BIO-ECOLOGY AND MANAGEMENT OF ANGOUMOIS GRAIN MOTH, *Sitotroga cerealella* (Olivier) [LEPIDOPTERA : GELECHIIDAE] INFESTING MAIZE AND PADDY

मक्का एवम् धान को ग्रसित करने वाले ऐन्गमॉइस धान्य शलभ,
सिटोट्रोगा सीरियालेला (ओलिवर) [लेपिडॉप्टेरा : गेलीकाइडी] की
जैव-पारिस्थितिकी एवम् प्रबन्ध

YUGAL KISHORE YADU

THESIS

Doctor of Philosophy in Agriculture

[ENTOMOLOGY]

उत्तमा वतिस्तु कृषिकमैव

1996

DEPARTMENT OF AGRICULTURAL ZOOLOGY AND ENTOMOLOGY
RAJASTHAN COLLEGE OF AGRICULTURE
RAJASTHAN AGRICULTURAL UNIVERSITY, BIKANER
CAMPUS : UDAIPUR - 313 001 (RAJASTHAN)

BIO-ECOLOGY AND MANAGEMENT OF ANGOUMOIS GRAIN MOTH, *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae) INFESTING MAIZE AND PADDY

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A

THESIS

SUBMITTED TO
THE FACULTY OF AGRICULTURE
RAJASTHAN AGRICULTURAL UNIVERSITY
BIKANER

IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY
(ENTOMOLOGY)

By

YUGAL KISHORE YADU

1996

RAJASTHAN AGRICULTURAL UNIVERSITY, BIKANER

RAJASTHAN COLLEGE OF AGRICULTURE, UDAIPUR

DATED : January, 6 1996

CERTIFICATE — I

THIS IS TO CERTIFY THAT ***MR. YUGAL KISHORE YADU*** HAS SUCCESSFULLY COMPLETED THE PRELIMINARY EXAMINATION HELD ON 9TH FEBRUARY, 1995 AS REQUIRED UNDER THE REGULATION FOR DOCTOR OF PHILOSOPHY.

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THIS IS TO CERTIFY THAT THIS THESIS ENTITLED "BIO-ECOLOGY AND MANAGEMENT OF ANGOUMOIS GRAIN MOTH, *Sitotroga cerealella* (Olivier) (LEPIDOPTERA : GELECHIIDAE) INFESTING MAIZE AND PADDY" SUBMITTED FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN THE SUBJECT OF ENTOMOLOGY OF THE RAJASTHAN AGRICULTURAL UNIVERSITY. BIKANER. CAMPUS. UDAIPUR IS A BONAFIDE RESEARCH WORK CARRIED OUT BY ***MR. YUGAL KISHORE YADU*** UNDER MY SUPERVISION AND THAT NO PART OF THIS THESIS HAS BEEN SUBMITTED FOR ANY OTHER DEGREE. THE ASSISTANCE AND HELP RECEIVED DURING THE COURSE OF INVESTIGATION HAVE BEEN FULLY ACKNOWLEDGED. THE DRAFT OF THE THESIS WAS ALSO APPROVED BY THE ADVISORY COMMITTEE ON 1-1-1996..

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DATED : March. 27. 1996

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THIS IS TO CERTIFY THAT THIS THESIS ENTITLED "BIO-ECOLOGY AND MANAGEMENT OF ANGOUMOIS GRAIN MOTH, *Sitotroga cerealella* (Olivier) (LEPIDOPTERA : GELECHIIDAE) INFESTING MAIZE AND PADDY" SUBMITTED BY ***MR. YUGAL KISHORE YADU*** TO THE RAJASTHAN AGRICULTURAL UNIVERSITY, BIKANER, CAMPUS : UDAIPUR, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN THE SUBJECT OF ENTOMOLOGY WAS AFTER RECOMMENDATION BY THE EXTERNAL EXAMINORS WAS DEFENDED BY THE CANDIDATE BEFORE THE FOLLOWING MEMBERS OF THE EXAMINATION COMMITTEE. THE PERFORMANCE OF THE CANDIDATE IN THE ORAL EXAMINATION ON HIS THESIS HAS BEEN FOUND SATISFACTORY, WE THEREFORE, RECOMMEND THAT THE THESIS BE APPROVED.

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ACKNOWLEDGEMENT

It gives me immense pleasure to express my deep sense of gratitude to my Major Advisor **Dr.R.C. Saxena**, Maize Entomologist, Department of Entomology, Rajasthan College of Agriculture, Udaipur, under whose valuable guidance and sustained encouragement, I completed my research investigation. The affection I received from him is respectfully acknowledged.

I am extremely thankful to **Dr.L.S. Sharma**, Professor and Head, Department of Agril. Zoology and Entomology Rajasthan College of Agriculture, Udaipur for his incessant help and encouragement during the course of investigation.

I express my greatfulness to **Dr.P. Joshi** Dean, Rajasthan College of Agriculture, Udaipur and **Dr.G.L. Jain** Dean, Post Graduate Studies, Bikaner for providing necessary facilities and encouragement throughout my studies.

My hearty thanks are due to **Dr.S.C. Bhardwaj**, Associate Professor of Entomology, **Dr.B.L. Gaur**, Associate Professor of Agronomy and **Dr. Rakesh Shah**, Assistant Professor of Plant Pathology, members of my advisory committee for their valuable suggestions and continuous co-operation in every stage of my research period.

My sincere thanks are due to **Dr.M.S. Bhatnagar**, Assistant Professor, Department of Statistics and member of my advisory committee for his valuable suggestions and help in statistical analysis, **Dr. G. Rajamani**, Deptt. of Biochemistry for his help in biochemical analysis.

I extend my sincere thanks to Dr.K.N. Singh, Deputy director and Shri P.C. Gupta, Tech.Asstt., I.G.S.I., Udaipur Centre for their valuable suggestions and providing laboratory facilities during research works.

I am also thankful to Dr.H.C.L Gupta, Dr.F.L. Joshi, Dr.L.N. Dadheech, Dr.R. Swaminathan, Dr. Ashok Kumar, Dr.K.L. Jain, Dr.A. Shrivastava, Dr.T. Hussain, Dr.B.S. Rana, Dr.J.K. Batta and Shri Anil Vyas. Deptt. of Entomology R.C.A., Udaipur for their co-operation in my studies.

My special thanks to Dr.V.P. Shukla, Former Vice Chancellor and Dr.A. Alam Vice-Chancellor, I.G.A.U., Raipur for their benevolence, guidance and incessant encouragement.

Special mention is to be made about Dr.U.K. Kaushik, Professor and Head, Deptt. of Entomology and Dr.M.N. Shrivastava, Professor and Head, Deptt. of Plant Breeding and Genetics, I.G.A.U., Raipur (M.P.) for providing paddy germplasms and valuable guidance. I also acknowledge the Maize Breeder, Andhra Pradesh Agricultural University, Hyderabad for providing maize germplasms.

The help rendered by my teacher's Dr.S.B. Yadav (Deputy Registrar), Dr. Shiv.K. Shrivastava, Dr.R. Gupta, Dr.S.K. Taunk during the studies will be cherished.

I express my humble gratitude to my friends Dr.M.L. Sharma, Shri M.K. Chaturvedi, Dr.P.K. Chandraker, Dr.V.K. Dubey, Dr.R.B. Tiwari, Dr. Raman Trivedi, Dr. V.P. Saini, Dr. H.P. Agarwal, Veer Singh, Fateh Singh, Y.K. Sharma, during the studies and preparation of my thesis.

My special thanks are also due to Shri Vijay and Smt. Smita Patil, Miss Manju Deshmukh, Chittora and Parmar family for the help in providing a homely envioremen t, all through the course of investigation.

I am deeply indebted to the authorities of Indira Gandhi Agricultural University, Raipur (M.P.) for having deputed me to complete the Ph.D programme and also for extending all necessary facilities to carry out my research studies with commitment and self satisfaction.

I have no words to express my indebtedness to my elder brother Shri Onkar Yadu (Tehsildar), Mother Smt. K. Yadu, Vedvati (Bhabhiji), Shri K.K. Yadu, Shri R.S. Yadu, Amrit, Vinod, Yashwant and Yogesh yadu.

Sincere thanks are also to Mr. Alok & Miss. Anju (MATRIKA COMPUTERS) at Udaipur for their excellent typing of this dissertation.

I feel to spill over piles of thanks to my wife Smt. Sarita for her buoyant happiness on completion of this study. She has been a source of inspiration to me. The gaiety and smile shown by my son Lucky, nephew Vicky and niece Bhumika always induced in me a feeling of freshness and enthusiasm for work.

Last but not least, I bow my head in extreme regards to the Supreme Power with whose blessing's, I got success at every step in my life.

UDAIPUR

Dated : January, 6, 1996

(YUGAL KISHORE YADU)

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ILLUSTRATIONS

INTRODUCTION

In India, the maize is grown in 6.20 million hectare of land with a total production of 10.20 million tonnes annually. It is cultivated for human food, animal feed, fodder and industrial products. Among food grains it stands 5^{th}, 4^{th} and 3^{rd} in area, production and productivity, respectively. It is grown almost in all states of the country but Madhya Pradesh, Utter Pradesh, Rajasthan and Bihar are the major maize growing states. Paddy is the most important crop amongst cereal crops in India and is grown on 41.64 million hectares of land with an annual production of 72.61 million tonnes. (Anonymous, 1993-94).

In Rajasthan, maize and paddy occupy an area of 9.43 and 1.18 lac hectares, with total production of 13.75 and 1.51 lac tonnes, respectively. Udaipur division alone accounts for 5.08 and 0.75 lac hectares with 5.46 and 0.40 lac tonnes of production for maize and paddy, respectively (Anonymous, 1990-91).

Among maize growing states, Rajasthan ranks second in India (Anonymous 1993-94). The districts where maize is extensively grown are Banswara, Bhilwara, Chittorgarh, Dungarpur, Jhalawar and Udaipur, while paddy is mostly grown in Banswara, Dungarpur, Udaipur, Sriganganagar, Bundi, Kota and Sawai Madhopur districts of the state (Anonymous, 1990-91).

In India post-harvest losses caused by the unscientific storage, rodents, insects, micro-organisms, moisture etc. account for about 10 per cent of total food grains (Anonymous, 1971). A world survey by F.A.O. indicated about 5 per cent loss of cereals in storage annually (Herford, 1952).

Among the various pests that have been commonly reported infesting stored grains, the Angoumois grain moth, *Sitotroga cerealella* (Olivier) is one of the most destructive pests of un-milled grain (paddy, maize, oats, sorghum, wheat and other cereals), being second only to the rice weevil, *Sitophillus oryzae* L. in economic importance. The losses caused by this moth to different grains to stored maize have been estimated ranging from 6 to 21 per cent (Anonymous, 1979) and in stored paddy from 3 to 12 per cent (Shahjahan, 1974).

The initial infestation by this pest may take place in the field when the grains are in the "milky stage" and usually one per cent of grain kernels are infested (Cotton, 1956; Singh et. al., 1978). By the time the grains are threshed and stored, infestation by the moth increases rapidly. The larva eats off the kernels and the infested grains are hollowed out without apparent symptoms of feeding. It is only visible when the moth leaves the grain, leaving the emergence hole.

More than half of the total produce of grain is retained by the farmers for consumption and seed, the remaining amount is marketable surplus or utilized for payment in kind to labour. The stored cereals (grains) undergo qualitative and quantitative losses to varying degree, depending upon the storage structures used and storage practices followed from region to region. It has been observed that the storage conditions and practices vary from place to place in our country which envisage the need to survey the practices followed and damage incurred by insects in different agro-climatic conditions. Hence, the information about the storage conditions and practices prevailing around Udaipur and assessment of losses caused by *S.cerealella* in different storage structures was needed.

In order to develop economic and effective control measures for *S.cerealella*, detailed and accurate knowledge of its bio-ecology is essential which leads to the possible prediction of population levels and study of the various mortality factors regulating pest abundance. These aspects need more intensive investigations. For example abiotic factors such as temperature, relative humidity and moisture percentage of stored products vis- a-vis pest interaction was one of the important aspects of the proposed work.

The habit of remaining inside the kernels during most of its active period, makes the control of this pest some what difficult. The development of resistance (or least susceptible varieties) appears to be one of the most successful way of combating this pest. Hence, in the proposed investigation, efforts have been made for searching the sources of resistance in some germplasm of maize and paddy.

Chemical insecticides play an important role in reducing the population of this pest. Consequently, the application of insecticides have been recommended on floor and walls of the godowns as well as on kernels which are used as seeds. But the use of chemicals should be with the proper knowledge in relation to the pest condition in the storage, otherwise they prove not only uneconomical, but also create a number of serious problems such as resistance to pesticides, resurgence of pests and hazards to human life. To reduce these adverse effects, certain non-insecticidal substances (plant products) have been recommended(Girish and Jain, 1974; Prakash et al., 1984 and Dakshinamurthy, 1988). In case of Angoumois grain moth, *S.cerealella*, meagre information is available in literature regarding the efficacy of vegetable oils and plant materials. Under the present investigation, therefore, many plant products have been evaluated to find out their effectiveness against this pest.

The objectives of the investigations were as follows :

1. Studies on the biology of *S.cerealella* (Oliv) at different temperature and humidity.
2. Screening of different varieties of maize and paddy against *S. cerealella* (Oliv.), and to determine the basis of host plant resistance in selected genotypes.
3. Evaluation of insecticides and plant products for the management of *S. cerealella* (Oliv.).
4. To assess the losses caused by *S. cerealella* (Oliv.) in storage.

REVIEW OF LITERATURE

Sitotroga cerealella (Olivier) was first described by Olivier in 1789 as *Alucita cerealella*. Later on Heinmann, in 1870 erected genus *Sitotroga* and named it as *Sitotroga cerealella* Olivier (Sattler, 1973). This insect obtained its common name, Angoumois grain moth due to its depredations in wheat in the province of Angoumois, France where it was known to have been injurious since 1736 (Cotton, 1941).

The Angoumois grain moth has been reported to cause considerable damage to all kinds of stored cereals and also some other stored products in India. Since the present investigations were carried out on the bioecology and management of Angoumois grain moth, *Sitotroga cerealella* Olivier (Gelechiidae, Lepidoptera) infesting maize and paddy in storage, the pertinent literature has been reviewed mainly on the following aspects :-

I. Bioecological studies and mass rearing technique.

II. Management :

(A) Host-plant resistance

(i) Screening of different varieties of maize and paddy

(ii) Basis of resistance

(a) Physical factors

(b) Bio-chemical factors

(B) Evaluation of insecticides and plant products.

III. Extent of losses in storage

I. BIO-ECOLOGICAL STUDIES :

The biology of *S. cerealella* on different hosts has been worked out by a number of workers (King, 1918., Simmons and Ellington, 1924 and 1933., Crombie, 1943., Warren, 1956.,Thomas et al., 1960., Cotton, 1963., Mills and Wilbur, 1967.,Khare and Mills, 1968 and Raghavaih et al., 1983) in different countries but most of the studies were carried out in temperate regions on wheat and maize. Very little works appear to have been done on paddy (Dhotmal and Dumbre, 1982., Pandey and Bimal Singh, 1983).

The temperature and humidity play a vital role in the development of *S. cerealella*. On the basis of the studies conducted on the cause of out-break of *S. cerealella*, Simmons and Ellington (1927) reported that the hot weather months in Maryland, U.S.A favoured the emergence, multiplication and the threshold of development of this pest. In the month of August and September, heavy infestation was observed on stored grains in Utter Pradesh by Lal (1944). In West Bengal, the damage by this pest was observed throughout the year, but the population was found at peak during April-May when the temperature ranged from 24 to 37°C and minimum during November-January when it ranged from 12 to 17°C (Karan Singh, 1977).

Studies conducted so far on the effect of temperature and humidity on the development of various stages revealed that minimum relative humidity required for the development of *S. cerealella* has been reported to be 30 per cent, the larval stage was rarely completed at 15°C (Harukawa and Kumashiro, 1938). According to Boldt (1974), the fecundity of *S. cerealella* in wheat was highest at 25 to 30°C. The development of pupa was shortest at 30 — 32°C and differences due to relative humidity were not significant; but in general, development of moth has been reported more rapid at higher humidity (Thomas and Shepard, 1940., Chatterjee, 1953., Warren, 1956., Joubert, 1964., Grewal and Atwal, 1969., Hammad et al, 1969., Shajahan, 1974 and Shazali and Smith, 1985). According to Howe (1965) the minimum limit and optimum range for the development of *S. cerealella* was 16°C and 26 to 30°C, respectively. According to Grewal and Atwal (1969) the eggs of *S. cerealella* could not survive at 40°C.

Studies conducted by Shazali and Smith (1985) on sorghum revealed that temperature ranging from 20 to 30°C and the relative humidity ranging from 60 to 80 per cent provided optimum conditions for the multiplication of *S. cerealella*. Almost similiar result were obtained by Grewal and Atwal (1969) on maize.

The moisture content of the grains had a definite effect on the development of *S. cerealella*. At 12 per cent or more moisture content, the larvae easily reached the adult stage (Harukawa and Kumashiro, 1938). The larval period was shortest at higher moisture content (Warren, 1956) and it was prolonged in dry materials (Candura, 1950). As the moisture content increased within 14 to 17 per cent, the average period of larval stage was reduced by an average of three days (Pingale and Girish, 1967).

Mass rearing technique :

The methods used at Kansas State University and the University of California have been reported successful in mass rearing of *S. cerealella* (Strong et al., 1967., Pederson et al., 1974). They raised the stock culture by using the insects collected from infested grains of the godowns and by releasing 25 pairs per half Kg. of medium which produced 400 to 450 adults.

Screening of varieties :

Russell (1976) reported that the yield obtained with 200 eggs or with 5 pairs of adults per half a kg of medium is essentially same and does not differ statistically. Khare and Johari (1979) used one pair of 8 to 12 hrs old adult in one hundred grains for screening the different varieties of paddy.

II. MANAGEMENT :

(A) Host-plant resistance :

(i) Screening of different varieties of maize and paddy :

Stockel (1968) reported that the percentage of ears and percentage of individual grains attacked by *S. cerealella* were significantly lower in corn variety Funk.G-34 in which husk was tightly wrapped round the ear at the time of grain maturity than other varieties. The degree of susceptibility among the ten lines of hybrid maize to the attack of *S. cerealella* and *Sitophilus zeamais* Motsch. was assayed by Villacis et al. (1976). He found that the hybrid "Dulce" showed considerable resistance to both the species while another hybrid showed resistance to *S. cerealella*. He attributed resistance mainly to the antibiosis. Mathur and Gupta (1973) screened tweleve maize varieties against this pest on the basis of average adult population and loss in grain weight. Pandey and Pandey (1982) however, evaluated fifteen different maize varieties against *S. cerealella* on the basis of growth index and loss in grain weight due to insect infestation. According to them Jaunpuri was found resistant as compared to Vijay, Protina and Shakti. Heinrichs et al. (1985) evaluated paddy varieties on the basis survival of adults. According to them the varieties allowing less than 10 per cent survival of adults were identified as resistant whereas, the varieties in which survival percentage varied from 10 to 20 were considered as moderately resistant. Those varieties which had more than 20 per cent survival of adults were considered as susceptible varieties. Acharyulu and Choudhary (1992) while screening different maize inbred lines against *S. cerealella* on the basis of loss in grain weight and Howe's growth index, reported that inbred lines having upto 3 per cent loss in grain weight were considered resistant or least susceptible against *S. cerealella*. Inbred lines showing loss in grain weight from 3 to 5 per cent were considered as moderately resistant.

In free choice test based on adult presence, oviposition and the production of F1 progeny, the paddy variety "Dawn" was found to be resistant in U.S.A. (Cogburn, 1974). Under Indian conditions considering the percentage infestation and the adult population, the variety IR-8, Kannaki and Cauveri were found least susceptible against *S. cerealella* (Chellappa and Chelliah, 1976). C_4-63 was found resistant by Dakshinamurthy et al. (1978) and Saket-4 and IR-8 were reported least susceptible by Khare and Johari (1979). Based on egg laying, hatching, penetration of larvae, adult emergence and duration of life cycle, China-1039 and Phouranmubi were least preferred (Pandey and Bimal Singh, 1983). Paddy varieties viz., T-26, Bala, Chakia-59, IR-24, Saket-4, Pankaj, Jagnnath, IR-8, Prasad and Cauveri were observed as moderately resistant against the pest by Uttam et al. (1984). Grain of IR rice cultivators (IR-5 to IR-52) were evaluated for the susceptibility against *S. cerealella* by Medina and Henrich (1986). They found that insect emergence was lowest in IR-52 and IR-46. Anuradha et al. (1989) tested thirty six cultivars of paddy against this pest and found that nine cultivars viz., Gouthami, Vijaya, Mashuri, NLR.9672-76, Dhanyalaxmi, Pratibha, Kottamolagolukulu, WGL 26889, Katatiya and Vasista were moderately resistant and eight cultivars viz., Nagavali, RGL-2831, RGL-1212, Rasi, BPT-8233, Mahendra, Srinivas and Vajram were highly susceptible. The remaining nineteen cultivars were intermediate in their reaction. Vasista and Gouthami cultivars of paddy were also reported as moderately resistant against *S. cerealella* by Sudhakar (1987). Sundrarajan and Sundrarajan (1990) reported CO-43, Redponni, Puduvaiponni, TKM-9 and CR-1009 as least susceptible varieties of paddy. According to Verma and Uttam (1990) Usar-1, Aswani, Jaya and IR-8 were the least susceptible varieties against *S. cerealella* while CR 2371-1, Basmati-370, T-23, T-3 and Prasad were found susceptible.

(ii) Basis of resistance :

Variations in the susceptibility of maize and paddy grains to the infestation of *S. cerealella* have been attributed to the physical and bio-chemical factors. These factors play a vital role in relation to the damage, growth and development of the pest.

(a) Physical factors :

Regarding the relation between the size, volume and moisture content of maize grain with growthindex and losses in weight caused by *S. cerealella*, Pandey and Pandey (1982) reported that there is no correlation. However, Manojlovic (1987) described that post-embryonal development of *S. cerealella* lasted longer with corn sorts which have larger and heavier grains.

In paddy, Israel and Vedamoorthy (1956) reported that fine-grained varieties (more L/B ratio) preferred mostly by the pest.'The moths reared on rice varieties having large sized grains were bigger than those reared on small sized grains (Sikder, 1965). Abraham and Thomas (1969) found the positive but non significant correlation between fineness (L/B ratio) and mean percentage of damage to roughrice but Chatterjee et al. (1977) reported that there is no correlation between size of the grain and degree of infestation. They further stated that loss in weight of grain was less in fine grained varieties when compared with coarse medium type grains. Dhotmal and Dumbre (1982) reported that preference for oviposition, incubation period and hatching percentage were independent of fineness or coarseness of paddy grains. Prakash et al. (1983) reported that length breath ratio of the grains was positively correlated with both number of adults emerged and per cent damage to grains. Pophaly and Rana (1992) also found that coarse and long duration varieties were least preferred as compared to fine to medium grain and short to medium duration varieties of paddy.

In wheat Sudhaker and Pandey (1982) reported that association of pericarp and seedcoat with endoplasmic region of the grain and their thickness varied from variety to variety. This variation in thickness and the association were responsible for the preference of *S. oryzae*. In paddy various workers (Upadhyay et al., 1979., Prakash et al., 1983., Anuradha et al., 1989. and Takeshita and Imura, 1990) have reported that thickness of the husk of paddy grain had a negative correlation with the number of adults emerged and the per cent damaged grains by *S. cerealella*. However, Abraham and Thomas (1969), Prakash and Rao (1993) reported that thickness of husk was negatively correlated with susceptibility index but that was not significant.

Samual and Chatterjee (1953) observed that the degree of resistance among different varieties of sorghum against stored pest depends upon hardness of the grain, per cent moisture content and the looseness or tightness of the grain. Davey (1965) observed a clear correlation between hardness and amount of vitreous endosperm (vitreous varieties of sorghum) having harder seed than mealy endosperm (mealy varieties).

Sudhakar and Pandey (1982) reported that hardness (breaking strength) of the wheat grain was negatively correlated with indices of susceptibility, egg laying capacity and total number of progeny against *S. oryzae*.

Similarly in maize a negative correlation between hardness of grain with growth index of *S. cerealella* was found by Pandey and Pandey (1982).

In paddy also Rout et al. (1976) while screening the varieties against *S. oryzae* observed a negative correlation between the grain hardness and relative susceptibility to the pest.

The alkali-spreading value, a measure of hardness, has been reported negatively correlated with the developmental period, progeny number and weight of rice weevil, *S. oryzae* (Rout et al., 1976). According to Russel (1976) the paddy variety with alkali spreading values of 3.5 to 4.0, were more resistant to the moth than those with alkali spreading value ranging from 6.2 to 7.0. Alkali value of the grain kernels was positively correlated with both number of adults and per cent damaged grains (Prakash et al., 1983). Ragumoorthy and Gunthaligaraja (1988) also reported low alkali values in resistant varieties of paddy. A positive relationship between alkali spreading value and susceptibility index was obtained by Prakash and Rao (1993) in four successive generation of *S. cerealella.*

Imperfect hull, hullintectness, splitting husk and less water absorption indices are other physical factors which have also been considered responsible for imparting resistance/ susceptibility (Cohen and Russell, 1970., Link and Rossetto, 1971., Pandey and Pandey, 1982 and Cogburn et al., 1983).

(b) Bio-chemical factors :

Preliminary evidence of higher infestation of *S. cerealella* in maize having high amylose content was first obtained by Peters et al. (1960). Retardation in larval growth coupled with fewer emergence of adults with lesser weight was observed by Peters et al. (1960) and Rhine and Staples (1968) when the larvae of *S. cerealella* were allowed to feed on corn having high amylose contents. Chippendale and Mann (1972) also demonstrated the inability of the larvae of *S. cerealella* to develop on high amylose content. According to Peters et al. (1972 a, b) the small size and weight of kernels of popcorn strains appeared to reduce the size of the female moths possibly due to high amylose content. They further reported that amylose and fat contents of the corn kernels were negatively correlated with the weight of the moth. Pandey and Pandey (1983) reported that no individual factor of chemical constituent is responsible for growth index. The combined effect of the constituents (protein, sugar, starch, ash and oil) may induce the variable growth and development of angoumois grain moth in different varieties of maize.

Regarding the effect of **amylose** contents on the susceptility of **paddy** varieties against *S. cerealella*, controversial reports are available. Abraham et al. (1972) tested susceptibility of fourteen varieties of paddy to *S. cerealella* and found that although the varieties were having different amylose content in the grains but it had no influence on the susceptibility against the pest. Chatterjee et al. (1977) also reported than amylose content of the different varieties of paddy had no correlation with the susceptibility or resistance of grains to this pest. On the other hand Kittur and Patel (1972) reported that a low amylose rice, "Casariot" was more susceptible to *S. cerealella* than intermediate and high amylose rices. Similarly Ragumoorthy and Gunthilagaraj (1988) observed higher amylose content in resistant varieties of paddy in comparision to susceptible ones.

The results obtained by Abraham and Thomas (1969) revealed that varietal susceptibility in paddy to grain moth infestation was not influenced by grain character viz., fineness, husk thickness and protein content. Protein content was also reported to have no correlation with the resistance of roughrice to *S. cerealella* and brownrice to *S. oryzae* (Abraham et al., 1972., Rout et al., 1976., Nigam et al., 1977 and Russell, 1976). However, low protein content was observed to contribute resistance in roughrice to *S. cerealella* but the relationship was not distinct (Chatterjee et al., 1977). The negative but distinct relationship between adult emergence, development of angoumois grain moth and index of susceptibility of paddy varieties was reported by Sudhakar et al., (1989). On the other hand Ragumoorthy and Gunthilagaraj (1988) reported that resistant varieties of paddy had high protein content. According to Anuradha et al. (1989) protein content in paddy kernels was positively correlated with susceptibility index of rice cultivars.

The influence of amino acids to pest attack was studied mostly on field crop. Very little work has been done on storage products. Field crop like pea varieties susceptible to pea aphid contained higher concentration of free and total amino acids than resistant varieties (Auclair et al., 1957). Kalode and Pant (1967) pointed out that resistance of sorghum and maize varieties to *Chillo partellus* Swinhoe was associated with the host plant composition. The susceptible varieties "Bubush" (sorghum) and "Ganga hybrid-101" (maize) were found to contain higher number of amino acids. David and Paul (1973) studied the preference of white fly, *Trileurodes rasa* Singh to castor varieties and found that the total free amino acid contents were less in resistant varieties than the susceptible ones. Chelliah and Sambandam (1973) also reported that susceptible varieties of *Cucumis melon* L. contained higher number of amino acids as compared to the resistant wild melon *Cucumis callous* (Rottl.) and concluded that either low concentration of essential amino acid or their imbalance were responsible for antibiosis in *C. callous*. Pandey and Pandey (1978) observed that eight essential amino acids were present in least preferred maize variety "Jaunpuri" and ten essential amino acids in the most preferred varieties Protina and Shakti to *S. cerealella*. Sudhakar and Pandey (1981) reported that the quantity of amino acids present in wheat, raw and parboiled rice varieties decreased due to infestation of *S. cerealella* and susceptible varieties were positively correlated with the amino acids concentration.

According to Sasamoto (1957), rice plants with higher silica content were resistant to the attack of *Chillo supressalis* (Wlk.). Sharma and Chatterjii (1971) also reported that susceptible maize parts had lower content of silica as compared to resistant varieties against *C. partellus*. Similiar results were obtained by Narwal (1973) on sorghum against *C. partellus* and fungus (*Collectrotrichum graminicola*). The amount of silica present in paddy husk was found negatively correlated with infestation and susceptibility index of *R. dominica* (Suzuki and Juliano, 1975), *S. oryzae* (Prakash et al., 1981.,) and *S. cerealella* (Sriramulu and Subramanyam, 1981., Prakash et al., 1983 and Anuradha et al., 1989).

The ash content in the husk and grain also play an important role as physical barrier for pest entry and completing the life cycle. Pandey and Pandey (1983) observed that correlation coefficient of chemical constituents viz., protein, sugar, starch, ash and oil content of healthy maize grains with growth index and loss in weight in grains were not significant. However, Sudhakar et al. (1989) reported the negative correlation of ash content in paddy grain with the developmental period of grain moth. Ash content in the paddy husk was negatively correlated with susceptibility index of rice cultivers to the *S. cerealella* (Anuradha et al., 1989).

Peters <u>et al</u>. (1972 b.) reported negative correlation between the fat content and moth weight, indicating that higher fat levels had a detrimental effect on moth weight in maize grains. However, the results obtained by Flores (1970) indicated that the life of *S. cerealella* prolonged when they were allowed to feed on maize grains having higher amount of lipids. According to Panday and Panday (1983) no correlation between protein, sugar, starch, ash and oil content of maize grain with growth index of the moth was observed.

(B) Evaluation of insecticides and plant products :

More and Decker (1961) protected maize against the attack of Angoumois grain moth by scattering 20-25 lbs of 1 per cent malathion dust over the surface of maize and spraying of malathion (2.75%) on the side of the cribs.

Teotia and Singh (1966) made preliminary studies with Sevin and malathion as grain protectants on maize and rice. They found that treatment with 500 ppm of Sevin and 5 ppm of malathion protected infestation of maize and rice by *S. oryzae* under natural storage conditions.

Saxena <u>et al</u>. (1973) used parathion, carbaryl and BHC dust (@ 1:1000, 2:1000, 3:1000 ratio w/w) against *S. cerealella* in shelled maize and reported that percentage mortality of the pest was significantly higher in all the treatments than the control even after 9 months of storage. No significant differences were found in the germination except with BHC.

According to Schulten (1975) application of 0.5 per cent BHC have good protection during storage of maize in Central Africa for about 10 months. They also reported that mixing of 1 per cent malathion dust with shelled maize also gave good protection.

Malathion (12 ppm), tetrachlorvinphos (12 ppm) and idofenphos (12 ppm) applied as dust mixture to shelled maize in traditional mud walled, timber and thatched storage cribs in Zambia, kept the damage by *S. zeamais* and *S. cerealella* below 10 per cent up to ten months after harvest. Primiphosmethyl (4 ppm) and fenitrothion (2 ppm) maintained the low damage levels up to 8 months after harvest (Hindmarsh and Macdonald, 1980).

Mookerjee and Bose (1967) reported that paddy seed exclusively meant for sowing purpose can be kept free from infestation by treating it with 10 per cent DDT dust or 0.5 per cent gammaBHC @ 1 part of the insecticidal dust and 1000 parts of the seed grain by weight.

Pyrethrum 0.5 per cent, DDT 10 per cent, malathion 1 per cent, lindane 1 per cent, *Acorus calamus* powder, burnt paddy husk powder, silica gel were used as protectant against *S. cerealella*, *S. oryzae* and *T. castaneum* in paddy (Mammen et al., 1968).

Direct mixing of various insecticides viz., Diazinon (Rout and Biswal, 1973), primiphos-methyl 10 ppm (Cogburn, 1976., Rai, 1977), primiphos methyl fenitrothion and chlorpyriphos methyl @ 14 ppm (Cogburn, 1981), permethrin 30 ppm (Prakash and Pasalu, 1981), etrimphos 10 ppm (Prakash, 1983), phoxim, fenitrothion (Lazro et al., 1986), sevin dust 15 ppm and gardona 5 ppm (Ismail et al., 1988), deltamethrin @ 8 mg/Kg seed (Prakash and Rao, 1992), with grains was found effective against *S. cerealella*.

The impregnation of jute or cloth bags with insecticides prevent the penetration of pest through bags. Several chemicals viz., piperonyl butoxide, pyrethrin, DDT, DDT + BHC (1:1), malathion, fenitrothion, indofenphos, malathion phoxim and primiphosmethyl have been used for impregnation or dusting of jute bags by various workers (Pingale, 1953., Ratan lal et al., 1960., Joshi and Kaul, 1965., Kane and Green, 1968., Girish et al., 1970., Rai and Crol, 1973 and Ramzan et al., 1989).

A field trial on the impregnation of gunny bags with synthetic pyrethriod against storage pest were carried out by Ramzan et al. (1987). They found that all the synthetic pyrethriods even at 0.0125 per cent concentration proved significantly better than malathion. Impregnation of gunny bags with deltamethrin even at 0.005% concentration proved significantly better than other pyrethriodes.

Bareth and Gupta (1992) also reported that jute bags treated with deltamethrin at 0.001% concentration resulted minimum damage by *R. dominica* during 15 months of storage of wheat with no adverse effect on the germination of the seeds.

Most of the work using vegetable oils for the protection of grains against insect pests has been conducted on pulse against *Callosobruchus* sp. and very little work has been carried out on stored maize and paddy against *S. cerealella*.

Pandey et al. (1981) reported that green gram *(Vigna radiata)* could be protected against attack of *C. maculatus* for 5-6 months by treating them with the oil of sal *(Shorea robusta)*, cotton seed or rice bran at 0.3 and 0.5 per cent (w/w).

Ali et al. (1983) tested the effectiveness of different plant oil including neemoil against *C. chinensis* in greengram in laboratory and reported that at higher dosage of neem, coconut, mustard, mahuva and sesame oil caused 100 per cent mortality.

The other vegetable oils viz., neem kernel oil, karit oil, groundnut oil, palm kernel oil, safflower oil, sunflower oil, taramira oil, karanj oil, pilu oil, undi oil, palas oil, dhupa oil, maize oil, caster oil, soybean oil have been used for protection of different stored products by various workers (Pereira, 1983, Doharey et al., 1983 and 1985., Naik and Dumbre, 1985., Pandey et al., 1985., Das, 1986., Gupta et al., 1992., Khare et al., 1992 and Singh et al., 1993).

Cobbinah and Kwarteng (1990) studied various neem products and copra oil, palm kernel oil for protection of stored maize against *S. zeamais* and reported that maize kernels treated with neem oil or ash were damaged less than untreated kernels. Although copra oil, palm kernel oil reduced the attack of the pest.

Prakash et al. (1980) tested some plant products against angoumois grain moth, *S. cerealella* to find out a safe and indigenous grain protectants and reported that the order of effectiveness was found to be pyrethrum > garlic extract > neem oil > onion extract in stored paddy.

The use of powders of botanical materials is an indigenous practice for the protection of stored grains against the stored grain pests. Most of the work on this aspect has been done on pulses and wheat Narasimhan and Krishnamurthy, 1944., Jotwani and Sircar, 1967., Sharma and Verma, 1971., Teotia and Tiwari, 1971., Girish and Jain, 1974., Singh and Shrivastava, 1980., Yadav and Bhatnagar, 1987., Chiranjeevi, 1991 and Mohan et al., 1991).

Glob et al. (1982) used botanical materials to protect the maize grains against *S. cerealella* in storage by mixing of wood ash, tobacco dust, saw dust etc. with maize grain. Bowry et al. (1984) tested powder of neem, linseed, mustard, castor and mahuva cake for their effectiveness against *S. oryzae* (L.) infesting maize seed. The result showed that powder of neem cake was the most effective followed by linseed, mustard, mahuva and caster cake. Makanjuola (1989) reported that extract of neem *(Azadirachta indica)* seed gave moderate protection to maize grain against *S. zeamais* for five months.

The relative efficiency of plant products in controlling infestation the Angoumois grain moth, *S. cerealella* in stored paddy was worked out by Abraham et al. (1972) in Kerala. They found that adding of chopped leaves of *Azadirachta indica* to stored rice gave the best results. Powdered neem kernel directly mixed with paddy was found to be effective in reducing the oviposition of *S. cerealella*. According to Savitri and Rao (1976), paddy can safely and economically protected from the pest by mixing of neem powder @ 2 per cent concentration. Dried leaves of wild sage *Lippa germinata* were found to be an effective repellent against *S. cerealella* under natural or controlled condition of stored paddy @ 2% (w/w) by Prakash and Rao (1986). Dakshinamurthy (1988) tested eucalyptus leaf powder @ 1 per cent by weight against *S. cerealella* and reported that it reduced the number of adults emerged to 77 per 100 g of rice as compared to 369 in untreated check.

III. EXTENT OF LOSSES IN STORAGE :

It has been observed that storage conditions and practices vary from place to place in this country which envisages the need to survey the practices followed and damage incurred by insects in different storage conditions.

A survey of wheat stored on farms in Delhi carried out between October 1965 and February, 1966, showed an average insect infestation of 21.10, 8.20, 9.50, 6.00 and 2.50 per cent when the grains were stored loose in rooms, in gunny bags, jute bins, metal bins and earthen pots, respectively. The insects observed included *T. granarium, R. dominica, S. oryzae, T. castaneum, S. cerealella and C. cephalonica* (Zutzhi, 1966). Actual storage losses in wheat in different region of Uttar Pradesh was assessed by Girish et al. (1974). They found 0.06 to 9.70 per cent of wheat loss after six months of storage by different insect pests including *S. cerealella*. In Punjab ninety samples of wheat were collected after ten months of storage at farmer level by Doharey et al. (1975). They reported that moisture content was 8.08 per cent in wheat stored in bags in 'bhusa' while maximum was 11.00 per cent in the grain stored in pucca rooms. Maximum weevilization, germ-eaten grains and loss were observed to be 10 per cent, 15 per cent and 4.02 per cent, respectively in the grain stored in kuthla.

Dhaliwal (1977) recorded storage losses of wheat in Punjab by insect pest collecting the samples after 3, 6 and

9 months of storage from different storage structure viz., PAU type tight metal bin, 'pucci kothi', 'bharoli', 'bukhari', bag storage and loose storage, the maximum insect damage (6.67 per cent) after 9 months of storage occurred in bharoli and minimum (1.33 per cent) in 'pucci kothi' followed by metal bin (1.66 per cent). The maximum variation in moisture content were also observed in wheat stored in 'bukhari' followed by bag storage and 'bharoli' and minimum in metal bin.

Singh et al. (1977) studied the loss of wheat grain in different storage conditions used by farmers around the Varanasi.

The loss in weight of an individual maize grain attacked by one larva was more than 10.00 per cent (Back, 1929., Gerberg and Goldheim, 1957., More et al., 1966). In smaller cereal grains this weight loss was proportionately higher. It has also been reported that in a period of ten weeks, four pairs of angoumois grain moth can cause the infestation to a depth of 12, 6 and 5 cms. in grain columns (4.8 cm. diameter) of maize, sorghum and wheat, respectively (Muhihu, 1984).

Bhardwaj et al. (1979) collected one hundred and twenty samples of maize from eight district of Punjab after six months of storage and concluded after analysis of the samples that moisture content of the grains, germination, weevilization, germ-eaten grains and loss in weight was

11.80, 86.60, 8.80, 0.70 and 2.03 per cent, respectively. The maximum weight loss recorded was 28.08 per cent.

Giga et al. (1991) estimated damage and losses in untreated and pesticide treated maize stored on farm in Zimbabwe after the storage of eight months. They reported that damage to untreated grain and grains treated with malathion, primiphos-methyl and methacrifos was 76, 36, 17 and 10 per cent, respectively and weight losses recorded were approximately 13, 6, 4 and 2 per cent, respectively. Major insect pests were *S. cerealella, S. zeamais* and *T. castaneum*.

In storage over a period of 6 to 9 months, 3 to 12 per cent of rice kernel were attacked by *S. cerealella*. This caused a total weight loss varying from 4.20 to 11.90 per cent with an average of 8.10 per cent. In a single generation, the grain weight loss was between 1.47 and 5.07 per cent in IR varieties (Medina and Henrich, 1986) and percentage of damaged grains of paddy ranged from 0.33 to 33.33 (Prakash et al., 1983).

Adult populations of *S. cerealella, R. dominica, S. oryzae* and *T. castaneum* were monitored by Prakash et al. (1983) for two years in Orrisa in stored rice and found that *S. cerealella* populations built up rapidly in grains with a high moisture content under natural storage conditions.

MATERIALS AND METHODS

Studiés on "Bio-ecology and management of Angoumois grain moth, ***Sitotroga cerealella*** (Olivier) (Lepidoptera : Gelechiidae) infesting stored maize and paddy" were carried out in the Department of Agricultural Zoology and Entomology, Rajasthan College of Agriculture, Udaipur, Rajasthan. A preliminary survey for the assessment of losses caused by the pest in different storage structures was conducted at Udaipur and Banswara districts. The details of the experimental treatments, materials used, techniques followed and criteria adopted for treatment evaluation during the course of present investigation are presented in forthcoming text.

EXPERIMENTAL SITE AND CLIMATIC CONDITIONS :

The investigations were carried out at Udaipur campus of Rajasthan Agricultural University, which is situated in the lap of Aravali hills at 24°35' North latitude and 73°42' East longitude with an altitude of 582.17 meters above the MSL. It falls under agro-climatic zone number IV A, the "Sub-humid Southern plain" of Rajasthan.

This area has typical subtropical semi-arid to sub-humid climatic condition characterized by mild winter and moderate summer. The mean rain fall is 620 mm occurring mostly from the last week of June to September. The weather conditions during the present investigations were, however, normal.

PREPARATION OF CULTURE MEDIUM :

The seeds of maize (Mahikanchan) and paddy (Ratna) were cleaned and sieved to remove the fractions of grains or insects if any. The seeds were taken in enamel plate and disinfested by heating in an oven at 55°C for 6 hours in order to eliminate the traces of insects and mite infestation. Half kilogram of disinfested maize and paddy grains were taken in glass jars (15 X 10 cm) separately (plate-1). The moisture content of the grains was measured, using OSAW digital moisture meter and was then adjusted to 12.5 to 13.5 per cent by adding required quantity of water as per the following formula (Prakash et al., 1987).

$$\text{Weight of water to be added (g)} = \text{weight of grains} \times \frac{\text{Required \% moisture content} - \text{Initial \% moisture content}}{100 - \text{Required \% moisture content}}$$

PREPARATION OF STOCK CULTURE :

For stock culture methods developed at the Kansas State University (Padersen et al., 1977) and the University of California (Strong et al., 1967) were adopted in the present study. Adult moths of *S. cerealella* were collected from infested grains of godowns using an aspirator. Single pair of adults was then released in jars containing conditioned maize and paddy grains. The jars were kept in incubator at

PLATE NO. 3 : EGG LAYING APPARATUS.

PLATE NO. 4 : CAGE FOR MOTH COLLECTIONS.

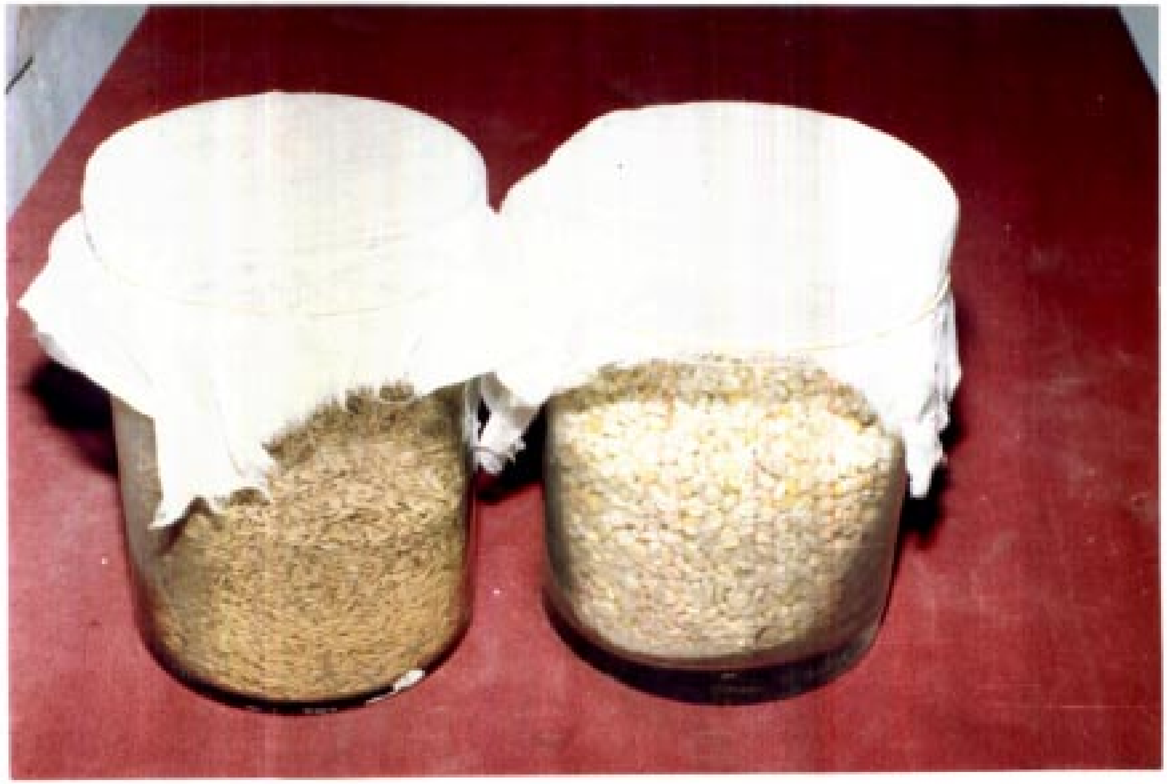


PLATE NO. 1 : CULTURE JARS.

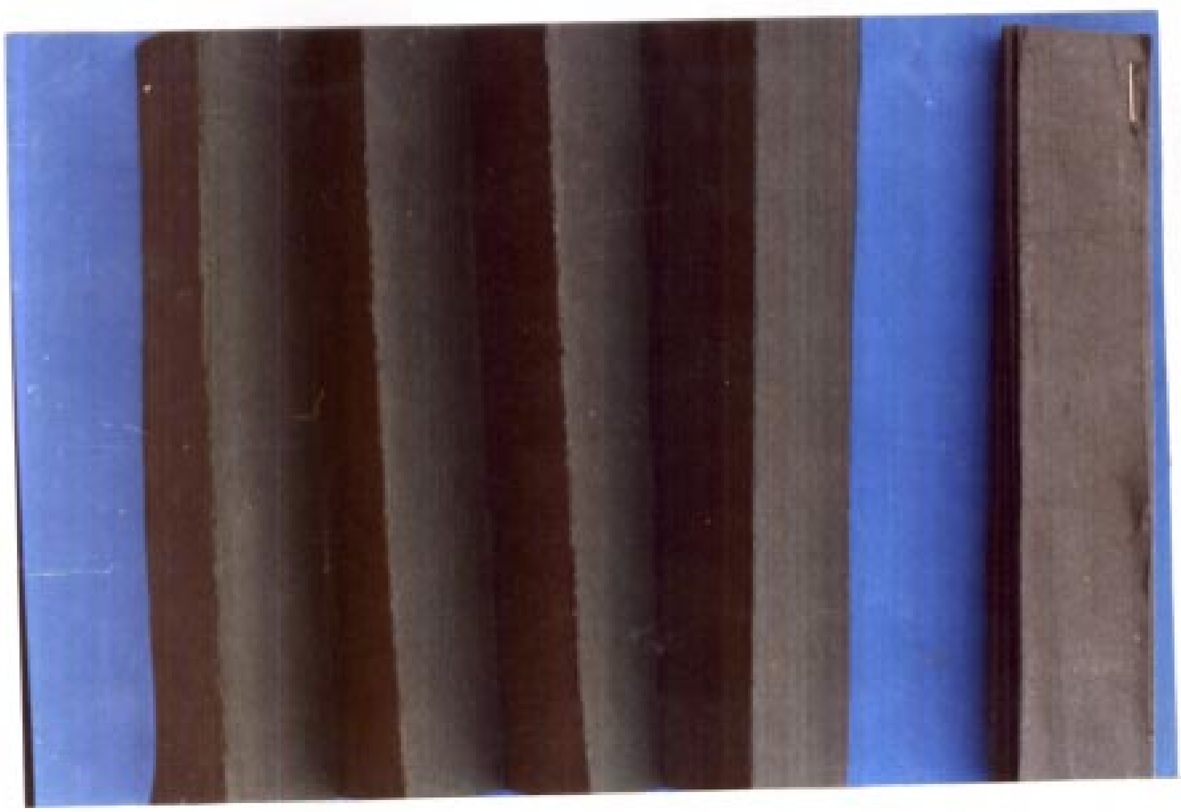


PLATE NO. 2 : EGG COLLECTION PAPERS (A) UNFOLDED (B) FOLDED.

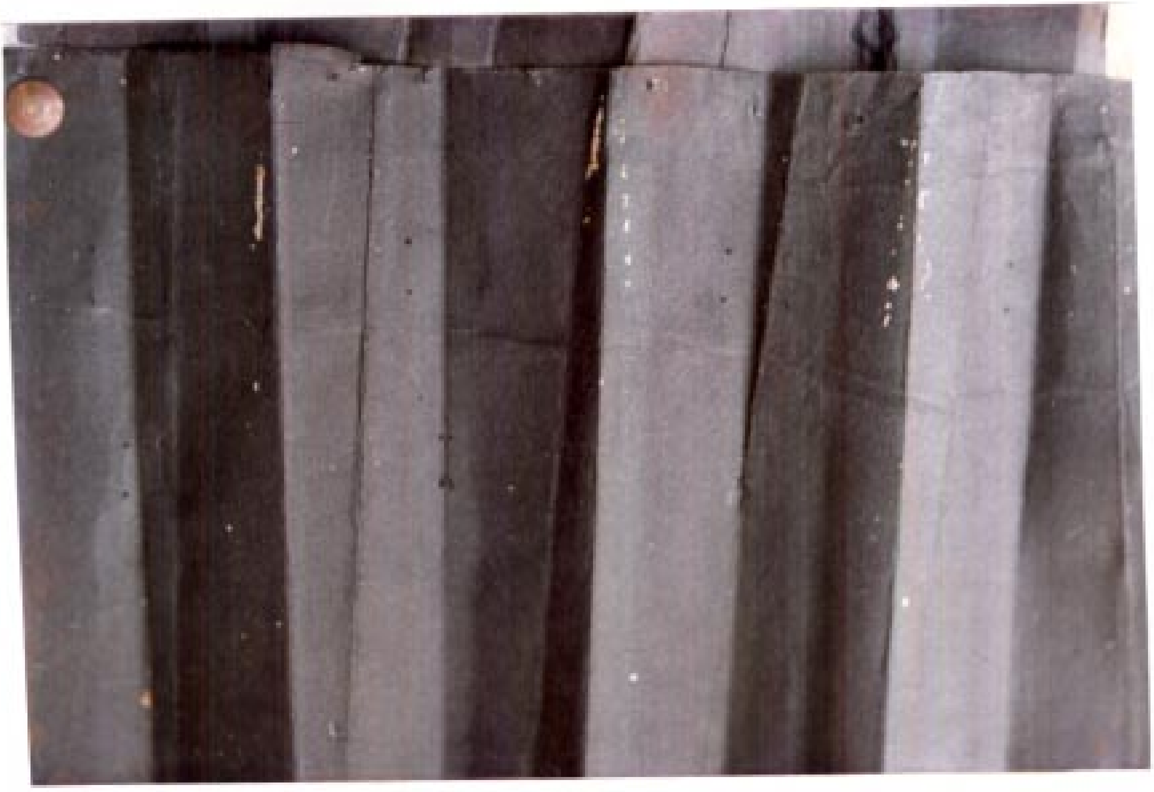


PLATE NO. 5(A) : EGGS OF *S. cerealella* (UNHATCHED).

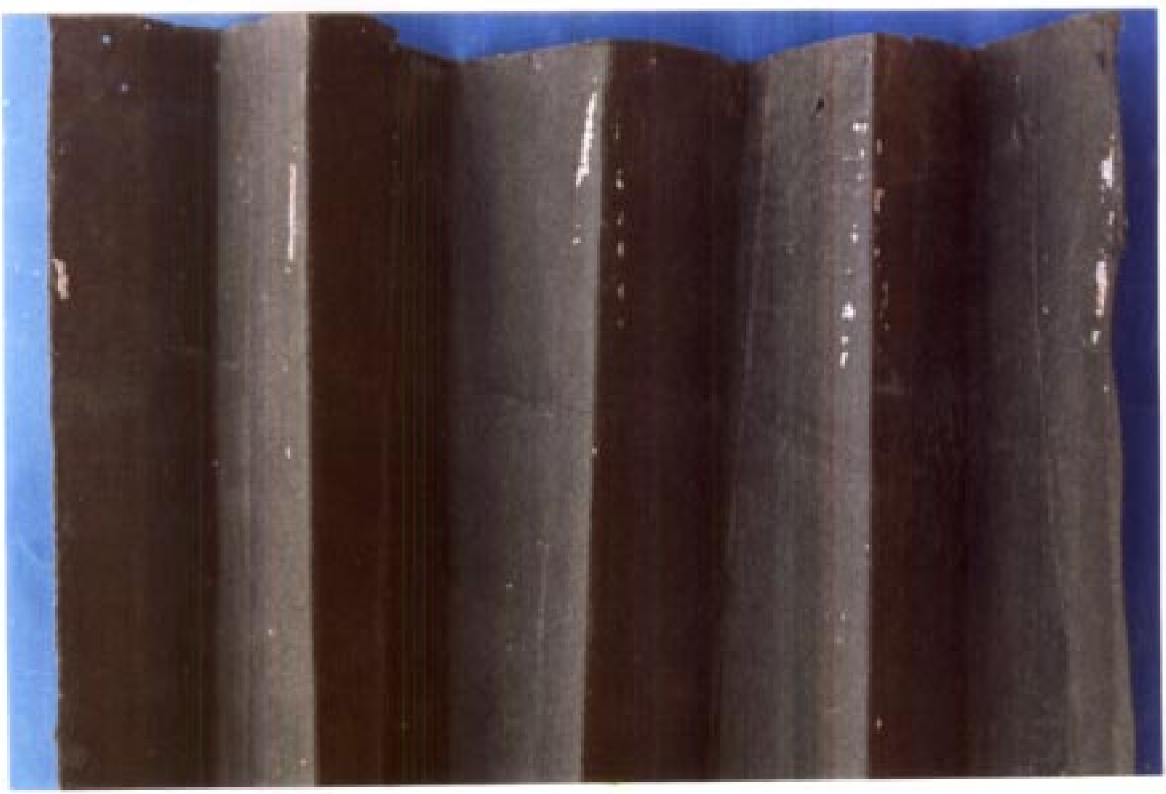


PLATE NO. 5(B) : EGGS SHELL OF *S. cerealella* (AFTER HATCHING)

$28\pm1^{\circ}C$ temperature and 70 ± 5 per cent relative humidity. After emergence, pairs of freshly emerged adults from this uniparental culture were taken for experimentation.

EGG COLLECTION :

Black thick papers (15 X 22.5 cm) were folded accordion - like at 2.5 cm. intervals and secured with staples at one side (plate-2). This provided 8 seems for egg deposition (Peters, 1971). These folded paper were kept in plastic jars of 15 X 7 cm (plate-3). Moths collected from stock culture using a net cage and an aspirator (plate-4) were introduced into these plastic jars through the holes made on the lid. The holes were then plugged with cotton. The papers were removed from the jars after egg laying. After removing from the jars the papers were unfolded cut into pieces and the eggs adhering to them were used for experimental purpose (plate-5 a, b)

EXPERIMENTAL DETAILS AND DESIGN

I. BIOLOGICAL STUDIES :

Biological studies of *S. cerealella* were undertaken in the laboratory at four different temperature and humidity levels on maize and paddy grain in order to study their effect on fecundity, incubation period, per cent hatching, duration of larval and pupal stages, adult longevity, survival percentage of adult and sex ratio.

The temperature levels of 20±1, 25±1, 30±1 and 35±1°C were maintained in laboratory by using BOD (Biochemical Oxygen Demand) incubators. The required humidity levels were maintained in dessicators (20 cm) by using different salt solutions (Solomen, 1951). The details are given in Table-1.

Experimental procedure :

In order to obtain vergin adult moths for estimation of oviposition rates, infested maize and paddy grains (identified by the presence of emergence windows or caps) were selected and placed separately in glass vials (5 X 2.5 cm) having perforated lids. These glass vials were kept at 70±5 per cent relative humidity and 28±1°C and inspected daily. On the day adults emerged, one male and one female moth was placed in a 5 X 2.5 cm vial. The vial was closed by perforated plastic lid. A piece of black thick paper (4 X 5 cm) on which the milky white eggs could be seen easily was folded accordian-like having 4 folds of 4 X 1 cm strip (Peters, 1971) and this paper was then placed in the vial. No grain was provided to moth. Each day the pair of moths was transferred to a similar vial using a small steel framed nylon covered cage provided with sleeve (plate-4). The process was repeated till the death of female. The black paper from the original vials was carefully unfolded and the number of eggs laid (usually deposited in cluster and rows) were counted daily under a binocular microscope. Every portion of the vials and lids was thoroughly examined for

Table 1 : Different salt solutions used to maintain humidity at different temperatures

Relative humidity (%)	Temperature (°C)			
	20	25	30	35
50	Potassium hydroxide 33.70g per 100ml water	Saturated solution of magnesium nitrate	Saturated solution of magnesium nitrate	Saturated solution of magnesium nitrate
60	Potassium hydroxide 29.50g per 100ml water	Saturate solution of sodium bromide	Saturated solution of sodium nitrate	Saturated solution of sodium nitrate
70	Poatassium hydroxide 25.00g per 100ml water	Saturated solution of strontium chlorid	Saturated solution of sodium acetate	Saturate solution of sodium acetate
80	Potassium hydroxide 19.25g per 100ml water	Saturated solution of potassium bromide	Saturated solution of potassium bromide	Saturated solution of potassium bromide

eggs. Four replicates were set up for each combination of temperature and relative humidity.

In order to obtain eggs to study the developmental period and mortality, the folded black thick papers were introduced into culture jars containing 1 to 2 days old *S. cerealella* adult moths. After twenty four hours, the black thick papers were removed and unfolded. The black paper bearing 20 eggs was cut and kept in glass vials (10 X 4 cm).

Each vial was provided with fifty grains. The piece of black paper was removed from the vial and the eggs were carefully examined for hatching under a binocular microscope. The number of eggs hatched were recorded by counting the empty egg shell (transparent, white and shiny) and verified by counting the unhatched fertilized (red in colour) and the sterile eggs (wrinkled and milky white in colour).

Ten days after introducing the eggs, and each day there after, the vials were examined for the study of development of the *S. cerealella*. Observations were continued till the adults' emergence ceased.

The larval period was worked out by recording the date of hatching and date of emergence of window (cap) on the grains. The period between cap formation and adult emergence was considered as pupal period. Longevity of adults was determined by recording the date of their emergence from pupae and date of natural death. The survival percentage was worked out on the basis of number of eggs placed in vial and number of moths emerged after completion of life cycle.

The male and female moths emerged after completion of life cycle were separated and sex ratio was worked out. A blunt abdominal tip in female and a pointed one with blackish abdomen in male facilitated sexing.

II. HOST PLANT RESISTANCE :

(i) Screening of varieties :

Resistance to *S. cerealella* was evaluated adopting the screening procedure of Khare and Johari (1979) and Prakash et al. (1983).

Test materials :

Detailed information about maize and paddy varieties are given in Table 2 and 3.

Grains of all the paddy and maize varieties to be screened were cleaned, seived and sterilized at 55°C for 6 hours to remove the source of infestation if any. Subsequently the moisture content of all the varieties was adjusted from 12.50 to 13.50 per cent by adding water, as described by Prakash et al. (1987) The grains of all the varieties were then kept at room temperature for four days. One hundred grains of each variety were weighed on analytical balance (Sartorius electronic balance) and confined in glass containers measuring 10 X 4 cm for paddy

Table 2 : Detailed information about maize varieties.

Sn	Name of maize varieties	Parantage	Duration	Grain type	Colour
1	Ageti - 76	Composite	Medium	Semi flint	Yellow
2	Aswani	Composite	Medium	Semi flint	Yellow
3	Arun	Composite	Early	Semi flint	Yellow
4	CM - 111	Inbreds	Full	Semi flint	Yellow
5	CM - 501	Inbreds	Full	Semi flint	Yellow
6	Devki	Composite	Medium	Semi flint	White
7	Diara - 3	Composite	Early	Semi flint	Yellow
8	D - 765	Composite	Early	Semi flint	Yellow
9	Dhawal	Composite	Full	Semi flint	White
10	Harsh	Composite	Medium	Semi flint	Yellow
11	Hement	Composite	Medium	Semi flint	White
12	Kisan	Composite	Full	Semi flint	Yellow
13	Laxmi	Composite	Full	Semi flint	White
14	Madhuri	Composite	Medium	Semi flint	Yellow
15	Mahikanchan	Composite	Early	Semi flint	Yellow
16	Malan	Local (Mewar region)	Full	Semi flint	White
17	MCU - 508	Composite	Early	Semi flint	Yellow
18	NLD	Composite	Full	Semi flint	White
19	Prabhat	Composite	Full	Semi flint	Yellow
20	Pusa-I	Composite	Medium	Semi flint	Yellow
21	Pusa-II	Composite	Medium	Semi flint	Yellow
22	Renuka	Composite	Medium	Semi flint	Yellow
23	Surya	Composite	Early	Semi flint	Yellow
24	Vikram	Composite	Full	Semi flint	Yellow
25	V L-88	Composite	Early	Semi flint	Yellow

Early = 75 to 85 days. Medium = 86 to 95 days and Full = 96 to 105 days.

Table 3 : Detailed information about paddy varieties

Sn	Name of paddy varieties	Parentage	Duration	Grain type	Odour
1	R 574 -11	IR 54 x Kranti	Medium	L.B	Normal
2	Swarna	Vashista x Masuri	Late	M.S	Normal
3	Kranti	Cross-116 x IR -8	Medium	S.B	Normal
4	BK-79	(TN.1 x NP. 130) x Basmati-370	Medium	L.S.S	Scented
5	IR-54	Namsagui - 19 x IR 2071 - 88 x IR 2061 - 214 - 3 - 6 - 20	Medium	L.S	Normal
6	Masuri	Taichung 65 x Mayong ebas	Late	M.S	Normal
7	Jaya	TN.1 x T.141	Medium	L.B	Normal
8	Safri - 17	Selection	Late	L.S	Normal
9	Annada	Mutant	Early	S.B	Normal
10	Basmati - 370	Selection	Late	L.S.S	Scented
11	R.296 - 128	CR-157 - 392 x CR.57 -21	Medium	L.B	Normal
12	Kalimuchh	Selection	Medium	M.S.S	Scented
13	Dubraj	Selection	Late	M.S.S	Scented
14	Surekha	IR.8 x Siam 29	Late	L.B	Normal
15	Phalguna	IR.8 x Siam 29	Late	L.B	Normal
16	Ratna	TKM.6 x IR.8	Early	L.S	Normal
17	Mahisugandha	BK-79 x Basmati-370		L.S.S	Scented
18	BK-190	R - 14 x IR-8	Late	S.B	Normal
19	Chamble	IR-8 x NP-130	Late	S.B	Normal
20	Pusa.2-21	IR-8 x TKM-6	Early	S.B	Normal
21	Bala	N-22 x TN-1	Early	S.B	Normal
22	Cauveri	TN-1 x TKM - 6	Early	S.B	Normal
23	Poorva	CR-44-35 x JR 2 - 331	Early	L.S	Normal
24	Madhuri selection -11	Selection of Madhuri	Medium	L.S.S	Scented
25	IR-36	IR 8 x Tadukan x TKM-62 x TN - 1 x IR-243 x <u>O. nivara</u> x IR-8 x Ptb.21	Medium	L.S	Normal

Early : Below 120 days, Medium : 120 to 135 days and Late : More than 135 days

L.B : Long Bold, L.S : Long Slender, L.S.S : Long Selender Scente

S.B : Short Bold, M.S : Medium Slender, M.S.S : Medium Slender Scented and 15 X 10 cm for maize. These were covered with muslin cloth (plate-6 a, b). Freshly emerged (8-12 hours old) pair of *S. cerealella* was introduced in each glass container. These were kept in incubator at 28±1°C temperature and 70±5 per cent relative humidity. For the evaluation of susceptibility/ resistance the paramerters viz., adult emergance, per cent grain damage, per cent loss in grain weight, survival percentage of adults and susceptibility index were taken into consideration. After the completion of life cycle, the following observation were also made for each commodity and variety.

a. Adult emergence (Number of adults emerged).

b. Grain damage.

c. Loss in grain weight.

a. Adult emergence :

Number of adults that emerged after completion of successful development of one generation was recorded by counting the total number of adults 'n' (dead and alive) present in each container and `n-2' was applied to calculate number of adults emerged.

b. Grain damage :

At the end of experiment all the grain samples from each glass containers were examined for the infested grains. Individual grain with one or more circular hole was considered as infested. Both the infested and total number

PLATE NO. 6(A) : SCREENING OF MAIZE VARIETIES.

PLATE NO. 6(B) : SCREENING OF PADDY VARIETIES.

of grains were counted, using counting board for calculating percentage of damaged grains (Samuel and Chatterjee, 1953).

c. Loss in grain weight :

The difference between the initial weight and the final weight of grains of each variety was used for calculating per cent loss in grain weight by using the formula as given by Harris and Lindblad (1978). The final moisture content of

each variety was measured using digital moisture meter and a correction factor was added with final weight of the sample to compansate the weight loss which might have occurred due to the reduction in the moisture content of the grain during the experimental period.

$$\text{Percent weight loss} = \frac{OW - CW}{OW} \times 100$$

where,

OW = Original weight on dry matter basis

CW = Current weight on dry matter basis

Percent hatching and survival percentage of adult :

In the second set of experiment, the survival of adults was studied. For this, black paper having two hundred eggs, was placed in glass jars (15x10 cm) containing one thousand conditioned grains of the varieties to be tested. The papers were removed after hatching and examined for the number of eggs hatched. Further the observations were recorded on the emergence of the adult moths till the adult emergence stopped. From the data gathered, the survival percentage of adult, mean developmental period, total number of moths emerged and susceptibility index were worked out as follows :-

Survival percentage of *S. cerealella* :

Survival percentage of *S. cerealella* was worked out by the following formula : (Heinrichs et al., 1985)

$$\text{Survival Percentage} = \frac{\text{Total number of adult emerged}}{\text{Total number of larvae that hatched from 200 eggs placed in each sample}} \times 100$$

Mean developmental period :

Mean developmental period was considered as the time taken for fifty per cent adult emergence from the medium. It was calculated by taking the daily counts of adult emergence, after introduction of eggs. Emerging adults were collected daily by the aspirator and the number of adults emerging per sample was counted till the emergence ceased. From this the mean developmental period in different varieties of maize and paddy was calculated. The number of adults emerged from each test variety was also counted.

Susceptibility index :

Based on the number of moths emerged in each test variety and mean developmental period. Index of susceptibility was calculated by the following formula (Dobie, 1977).

$$\text{Suceptibility Index} = \frac{\text{Natural log 'F'}}{D} \times 100$$

where,

F = Total number of moths counted

D = Mean developmental period in days

Based on these parameters all the maize varieties were grouped.

Based on these parameters all the maize varieties were grouped into three categories - least susceptible, moderately susceptible and susceptible. The varieties having 0 to 1 per cent grain damage, 0 to 1 average number of adult emergence, 0 to 1 per cent loss in grain weight, 0 to 10 per cent adult survival and 0 to 6 suceptibility index were identified as least susceptible, whereas the varieties exhibiting 1.1 to 6 per cent grain damage, 1.1 to 6 average adult emergence, 1 to 3 per cent loss in grain weight, 10 to 20 per cent adult survival and 6 to 10 susceptibility index were considered moderately susceptible. The varieties having higher values than moderate group were considered susceptible.

Similarly, in paddy the varieties showing grain damage from 0 to 1 per cent, 0 to 1 average number of adult emergence, 0 to 1 per cent loss in grain weight, 0 to 10 per cent adult survival and 0 to 8 susceptibility index were identified as least susceptible whereas varieties having 1.1

to 6 per cent grain damage, 1.1 to 6 average adult emergence, 1 to 3 per cent loss in grain weight, 10 to 20 per cent adult survival and 9 to 12 susceptibility index were considred moderately susceptible. The varieties having higher values than moderate group were categorised under susceptible group.

(ii) Basis for resistance

The following physical and biochemical factors were taken into consideration for evaluating the basis of susceptibility/resistance of maize and paddy varieties against *S. cerealella.*

Physical factors :

Maize :-

Volume of grains :

The volume of maize grain was determined by standard water displacement method. In a 25 ml graduated (measuring) cylinder, distilled water was taken up to 10 ml mark and 10 seeds of each maize variety were added to it. The raised water level was noted for determination of grain volume. It was replicated for three times.

Thickness of pericarp and seed coat :

To find out the thickness of the pericarp and seed coat, ten grains of each maize variety were soaked separately in distilled water for 24 hours and fine transverse section were cut with the help of a fine blade.

The sections were passed through different grades of alcohol for dehydration. The clean unstained fine sections were mounted in glycerin on microscopic slide and the thickness of seed coat and pericarp was measured under compound microscope.

A simple correlation was worked out between the thickness of the pericarp and seed coat with the different parameters of susceptibility/resistance of maize varieties.

Relative hardness:

Relative hardness of each variety of maize grain was estimated as described by Davey (1965).It was estimated by grinding of 500 g quantity of grain. The ground material was passed through a 60 mesh sieve and weighed. The hard grain yielded least quantity of flour.

Water absorption index :

For studying the water absorption index of maize grains, ten seeds of each variety in three replicates were weighted. Each sample was put inЭto a muslin cloth bag and placed in tray filled with tap water. The tray was then put in an incubator at 20°C for sixty hours. After this period the inactive seeds i.e., harder ones were removed and rest were dried with blotting paper and then weighed. The absorption index of grain of each variety was worked out by the following formula (Pandey and Pandey, 1982).

$$\text{Absorption Index} = \frac{A}{B} \times \frac{10}{Y}$$

Where,
A = Weight of soaked seeds
B = Weight of dry seeds
Y = Number of soaked seeds.

Paddy :

Length breath (L/B) ratio :

The L/B ratio of paddy grains was worked out by measuring the length and breath of the grains, using a dial micrometer. Seven grains of each variety of paddy were randomly selected for this purpose. (Prakash et. al., 1987)

Husk thickness :

The thickness of husk of paddy was measured with the help of a dial micrometer at various locations of lemma and palea. After measuring the thickness of grains with husk (T_1) and without husk (T_2), the thickness of husk was measured by the formula given by Raghaviah et al, (1983) :

$$\text{Husk Thickness} = \frac{T_1 - T_2}{2} \text{ mm}$$

Relative hardness (alkali spreading value) :

Relative hardness of paddy grains was recorded by "Alkali method " as proposed by Little et al, (1958) and modified by Bhattacharya (1979). Seven grains of each paddy variety were kept in separate petridishes for 24 hours. The alkali value was calculated based on digested (degraded) area of kernel categorized on a 2 - 8 scale (Prakash *et al*, 1987). Higher alkali value indicated lesser hardness of grains.

Scoring pattern

Score (S)	Observations
1 - 2	No disintegration of kernel
3 - 4	Collar disintegration of kernel
5	Half kernel disintegration
6	More than half to complete disintegration
7 - 8	Complete opaque.

Biochemical factors

Estimation of amylose :

The estimation of amylose content in maize and paddy grain was done by modified Juliano method (Sadasivam and Manikam, 1992)

Principle :

The idonine is adsorbed within the hilical coils of amylose to produce a blue coloured complex which is measured colorimetrically.

Materials :

Distilled ethanol

1 N NaOH

0.1 % Phenolphthalein

Iodine reagent :

One g iodine and 10 g KI dissolved in water and volume was made up to 500 ml.

Standard :

Hundred mg. amylose dissolved in 10 ml. 1 NaOH and the volume was made up to 100 ml. with distilled water.

Procedure :

Hundred mg. of powdered samples of maize and paddy grains were taken in test tubes, then 1 ml. of distilled ethanol and 10 ml. of 1 NaOH were added and left for overnight. Next day the content was transferred to 100 ml. volumetric flask with repeated washing and a total of volume of 100 ml. was made with distilled water. Out of this 2.5 ml of the extract content was taken in 50 ml. volumetric flask. To it 20 ml. distilled water and 3 drops of phenolpthalein were added which gave pink colour. After this some drops of HCl (0.1 N) was also added till the disappearance of pink colour. Then 1 ml of iodine reagent was added and volume was made to 50 ml. The intensity of blue colour was measured in colorimeter at 590 nm. A blank was also run by using colorimeter at 590 nm. reading. Standard amylose solution was made by taking 0.2, 0.4, 0.6, 0.8 and 1.0 ml. of the standard amylose solution and the color was developed as in case of sample. The amount of amylose present in the sample was calculated using the standard graph.

Calculation :

Absorbance corresponds to 2.5 ml of the test solution

$$= x \text{ mg. amylose}$$

100 ml. contains

$$= \frac{x}{2.5} \times 100 \text{ mg. amylose}$$

$$= \% \text{ amylose}$$

Estimation of protein :

Estimation of total nitrogen :

Principle :

The nitrogen content are transferred into ammonium sulphate by acid digestion with boiling suphuric acid. The acid-digest is cooled, diluted with water and made strongly basic with sodium hydroxide. The released ammonia is collected in a boric acid solution, then it is titrated with standard hydrochloric acid to a blue end point.

Procedure :

Hundred miligrams dried grains were powdered and placed into microkjeldahl flask. Then a pinch of digestion mixture ($CuSO_4$ and K_2SO_4., 1 : 9) and 2 ml of concentrated sulphuric acid (Emerck) was added. The flask was then gently heated on a hotplate until the frothing ceases. The temperature was raised to boiling till a clear white solution was formed. It was then cooled. The digestion mixture was transferred to a steam distillation apparatus via the sample funnel. Five ml. of boric acid and 4 drops of mixed indicator dye were taken in 50 ml Erlenmeger flask and kept beneath the condenser. In the digestion mixture, 15 ml. of sodium hydroxide - sodium thiosulphate solution was added and distillation was done. The distillate was collected for 4 - 5 times and titrated with standard hydrochloric acid in a microburatte to a grey or blue end point.

A blank containing the same quantities of all reagents but without sample was also run.

Calculation :

(i) Per cent nitrogen was calculated by the following formula,

$$\text{Per cent N} = \frac{(V_1 - V_2) \times 1.4}{W} \times 100$$

Where,

V_1 = Volume of 0.1 N HCl consumed by the sample
V_2 = Volume of 0.1 N HCl consumed by the blank
W = Weight of the sample.

Total protein :

Per cent N X conversion factor

Where, conversion factor - 6.25 for maize and 5.95 for paddy (Sadasivam and Manikam, 1992).

Estimation of free amino acids

Principle :

Ninhydrin, a powerful oxidizing agent, decarboxylates the alpha - amino acid and yields an intensely coloured bluish purple product which is colorimetrically measured at 570 nm.

Ninhydrin + alpha - amino acid ----> Hydrindantin + Decarboxylate Amino acid + Carbon dioxide + Ammonia.

Hydrindantin+Ninhydrin+Ammonia ----> Purple coloured product + Water.

Materials :

Ninhydrin :- 0.8 g. stannous chloride ($SnCl_2.2H_2O$) was dissolved in 500 ml. of 0.2M citrate buffer (ph 5.00). This solution was added in other solution which was made by taking 20g of ninhydrin in 500ml. of methyl cellosolve.

Diluent Solvent :- Mixture of equal volumes of water and n-propanol.

Procedure :

Extraction of amino acids :- Five hundred miligrams of dried grain sample were ground in a pestle and morter with a small quantity of acid-washed sand. To this homogenate, 10ml of 80% ethanol, was added and centrifuged at 3000 rpm for 10 minutes. The supernatant solution was collected in tubes. The extraction process was repeated for two times and all the supernatants were pooled and transferred in to a small beaker. The volume was reduced by evaporation. The reduced supernatant (extract) was used for quantitative estimation of total free amino acids.

Estimation :

In 0.1ml of extract, 1 ml of ninhydrin solution was added. Then volume was made up to 2 ml with distilled water in a tube. This tube was heated in a boiling water bath for 20 minutes. To this 5 ml of the diluent was added and it was mixed thoroughly. After 15 minutes the intensity of purple coloured against a reagent blank was read in a colorimeter at 570 nm. A reagent blank was prepared as above by taking 0.1 ml of 80% ethanol of the extract.

Standard :- 50 mg of Leucine was dissolved in 50 ml of distilled water in a volumetric flask. From the flask 10 ml of solution was taken and diluted to 100 ml in other volumetric flask for working standard solution. A series from 0.1 to 1.0 ml of this standard solution gave a concentration range 10 µg to 100 µg which was proceeded as that of the sample and colour was read.

Estimation of total ash :

The method followed for the estimation of total ash was of A.O.A.C (1970).

The silica crucibles were heated in mufflefurnace at about 600°C till the constant weight was obtained and then these were allowed to cool down and kept in the desiccator and weighed. These crucibles were labelled and 2 g of finely powdered test sample was added in each crucible then these were put in mufflefurnace and allowed to heat up slowly in the starting and later the temperature was raised up to

600°C. The sample were heated for about 12 hours at 600°C temperature. The temperature was allowed to come down to about 100°C. The crucibles were transferred to desiccator for further cooling. After cooling crucibles were weighed. The differences of the two readings gave the weight of ash. The per cent of ash was calculated as follows :-

$$\text{Per cent Ash} = \frac{W_2 - W_1}{W} \times 100$$

where,

W = Weight of test sample

W_1 = Initial weight of crucibles

W_2 = Final weight of crucibles

Estimation of silica content in husk :

Silica content of the test varieties of paddy were estimated by the method adopted by Piper, 1960.

Procedure :

For this purpose the insoluble residue of the digested material was transferred on to a Whatman filter paper No.42. The residue was made free from trace of soluble imparity by continuous washing with distilled water and dried, ignited and weighed. Required quantities of hydrofloric acid and sulphuric acid were added to the dried residue and left for volatilization. The left over material was strongly ignited to expell all the acid and weighed again. The quantity of silica was estimated by the loss in weight.

Estimation of oil in grain :

Preparation of Thimble :- Filter paper (Whatman No. 1) pieces of about 8 X 8 cm were taken and wrapped around wooden stick of 2 cm diameter. These were then tied with thread, so that the thimble may not be opened easily during extraction.

Procedure :

Samples of maize and paddy were hand pounded and then 2 g. of dried material was transferred in a thimble. The mouth of the thimble was plugged with fat free absorbant cotton and transferred to pre-weighed clean, dry receiver flask of the soxhlet assembly. The apparatus was assembled and flask was filled with petroleum ether through the condenser. Then the apparatus was placed on a water bath at 60°C and extracted for 8 hours. When extraction was over, the thimble was removed from the soxhlet. The apparatus was again assembled and heated on the water bath to recover all the ether from the receiver flask. The flask now contains only the crude fat. Then the receiver flask was removed and wiped thoroughly with a clean dry cloth to remove the film of moisture and dust from the outside. It was dried in a hot air oven at 100°C for 1 hour, then cooled in a desiccator and weighed.

Calculation :

$$\text{Oil per cent} = \frac{W_1 - W}{M} \times 100$$

where,

W = Weight of empty flask

W_1 = Weight of flask after extraction

M = Weight of dried sample

(B) Evaluation of insecticides and plant products :

(i) Insecticides :

In the present study the dust formulations of some synthetic insecticides were used for mixing with seeds for seed protection, whereas the emulsifiable concentration of insecticides were used for impregnation of jute and cotton bags. Detailed information about insecticides used is given in Table 4.

(a) Mixing of insecticidal dust with grains :

In the first set of experiment, previously conditioned grains of maize and paddy were taken separately in battery jars and 0.6 and 1.20 g quantity of dust formulation of each insecticide was thoroughly mixed with 300 g of grains separately and one hundred grams of treated seeds were transferred in glass jar (15 X 10 cm). Then a paper strip containing of 200 eggs of *S. cerealella* were placed inside each jar and covered with muslin cloth tied with rubber bands. The treatment was replicated three times and all jars

Table 4 : Detailed information of insecticides used.

SN	Technical name	Trade name	Formulations	Chemical name	Manufacturer
1	Malathion	Malathion	50 EC 5% Dust	O, O - dimethyl S-1,2-dicarbe thoxye phosphoro di thioa	Northern Mineral Ltd Rajendra Mansion 19. A Ansari Road New Delhi-2
2	Methyl Parathion	Methyl Parathion	50 Ec 2% Dust	Dimethyl 4-nitroph enyl phosphorothio nate	Northern Minerals Ltd Rajendra Mansion 19. A Ansari road N-Delhi-2
3	Endosulfan	Endocel	35 EC 4% Dust	6,7,8,9,10,10-hexa cloro-1,5,5a,6,9,9a hexahydro-6,9-metha no-2, 4, 3-benzodio xathiepin-3-oxide	Excel Industries Ltd 184-87. Swami Vivekanand Road, Jogeshwari, Bombay-12
4	Quinalphos	Ekalux	25 EC 1.5% Dust	O, O-diethyl O-quino xalin-2-yl phosphor thioate	Sandoze India Ltd. 3 Wetlat Road Bomaby-400 001
5	Carbaryl	Sevin	50% W.P 5% Dust	1-naphthyl N-methyl carbamate	Rhone Poulenc Agro-chemicals (India) Ltd Rhone Poulenc House Worli, Bombay-400 025
6	Fenvalerate	Trimphcard	20 EC 0.4% Dust	α-cyano-m-phenoxy benzyl (isopropyl-p chloro-phenyl acet	Northern Minerals Ltd Rajendra Mansion 19. A Ansari Road. New Delhi
7	Deltamethrin	Decis K(Othrine)	2.8 EC	[(S)-α-cyno-methyl m-phenoxy benyl (1R, 3R)-3-(2,2 dibromovin yl-2,2-dimethyl-cyclo propane carboxy late)]	Roussel Pharma centicals (India) Ltd. New Delhi

were kept at controlled temperature and humidity (28±1°C and 70±5 % relative humidity) for eight months. At the end of the experimentation data were obtained on the per cent damage of grains, number of moth emerged and germination percentage.

(b) Impregnation of jute and cotton bags :

For the second series of chemical treatment, the seeds of maize variety, Malan (purchased from the market) and paddy variety, Ratna (obtained from the Dept. of Plant Breeding and Genetics I.G.A.U., Raipur) were first sterilized at 55°C for 6 hours and then moisture content was adjusted to 12.5 to 13.00 per cent. The insecticides along with their concentration used are given in Table 5.

Table - 5 : Insecticides used for the impregnation of bags :

sn.	Insecticides	Formulation	Concentration (%)
1.	Malathion	50EC	0.10
2.	Methyl parathion	50EC	0.10
3.	Endosulfan	35EC	0.10
4.	Quinalphos	25EC	0.10
5.	Carbaryl	50WP	0.10
6.	Fenvalerate	20EC	0.025
7.	Deltamethrin	2.8EC	0.025

The jute and cotton bags (15 X 15 cm) were treated with insecticide uniformly by dipping the bags in insecticidal solution for 15-20 minutes. The untreated (control) bag was also treated (dipped) with tap water. The treated bags were dried in shade before filling the maize and paddy seed. The bags were properly labelled and stacked in severely infested godown (storage) on a raised plateform for about eight months. There were three replicates in each case. The observation on mean percentage of damage was worked out by drawing the samples from each bag. The samples from all the three replicated were pooled and mixed out of this 100 grains were selected randomly and healthy and damaged grains were counted on the basis of presence of emergence holes. The reduction in weight was calculated at the end of experiment. The germination per cent of grains kept in treated and untreated bags was also worked out as procedure described under germination test.

(ii) Vegetable oils and other plant products :

Different vegetable oils and plant products were tried to explore the possibilities for using them as prophylactic measures against *S. cerealella* infesting maize and paddy. The details about the oils and plant products used are given in Table 6 and 7.

Vegetable oils :

The vegetable oils were purchased from the local market except neem oil which was procured from Khadi Gram Udyog Udaipur (Rajasthan). All oils were used as such. Seeds of maize and paddy were treated with different oils @ 0.5 and

1.0ml/100 g grains separately. The 1.5 Kg seeds in two sets were put in the polythene bags and 7.5 and 15 ml oil was poured over the seeds of these two sets. The polythene bags were shaken thoroughly till all the seeds were coated uniformly. The same procedure was used for all the oils tested and both the commodities (maize and paddy) separately. A control (untreated) was also kept simultaneously. A sample of 100 g grain from each treatment was transferred to the glass jar (15 X 10 cm) and labelled. The treatments were replicated three times. A lot of 200 eggs (strip) was placed in each jar. The jar was covered with muslin cloth and tied with rubber band and then kept in controlled temperature and humidity (CTH) at 28±1°C and 70±5 % relative humidity for eight months. At the end of experiment, observations on per cent damage, number of insects emerged and germination percentage were recorded as per the procedure described and the data were compared with untreated check.

Table 6 :- Details of different vegetable oils used

Sn	Common name	Scientific name	Doses ml/100 g of grain(V/W)
1.	Groundnut oil	*Arachis hypogaea* Linn	0.5 and 1.0
2.	Coconut oil	*Cocos nucifera* Linn	0.5 and 1.0
3.	Mustard oil	*Brassica comprestris* Linn	0.5 and 1.0
4.	Neem oil	*Azadirachta indica* A.Juss.	0.5 and 1.0
5.	Sesame oil	*Sesamum indicum* Linn.	0.5 and 1.0

Other plant products :

The powders of different plant products <u>viz</u>., neem leaf, neem kernel, sarifa leaf, eucalyptus leaf and lantana leaf were prepared by drying them in shade and then grinding them in electronic grinder to get fine powder. The powder was seived through 60 mesh sieve. The plant products were mixed with already conditioned maize and paddy seed @ 1 and 2 g/100 g of grains separately. A control (untreated) was also kept simultaneously. A sample of 200 g grains of maize and 100 g of paddy from each treatment was transferred to the jar. The treatments were replicated three times. A lot of 200 eggs was placed in each jar. The jar was covered with muslin cloth and tied with rubber band, then kept in CTH room for eight months. The data on grain damage, insect population emerged and per cent germination of seeds were recorded.

Table 7 :- Details of plant products used.

Sn	Common name	Scientific name	Doses g/100 g of grain(wt/wt)
1.	Neem Leaf	*Azadirachta indica* A.Juss.	1 and 2
2.	Neem kernel	*Azadirachta indica* A.Juss.	1 and 2
3.	Sarifa leaf	*Annona squamosa* Linn.	1 and 2
4.	Eucalyptus leaf	*Eucalyptus globulus* Labill.	1 and 2
5.	Lantana leaf	*Lantana camera* Linn.	1 and 2

Germination test :

At random one hundred seeds were taken from each treatment (including untreated) and soaked in water for 24 hours and then placed in petridishes (15 cm diameter) lined with wet blotting paper. These plates were kept in incubator for 5-7 days to allow sufficient time for all the seeds to germinate. Water was poured regularly to prevent drying. There were three replications in each treatment. The number of sprouted and unsprouted seeds were counted and the per cent of germination was calculated.

$$\text{Germination per cent} = \frac{\text{Number of seeds germinated}}{\text{Number of seeds kept for germination}} \times 100$$

III. **ASSESSMENT OF LOSSES IN STORAGE STRUCTURES :**

Losses caused by *S. cerealella* in stored maize and paddy were analysed by collecting the samples from different types of storage structures like mud bin/kachchi kothi, jute bag, pucci kothi and loose storage in rooms from eight villages of Udaipur district namely. Kherwada, Kagdar, Bedla, Loara, Sabina, Kewda ki nal, Khemli and Ghasa for maize samples and four villages of Banswara district namely, Borwat, Barodia, Karji and Chhichh for paddy samples. In addition to this some samples of paddy were also collected from the villages namely Fingeshwar, Biroda, Rajim, Kurud of Raipur district (M.P.).

Five houses were selected randomly from each village for each commodity. The samples were collected during June-July. The samples were drawn with the help of medium sized sampler from different layers (upper, middle and lower) of the storage structures. In each sample 500 g grains were collected and immediately sealed in polythene bags alongwith the detailed information on the condition of store, variety and type of storage structures. The moisture percentage of the maize and paddy grains were determined in the laboratory by using the "Digital moisture meter". The percentage of damage was recorded by counting the damaged seed out of 100 g grain taken randomly from the sample. It was replicated three times. Doubtful grains were dissected for confirmation of infestation. The germination test was carried out by placing 100 grains in the petri dishes with the wet blotting papers at the bottom. It was replicated three times for each samples and the number of germinated seeds were recorded.

STATISTICAL ANALYSIS :

The data obtained on various characters/parameters were subjected to analysis of variance technique applicable for complete randomized design and interpretation of the data was carried out in accordance with Gomez and Gomez (1984) and Panse and Sukhatme (1985). The level of significance used in 'F' test was P=0.05 where ever F calculated was significant, critical difference values were calculated for treatment comparisons, The values obtained on the adult population was subjected to square root transformation and the values obtained on per cent hatching, per cent adult survival per cent, per cent grain damage, per cent loss in grain weight, germination per cent and relative hardness were subjected to angular transformation according to the Table give by Snedecor and Cochran (1967).

The result of storage losses in different storage structures have been discussed on the basis of average losses.

RESULTS

I. BIO-ECOLOGICAL STUDIES :

Fecundity :

The data on the effect of temperature, relative humidity and interaction of both the factors on the fecundity of *S. cerealella* are presented in Table 8, 9 and 10. It is evident from the data that mean number of eggs laid by a single female on maize was maximum (174.30 eggs) at 30°C and followed at 25°C (172.72 eggs). However, no significant difference in egg laying was found at these temperatures. Low (20°C) and high (35°C) temperature reduced the fecundity of *S. cerealella*. The average number of eggs laid by a single female at 20°C and 35°C were 143.21 and 100.62, respectively.

The average number of eggs laid per female was found maximum (166.77) at 80 per cent relative humidity (Table 9) followed at 70 (159.40) and 60 per cent (144.09) relative humidity. Lower number of eggs (115.80) were laid at 50 per cent relative humidity.

The combined effect (interaction) of temperature and relative humidity revealed that most suitable combination for egg laying was 25°C and 80 per cent relative humidity on which maximum number of eggs (198.49/female) were laid. It was followed by the combination of 30°C and 70 per cent relative humidity, where 198.34 eggs were laid by a single female. Under the combined effect of 30°C and 80 per cent relative humidity 195.99 eggs/female were produced. (Table-10 and Fig. 1)

The data obtained on the effect of different temperature and humidity levels on the egg laying of *S. cerealella* infesting paddy are presented in Table 11, 12 and 13. The data revealed that the maximum number of eggs laid by a single female (90.22) was obtained at 30°C (Table 11) and lowest (37.47) at 35°C followed by 20°C (53.30).

The data obtained on the effect of different levels of relative humidity revealed that the most favourable relative humidity required for maximum egg laying was 80 per cent on which 79.49 eggs were laid by a single female (Table 12). At 50 per cent relative humidity lowest number of eggs (64.42) were recorded.

The combined effect of temperature and relative humidity has been depicted in Table 13 and Fig. 9. The data revealed that the combination of 25°C and 80 per cent relative humidity was optimum for the egg laying in the case of paddy, where 109.23 eggs were produced by a single female. It was followed by the combination of 30°C and 70 per cent relative humidity and 30°C and 80 per cent relative humidity, where the eggs laid by a single female were 99.99 and 96.24, respectively.

Incubation period :

The data obtained on the effect of temperature on incubation period revealed that the temperature at which faster development of eggs was observed in maize was 35°C. At this temperature the incubation period was found to be 4.06 days followed by 30°C, where the hatching took place in 4.10 days (Table 8). The maximum time of 12.88 days was recorded at 20°C followed by 5.52 days at 25°C.

The effect of relative humidity on incubation period showed that at 50 per cent relative humidity the eggs hatched in 7.53 days, whereas 6.00 days were taken at 80 per cent relative humidity. At 60 and 70 per cent relative humidity levels the incubation period was recorded as 6.82 and 6.53 days, respectively.

The data recorded on the combined effect of temperature and relative humidity depicted in Table-10 and Fig. 2. revealed that the shortest incubation period of 3.75 days was found at 30°C and 80 per cent relative humidity, whereas the longest duration of 15.00 days was recorded at 20°C under 50 per cent relative humidity.

In the case of paddy, the shortest incubation period of 3.86 days was recorded at 35°C and the longest of 11.31 days at 20°C (Table-11). At 25 and 30°C it was recorded 5.61 and 4.08 days, respectively.

The data obtained on the incubation period at different relative humidity levels are presented in Table-12. The data revealed that minimum time of 5.36 days was taken for hatching at 80 per cent relative humidity and maximum time of 7.33 days was observed at 50 per cent relative humidity. At 60 and 70 per cent relative humidity the incubation period was recorded as 6.40 and 5.77 days, respectively.

The combined effect of temperature and relative humidity showed that most favourable condition for incubation was 30°C and 80 per cent relative humidity where it took minimum period of 3.70 days for hatching (Table 13 and Fig. 10). The longest incubation period of 15.00 days was recorded at 20°C under 50 per cent relative humidity.

Hatching :

The data recorded on the individual and combined effect of the temperature and humidity on the hatching are presented in Table 8, 9 and 10. It is evident from the data that in maize maximum number of eggs hatched at 25°C. At this temperature the hatching percentage was recorded as 89.64, whereas, the hatching was 81.74 per cent at 30°C temperature. However, hatching percentage was reduced at 20°C and 35°C.

Maximum hatching was observed at 70 per cent relative humidity. However, no significant difference in hatching was noticed at 70 and 80 per cent relative humidity (Table-9).

Lower levels of relative humidity viz., 50 and 60 per cent resulted 65.07 and 75.82 per cent hatching of the eggs.

The combined effect of temperature and relative humidity revealed that in maize most favourable combination of these factors was 25°C and 80 per cent relative humidity, where 94.28 per cent hatching was observed. However, no significant difference in hatching was observed between 70 and 80 per cent relative humidity at 30°C. (Table-10 and Fig. 3)

Like maize in paddy also maximum hatching was recorded at 25°C, where 91.85 per cent eggs hatched, followed by 84.93 per cent at 30°C. At 20 and 35°C the hatching percentage of eggs was reduced (Table-11).

The effect of relative humidity on the hatching of eggs also showed similar trend as observed in maize. Maximum hatching was recorded at 70 per cent humidity followed by 80 per cent humidity (Table-12). Lower levels of relative humidity i.e 50 and 60 per cent resulted 64.42 and 77.89 per cent hatching, respectively.

The data obtained on the combined effect of temperature and relative humidity (Table-13 and Fig. 11) revelaed that like maize in paddy also most suitable combination for maximum hatching was provided by 25°C and 80 per cent relative humidity combination. The combination of 35°C and 80 per cent relative humidity affected the development of eggs adversely as only 42.99 per cent eggs could be hatched at this combination.

Larval period :

The larvel period of *S. cerealella* on maize varied with the temperature. At 30°C the larvae completed their development in 19.51 days. Rest of the temperature levels increased the larval period. Maximum duration of 23.90 days was recorded at 20°C.

The data obtained on the effect of relative humidity revealed that the, larvae took 20.11 days for completing their development at 80 per ent relative humidity (Table 9). At 50 per cent relative humidity, the larvae took maximum time (22.69 days) in completing their development. The larval period of 21.67 and 21.20 days was recorded at 60 and 70 per cent relative humidity, respectively.

The combined effect of both the factors revealed that larvae completed their development in 18.20 days at 30°C and 80 per cent relative humidity whereas the maximum larval period of 26.11 days was recorded at 20°C under 50 per cent relative humidity. (Table-10 and Fig. 4)

Similar to maize the shortest larval period of 13.53 days was observed at 30°C in paddy (Table-11). At 20°C the larval development was completed in 19.39 days.

The average larval period varied with different relative humidity levels (Table-12). At 80 per cent relative humidity the larvae took 16.25 days to complete their development, whereas the duration increased at 50 per cent relative humidity. The larval period did not differ significantly at 70 and 80 per cent relative humidity levels. At these levels the larvae completed their development in 16.52 and 16.25 days, respectively.

The combined effect of temperature and relative humidity levels on larval development are presented in Table 13 and Fig. 12. The result showed that minimum time taken by the larvae for the completion of their development was 12.30 days at 30°C and 80 per cent relative humidity, whereas it was found maximum of (20.50 days) at 20°C under 50 per cent relative humidity combination.

Pupal period :

The data obtained on the effect of temperature and humidity on the duration of pupal stage in maize are depicted in Table 8, 9 and 10. It is evident from the data that the pupae took minimum time of 6.50 days for their development at 30°C, whereas the pupal development was completed in 12.66 and 12.05 days at 20 and 35°C, respectively. (Table-8).

The data presented in Table-9 revealed that pupae took almost equal time to complete their development at 60, 70 and 80 per cent relative humidity levels. However, at 50 per cent relative humidity, the pupal period prolonged and the pupae completed their development in 11.40 days.

The interaction of temperature and relative humidity showed no significant difference in pupal period at 60, 70 and 80 per cent relative humidity levels at all temperature levels tested (Table 10). At 20°C and 50 per cent relative humidity the time required for completion of pupal period was recorded 14.60 days, whereas only 6.10 days were required to complete the pupal development at 30°C and 80 per cent relative humidity combination. (Table-10 and Fig. 5)

Similar to maize in **paddy** also shortest pupal period of 5.03 days was observed at 30°C, whereas at 20 and 35°C the pupal development was completed in 9.62 and 8.18 days, respectively (Table-11).

The effect of relative humidity on pupal development (Table-12), revealed that pupae took almost equal time to complete their development at 60, 70 and 80 per cent relative humidity levels. However, at 50 per cent relative humidity the pupal period prolonged and the puape completed their development in 8.62 days.

The combined effect of temperature and relative humidity showed no significant difference in pupal period at 60, 70 and 80 per cent relative humidity levels at all temperature levels tested (Table 13). At 20°C and 50 per cent relative humidity the time required for completion of pupal development was 10.90 days, whereas only 4.72 days were required to complete the pupal development at 30°C and 80 per cent relative humidity combination. (Table-13 and Fig. 13)

Longevity of adult :

The mean adult longivity of *S. cerealella* reared on maize as influeuced by temperature and humidity is depicted in Table 8, 9 and 10. The data revealed that at 20°C maximum longevity (11.78 days) of adults was recorded. The minimum longevity (3.94 days) was observed at 35°C (Table-8).

The observations recorded on the effect of relative humidity on the longevity of the adults indicated that the adults could survive up to 10.19 days at 70 per cent relative humidity followed by 9.76 days at 80 per cent relative humidity. However, no significant difference in adult longevity was observed at these two levels of relative humidity. Minimum adult longevity of 6.13 days was recorded at 50 per cent relative humidity (Table-9).

Regarding the combined effect of temprature and relative humidity on the longevity of adult, it was observed that at 25°C and 80 per cent relative humidity, the adults survived up to 15.25 days, whereas minimum longevity of 3.25

days was observed at 35°C and 50 per cent relative humidity combination. (Table-10 and Fig. 6)

Similarly in paddy the maximum adult longevity of 9.38 days was recorded at 20°C and minimum of 3.19 days at 35°C (Table-11).

The data on the effect of relative humidity on the longevity of adults depicted in Table-12 indicated that maximum longevity of adults (7.69 days) was noticed at 80 per cent relative humidity. However, no significant difference between 60, 70 and 80 per cent relative humidity levels was observed. Minimum longevity of adults (4.57 days) was recorded in 50 per cent relative humidity.

The combined effect of temperature and relative humidity is presented in Table 13 and Fig. 14. Maximum longevity of adults was recorded at 20°C and 70 per cent relative humidity on which adults survived for 12 days. The shortest longevity was observed at 35°C under 50 per cent relative humidity.

Survival of *S.cerealella* :

The maximum pest survival (41.35%) was recorded on maize at 30°C and minimum (5.14%) at 35°C (Table-8).

The data presented in Table-9 indicated that 80 per cent relative humidity was found to be most favourable for the survival of *S. cerealella*. At 50 per cent relative humidity only 15.28 per cent survival could be obtained.

The combined effect of temperature and relative humidity (Table-10 and Fig. 7) revelaed that 30°C and 80 per cent humidity combination resulted in maximum survival of the pest from eggs. The minimum (3.81%) survival was obtained at 35°C and 50 per cent relative humidity.

Like maize in paddy also the maximum pest survival (33.58%) was recorded at 30°C and minimum (4.43%) at 35°C (Table-11).

The data recorded on the effect of relative humidity on pest survival are presented in Table-12. It is evident from the data that 80 per cent humidity was found most favourable for the survival. At 50 per cent relative humidity only 12.36 per cent survival could be recorded.

The combined effect of temperature and relative humidity (Table-13 and Fig. 15) revealed that the combination of 30°C and 80 per cent relative humidity resulted in maximum survival, whereas it was minimum (3.00%) at 35°C under 50 per cent relative humidity.

Sex ratio :

The sex ratio of moths (M:F) obtained at different temperature and relative humidity levels and the interaction there-of in maize are presented in Table 8, 9 and 10. The data revealed that sex ratio was highest (1:1.37) at 30°C and lowest (1:0.97) at 20°C.

Maximum sex ratio (1:1.19) was obtained at 70 and 80 per cent relative humidity, whereas at 50 per cent relative humidity the minimum (1:1.12) sex ratio was observed. However, no significant difference among 60, 70 and 80 per cent relative humidity levels could be noticed.

The effect of both factors on sex ratio presented in Table 10 and Fig. 8 revealed that the sex ratio was maximum (1:1.40) at 30°C and 80 per cent relative humidity combination and minimum (1:0.95) at 20°C and 80 per cent relative humidity.

Similar to maize in paddy also the sex ratio was recorded maximum (1:1.40) at 30°C and minimum (1:0.96) at 20°C (Table-11).

The data depicted in Table-12 indicated that maximum sex ratio (1:1.19) was recorded at 70 per cent relative humidity, whereas the minimum (1:1.12) sex ratio was observed at 50 per cent relative humidity. However, no significant difference among 60, 70 and 80 per cent relative humidity levels could be noticed.

The combined effect of temperature and relative humidity on sex ratio showed that at 30°C and 80 per cent relative humidity, the sex ratio was maximum (1:1.45),

Table 8 : Effect of different temperature levels on the development of *S.cerealella* infesting maize.*

Temperature	Average number of eggs/female **	Incubation period (days)	Per cent hatching ***	Larval period (days)	Pupal period (days)	Longevity of adult (days)	Survival per cent (egg to adult)	Sex ratio (male:female)
20°C	143.21 (11.97)	12.88	68.91 (56.11)	23.90	12.66	11.78	16.73 (24.14)	1:0.97
25°C	172.72 (13.14)	5.52	89.64 (71.22)	20.04	9.05	10.13	39.73 (39.07)	1:1.16
30°C	174.30 (13.20)	4.10	81.74 (64.70)	19.51	6.50	9.63	41.35 (40.02)	1:1.37
35°C	100.62 (10.03)	4.06	54.66 (47.67)	22.22	12.05	3.94	5.14 (13.09)	1:1.18
S.Em.	0.0277	0.0240	0.3081	0.1209	0.0599	0.1821	0.1757	0.0171
C.D. at 5%	0.0788	0.2693	0.8760	0.3438	0.1703	0.5178	0.4996	0.0486
C.D. at 1%	0.1051	0.3568	1.1686	0.4587	0.2272	0.6907	0.6665	0.0649

Note - The temperature means are averaged over relative humidity in the range of 50 to 80 per cent

* Mean of four replications

** Figures in parentheses are square root transformed values.

*** Figures in parentheses are angular transformed values.

Table 9 : Effect of different relative humidity levels on the development of *S.cerealella* infesting maize.*

Relative humidity	Average** number of eggs/female	Incubation period (days)	Per cent*** hatching	Larval period (days)	Pupal period (days)	Longevity of adult (days)	Survival per cent (egg to adult)	Sex ratio (male:female)
50 %	115.80 (10.76)	7.53	65.07 (53.77)	22.69	11.40	6.13	15.28 (23.00)	1:1.12
60 %	144.09 (12.00)	6.82	75.82 (60.55)	21.67	9.76	9.39	23.12 (28.74)	1:1.17
70 %	159.40 (12.63)	6.53	79.35 (62.97)	21.20	9.63	10.19	27.21 (31.44)	1:1.19
80 %	166.77 (12.91)	6.00	78.56 (62.41)	20.11	9.46	9.76	29.88 (33.13)	1:1.19
S.Em.	0.0277	0.0940	0.3081	0.1209	0.0599	0.1821	0.1757	0.0171
C.D. at 5%	0.0788	0.2673	0.8760	0.3438	0.1703	0.5178	0.4996	0.0486
C.D. at 1%	0.1051	0.3566	1.1686	0.4587	0.2272	0.6907	0.6665	0.0649

Note - The relative humidity means are averaged over temperature in the range of 20 to 35°C

* Mean of four replications

** Figures in parentheses are square root transformed values.

*** Figures in parentheses are angular transformed values.

Table 10 : Combined effect of different levels of temperature and relative humidity on the development of *S. cerealalla* infesting **maize**.

Temperature	Relative humidity	Average** number of eggs/female	Incubation period (days)	Per cent*** hatching	Larval period (days)	Pupal period (days)	Longevity of adult (days)	Survival per cent (egg to adult)	Sex ratio (male:female)
20°C	50%	125.73 (11.21)	15.00	53.25 (46.87)	26.11	14.60	8.50	13.20 (21.30)	1:1.01
	60%	139.23 (11.80)	13.00	65.78 (54.20)	24.20	12.15	15.30	15.50 (23.18)	1:0.96
	70%	148.75 (12.20)	12.25	77.01 (61.35)	23.30	12.05	13.78	18.55 (25.51)	1:0.96
	80%	160.25 (12.66)	11.25	78.00 (62.03)	22.00	11.85	9.55	19.99 (26.56)	1:0.95
25°C	50%	132.74 (11.52)	6.50	81.25 (64.35)	21.50	10.20	5.50	23.25 (28.83)	1:1.02
	60%	171.74 (13.10)	6.33	91.01 (72.56)	20.10	8.80	8.50	43.00 (40.98)	1:1.15
	70%	187.75 (13.70)	4.75	90.27 (71.82)	19.71	8.70	11.25	43.88 (41.49)	1:1.18
	80%	198.49 (14.09)	4.50	94.28 (76.16)	18.85	8.50	15.25	50.00 (45.00)	1:1.30
30°C	50%	134.73 (11.61)	4.38	73.27 (58.87)	20.15	7.20	7.25	26.00 (30.66)	1:1.35
	60%	171.24 (13.09)	4.25	83.04 (65.68)	19.98	6.40	9.75	38.25 (38.20)	1:1.35
	70%	198.34 (14.08)	4.00	85.00 (67.22)	19.70	6.30	11.50	50.75 (45.43)	1:1.38
	80%	195.99 (13.99)	3.75	84.78 (67.04)	18.20	6.10	10.00	51.38 (45.79)	1:1.40
35°C	50%	75.73 (8.70)	4.25	50.00 (45.00)	23.00	13.60	3.25	3.81 (11.26)	1:1.10
	60%	100.50 (10.20)	4.13	58.25 (49.75)	22.40	11.70	4.00	4.75 (12.59)	1:1.30
	70%	109.99 (10.49)	4.00	61.26 (51.51)	22.09	11.50	4.25	5.32 (13.34)	1:1.15
	80%	118.99 (10.90)	3.88	48.99 (44.42)	21.40	11.40	4.25	6.86 (15.19)	1:1.20
S.Em.		0.0554	0.1880	0.6162	0.2418	0.1198	0.3642	0.3514	0.0342
C.D. at 5 %		0.1576	0.5346	1.7520	0.6877	0.3406	1.0356	0.9992	0.0973
C.D. at 1 %		0.2103	0.7132	2.3372	0.9174	0.4544	1.3815	1.3329	0.1298

* Mean of four replications

** Figures in parentheses are square root transformed values.

*** Figures in parentheses are angular transformed values.

Fig.1 : Combined effect of different levels of temp. and rh on the fecundity of *S.cerealella* infesting maize

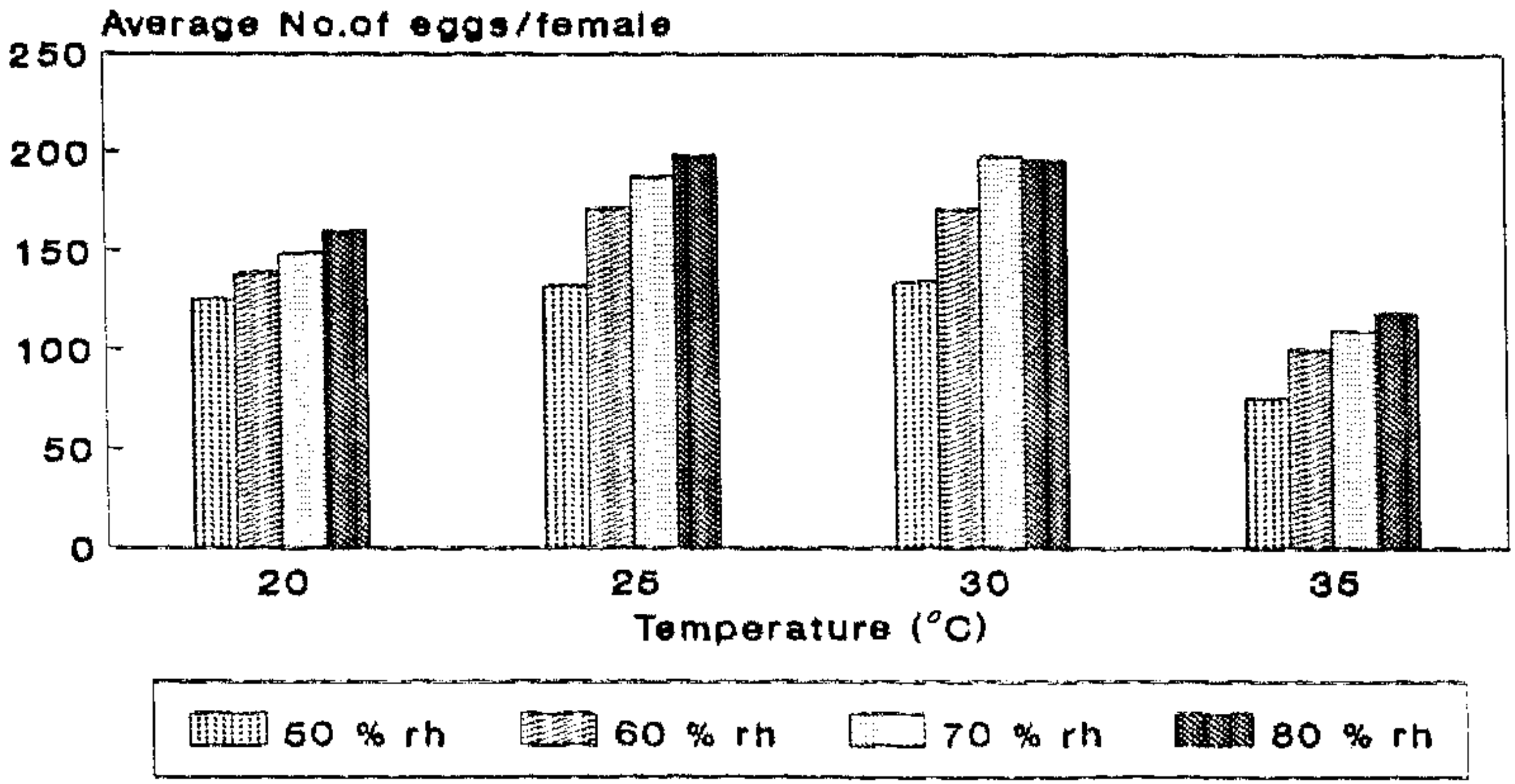


Fig.2 : Combined effect of different levels of temp. and rh on the incubation period of *S.cerealella* infesting maize

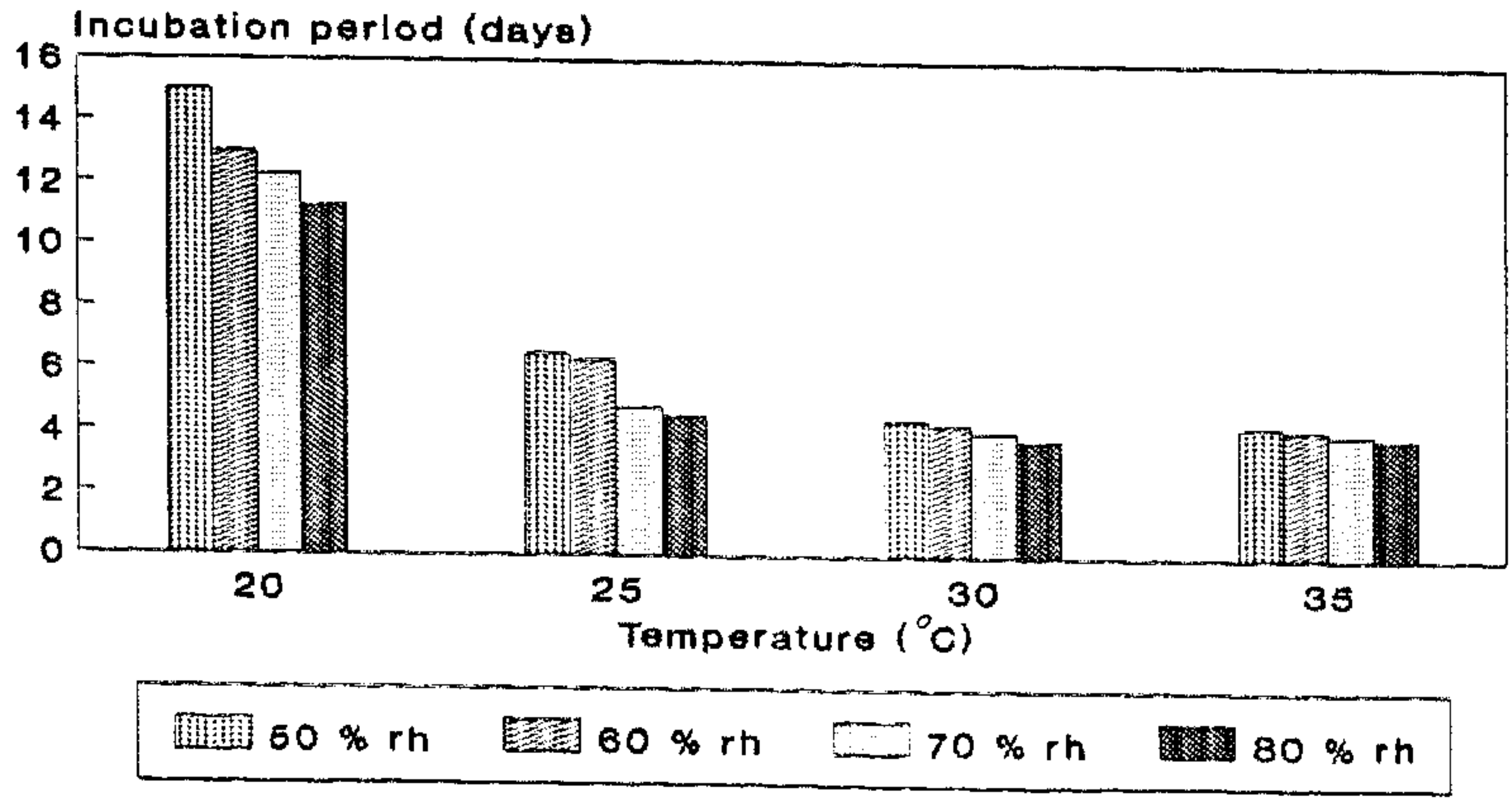


Fig.3 : Combined effect of different levels of temp. and rh on the hatching of *S.cerealella* infesting maize

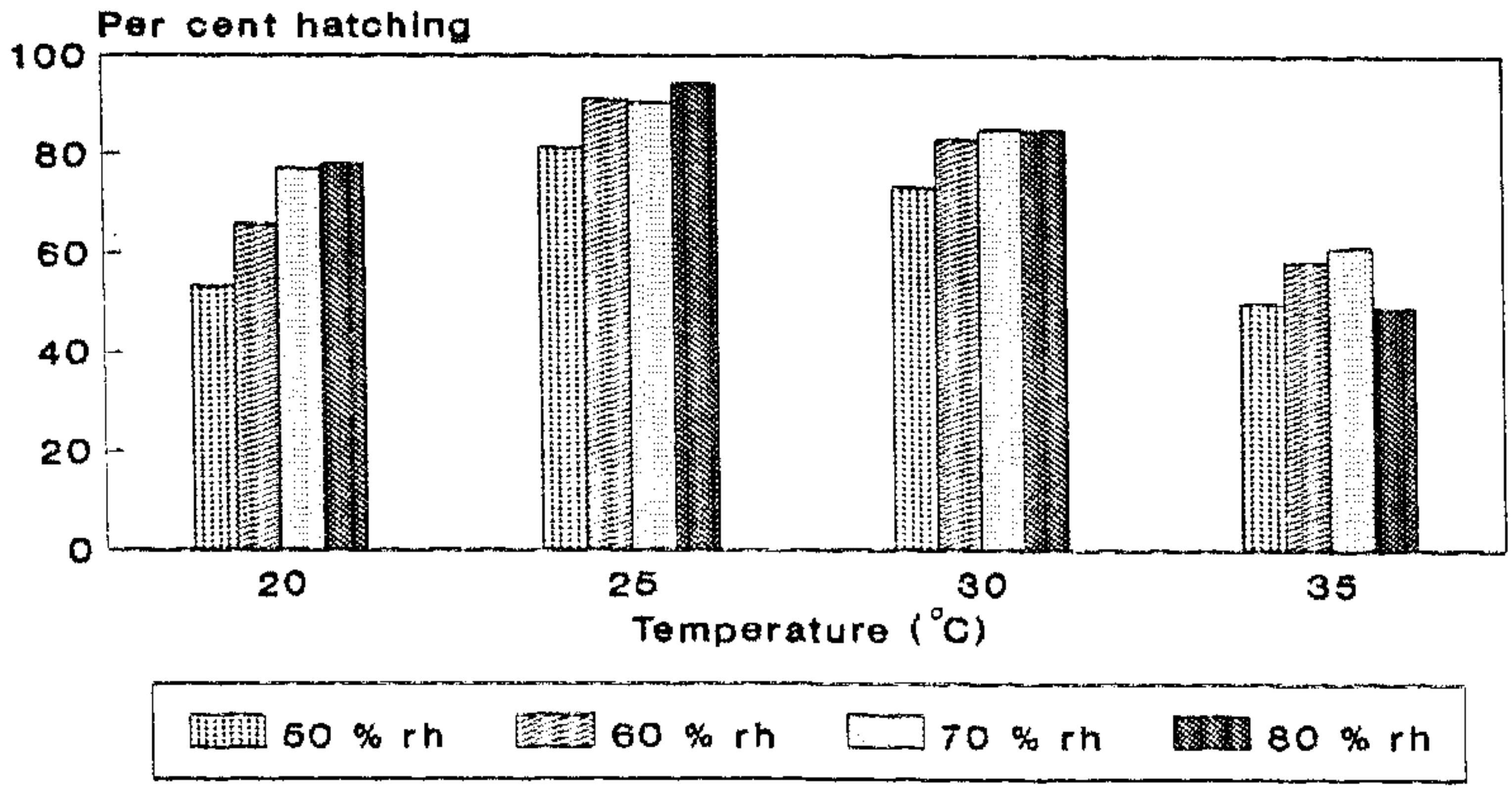


Fig.4 : Combined effect of different levels of temp. and rh on the larval period of *S.cerealella* infesting maize

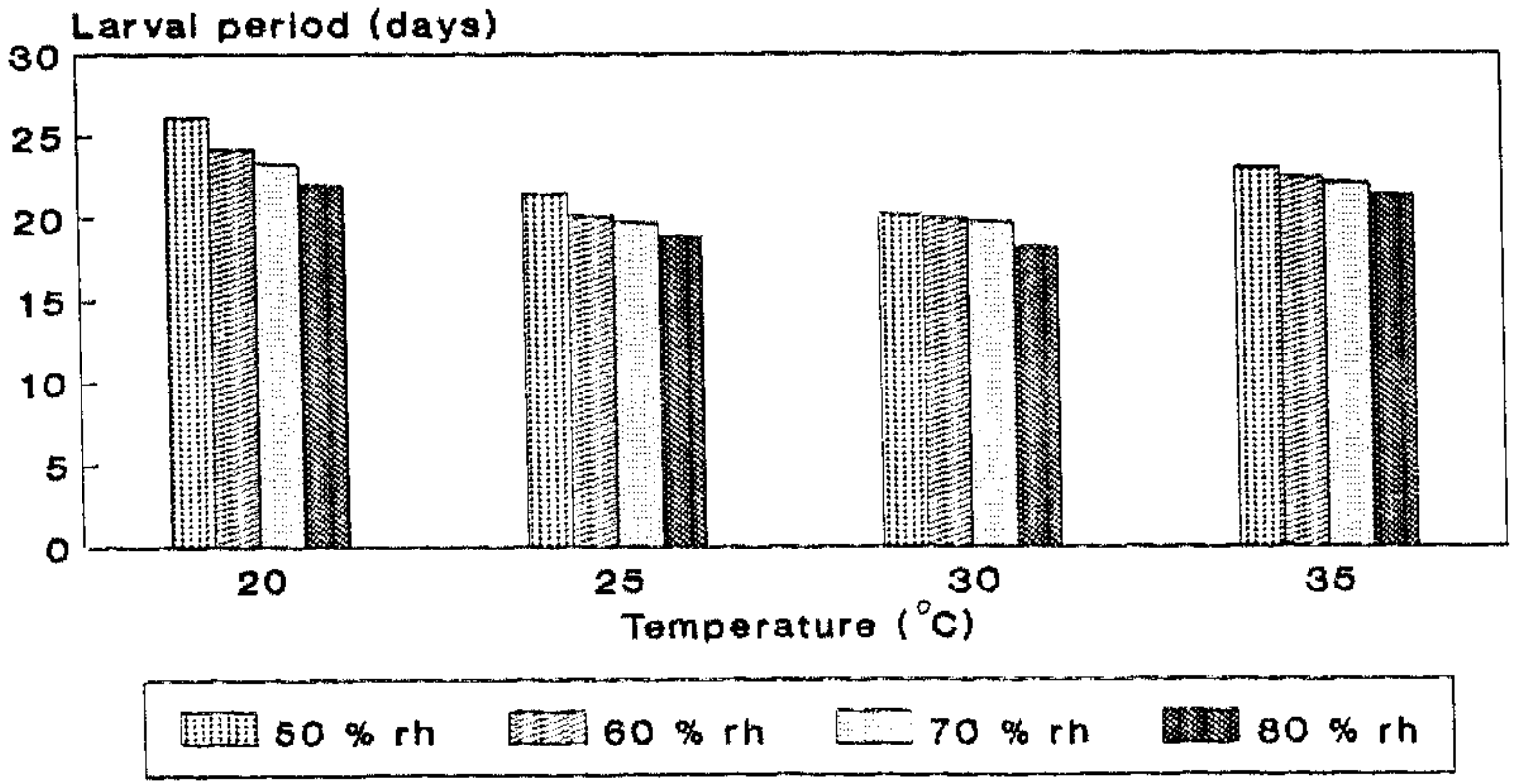


Fig.5 : Combined effect of different levels of temp. and rh on the pupal period of *S.cerealella* infesting maize

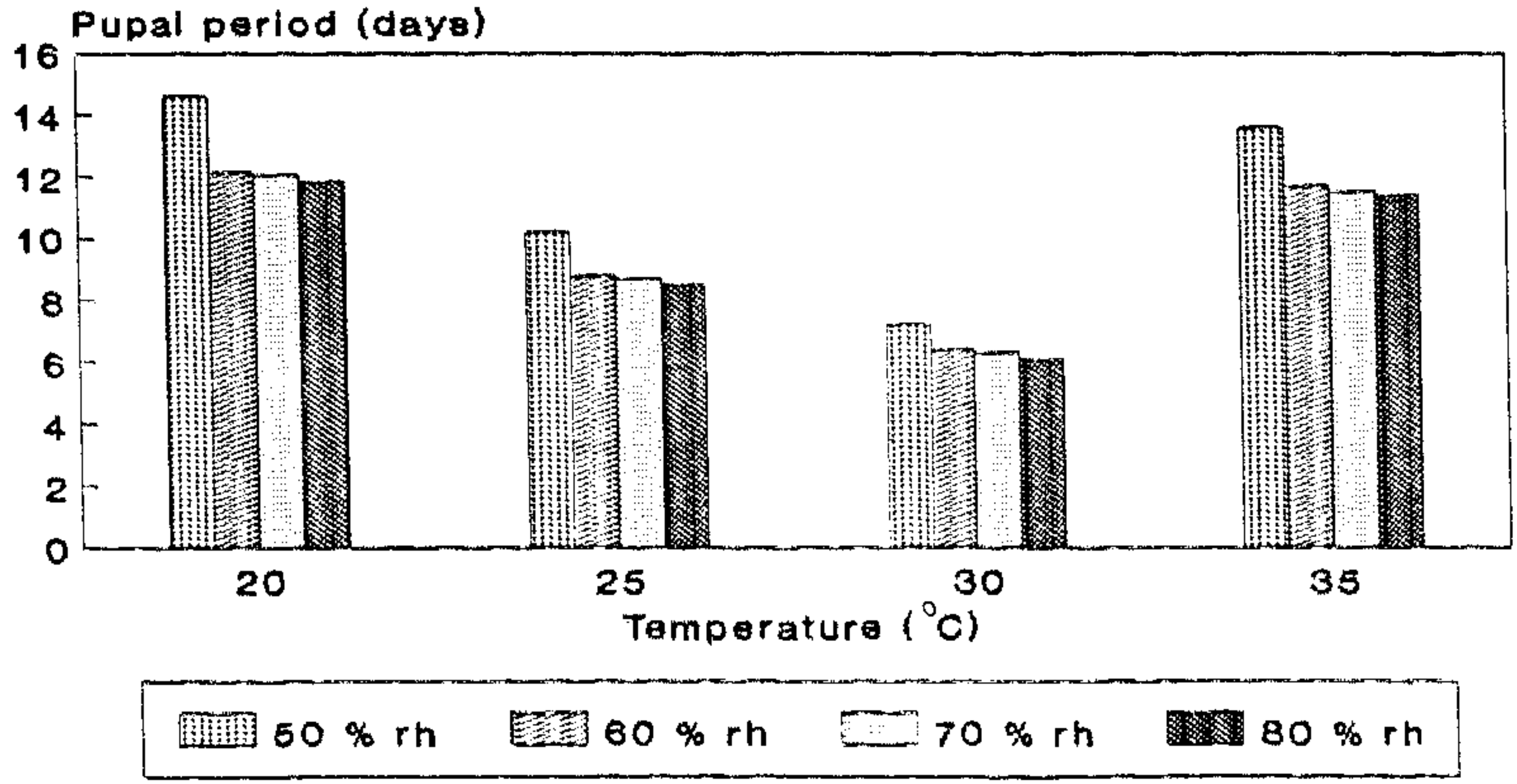


Fig.6 : Combined effect of different levels of temp. and rh on longevity of adults of *S.cerealella* infesting maize

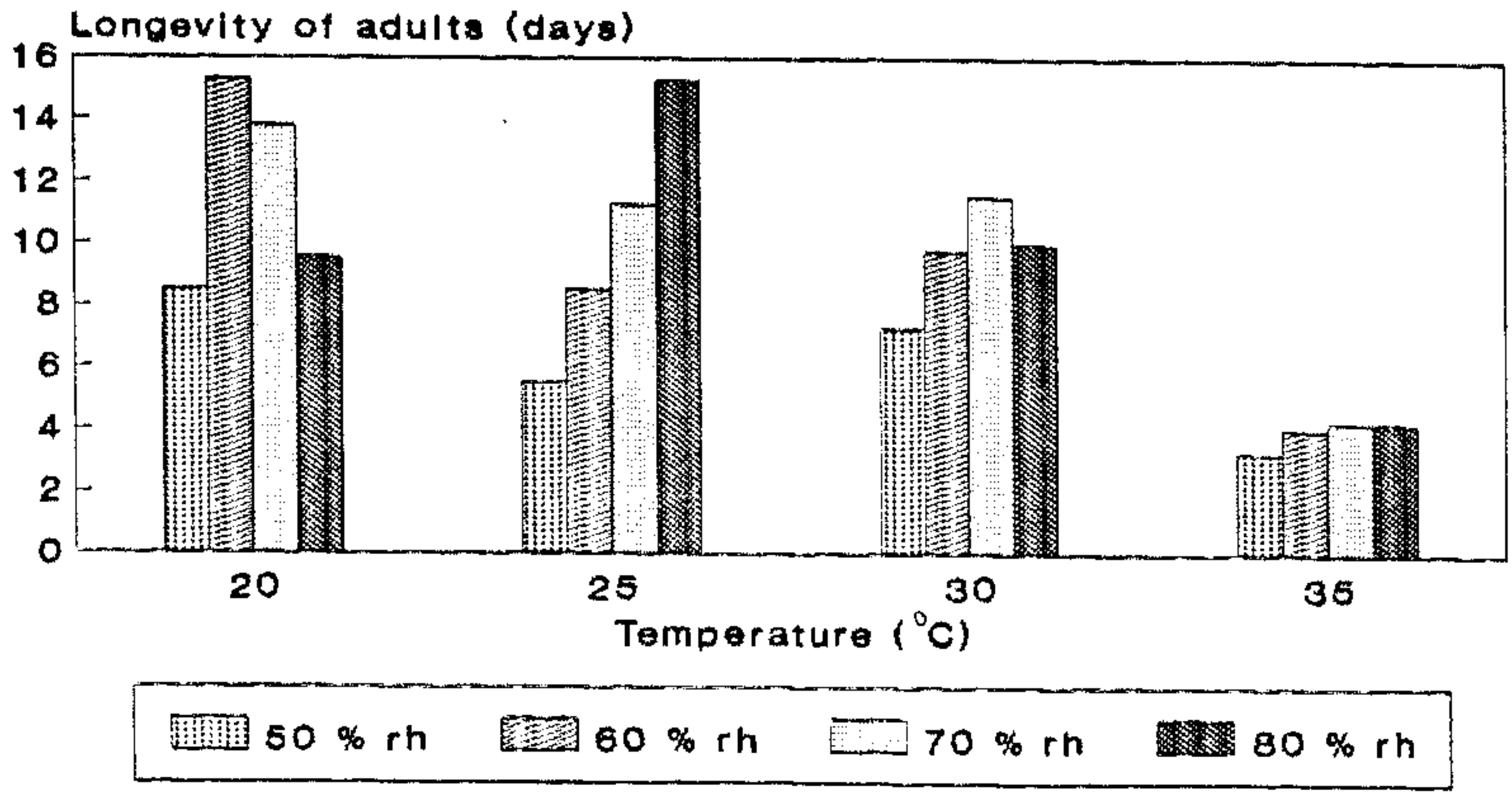


Fig.7 : Combined effect of different levels of temp. and rh on the survival of *S.cerealella* infesting maize

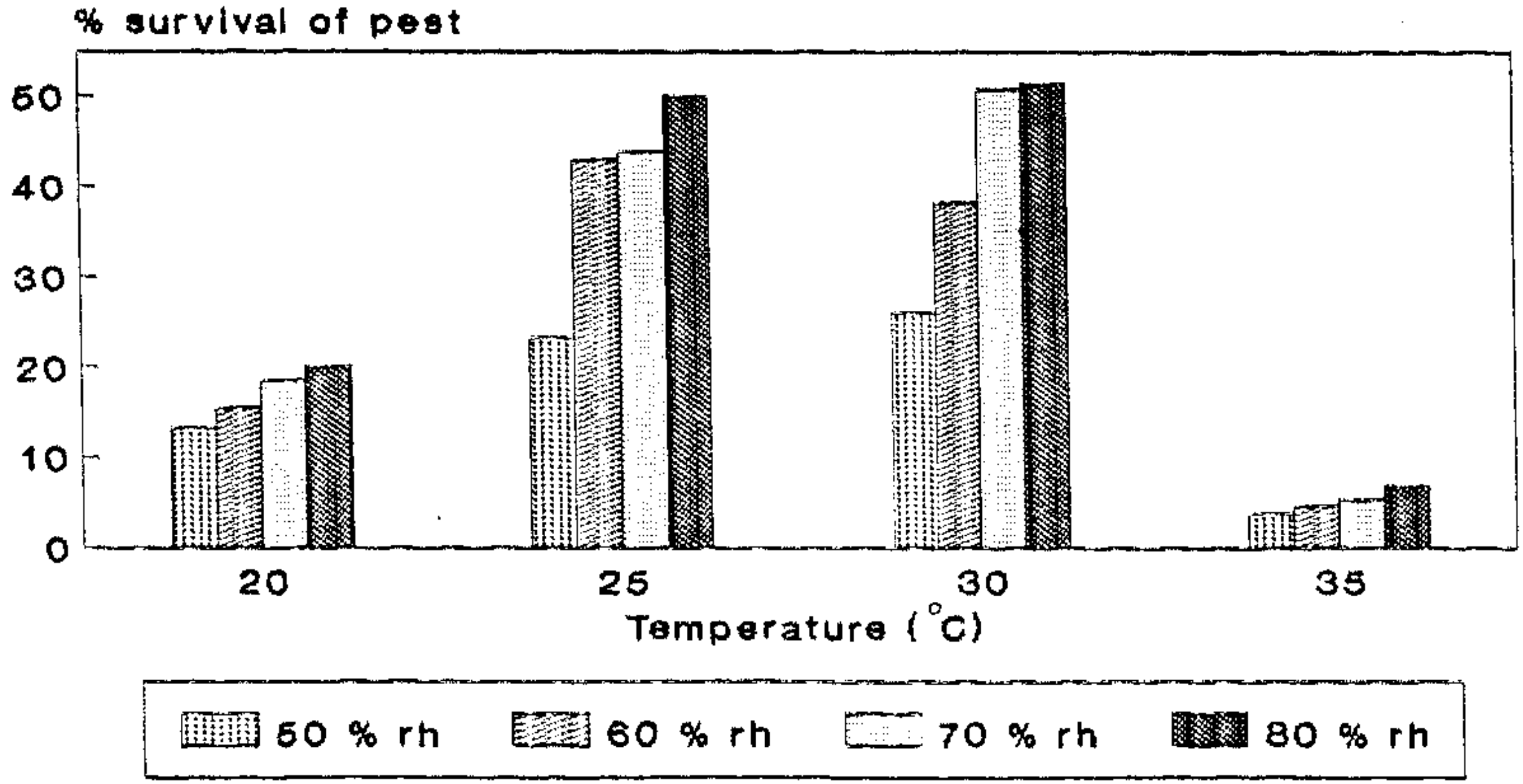


Fig.8 : Combined effect of different levels of temp. and rh on the sex ratio of *S.cerealella* infesting maize

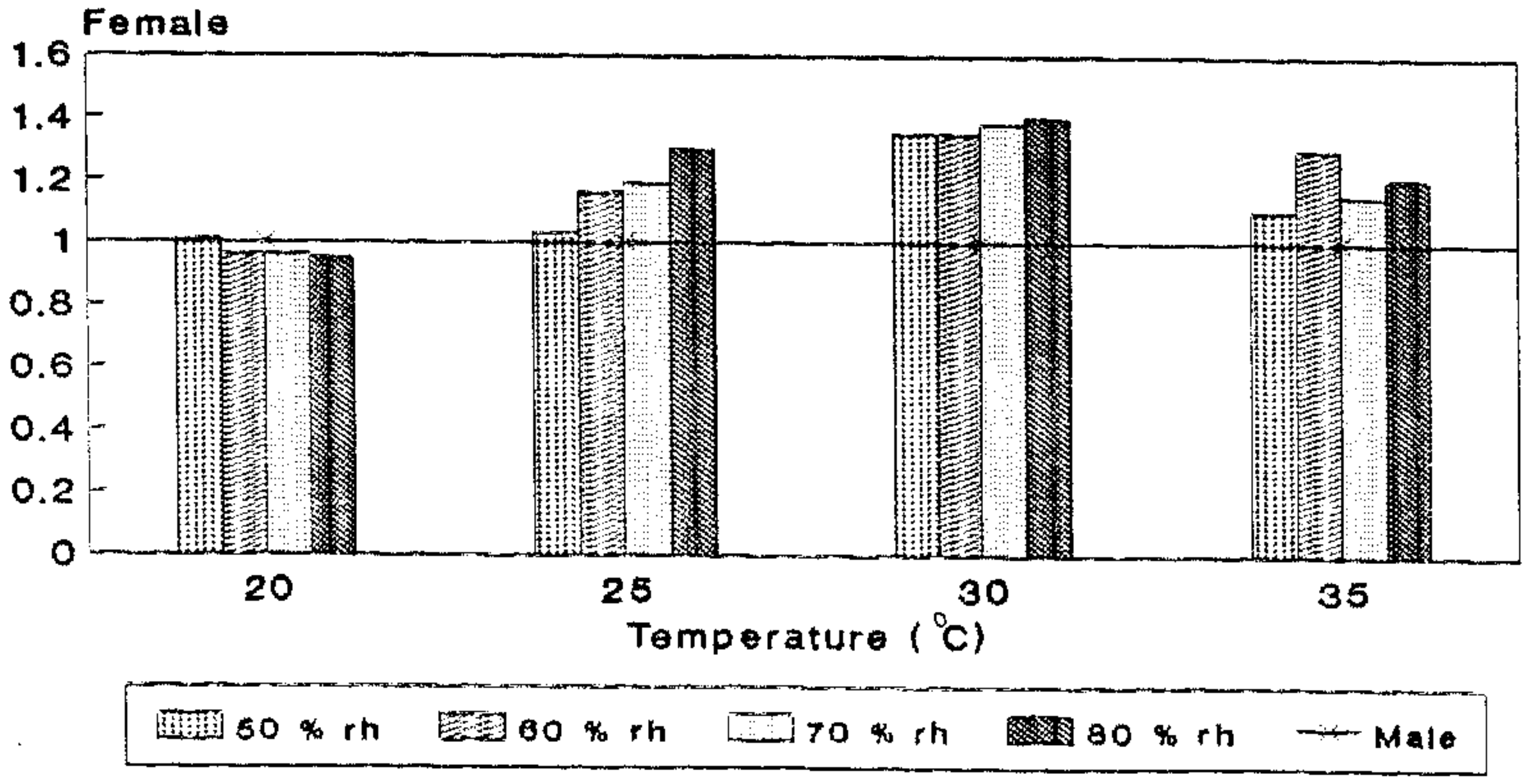


Table 11 : Effect of different temperature levels on the development of *S. cerealalla* infesting paddy*

Temperature	Average** number of eggs/female	Incubation period (days)	Per cent*** hatching	Larval period (days)	Pupal period (days)	Longevity of adult (days)	Survival per cent (egg to adult)	Sex ratio (male:female)
20°C	53.30 (7.30)	11.31	68.16 (55.65)	19.39	9.62	9.38	13.89 (21.88)	1:0.96
25°C	78.72 (8.87)	5.61	91.85 (73.42)	17.00	7.38	7.19	31.93 (34.40)	1:1.20
30°C	90.22 (9.50)	4.08	84.93 (67.16)	13.53	5.03	7.69	33.58 (35.40)	1:1.40
35°C	37.47 (6.12)	3.86	51.95 (46.12)	18.88	8.18	3.19	4.43 (12.16)	1:1.25
S.Em.	0.0290	0.0960	0.2290	0.1553	0.0570	0.1935	0.1664	0.0189
C.D. at 5 %	0.0824	0.2729	0.6511	0.4415	0.1622	0.5501	0.4730	0.0539
C.D. at 1 %	0.1099	0.3640	0.8686	0.5890	0.2164	0.7339	0.6310	0.0718

Note : The temperature means are averaged over relative humidity in the range of 50 to 80 per cent.

* Mean of four replications

** Figures in parentheses are square root transformed values.

*** Figures in parentheses are angular transformed values.

Table 12 : Effect of different relative humidity levels on the development of *S. cerealalla* infesting paddy*

Relative humidity	Average** number of eggs/female	Incubation period (days)	Per cent*** hatching	Larval period (days)	Pupal period (days)	Longevity of adult (days)	Survival per cent (egg to adult)	Sex ratio (male:female)
50 %	45.41 (6.74)	7.33	64.42 (53.38)	18.40	8.62	4.57	12.36 (20.59)	1:1.12
60 %	60.31 (7.71)	6.40	77.89 (61.95)	17.62	7.40	7.63	19.11 (25.92)	1:1.17
70 %	70.10 (8.37)	5.77	80.98 (64.15)	16.52	7.17	7.56	21.95 (27.94)	1:1.19
80 %	79.49 (8.92)	5.36	79.19 (62.86)	16.25	7.02	7.69	25.73 (30.50)	1:1.18
S.Em.	0.0290	0.0960	0.2290	0.1553	0.0570	0.1935	0.1664	0.0189
C.D. at 5%	0.0824	0.2729	0.6511	0.4415	0.1622	0.5501	0.4730	0.0539
C.D. at 1%	0.1099	0.3640	0.8686	0.5890	0.2164	0.7339	0.6310	0.0718

Note : The relative humidity means are averaged over temperature in the range of 20 to 35°C

* Mean of four replications

** Figures in parentheses are square root transformed values.

*** Figures in parentheses are angular transformed values.

Table 13 : Combined effect of different levels of temperature and relative humidity on the development of *S. cerealalla* infesting paddy*

Temperature	Relative humidity	Average** number of eggs/female	Incubation period (days)	Per cent*** hatching	Larval period (days)	Pupal period (days)	Longevity of adult (days)	Survival per cent (egg to adult)	Sex ratio (male:female)
20°C	50 %	34.74 (5.89)	15.00	50.25 (45.14)	20.50	10.90	4.75	8.99 (17.45)	1:1.01
	60 %	50.99 (7.14)	11.50	71.51 (57.74)	19.38	9.50	11.25	12.44 (20.65)	1:1.00
	70 %	59.49 (7.71)	9.75	73.25 (58.85)	18.88	9.18	12.00	16.35 (23.77)	1:0.92
	80 %	71.49 (8.45)	9.00	76.26 (60.84)	18.80	8.90	9.50	18.74 (25.65)	1:0.90
25°C	50 %	50.99 (7.14)	6.00	80.50 (63.79)	18.10	8.12	5.00	20.06 (26.61)	1:1.10
	60 %	70.99 (8.43)	5.99	92.26 (73.85)	17.80	7.30	7.00	31.94 (34.41)	1:1.15
	70 %	89.74 (9.47)	5.44	95.31 (77.50)	16.20	7.10	7.75	37.81 (37.94)	1:1.25
	80 %	109.23 (10.45)	5.00	96.03 (78.50)	15.90	7.00	9.00	39.00 (38.68)	1:1.30
30°C	50 %	72.49 (8.51)	4.30	75.25 (60.16)	15.00	5.50	5.75	22.50 (28.31)	1:1.33
	60 %	93.49 (9.67)	4.20	85.50 (67.62)	14.30	5.10	9.25	36.37 (37.09)	1:1.40
	70 %	99.99 (9.99)	4.10	88.01 (69.75)	12.50	4.80	7.25	37.12 (37.54)	1:1.40
	80 %	96.24 (9.81)	3.70	89.51 (71.10)	12.30	4.72	8.50	39.06 (38.64)	1:1.45
35°C	50 %	29.23 (5.40)	4.00	48.99 (44.42)	20.00	9.97	2.75	3.00 (9.97)	1:1.05
	60 %	33.99 (5.83)	3.30	56.25 (48.59)	19.01	7.70	3.00	4.00 (11.53)	1:1.15
	70 %	39.75 (6.30)	3.80	59.50 (50.47)	18.50	7.60	3.25	4.69 (12.50)	1:1.20
	80 %	48.23 (6.95)	3.75	42.99 (40.97)	18.00	7.45	3.75	6.37 (14.62)	1:1.10
S.Em.		0.0579	0.1919	0.4580	0.3106	0.1141	0.3870	0.3327	0.0379
C.D. at 5%		0.1648	0.5458	1.3022	0.8830	0.3244	1.1003	0.9461	0.1077
C.D. at 1%		0.2198	0.7281	1.7372	1.1780	0.4328	1.4678	1.2621	0.1437

* Mean of four replications

** Figures in parentheses are square root transformed values.

*** Figures in parentheses are angular transformed values.

Fig.9 : Combined effect of different levels of temp. and rh on the fecundity of *S.cerealella*(Olivier) infesting paddy

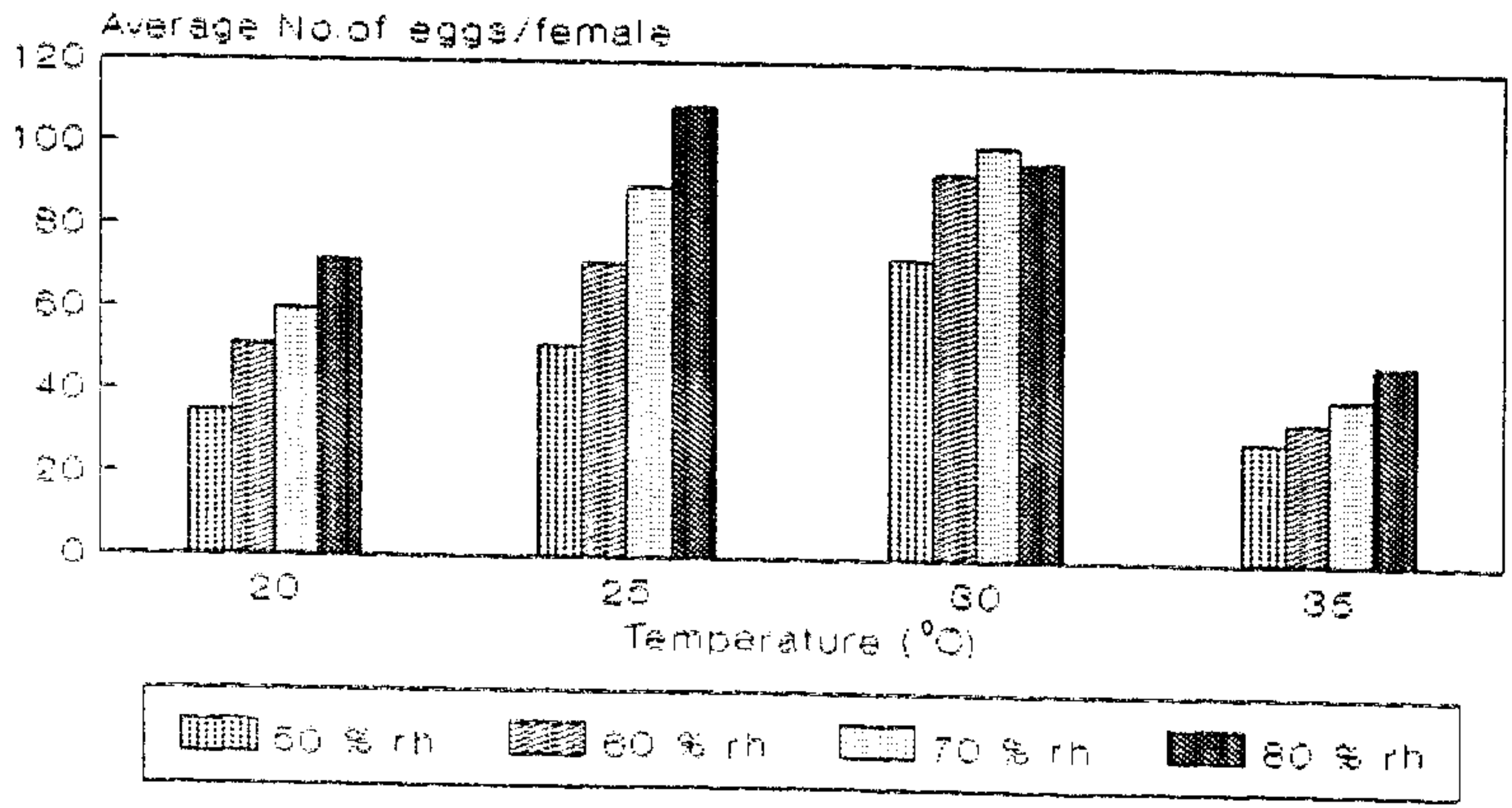


Fig.10 : Combined effect of different levels of temp. and rh on the incubation period of S.cerealella infesting paddy

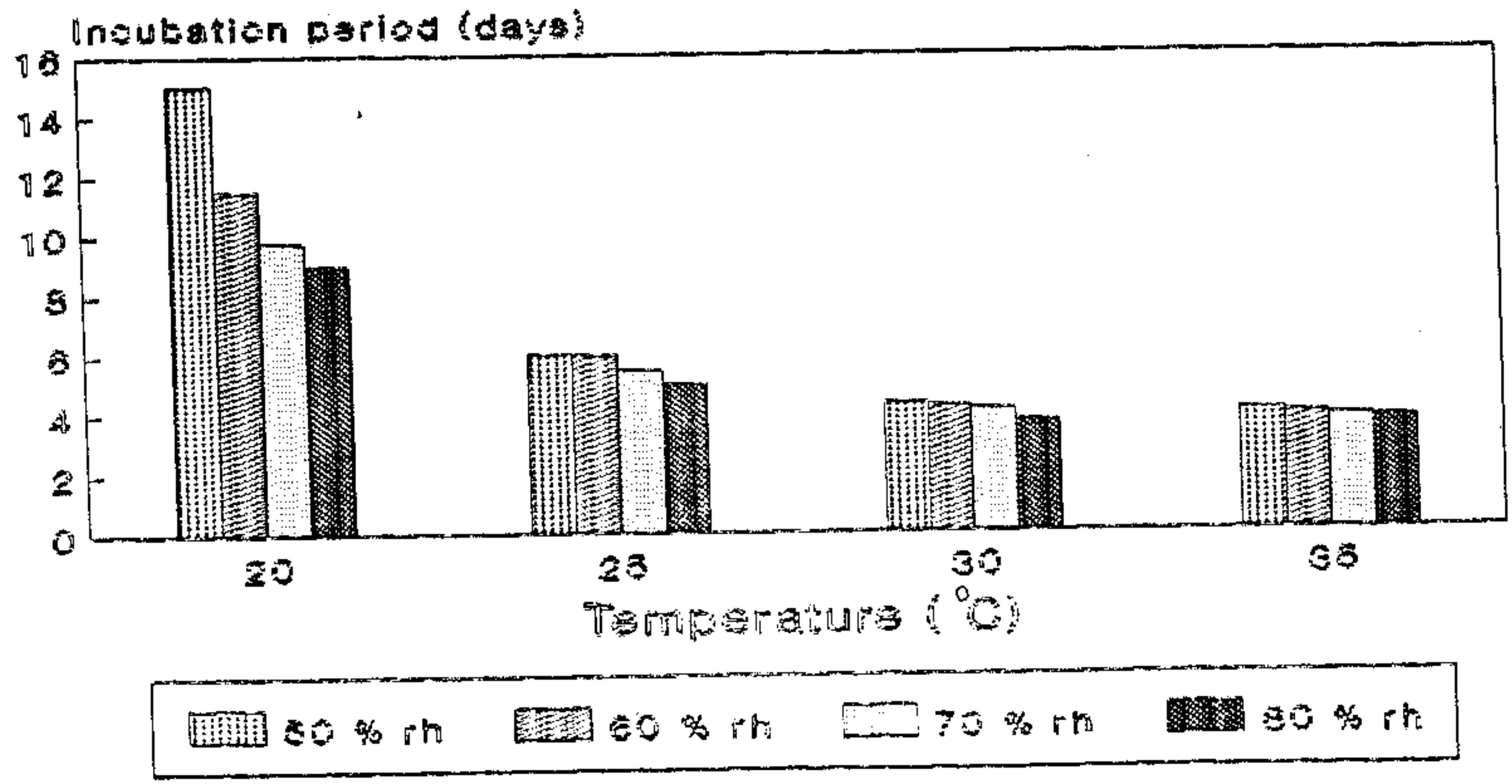


Fig.11 : Combined effect of different levels of temp. and rh on the hatching of S.cerealella infesting paddy

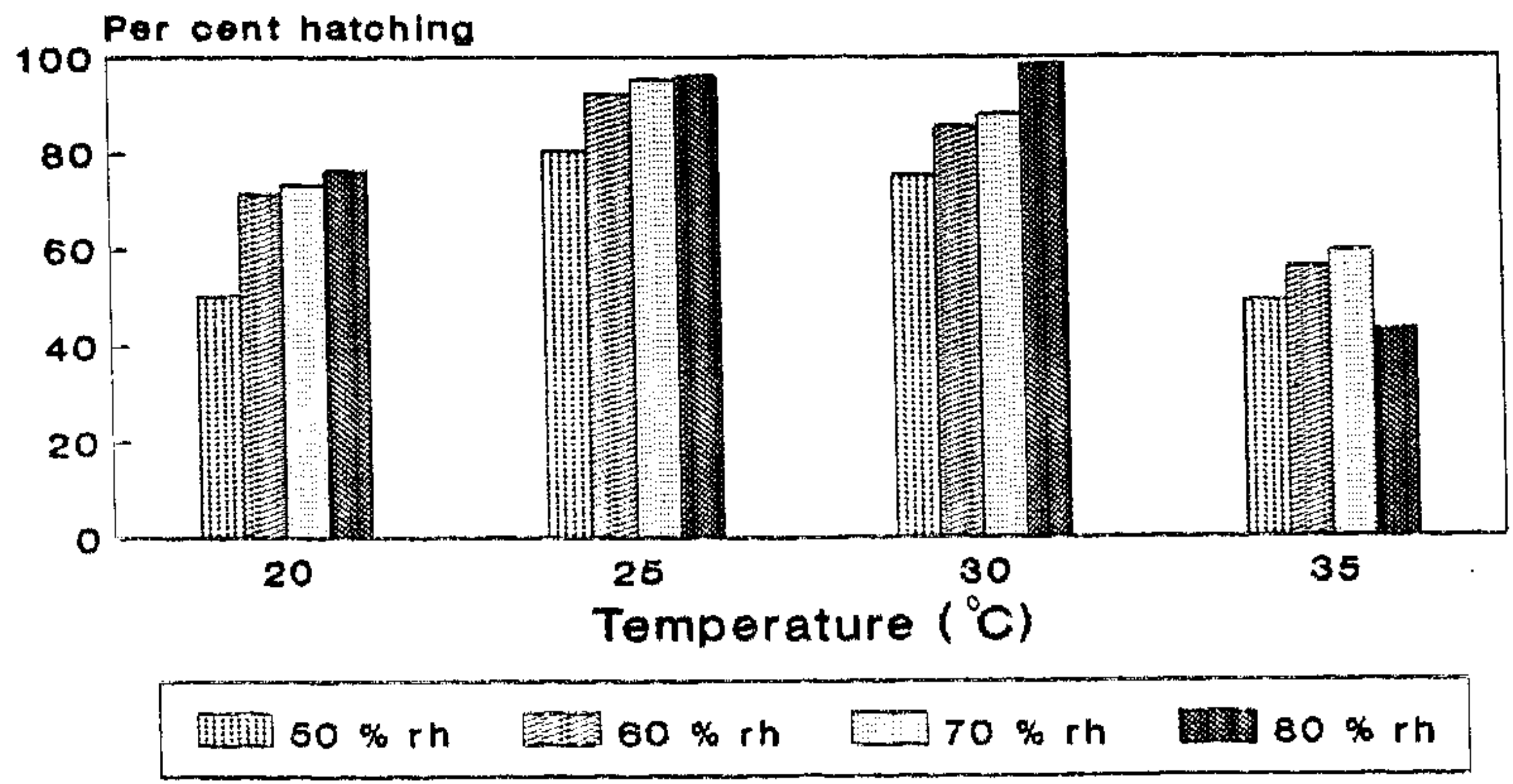


Fig.12 : Combined effect of different levels of temp. and rh on the larval period of *S.cerealella* infesting paddy

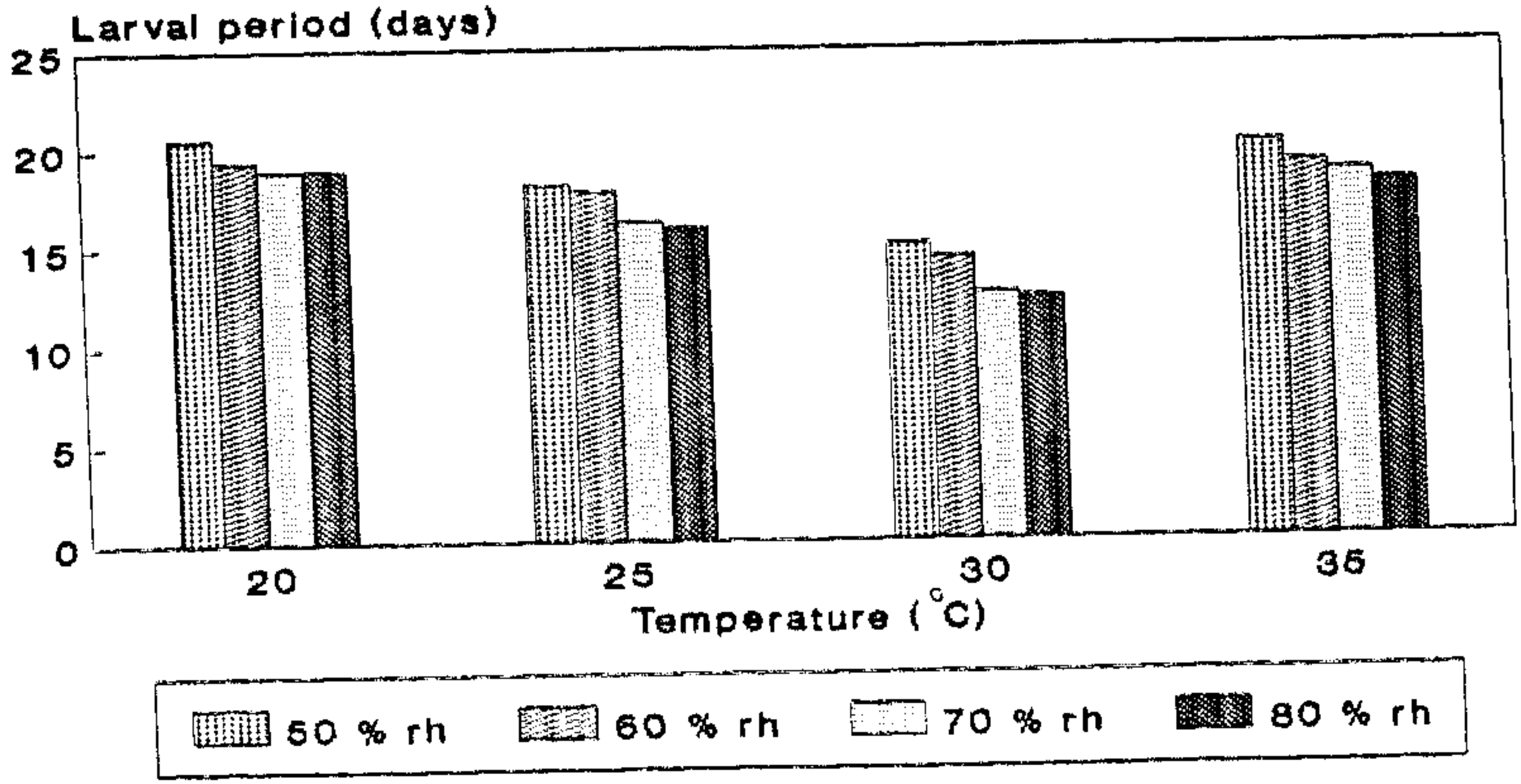


Fig.13 : Combined effect of different levels of temp. and rh on the pupal period of *S.cerealella* infesting paddy.

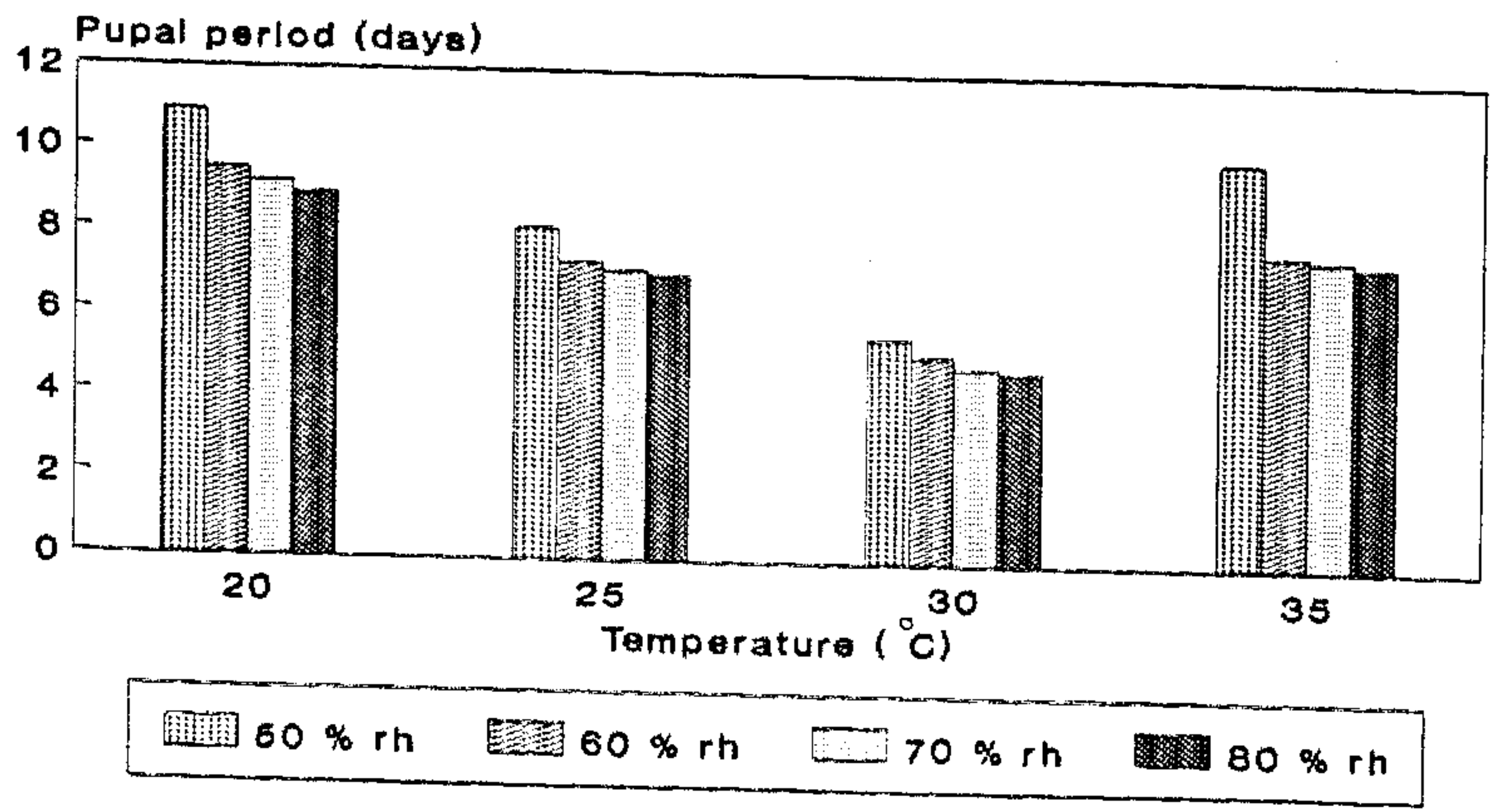


Fig.14 : Combined effect of different levels of temp. and rh on longevity of adults of *S.cerealella* infesting paddy

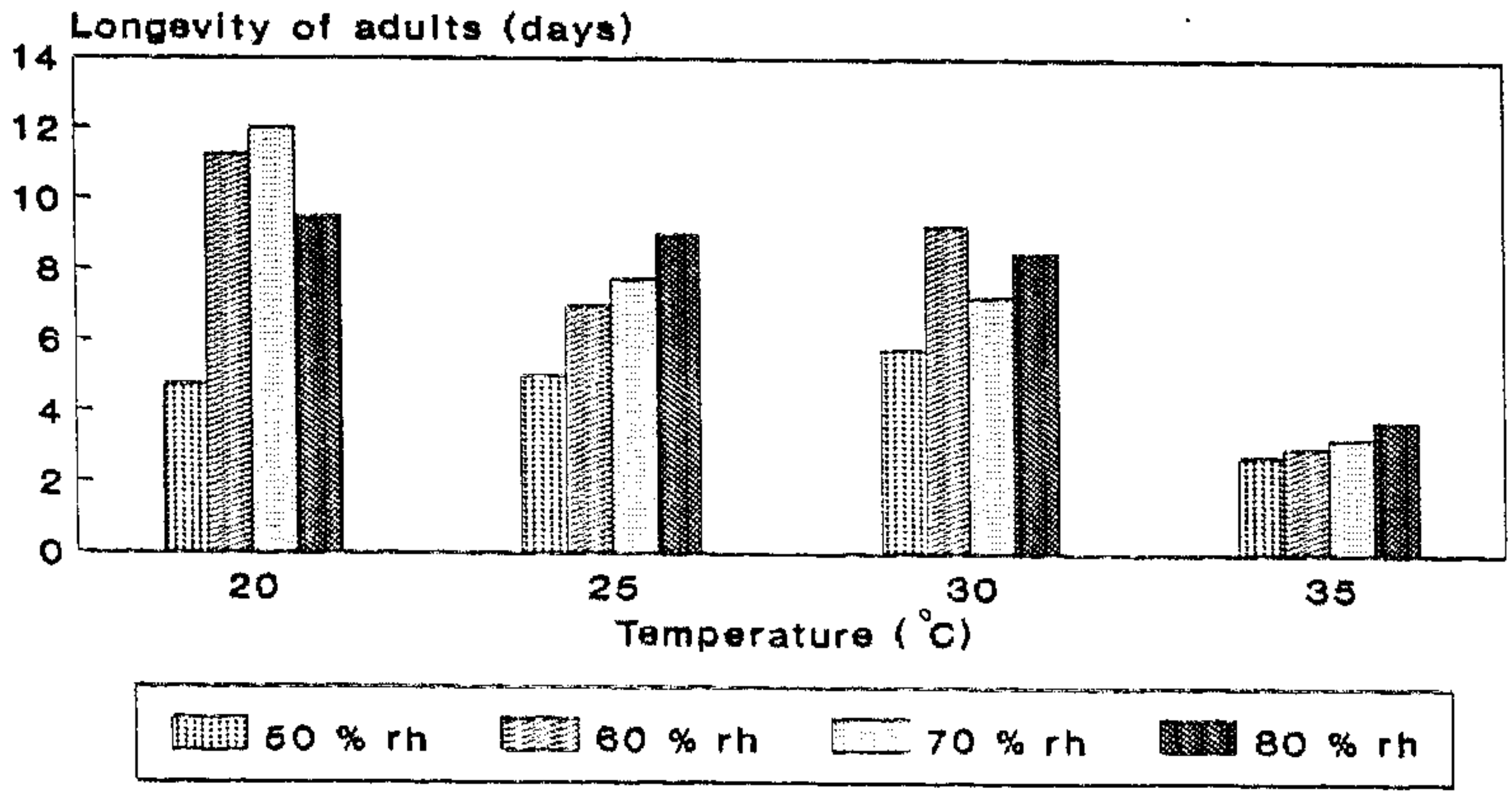


Fig.15 : Combined effect of different levels of temp. and rh on the survival of S.cere*alella infes*ting paddy

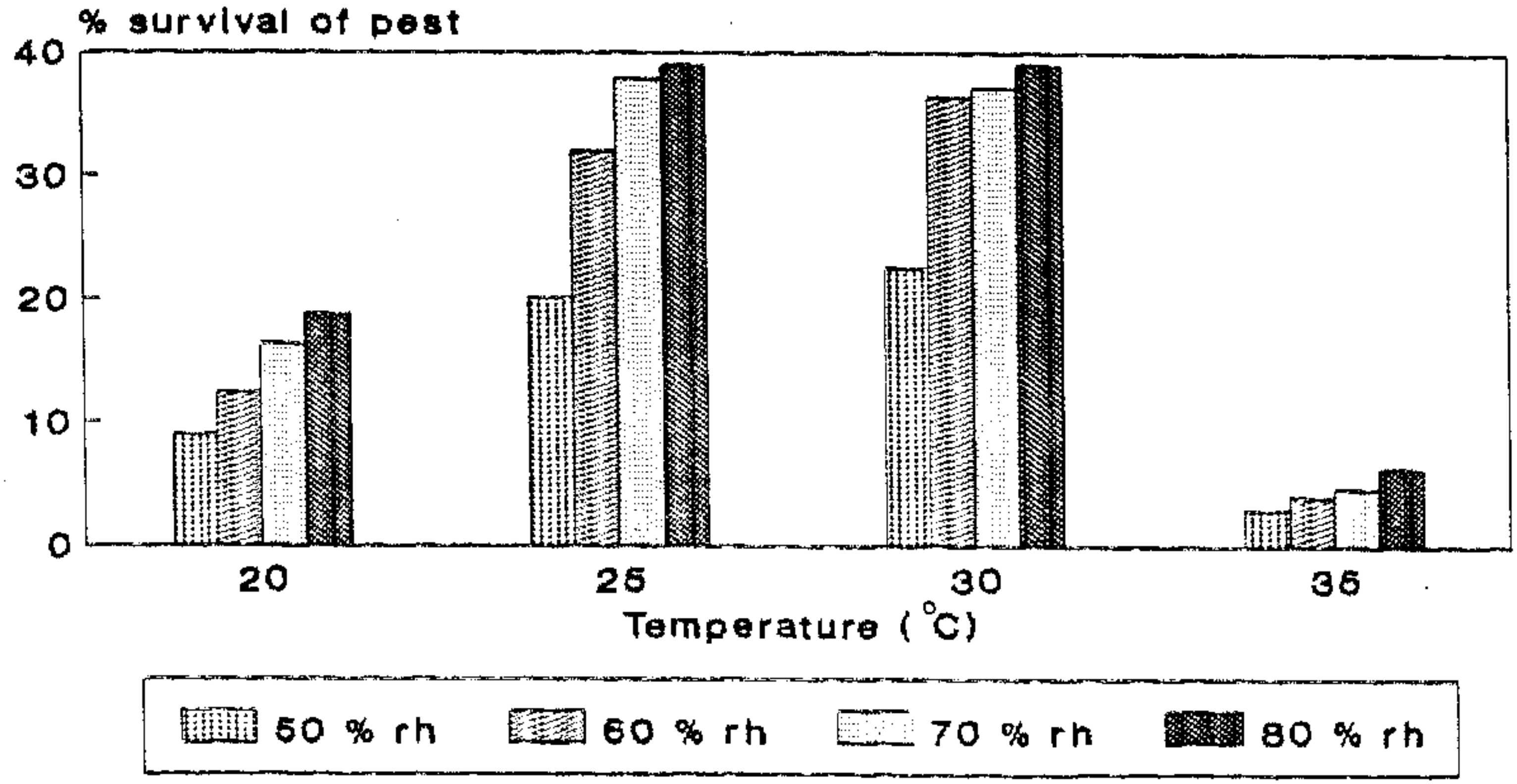
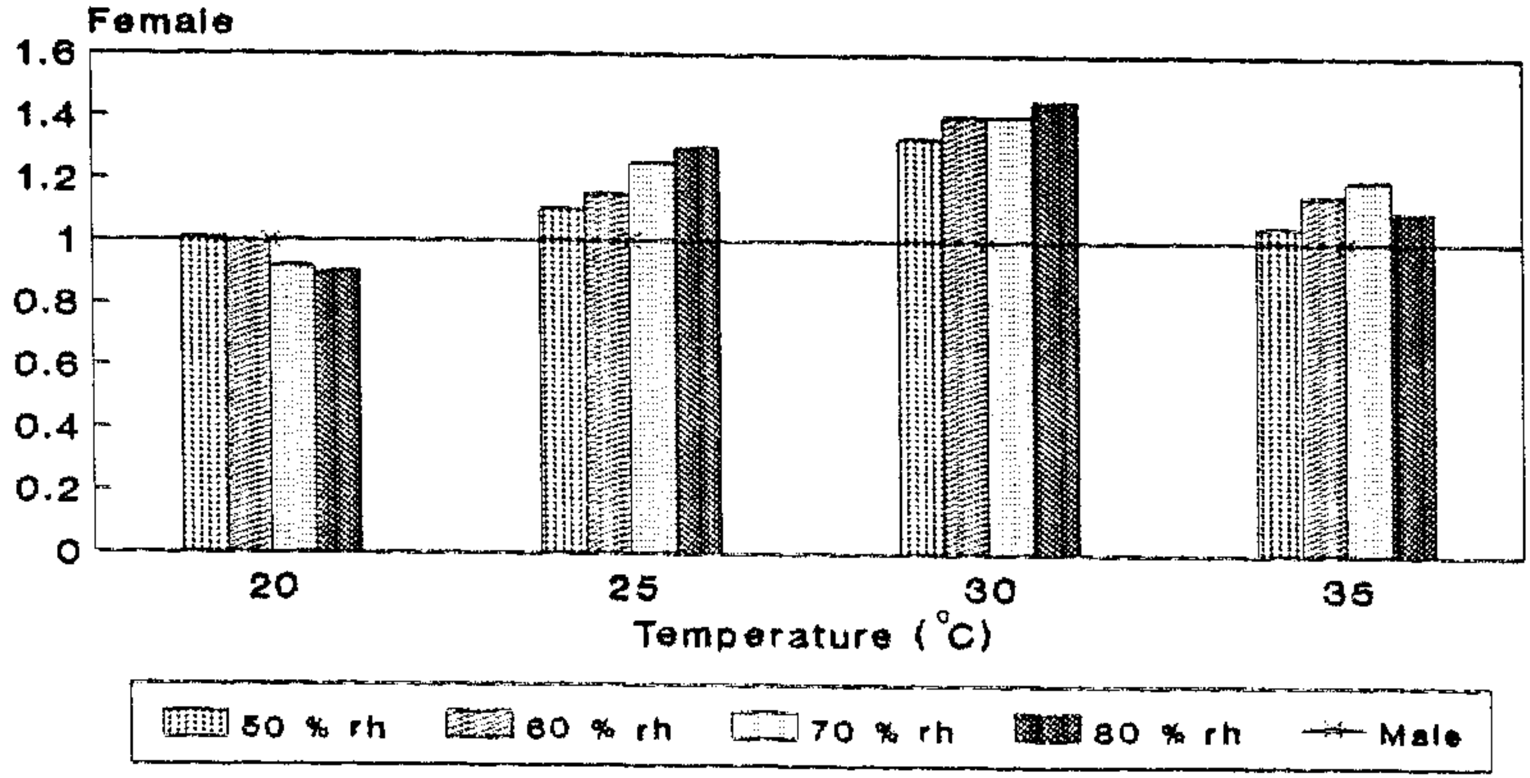


Fig.16 : Combined effect of different levels of temp. and rh on the sex ratio of *S.cerealella* infesting paddy



whereas at 20°C and 80 per cent relative humidity, it was minimum (1:0.90). (Table-13 and Fig. 16).

II. MANAGEMENT

(A). Host-plant resistance

(a) Screening of different varieties of maize and paddy.

Twenty five varieties of maize and paddy each were evaluated for resistance to *S.cerealella*. The parameters for evaluation were per cent grain damage, adult emergence, percent loss in grain weight, survival percent of pest, mean developmental period of pest and susceptibility index.

Per cent grain damage :

The extent of damage to maize grains by *S.cerealella* ranged from 1.00 to 14.64 per cent in different varieties (Table-14). Variety Surya was found to be least susceptible with 1.00 per cent grain damagefollowed by Ageti-76 and CM-111 where the grain damage was found 1.30 and 1.63 per cent, respectively. However, no significant difference was observed between them. The next group of grain damage level ranged from 1.10 to 6.00 per cent and the varieties under this group were considered as moderately susceptible. Under this group D-765, Harsh, Dhawal, Diara-3 Kisan and Arun were identified. The higher level of grain damage was noticed in sixhteen maize varieties viz., Renuka, Prabhat, MCU-508, Devki, Hement, Malan, Aswani, Laxmi, Vikram, NLD, Mahikanchan, Pusa-I, CM-501, Pusa-II, VL-88 and Madhuri. In these varieties, 6.33, 6.33, 6.66, 7.33, 7.62, 7.66, 9.33, 9.33, 9.66, 9.96, 9.99, 9.99, 10.33, 11.64, 11.64 and 14.64 per cent grain damage was recorded, respectively. These varieties were identified as susceptible to the attack of *S.cerealella*.

Adult emergence :

The average number of adults emerged from different maize varieties ranged from 0.87 to 14.66 (Table-14). The variety Surya was found to be least susceptible in terms of adult emergence having least number of adults (0.87) followed by Ageti-76 and CM-111, permitting an average emergence of 1.31 and 1.64 adult moths, respectively. Since no significant difference was found between Surya, Ageti-76 and CM-111, the latter were also considered as least susceptible varieties. The next order of average adult emergence ranged from 1.10 to 6.00 under which six maize varieties viz., D-765, Harsh, Dhawal, Diara-3, Kisan and Arun, permitting an average emergence of 2.00, 2.31, 2.95 2.95, 5.97 and 5.97 adults, respectively. These varieties were found moderately susceptibile to *S.cerealella*. The highest adult emergence (14.66) was observed in Madhuri followed by VL-88, Pusa-II, Pusa-I, Mahikanchan, CM-501, Vikram, NLD, Laxmi, Aswani, Malan, Hement, Devki, MCU-508, Prabhat and Renuka in which average adult emergence ranged from 6.28 to 11.66. These varieties were considered as susceptible to the pest.

Percent loss in grain weight :

The relative susceptibility in terms of per cent loss in grain weight in different maize varieties differed significantly (Table-14). The average grain weight loss ranged from 0.53 to 8.10 per cent. It was less than one per cent in three varieties viz., Surya, Ageti-76 and CM-111. These varieties exhibited 0.53, 0.65 and 0.70 per cent loss in grain weight, respectively and, therefore, were identified as least susceptible. The other group of maize varieties with a range of 1.11 to 1.67 per cent loss in grain weight were considered as moderately susceptible against the attack of *S.cerealella*. D-765, Harsh, Dhawal and Diara-3 were categorised under this group. Rest of the varieties viz., Kisan, Prabhat, Arun, Renuka, Devki, Hement, Malan, MCU-508, Aswani, NLD, Laxmi, CM-501, Mahikanchan, Vikram, Pusa-I, Pusa-II, VL-88 and Madhuri had average loss in grain weight ranging from 3.03 to 8.10 per cent and were considered as susceptible.

Survival percentage of *S.cerealella* :

The adult survival varied widely among the maize varieties (Table-14) Surya exhibited the lowest percentage of adult survival (4.34%) followed by Ageti-76 (4.98%) and CM-111 (6.0%), All these varieties permitted survival of adults below 10 per cent, therefore, these were identified as least susceptible. The adult survival ranged from 10 to 20 per cent in D-765, Harsh, Dhawal and Diara-3. These varieties, therefore, were considered as moderately susceptible against the pest. More than 20 per cent (from 21.04 to 46.25%) survival was observed in the rest of the varieties, therefore, they were considered as susceptible. The maximum percentage of adults survival was recorded in the variety Madhuri (46.25%) which was nearly ten times more than Surya in which the lowest survival of adults was recorded.

Mean developmental period :

The data on mean developmental period of *S.cerealella* in different maize varieties tested are present in Table-14. The mean developmental period of 36.67, 36.67, 36.00, 35.67, 35.67, 35.00 and 34.67 days was recorded on CM-111, D-765, Dhawal, Surya, Ageti-76, Harsh and Diara-3, respectively. The shortest mean developmental period of 29.67 days was observed on Madhuri. It was followed by Laxmi (30.33), NLD (30.33), MCU-508 (30.33), Malan (31.33), Prabhat (31.33), Pusa-II (31.33), Pusa-I (31.67), Vikram (31.67), Kisan (31.67), VL-88 (32.00), Mahikanchan (32.00), Hement (32.33), Devki (32.33), Renuka (32.33), Aswani (32.33), CM-501 (32.67) and Arun (33.33).

Susceptibility index :

The susceptibility index of the different maize varieties ranged from 5.03 to 14.53 (Table-14). The varieties having low susceptibility index were Surya (5.03), Ageti-76 (5.81), CM-111 (5.89). Based on susceptibility

Table 14 : Reaction of different varieties of maize against *S. cerealela**

S.N.	Varieties	Per cent** grain damage	No.of*** adults emerged	Survival** percentage (egg to adult)	Per cent** loss in grain weight	Mean devlop-mental period (days)	Susceptibility index
1	Ageti-76	1.30 (6.54)	1.31 (1.34)	4.98 (12.90)	0.65 (4.62)	35.67	5.81
2	Aswani	9.33 (17.78)	9.31 (3.13)	29.22 (32.72)	3.80 (11.24)	32.33	12.18
3	Arun	6.00 (14.18)	5.97 (2.54)	23.03 (28.68)	3.04 (10.04)	33.33	10.48
4	CM-111	1.63 (7.33)	1.64 (1.46)	6.00 (14.18)	0.70 (4.80)	36.67	5.89
5	CM-501	10.33 (18.75)	9.94 (3.23)	33.32 (35.36)	4.33 (12.00)	32.67	12.34
6	Devki	7.33 (15.70)	7.28 (2.79)	25.26 (30.17)	3.10 (10.14)	32.33	11.24
7	Diara-3	2.94 (9.88)	2.95 (1.86)	14.31 (22.23)	1.67 (7.42)	34.67	8.06
8	D-765	2.00 (8.13)	2.00 (1.58)	11.93 (20.21)	1.11 (6.04)	36.67	6.36
9	Dhawal	2.94 (9.87)	2.95 (1.86)	12.95 (21.09)	1.22 (6.34)	36.00	7.58
10	Harsh	2.31 (8.74)	2.31 (1.68)	12.09 (20.35)	1.13 (6.11)	35.00	7.02
11	Hemant	7.62 (16.02)	7.62 (2.85)	26.79 (31.17)	3.15 (10.22)	32.33	11.51
12	Kisan	5.97 (14.14)	5.97 (2.54)	21.04 (27.30)	3.03 (10.03)	31.67	10.87
13	Laxmi	9.33 (17.78)	9.66 (3.19)	31.11 (33.90)	4.07 (11.63)	30.33	12.69
14	Madhuri	14.64 (22.50)	14.66 (3.89)	46.25 (42.85)	8.10 (16.54)	29.67	14.53
15	Mahikanchan	9.99 (18.43)	9.95 (3.23)	33.03 (35.08)	4.49 (12.24)	32.00	12.41
16	Malan	7.66 (16.07)	7.66 (2.86)	27.16 (31.41)	3.25 (10.38)	31.33	11.87
17	MCU-508	6.66 (14.95)	6.98 (2.73)	28.16 (32.05)	3.60 (10.94)	30.33	11.90
18	NLD	9.96 (18.39)	9.88 (3.22)	33.33 (35.26)	4.00 (11.53)	30.33	12.94
19	Prabhat	6.33 (14.57)	6.28 (2.60)	22.58 (28.37)	3.08 (10.11)	31.33	11.18
20	Pusa-I	9.99 (18.42)	9.98 (3.24)	33.75 (35.52)	6.03 (14.22)	31.67	12.45
21	Pusa-II	11.64 (19.95)	11.33 (3.44)	37.33 (37.66)	6.22 (14.44)	31.33	13.15
22	Renuka	6.33 (14.57)	6.28 (2.60)	23.50 (29.00)	3.10 (10.14)	32.33	10.83
23	Surya	1.00 (5.74)	0.87 (1.17)	4.34 (12.02)	0.53 (4.18)	35.67	5.03
24	Vikram	9.66 (18.11)	9.94 (3.23)	30.58 (33.57)	4.77 (12.61)	31.67	12.39
25	V L-88	11.64 (19.95)	11.61 (3.48)	38.58 (38.40)	6.38 (14.63)	32.00	12.91
	Mean	6.98	6.98	24.42	3.38	32.77	10.54
	S.Em	0.6136	0.1460	0.2494	0.1478	0.5033	0.1729
	C.D. at 5%	1.7431	0.4148	0.7083	0.4198	1.4297	0.4911
	C.D. at 1%	2.3200	0.5531	0.9443	0.5596	1.9061	0.6548

* Mean of three replications

** Figures in parentheses are angular transformed values

*** Figures in parentheses are square root transformed values

index these varieties were identified as least susceptible to the attack of *S.cerealella*. D-765, Harsh, Dhawal and Diara-3 having susceptibility index 6.36, 7.02, 7.58 and 8.06, respectively registered moderate susceptibility, whereas the varieties viz., Arun, Renuka, Kisan, Prabhat, Devki, Hement, Malan, MCU-508, Aswani, CM-501, Vikram, Pusa-I, Mahikanchan, Laxmi, VL-88, NLD, Pusa-II and Madhuri exhibiting high susceptibility index ranging from 10.48 to 14.53 were considered as susceptible to the attack of *S.cerealella*.

Per cent grain damage :

The infestation level of grains damage in paddy varieties viz., Bala, Pusa 2.21 and Cauveri was recorded as 0.64, 0.97 and 1.00 per cent, respectively. These varieties were, therefore, identified as least susptible. The grain damage ranging from 3.32 to 5.97 per cent was recorded in twelve varieties viz., IR-54, Safri-17, R.574-11, R.296-128, Kranti, IR-36, Phalguna, Poorva, Annada, Jaya, Surekha and Swarna. The per cent grain damage recorded in these varieties was 3.32, 3.32, 3.65, 3.65, 3.96, 3.96, 4.00, 4.32, 4.65, 4.65, 5.32 and 5.97 per cent, respectively and were considered as moderately susceptible to the attack of *S.cerealella*. The paddy varieties having grain damage more than 6.00 per cent were considered as susceptible. Kalimuchh, Mahisugandha, Chamble, Dubraj, BK-79, Basmati-370, Masuri, Madhuri selection-11, Ratna and BK-190 had

13.31, 11.33, 10.66, 10.60, 8.33, 7.33, 7.33, 7.33, 6.66 and 6.30 per cent grain damage, respectively and were identified as susceptible varieties. (Table -15).

Adult emergence :

The number of adults (moths) emerged in different varieties of paddy from 100 grains has been depicted in Table-15. The average adult emergence was least in three varieties viz., Bala, Pusa.2-21 and Cauveri where 0.61, 0.87 and 0.87 adults emerged. However, they were at par with each other and therefore, on the basis of adult emeregence these were identified as least susceptible to the attack of *S.cerealella*. The average number of adult emergence ranged from 3.32 to 5.97 in the twelve paddy varieties viz., IR-54, Safri-17, R.574-11, R.296-128, IR-36, Kranti, Phalguna, Poorva, Annada, Jaya, Surekha and Swarna, which permitted an average adult emergence of 3.32, 3.32, 3.65, 3.65, 3.65, 3.96, 3.96, 4.32, 4.66, 4.66, 5.32 and 5.97, respectively, and these varieties were considered as moderately susceptible to the pest. Rest of the varieties viz., BK-190, Ratna, Masuri, Madhuri selection-11, Basmati-370, BK-79, Dubraj, Chamble, Mahisugandha and Kalimuchh allowing an average adult emergence ranging from 6.61 to 12.92 were considered as susceptible varieties against *S.cerealella*.

Per cent loss in grain weight :

The average grain weight loss due to insect damage ranged from 0.30 to 6.70 per cent in different paddy varieties tested (Table-15). Bala suffered the minimum loss in grain weight (0.30 per cent). It was followed by Pusa 2.21 and Cauveri which incurred a grain weight loss of 0.59 and 0.62 per cent, respectively. These varieties on the basis of loss in grain weight were identified as least susceptible to the pest attack. The per cent loss in grain weight ranging from 1.28 to 2.00 was recorded in the varieties IR-54, R.574-11, Kranti, Phalguna, Safri-17, R.296-128, Annada, IR-36, Jaya, Surekha and Poorva These were considered as moderately susceptible. The maximum weight loss was noticed in the Kalimuchh (6.70%) followed by Mahisugandha (6.11%), Chamble (6.09%), Dubraj (6.01%) BK.79 (4.47%), Basmati-370 (3.95%), Masuri (3.80%), Madhuri selection-11 (3.68%), Swarna (3.45%), Ratana (3.10%) and BK-190 (3.10%) and were considered as susceptible to *S.cerealella*.

Survival percentage of pest :

The percentage of adult survival was recorded less than 10 per cent in Bala, Pusa 2.21 and Cauveri varieties of paddy (Table-15). In these the adult survival was recorded 4.09, 4.43 and 4.72 per cent, respectively, and were identified as least susceptible against the attack of *S.cerealella* on the basis of pest survival. More than 10 but below 20 per cent adult survival was recorded in IR-54, Safri-17, R.296-128, Kranti, IR-36, Phalguna, Poorva, R.574-11, Jaya, Annada, Swarna and Surekha, and these varieties were considered as moderately susceptible. More than 20 per cent adult survival ranging from 20.08 to 35.26 per cent was recorded in the rest of the varieties which were considered as susceptible to the attack of *S.cerealella*. The variety Kalimuchh had the maximum adult survival (35.26%), whereas in Madhuri selection-11, BK-190, Ratna, Basmati-370, Masuri, BK-79, Dubraj, Chamble and Mahisugandha had 20.08, 20.10, 20.11, 20.30, 20.49, 22.46, 25.69, 30.16 and 32.52 per cent adult survival, respectively.

Mean developmental period :

The average mean developmental period of *S.cerealella* in different **paddy** varieties tested ranged from 27.00 to 31.33 days (Table-15). The insect took more than 30 days to develop on Bala, Cauveri, Pusa.2-21 and IR-54. The shortest mean developmental period of 27 days was observed in Kalimuchh, Masuri and Jaya varieties. It was followed by Basmati-370 (27.33), Dubraj (27.33), Mahisugandha (27.33), Bk-190 (27.33), Madhuri selection-11 (27.33), Kranti, BK-79 (27.33), Safri-17 (27.67), Ratna (27.67), R.574-11 (28.00), R.296-128 (28.00), Swarna (28.00), Annada (28.00), Surekha (28.33), Chamble (28.33), IR-36 (28.33), Phalguna (29.00) and Poorva (29.33).

Susceptibility index :

The susceptibility index of **paddy** varieties screened against *S.cerealella* is presented in (Table-15). The susceptibility index of Bala was the lowest (6.49) followed

Table 15 : Reaction of different varieties of paddy against *S. cerealela**

S.N.	Varieties	Per cent** grain damage	No. of*** adults emerged	Survival** percentage (egg to adult)	Per cent** loss in grain weight	Mean devlop-mental period (days)	Susceptibility index
1	R574-11	3.65 (11.02)	3.65 (2.04)	11.98 (20.25)	1.46 (6.94)	28.33	10.50
2	Swarna	5.97 (14.15)	5.97 (2.54)	15.25 (22.99)	3.45 (10.70)	28.00	11.67
3	Kranti	3.96 (11.48)	3.96 (2.11)	10.78 (19.17)	1.55 (7.14)	27.00	10.96
4	BK-79	8.31 (16.75)	8.33 (2.97)	22.46 (28.29)	4.77 (12.62)	27.33	13.56
5	IR-54	3.32 (10.50)	3.32 (1.95)	10.09 (18.51)	1.28 (6.49)	30.33	9.46
6	Masuri	7.33 (15.70)	7.23 (2.78)	20.49 (26.91)	3.80 (11.24)	26.67	13.40
7	Jaya	4.65 (12.46)	4.65 (2.27)	12.25 (20.49)	1.99 (8.11)	26.67	11.53
8	Safri-17	3.32 (10.50)	3.32 (1.95)	10.10 (18.53)	1.65 (7.38)	27.67	9.94
9	Annada	4.65 (12.46)	4.65 (2.27)	13.54 (21.59)	1.85 (7.82)	28.00	11.44
10	Basmati-370	7.66 (16.07)	7.66 (2.86)	20.31 (26.78)	3.95 (11.46)	27.33	13.04
11	R296-128	3.65 (11.02)	3.65 (2.04)	10.64 (19.03)	1.70 (7.49)	28.00	10.63
12	Kalimuchh	13.31 (21.40)	12.92 (3.66)	35.26 (36.43)	6.70 (15.00)	28.00	14.92
13	Dubraj	9.66 (18.11)	9.98 (3.24)	25.69 (30.45)	6.00 (14.20)	27.33	13.98
14	Surekha	5.32 (13.34)	5.32 (2.41)	16.63 (24.07)	2.00 (8.14)	28.33	11.97
15	Phalguna	4.00 (11.54)	3.96 (2.11)	11.29 (19.64)	1.55 (7.15)	29.00	10.44
16	Ratna	6.66 (14.95)	6.64 (2.67)	20.11 (26.65)	3.10 (10.14)	27.67	12.48
17	Mahisugandha	11.64 (19.95)	11.31 (3.44)	32.52 (34.77)	6.09 (14.29)	27.33	14.85
18	BK-190	6.30 (14.53)	6.61 (2.67)	20.10 (26.64)	3.10 (10.14)	27.33	12.48
19	Chamble	10.65 (19.05)	10.63 (3.34)	30.16 (33.31)	6.11 (14.31)	28.33	14.07
20	Pusa.2-21	0.97 (5.66)	0.87 (1.17)	4.43 (12.15)	0.59 (4.40)	30.33	6.98
21	Bala	0.64 (4.60)	0.61 (1.05)	4.09 (11.67)	0.30 (3.14)	31.33	6.49
22	Cauveri	1.00 (5.74)	0.87 (1.17)	4.72 (12.55)	0.62 (4.51)	30.33	7.11
23	Poorva	4.32 (11.99)	4.32 (2.20)	11.85 (20.13)	2.00 (8.13)	29.33	10.48
24	Madhrui selection-11	7.33 (15.70)	7.33 (2.80)	20.08 (26.62)	3.68 (11.06)	27.33	13.27
25	I.R. 36	3.96 (11.48)	3.65 (2.04)	10.91 (19.29)	1.98 (8.09)	28.33	10.63
	Mean	5.68	5.66	16.23	2.85	28.23	11.45
	S.Em.	0.5668	0.1335	0.3515	0.1149	0.3333	0.1558
	C.D. at 5%	1.6099	0.3791	0.9983	0.3264	0.9469	0.4425
	C.D. at 1%	2.1463	0.5055	1.3309	0.4352	1.2623	0.5899

* Mean of three replications
** Figures in parentheses are angular transformed values
*** Figures in parentheses are square root transformed values

by Pusa.2-21 (6.98) and Cauveri (7.11). On the basis of susceptibility index these varieties were identified as leastsuscptible. The varieties with high susceptibility index were Kalimuchh (14.92), Mahisugandha (14.85), Chamble (14.07), Dubraj (13.98), BK-79 (13.56), Masuri (13.40), Madhuri selection-11 (13.27), Basmati-370 (13.04), Ratna (12.48) and BK-190 (12.48). Rest of the paddy varieties had intermediate values ranging from 9.46 to 11.67 and were considered as moderately susceptible against the pest.

(b) Basis for resistance :

(i) Physical characters : Maize

Volume of grain :

The volume of the **maize** grains of the different varieties tested has been given in Table-16. The volume of grains varied from 1.43 to 2.63 ml/10 grains. The lowest volume (1.43 ml) was observed in Madhuri and maximum in NLD (2.63 ml).

The correlation coefficient of grain volume with different parameters imparting resistance such as per cent grain damage, adult emergence per cent loss in grain weight, survival percentage of pest and susceptibility index was worked out but it was found non significant (Appendix-I).

Thickness of pericarp and seed coat :

The thickness of pericarp and seed coat of different maize varieties varied from 91.67 to 147.67 μ (Table-16).

Thickest pericarp and seed coat was found in Surya (147.67 μ) and minimum thickness was recorded in Aswani (91.67 μ).

A significant negative correlation was observed in thickness of pericarp and seed coat with per cent grain damage, adult emergence, percent loss in grain weight, survival percentage of adults and susceptibility index (Appendix-I).

Relative hardness :

The relative hardness based on per cent yield of flour of different varieties of maize is presented in Table-16. It is clear from the table that the hardness of maize grains in terms of flour yield differed in different varieties. Maximum flour yield (18.05%) was obtained from Madhuri and minimum (7.63%) from Surya which were considered as comparatively soft and hard varieties, respectively. The next lower yield of flour was recorded in Ageti-76 (8.10%) followed by D-765 (9.10%), Harsh (9.31%) and Dhawal (9.65%) these were considered as moderate (medium) hard varieties.

The correlation coefficient of hardness of grains (in terms of per cent flour yield) was found positive and significant with per cent grain damage, adult emergence, per cent loss in grain weight survival percentage of adults and susceptibility index. (Appendix-I).

Table 16 : Physical characters of maize varieties *

S.N.	Varities	Volume of ten grains(ml)	Thickness of Pericarp and seed coat(µ)	Relative hardness** (% passing of flour through 60 mesh sieve)	Water absorption Index
1	Ageti -76	1.90	140.67	8.10 (16.54)	1.20
2	Aswani	1.98	99.67	12.83 (20.99)	1.36
3	Arun	1.85	110.67	10.18 (18.60)	1.39
4	CH-111	2.03	136.33	8.16 (16.59)	1.26
5	CH-501	2.40	100.67	13.00 (21.13)	1.36
6	Devki	2.73	111.67	11.80 (20.09)	1.38
7	Diara-3	1.77	119.00	10.20 (18.62)	1.31
8	D-765	1.70	126.00	9.10 (17.56)	1.28
9	Dhawal	2.53	120.33	9.65 (18.10)	1.30
10	Harsh	2.70	120.67	9.31 (17.77)	1.30
11	Hemant	2.67	91.67	12.00 (20.27)	1.36
12	Kisan	2.13	113.33	10.99 (19.36)	1.35
13	Laxmi	2.27	100.33	13.89 (21.88)	1.44
14	Madhuri	1.43	91.67	18.05 (25.14)	1.83
15	Mahikanchan	2.17	96.33	13.35 (21.43)	1.42
16	Malan	2.43	105.33	12.30 (20.52)	1.42
17	MCU-508	1.87	111.67	12.50 (20.70)	1.40
18	MLD	2.63	100.67	15.11 (22.87)	1.42
19	Prabhat	2.37	116.33	11.50 (19.82)	1.40
20	Pusa-I	1.70	104.00	13.80 (21.80)	1.41
21	Pusa-II	2.00	94.67	15.00 (22.79)	1.39
22	Renuka	2.20	114.00	10.69 (19.08)	1.38
23	Surya	1.93	147.67	7.63 (16.03)	1.17
24	Vikram	2.00	97.00	13.18 (21.29)	1.32
25	VL-88	1.70	92.00	14.00 (21.97)	1.38
	Mean	2.12	110.49	11.85	1.36
	S.Em.	0.0643	5.8758	0.3607	0.0247
	CD at 5 %	0.1826	16.6906	1.0247	0.0701
	CD at 1 %	0.2435	22.2514	1.3660	0.0934

* Mean of three replications
** Figures in parentheses are angular transformed values

Water absorption index :

The water absorption indices of different maize varieties are presented in Table-16. The water absorption index was found comparatively less in Surya, Ageti-76, D-765, Harsh and Dhawal ranging from 1.17 to 1.30 The water absorption index ranging from 1.31 to 1.83 was recorded in Diara-3, Vikram, Kisan, CM-501, Aswani, Hement, Renuka, Devki, VL-88, Arun, Pusa-II, Prabhat, MCU-508, Pusa-I, Mahikanchan, NLD, Malan, Laxmi and Madhuri.

The correlation coefficient of water absorption index showed significant positive correlation with per cent grain damage, adult emergence, per cent grain loss in weight, survival percentage of pest and susceptibility index. (Appendix-I).

(ii) Biochemical characters : Maize

Amylose content :

The total amylose content in maize grains of different varieties presented in table-17, varied from 12.15 to 48.69 per cent. Comparatively higher percentage of amylose was found in Surya (48.69%), Ageti-76 (43.11%) and CM-111 (39.66 %) followed by D-765 (30.66%), Dhawal (30.00%), Harsh (30.00%), Diara-3 (29.16%) and Arun (29.00%). Amongst the maize varieties tested Madhuri accounted for only 12.15 per cent amylose followed by Pusa-I, MCU-508, Pusa- II, Malan, Vikram, VL-88, Laxmi and Hement in which the percentage amylose ranged from 14.00 to 16.33. In rest of the varieties the amylose percentage varied from 20.03 to 27.30.

The amylose content had a significant negative correlation with percent grain damage, adult emergence, percent loss in grain weight, survival percentage of pest and susceptibility index. (Appendix-I).

Protein Content :

The total protein content in different maize varieties presented in Table-17 revealed that Madhuri and NLD had 12.70 per cent protein followed by Vikram, Pusa-II, Arun, Renuka and Pusa-I, in which total protein was found 12.02, 11.83, 11.83, 11.45 and 11.45 per cent, respectively. However, all these varieties were at par with each other. Relatively lower percentage of protein was observed in Surya, CM-111, Ageti-76, D-765 contaning 9.40, 9.45, 9.75 and 9.80 per cent, respectively. In rest of the varieties protein content varied from 10.06 to 11.10 per cent.

The protein content was found positively correlated with the per cent grain damage, adult emergence, percent grain loss in weight, survival percentage of pest and susceptibility index. (Appendix-I).

Free amino acid :

The free amino acids in different maize varieties presented in Table-18 revealed that Surya and Ageti-76 had 1.22 and 1.45 per cent free amino acids, respectively.

Comparatively higher percentage of free amino acids was recorded in Madhuri (2.10%) and VL-88(2.00%). It was moderate in the variety D-765 (1.61 %) and Harsh (1.6. %).

A positive correlation was found between free amino acids of maize grains and per cent grain damage, adult emergence, percent loss in grain weight and su bility index. (Table-19).

Ash content :

Although significant variations in ash content of different maize varieties was recorded ranging from 1.39 to 1.75 per cent, no significant correlation with per cent grain damage, adult emergence, per cent loss in grain weight, survival percentage of pest, and susceptibility index could be obtained (Table-17 and Appendix-I).

Oil content :

The oil content in different maize grains differed significantly and varied from 4.10 to 6.28 per cent. Maximum percentage of oils was recorded in Ageti-76 (6.28%) followed by Surya (6.26) and CM-111 (6.16%). No significant difference was found between these varieties. Similarly in Devki minimum oil content (4.10%) was recorded followed by Madhuri from which 4.31% oil was extracted. Stastically no significant difference between these two varieties was observed.

Table 17 : Biochemical characters of maize varities*

S.N.	Varities	Amylose content (%)	Protein content (%)	Ash content (%)	Oil content (%)
1	Ageti -76	43.11	9.75	1.68	6.28
2	Aswani	21.56	11.10	1.41	5.36
3	Arun	29.00	11.83	1.50	5.42
4	CM-111	39.66	9.45	1.60	6.16
5	CM-501	20.11	10.43	1.75	5.10
6	Devki	20.10	10.06	1.39	4.10
7	Diara-3	29.16	10.12	1.45	5.80
8	D-765	30.66	9.80	1.65	5.95
9	Dhawal	30.00	11.10	1.67	5.76
10	Harsh	30.00	10.13	1.62	5.70
11	Hemant	16.33	10.58	1.63	4.99
12	Kisan	25.03	10.08	1.50	4.80
13	Laxmi	15.35	10.44	1.59	4.80
14	Madhuri	12.15	12.70	1.58	4.31
15	Mahikanchan	20.03	10.44	1.73	4.76
16	Malan	14.30	11.10	1.50	4.82
17	MCU-508	14.00	10.75	1.62	5.00
18	NLD	15.66	12.70	1.49	4.78
19	Prabhat	27.30	11.10	1.56	4.81
20	Pusa-I	14.00	11.45	1.40	4.80
21	Pusa-II	14.20	11.83	1.69	4.73
22	Renuka	26.22	11.45	1.46	4.91
23	Surya	48.69	9.40	1.73	6.26
24	Vikram	15.11	12.02	1.43	5.38
25	VL-88	15.33	10.93	1.55	4.98
	Mean	23.48	10.83	1.56	5.19
	S.Em	0.3862	0.4863	0.0293	0.0965
	C.D. at 5%	1.0969	1.3814	0.0832	0.2741
	C.D. at 1%	1.4624	1.8417	0.1109	0.3654

* Mean of three replications

Table 18 : Free amino acids in maize varieties.*

S.No.	Name of Varieties	Total free amino acids (%)
1.	Surya	1.22
2.	Ageti-76	1.45
3.	D-765	1.61
4.	Harsh	1.63
5.	VL-88	2.00
6.	Madhuri	2.10
	Mean	1.67
	S.Em.	0.0306
	C.D. at 5 %	0.0942
	C.D. at 1 %	0.1321

* Mean of three replications

Table 19 : Correlation coefficient of free amino acids of maize varieties with different parameters.

S.No.	Parameters	Correlation coefficient (r)
1.	Percent grain damage	0.92**
2.	Adult emergence (No.)	0.93**
3.	Survival percentage of adults	0.78**
4.	Percent loss in graing wt.	0.92**
5.	Susceptibility Index	0.95**

** Significant at 1 % level of significance.

The oil content of the maize grains was found negatively correlated with per cent grain damage, adult emergence, percent loss in grain weight, survival percentage of adults and susceptibility index. The mean developmental period of the pest prolonged when fed on varieties having higher amount of oil as compared to the varieties having low percentage of oil. (Table 17 and Appendix-I).

(iii) Physical characters : Paddy

Length Breath Ratio :

The L/B ratio of different paddy varieties recorded has been depicted in Table-20. The data revealed that the L/B ratio varied from 2.37 to 4.99. The low L/B ratio ranging from 2.37 to 2.97 were recorded in BK-190, Kranti, Annada, R 296-128, Cauveri, Jaya and Chamble, whereas it varied from 3.04 to 3.99 in R574-11, Swarna, IR-54, Masuri, Safri-17, Kalimuchh, Dubraj, Surekha, Phalguna, Pusa.2-21, Bala and Poorva. In rest of the paddy varieties the L/B ratio was recorded more than 4.00.

A positive correlation between L/B ratio and per cent grain damage, adult emergence, survival per centage of adults, percent loss in grain weight and susceptibility index was obtained but it was not significant (Appendix -II)

Thickness of husk :

The thickness of paddy husk of various varieties varied from 0.10 to 0.19 mm (Table-20). Comparatively more thickness of husks was recorded in Bala (0.19 mm), Pusa 2-21, (0.18 mm), Cauveri (0.17 mm) and IR-54 (0.16mm), whereas, the varieties having thin husk were Dubraj (0.10 mm), Kalimuchh (0.10 mm), Madhuri selection-11 (0.11 mm) Poorva (0.12 mm), Bk-190 (0.12 mm), Ratna (0.12 mm) Jaya (0.12 mm), BK-79 (0.12 mm), Swarna (0.13 mm), Kranti (0.13 mm), Masuri (0.13 mm), Annada (0.13 mm), IR-36 (0.13 mm) and Chamble (0.13 mm). The medium thickness of husk was recorded in R.296-128 (0.14 mm) R.574-11 (0.15), Surekha (0.15 mm) and Phalguna (0.15 mm)

Significant negative correlation was obtained between the husk thickness of paddy and per cent grain damage, adult emergence, per cent loss in grain weight,survival percentage of pest and susceptibility index. (Appendix-II).

Relative hardness :

The hardness of paddy grains based on the alkali spreading value of the milled rice has been tabulated in Table 20. The higher alkali value ranging from 6 to 7 was recorded in Chamble, Jaya, Dubraj, Mahisugandha, Kalimuchh, BK-79, Ratna and BK-190 In Bala, Pusa.2.21 and Cauveri the alkali values ranged from 2.94 to 3.63. Rest of the varieties showed alkali values ranging from 4.41 to 5.99.

The relative hardness of paddy grains in terms of alkali spreading value had significant positive correlation with per cent grain damage, adult emergence, per cent loss

Table 20 : Physical characters of paddy varities.

S.N.	Varities	Length Breath ratio	Thickness of** husk (mm)	Relative hardness** (alkali spreading value from 2-8 scale)
1	R.574-11	3.04	0.15	4.41
2	Swarna	3.28	0.13	4.60
3	Kranti	2.57	0.13	4.50
4	BK-79	4.32	0.12	6.90
5	IR-54	3.97	0.16	4.52
6	Masuri	3.38	0.13	5.20
7	Jaya	2.97	0.12	6.59
8	Safri-17	3.77	0.15	5.21
9	Annada	2.69	0.13	5.49
10	Basmati-370	4.47	0.11	5.99
11	R296-128	2.78	0.14	4.93
12	Kalimuchh	3.70	0.10	6.87
13	Dubraj	3.82	0.10	6.72
14	Surekha	3.54	0.15	5.20
15	Phalguna	3.99	0.15	5.00
16	Ratna	4.47	0.12	7.00
17	Mahisugandha	4.42	0.10	6.77
18	BK-190	2.37	0.12	7.00
19	Chamble	2.88	0.13	6.52
20	Pusa.2-21	3.06	0.18	3.29
21	Bala	3.13	0.19	2.94
22	Cauveri	2.86	0.17	3.63
23	Poorva	3.83	0.12	4.69
24	Madhrui Selection-11	4.99	0.11	5.93
25	IR-36	4.10	0.13	4.75
	Mean	3.54	0.13	5.38
	S.Em	0.0981	0.0038	0.1524
	C.D. at 5%	0.2741	0.0105	0.4259
	C.D. at 1%	0.3619	0.0138	0.5624

* Mean of three replications

** Mean of seven grains

in grain weight, survival percentage of pest and susceptibility index. (Appendix -II).

(iv) Biochemical characters : Paddy

Amylose content :

Amylose content of different varieties of paddy screened varied from 15.33 to 38.06 per cent. Bala had 38.06 per cent amylose which was the maximum followed by Cauveri and Pusa.2-21 containing 37.40 and 37.33 per cent, respectively. These three varieties, however, did not differ significantly in their amylose content. Minimum percentage of amylose (15.33) was found in Kalimuchh. It was followed by Mahisugandha, Chamble, Dubraj, Masuri, BK-79 and Madhuri selection-11 having 16.38, 17.31, 18.91, 19.10, 19.60 and 19.88 per cent amylose, respectively. In rest of the varieties the percentage of amylose varied from 27.02 to 30.03 (Table-21).

The amylose content was found negatively correlated with the per cent grain damage, adult emergence, per cent loss in grain weight, survival percentage of pests and susceptibility index (Appendix-II).

Protein content :

The total protein content in different paddy varieties presented in Table-21 revealed that Bala, Pusa.2-21, Cauveri had 6.60, 7.60 and 7.63 per cent protein, respectively. Comparatively higher protein content was recorded in

Kalimuchh (10.10%) followed by Mahisugandha (10.00%), Dubraj (9.25%), Chamble (9.20%), Masuri (9.10%), Madhuri selection-11 (9.07%) and BK-79 (9.00%). The other varieties had various levels of protein content ranging from 7.82 to 8.92 per cent.

A positive correlation was found between protein content of paddy grains and per cent grain damage, adult emergence, per cent loss in grain weight, survival percentage of adults and susceptibility index. The pest took more time for their development on the varieties in which low protein content was recorded. (Appendix-II).

Free amino acids :

The free amino acids in different paddy varieties showed significant variations. The data presented in Table-22 revealed that Bala and Pusa.2-21 had 0.56 and 0.60 per cent free amino acids, respectively. Relatively high percentage of free amino acids was recorded in susceptible varieties of paddy viz., Kalimuchh (1.31%) and Mahisugandha (1.22%). It was recorded 0.75 and 0.80 per cent in IR-54 and Phalguna, respectively.

The free amino acids were found positively correlated with the per cent grain damage, adult emergence, per cent loss in grain weight, survival percentage of the pest and susceptibility index (Table-23).

Silica content :

The levels of silica content in paddy husk is presented in Table-21. In paddy husk silica content varied from 10.38 to 17.96 per cent. In Pusa.2-21, Bala and Cauveri the levels ranged from 17.72 to 17.96 per cent, whereas in Kalimuchh and Mahisugandha the levels of silica content were only 10.38 and 11.70 per cent, respectively. In rest of the varieties the levels of silica ranged from 12.50 to 17.00 per cent.

The statistical analysis revealed significant negative correlation of silica content with per cent grain damage, adult emergence, per cent loss in grain weight, survival percentage of pest and susceptibility index. (Appendix-II).

Ash content :

Similar to silica content, the husk ash of paddy grains in different varieties varied from 11.20 to 18.98 per cent. The ash content in Kalimuchh and mahisugandha was 11.20 and 12.60 per cent respectively. In rest of the varieties the ash content varied from 13.20 to 17.80 per cent (Table-21)

A significant negative correlation of ash content with per cent grain damage, adult emergence per cent grain loss in weight survival percentage of pest and susceptibility index was found (Appendix-II).

Table 21 : Biochemical characters of paddy varities*

S.N.	Varities	Amylose content (%)	Protein content (%)	Husk silica content (%)	Husk ash content (%)	Oil content (%)
1	R.574-11	28.00	8.29	16.06	17.12	3.53
2	Swarna	23.20	8.68	12.66	13.36	3.20
3	Kranti	26.16	8.40	16.00	16.93	3.45
4	BK-79	19.60	9.00	13.70	14.60	3.20
5	IR-54	23.50	7.80	17.00	17.80	4.13
6	Masuri	19.10	9.10	13.80	14.62	2.15
7	Jaya	24.11	8.63	15.42	16.53	3.96
8	Safri-17	30.03	7.82	16.00	17.00	3.35
9	Annada	24.60	8.50	15.30	16.43	3.62
10	Basmati-370	21.02	8.92	14.81	15.53	3.40
11	R296-128	27.00	8.32	16.10	17.00	3.70
12	Kalimuchh	15.33	10.10	10.38	11.20	3.21
13	Dubraj	18.91	9.25	13.00	13.61	3.32
14	Surekha	22.30	8.72	14.90	15.66	3.85
15	Phalguna	25.00	8.00	16.46	17.10	3.95
16	Ratna	22.00	8.80	14.80	15.39	3.74
17	Mahisugandha	16.38	10.00	11.70	12.60	3.20
18	BK-190	21.66	8.82	14.95	15.73	3.30
19	Chamble	17.31	9.20	12.50	13.20	3.96
20	Pusa.2-21	37.33	7.60	17.96	18.98	4.69
21	Bala	38.06	6.60	17.74	18.80	4.90
22	Cauveri	37.40	7.63	17.72	18.53	4.87
23	Poorva	25.03	8.92	15.21	16.00	3.91
24	Madhrui Selection-11	19.88	9.07	14.00	14.61	3.20
25	IR-36	26.06	8.36	15.50	16.60	4.00
	Mean	24.36	8.58	14.94	15.79	3.67
	S.Em	0.1901	0.2441	0.0898	0.0884	0.0555
	C.D. at 5 %	0.5400	0.6933	0.2550	0.2512	0.1577
	C.D. at 1 %	0.7199	0.9243	0.3400	0.3349	0.2103

* Mean of three replications

Table 22 : Free amino acids in paddy varieties.*

S.No.	Name of Varieties	Free amino acids (%)
1.	Bala	0.56
2.	Pusa.2-21	0.60
3.	IR-54	0.75
4.	Phalguna	0.80
5.	Mahisugandha	1.22
6.	Kalimuchh	1.31
	Mean	0.87
	S.Em.	0.0392
	C.D. at 5 %	0.1207
	C.D. at 1 %	0.1693

* Mean of three replications

Table 23 : Correlation coefficient of free amino acids of paddy varieties with different parameters.

S.No.	Parameters	Correlation coefficient (r)
1.	Percent grain damage	0.98**
2.	Adult emergence (No.)	0.98**
3.	Survival percentage of adults	0.99**
4.	Percent loss in graing wt.	0.98**
5.	Susceptibility Index	0.98**

** Significant at 1 % level of significance.

Oil content :

The data recorded on the amount of oil present in different varieties of paddy are presented in Table-21. It is evident from the data that the amount of oil extracted from paddy grains was found lesser than the maize grains ranging from 2.15 to 4.90 per cent. Maximum oil was found in Bala (4.90%) followed by Cauveri (4.87%) and Pusa 2.21 (4.77%). Minimum quantity of oil was recorded in Masuri (2.15%). In rest of the varieties the oil content ranged from 3.20 to 4.13 per cent.

Significant negative correlation was found between the oil content and per cent grain damage, adult emergence, per cent loss in grain weight, survival percentage of the pest and susceptibility index (Appendix-II).

(B) Evaluation of insecticides and plant products :

(a) Insecticidal dusts :

The data obtained on the per cent damage to grains, number of adults and per cent germination, when the dusts of different insecticides were mixed with maize grains for the protection of grains against the damage of *S. cerealella* are presented in Table-24. It is evident from the data that 28.60 per cent grains were damaged by the pest in control and no damage to grain was observed in insecticidal treatment due to absolute protection of grains by these insecticides.

Table 24 : Effect of insecticidal dust on the damage due to *S.cerealella*, adult population and germination of maize grains.*

S.N.	Treatments (dust)	Doses (wt/wt)	Per cent** grain damage	Adult Population (No.)***	Per cent** germination	Benefit Cost ratio
1	Control	Untreated	28.68	308.94	70.67	-
			(32.38)	(17.59)	(57.21)	
2	Malathion	2:1000	0.00	0.00	68.35	63.92
			(0.00)	(0.70)	(55.76)	
3	Malathion	4:1000	0.00	0.00	67.74	31.96
			(0.00)	(0.70)	(55.39)	
4	Methyl parathion	2:1000	0.00	0.00	65.38	74.69
			(0.00)	(0.70)	(53.95)	
5	Methyl parathion	4:1000	0.00	0.00	69.36	37.34
			(0.00)	(0.70)	(56.39)	
6	Endosulfan	2:1000	0.00	0.00	67.34	44.81
			(0.00)	(0.70)	(55.14)	
7	Endosulfan	4:1000	0.00	0.00	66.68	22.40
			(0.00)	(0.70)	(54.74)	
8	Quinalphos	2:1000	0.00	0.00	68.33	48.44
			(0.00)	(0.70)	(55.75)	
9	Quinalphos	4:1000	0.00	0.00	66.67	24.22
			(0.00)	(0.70)	(54.73)	
10	Carbaryl	2:1000	0.00	0.00	71.81	35.85
			(0.00)	(0.70)	(57.93)	
11	Carbaryl	4:1000	0.00	0.00	72.67	17.93
			(0.00)	(0.70)	(58.48)	
12	Fenvalerate	2:1000	0.00	0.00	69.67	51.21
			(0.00)	(0.70)	(56.58)	
13	Fenvalerate	4:1000	0.00	0.00	68.33	25.60
			(0.00)	(0.70)	(55.75)	
	S.Em.	-	0.2063	0.0484	1.1367	-
	C.D. at 5%	-	0.5997	0.1396	NS	-
	C.D. at 1%	-	0.8106	0.1887	NS	-

* Mean of three replications

** Figures in parentheses are angular transformed values

*** Figures in parentheses are square root transformed values

As there was no damage to grains, it becomes clear that all the insecticides tested inhibited the multiplication of *S. cerealella* completely up to eight month of storage in both the dosages viz., 2:1000 and 4:1000 wt/wt. Consequently no adult could emerge in all the treatments, whereas in control 308.94 moths emerged.

No adverse effect of all the insecticides tested on grain viability was observed as revealed by the germination test. The germination percentage of treated grains varied from 65.38 to 72.67 as against the untreated grains where 70.67 per cent grains germinated. Maximum germination percentage was recorded in grains treated with carbaryl.

Similar to maize no grain damage was observed in paddy treated with different insecticidal dusts (Table-25). In control, however, 9.96 per cent grain damage was recorded.

In the absence of any damage caused to paddy grains by *S. cerealella*, no population of this pest was found in the treated grains. However, in untreated check 427.80 adults were recorded (Table-25).

As observed in maize no adverse effect of insecticides could be noticed on the germination of paddy grains. The germination percentage varied from 90.34 to 92.05 in insecticidal treatments as against 92.08 in untreated check.

Table 25 : Effect of insecticidal dust on the damage due to *S.cerealella*, adult population and germination of paddy grains. *

S.N	Treatments (dust)	Doses (wt/wt)	Percent ** grain damage	Adult Population (No.) ***	Per cent ** germination	Benefit Cost ratio
1	Control	–	9.96	427.80	92.08	-
			(18.40)	(20.70)	(73.65)	
2	Malathion	2:1000	0.00	0.00	91.07	17.79
			(0.00)	(0.70)	(72.61)	
3	Malathion	4:1000	0.00	0.00	90.44	8.90
			(0.00)	(0.70)	(71.99)	
4	Methyl parathion	2:1000	0.00	0.00	90.34	20.75
			(0.00)	(0.70)	(71.89)	
5	Methyl parathion	4:100	0.00	0.00	90.69	10.38
			(0.00)	(0.70)	(72.23)	
6	Endosulfan	2:1000	0.00	0.00	91.07	12.45
			(0.00)	(0.70)	(72.61)	
7	Endosulfan	4:1000	0.00	0.00	90.69	6.23
			(0.00)	(0.70)	(72.23)	
8	Quinalphos	2:1000	0.00	0.00	91.38	13.45
			(0.00)	(0.70)	(72.92)	
9	Quinalphos	4:1000	0.00	0.00	90.69	6.73
			(0.00)	(0.70)	(72.23)	
10	Carbaryl	2:1000	0.00	0.00	91.02	9.96
			(0.00)	(0.70)	(72.56)	
11	Carbaryl	4:1000	0.00	0.00	91.38	4.98
			(0.00)	(0.70)	(72.92)	
12	Fenvalerate	2:1000	0.00	0.00	92.05	14.23
			(0.00)	(0.70)	(73.62)	
13	Fenvalerate	4:1000	0.00	0.00	91.36	7.11
			(0.00)	(0.70)	(72.90)	
	S.Em.		0.1539	0.1426	0.9299	-
	C.D. at 5%		0.4474	0.4146	NS	-
	C.D. at 1%		0.6048	0.5605	NS	-

* Mean of three replications

** Figures in parentheses are angular transformed values

*** Figures in parentheses are square root transformed values

(b) Impregnation of jute and cotton bags :

Observations on damaged grains, weight loss and germination of maize grains when kept in jute bags impregnated with different insecticidal solution are presented in Table-26. The data revealed that deltamethrin was more effective in preventing the grains from insect attack as no grain damage could be observed in this treatment even after eight month of storage in an infested storage structure. Next in order of efficacy for reducing the grain damage was fenvalerate, where 0.18 per cent grains were damaged. In bags treated with carbaryl 3.99 per cent grain damage was noticed which was significantly superior than rest of the insecticides used. However, it was inferior than synthetic pyrethroids. Further, methyl parathion, endosulfan and quinalphos were found at par having 5.90, 6.60 and 5.99 per cent grain damage, respectively. Though malathion was found least effective insecticide in which 9.13 per cent grain damage was recorded even then it was significantly superior as compared to untreated check. In untreated check 17.83 per cent grain damage was recorded.

Results obtained on the per cent weight loss of maize grains stored in jute bags impregnated with insecticides are presented in Table-26. The results revealed that in untreated bags 8.98 per cent loss occurred due to infestation of *S. cerealella*, whereas in the bags treated with insecticides, the per cent loss ranged from 0.00 to

4.58 per cent. Since there was no damage of *S. cerealella* in bags treated with deltamethrin no weight loss was observed in this treatment. In bags treated with fenvalerate, carbaryl, quinalphos, methyl parathion, endosulfan and malathion the loss was 0.11, 1.63, 2.51, 2.83, 3.12 and 4.58 per cent, respectively. There were no significant difference between methyl parathion and quinalphos; methyl parathion and endosulfan. Significant difference was observed between malathion and all other insecticides. Malathion was proved as the least effective insecticide and deltamethrin was found the most effective for jute bags impregnation.

Results on viability of maize grains stored in jute bags impregnated with different insecticides are presented in Table-26. The results revealed that insecticide used for impregnation of jute bags had no adverse effect on grain viability even after eight month of storage.

Almost similar results were obtained when paddy grains were kept in jute bags treated with different insecticides and exposed to insect infestation for eight months (Table-28). The data obtained on grain damage revealed that synthethic pyrethroides (deltamethrin and fenvalerate) were found more effective in protecting the paddy grains from the attack of *S. cerealella* as only 0.19 to 0.32 per cent grains were found damaged after eight months of storage. Both these insecticides were superior than other insecticides. Statistically malathion was found to be the least effective insecticide for impregnation of jute bags, but it was better than untreated check in which maximum grain damage of 8.19 per cent was recorded.

Results obtained on the per cent weight loss of paddy grains stored in jute bags treated with insecticides are presented in Table-28. These results revealed that in untreated bags 5.03 per cent weight loss occurred due to infestation of *S. cerealella*, whereas in the bags treated with insecticides, the per cent weight loss ranged from 0.10 to 2.80 per cent. Since there was least damage of *S. cerealella* in bags treated with deltamethrin and fenvalerate negligible weight loss was noticed in these treatment. In bags treated with carbaryl, quinalphos, endosulfan, methyl parathion and malathion, 1.01, 1.12, 1.57, 1.68 and 2.80 per cent weight loss was recorded, respectively. There was no significant difference between deltamethrin and fenvalelaret; carbaryl and quinolphos; endosulfan and malathion. However, significant difference was observed between malathion and all other insecticides used. Malathion was proved as the least effective insecticide and deltamethrin was found the most effective for jute bags impregnation.

Results on viability of paddy grains stored in jute bags impregnated with different insecticides are presented in Table 29. The results revealed that insecticides used for

Table 26 : Per cent grain damage, weight loss and germination of maize grains stored in jute bags impregnated with different insecticides.*

S.N.	Treatments	Concentration (%)	Per cent grain damage **	Per cent weight loss **	Per cent germination **	Benefit Cost ratio
1	Control	Untreated	17.83	8.98	71.67	-
			(24.97)	(7.43)	(57.84)	
2	Malathion	0.10	9.13	4.58	70.00	17.40
			(17.59)	(12.36)	(56.79)	
3	Methyl parathion	0.10	5.90	2.83	69.66	22.51
			(14.06)	(9.69)	(56.58)	
4	Endosulfan	0.10	6.60	3.12	70.00	20.80
			(14.88)	(10.18)	(56.79)	
5	Quinalphos	0.10	5.99	2.51	70.33	10.96
			(14.17)	(9.13)	(56.99)	
6	Carbaryl	0.10	3.99	1.63	71.34	28.83
			(11.53)	(7.35)	(57.63)	
7	Fenvalerate	0.025	0.18	0.11	70.00	42.02
			(2.42)	(1.90)	(56.79)	
8	Deltamethrin	0.025	0.00	0.00	70.35	11.14
			(0.00)	(0.00)	(57.01)	
	S.Em		0.3934	0.2500	0.4925	-
	C.D. at 5%		1.1794	0.7495	NS	-
	C.D. at 1 %		1.6250	1.0327	NS	-

* Mean of three replications

** Figures in parentheses are angular transformed values

Table 27 : Per cent grain damage, weight loss and germination of maize grains stored in cotton bags impregnated with different insecticides.*

S.N.	Treatments	Concentr-ation(%)	Percent ** grain damage	Per cent ** weight loss	Per cent ** germination	Benefit Cost ratio
1	Control	Untreated	14.19	6.81	70.33	-
			(22.13)	(15.13)	(56.99)	
2	Malathion	0.10	7.86	3.58	67.33	12.66
			(16.29)	(10.91)	(55.14)	
3	Methyl parathion	0.10	5.24	2.43	67.33	16.87
			(13.24)	(8.96)	(55.14)	
4	Endosulfan	0.10	5.98	2.76	67.68	15.20
			(14.15)	(9.55)	(55.35)	
5	Quinalphos	0.10	4.03	1.85	68.11	9.41
			(11.58)	(7.82)	(55.62)	
6	Carbaryl	0.10	2.98	1.38	69.36	23.35
			(9.94)	(6.74)	(56.40)	
7	Fenvalerate	0.025	0.00	0.00	69.03	33.78
			(0.00)	(0.00)	(56.19)	
8	Deltamethrin	0.025	0.00	0.00	69.33	8.86
			(0.00)	(0.00)	(56.37)	
	S.Em		0.4086	0.2082	1.0384	-
	C.D. at 5%		1.2249	0.6243	NS	-
	C.D. at 1 %		1.6876	0.8601	NS	-

* Mean of three replications

** Figures in parentheses are angular transformed values

Table 28 : Per cent grain damage, weight loss and germination of paddy grains stored in jute bags mpregnated with different insecticides.*

S.N	Treatments	Concentration (%)	Percent grain damage **	Per cent weight loss **	Pe cent germination **	Benefit Cost Ratio
1	Control	Untreated	8.19	5.03	92.67	-
			(16.63)	(12.96)	(74.30)	
2	Malathion	0.10	4.70	2.80	91.70	5.58
			(12.52)	(9.63)	(73.26)	
3	Methyl parathion	0.10	2.90	1.68	91.12	7.98
			(9.80)	(7.45)	(72.67)	
4	Endosulfan	0.10	2.70	1.57	94.52	8.13
			(9.46)	(7.19)	(76.47)	
5	Quinalphos	0.10	2.05	1.12	92.41	4.55
			(8.23)	(6.06)	(74.01)	
6	Carbaryl	0.10	1.83	1.01	94.10	10.60
			(7.78)	(5.76)	(75.95)	
7	Fenvalerate	0.025	0.32	0.19	92.57	14.99
			(3.22)	(2.51)	(74.19)	
8	Deltamethrin	0.025	0.19	0.10	93.17	4.00
			(2.51)	(1.81)	(74.85)	
	S Em	_	0.2423	0.1295	1.5279	-
	C.D. at 5%	_	0.7265	0.3882	NS	-
	C.D. at 1 %	_	1.0009	0.5349	NS	-

* Mean of three replications

** Figures in parantheses are angular transformed values

Table 29 : Per cent grain damage, weight loss and germination of paddy grains stored in cotton bags impregnated with different insecticides.*

S N	Treatments	Concentration (%)	Percent grain damage *	Per cent weight loss **	Per cent germination **	Benefit Cost ratio
1	Control	Untreated	7.20	3.91	95.34	-
			(15.56)	(11.40)	(77.54)	
2	Malathion	0.10	3.50	1.80	92.35	5.92
			(10.78)	(7.71)	(73.95)	
3	Methyl parathion	0.10	2.82	1.56	95.03	6.61
			(9.66)	(7.18)	(77.12)	
4	Endosulfan	0.10	2.97	1.50	94.73	6.26
			(9.92)	(7.03)	(76.73)	
5	Quinalphos	0.10	2.65	1.10	94.34	3.37
			(9.37)	(6.02)	(76.24)	
6	Carbaryl	0.10	1.68	0.91	93.47	9.20
			(7.45)	(5.47)	(75.20)	
7	Fenvalerate	0.025	0.20	0.10	95.37	13.33
			(2.56)	(1.81)	(77.58)	
8	Deltamethrin	0.025	0.00	0.00	94.70	3.50
			(0.00)	(0.00)	(76.70)	
	S.Em		0.2954	0.0789	0.9297	-
	C.D. at 5%		0.8857	0.2364	NS	-
	C.D. at 1 %		1.2202	0.3258	NS	-

* Mean of three replications

** Figures in parentheses are angular transformed values

impregnation of jute bags had no adverse effect on grain viability even after eight month of storage.

More or less similar results were obtained on damage, weight loss and germination of maize and paddy grains when stored in cotton bags impregnated with these insecticides (Table 27 and 29).

(c) Vegetable oils :

The data obtained on the effect of different vegetable oils on the grain damage by *S. cerealella*, adult emergence and germination of maize grains depicted in Table-30 revealed that all the treatments were significantly effective in protecting the maize grains from the attack of *S. cerealella*. No damage could be observed when neem oil was mixed with the grains @ 1 ml/100 g of grains. It was followed by mustard, sesame, coconut and groundnut oil @ 1 ml/100 g of grains, where grain damage was 0.16, 0.49, 0.79 and 3.10 per cent, respectively. However, no significant different among these treatments could be observed.

At the lower doses tested (0.5 ml oil/100 g of grains) neem oil again proved as the best treatment and was found significantly superior than other treatments. The ranking order of efficacy was neem oil (0.79%) > sesame oil (0.91%) > mustard oil (1.16%) > coconut oil (5.53%) > ground nut oil (9.55%).

Table 30 : Effect of Vegetable oils on the damage due to *S.cerealella*, adult population and germination of maize grains.*

S.N.	Vegetable Oil	Dose per 100 g of seed	Per cent ** Grain damage	Adult Population (NO.) ***	Per cent ** germination	Benefit Cost ratio
1	Control	Untreated	43.35	291.35	70.68	-
			(41.18)	(17.08)	(57.22)	
2	+Coconut	0.5ml	5.53	27.96	24.90	6.75
			(13.60)	(5.33)	(29.93)	
3	+Coconut	1.0ml	0.71	10.98	0.00	3.80
			(4.82)	(3.39)	(0.00)	
4	Groundnut	0.5ml	9.55	31.28	41.00	10.56
			(18.00)	(5.64)	(39.81)	
5	Groundnut	1.0ml	3.10	11.91	30.66	6.29
			(10.15)	(3.52)	(33.62)	
6	Mustard	0.5ml	1.16	6.28	33.32	12.05
			(6.18)	(2.60)	(35.26)	
7	Mustard	1.0ml	0.16	2.65	21.64	6.17
			(2.26)	(1.77)	(27.72)	
8	Neem	0.5ml	0.79	3.90	54.67	14.19
			(5.11)	(2.10)	(47.68)	
9	Neem	1.0ml	0.00	0.00	32.65	7.23
			(0.00)	(0.70)	(34.85)	
10	Sesame	0.5ml	0.91	10.33	35.98	11.17
			(5.47)	(3.29)	(36.86)	
11	Sesame	1.0ml	0.49	3.32	22.33	5.64
			(4.00)	(1.95)	(28.18)	
	S.Em.		1.8373	0.1796	0.8560	-
	C.D. at 5%		5.3887	0.5269	2.5106	-
	C.D. at 1%		7.3242	0.7161	3.4123	-

* Mean of three replications

** Figures in parentheses are angular transformed values

*** Figures in parentheses are square root transformed values

\+ Effect of laboratory extracted coconut oil on germination

Coconut oil - 1 ml/100 g grains - 23.5 % germination

Coconut oil - 0.5 ml/100 g grains - 36.5 % germination

The observations recorded on the number of adults emerged after eight moths of storage are presented in Table-30. As there was no damage to grains treated with neem oil @ 1 ml/100 g of grains, no adult could emerge in this treatment. In rest of the treatments the mean number of adults emerged varied from 2.65 to 31.28. In untreated check the mean number of adults emerged was 291.35.

Grains treated with different vegetable oils showed poor germination as compared to control (Table-30). In untreated check the germination was 70.68 per cent. The germination in all the treatments reduced significantly as compared to untreated check. NO seed could germinate when treated with coconut oil @ 1 ml/100 g of grains.

In **paddy** more pronounced effect of these oils was observed (Table-31). The results indicated that all the treatments were effective and were found superior than untreated check in controlling the grain damage caused by angoumois grain moth. Hundred per cent grain protection was recorded in grains treated with coconut, groundnut, mustard, neem and sesame oil @ 1 ml/100 g of grains. The lower concentrations (0.5 ml/100 g of grains) of coconut, groundnut and sesame oils were also effective exhibiting 0.27, 0.23 and 0.10 per cent damage, respectively. Neem and mustard oil even at lower concentration resulted cent per cent protection to paddy grains. The highest grain damage (7.75) was recorded in untreated check.

As a matter of fact no emergence of adult could be observed in treatments where cent per cent grains were protected.

At lower dose (@ 0.5 ml/100 g of grains), the mean adult population of 19.65, 12.61 and 5.27 was obtained from the grains treated with coconut, groundnut and sesame oil, respectively. In untreated check the highest mean adult population of 310.72 was recorded after the eight months of storage.

Significant adverse effect on germination was observed when the paddy grains were mixed with different vegetable oils in order to protect them against the damage of *S. cerealella* (Table-31). Germination was completely inhibited when paddy grains were treated with coconut oils @ 1 ml/100 g grains, whereas it was reduced to almost 50 per cent in lower dose (0.5 ml/100 g of grains). The higher concentrations of oil treatments had more adverse effect on germination than lower concentrations. Highest germination 81.82 per cent was recorded in groundnut oil followed by sesame oil (80.13%), mustard oil (67.67%), neem oil (63.08%) and coconut oil (50.33%) when mixed @ 0.5 ml/100 g of grians. In untreated check it was 93.27 per cent which was significantly superior than all the treatments.

As described earlier all the oils used (except neem oil) were purchased from local oil expellers. The coconut

Table 31 : Effect of vegetable oils on the damage due to *S.cerealella*, adult population and germination of paddy grains. *

S.N.	Vegetable oils	Dose per 100 g of seed	Per cent ** grain damage	Adult Population(NO.) ***	Per cent ** germination	Benefit Cost ratio
1	Control	–	7.75 (16.17)	310.72 (17.64)	93.21 (74.90)	–
2	+Coconut	0.5ml	0.27 (2.99)	19.65 (4.49)	50.33 (45.19)	1.06
3	+Coconut	1.0ml	0.00 (0.00)	0.00 (0.70)	0.00 (0.00)	0.55
4	Groundnut	0.5ml	0.23 (2.76)	12.61 (3.62)	81.82 (64.76)	1.88
5	Groundnut	1.0ml	0.00 (0.00)	0.00 (0.70)	50.33 (45.19)	0.96
6	Mustard	0.5ml	0.00 (0.00)	0.00 (0.70)	67.67 (55.35)	1.77
7	Mustard	1.0ml	0.00 (0.00)	0.00 (0.70)	47.33 (43.47)	0.88
8	Neem	0.5ml	0.00 (0.00)	0.00 (0.70)	63.08 (52.58)	2.06
9	Neem	1.0ml	0.00 (0.00)	0.00 (0.70)	30.64 (33.61)	1.03
10	Sesame	0.5ml	0.10 (1.79)	5.27 (2.40)	80.13 (63.53)	1.61
11	Sesame	1.0ml	0.00 (0.00)	0.00 (0.70)	35.31 (36.46)	0.81
	S.Em.					
	C.D. at 5%	–	0.1280	0.2815	1.6827	–
	C.D. at 1%	–	0.3755	0.8257	4.9352	–
		–	0.5104	1.1223	6.7078	–

* Mean of three replications

** Figures in parentheses are angular transformed values

*** Figures in parentheses are square root transformed values

+ Effect of laboratory extracted coconut oil on germination

Coconut oil - 1 ml/100 g grains - 0.00 % germination

Coconut oil - 0.5 ml/100 g grains - 50.00 % germination oil, however, due to its non-availability with the expellers, was purchased from the market. This oil brand (Parachute) is basically used as hair oil. Hence, it was thought that due to some solvent used in Parachute oil, the germination was reduced. Therefore, in an another experiment the coconut oil was extracted in the laboratory and mixed with the grains. At the end of expriment it was observed that in maize the germination was 36.5 and 23.5 per cent in 0.5 ml and 1.0 ml/100 g of grains, respectively. In paddy again at the dose of 1 ml/100 g of grains no grain could germinate. The role of solvent, there, may be questionable and requires further investigation but it is clear that coconut oil has definite detrimental effect on germination. In paddy, however, it is more pronounced.

(d) Other plant products :

The result presented in Table-32 revealed that on the basis of maize grain damage after eight month of storage, neem kernel powder @ 2 g/100 g of grains was significantly superior than rest of the treatments. The lowest grain damage (2.13%) was recorded in neem kernel powder @ 2 g/100 g of grains followed by nemm leaf powder @ 2g/100g of grains. These treatments were found significantly superior to rest of the treatments. The lantana leaf proved least effective even in higher dose, but was found significantly superior over control. The order of effectiveness of plant

Table 32 : Effect of different plant products on the damage due to *S.cerealella*, adult population and germination of maize grains.*

S.N.	Plants products	Doses per 100g seed (wt/wt)	Percent ** grain damage	Adult Population (No.)***	Per cent ** germination
1	Control	Untreated	59.96 (50.75)	529.87 (23.02)	71.00 (57.42)
2	Neemleaf	1.00	4.91 (12.81)	44.29 (6.69)	69.34 (56.38)
3	Neemleaf	2.00	3.10 (10.14)	24.99 (5.04)	70.01 (56.80)
4	Neemkernel	1.00	4.01 (11.56)	33.30 (5.81)	70.00 (56.79)
5	Neemkernel	2.00	2.13 (8.40)	21.29 (4.66)	69.33 (56.37)
6	Eucalyptus leaf	1.00	6.90 (15.32)	59.50 (7.74)	69.33 (56.37)
7	Eucalyptus leaf	2.00	4.08 (11.66)	32.65 (5.76)	69.68 (56.59)
8	Sarifa leaf	1.00	17.48 (24.71)	151.33 (12.29)	69.00 (56.17)
9	Sarifa leaf	2.00	9.19 (17.65)	81.33 (9.01)	69.33 (56.37)
10	Lantana leaf	1.00	21.62 (27.71)	169.33 (13.01)	69.33 (56.37)
11	Lantana leaf	2.00	12.82 (20.98)	99.60 (9.97)	69.67 (56.58)
	S.Em.		0.4540	0.3034	0.4512
	C.D. at 5%		1.3316	0.8899	NS
	C.D. at 1%		1.8109	1.2090	NS

* Mean of three replications

** Figures in parentheses are angular transformed values

*** Figures in parentheses are square root transformed values

products were neem kernel > neem leaf > eucalyptus > sarifa leaf > lantana leaf.

Results on adults emerged from the grain admixed with different plant products showed significant difference when compared with the control (Table-32). The mean number of adults emerged ranged from 21.29 to 169.33 in different treatments as against 529.87 adults in untreated check. Minimum number of adults emerged in grain treated with neem kernel powder @ 2 g/100 g of grains. Lantana leaf powder was found to be the least effective. The order of effectiveness was neem kernel > neem leaf > eucalyptus leaf > sarifa leaf > lantana leaf.

The effect of these plant products on germination was also studied by adopting standard germination test in the laboratory and the results are presented in Table-32. The data revealed that there was no significant difference in germination due to mixing of plant products with the maize grains. The germination ranged from 69.00 to 71.01 per cent in different treatment as against 71.00 per cent in control.

In paddy the results showed almost similar trend as obtained in the case of maize (Table-33). The minimum damage to grain by *S. cerealella* was recorded in neem kernel powder when mixed @ 2 g/100 g of grains. No significant difference could be observed in neem kernel powder @ 2 g/100 g of grains and neem leaf powder at the same dose. The order of

Table 33 : Effect of different plant products on the damage due to *S.cerealella*, adult population and germination of paddy grains. *

S.N.	Plant products	Doses per 100g seed (wt/wt)	Percent grain damage *	Adult Populations (No.) ***	Per cent germination **
1	Control	Untreated	10.89 (19.27)	430.83 (20.77)	92.02 (73.59)
2	Neemleaf	1.00	1.25 (6.44)	45.97 (6.81)	91.34 (72.89)
3	Neemleaf	2.00	0.63 (4.55)	22.65 (4.81)	91.71 (73.26)
4	Neemkernel	1.00	1.09 (5.99)	38.66 (6.26)	91.11 (73.65)
5	Neemkernel	2.00	0.60 (4.430	20.99 (4.64)	90.37 (71.92)
6	Eucalyptus leaf	1.00	1.95 (8.03)	68.32 (8.30)	91.38 (72.92)
7	Eucalyptus leaf	2.00	0.78 (5.08)	29.99 (5.25)	90.69 (72.23)
8	Sarifa leaf	1.00	2.23 (8.59)	81.63 (9.06)	92.38 (73.98)
9	Sarifa leaf	2.00	1.18 (6.23)	42.00 (6.52)	92.02 (73.59)
10	Lantana leaf	1.00	2.55 (9.18)	88.33 (9.43)	91.07 (72.61)
11	Lantana leaf	2.00	1.24 (6.38)	45.97 (6.82)	90.70 (72.25)
	S.Em.		0.1115	0.2097	0.9036
	C.D. at 5%		0.3269	0.6150	NS
	C.D. at 1%		0.4443	0.8359	NS

* Mean of three replications

** Figures in parentheses are angular transformed values

*** Figures in parentheses are square root transformed values

effectiveness was neem kernel powder > neem leaf powder > eucalyptus leaf powder > sarifa leaf powder > lantana leaf powder.

Results on the number of adults emerged from treated and untreated samples showed significant difference (Table-33). The maximum moth population of 430.83 was recorded in control, whereas it was found minimum (20.99) in the paddy grains treated with neem kernel powder @ 2 g/100 g of grains. It was followed by the neem leaf powder @ 2 g/100 g of grains where 22.65 adults emerged. Both these treatments were significantly superior to rest of the treatments. The order of effectiveness was neem seed kernel powder > neem leaf powder > eucalyptus leaf powder > sarifa leaf powder > lantana leaf powder.

No significant difference was found in germination among the treatments and untreated check (Table-33).

III. ASSESSMENT OF LOSSES IN STORAGE STRUCTURES :

Though several varieties of maize and paddy are in vouge in different parts of the Rajasthan, mostly Malan, Mahikanchan, Ganga-5, Sathi, Bassi, Adanga, Kiran of maize and Bala, Cauveri, Ratna, Jaya, Kamod, Akashi Pusa.2-21, BK-79, BK-190, Chambel, Dagar, Mahisugandha and Jalzera of paddy varieties were found very common in the state. Paddy varieties viz., Safri-17, Kranti, Dubraj, Gurmatiya, Ruchi, Ganga safri, Masuri etc. were commonly found in Raipur district of Madhya Pradesh where the losses in storage due to *S. cerealella* were also worked out.

Moisture content of the grain plays an important role in deterioration of the stored produce. The moisture content of grains samples from different storage conditions was, therefore, determined in the laboratory. The data collected are presented in Table 34 and 35.

The moisture content of **maize grains** ranged from 11.17 to 13.05 per cent in different storage structures at the time of collection (June-July). The grains stored in mud bins had higher moisture (13.05%) than other storage structures. The grains stored in pakki kothies had minimum moisture (11.71%). In jute bags and loose storage the moisture content was recorded 11.91 and 12.97 per cent, respectively.

In **paddy grains** stored in different storage condition, the moisture content ranged from 11.99 to 13.63 per cent (Table-35). The grains stored in kachchi kothi (mud structure) had higher moisture (13.63%) than other storage structures. The moisture content was minimum (11.99%) in pakki kothi. In jute bags and loose storage conditions the moisture content was recorded 12.31 and 13.10 per cent, respectively.

(a) Grain damage :

The per cent grains damage caused by *S. cerealella* to maize was recorded on the basis of visible symptoms and internal infestation. It is evident from data (Table-34) that maximum grain damage (16.70%) was in maize grains when stored in 'kachchi kothi'. In the grains stored in jute bags 11.92 per cent damage was recorded, whereas 15.19 per cent damage was observed in loose storage. Minimum grain damage (10.01%) was recorded in grains which were stored in 'pakki kothi.'

Similarly, in paddy the maximum (18.31 %) grain damage was recorded in 'kachchi kothi' (Table-35). In loose storage and jute bags the grain damage was 16.87 and 11.20 per cent, respectively. Minimum grain damage (10.12%) was found in 'pakki kothi.'

(b) Weight loss :

The weight loss of maize grains due to infestation of *S. cerealella* was calculated for different types of storage conditions (Table-34). The grains stored in 'pakki kothi' suffered minimum with weight loss of 3.69 per cent, whereas maximum weight loss of 9.1 per cent was found in 'kachchi kothi.' The loss in grain weight in loose storage and jute bags was 8.15 and 4.26 per cent, respectively.

In paddy like maize the per cent grain weight loss was recorded minimum (4.1%) in 'pakki kothi'. The grain stored in

Table 34 : Assessment of losses in **maize** grains stored under different storage structures.

Storage structures	Moisture content(%)	Grain damage (%)	Weight loss (%)	Germination (%)
1. Jute bags	11.91	11.82	4.26	74.66
	(20.16)	(20.09)	(11.90)	(59.83)
2. Kachchi kothi	13.05	16.70	9.10	69.33
(mud structure)	(21.17)	(24.11)	(17.52)	(56.40)
3. Pakki kothi	11.17	10.01	3.69	77.33
	(19.50)	(18.40)	(11.05)	(62.20)
4. Loose storage	12.70	15.19	8.15	70.66
	(20.86)	(22.92)	(16.57)	(57.21)
S.Em.	0.37	0.40	0.29	2.83
C.D. at 5 %	1.07	1.18	0.83	NS

Note : Figures in parentheses are angular transformed values

Table 35 : Assessment of losses in **paddy** grains stored under different storage structures.

Storage structures	Moisture content(%)	Grain damage (%)	Weight loss (%)	Germination (%)
1. Jute bags	12.31	11.20	4.69	90.33
	(20.53)	(19.54)	(12.46)	(72.08)
2. Kachchi kothi	13.63	18.31	8.62	84.33
(mud structure)	(21.66)	(25.31)	(17.06)	(66.88)
3. Pakki kothi	11.99	10.12	4.10	91.66
	(20.24)	(18.50)	(11.66)	(73.55)
4. Loose storage	13.10	16.87	7.68	87.90
	(21.20)	(24.34)	(16.07)	(69.70)
S. Em.	0.30	0.38	0.31	2.10
C.D. at 5 %	0.87	1.09	0.89	NS

Note : Figures in parentheses are angular transformed values loose and jute bags exhibited 7.68 and 4.69 per cent loss. Maximum loss of 8.62 per cent was recorded in 'kachchi kothi.'

(c) Effect on germination :

The viability of the grains stored in various conditions was also tested. The germination of maize grains (seeds) varied from 69.33 to 77.33 per cent. Maximum viability (77.33%) was recorded in grains stored in 'pakki kothi' and minimum in 'kachchi kothi' (Table-34). The grains stored in jute bags and loose storage exhibited 74.66 and 70.66 per cent germination, respectively.

Almost similar results were obtained in paddy. Maximum germination (91.66%) was recorded in grains stored in 'pakki kothi' followed by jute bags (90.33%). The grains stored in loose storage exhibited 87.90% germination. Minimum germination was recorded in the grains stored in the 'kachchi kothi' (Table-35).

DISCUSSION

Maize (*Zea mays* L.) and Paddy (*Oryza sativa* L.) are widely grown in Rajasthan in the areas of sufficient rainfall or irrigation. The stored maize and paddy are liable to be attacked by a number of stored insect pests. Out of which Angoumois grain moth, *S.cerealella* (Olivier) has been reported to be the serious one. The results obtained under the present investigation on the bioecology and management of *S.cerealella* on stored maize and paddy are discussed in this chapter.

Temperature is an important component of the environment and the rate of metabolism, growth, development, reproduction, general behaviour and distribution of insect pests are largely controlled by it. The effect of humidity on the development of storage pest is almost intimately associated with that of temperature and operates indirectly through the moisture content of grains. The results under the present studies indicated that the fecundity of the female was increased with the increase of temperature from 20 to 30°C ; the maximum being at 30°C. Further increase in temperature to 35°C resulted in the drastic reduction of the fecundity. In both the cereals similar trend was found. Similarly the survival and rate of the development of *S.cerealella* increased with the temperature from 20 to 30°C but at 35°C decrease in the rate of development and survival was observed. Maximum hatching was, however, recorded at 25°C in both the commodities under study. Longevity increased with the decrease of temperature.

On the other hand the increase of relative humidity from 50 to 80 per cent increased the fecundity, hatching, rate of development, longevity and survival of the pest in both maize and paddy. Higher humidity has also been reported favourable to this pest by Pingale et al. (1967).

The combined effect of temperature and relative humidity revealed that the temperature range of 25-30°C and relative humidity range of 70-80 per cent were found most favourable for the activity of *S.cerealella*. Within this range the combination of 25°C with 80 per cent relative humidity was found most favourable for fecundity and per cent hatching whereas, the combination of 30°C and 80 per cent relative humidity favoured the rate of development and survival of the pest in both the cereals.

As most of the work has been done on cereals other than paddy, the results obtained here on paddy are not directly comparable. However, in maize the results are in agreement with the findings of Grewal and Atwal (1969), Singh and Khare (1993). Shazali and Smith (1985) and Boldt (1974) while working on sorghum and wheat also obtained more or less similar results.

Comparing the fecundity and rate of development of *S.cerealella* on two cereals i.e. maize and paddy under the present investigation, it was observed that average number of eggs laid by a single female was more on maize (198.49) than paddy (109.23), the speed of development was, however, faster on paddy (20.72 days) than maize (28.05 days) at the most favourable combination of 30°C and 80 per cent relative humidity. It clearly indicated that paddy was favoured over maize by the *S.cerealella*. Khare and Agarwal (1963) reported that maize grains being big in size were preferred over wheat by *Sitophilus oryzae* and *Rhizopertha domonica*. In the case of *S.cerealella* this contention does not hold true. Although, the eggs laid on maize grains were more than paddy but the speed of development was, however, faster on paddy than maize. Therefore, it is evident that preference of *S.cerealella* goes to paddy and the size of the grain has no role in deciding the preference. According to Singh and Khare (1993) the preference of *S.cerealella* was for sorghum when compared with maize. Therefore, it is not the size of the grain but probably is the nutritional value which decides the preference.

In varietal screening or evaluation, difficulty is often encountered in grouping the varieties under least susceptible, moderately susceptible and susceptible categories on the basis of their relative performance. Heinrichs et al. (1985) categorised the paddy varieties into three groups - resistant, moderately resistant and susceptible on the basis of survival percentage of *S.cerealella.* According to them the varieties in which 0 to 10 per cent survival was found were identified as resistant whereas varieties permitting 10 to 20 per cent survival were considered moderately resistant. More than 20 per cent survival was taken as detrimental to the paddy grains and hence varieties allowing more than 20 per cent survival were considered as susceptible. Several other workers have screened the paddy varieties on the basis of one or more parameters like grain damage, adult emergence, susceptibility index etc. but most of them have not logically categorised the varieties into susceptible or resistant groups and if categorised, the basis of their categorisation was either arbitrary or as per their own convenience. In such type of studies invariably more varieties appear resistant than actually are. More-over, with one or two parameters and lesser number of test varieties, the actual reaction of varieties can not be expressed.

In the present investigation, therefore, all possible parameters viz., grain damage, emergence of adults, grain weight loss, adult survival percentage and susceptibility index were taken into consideration and efforts were made to categories the varieties on the basis of interrelationship of these parameters.

Prakash et al. (1983) screened different paddy varieties on the basis of grain damage and number of adults emerged. According to them the varieties having 1 per cent or less unavoidable grain damage and 1 or less than 1 average adult emergence were scored as resistant and rest were considered as susceptible. No further grouping was done. No efforts have been made for grouping of varieties on the basis of grain weight loss and susceptibility index.

The results obtained under the present investigation revealed that on the basis of criterion adopted by Heinrichs et al. (1985) Bala, Pusa.2-21 and Cauveri were the paddy varieties in which survival percentage of *S.cerealella* was recorded below 10 per cent and, therefore, these were identified as least susceptible (Table 15). It is interesting to note that in these varieties the grain damage was recorded up to 1 per cent and average number of adults emerged was also below one. These varieties, therefore, very well fit in the criteria used by Prakash et al. (1983) and Heinrichs et al. (1985) for resistant category. Similarly 12 varieties were found to have survival percentage ranging from 10.09 to 16.63. According to Heinrichs et al. (1985) varieties having survival percentage 10 to 20 were grouped under moderately susceptible. Now if the grain damage and adult emergence are taken into consideration it will be observed that these varieties fall under a distinct group having grain damage ranging from 3.32 to 5.97 per cent so also the average adult emergence from 3.32 to 5.97. Same situation is viewed when other parameters such as per cent loss in grain weight and susceptibility index are taken into consideration. Therefore, there should be no hesitation in putting all these varieties under moderately susceptible group.

In the present investigations, therefore, paddy varieties having grain damage, upto 1 per cent, average adult emergence, up to 1, adult survival up to 10 per cent, loss in grain weight up to 1 per cent and susceptibility index below 8, were identified as least susceptible varieties. The varieties showing more than 1 to 6 per cent grain damage, more than 1 to 6 average adult emergence, more than 10 to 20 per cent adult survival, more than 1 to 3 per cent grain weight loss and 8 to 12 susceptibility index were considered moderately resistant. Rest of the varieties having higher values than the moderate group were considered as susceptible.

Based on the above discussion the different paddy varieties screened under the present investigation, were categorised as under :-

Least susceptible :- Bala, Pusa.2-21 and Cauveri

Moderately susceptible :- IR-54, Safri-17, R296-128, Kranti, IR-36, Phalguna, Poorva, R 574-11, Jaya, Annada, Swarna and Surekha.

Susceptible :- Madhuri selection-11, BK-190, Ratna, Basmati-370, Masuri, BK-79, Dubraj, Chamble, Mahisugandha, Kalimuchh.

Bala has been reported to have moderate resistant by Chatterjee et al. (1977) and Khare and Johari (1979). However, Uttam et al. (1984) identified this variety as least susceptible. On the basis of several parameters taken under present investigation Bala was found to be the least susceptible thus confirming the observations of Uttam et al. (1984). Similarly Cauveri and Pusa.2-21 were found least susceptible as reported by Chellappa and Chelliah (1976), Uttam et al. (1984) and Prakash and Rao (1993). However, Khare and Johari (1979) considered Cauveri as moderately susceptible on the basis of adult emergence and developmental period. On what logical basis the varieties have been grouped by Khare and Johari (1979) is not clear.

Jaya, Surekha and Safri-17 were found moderately susceptible during the present investigation. The results are in conformity with the findings of Chatterjee et al. (1977), Upadhyay et al. (1979) and Uttam et al. (1984). The results, however, failed to confirm the findings of Abraham et al. (1972), Khare and Johari (1979) and Prakash et al. (1983) who reported Jaya as susceptible variety. Ratna Basmati-370, Swarna, Madhuri, Dubraj and Masuri were found susceptible as reported by earlier workers (Chellappa and Chelliah, 1976; Khare and Johari, 1979., Upadhyay et al.

1979; Prakash et al. 1983; Uttam et al. 1984 and Prakash and Rao, 1993).

Unfortunately, in maize no valid justification has been given by the previous workers to categories the variety into resistant or susceptible groups. Mathur and Gupta (1973) reported maize varieties Jawahar, Vikram, Sona, Ganga-5 as most resistant and Ganga-7 as highly susceptible. On the contrary Pandey and Pandey (1982) categorised Jawahar, Vikram, Sona, Ganga-5 and even Ganga-7 in the moderate group in spite of the fact that these workers based their findings on the same parameter i.e. loss in grain weight. Acharyulu and Chaudhary (1992) while screening some maize inbred lines regarded those inbred lines resistant which had 20 per cent kernel infestation. In addition, based on loss in grain weight due to *S.cerealella* they considered those inbred lines resistant which had loss in grain weight up to 3 per cent. If this criterion is taken into consideration then all the varieties screened by Mathur and Gupta (1973) and most of the varieties screened by Pandey and Pandey (1982) become resistant which is difficult to admit. Such type of contradictory results are obtained simply due to lack of uniformity and standardization.

In the present investigation, therefore, similar to paddy, in maize also the grain damage up to 1 per cent was taken as unavoidable loss and maize varieties having up to 1 per cent grain damage due to feeding of *S.cerealella* were identified as least susceptible. Further if these varieties are judged on the basis of loss in grain weight, adult emergence, survival percentage and susceptibility index then also they come under least susceptible group. Therefore, the criteria fixed for different parameters in the screening of the paddy varieties were adopted in the screening of maize varieties also except the susceptibility index which was taken up to 6 in maize. The reason for this was that developmental period of *S.cerealella* prolonged in maize which affected the susceptibility index.

On the basis of above discussion the maize varieties therefore, were categorised as under :-

Least susceptible - Surya, Ageti-76 and CM-111

Moderately susceptible - D-765, Harsh, Dhawal and Diara-3

Susceptible - Kisan, Arun, Renuka, Prabhat, MCU-508, Devki, Hement, Malan, Aswani, Laxmi, Vikram, NLD, Mahikanchan, Pusa-I, CM- 501, Pusa-II, VL-88 and Madhuri.

Kisan and Arun, however, behaved differently when studied on the basis of these parameters. Based on grain damage and adult emergence, these were categorised under moderate group but on the basis of survival percentage of adults, loss in grain weight and susceptibility index these fell into susceptible group. But it was evident that these varieties can not be considered as least susceptible.

The mechanism of resistance is a complicated phenomenon because a number of physical and bio-chemical factors are involved in it. In the present investigation efforts have been made to explain the basis of differential susceptibility of maize and paddy varieties against *S.cerealella* by studying a number of physical and biochemical factors and correlating them with the susceptibility /resistance.

The **husk thickness** has been reported to have a significant negative correlation with the susceptibility of paddy varieties to *S.cerealella* by a number of workers (Upadhyay et al., 1979; Prakash et al., 1983; Ragumoorthy and Gunthaligaraj, 1988; Anuradha et al., 1989 and Takeshita and Imura, 1990). More or less similar results, were obtained under the present investigation. In maize also the thickness of the pericarp and seed coat was found negatively correlated with the susceptibility of maize to *S.cerealella.* As no work has been done in maize on this aspect, the results could not be compared.

Hardness of the seed seems to be an important physical character contributing a major share in imparting resistance/susceptibility to a variety. A number of workers Samual and Chatterjee, 1953; Rout et al., 1976; Sudhakar and Pandey, 1981; Pandey and Pandey, 1982; Sudhakar and Pandey, 1982; Prakash et al., 1983; Ragumoorthy and Gunthaligaraj, 1988; Anuradha et al., 1989 and Prakash and

Rao, 1993) have amply documented this fact. In the present investigation also a negative correlation of hardness was obtained with the different parameters studied in both the cereals.

Among the biochemical factors the effect of amylose, proteins, free amino acids, silica and ash content of paddy husk and oil content of grains on the varietal susceptibility was studied under the present investigation.

Peters et al. (1960., 1972 abc) reported higher **amylose** content **in resistant varieties of corn than the susceptible** varieties. Similarly, in paddy, Kittur and Patel (1972) and Ragumoorthy and Gunthaligaraj (1988) also recorded higher amylose content in resistant varieties. Although Abraham et al. (1972) observed no relationship between amylose content and infestation of rough rice by *S.cerealella.*, but reported that in the most susceptible variety, Tainan-3, amylose content was lowest. Chatterjee et al., (1977) did not find any significant relationship between the extent of damage to rough rice by *S.cerealella* and amylose content. Prakash and Rao (1993) also could not observe significant correlation between amylose content and susceptibility index, however, they recorded comparatively higher amount of amylose in resistant varieties of paddy.

In the present studies a significant negative correlation was observed between amylose content and the percent grain damage, adult emergence, per cent loss in grain weight, per cent survival of adults and susceptibility index.

As grains of maize with higher amylose content have been reported harder than grains with lower amylose content by Peters et al. (1960), it may be concluded that amylose is responsible for imparting hardness to the grains which in turn probably results in lesser grain damage, lesser loss in grain weight and lower adult emergence, making the variety least susceptible.

Low protein content has been observed to contribute resistance to rough rice against *S.cerealella,* but relationship was not distinct (Chatterjee et al., 1977). Rout et al., (1976) did not find any consistency in relationship between protein content and susceptibility of *S.oryzae* in paddy. However, Pandey and Pandey (1978 and 1982) reported a positive relationship between protein content and damage by *S.cerealella* to maize. Anuradha et al. (1989) also reported positive correlationship of protein content of paddy with susceptibility index. The present investigation also revealed a positive correlation of protein content with all the parameters studied. The low protein content of the grains probably had a detrimental effect on the development of *S.cerealella* as the grains are unable to provide optimum protein requirement to the insect.

Susceptibility of varieties has also been related to the higher concentration of total and free amino acids (Pandey and Pandey, 1978 and Sudhakar and Pandey, 1981). Pandey and Pandey (1978) found ten essential amino acids in susceptible varieties of maize whereas, only eight essential amino acids could be identified in Jaunpuri, the least susceptible variety. In field crops also susceptible varieties have been reported to contain higher number of amino acids than resistant varieties (Auclair, et al., 1957; David and Paul, 1973; Chelliah and Sambandam, 1973). In the present investigation a positive significant correlation was found between the concentration of free amino acid and susceptibility of maize and paddy varieties. It may therefore, be concluded that lower concentration of amino acids in least susceptible maize and paddy varieties probably did not fulfil the nutritional requirements of *S.cerealella* thus resulting in antibiosis.

Significant negative correlation between Silica content of the husk and the degree of infestation of *S.cerealella* in paddy has been documented by Sriramulu and Subramanyam (1981), Prakash et al. (1983) and Anuradha et al. (1989). Not only this the higher silica content of the husk has also been reported imparting resistance to other pests such *R.dominica* and *S.oryzae* infesting paddy (Suzuki and Juliano, 1975 and Prakash et al., 1981). On the other hand, Prakash and Rao (1992) obtained a non significant correlation-ship between silica content of husk and susceptibility of *S.cerealella*. The present studies, however, could not confirm the findings of Prakash and Rao (1992) as a significant negative correlation of silica content of husk was found not only with the susceptibility index but also with the other parameters studied. Whether it is the hardness of the husk contributed by silica or it is abrasive action of silica exerted on the insect integument which checks the insect activities, remains unclear.

Similar to silica content of husk the ash content was also more in least susceptible varieties of paddy, and a negative significant correlation was established with the different parameters under the present studies as reported by Anuradha et al. (1989) and Pandey and Pandey (1983). Since there is direct relation between silica and ash content of the husk, it may be inferred than higher ash content is the indication of higher silica in the husk and therefore, the varieties having high ash content were least susceptible. The present finding could not confirm the findings of Sudhakar et al. (1989) where they reported a negative correlation between ash content and mean developmental period.

In maize, very low level of ash content was recorded which had no significant correlation with the parameters studied. The results are in agreement with the work of Pandey and Pandey (1983).

Contradictory reports are available regarding the relation of oil with the developmental period of *S.cerealella*. According to Peters *et al.* (1972 b) the maize varieties having higher fat content prolonged the developmental period of *S.cerealella*. Pandey and Pandey (1983), however, reported that correlation coefficient of oil content with growth index was not significant. In the present investigation a significant negative correlation of oil contents of maize and paddy varieties with grain damage, adult emergence, loss in grain weight, survival percentage of adults was obtained which confirmed the findings of Peters et al. (1972 b).

The oil content in grain, seems to be an important factor for imparting resistance or susceptibility to maize and paddy varieties against *S.cerealella* due to two reasons, firstly that it has positive correlation with amylose ; the increase in oil content also increases the amylose content of grains which imparts hardness to the grains. Secondly higher oil content may have some detrimental effect on the growth of the insect because of presence of various compounds in the oil fractions of the kernels.

Losses of serious dimensions due to damage and deterioration by insect pests of maize and paddy in storage, have been reported by various worker under normal conditions of grain storage. Maize and paddy are damaged to a great extent mainly by *S.cerealella* (Olivier). In order to minimise the loss caused by this pest, safe storage of these cereals with suitable and safe grain protectants, can be highly rewarding. The results obtained during the present investigation on the effectiveness of different grain protectants are discussed in the following paragraphs.

A number of synthetic insecticides have been reported as grain protectants against storage insects under both normal and controlled conditions (Mammen et al., 1968; Mc Gaughey, 1973; Rai, 1977; Prakash et al., 1981, 1983, 1984 and 1987). Many of the conventional insecticides like DDT, BHC, aldrin have been discarded due to their objectionable residues or development of resistance by the insect pests. The synthetic pyrethroides which are the late comers in the pest control scenario required very low doses of application and are quickly degraded, leaving no harmful residue in the treated materials. Therefore, during the present investigation the efficacy of fenvalerate along with low persistence insecticides was studied for the protection of maize and paddy grains. The results revealed that admixing of the insecticidal dusts with maize and paddy grains was effective at both the doses tested giving cent per cent mortality of the pest (Table 24 and 25) whereas in control 28.68 per cent grain damage and an average adult population of 308.94 was found in maize. In paddy 9.96 per cent grain damage was recorded along with 427.8 average adult population. No significant difference in germination of treated and untreated grains could be observed. It may, therefore, be concluded that these insecticides can safely be used in maize and paddy grains which are to be used for seed purpose only. The results confirmed the findings of Moore and Decker (1961), Teotia and Singh (1966), Saxena et al. (1973), Girish and Jain (1974), Schulten (1975), Hindmarsh and Macdonald (1980), Prakash and Pasalu (1981), Ismail et al. (1988) and Prakash and Rao (1992) who used malathion, methyl parathion, endosulfan, quinalphos, carbaryl and synthetic pyrethroides as grain protectants without having any adverse effect on the germination.

Generally the impregnation of bags with insecticidal solution has been followed for the prevention of cross infestation from external sources against the insect pest in storage. Therefore, during the present investigation, the effect of impregnation of jute and cotton bags with insecticides on grain damage and loss in grain weight caused by *S.cerealella* was studied. Earlier, several insecticides have been tested for impregnation of jute bags by Joshi and Kaul (1965), Girish et al. (1970), Ramzan et al. (1987, 1989). The results obtained during the present studies revealed that deltamethrin was found to be the best insecticide for impregnation of jute bags as no damage could be recorded in maize grains stored in jute bags impregnated with deltamethrin. However, in paddy only 0.19 per cent grain damage was observed when stored in jute bags impregnated with deltamethrin whereas in untreated control the per cent damage was recorded 17.83 per cent and 8.19 per cent in maize and paddy, respectively.

Several workers have reported various plant materials including oils, effective in checking the multiplication of pest in storage (Sangappa, 1977; Mummigatti and Ragunathan, 1977; Nanda, 1990 and Patel, 1992). These workers, however, used oil after diluting them in some organic solvents and reported their effect on pest. In the present studies oils were used as such, and their effect on adult emergence, grain damage and germination was investigated.

It is obvious from the results that coconut, groundnut, mustard, neem and sesame oil were effective against angoumois grain moth when these were mixed with maize and paddy grains @ 1 ml/100 g grains (Table 32 and 33). Neem oil was proved as the best treatment which gave cent per cent protection in terms of grain damage and adult emergence followed by mustard, sesame, coconut and groundnut oil in which very little damage (0.00 to 9.55%) and average adult population (0.00 to 31.28) was observed. Comparatively more grain damage and adult population was observed when maize grains were treated with lower doses (0.5 ml/100 g grain) of different oils. When comparative efficacy of these oils was studied on paddy grains the complete protection of grains from the *S.cerealella* was observed in both the doses of oils tested. However, in groundnut, coconut and sesame oil the infestation ranged from 0.10 to 0.27 %.

Most of the work on this aspect has been done in pulses. However, Prakash et al. (1980) while working on paddy reported neem oil effective against *S.cerealella*. Cobbinah and Kwarteng (1990) also found neem and coconut oil effective in protecting maize from *Sitophilus zeamais* Motsch. Since no work appears to have been done on maize against *S.cerealella*, the results obtained under the present investigation are not comparable.

The results of germination test conducted for both the cereals revealed significant adverse effect on the germination in all the oils at both doses. The adverse effect of oil treatment on the germination of different pulses, wheat and cow pea has also been reported by Doharey et al. (1983), Nanda (1990) and Patel (1992).

Mixing of different plant materials with grains for the protection of insect pests constitutes one of the age old and indigenous practices adopted by the farmers, particularly in developing and under developed countries. Different plants are known to posses some insecticidal properties and as such they have been used in protecting the grains against the damage of number of stored grain pests in different parts of country according to local availability of such materials. Information on the botanical products as grain protectants against angoumois grain moth, *S.cerealella,* a potential pest of maize and paddy in South eastern region of Rajasthan, is not adequate. Therefore, in the present studies efforts have been made to evaluate certain indigenous plant products against angoumois grain moth as grain protectants under laboratory conditions.

The persual of results (Table 32) revealed that neem kernel powder @ 2 g/100 g of maize grain was found best giving lesser grain damage and adult population after eight months of storage. The other plant products in order of descending effectiveness against angoumois grain moth were neem leaf powder @ 2 g, neem kernel 1 g, eucalyptus 2 g, neem leaf 1 g, sarifa leaf 2 g, lantana leaf 2 g, sarifa leaf 1 g and lantana leaf 1 g, per 100 g of maize grains.

The effectiveness of plant materials in paddy grains against angoumois grain moth showed similar trend as observed in maize. Neem kernel powder @ 2 g/100 g grain was found best and least effective plant material was lantana leaf powder @ 1 g/100 g grains (Table 33).

Earlier, Girish and Jain (1974) and Savitri and Rao (1976) reported that neem kernel powder @ 0.5 to 4.0 g/100 g grains was found effective in protecting paddy from *S.cerealella*. They also reported that mixing of 2 and 4 per cent kernel powder was economical; it controlled other stored product pests also.

Dakshinamurthy (1988) reported 1 per cent eucalyptus leaf powder effective against *S.cerealella* in stored paddy grains. The present studies confirmed the finding of Dakshinamurthy (1988) but better control was obtained in 2 per cent.

Lantana leaf and sarifa leaf powder were found least effective but better than untreated check.

Teotia et al. (1971), Bowry et al. (1984), Prakash et al. (1984) Yadav and Bhatnagar (1987) and Chiranjeevi (1991) found no adverse effect on germination when dharek drup, bel, neem leaf powder, neem seed powder, lantana leaf and cake powders of linseed, neem, mahuva, castor were mixed with wheat, paddy and pulses. In present investigation also maize and paddy grains treated with different plant materials did not reveal any adverse effect on the germination.

Maize and paddy grains are stored by the farmers for considerable period in Kachchi kothi (mud structure) pakki kothi, jute bags, loose storage in rooms. Sometimes these are stored in metal bin/tin drum but for a very short duration. During this period, these are subjected to the attack of various insect pests which ultimately results in qualitative and quantitative losses.

The results obtained under the present investigation on moisture content, per cent grain damage, per cent weight loss, and germination per cent of the maize and paddy samples collected from the different storage structures of the farmers revealed that the maximum moisture content, grain damage, loss in grain weight and minimum germination was recorded in the grains stored in Kachchi kothi followed by loose storage in room and jute bags. The minimum moisture content, grain damage, loss in grain weight and maximum germination of maize and paddy grains was recorded in the sample collected from Pucci kothi as compared to other storage structures.

Singh et al. (1977, 1991) also recorded similar observations. The reason is simple that in 'kachchi kothi' (mud structure) there is no check on moisture hence, the moisture content of the sample was found maximum. As the insect received optimum moisture requirement it multiplied resulting in maximum grain damage, loss in grain weight and minimum germination. In 'pakki kothi', on the other hand the entry of moisture was restricted which subsequently resulted in the minimum grain damage, loss in grain weight and maximum germination of grains.

SUMMARY

The results obtained under the present investigation on the bio-ecology and management of Angoumois grain moth, *Sitotroga cerealella* (Olivier) (Lepidoptera Gelechiidae) infesting stored maize and paddy are summarised below :-

1. The bio-ecological studies of *S. cerealella* on maize revealed that a female laid maximum eggs (174.30) at 30°C followed by 25°C (172.72) (Table 8). At 80 per cent relative humidity maximum egg laying (166.77) was recorded as compared to other humidity levels (Table-9). The optimum condition for maximum egg laying was the combination of 25°C and 80 per cent relative humidity. In paddy single female laid maximum eggs (90.22) at 30°C. The maximum eggs (79.49) were also laid at 80 per cent relative humidity as compared to other humidity levels (Table-12). The combination of 25°C and 80 per cent relative humidity was found most favourable for egg laying (Table-13).

2. At 30°C and 80 per cent relative humidity, the development was more rapid, the egg, larval and pupal durations being 3.75, 18.20 and 6.10, respectively in maize while 3.70, 12.30 and 4.72 days, respectively in paddy.

3. The maximum hatching (89.66%) was recorded at 25°C followed by 30°C in maize. At 70 per cent relative humidity also it was maximum (79.35%) as compared to other humidity levels. The most suitable combination of temperature and humidity was 25°C and 80 per cent relative humidity on which 94.28 per cent hatching was recorded. Almost similar trend was found in paddy.

4. In the maize longevity of male and female (average of both sex) was found maximum at 20°C (11.78 days). It was also maximum at 70 per cent relative humidity (9.76 days) as compared to other humidity levels. The combination of 20°C and 70 per cent relative humidity was found most favourable where the adults remained alive up to 13.78 days (Tables 8, 9, and 10). In paddy almost similar trend was observed (Tables 11, 12 and 13).

5. The sex ratio (male : female) was found highest at 30°C (1 : 1.37) in maize. It was also highest at 70 per cent relative humidity (1 : 1.1925) but no significant difference was observed among 60, 70 and 80 per cent relative humidity levels tested. The combination of 30°C and 80 per cent relative humidity was found the most favourable at which maximum sex ratio (1 : 1.40) was observed (Tables 8, 9 and 10). Almost similar trend was observed in paddy.

6. Varietal screening was concluded employing the different parameters *viz.*, per cent grain damage, adult emergence, per cent loss in grain weight, survival percentage of adults and susceptibility index. The varieties showed varying levels of resistance/ susceptibility to the *S. cerealella*.

7. Least susceptible varieties exhibited less percentage of grain damage, less number of adult emergence, lower per cent loss in grain weight, low survival percentage of adults and lower susceptibility index.

8. The extent of grain damage was less in least susceptible varieties (1.00 to 1.63% in maize and 0.64 to 1.00 % in paddy) than susceptible varieties (6.33 to 14.64 % in maize and 6.30 to 13.31 % in paddy).

9. The average adult emergence was minimum in least susceptible varieties (0.87 to 1.64 in maize and 0.61 to 0.87 in paddy) than the susceptible varieties (6.28 to 14.66 in maize and 6.61 to 12.92 in paddy).

10. Least preferred varieties showed low per cent loss in grain weight ranging from 0.53 to 0.70 per cent in maize and 0.30 to 0.62 per cent in paddy, whereas, in the susceptible varieties the loss in grain weight ranged from 3.03 to 8.10 per cent in maize and 3.45 to 6.70 per cent in paddy.

11. Adult survival percentage was also less in least susceptible varieties of maize (4.34 to 6.00 %) and paddy (4.09 to 4.72 %) than susceptible varieties of maize (21.04 to 46.25%) and paddy (20.08 to 35.26 %).

12. Similarly susceptibility index was found less in least susceptible varieties of maize (5.03 to 5.89) and paddy (6.98 to 7.11).

13. On the basis of all the parameters under investigation only three varieties of maize viz., Surya, Ageti-76 and CM-111 and three varieties of paddy viz., Bala, Pusa.2-21 and Cauveri were found least susceptible against angoumois grain moth.

14. The non-preference effect of the least susceptible varieties was correlated with the grain hardness and thickness of husk. The least susceptible varieties had comparatively more thicker husk and were found harder than susceptible varieties of both the hosts.

15. The antibiosis in least susceptible varieties was correlated with the nutritional imbalance. The least susceptible varieties had comparatively lesser amount of total protein and free amino acid concentration than the susceptible varieties of both the hosts.

16. Admixing of all insecticidal dusts viz., malathion. methyl parathion, endosulfan, quinalphos, carbaryl and

fenvalerate (@ 2 : 1000 and 4 : 1000 parts wt./wt.) was found to be effective in checking the infestation of *S. cerealella*.

17. Impregnation of jute and cotton bags with insecticidal solutions was found to reduce the moth multiplication in storage from field carry over. The impregnation of bags with deltamethrin and fenvalerate was found very effective.

18. Mixing of different vegetable oils with maize and paddy grains significantly reduced the multiplication and damage of *S. cerealella* at both level of dose (0.5/100 g grains and 1.00 ml/100 g grains). The efficacy of different oils was neem oil > mustard oil > sesame oil > coconut oil > groundnut oil.

19. Evaluation of plant material for the protection of maize and paddy grains indicated that neem kernel powder @ 2 g /100 g grains was found the best plant material giving good protection upto eight month of storage. The grain damage in the grains treated with neem kernel powder @ 2 g /100 g of grains was found 2.13 per cent in maize and 1.09 per cent in paddy. The second in order of effectiveness was neem leaf powder followed by eucalyptus leaf powder, sarifa leaf powder and lantana leaf powder.

20. The grains stored in bags impregnated with different insecticidal solution had no adverse effect on germination. Similarly, the admixing of insecticidal dust and powdered plant materials with maize and paddy grains did not affect the germination but the mixing of vegetable oils was found to affect the germination adversely at both the doses, the higher doses being more detrimental.

21. The samples taken from different storage structures used in this region revealed that higher percentage of grain damage, weight loss, germination loss and higher moisture content was observed in kachchi kothi (mud structure) than in 'pakki kothi.'

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Ph.D. Thesis	ABSTRACT	1996
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BIO-ECOLOGY AND MANAGEMENT OF ANGOUMOIS GRAIN MOTH, *Sitotrogra cerealella* (OLIVIER) (LEPIDOPTERA : GELECHIIDAE) INFESTING STORED MAIZE AND PADDY.

Ecological investigations were carried out on *Sitotroga cerealella* (Olivier) in the laboratory. The effect of four different temperature (20, 25, 30 and 35°C) and four relative humidity levels (50, 60, 70 and 80%) on the life cycle of *S.cerealella* was studied. At 30°C and 80% relative humidity the developmental was the fastest, the egg, larval and pupal duration being 3.75, 18.20, 6.10 days, respectively in maize and 3.70, 12.30, 4.20 days, respectively in paddy. Under these conditions survival of adults and sex ratio was also high. The moth lived longest (11.70 and 9.38 days in maize and paddy, respectively) at 20°C followed by 25°C.

A total of 50 (25 maize and 25 paddy) varieties were screened for their resistance to *S. cerealella*. Out of 50, three varieties of maize (Surya, Ageti-76 and CM-111) and three varieties of paddy (Bala, Pusa.2-21 and Cauveri) were

found least susceptible as they showed lesser grain damage, lesser adult emergence, lesser adult survival, lower grain weight loss and lower susceptibility index.

Qualitative and quantitative variations were observed in the physical characters of grains viz., length and width ratio, thickness of husk, hardness of grain, water absorption index, volume of grains and biochemical characters viz., amylose content, total proteins, free amino acids, silica and ash content of paddy husk and oil content of grains between least susceptible and susceptible varieties. Grain characters viz., husk thickness, hardness of grain, amylose content, silica and ash content were found negatively correlated, while water absorption index of maize, total protein and amino acids were found positively correlated with adult emergence and other parameters. However, L/B ratio of paddy showed positive correlation but was not significant. Volume of maize grains also showed no correlation.

For the management of this pest, different insecticidal dusts were mixed with maize and paddy grains (to be used for seed purpose only) at the rate of 2:1000 and 4:1000 parts W/W. All the insecticidal dusts at both doses tested provided effective control against the pest. Impregnation of jute/cotton bags with deltamethrin and fenvalerate was found superior in preventing the moth multiplication in storage coming as field carry over.

Among different vegetable oils tested, 1 ml/100 g. dose of coconut, ground nut, mustard, neem and sesame oil proved to be very effective in checking infestation of *S. cerealella in maize upto eight months, whereas in paddy, the* lower doses of all the oils gave practically effective protection against the attack of *S. cerealella* upto 8 months.

Among different plant materials (products) tested for protection, neem kernel powder and neem leaf powder @ 2 g/100 g grains proved to be the most effective materials. Lantana leaf powder was found less effective in protecting the grains against the pest.

The germination of maize and paddy grains was hampered when the oils were mixed with the grains. However, insecticidal dusts and plant materials at all the doses tested did not hamper the germination of both the cereals.

The losses caused by *S. cerealella* under different storage structures were assessed by collecting samples of maize and paddy. The maximum grain damage and grain weight loss was observed in grains stored in 'Kachchi kothi' (mud structure) and minimum in 'pakki kothi'. Moderate grain damage and loss in grain weight was found in grains stored in jute bags and loose storage. The germination per cent was also higher in grains stored the 'pakki kothi' followed by loose storage and jute bags. Lowest germination and high moisture content was observed in grains stored in 'kachchi kothi'.

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शोधकर्ता
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मुख्य सलाहकार
डॉ॰ आर॰ सी॰ सक्सेना

"मक्का एवं धान को ग्रसित करने वाले एन्गोमॉइस धान्य शलभ, सिटोट्रोगा सीरियालेला (ओलिवर) (लेपिडॉप्टेरा: गेलीकाइडी) की जैव-पारिस्थिति की एवम् प्रबंध"

प्रयोगशाला में सिटोट्रोगा सीरियालेला की जैव-पारिस्थिति की का अध्ययन चार तापक्रम (20, 25, 30, एवम् 35 डिग्री सेल्सियस) एवम् चार आपेक्षिक आर्द्रता (50, 60, 70 एवम् 80 प्रतिशत) के स्तर पर करने से ज्ञात हुआ कि 30 डिग्री सेल्सियस तापक्रम एवम् 80 प्रतिशत आपेक्षिक आर्द्रता पर विकास बहुत तीव्रता से सम्पन्न हुआ । उपरोक्त वातावरण में मक्का में कीट के अंडे की औसत उष्मायन अवधि, औसत डिम्भक एवं औसत प्यूपीय अवधि क्रमशः 3.75, 18.20 एवम् 6.10 दिवसों की एवम् धान में यह अवधि क्रमशः 3.70, 12.30 एवम् 4.20 दिवसों की पाई गयी । इस तापक्रम एवम् आर्द्रता पर वयस्क जीविवता प्रतिशत एवम् लिंग अनुपात (नर : मादा) भी अधिक रहे। प्रौढ़ कीट 20 डिग्री सेल्सियस तापक्रम पर अधिक अवधि (11. 78 दिवस मक्का में एवम् 9.38 दिवस धान में)तक जीवित रहे । यह अवधि 25 डिग्री सेल्सियस तापक्रम द्वारा अनुसरित की गई ।

सिटोट्रोगा सीरियालेला के लिए विभिन्न किस्मों की अवरोधिता के अभिनिर्धारण हेतु मक्का एवं धान की 25-25 किस्मों को स्क्रीनित किया गया। अध्ययन से यह ज्ञात हुआ कि मक्का की तीन किस्मों (सूर्या, अगेती-76 एवम् सी॰ एम-111) तथा धान की तीन किस्में (बाला, पूसा .2-21 एवम् कावेरी) दूसरी अन्य किस्मों की तुलना में न्यूनतम अनुशीलित (प्रभावित) पाई गई। तुलनात्मक दृष्टि से इन किस्मों के दानों में प्रकोप, कीटों की संख्या, जीविवता प्रतिशत, दानों के भार में कमी एवम् अनुशीलता सूचकांक कम देखा गया।

न्यूनतम एवं अधिकतम् अनुशीलित किस्मों के गुणात्मक एवम् मात्रात्मक अध्ययन से इनके भौतिक गुण जैसे दाने की लंबाई, चौड़ाई का अनुपात, छिलका की मोटाई, दाने की कठोरता, जल अवशोषण सूचकांक, दानों का आयतन एवं जीव-रासायनिक गुणों जैसे एमाइलोस, कुल प्रोटीन एवम् मुक्त अमीनो अम्लो की मात्रा, धान के छिलके में सिलिका एवं राख की मात्रा, दानों में तेल की मात्रा में भिन्नता पाई गई। धान्य गुणों जैसे छिलके की मोटाई, दानों की कठोरता

तथा सिलिका, राख एवम् तैल की मात्रा का कीट अनुशीलता से पारस्परिक संबंध नकारात्मक पाया गया। जबकि जल अवशोषण सुचकांक कुल प्रोटीन एवम् मुक्त अमीनो अम्लों की मात्रा ने कीट अनुशीलता से सकारात्मक संबंध प्रदर्शित किया। धान के दानों की लम्बाई/मोटाई अनुपात एवम् मक्का के दानों की आयतन ने यद्यपि कीट अनुशीलता से धनात्मक सम्बन्ध प्रदर्शित किया किंतु ये सार्थक नहीं पाया गया।

इस कीट के प्रकोप से संग्रहित मक्का एवम् धान के बचाव हेतु कीटनाशक चूर्णों का बीज मिश्रित कर अध्ययन किया गया जिसमें कीटनाशक चूर्णों को अनाजों में 2: 1000 एवम् 4: 1000 भार। भार के अनुपात से मिलाया गया। सभी कीटनाशकों की दोनों मात्राएँ कीट नियंत्रण हेतु प्रभावी पाई गई। अतः इसका उपयोग ऐसे अन्न जिन्हें अगले वर्ष बीज के रूप में करना है, उपयोग किया जा सकता है। जूट एवम् कपड़े की थैलियों का उपचार विभीन्न प्रकार की कीटनाशकों (घोल) से किया गया जिसमें डेल्टामेथ्रिन एवम् फेनवेलेरेट से उपचारित थैलियाँ, भंडारगृह में रखे अनाजों के कीट नियंत्रण हेतु सर्वोतम पायी गई।

विभिन्न वानस्पतिक तैलों का परीक्षण कीट नियंत्रण हेतु किया जिसमें यह ज्ञात हुआ कि मक्का एवम् धान के दानों को इस कीट से बचाने में फल्ली, नारियल, सरसों, नीम एवम् तिल के तैल प्रभावी पाये गए। दानों को 1 मि.ली/ 100 ग्राम अनाज की दर से उपचारित करने पर ये तैल दानों को आठ माह तक कीट प्रकोप से बचाने में प्रभावी पाये गए। जबकि धान के उपचार में उपरोक्त सभी तैलों की कम मात्रा (0.5 मि.ली/ 100 ग्राम अनाज) कीट प्रकोप रोकने में प्रभावी रहे।

विभिन्न पादप पदार्थो को अनाज में मिलाकर परीक्षण करने से ज्ञात हुआ कि नीम बीज चूर्ण एवं नीम पत्तियों के चूर्ण 2 ग्राम प्रति 100 ग्राम अनाज की दर से मिला कर रखने पर कीट नियंत्रण में ज्यादा प्रभावी रहे। लेन्टाना पत्तियों का चूर्ण कीट नियंत्रण करने में बहुत कम प्रभावी पाया गया।

तैलों द्वारा बीजोपचार करने पर बीजों की अकुंर क्षमता में कमी पाई गई जबकि कीटनाशक तथा पादप चूर्ण से उपचार करने पर अकुंरण क्षमता में कोई कमी नहीं पायी गई।

सिटोट्रोगा सीरियालेला से विभीन्न धानियों (कोठियों) में रखे गए अनाजों को होने वाली क्षति का अध्ययन करने हेतु अनाजों के नमूने इकट्ठा किए गए तथा उनका अवलोकन करने से ज्ञात हुआ कि कच्ची कोठियों में रखे अनाजों में अपेक्षाकृत अधिक कीट प्रकोपित दाने, अनाज भार में कमी एवम् अधिक आर्द्रता प्रतिशत पाया गया। जबकि पक्की कोठियों में रखे अनाजों में कम प्रकोप पाया गया। जूट के बोरो एवम् कमरों में खुले अनाजों में यह हानि मध्य स्तर की पाई गयी । साथ ही कच्ची कोठियों में रखें अनाजों की अंकुरण क्षमता भी कम पाई गयी।

PLATE NO. 7 : EGGS OF *S. cerealella.*

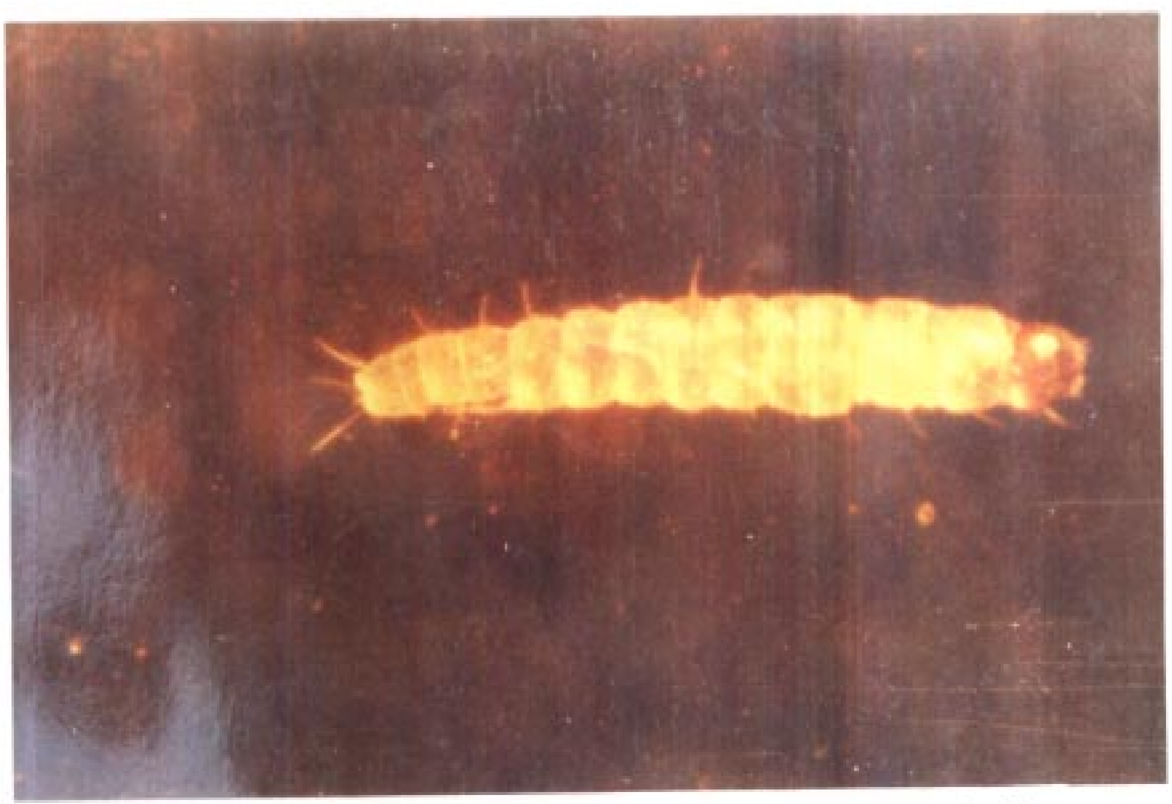

PLATE NO. 8 : FIRST INSTAR LARVA OF *S. cerealella.*

PLATE NO. 9 : SECOND INSTAR LARVA OF *S. cerealella.*

PLATE NO. 10 : THIRD INSTAR LARVA OF *S. cerealella.*