Woodroffe (1963a) considered some interspecific relationships of Sitophilus granarius. They investigated the effect of S.granarius upon the mortality of eggs and newly-emerged larvae and pupae of Ptinus tectus Boield at 25^{o}C and 70% R.H. in wheat and in flour. The adults of S.granarius and Ptinus tectus appeared to cause mortality of P.tectus immatures but the effect was lower in flour than in wheat. This may have been due to Sitophilus adults often feeding on the germ of the kernel and thus damaging the seed coat. Although this provided shelter for P.tectus larvae it left them more susceptible to injury by Sitophilus. The overall effect was an increase in Sitophilus population and considerable decrease in P.tectus numbers. The authors imply that certain species depend on suitable structure of the food source.

Lefkovitch and Milnes (1963) studied interactions between the larval stages of Cryptolestes ferrugineus and C.turcicus and agreed with Birch (1953c) that relations between the two species were directly conditioned by habitat structure.

Ciesielska's study (1972) on population development of Calandra (Sitophilus) granaria L., Oryzaephilus surinamensis L. and Rhizopertha dominica F. in three two-species combinations was to determine the effect of interaction on the course of population development. Numbers of C.granaria in combination with O.surinamensis were almost twice as great as in single-species culture. C.granaria in this combination is a dominating species. When combined with Rhizopertha dominica F., however, the numbers of C.granaria were maintained at a very even and low level, far lower than when this species is combined with O.surinamensis, and lower than in single species culture. In the case of R.dominica, intensive development took place in combination with C.granaria. Similarly, in combination with O.surinamensis and R.dominica, the latter was again dominant. In these studies the total number of individuals obtained in two-species cultures was always greater than the number of individuals obtained in corresponding single-species cultures.

Ciesielska (1972) showed that when there is interaction between two species, depending on the combination, it either stimulates development in both species or inhibits development of one of the species, with simultaneous intensive development of the other. Ousting of a species takes place through inhibition of development, and not through a rise in its mortality.

In most experiments concerned with interspecific competition in closed laboratory populations, there is elimination of one species, the rate of elimination depending among other things, on the environmental conditions, the biology of the interacting species and on their genetic tendencies (Crombie, 1947; Park, 1948, 1954). It is necessary to find out when, during the development of a population, the competitive interaction is most severe and under what conditions coexistence is possible. In the granary weevil populations studied to date under favourable conditions, a number of interaction types have been identified:

(a) inhibition of the growth of the population of one species.

(b) inhibition of the growth of the populations of both species.

(c) stimulation of the growth of one population with a simultaneous inhibition of the growth of the other population (Ciesielska, 1972).

The latter is the most characteristic interspecific interaction of the competitive type.

In 1975, Ciesielska investigated in further detail, the mechanism of elimination of one species, aimed at establishing the stage of population growth at which the above processes are most intense. In the O.surinamensis and S.granarius combination, there was a lower fecundity for O.surinamensis. While S.granarius seems most affected by environmental factors (microclimate, amount of food), fecundity and development rate of O.surinamensis are controlled largely by the competitive action of S.granarius. Ciesielska concludes that competition between the two species begins during the initial period of population growth.

In 1982, Pontin published a book 'Competition and Coexistence of Species' in the broad sense. It has an indepth background on all aspects of competition and coexistence between various animal species. Relevant aspects will be discussed in relation to the present study in Chapter Five.