INTERSPECIFIC COMPETITION AMONG SOME MAJOR PESTS OF STORED WHEAT

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3.9.79

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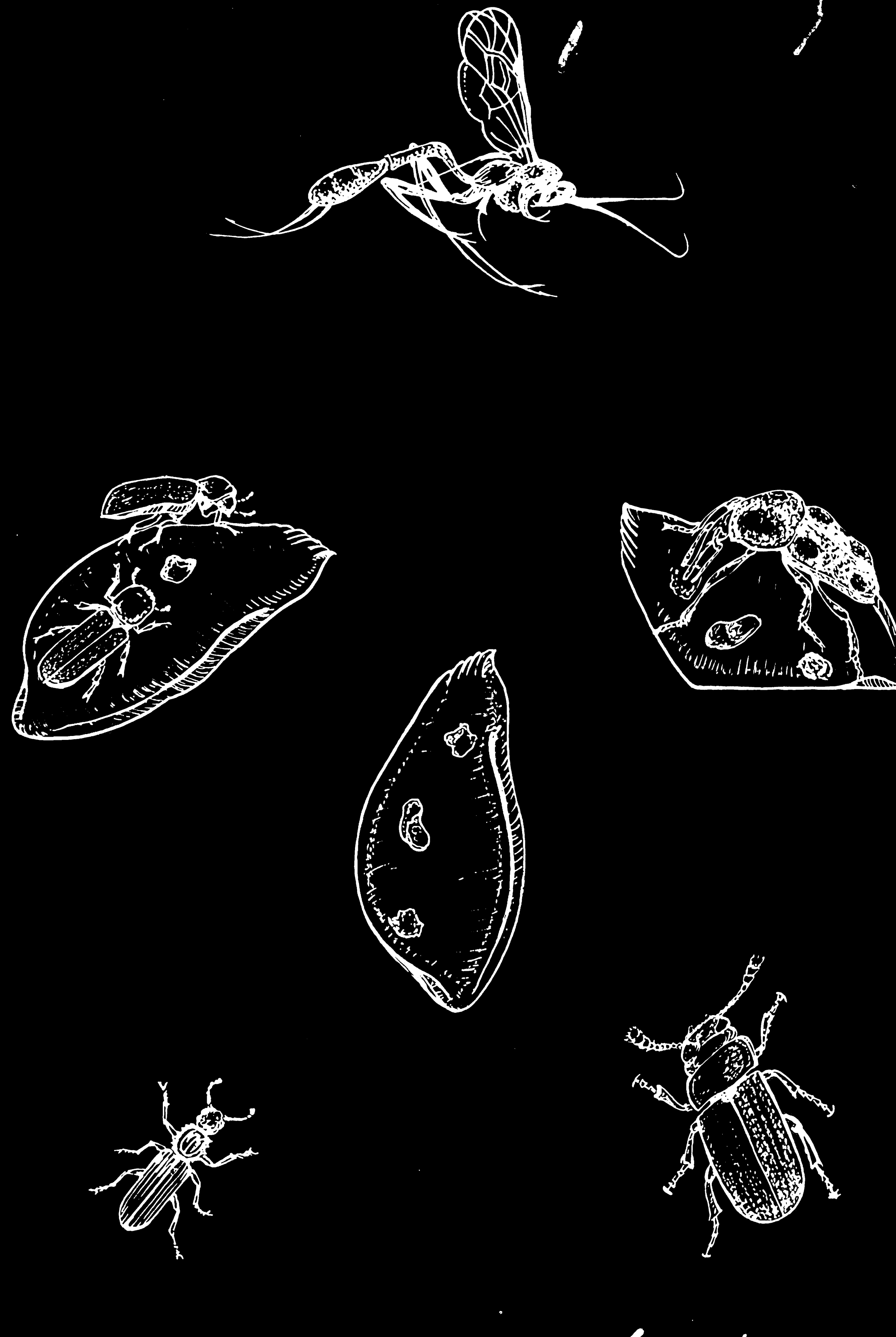
CONTENTS

LIST OF TABLES

TABLE	TITLE	PAGE
9	Population of S. cryzae, R. dominica, O. surinamensis and T. castaneum in presence of a parasite, A. calandrae, in various combinations after 90 days of release and % weight loss of wheat at 29 ± 1 °C and 73 ± 3 % R.H.	47
10	Population of S. oryzae, R. dominica, T. castaneum and O. surinamensis in presence of a parasite, A. calandrae in various combinations after 90 days of release and % weight loss of wheat at laboratory conditions.	48



INTERSPECIES COMPETITION

CHAPTER-I
INTRODUCTION

INTRODUCTION

Wheat is infested by a larger number of insects in storage as compared to infestation of the crop in the field. A major problem that is being faced by the farmer is to keep the seed wheat free of insect infestation under ecological conditions of Orissa State. Some of these insects are primary pests, capable of damaging sound grains, and few others cause damage only under favourable conditions or in presence of a primary pest. On the other hand, two or more species of pests may infest a single type of commodity but one species may outnumber others even if enough food material is available to support all the infesting insects. Sometimes artificial conditions are created by one grain infesting species which may be favourable or unfavourable for the development of the other, resulting in an imbalance in the insect population.

Graminivorous organisms may exploit their food source in grain storage with little chance of ultimate starvation, and in turn supply food for the wide variety of parasites and predators associated with them, thus ensuring the population growth of their enemies. Among the wheat damaging insects in storage, rice weevil *Sitophilus oryzae* (L.) and lesser grain borer *Rhizopertha dominica* (F.) are more injurious in India particularly under Orissa conditions. These two major pests are often observed to occur along with so called secondary pests like red flour beetle *Tribolium castaneum* (Hbst.) and saw toothed grain beetle *Oryzaephilus surinamensis* L. in large numbers and sometimes their population becomes so variable that it poses a problem to investigate if the presence or absence of any of these species determines the growth or suppression of an individual species. In single species and mixed species culture or infestation, particularly in combined infestation of wheat by rice weevil and lesser grain borer, a parasite *Anisopteromalus calandrae* How. has been observed in Orissa. It has been further noticed that the population of these insects have not been completely eliminated due to parasitisation. It becomes difficult to conclude from these observations that biological control of these major pests is possible unless the extent of parasitisation or suppression of population of these pests are worked out.

Lecato (1976) reported that in a culture of *T. castaneum* and *O. surinamensis*, the red flour beetle killed eggs, early instar larvae and pupae of the latter and retarded the population growth of the saw-toothed grain beetle. Jacob and Mohan (1976) observed the predation of T. castaneum on the eggs of R. dominica. On the other hand Lecato (1976) concluded from his experiments that T. castaneum or O. surinamensis produced relatively more progeny and caused greater damage when combined with either R. dominica or S. oryzae. Adeyemi (1968) studied the competition between Tribolium castaneum and Cadra cautella (Wlk.) and found that adults of T. castaneum ate eggs and killed moth larvae. The silk produced by the moth larvae was harmful to the larvae of T. castaneum. One becomes confused to see that occurrence of two or more species of insects in an infested material sometimes encourages population growth and also suppresses population of one or the other.

Dhaliwal and Sattu (1978) reported the occurrence of A. calandrae in the laboratory cultures of R. dominica in stored wheat. It was concluded that although the parasite was able to restrict the population growth of R. dominica, the decrease in host number adversely affected the population of A. calandrae. This finding does not make it clear to what extent the population of the pest was controlled.

Considering these lacunae in our knowledge in the effect of interspecific or intraspecific competition among stored grain insects infesting wheat, experiments were carried out with rice weevil, lesser grain borer, red flour beetle and saw-toothed grain beetle to study the effect of their interspecific competition on their population growth and degree of damage to wheat stored at controlled and laboratory conditions. The findings of these experiments may reveal the importance of occurrence of primary and secondary insect pests of stored grain with similar and disimilar habits and the presence or absence of a parasite in the ultimate fate of the infested commodity. The results of the investigations and a brief discussion thereof havebeen described in the following pages.

CHAPTER-II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Published information on the subject of interspecific or intraspecific competition among insects occuring in stored grain is meagre as compared to other aspects of study of storage problems without which it becomes difficult to plan for sound future programmes of experiments, and to compare the present findings. However, a brief review of the available literature on " Interspecific competition among major pests of stored wheat " is presented in the following paragraphs.

Jablonowski (1916) observed Oryzaephilus surinamensis (L.)to be carnivorous and reported that the larvae and adult stages of saw toothed grain beetle failed to grow on ininjured grains and died unless other food was available. They also could not live on animal remains (exuviae of flour beetle larvae etc.). However, they survived on coarse ground grains.

Durant (1921) stated that " O. surinamensis generally destroys only when it has been injured by primary pests but they are undoubtedly real pests of flour, biscuits, raisins, stored foods etc."

Back and Cotton (1926) reported that O. surinamensis feeds both in adult and larval stages on almost any stored products of vegetables origin such as flour, stock, poultry feed and copra etc., dried fruits are particularly liable to infestation and stored grain if often badly damaged. Adults confined with sound wheat were found dying of starvation.

Crombie (1943) conducted experiments to determine the effect of competition and population density on oviposition by Rhizopertha dominica F., Oryzaephilus surinamensis L., and Sitotroga cerealella (Oliv.) in wheat or flour and Bruchus (Acanthoscelides) obtectus, Say in beans at 30° C and a relative humidity of about 70 percent. The crowding of adults invariably depressed the rate of oviposition, while the egg fertility was not affected. In unconditioned media, there was a reduction in fecundity which was due to competition for the oviposition and feeding. When the two species were in the same environment their effect on each other's fecundity was more or less dependent on the niches for which they were competing. The reduction of fecundity of R. dominica by flour beetle conditioned by its own species or by O. surinamensis or S. cerealella was at first roughly proportional to the degree of conditioning, but after a time the effect of all media was the same. It is believed that a conditioned medium operates upon fecundity through poisoning and the effect is upon oviposition rather than egg production.

Park (1944) studied the inter-species competition within populations of the genus Tribolium. His preliminary findings were that Tribolium castaneum(Hbst.) produced larger total populations than Tribolium confusum Duv.,although the cultures of the latter had a higher percentage of adults. Interspecific competition reduced the total population size and that T. castaneum appeared to be the more successful competitor in the population.

Crombie (1946) conducted experiments to study the growth of pure populations of R. dominica, O. surinamensis, and S. cerealella in a standard medium of wheat maintained at a constant level. The population of each species rose to a maximum and remained fluctuating about this value indefinitely. A comparison of the rates of oviposition with the rates at which adults emerged showed that in the maximum population there was an enormous mortality (always over 90 %) in the immature stages. When pairs of species competed, R. dominica eliminated S. cerealella because their larvae, between which most of the competition occurred, had the same needs and habits. Each of these species was able to survive with O. surinamensis because the latter occupied a different ecological niche. Populations living in a medium of unrenewed wheat rose to a maximum and then declined as the food became exhausted. The eventual extinsion of the population was due; not to the cessation of oviposition, but to the failure of the larvae to survive. The duration of life of adults of *R. dominica* was shorter in unrenewed than renewed medium and shorter still when this species was competing with *S. cerealella* in unrenewed medium. The duration of the life of the other species and the sex ratio of *S. cerealella* was apparently unaffected by these conditions. The fecundity of *R. dominica* females decreased in succeding generations. The competitive relationship between *O. surinamensis* and either *S. cerealella* or *R. dominica* shifted slightly in favour of the latter species in unrenewed as compared in the renewed media. In renewed media this relationship probably depended chiefly on the destruction of eggs and pupae by adults and larvae particularly by *O. surinamensis.*

Birch (1947) conducted an experiment to study survival of *T. castaneum* in medium hard wheat grains. It was evident that the beetle could live and reproduce in whole grains of wheat. After 6 months about one-third of the whole grains were destroyed.

Crombie (1947) carried out experiments in a dark incubator at 30° C and 70 % relative humidity with *R. dominica* and *S. cerealella* to study the inter-and intra-specific competition. Overcrowding tended to favour the survival of S. cerealella. Migration from the grains tended to decrease with latter instars. When two species were competing, the average ratio of the survival was 1.3 : 1 for R. dominica to S. cerealella. S. cerealella was able to take advantage of this decreased competition because of the occurrence of larvae with a typical rates of development in this species. Overcrowding in the immature stages had no effect upon the average developmental period of the larvae or upon the sex ratio, weight or fecundity of the adults of either species.

Barnes and Simmons (1952) attempted to establish a mixed population of saw-toothed grain beetle and the Indian meal moth which usually resulted in the decline of the latter species. In stored raisins the saw toothed grain beetle attained dominance during the summer following harvest and the Indian meal moth rarely became abundant during any part of the experimental period.

Narayan (1953) stated that this insect is a secondary pest of stored grain and feeds on broken grains, grain dusts and grain damaged by other pests like Sitophilus oryzae and Rhizopertha dominica. This beetle can not damage the sound grains either in adult or larval stages.

Park (1956) reported the effect in all the six combinations of temperatures of 34, 29 and 24° C and relative humidities of 70 and 30 percent on populations of *T. confusum* and *T. castaneum* kept in flour separately, and in competition with each other. In all, 400 cultures were used and population counts were made every 30 days, with the exception of T. castaneum at 24° C and 30 percent relative humidity, both species persisted indefenitely when kept alone, but they differed in the size of the populations that developed in particular environment as well as in the proportion of adults present. When the two species were kept together, one always eliminated the other, but the one that did so varied with the physical environment and in some cases was and in others was not the one expected to do so from the trends observed when the species were kept separately.

Lloyd and Park (1964) observed the mortality resulting from interactions between adult flour beetles in labouratory cultures by pairing the pupae of males and females of *T. confusum* and *T. castaneum* in all possible combinations. Either sex of either species survived a markedly shorter time when incarcerated with males of *T. confusum*. In *Tribolium* the males commonly mount females of the wrong species, or even other males and attempt to copulate. During these attacks, the aedeagus may injure soft structures under the elytra, leading to a gradual but fatal loss of body fluids. The males of T. confusum were decidedly more injurious to females of their own species than they were to each other, but were about equally injurious to the two sexes of T. castaneum.

Dawson (1966) studied the developmental rates of three strains of T. castaneum and five of T. confusum in wheat flour measured in the laboratory at 29° C and relative humidities of 40, 60 and 70 percent. The results showed that the time required for development was influenced not only by strain and humidity but also, significantly by interactions between genotype (strain) and environment. The results also indicated that the response to different humidities of some strains depended on their genetic composition.

Park, Leslie and Mertz (1966) studied competition in populations of four genetic strains of each species of T. castaneum and T. confusum and they were shown to differ in the densities at which they survived and their age distributions in primary characteristics (fertility, fecundity, rate of development and adult survival) and in the extent to which they are cannibalistic. When the species were reared alone, the greatest differences in density occurred between strains of *T. confusum* and the smallest between strains of *T. castaneum* and these facts were causally related to the primary characteristics and the predatory activities of each of the eight strains. When the two species were reared together, one always eliminated the other. *T. castaneum* characteristically determined the eventual outcome of competition with *T. confusum*.

Adeyemi (1968) carried out an experiment in the laboratory with a constant temperature of 25.5°C and 70 percent relative humidity in England to study the competition between *T. castaneum* and three moth species viz. *Cadra cautella* (Wlk.), *Plodia interpunctella* (Hs.), and *Corcyra cephalonica* (Stnt.). All experiments were conducted on decorticated groundnuts in specimen tubes, crystallising dishes or jam jars. The survival and development of the immature stages of the moth species were studied and the number of eggs laid by the adults in presence of *T. castaneum* were recorded. The reciprocal effects of moth larvae on *Tribolium* were briefly studied. The most important harmful effects of *T. castaneum* were on couplating moths and on moth eggs. Adults were frequently disturbed and sometimes killed or if they survived, laid fewer eggs. The eggs were also eaten, especially those laid loose in the medium. Adults of T. castaneum attached and killed moth larvae and pupae but this was considered to be of minor importance. The silk produced by moth larvae was harmful to the larvae of T. castaneum but any reduction effected in the population of T. castaneum was probably offset by the beneficial effect of moth cocoons, which sheltered larvae of T. castaneum from cannibalism. It is concluded that, as a result of competition for food or space or both between T. castaneum and the moth species, the moth populations were likely to be exterminated despite their apparently higher intrinsic rate of increase.

Lefkovitch (1968) made a multifactional study with two replicates of each combination on wheat and wheat feed, of the interactions between Sitophilus oryzae (L.), Lasioderma serricorne (F.), T. castaneum and Cryptolestes ferrugineus (Steph.) at 30° C and 60 percent relative humidity for six weeks in small cultures and reported that L. serricorne was seriously affected by the presence of S. oryzae on wheat and by all three others in wheat feed. S. oryzae was harmed by the presence of C. ferrugineus on wheat, but was unaffected by it on wheat feed. C. ferrugineus had a harmful effect on T. castaneum on both foods and was favoured by the presence of L. serricorne on wheat. It was concluded that under such conditions C. ferrugineus was the species most likely to persist.

Golebiowska (1970) studied the feeding and fecundity of S. granarius, S. oryzae and R. dominica in wheat grains over 30 consecutive days in the laboratory at 28° C and 75 percent relative humidity. It was found that adults of S. oryzae fed at the same rate throughout the experiment and laid most of their eggs during the first few days after reaching maturity. Those of S. granarius, however, began to lay only after several days of intensive feeding. Adults of R. dominica also at first ate intensively and latter at a decreased rate. They laid most eggs during the first few days and again in the fourth week. Intensive oviposition was preceded by intensive feeding. The amount of food eaten by the larvae and adults, together with the quantity of grain dust produced in relation to adult body weight, indicated that, of the three species, R. dominica was the most voracious and destructive.

Pingale (1970) made studies on interspecific competition between T. confusum, Gnathocerus cornutus, Trogoderma versicolor (Creutz), S. cerealella, O. surinamensis, C. chinensis and C. maculatus in various combinations and showed that between species of which the habits were similar, the weaker was eliminated, but that species occupying different ecological niches developed normally together.

Stoyanovic (1970) determined the loss of weight of stored wheat infested with S. granarius and S. oryzae at initial population densities of 1, 2 or 3 pairs per 0.5 kg. The weevils caused serious damage even when the conditions for their development were not optimal. After 200 days, the percentage weight loss for grain infested by S. granarius was 59-78 at 20° C and 10-71 at 10° C, the corresponding percentages for S. oryzae were 12 - 71 and 5 - 14.

Beratlief (1971) stated that Anisopteromalus calandrae How., reared from immature stages of S. oryzae infesting stored cereals near Bucharest at temperatures of 19 - 25°C and a relative humidity of 14.7 - 16.5 percent, the parasite developed from egg to adult in 13 - 27 days and the adults lived for upto 18 days; only females were obtained. The rate of parasitism varied from 7.2 to 18 percent and it was thought probably that the pteromalid played an important part in limiting the infestation of stored grain.

Golebiowska, Filipek and Krzymanska (1972) conducted an experiment in the laboratory in Poland at 14, 24 and 27°C and 75 percent relative humidity to determine the injuriousness of S. granarius, S. oryzae and R. dominica to grains of wheat and rye and showed that S. granarius was the most injurious at 24° C, the adults consumed an average of 0.78 mg of wheat per day each and the larvae in course of their development about 30 mg each. Adults of S. oryzae and R. dominica consumed averages of 0.4 and 0.42 mg wheat per day each, and the larvae 14 and 16 mg each in the course of their development respectively. In relation to body weight, R. dominica was the most voracious and left the largest amount of grain dust after feeding the germination rate of the grain was impaired by the feeding of the beetles, especially by R. dominica. In grain damaged by S. granarius the percentage of dry matter was reduced and the fat and the nitrogen contents were increased. Feeding and consequently injuriousness were greater at higher temperature.

Golebiowska, Chmielewski and Filipek (1972) carried out an experiment in the laboratory in Poland in 1961-68 with stored wheat infested with insects and mites. Both insects and mites produced an increased number of progeny when the initial population was small.

When population was high, the number of progeny decreased, partly as a result of physical disturbances of the ovipositing females by feeding individuals and partly because the young larval instars were at a dis-advantage for feeding. Adult weevils sometimes damaged individual grains to such an extent that the immature stages could not develop in them and in some cases adults fed on the eggs of their own species. Acarus siro L. and Tyrophagus putrescentiae (Schr.) reproduced poorly in the presence of insects. R. dominica and T. confusum developed more strongly in the presence of other species of insects, and mites, but T. granarium was adversely affected by the presence of other species. The development of S. oryzae and S. granarius was unaffected by the presence of other species.

Lecato (1976) reported that when both T. castaneum and O. surinamensis occurred in fine diets that were more favourable to movement by T. castaneum, the predation of T. castaneum on O. surinamensis was accentuated. When the two species occurred in a 1:1 mixture of rolled oats and standard T. castaneum medium Oryzaephilus remained in the rolled oats and T. castaneum generally segregated themselves in the standard medium, which reduced predation. Predation by T. castaneum on Oryzaephilus in cracked corn (a sub-standard diet for

T. castaneum) was increased but in shelled whole groundnuts, it was decreased. In both standard medium and cracked corn, both late instar larvae and adults of T. castaneum killed more eggs, early instar larvae and pupae of Oryzaephilus than did late instar larvae. This feeding resulted in an increase in the number of progeny produced by T. castaneum.

Jacob and Mohan (1976) conducted Laboratory tests in India and reported that larvae and adults of T. castaneum readily preyed on eggs, larvae and pupae of the other stored product pests viz. Stegobium paniceum (L.) and R. dominica and on eggs and adults of Lasioderma serricorne (F.). Full grown larvae of L. serricorne were not attacked, perhaps because of the thick setal growth on their bodies. O. surinamensis was generally, less susceptible to attack than the other species.

Girish, Tripathy, Tomar and Krishnamurthy(1976) made a survey in U.P., India in 1973-74 to represent the actual losses of grain that occurred during storage, due to insect pests including S. oryzae, R. dominica, S. cerealella, T. castaneum, O. surinamensis, T. granarium and Ephestia cautella (Wlk.). The loss in weight after storage for six months varied from 0.06 to 9.7 % and the loss in viability from 7.0 to 22.0 %.

Lecato (1976) conducted jar tests in the laboratory in Georgia with various species of stored product insects and reported that population growth and the weight loss of whole kernels of rice, wheat or maize were found to be affected by the combination of species confined together in the jar. Populations of Cryptolestes pusillus, (Schonh.), O. surinamensis and T. castaneum produced relatively more progeny and caused greater weight losses when confined with either R. dominica and S. oryzae than when they developed alone.

Kemal, Rasvi, Ahmad and Khan (1977) reported cannibalistic behaviour by adults (on other adults) of R. dominica for the first time from observations on populations in rearing jars in the laboratory. Cannibalism was more pronounced at high temperature (32°C) than lower one (25°C) and did not occur when populations were sparse.

Mookherjee, Bhatia and Verma (1978) made studies in India on the survival of T. castaneum and Corcyra cephalonica (Stnt.) in single-species and mixed species cultures in vials containing 8 g crushed wheat or flour started with 50 eggs of each species. There was considerable intraspecific competition in the Corcyra cultures but little in the Tribolium cultures. In the mixed cultures, mortality of Tribolium increased, markedly but this was not true of Corcyra. The results were similar when the ratio of eggs of the two species was changed from 10.90 to 90.10.

Press, Flaherty and Arbogast (1978) worked on the possibility of using Bracon hebetor, Say and Venturia canescens (Grav.) (Nemeritis canescens) in combination for greater efficiency in the biological control of Ephestia cautella (Wlk.) in stored products by exposing host larvae on an artificial diet in a petridish to one or both parasites, B. hebetor alone proved to be slightly more efficient parasite than was V. canescens alone. When both parasites were present, B. hebetor was found to be able to develop in host larvae that had already been parasitised by V. canescens, but V. canescens could not develop in larvae already parasitised and thus eventually eliminated by B. hebetor. The presence of both parasites therefore caused an increase in host mortality (as compared with that caused by either species alone) that was only temporary.

Dhaliwal and Battu (1978) reported the occurrence of Anisopteromalus calandrae (Howard) in the laboratory culture of Rhizopertha dominica in stored wheat in India for the first time in June,1975. In population counts in samples of cultures weighing 10 g.

The numbers of hosts and (in brackets) parasites averaged 61 (13) in June, 92 (29) in July, 74 (20) in August and 50 (9) in September. It was concluded that although A. calandrae was able to restrict the growth of populations of R. dominica,the decrease in host numbers adversely affected the population of the parasite.

Phadke and Bhatia (1978) studied that when populations of S. oryzae and R. dominica were allowed to develop together in the grain of 7 varieties of wheat, S. oryzae outnumbered R. dominica during the period of population increase. For both species, the populations were lower than, when grown separately, indicating mututal suppression. The multiplication of S. oryzae was related to the susceptibility of the variety, but that of R. dominica was not apparently because of the pressure exerted by the dominant species. It was concluded that varietal susceptibility could not be assessed if more than one species were present at the same time.

CHAPTER-III

MATERIALS AND METHODS

MATERIALS AND METHODS

The materials used and methods adopted during the present investigations to study the competition among major pests (Rice weevil, Red flour beetle, Saw-toothed grain beetle, and Lesser grain borer) of stored wheat and the effect of a parasite on them, in the laboratory of the Department of Entomology, College of Agriculture, Bhubaneswar during the year 1979 are described in the following pages.

MATERIALS

A. Materials used in rearing the insects :

1. Insects : (i) Rice weevil *Sitophilus oryzae* Linn., Curculionidae :Coleoptera.
   - (ii) Red flour beetle, *Tribolium castaneum* Herbst, Tenebrionidae: Coleoptera.
   - (iii) Saw-toothed grain beetle, *Oryzaephilus surinamensis* (L.), Cucujidae : Coleoptera.
   - (iv) Lesser grain borer, *Rhizopertha dominica* (F.), Bostrichidae : Coleoptera.

(v) A parasite <u>Anisopteromalus calandrae</u> (How.) Pteromalidae Hymenoptera.

2. Food materials used in rearing and breeding the test insects.

	Food stuff	Sources of supply
(a)	Whole wheat	Local market and Central Research Farm, O.U.A.T.
(b)	Wheat flour	Prepared from available wheat.
(c)	Raw rice	Local market.
(d)	Mung flour	Prepared in the laboratory
(e)	Brewer's dry yeast	Local market.

3. Apparatus used in rearing and breeding the test insects.

(a) Rearing glass jars of size 20 x 10 cm for breeding the insects.

(b) 60 mesh sieve supplied by Ende cotts (Filter) Ltd., London.

(c) Camel hair brush.

(d) Muslin cloth.

(e) Rubber bands

(f) Forceps and needles

(g) Maximum and minimum thermometers

(h) Aspirator - prepared in the laboratory.

A rubber cork, having two holes of size 1.5 mm diameter was tightly fitted to a wide mouthed bottle. Two glass tubes of 18 - 20 cm long were fitted to the holes. One tube was made to bend at right angle and the other at an angle of 120° over Bunsen burner so that it was convenient to catch the insect species easily inside the insect collection cage.

(i) Low temperature incubator supplied by Sow India Co. Scientific Equipment Delhi was used for rearing the insects throughout the experimental period. The incubator with a temperature range 5 - 40° C was operated at 220 volts to maintain a temperature of 29° ± 1°C and 73 ± 3 % RH. inside the chamber throughout the experimental period.

(j) Insect collection cage : It is a rectangular box of size 45 x 36 x 20 cm having glass walls on the top, front and backsides. On the two sides, arm holes fitted with cloth around the hole were provided to work with the hands inside without the chance of escape of any insect.

4. Fumigant used to make the wheat, wheat flour, mung flour, and raw rice free of insect and mite infestation.

B. <u>Materials used in the experiments</u> :

1. Test insects : (a) Rice weevil

(b) Red flour beetle

(c) Saw-toothed grain beetle

(d) Lesser grain borer

(e) The pteromalid parasite

2. Commodity : Sound wheat grains with 12.6 % of moisture was used as food for test insects.

3. Plastic jars of size 4 cm x 5 cm.

4. Muslin cloth

5. Camel hair brush

6. Rubber band

7. Sieve (60 mesh) supplied by Hargopal and Sons Ambala

8. Aspirator

9. Forceps and needles

10. Incubator : maintained at $29^{\circ} \pm 1^{\circ}C$ and 73 ± 3 % R.H.

11. Desicator : These were used as relative humidity chambers. A constant relative humidity of 73 ± 3% was maintained by mixing 17.91 g sulphuric acid with 82.09 cc of water (Sobman, 1957).

12. Electric oven : The oven supplied by Research Instrument House Calcutta was used to determine the moisture content of the grain.

13. Physical balance and weight box.

14. Ice chamber.

METHODS

Rearing of insects :

The adults of Sitophilus oryzae Linn. were taken from the laboratory cultures maintained in the laboratory reared for experimental purposes. Five hundred grams of disinfected whole wheat was taken in each rearing jar to which about 300 - 400 number of unsexed adult rice weevils were released. The rearing jars were covered with muslin cloth and wrapped with a rubber band. The cultures were kept in incubator at $29^{\circ} \pm 1^{\circ}C$ temperature. The adults were separated from the grains after seven days and were rejected. Freshly emerged adults from these jars were utilised in the experiments.

The adults of Tribolium castaneum Herbst. were collected from local flour mills of Bhubaneswar and reared in a food medium of whole wheat flour containing 5 % dried brewer's yeast. Wheat flour was sieved through 60 mesh sieve and 250 g of sieved wheat flour was taken in each culture jars. About 400 unsexed red flour beetles were released in each rearing jar for breeding. The rearing jars were covered with muslin cloth and wrapped with a rubber band. The cultures were kept in incubators at $29^{\circ} \pm 1^{\circ}C$ temperature.

A large number of properly identified adults of saw-toothed grain beetle Oryzaephilus surinamensis Linn. were collected from the local food and feed go downs and were used for further breeding in the laboratory. A mixture of wheat flour with 12 - 13 % moisture content and rice and mung flour in the proportion of 90 : 5 : 5 respectively were taken in rearing glass jars of size 20 x 15 cm. In each rearing jar containing food, about 100 adult beetles of both sexes were released which was then wrapped with muslin cloth with the help of a rubber band and kept undisturbed in semi-dark place for about 4 days for egg laying. After the targetted period, the adults were removed and the eggs were allowed to develop at temperature of 29° ± 1°C. The newly emerged adults were taken for the investigation.

The adults of Rhizopertha dominica (F.) were collected from local godowns and were used for breeding in the laboratory. Five hundred grams of whole wheat was taken in each rearing jar to which about 200-300 number of unsexed adults were released. The rearing jars were covered with muslin cloth and wrapped with a rubber band. The cultures were kept in incubator at 29° ± 1°C temperature. The adults were separated from the grains after 7 - 10 days and were rejected. Newly emerged adults were utilised in the experiments.

The adults of <u>Anisopteromalus calandrae</u> (How.) were collected from a mixed culture of rice weevils and lesser grain borer maintained in the laboratory of the Department of Entomology, College of Agriculture, Bhubaneswar. Five hundred grams of whole wheat was taken in each rearing jar. About 200 adults of rice weevils or lesser grain borers were taken separately to which 50 - 70 adult parasites were released after a week and then the jars were again wrapped with muslin cloth with the help of a rubber band and kept undisturbed inside the low incubator. The newly emerged adult parasites were taken for further study.

The process of rearing was repeated at 7 days interval in order to get a steady supply of freshly emerged adults.

The food materials used for cultures and experiments were fumigated with alumunium phosphide @ 1 tab/q with 3 days exposure period to make these free from other insects and mites before use.

<u>Determination of moistures content of wheat</u>

The moisture content of wheat was determined by direct heating method. Three samples of known weight of wheat were taken in alluminum basins and kept inside the oven at a temperature of 130°C for 24 hours. After that the basins were transferred to desicator containing calcium chloride for cooling and each weighed after 2 hours. Further they were kept in oven for 12 hours after which second weight was taken in order to get constant weight of the commodity. Finally the moisture content was calculated as follows :

$$\frac{X - Y}{X} \times 100 = \text{Percentage of moisture content}$$

where-as X = known weight of commodity

Y = final weight of commodity after heating

Average weight of 3 samples of commodity in grams

(X) = 10

Average dry constant weight of 3 samples of commodity

in grams (Y) = 8.74

$$\text{Moisture content in percentage} = \frac{10 - 8.74}{10} \times 100$$

$$= 12.6$$

Hence the moisture content of wheat = 12.6 %

<u>Study of interspecific competition of different insects</u>

Experiments were conducted with three replications of each treatment in two sets. One set of experiments were done in laboratory conditions and the other at a constant temperature of 29° ± 1°C and a relative humidity of 73 ± 3 % inside the incubator. Growth of population and weight loss of grains were taken as the factors to determine interspecific competition, by allowing one species of insect to multiply alone in combination with other pests or the parasite.

Population growth of a single species of insect in wheat (at 29° ± 1° C and 73 ± 3 % R. H.) :

100 grams of disinfected whole wheat grains were separately taken in several plastic jars in which 10 pairs of freshly emerged adults of rice weevil, lesser grain borer, saw-toothed grain beetle and red flour beetle were released separately in each jar. The adult insects were picked up by means of camel hair brush and put into the experimental jar. The jars were then wrapped with muslin cloth with the help of a rubber band. Each treatment was replicated thrice and kept undisturbed inside the low temperature incubator maintained at 29° ± 1° C and a relative humidity of 73 ± 3 %.

Population growth of different insect species (without parasite) occuring together in various combinations in wheat :

10 pairs of freshly emerged adult insects of each species of the four insects studied were released in each jar containing 100 g of disinfected whole wheat grains.

The combinations were as follows :

1. Rice weevil + Red flour beetle
2. Saw-toothed grain beetle + Red flour beetle
3. Lesser grain borer + Red flour beetle
4. Rice weevil + Lesser grain borer + Red flour beetle
5. Rice weevil + Lesser grain borer + Saw-toothed grain beetle
6. Rice weevil + Lesser grain borer + Saw-toothed grain beetle + Red flour beetle.

Then each treatment was replicated thrice and kept inside the incubator and the observations were taken after 90 days of the experiments.

Population growth of different insects in the presence of parasite in wheat.

100 grams of disinfected wheat grains were weighed into plastic jars to which 10 pairs of each insect species with 10 pairs of adult parasites were released in various combinations. After a week the parasite culture jar was put inside the insect collection cage and by means of aspirator, the parasites were collected and were released to jars carefully containing 100 grams of wheat with different insects and then the jars were immediately

wrapped with muslin cloth with the help of a rubber bond. Each treatment was replicated thrice. The combinations were as follows :

1. Rice weevil + A. calandrae
2. Lesser grain borer + A. calandrae
3. Rice weevil + Lesser grain borer + A. calandrae
4. Rice weevil + Lesser grain borer + Red flour beetle + Saw-toothed grain beetle + A. calandrae

The replicates were kept inside the incubator and the observations were taken after 90 days of the experiments.

Similar sets of experiments were set up in the laboratory at variable temperatures (33° - 35° C) and relative humidities (70 - 76 %) to study and compare the effect of varied temperatures and relative humidities on interspecific competition among the pests infesting wheat.

Population count.

After 90 days of the experiments, the jars were taken out to record the populations of each insect species. For convenience of count of the insects, the experimental jars were kept inside the ice chamber of refrigerator in order to inactivate the insects. The muslin cloth was removed and the infested material with insects were spread over a plain white paper and then insects were counted by the help of a brush, only taking alive insects into account.

<u>Calculation of percentage of weight loss of wheat due to insect feeding.</u>

The initial weight of the grains was recorded while setting the experiments. The final weight was taken after separating the frass, the dead and alive insects, and immature stages of insects. The following formula was used to calculate the final percentage of weight loss taking loss or gain of moisture at the final stage of experiments into consideration under laboratory conditions only. The initial moisture content of wheat was 12.6 % and the final moisture content was calculated to be 11.6 % thereby resulting a net loss of weight 1.0 % due to moisture loss. Therefore the weight of grain taken was 99.0 grams.

$$\% \text{ weight loss} = \frac{\text{final weight of the grains}}{\text{Initial weight of the grain}} \times 100$$

CHAPTER-IV

EXPERIMENTAL FINDINGS

EXPERIMENTAL FINDINGS

The size of the population of four species of insect pests of wheat and the extent of loss caused by them was studied both at controlled and laboratory conditions. To determine the effect of interspecific competition among these insects, experiments were planned to study the above factors by allowing them to multiply singly or in various combinations along with or without the presence of a parasite. The results of the experiments are described in following pages.

<u>Population growth and extent of damage caused to stored wheat by different insects when only a single species is allowed to multiply:</u>

To assess the population growth of *Sitophilus oryzae*, *Rizopertha dominica*, *Tribolium castaneum* and *Oryzaephilus surinamensis* and the relative extent of damage these insects could cause to sound wheat grains, 10 pairs of adults of each species were reared in 100 g of wheat each separately and kept for 90 days at a constant temperature of $29^{\circ} \pm 1^{\circ}C$ and 73 ± 3 % R.H. A series of similar experiments were run in the laboratory conditions to study the effect of the temperature and humidity on population growth and the extent of damage. The results obtained have been presented in tables 1 and 2. It was seen that the population of adults of rice weevil, lesser grain borer, red flour beetle, and saw-toothed grain beetle were 1177.3, 203.6, 32.3 and 0 and % weight loss of wheat was 45.1, 38.3, 5.2 and 0 in an average respectively during a period of 90 days clearly indicating the success of rice weevil in building its population and causing damage to sound wheat than any other insect studied in the experiments when the insects were allowed to grow at a constant temperature of $29^{\circ} \pm 1^{\circ}C$.

The results of the experiments carried out under laboratory conditions indicated that, the mean population of S. oryzae was the highest (881) followed by lesser grain borer, red flour beetle and saw-toothed grain beetle, which was 357.6, 28.3 and 0 respectively. The percentage of weight loss due to feeding of insects was 48.2 by lesser grain borer and 42.6, 4.1 and 0 by rice weevil, red flour beetle and saw-toothed grain beetle respectively. It was interesting to note that there was maximum loss in weight of wheat with 357.6 adults of lesser grain borer as compared to the loss in weight of 42.6 % with rice weevil having larger population of 881.

Rice weevil had a bigger population at constant temperature than laboratory cultures though it outnumbered others under both the conditions. It was further observed that the population of lesser grain borer was more at variable temperature and humidity in the laboratory than at a lower constant temperature of 29° ± 1°C and 73 ± 3 % R.H. Saw-toothed grain beetle failed completely to grow with sound wheat but T. castaneum could survive with a very low population.

Table 1

Population of S. oryzae, R. dominica, T. castaneum and O. surinamensis after 90 days of release of 10 pairs of adults of each species separately and % weight loss of wheat kept at 29° ± 1°C and 73 ± 3 % R.H.

Insect species	No. of living adults				% weight loss			
	R_1	R_2	R_3	Av.	R_1	R_2	R_3	Av.
Rice weevil S. oryzae	1254	1058	1220	1177.3	44.8	45.5	45.0	45.1
Lesser grain borer R. dominica	198	211	202	203.6	38.1	37.8	39.1	38.3
Red flour beetle T. castaneum	29	37	31	32.3	5.2	5.0	5.4	5.2
Saw-toothed grain beetle O. surinamensis	0	0	0	0	0	0	0	0

Table 2

Population of S. oryzae, R. dominica, T. castaneum and O. surinamensis after 90 days of release of 10 pairs of adults of each species separately and % weight loss of wheat kept at laboratory conditions.

Insect species	No. of living adults				% weight loss			
	R_1	R_2	R_3	Av.	R_1	R_2	R_3	Av.
S. oryzae	970	922	851	881.0	42.0	43.1	42.7	42.6
R. dominica	357	355	361	357.6	47.2	49.3	48.2	48.2
T. castaneum	25	29	31	28.3	4.2	3.9	4.2	4.1
O. surinamensis	0	0	0	0	0	0	0	0

Population of different species of insects and the weight loss of wheat when two species were allowed to multiply together :

To study the effect of interspecific competition between an internal borer and an external feeder, T. castaneum was allowed to multiply with S. oryzae and R. dominica. The effect of interspecific competition between T. castaneum and O. surinamensis, both being external feeders, on the population growth and the extent of loss of weight of infested wheat was also studied. The data on population and weight loss obtained at a constant temperature and humidity are presented in Table 3 and the data obtained under laboratory temperature and humidity are presented in Table 4. It was found that the mean population of *T. castaneum* and *S. oryzae* was 131 and 512.6, *T. castaneum* and *R. dominica* 170.6 and 201.3, *T. castaneum* and *O. surinamensis* 33.6 and 0 respectively when experiments were conducted at a constant temperature of $29^{\circ} \pm 1^{\circ}$ C and 73 ± 3 % R.H. The combination *T. castaneum* with *S. oryzae*, *T. castaneum* with *R. dominica* and *T. castaneum* with *O. surinamensis* resulted in 54.4, 40.4 and 6.6 % loss in weight in an average of the infested wheat respectively. It was clearly observed the degree of weight loss was more in any combination of two insects than the weight loss caused individually. However, *O. surinamensis* could not survive when allowed to multiply alone or in combination with *T. castaneum*, another external feeder. The population of each species became less in case of the grain borers and more in case of *T. castaneum*, an external feeder.

When above experiments were conducted under laboratory conditions the mean population of the combination of *T. castaneum* and *S. oryzae*, *T. castaneum* and *R. dominica*, and *T. castaneum* and *O. surinamensis* was 135.6 and 209.3, 157.3 and 255.3 and 31.6 and 0 respectively. The corresponding mean percentage of weight loss of infested wheat was 35.5, 41.2 and 7.1 in the above combinations. It was observed that the population of S. oryzae decreased under the laboratory condition as compared to results obtained at constant temperature and humidity, whereas there was an increase in the population of R. dominica under laboratory condition. There was not much difference in the population of T. castaneum and O. surinamensis. Considering the % weight loss of wheat in different treatments, there was more damage in the combination of T. castaneum and R. dominica. Saw-toothed grain beetle also could not grow in sound wheat in absence of either rice weevil or lesser grain borer.

Table 3

Population of T. castaneum in presence of S. oryzae, or R. dominica or O. surinamensis after 90 days of release of 10 pairs of each species and % weight loss of wheat kept at $29^{\circ} \pm 1^{\circ}$ C and 73 $\pm$ 3 % R.H.

Combination	Adult population				% weight loss			
	R_1	R_2	R_3	Av.	R_1	R_2	R_3	Av.
T. castaneum +	122	141	130	131.0	53.8	54.2	55.3	54.4
S. oryzae	509	521	508	512.6				
T. castaneum +	174	180	158	170.6	40.0	41.2	40.1	40.4
R. dominica	202	180	222	201.3				
T. castaneum +	32	35	34	33.6	6.8	6.0	7.2	6.6
O. surinamensis	0	0	0	0				

Table 4

Population of *T. castaneum* in presence of *S. oryzae*, *R. dominica* and *O. surinamensis* after 90 days of release of 10 pairs of each species and % weight loss of wheat at laboratory conditions.

Combinations	Adult population				% weight loss			
	R_1	R_2	R_3	Av.	R_1	R_2	R_3	Av.
T. castaneum +	132	123	152	135.6	34.0	36.2	36.5	35.5
S. oryzae	204	223	201	209.3				
T. castaneum +	158	169	145	157.3	40.2	43.5	40.0	41.2
R. dominica	281	249	236	255.3				
T. castaneum +	36	24	35	31.6	8.8	4.9	7.6	7.1
O. surinamensis	0	0	0	0				

Population of different species of insects and the weight loss of wheat when three or more species allowed to multiply together :

T. castaneum or *O. surinamensis* were allowed to multiply in presence of both *S. oryzae* and *R. dominica* and both the external feeders are also allowed to compete in presence of *S. oryzae* and *R. dominica* together. The results of the experiments conducted at a constant temperature and humidity are presented in Table 5 and the data obtained from experiments conducted under laboratory conditions in Table 6. It was observed in Table 5 that in the combination of

O. surinamensis with S. oryzae and R. dominica, the population of rice weevil, lesser grain borer and saw-toothed grain beetle was 1109, 136 and 226.6 respectively and the mean percentage of weight loss was 36.6. In other combination of two grain borers the population of rice weevil, lesser grain borer and T. castaneum was 1044,146 and 44 respectively and the mean percentage of weight loss was 36.03. When all four species were allowed to multiply together, the population of S. oryzae, R. dominica, T. castaneum and O. surinamensis was 1046.6, 61.3, 142.3 and 27 respectively. The mean percentage of weight loss of wheat was 38.2 . The data indicated that O. surinamensis could survive and develop in presence of S. oryzae and/or R. dominica. The population of lesser grain borer was affected in presence of T. castaneum but the population of rice weevil was not much affected in presence or absence of T. castaneum. When all the insect species infested wheat, there was more loss in weight than the combination of three.

The results obtained from experiments conducted under laboratory conditions (Table 6) indicated that there was a suppression to the population of S. royzae and increase of population in case of R. dominica, O. surinamensis and T. castanaum as compared to the population growth at constant temperature and humidity. The mean percentage of weight loss was a maximum of 36.8 % in the combination of all the four species of insects and minimum of 24.3 %, when *T. castaneum* was combined with *S. oryzae* and *R. dominica*. The combination of *O. surinamensis* with *S. oryzae* and *R. dominica* resulted in a reduced loss in weight by 35.6 %.

Table 5

Population of different species of insects when reared in combination with 3 or more species together and % weight loss of wheat kept at $29^{\circ} \pm 1^{\circ}$ C and 73 ± 3 % R.H.

Combinations	Adult population				% weight loss			
	R_1	R_2	R_3	Av.	R_1	R_2	R_3	Av.
S. oryzae	1210	997	1120	1109.0				
+ *R. dominica*	134	135	139	136.0	35.2	36.5	38.1	36.6
+ *O. surinamensis*	231	227	222	226.6				
S. oryzae	1115	996	1021	1044.0				
+ *T. castaneum*	148	151	139	146.0	36.3	33.8	38.0	36.03
+ *R. dominica*	40	43	49	44.0				
S. oryzae	1139	980	1021	1046.6				
+ *R. dominica*	72	58	54	61.3	39.2	37.5	37.8	38.2
+ *T. castaneum*	142	136	149	142.3				
+ *O. surinamensis*	26	33	22	27.0				

Table 6

Population of different species of insects when reared in combination with 3 or more species together in wheat at laboratory conditions.

Combinations	Adult population				% weight loss			
	R_1	R_2	R_3	Av.	R_1	R_2	R_3	Av.
S. oryzae	192	178	204	191.3				
+ R. dominica	203	198	213	204.6	34.8	35.0	37.1	35.6
+ O. surinamensis	412	379	435	408.6				
S. oryzae	178	193	168	179.6				
+ T. castaneum	181	163	189	177.6	22.0	25.2	23.1	23.4
+ R. dominica	95	101	124	106.6				
S. oryzae	181	191	176	182.6				
+ R. dominica	225	210	196	210.3	36.2	38.7	35.5	36.8
+ T. castaneum	163	191	142	165.3				
+ O. surinamensis	137	127	131	131.6				

Population of S. oryzae or R. dominica in presence of a parasite and the extent of loss in weight of wheat :

S. oryzae and R. dominica were allowed to multiply separately along with the parasite A. calandrae at a constant temperature and relative humidity. During a period of 90 days the mean population of S. oryzae and A. calandrae was 508.0 and 134.0 and that of R. dominica and A. calandrae was 188.6 and 83.6 respectively (Table 7). The loss in weight of grain was more (26.5 %) in case of S. oryzae and A. calandrae combination than the other combination of R. dominica and A. calandrae i.e. 24.4 %. It was clear that the parasite, to certain extent, was effective in controlling the population growth of S. oryzae and to a lesser extent that of R. dominica as evidenced from their populations when the pests were reared in absence of the parasite. The percentage of weight loss of wheat was lower than the loss when these two insects were reared in absence of the parasite separately.

In the laboratory it was observed (Table 8) that the population of S. oryzae and A. calandrae ; R. dominica and A. calandrae was 457.6 and 104.6; 195.0 and 80.0 respectively. It can be seen that though the loss in weight of grains was much lower in presence of the parasite, yet it was about 25 % which is no doubt a substantial loss.

Table 7

Population of S. oryzae and R. dominica in presence of a parasite after 90 days of release and % weight loss of wheat when stored at 29° ± 1°C and 73 ± 3 % R.H.

Combinations	Adult population				% weight loss			
	R_1	R_2	R_3	Av.	R_1	R_2	R_3	Av.
S. oryzae	410	495	619	508.0				
+					26.2	27.5	25.8	26.5
A. calandrae	122	138	142	134.0				
R. dominica	189	202	175	188.6				
+					25.2	23.5	24.2	24.3
A. calandrae	76	79	96	83.6				

Table 8

Population of S. oryzae and R. dominica in presence of a parasite after 90 days of release and % weight loss of wheat when kept at laboratory conditions.

Combinations	Adult population				% weight loss			
	R_1	R_2	R_3	Av.	R_1	R_2	R_3	Av.
S. oryzae	412	478	483	457.6				
+					24.2	23.0	25.1	24.1
A. calandrae	106	96	112	104.6				
R. dominica	195	202	188	195.0				
+					24.2	22.7	25.8	24.2
A. calandrae	77	72	91	80.0				

Population of S. oryzae, R. dominica, O. surinamensis and T. castaneum in presence of a parasite A. calandrae and the extent of loss in weight of wheat:

To find out the effect of the parasite *A. calandrae* on the population growth of *S. oryzae* and *R. dominica* in presence of external feeders like *T. castaneum* and *O. surinamensis*, the parasite was allowed to multiply in a culture having equal number of both the hosts and then with both the hosts in presence of *T. cantaneum* and *O. surinamensis* at a constant temperature and humidity and in the laboratory. The data presented in Table 9 showed that the mean population of *S. oryzae*, *R. dominica* and *A. calandrae* was 421.3, 110.0 and 119.3 respectively and weight loss was 28.9 %, whereas the population of *S. oryzae*, *R. dominica*, *T. castaneum*, *O. surinamensis* and *A. calandrae* was 828.6, 92.3, 89.6, 39.0 and 137.6 respectively and weight loss was 33.8 % when the experiment was conducted by rearing all insects together under controlled condition. The population of external feeders was not affected in presence of the parasite as a result the percentage loss of weight of grains remained high, although the host numbers i.e. *S. oryzae* and *O. surinamensis* became smaller.

The results (Table 10) obtained from experiments under the laboratory conditions showed that the population of hosts became less in presence of the parasite though there was slight increase in the p opulation of *R. dominica* as compared to the results obtained at a constant temperature and R.H. When all the four pests and the parasite were reared together, the population of *S. oryzae* and *R. dominica* was checked to some extent by *A. calandrae*. *O. surinamensis* could survive and multiply which otherwise failed to develop when reared alone in sound wheat. The percentage of weight loss was 36.3, when all the insects were taken together as compared to 36.8 % by all insects in absence of the parasite. It may be concluded that the parasite *A. calandrae* could not prevent damage satisfactorily i.e. loss in weight to grains though it resulted in smaller population of *S. oryzae* and *R. dominica*.

Table 9

Population of *S. oryzae*, *R. dominica*, *O. surinamensis* and *T. castaneum* in presence of a parasite, *A. calandrae*, in various combinations after 90 days of release and % weight loss of wheat at $29^{\circ} \pm 1^{\circ}$ C and 73 ± 3 % R.H.

Combinations	Adult population				% weight loss			
	R_1	R_2	R_3	Av.	R_1	R_2	R_3	Av.
S. oryzae +	417	439	408	421.3				
R. dominica +	103	119	108	110.0	27.5	29.1	28.0	28.9
A. calandrae	131	105	122	119.3				
S. oryzae +	791	815	880	828.6				
R. dominica +	97	78	102	92.3				
T. castaneum +	82	92	95	89.6	34.5	33.0	33.8	33.8
O. surinamensis +	38	47	32	39.0				
A. calandrae	158	120	135	137.6				

Table 10

Population of *S. oryzae*, *R. dominica*, *T. castaneum* and *O. surinamensis* in presence of a parasite, *A. calandrae* in various combinations after 90 days of release and % weight loss of wheat at laboratory conditions.

Combinations	Adult population				% weight loss			
	R_1	R_2	R_3	Av.	R_1	R_2	R_3	Av.
S. oryzae	390	366	412	389.3				
+								
R. dominica	110	96	111	105.6	25.5	26.2	26.8	26.1
+								
A. calandrae	124	117	131	124.0				
S. oryzae	431	406	421	419.3				
+								
R. dominica	149	122	135	135.3				
+								
T. castaneum	112	93	106	103.6	35.2	38.1	35.6	36.3
+								
O. surinamensis	29	24	33	28.6				
+								
A. calandrae	232	197	225	218.0				

CHAPTER-V

DISCUSSION

DISCUSSION

Among the insect pests those attack wheat in storage, some are internal grain borers which can survive and multiply in sound grains and others such as red flour beetle and saw-toothed grain beetle can multiply in stored wheat and may attend the status of a pest under favourable conditions only. Rice weevil and lesser grain borer come under the first group and are capable of infesting wheat under normal conditions of storage. When more than one species of insects occur in a commodity interspecific competition may come in even if sufficient food material is available to support the pests. When certain factors such as limitation of food, space, peculiar habit of living, cannibalism and predatory habits occur one species may dominate or suppress the other within a time limit. *Sitophilus oryzae*, *Rhizopertha dominica*, *Tribolium castaneum* and *Oryzaephilus surinamensis* have been observed to occur together or singly in stored wheat. Sometimes a parasite, *Anisopteromalus calandrae* was also noted in cultures of *S. oryzae* and *R. dominica*. Therefore experiments were planned to study the effect of interspecific competition if any and the effect of parasitisation on the population growth of these pests. The number of living adults at the end of the experiments was taken as a criterion of population and the percentage of weight loss of infested grains was taken as a factor to determine the extent of damage caused by different insects. These five species of insects were allowed to multiply singly or in various combination of species at controlled conditions of experiments and under laboratory conditions.

When equal number of rice weevils, lesser grain borers, red flour beetles and saw-toothed grain beetles were reared separately on sound wheat grains with moisture content of 12.6 % kept at $29^{\circ} \pm 1^{\circ}C$ and 73 ± 3 % R.H., it was seen that the population of rice weevil was the maximum of 1177.3, in an average, with a maximum percentage of weight loss of 45.1. Lesser grain borer was the second with a mean population size of 203.6 and 38.3 % loss in weight of the infested wheat. The mean population of red flour beetle was only 32.3 and loss in weight was 5.2 %. There was no survival of saw-toothed grain beetle resulting in no loss in weight of wheat.

The same experiments when conducted under laboratory conditions the results on population showed the same trend with an increase in number of lesser grain borer. There was more loss in weight with *R. dominica* than *S. oryzae* though the number of weevils were more. It is interesting to note that S. oryzae produced more population at a constant temperature and humidity than under laboratory conditions, whereas R. dominica resulted in a higher population under laboratory conditions than at controlled temperature and humidity. Further R. dominica resulted in a higher percentage of weight loss of wheat with a smaller population than S. oryzae with a larger population. Data indicated that R. dominica could multiply better at variable temperature and humidity than S. oryzae and caused more damage as compared to its population. T. castaneum could survive on sound wheat but its rate of multiplication was very slow as seen from the size of the population. O. surinamensis completely failed to develop on sound wheat.

Until recently it was assumed that T. castaneum fails to survive among sound kernels but rather needed either cracked kernels or grain dusts resulting from the feeding of other pests. Birch (1947) reported that the beetle could live and reproduce in whole wheat grains. Narayan (1953) advanced the idea that the genus Tribolium can not feed on whole wheat grains. The present findings indicate that Tribolium can infest sound wheat grains. Back and Cotton (1926) stated that adults of O. surinamensis confined with sound wheat were found dying of starvation. The data presented in Tables 1 and 2 clearly show that

O. surinamensis fails to multiply on sound wheat grains.

When T. castaneum was reared with either S. oryzae or R. dominica, its population was more with R. dominica than with S. oryzae both at controlled and laboratory conditions. But when T. castaneum was combined with O. surinamensis its population was much low as compared to its population with either S. oryzae or R. dominica. Here population of O. surinamensis remained as zero. These findings support the idea that T. castaneum feeds on grains damaged by other pests like S. oryzae (Narayan, 1953), because its population was much higher with S. oryzae or R. dominica but very low with O. surinamensis. O. surinamensis could not be helped to establish on sound grains by the presence of T. castaneum. The population data presented in Tables 3 and 4 show that the populations of S. oryzae and R. dominica are smaller in presence of T. castaneum as compared to their population when reared in its absence. This was probably due to the predatory habit of T. castaneum on eggs, larvae of R. dominica and the interspecific competition. Jacob and Mohan (1976) reported that larvae and adults of T. castaneum readily preyed on eggs, larvae and pupae of R. dominica.

S. oryzae, R. dominica were reared with O. surinamensis or T. castaneum or both under controlled and laboratory conditions. The data on population and the percentage of weight loss of wheat as presented in Tables 5 and 6 indicated that the populations of S. oryzae and R. dominica are smaller when reared with either O. surinamensis or T. castaneum but the population in presence of T. castaneum is more reduced as compared to the presence of O. surinamensis. This might be due to predatory habit of T. castaneum on R. dominica, (Lecato,1976). O. surinamensis which could not survive and multiply on sound wheat grains when reared alone, could grow in sound grains in presence of S. oryzae and R. dominica. This finding is supported by Durant (1921) who found out that " O. surinamensis generally destroys only when it has been injured by primary pests." Looking at the percentage of weight loss of grains it was observed that there was greater damage when all the four insects (Tables 5 and 6) occurred together in wheat than the other combinations of insects. Lecato (1976) reported that O. surinamensis and T. castaneum produced relatively more progeny and cause greater weight loss when confined with either R. dominica or S. oryzae than when they developed alone.

The effect of parasitisation on the population of S. oryzae and R. dominica by A. calandrae and % weight loss of the infested wheat were determined by releasing

10 pairs of adult parasites with either S. oryzae, or R. dominica at a constant temperature and humidity and under laboratory conditions (Tables 7 and 8). It was observed that the populations of S. oryzae and R. dominica were reduced in presence of the parasite, as compared to their population when reared in absence of the parasite. However, the reduction of population in case of S. oryzae was greater than R. dominica when the experiments were conducted either in the laboratory or under controlled conditions. The percentage of weight loss was about 25 % in presence of the parasite, as against of about 43 % in its absence, clearly indicating the efficacy of the parasite in suppressing the population of hosts and ultimately resulting a lesser degree of damage to grains.

When A.calandrae was introduced in cultures containing 10 pairs of each S. oryzae and R. dominica, the population of both the hosts remained checked but the population of the parasite was not high as compared to its population in presence of either of the host. When all the four pests were given equal chance to multiply together in a culture containing the parasite, the population of R. dominica was more suppressed than S. oryzae. However, the population of the parasite did not differ much from its progeny obtained with S. oryzae or R. dominica or with both. The trend in the population size obtained at controlled or laboratory conditions did not differ much. However, there was a greater percentage of weight loss when more species of insects were reared together than fewer insects infesting, the same food in presence of the parasite. Various authers have reported A. calandrae as a parasite on rice weevil and lesser grain borer. Beratlief (1971) stated that Anisopteromalus calandrae How. developed well from egg to adult in 13 - 27 days in the culture of S. oryzae. Dhaliwal and Battu (1978) reported the occurrence of A. calandrae as a parasite in the laboratory culture of R. dominica.

CHAPTER-VI

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

Experiments were conducted in the laboratory of Department of Entomology, College of Agriculture, Bhubaneswar, during the year 1979, to study the effect of interspecific competition among rice weevil, lesser grain borer, red flour beetle and saw-toothed grain beetle infesting wheat and A. calandrae, a pteromalid parasite on rice weevil and lesser grain borer, on the population growth and extent of damage caused by these insect pests to wheat. Population growth was studied by counting the number of living adults present after 90 days of their release on wheat grains and the extent of damage was determined on the basis of percentage of weight loss of grains due to insect feeding only. All the species of insects were reared on sound wheat grains separately or in various combinations in presence or absence of the parasite at $29^{\circ} \pm 1^{\circ}$ C and 73 ± 3 % R.H. and under laboratory conditions.

Accordingly two sets of experiments were run with S. oryzae, R. dominica, T. castaneum and O. surinamensis by rearing these insects with 100 g of wheat with moisture content of 12.6 % separately in rearing glass jars. The progeny produced by 10 pairs of adult beetles of each species was recorded after 90 days of their release. It was noted that rice weevil produced the maximum progeny of 1177.3 followed by lesser grain borer, red flour beetle and saw-toothed grain beetle with 203.6, 32.3 and 0 adults, in an average respectively at $29^{\circ} \pm 1^{\circ}$ C and 73 ± 3 % R.H. But when the insects were reared under laboratory conditions the proportion of progeny produced by these insects was not altered except that lesser grain borer population increased to 357.6 against 203.6 at controlled conditions. O. surinamensis failed to grow under both the conditions.

The percentage of weight loss showed that there was maximum loss in weight of 45.1 % in the rice weevil culture at controlled conditions whereas it was more with lesser grain borer than rice weevil under laboratory conditions indicating the greater damaging capacity of R. dominica.

When T. castaneum was reared with S. oryzae or R. dominica, the number of progeny of T. castaneum increased as compared to its number when reared alone. However, the population of S. oryzae and R. dominica was reduced. But in the combination of T. castaneum and O. surinamensis, the population of both the insects remained almost the same as compared to their individual rearing. It may be concluded from the data that T. castaneum could not help much in the growth of the population of O. surinamensis in sound wheat. On the other hand the population of R. dominica and S. oryzae was reduced probably because of the predatory habit of T. castaneum as reported by Jacob and Mohan (1976).

In another experiment it was interesting to note that O. surinamensis could survive and multiply when it was reared in presence of S. oryzae and R. dominica. This clearly indicated that O. surinamensis could not feed on sound grains but it could survive on grains damaged by primary pests. Presence of T. castaneum suppressed the population of R. dominica to a greater extent and the population of S. oryzae to a lesser degree resulting in a smaller degree of damage which might be due to the reduction in number of R. dominica, a dominating feeder. However, the population of R. dominica remained higher under laboratory conditions than its rearing at a constant temperature and humidity.

A. calandrae, a reported parasite on S. oryzae and R. dominica, was reared on these two hosts either separately or in combination with both. It was observed that the parasite was able to keep in check the population of both the hosts at controlled and laboratory conditions resulting in a reduced percentage of weight loss of wheat. But when O. surinamensis and T. castaneum were taken together in a culture of the hosts and the parasite, it was observed that the percentage of weight loss went up as compared to the loss due to their absence. It may be concluded that A. calandrae was of no use in either preventing the population growth of T. castaneum or O. surinamensis and the damage caused by them.

From the results of this experiments it can safely be said that an individual species can multiply at a faster rate than its occurrence with other pests. T. castaneum which has been reported as a secondary pests and unable to feed on sound grains was able to survive on sound wheat though the rate of growth of population was slow. O. surinamensis failed to grow on sound wheat grains but it could multiply in presence of primary pests. T. castaneum suppressed the population of R. dominica probably due to its predatory habit. The population of S. oryzae and R. dominica was suppressed to some extent by the parasite A. calandrae, and the extent of loss was reduced. However, the parasite failed to exterminate the destructive pests, therefore, the biological control of S. oryzae or R. dominica by A. calandrae may not be a sound suggestion.

The practical utility of the results of investigations may be that secondary pests like T. castaneum and O. surinamensis may cause little or no damage to undamaged grains but the infestation by a pest like S. oryzae and R. dominica may accelerate the growth of such secondary pests. Therefore stored wheat should be free from frasses, or partially damaged grains to avoid infestation by minor pests.

LITERATURE CITED

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Adeyemi, S.A.O. 1968 A laboratory study of competition between *Tribolium castaneum* (Hbst.)(Coleoptera, Tenebrionidae) and three moth species. Bull. ent. Res. 58(1): 31-45.

Barnes, D.F. and Simmons, P. 1952 Competition between saw-toothed grain beetle and Indian meal moth. J. econ. Ent. 45(4): 750 - 751.

Beratlief, C. 1967 Un parazit importantal gargaritelor cerealetor- *Anisopteromalus calandrae* How. (An important parasite of cereal weevils. *A. calandrae*). Anal. Inst. Cerc. Prot. Pl. 4 (253 - 254.

Back, E.A. and Cotton, R.T. 1926 Biology of the saw-toothed grain beetle. J. Agril. Res. 5 : 435 - 452.

Birch, L.C. 1947 The ability of flour beetles to breed in wheat. Ecology, 28 : 322-24.

Crombie, A.C. 1943 The effect of crowding upon the oviposition of grain-infesting insects. J. Exp. Biol. 19(3): 311-340.

________ 1946 On competition between different species of graminivorous insects. Proc. roy. Soc. (B) 132(869): 362 - 395.

________ 1947 On intra and inter-specific competition of larvae of graminivorous insects. Jour. Exptl. Biol. 20(2): 135-151.

Dawson, (P.S.) 1966 Genotype-environment interactions and developmental rate in the flour beetles *Tribolium castaneum* and *T. confusum* (Coleoptera, Tenebrionidae). Ann. appl. Biol. 56(1): 21-25.

Dhaliwal, G. S. and Battu, G. S.	1978	Occurrence of Anisopteromalus calandrae (How.) in the laboratory culture of Rhizopertha dominica F. Bull. Grain. Tech. 14(2): 156-157.
Durant, J.H.	1921	Insect associated with grain and C. Rep. Gr. Pes. Com. Ro. Soc. Lond. 9 : 33-52.
Golebiowska, Z., Chmielewski, W. and Filipek, P.	1972	An increase of the population of insects and mites in the wheat grain. Ekologia Polska (1970) 18(38) : 805-816.
Girish, G.K., Tripathi, B.P., Tomer, R.P.S. and Krishnamurthy, K.	1976	Studies on the assessment of losses- IV. conventional grain storage practices and losses in rural areas in U.P. Bull. Grain. Tech. 12(3): 199-210.
Golebiowska, Z.	1969	The feeding and fecundity of Sitophilus granarius (L.), Sitophilus oryzae (L.) and Rhyzopertha dominica (F.) in wheat grain. J. stored Prod. Res. 5 (2): 143-155.
Golebiowska, Z., Filipek, P. and Krzymanska, J.	1972	The injuriousness of the grain weevil (S. granarius L.) the rice weevil (S. oryzae L.) and the lesser grain borer (R. dominica F.) to the grain of wheat and rye). Szkodliwosc wolka zbozowego (S. granarius L.) Wolka. ryzowego (S. oryzae L.) i kapturnika zbozowca (R. dominica F.) dla ziarna pszenicy i zyta. Prace Naukowe Instytute ochrony Roslin. 10(1):31-56.
Jacob, S.A. and Mohan, M. S.	1976	Predation on certain stored product insects by red flour beetle. Indian J. Ent. 35(2): 95-98.
Jablonowski, J.	1925	Is Oryzaephilus surinamensis a pest of corn ? Zeitschr angew Ent. 11(1): 77-112.

Kamal, S., Razvi, A., Ahmed, M.M. and Khan, M.E.A. 1977 A preliminary observation on cannibalistic habit in lesser grain borer. *Rhizopertha dominica* F. (Coleoptera : Bostrychidae) Cur. Sc. 45 (7): 276.

Lloyd, M. and Park, T. 1964 Mortality resulting from interactions between adult flour beetles in lab. cultures. Physiol. Zool. 35 (4): 330-347.

Lefkovitch, L.P. 1968 Interaction between four species of beetles in wheat and wheat feed. J. stored prod. Res. 4(1): 1 - 8.

Lecato, G.L. 1976 Species composition influencing insect population growth and weight loss of stored rice, wheat and corn. J. Kansas. Ent. Soc. 48(2) : 224-231.

———— 1976 Predation by red flour beetle on saw-toothed grain beetle. Envirn. Ent. 4(3): 504-506.

Mookherjee, P.B., Bhatia, P and Verma, S. 1978 Interspecific competition between *Tribolium castaneum* (Herbst) and *Corcyra cephalonica* (Staint). Indian J. of Ent. 38(3) : 201-206.

Narayan, E.S. 1953 Insect pest of store grain and their control. Indian. Fmg. 3 (7): 8 - 18.

Park (T.) 1944 Inter-species competition within populations of the Genus *Tribolium* (Abstract.) Anat. Rec. 87(4):462.

Park, T., Leslie, P.H. and Mertz, D.B. 1966 Genetic strains and competition in populations of *Tribolium* Physiol. Zool. 37 : 97-162.

Park, T. 1956 Experimental studies of inter-species competition 11. Temperature, humidity and competition in two species of *Tribolium*. Physiol. Zool. 27(3): 177- 238.

Pingale, S.V. and Girish, G.K.	1970	Role of density on the multiplication of stored grain insect pests. Bull. Grain Tech. 5 (1) : 12-20.
Phadke, K.G. and Bhatia, S.K.	1978	Population growth of *S. oryzae* L. and *Rh. dominica* (F.) in different varieties of wheat when living together in the same medium. Bull. in Grain. Tech. 14 (3): 194-200.
Press, J.W., Flaherty, B.R. and Arbogast, R.T.	1978	Interactions among *Nemeritis canscens* (Hymenoptera: Ichneumonidae) *Bracon hebetor* (Hymenoptera : Braconidae). and *Ephestia cautella* (lep: pyralidae) J. Kansas Ent. Soc. 50(2): 259-262.
Stoyanovic, T.	1970	The effect of the initial population density of *S. granarius* and *S. oryzae* on the loss of weight in infested wheat. Let. nauc. Rad. 10 :63-72.
