"BIOLOGY, MORPHOMETRICS AND VARIETAL REACTIONS OF RICE GALL MIDGE POPULATIONS *Orseolia oryzae* (WOOD-MASON)(DIPTERA:CECIDOMYIIDAE)"

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UNIVERSITY OF AGRICULTURAL SCIENCES
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IN

Agricultural Entomology

BANGALORE **NOVEMBER 2004**

DEDICATED TO

LORD BALAJI

Affectionately dedicated to my

beloved parents, loving Sisters,

Brother and

Dr. A.K. Chakravarthy

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

UNIVERSITY OF AGRICULTURAL SCIENCES
BANGALORE-560 065

CERTIFICATE

This is to certify that the thesis entitled, "**Biology, morphometrics and varietal reactions of rice gall midge populations *Orseolia oryzae* (Wood-Mason) (Diptera:Cecidomyiidae)**" submitted in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL ENTOMOLOGY** of the University of Agricultural Sciences, Bangalore, is a bonafide record of research work done by **Mr. Jagadeesha kumar, B.D.** during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

A. K. Chakravarthy

Bangalore **(A.K. CHAKRAVARTHY)**

November, 2004 **Major Advisor**

APPROVED BY:

Chairman: A. K. Chakravarthy

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(M.P. RAJANNA)

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CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important crop in the world with over 1.5 billion hectares under paddy cultivation and a worldwide production of over 596 million tonnes (FAO, 1999). Rice is grown in 117 countries, being a staple food of 2.7 billion people in Asia alone. India has an area of 45 million hectares under rice cultivation with an annual production of 76.91 million tonnes and productivity of about 1700 kg/ha (Anon., 2002). Karnataka has 14.8 lakh hectares under rice with annual production of 38.5 lakh tonnes (Anon., 2003).

Rice crop in the field is subjected to attack by a number of insect pests, pathogens, weeds and other harmful organisms. Several studies have reported that insects alone often cause major yield losses of rice. Cramer (1967) reported a yield loss of 34 per cent due to insects in tropical rice. In India, annual yield loss varies from 28 per cent (Kalode, 1987) to 35 per cent (Way, 1976). Major rice insect pests that cause huge economic losses in Asia are the stemborer,*Scirpophaga incertulas* (Walker),rice earhead bug *Leptocorisa oratoria* (F.), Leaf folder, *Cnaphalocrosis medinalis* (Guenee),Green leafhoppers, *Nephotettix virescence*(Distant.*);Nephotettix nigropictus*(Stall) and gall midge *Orseolia oryzae* (Wood-Mason) are among the most important insects in South East Asia and China. While in South Asia, the gall midge, brown plant hopper, *Nilaparvatha lugens* (Stal.) and yellow stem borer are the ones that cause major damage (Herdt and Riely, 1987). Of the insects, the gall midge alone causes a damage of more than US $ 700 million annually (Herdt, 1991). Based on the estimates available for eastern (Widosky and Toole, 1996) and southern States of India (Ramaswamy *et al.*, 1996), gall midge causes an annual yield loss of about 477,000 tonnes of grains or 0.8 per cent of total production amounting to Rs. 330 crores.

The Asian rice gall midge, Orseolia *oryzae* (Wood-Mason) (Diptera: Cecidomyiidae) is one of the important rice pests causing significant yield losses in some areas viz., Srilanka and parts of India. The rice gall midge has been reported as the pest of rice from several Asian countries like Bangladesh, China, Cambodia, India, Indonesia, LaoPDR, Myanmar, Nepal, Srilanka, Thailand and Vietnam.

In India, gall midge has been reported from almost all the rice growing states except the Western Uttar pradesh, Uttaranchal, Punjab, Haryana and the hill states of Hiamchal pradesh, Jammu and Kashmir, though occasional outbreaks and severe damage to rice crop by gall midge prior to 1960s are reported (Pasalu and Rajamani, 1996).

Chemical and cultural methods for control of this pest are neither very effective nor environmentally safe. The gall midge problem is further compounded by the fact that there are many biotypes of this insect and new biotypes are continuously evolving (Sardesai *et al.,* 2001). So far 13 biotypes of the Asian rice gall midge are reported from across the world. From India, five biotypes of Asian rice gall midge have been reported (Kalode and Bentur, 1989; Nair and Devi, 1994). Breeding resistant rice varieties has proved to be a viable, ecologically acceptable approach for management of rice gall midge (Bentur *et al.,* 2003).

A range of natural enemies has been known to attack various life stages of gall midge. Though 8-10 species of parasitoids are commonly reported during recent survey (Pasalu and Rajamani, 1996a), it has been generally observed that species of genera, *Platygaster* and *Neanastatus* are active throughout the cropping season but the extent of parasitization is high only after the pest damage is noted. However, role of weed hosts in harboring *Orseolia* midges as reservoirs of natural enemies and in bringing out natural biological control of rice midge is yet to be critically studied.

To study the bio-ecology and host plant interaction of rice gall midge, an investigation on rice gall midge was undertaken with following objectives:

1. To screen rice germplasm against gall midge populations in field and laboratory
2. To study the biology of rice gall midge in field and laboratory
3. To determine the morphometrics of rice gall midge occurring in Coastal Karnataka and in Cauvery command area

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

In this Chapter selected aspects on rice gall midge (GM) *Orseolia oryzae*,(Wood-Mason) (Diptera:Cecidomyiidae) is reviewed. The literature published pertaining to screening rice germplasms, identification of biotypes through screening differentials, biology and morphometrics of rice GM are covered. Historically, the rice gall midge was first reported as an unidentified insect pest on rice in Monghyr district of Bihar by Riley (1881), which was later identified as *Cecidomyia oryzae* by Wood-Mason (Cotes, 1889). Felt (1921) renamed the insect as *Pachydiplosis oryzae* and then by Gagne (1973) as *Orseolia oryzae.* Its spread has been extensive following introduction of dwarf and high yielding cultivars and their widespread cultivation. . Based on the light trap catches and reports of pest damage,the pest endemic regions in the country are shown in Figure 1.

2.1 Screening rice germplasms to gall midge infestation

Rice germplasms have been extensively screened across several countries in the world against rice gall midge damage. Several workers (Vreden and Arifin, 1977; Sahu *et al.* 2001; Sardesai, *et al.* 2001) have also intensively studied rice germplasms and have elucidated mechanisms of resistance operating in the interactions between the rice plant and the gall midge population. The interpretations on results of screening trials have been compounded with the existence of biotypes in gall midge populations. This aspect has been of late being increasingly addressed (Elsy *et al.* 1990; Rajput *et al.* 1993; Sawant *et al.* 1995; Rao *et al.* 2002). Scientists are also being increasingly engaged in identifying precisely genetic populations of gall midge (Sharma and Mohapatra; 1996; Hussain and Bora, 1996). This is one of the main reasons for the importance of the rice gall midge in agro-ecosystem throughout the world. The situation warrants screening rice germplasm critically and comprehensively both in the field and laboratory. Therefore, published information on gall midge under this head is reviewed under two categories: i) Field Screening and ii) Laboratory Screening

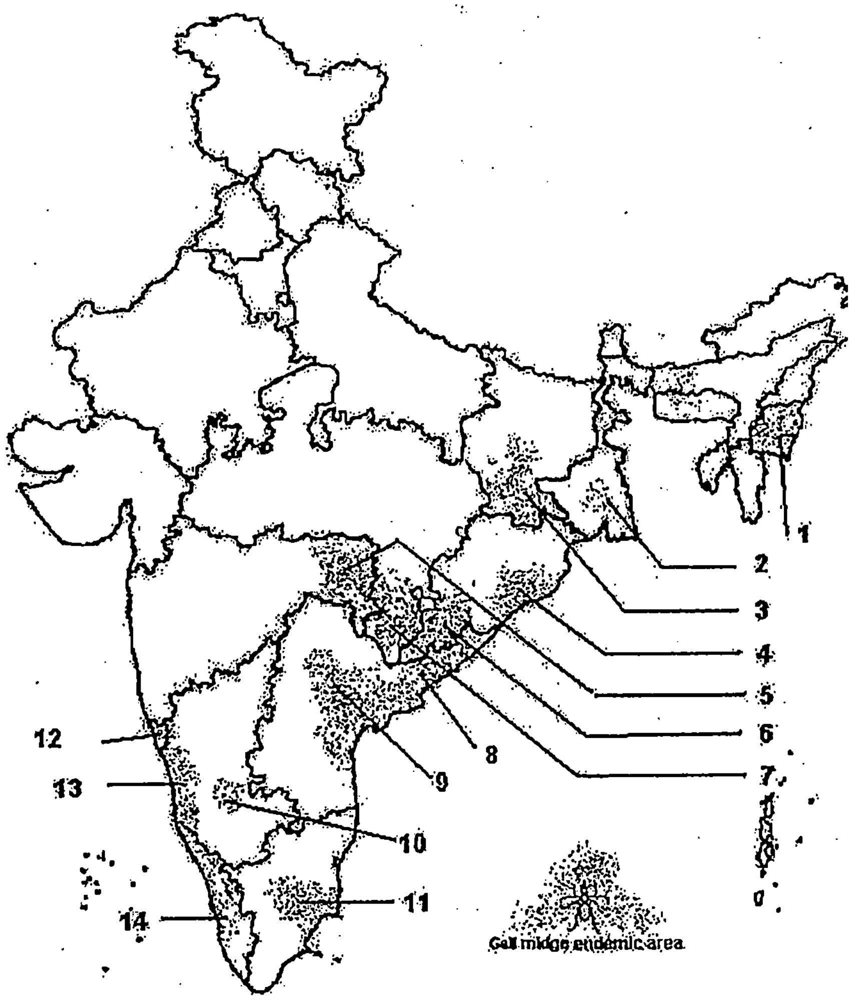

Figure 1 Gall midge endemic areas in India

1. Manipur 2. West bengal. 3. Jharkhand. 4. Coastal Orissa. 5. Vidarbha of Maharastra 6. Sambalpur region of Orissa. 7. Chhattisgarh 8. North coastal Andhra Pradesh 9. Telangana Andhra Pradesh 10. Mandya area of Karnataka. 11. Madhurai area of Tamil Nadu 12. Goa 13. Coastal area of Karnataka 14. Kuttanad area of Kerala

2.1.1 Field screening against rice gall midge

Panda *et al.* (1976) screened 1223 rice selections from various research stations in 1975 at Chiplima, Orissa for resistance to *O.oryzae* and to rice fungus, virus and its vectors viz., Nephotettix *virescence* (Dist) and *N.nigropictus* (Stal), under field conditions. Eighteen selections showed multiple resistances to the gall midge and the diseases and until harvest only one designated 52094 (IR8/MTU-1) showed immunity to *O.oryzae* (GM).

Vreden and Arifin (1977a) described three methods of screening rice varieties for resistance to *O.oryzae* viz., screenhouse testing with field collected midges and open field screening depending on natural infestation, their advantages and disadvantages are discussed. No Resistant varieties have yet been found in the Indonesian germpalsm collections; of which more than 3000 varieties have been tested. Among 18 rice varieties tested for resistance to *O. oryzae* in India, Leuang 152 was highly resistant and Vikram, CR 94-MR-1550 and Ptb 10 were resistant.

The reactions of nine rice varieties to various levels of infestation by *O. oryzae* were studied in the field in Madhya Pradesh, in 1978. In some rice varieties, yields were higher at low levels of infestation (1-10%) than at zero infestation, indicating that this infestation stimulated the production of an extra-healthy tiller which probably developed into a panicle to increase grain yield. At higher levels of infestation (up to 90%), yield was progressively affected (Deshmukh *et al.*, 1989).

Six genotypes were evaluated for resistance to natural infestation of GM in Iroisemba during the wet season of 1988. W1263 and Banglei showed no damage and Eswarakora showed slight damage. The reactions of the genotypes were taken to indicate that the Manipur GM biotype is similar to the Ranchi GM biotype (Singh, 1989). During a field trial in Kerala in 1988-89, 135 rice varieties were evaluated for resistance to the GM. Of these, IET10745 was highly resistant to the pest (Devika and Joseph, 1990).

During 1989 wet season, 16 medium-tall varieties were evaluated on a scale of 0-6 of increasing susceptibility for resistance to GM and leaf-folder *Cnaphalocrosis medinalis* (Guenee) RP2432-85-3-1 exhibited a high degree of resistance to GM (score 0) and gave fairly high yields (Elsy *et al.*, 1990).

Economic injury thresholds for the Cecidomyiid O.oryzae and the pyralid S. incertulas were estimated on the basis of pest incidence and protection costs under rice field conditions in India. The economic injury thresholds ranged from 7.6 to 9.0%, 5.7 to 12% and 9.4 to 14.7% for both pests as silver shoots, deadhearts and white ears, respectively (Rao et al., 1990).

Twenty-one traditional rice varieties were tested for resistance to *O.oryzae* in Manipur in 1986-88. The varieties Phouren and Moirangphou knokgangbi showed consistent resistance to the pest, while Akhanphou, Taothabi, Changphai, Kohima phou, Kakchengphou and Chakhao amubi showed less than 5% infestation (Singh, 1990a).

Divya, derived from WGL23022/Surekha, is a short-duration (125-130 days) variety which is compact, semidwarf and photoperiod-insensitive. It has long, slender grains with no white belly. In 1981-86, Divya had mean yields of 4.2 t/ha and gave high yields in several multilocation trials. It is resistant to GM with zero infestation at 8 out of 10 sites tested and is suitable for biotype1 endemic areas (Reddy *et al.*, 1990).

During a field trial in Manipur, in 1987-88, 137 rice varieties were tested for resistance to the midge [*O. oryzae*]. Eleven entries were highly resistant to the pest (Singh, 1990b).

During the wet seasons of 1988-89, nine genotypes, two potential donors of resistance and a susceptible control (TN1) were evaluated for resistance to *O. oryzae* biotype 1. Levels of infestation (percentage of silvershoots) were scored 30 and 50 days after transplanting. Infestation was the highest from the last week of September to the first week of October. Of the genotypes, only RTN84-5-1 was highly resistant to GM with no damage present (Rahman *et al.,* 1991). Kandalkar *et al.* (1991) screened 56 entries for field resistance to *O.oryzae*. Neela, Samalie and Sarasa varieties were resistant with 0 to 5 per cent silver shoots.

An outbreak of *O. oryzae* in rice fields in eastern Vidarbha, Andhra Pradesh, in *kharif* 1989 is reported. Almost all varieties of rice grown were infested, including Phalguna, Surekha and W-13418 (which had 30.2-41.6% silver shoots). IET 6080 (Vibhava) and Neela were not infested in farmers fields. In field trials using other varieties, Pratap, Daya and Gauri were not infested (Kandalkar *et al.,* 1992). Malik *et al.* (1992) evaluated 474 rice germplasm lines collected from Orissa and Bihar during 1988-89 under field condition in Cuttack, Orissa, against *O.oryzae*. Minja isolated as a new resistant donor for developing *O. oryzae*-resistant varieties.

In 1988-90, 1295 elite rice breeding lines from DRR-Coordinated National yield and observational nurseries were screened for resistance to GM biotypes 1 and 4. Sixty lines were resistant to both biotypes. No lines resistant to biotype 4 were susceptible to biotype 1 and all lines susceptible to biotype 1 were also susceptible to biotype 4. Resistance to both biotypes was contributed mainly by parents Orumundakan, Velluthacheera, Ptb10, Ptb21 and Ptb18. Nine of the resistant lines were derivatives of Siam 29 which, like its derivative Phalguna, is resistant to biotype 1 but susceptible to biotype 4 (Kalode *et al.,* 1993).

Thirty-nine cultivars of rice were screened for resistance to GM when grown on light and medium soils, either by broadcast sowing or transplanting, during kharif 1981. Resistance to gall midge, by either cultivation method, was greater on light sandy soils. When seedlings were transplanted on medium soil, Chhatri and Phalguna had low infestation rates, 0.04% and 0.01%, respectively. Pankaj had a low infestation rate, with either cultivation method, only on light soil (Rajput *et al.,* 1993).

Thirty six varieties from the Central Rice Research Institute germplasm collection were initialy evaluated under field conditions for resistance to prevailinig GM biotype (B) 2 All except 1 genotype were resistant. Subsequently, these varieties were tested under greenouse conditions against B1 and B4. B1 is endemic to Hyderabad and B4, which was collected from Srikakulam (Andhra Pradesh), has been maintained on rice cv. Phalguna since 1987. Twenty-two of the varieties were resistant to all three biotypes, thirteen were resistant to B1 and B2, and IR 9828-2-3-1 was resistant to B1 and B4 (Bentur *et al.*, 1994).

The coastal region of Karnataka is characterized by warm weather, heavy rainfall from June to September and high humidity throughout the year. The rice GM is endemic to this region, with heavy crop losses resulting during the *kharif* season. Twelve promising rice selections together with the susceptible standard Jaya were grown at Brahmavar during *kharif* 1989, 1990 and 1991. Mean GM incidence ranged from 0.4% in IET10765 to 21.2% in Jaya. IET10247 and IET10867, both of which mature in 132 days, gave low gall midge incidences (1.4 and 0.8%, respectively) and the highest yields (6193 and 6143 kg/ha, respectively)(Shetty *et al.,* 1994).

In trials conducted during *kharif* seasons of 1985-88 at Brahmavar, IET-7956 showed no incidence of gall midge in any year (Parameshwar *et al.,* 1995).

Ratnagiri-3 (RTN 121) was developed from the parents CR57-MR-1523, IR36 and Ratnagiri 68. It was tested for yield in trials from 1984 to 1992. It gave a mean grain yield of 4090 kg/ha, which was 29.8 to 36.5% higher than in resistant controls and 60.6 to 74.5% higher than in susceptible controls. In the All India co-ordinated trial, it gave an average of 13.96% more yield than the national high yielding control Pankaj. In 34 trials in farmers' fields, it gave 24.7% increase in yield (4430 kg/ha) over the control Vikram (3552 kg/ha). Ratnagiri-3 is late, mid-tall and coarse grained, with a high degree of resistance to two biotypes of gall midge (GM1 and GM4) (Sawant *et al.,* 1995). Severe infestation of rice by *O. oryzae* was recorded for the first time in southern Karnataka, during the *kharif* season of 1995 (Gubbaiah and Revanna, 1996).

Huang *et al.* (1996) conducted a survery on the distribution and damage of rice GM in Yuxi, Yunnan, China, when the rice is damaged, the number of useless tillers increases while the number of useful spikes decreases. In double-cropping areas, damage to late rice is more serious than damage to early rice. In single-crop rice areas, damage to late cultivated rice is more serious than that to early cultivated rice.

Nine thousand rice germplasms obtained from the Central Rice Research Institute, Cuttack, Orissa, were evaluated under field conditions in Madhya Pradesh against GM, 33 entries were found resistant to this pest, the plant damage score being 0-0.97% silver shoots (Gupta *et al.,* 1996).

Mukherjee *et al.* (1996) evaluated during *kharif* 1991/92 and 1992/93, 15 rice varieties were tested for resistance to *O.oryzae*. Phalguna, R-296-120, R335-6, R435-107, Samridhi, R296-260, Ruchi, Abhaya, R432-9 and Madhuri A9 were free from gall midge infestation.

Field experiments were conducted in wet seasons of 1990 to 1994 to study the performance of eight early, 12 midlate-late and eight gall midge resistant varieties in the eastern rice zone of Maharashtra, Coarse grain varieties IR-64 and Tara produced significantly higher grain yields in the early group. No significant differences in yield were recorded among the 12 midlate-late varieties. However, Pratap and Suraksha gave higher yields among the gall midge resistant group of varieties (Chore *et al.,* 1997).

Indur Samba is a short-duration rice variety derived from a cross of Samba Mahsuri and Surekha. It is resistant in gall midge endemic areas and is suitable for sowing the winter and summer seasons (Ganesh *et al.*, 1997). Ranjini was derived from the cross MO5 X Improved Sona and released for use in Kerala in 1966. It is a short-duration, dwarf variety with red medium-bold grains and it is tolerant of gall midge (Devika *et al.,* 1997).

Prophaly *et al.* (1997) screened seven F8 breeding lines were studied during 1993-95 monsoon seasons at Raipur Chhattisgarh, region of Madhya

Pradesh for stability of pest resistance and agronomic traits. At maximum tillering, plants were clip inoculated with *Xanthomonas oryzae* pv. *oryzae* and subsequent disease incidence recorded. Plants were also assessed 50 days after transplanting for incidence of gall midge Lines were screened for resistance to brown planthopper (*N. lugens)* in the greenhouse. R710-3-37-1-1-1 was resistant to both BPH and GM and the bacterial pathogen. It also had desirable agronomic characters.

Vijetha was developed from a cross between MTU5249 and MTU7014014 at ARS. In trials during 1991-94 dry seasons it yielded average 7.5 t/ha which is 22.8% more than that of control variety IR64. It is resistant to brownplanthopper, moderately resistant to gall midge, whiteback planthopper *Sogatella furcifera* (Horvath), stem borer, leaf folder and blast [*Magnaporthe grisea*]. Vijetha is semi-dwarf with dark green foliage and 8-10 productive tillers. It was released by the State Seed Subcommittee in 1995 (Suryanarayana *et al.*, 1997).

The mode of inheritance and allelic relationships of resistance imparting gene(s) against GM biotype-1 in rice cultivars Aganni and R 320-300 were investigated. The segregation behaviour of F1, F2 and F3 populations confirmed the presence of single dominant gene for resistance in Aganni and R 320-300. Allelic relationship studies confirmed the presence of gall midge resistant genes Gm 4 in Aganni and Gm 1 in R 320-300, as was evident from the absence of segregation in F2 and F3 populations of crosses between Aganni and Abhaya and between R 320-300 and Asha and Samridhi (Arvind *et al.*, 1998).

Three field trials were carried out at Bhandara, Maharashtra, in 1991/93 to screen rice donors and derivatives for resistance to GM. Those categorized as resistant to the pest were Aganni, Velluthacheera, NHTA8, T 1477, Pandy, Ptb2, RP 2457-111-259, R 296-260, R 296-120 and IET 9710. Moderately resistant were Shakti, Sarasa, Udaya, IR-50 and Tara. The remainder

(Kakatiya, IET 9177, Cr 317-166, CR 294-54-8, Lalat, Phalguna and Gauri) were susceptible (Kandalkar *et al.,* 1998).

Inheritance of resistance to rice GM was investigated in 14 F1, 10 F2 and 7 F3 rice populations derived from crosses between resistant (Samridhi, Usha, Surekha, R244-3012 and CR95-181-2) and susceptible parents. Segregation ratios indicated that only one dominant gene controlled resistance in each of the resistant parents. The resistance gene present in Surekha and CR95-181-2 was confirmed to be different to that present in Samridhi (Mishra *et al.*, 1998). Eleven rice cultivars were evaluated against GM. Cultivar R 320-298, designated as Mahamaya was highly resistant as no silver shoot was recorded (Mukherjee *et al.,* 1998).

During *kharif* 1993 and 1994, 15 rice cultivars were evaluated under conditions of natural infestation for resistance to gall midge. The number of healthy and infested tillers was recorded 50 days after transplanting and damage was assessed using an IRRI scale. Normal transplanting completely escaped gall midge infestation during 1993 while some damage occurred during 1994. The cultivar R-296-120 was rated highly resistant while the following were rated as moderately resistant: R-296-260, R-574-11, R-671, Madhuri A-9, Abhaya, Ruchi, Phalguna and Mahsuri (Awasthi *et al.*, 1999). In studies carried out with 30 hybrid rice cultivars, cv. Gouri showed zero incidence of GM (Misra and Patnaik, 1999).

Oudhia *et al.* (1999a) studied the effects of fertility level and hybrid rice variety on gall midge infestation at Raipur during *kharif* 1998-99. The hybrid rice varieties were HRI119, HRI129 and VRH704, with local high-yielding Mahamaya as control. Results showed that treatments having higher doses of nitrogen resulted in a higher gall midge infestation. Maximum infestation (34-56%) was noted under 120:80:50 NPK with HRI129 and 150:40:50 NPK with VRH704, followed by 120:80:50 NPK with HRI119 and 120:40:50 with VRH704. No infestation was noted on Mahamaya at all fertility levels.

Nine rice hybrids and the resistant control cv. Mahamaya, growing at Raipur, were observed for infestation by gall midge. Mahamaya was free from infestation and in the hybrids percentage of infested tillers ranged from 5.23% (PAC831) to 12.32% (Proagro 6111) (Oudhia *et al.,* 1999b).

The influence of various sowing dates on the incidence of GM was studied in Kerala, during rabi and *kharif* 1994-97. The pest was not recorded in any *kharif* sowings up to the 2nd week of June. It was therefore concluded that sowing should be carried out before the 3rd week of June to avoid infestation in the kharif season. The corresponding last sowing date for rabi rice was the 3rd week of November (Jacob and Jacob, 1999).

The inheritance of resistance in the rice cultivars Phalguna, ARC5984, ARC 5158, Veluthacheera, and T1477 to the Asian rice gall midge biotype 2 was studied under both natural and artificial infestation conditions against the susceptible cultivars Jaya and IR20. A single recessive gene in Veluthacheera and two recessive complementary genes in T1477 control resistance. Phalguna and ARC5984 possess a single dominant gene while ARC5158 has a single dominant and a single recessive gene for resistance. Allelism studies showed that genes for resistance in Veluthacheera and T1477 are allelic but non-allelic to the resistance genes in Phalguna and ARC5984, which are allelic to each other. Genes for resistance in ARC5158 are allelic to resistance genes of the other four donors. There was no cytoplasmic inhibition of resistance by the susceptible parents(Pani and Sahu, 2000).

The inheritance of resistance to *O. oryzae* in rice was studied in Raipur, in 1994 and 1995. Fifteen *O. oryzae*-resistant cultivars were crossed with a susceptible cultivar, MW 10. All the 15 F2 generations segregated into a ratio of 3 resistant:1 susceptible, indicating the presence of a single dominant gene in resistant cultivars. The F2 ratios were further confirmed by the segregation pattern of F3 progenies (1 true breeding resistant:2 segregating type:1 true breeding susceptible) (Shrivastava *et al.*, 2000).

Pelalu Vadlu (RDR8702) is a medium-duration (135-140 days) and gall midge-resistant rice cultivar derived from OBS677/IR2070-423-21-5. Released in Andhra Pradesh, it is suitable for cultivation in the wet season for rainfed lowland areas. Pelalu Vadlu, which is tolerant to gall midge is a tall (103 cm), medium-tillering, nonlodging, erect, semicompact, photoperiod-insensitive and fertilizer-responsive cultivar having a yield potential of seven t/ha. Its grain yields were 4-72% higher than those of Surekha, Mahsuri, and Samba Mahsuri. (Rao *et al.,* 2002).

2.1.2 Field Screening with mechanism of resistance

The proline content (in mμg/100 mg sample) in rice leaves in India damaged by gall midge averaged 16.5 as compared with 8.5-10.5 for healthy leaves (Roy *et* al., 1987).

Rice seedlings of the resistant variety Phalguna showed premature tillering, browning of central leaf and tissue necrosis at the apical meristem following artificial infestation with avirulent biotype 1 of the Cecidomyiid, *O. oryzae*. Tissue necrosis representing a typical hypersensitive reaction, accompanied by larval mortality was observed within four days after infestation. However, reinfestation of secondary tillers subsequent to hypersensitive reaction in primary tillers, did not lead to hypersensitive reactions in secondary tillers although larval mortality was seen. Artificial infestation with *O. fluvialis* did not result in a hypersensitive reaction either in susceptible TN 1 or resistant Phalguna rice varieties. Resistance in Phalguna against the virulent biotype 4 could be induced by either prior, simultaneous or subsequent infestation with the avirulent biotype 1. The duration of effectiveness of such induced resistance varied with the sequence and time lag between infestations (Bentur and Kalode, 1996).

An estimation of total phenols at the stem base in related rice varieties during infestation by GM revealed the role of the gene Gm2 in plant resistance. However, the role of Gm2 in genetically diverse rice varieties in conferring resistance to *O. oryzae* was not clear (Amudhan *et al.*, 1999).

2.2 Laboratory Screening

In India, molecular mapping and tagging of agronomically important genes using RFLP and RAPD markers have been carried out in three different crops: rice, Indian mustard (*Brassica juncea*) and chickpea(*Cicer arietinum*). In rice, tagging of genes for resistance to GM and blast (*Magnaporthe grisea*) has been accomplished. Molecular mapping of cooking quality traits in rice is in progress. For fingerprinting rice cultivars, suitable probe enzyme combinations have been identified. In mustard, a partial RFLP linkage map has been constructed and one of the yellow seed-coat loci has been mapped. Significant associations of RFLP markers with quantitative traits have also been established. Potential use of RAPD markers to identify heterotic groups among mustard accessions has been demonstrated. In chickpea, the occurrence of considerable interspecific DNA polymorphism as revealed by RAPD analysis has facilitated construction of a partial linkage map (Sharma and Mohapatra, 1996).

2.2.1 Genetic mechanisms of resistance

A study was conducted on the inheritance of gall midge resistance in two already known resistant cultivars (Samridhi and Surkeha) and four newly identified resistant cultivars (R 243-3041-1, Kodakuri, Jalpa, Bahawar Kanak) from Chhattisgarh rice germplasm. Samridhi, Surekha, R 243-3041-1, Kodakuri, Jalpa and Bahawarkanak were resistant, whereas Kalimoonch 64 showed some amount of susceptibility. The results indicated only one dominant gene for resistance in Samridhi and Surekha, i.e. Gm1 and Gm2, respectively. All the plants in F1 from the four crosses (Surekha/R 243-3041-1, Surekha/Kodakuri, Surekha/Jalpa and Surekha/Bahawarkankar) were found resistant and the F2 of these crosses did not segregate (Sahu *et al.,* 2001).

Information on combining ability is derived from data on Seven yield components evaluated in five high yielding, medium duration rice varieties and three gall midge resistant genotypes grown during rabi 1991-92. Parental types Co45, ADT38, ACM19 and W1263 were identified as good general combiners for use in multiple crosses to isolate segregants combining desired economic traits. Cross combinations ADT38 X ACM19, ADT38 X W1263 and Co45 X

W1263 were superior for more than one trait and thus have potential in recombination breeding (Koodalingam and Nadarajan, 1996).

Shrivastava *et al.* (2003) studied the mode of inheritance and allellic relationships of the resistance genes involved in resistant donor rice Line 9, a sib of a susceptible culitvar 'Madhuri'. The segregation behaviour of F1, F2 and F3 populations of the cross between Line 9 and susceptible cultivar MW 10 confirmed the presence of a single dominant gene for resistance. Tests of allelism with all the known genes giving resistance to this population indicated that Line 9 possessed a new gene, which was, designated GM 9.

2.2.2 Greenhouse evaluation of rice cultivars

A total of 2256 germplasm accessions, 3000 advanced generation breeding lines and 150 released varieties of rice were screened for resistance to *O. oryzae* in the greenhouse. Among these, 15 new germplasm accessions, 50 breeding lines derived from 16 crosses and 15 released varieties were resistant. Antibiosis was the predominant resistance mechanism; antixenosis-affecting oviposition was noted in 33 resistant varieties. The biochemical composition of a set of resistant varieties, along with susceptible varieties, revealed that the nitrogen content of seven test varieties was significantly higher than that of the susceptible varieties, while in six other varieties it was lower. Similarly, eight of the resistant varieties had a considerably higher percentage of polyphenolic compounds in the basal stem portion, but seven cultivars showed significantly lower concentration compared with the susceptible varieties. Thus, it was apparent that there was no clear trend among the resistant cultivars as a group in relation to quantitative differences of chemical components analysed (Sain and Kalode, 1994).

Mishra *et al.* (2003) studied field and greenhouse evaluation of about 50,000 germplasm accessions has resulted in identification of over 300 primary sources of resistance. Genetic analysis in some of these sources revealed seven dominant and one recessive gene conferring resistance against Indian biotypes. So far, six distinct biotypes have been characterized which differ in their reaction pattern against four groups of differentials. Seven of the resistance genes have been tagged and mapped. Mohan *et al.* (2003) used the techniques viz., mapping and tagging of insect resistance in rice.

Two hundred and seventy-three lines of the cultivated African rice species *O. glaberrima* were screened in a paddy screenhouse at the National Cereals Research Institute, near Bida, Niger State, Nigeria for resistance to *O. oryzivora,* an increasingly important pest of lowland rice in Nigeria. Twenty entries, which showed no galls in the screenhouse evaluation, were retested under natural infestation in a gall midge-endemic field location near Abakaliki, Ebonyl State. Whereas the susceptible check variety, FARO 37, had 39.6% of tillers infested 60 days after transplanting, damage in the test entries ranged from 0 to 3.7%, an indication that they were all highly to moderately resistant to the pest. Greater host plant resistance is a central requirement for more effective management of *O. oryzivora.* Using resistance genes from *O. glaberrima* is a promising approach for achieving this (Ukwungwu *et al.,* 1998).

2.2.3 Molecular Mechanisms of Resistances

A polymerase chain reaction (PCR)-based assay that could effectively reduce the time period required to screen and select for gall midge resistant rice lines under field conditions was developed. The primers for the assay were designed on the basis of sequence information on two phenotype specific random amplified polymorphic DNA fragments which were found to be tightly linked to gall midge biotype-1 resistance gene (Gm2). These markers can be of potential use in the marker-aided selection of gall midge biotype-1 resistant phenotypes. As screening for resistance can now be conducted independent of the availability of insects, the breeding of resistant varieties can be hastened (Nair *et al.*, 1995).

A PCR-based marker (E20570) linked to the gene Gm4t, which confers resistance to the gall midge, was mapped using the restriction fragment length polymorphism (RFLP) technique in rice. Gm4t is a dominant resistance gene. Initial attempts to detect useful polymorphism for this marker failed in a F3 mapping population derived from a cross between two indica parents, Abhaya X

Shyamala, with as many as 35 restriction enzymes. Abhaya carries the resistance gene Gm4t and Shyamala is susceptible to gall midge. Subsequently, E20570 was mapped using another mapping population represented by a F2 progeny from a cross between Nipponbare, a japonica variety and Kasalath, an indica variety, in which the gene Gm4t was not known to be present (Mohan *et al.,* 1997).

Ten yeast artificial chromosomes (YACs) spanning the Gm2 locus were isolated by screening high-density filters containing a total of approximately 7000 YAC (representing six genome equivalents) clones derived from a *japonica* rice, cv. *Nipponbare.* The screening was done with five RFLP markers flanking a gall midge, resistance gene, Gm2, which was previously mapped onto chromosome four of rice. This gene confers resistance to biotype 1 and 2 of gall midge a major insect pest of rice in Southern and Southeast Asia. All RFLP markers mapped to the long arm of chromosome four of the resistant variety of rice, Phalguna, confirming the previous RFLP mapping data (Rajyashri *et al.,* 1998). Laboratory studies on rice plants been damaged in the field by GM showed that, as for physiological or disease stresses, insect attack caused the accumulation of free proline in the plants (Roy *et al.*, 1988).

Degenerate oligonucleotide primers were designed on the basis of nucleotide-binding-site (NBS) motifs conserved between pathogen resistance genes of Arabidopsis, flax (*Linum usitatissimum*) and tobacco, *Nicotiana tobaccum* and were subsequently used as PCR primers to amplify resistance gene analogues (RGA) in rice. DNA from indica rice cv. Phalguna, resistant to gall midge biotype 1 and 2, was used as a template for all PCR amplifications. Primers amplified a major band of _500 bp. Restriction analysis of the amplified product revealed that the band was made up of several different fragments. These Results indicated that it is possible to use sequence homology from conserved motifs of known resistance genes to amplify candidate resistance genes from diverse plant taxa (Mago, *et al.,* 1999).

In an attempt to identify a specific marker for biotype 2 of the Asian rice gall midge, AFLP finger printing was used. The workers identified an AFLP marker that is specifically amplified in biotypes 1, 2 and 5 of the rice gall midge, but not in biotype 4. Biotypes 1, 2 and 5 are avirulent to hosts bearing the Gm2 resistance gene (found in rice variety Phalguna), whereas biotype 4 is virulent to Gm2. Based on the sequence of this AFLP marker. SCAR (Sequence Characterized Amplified Region) primers were designed and used in combination with previously developed SCAR primers to distinguish effectively all five biotypes in a multiplex PCR-based assay. The inheritance pattern of this marker in the progenies of inter-biotype crosses between biotypes 1, 2 and 4 shows that the marker can be amplified by PCR from all F1 females, irrespective of the biotype status of their parents. The specific amplification of this marker in the avirulent biotypes and its pattern of inheritance show that avirulence with respect to carriers of the Gm2 gene in rice gall midge is sex-linked (Behura *et al.*, 2000).

Multicopy DNA clones isolated from a partial genomic library of GM are described based on reverse genomic hybridization, suitable for studying genetic variation in *O. oryzae* and other isomorphic species. Three clones produced monomorphic DNA band patterns between biotypes of *O. oryzae*, but polymorphic patterns were produced between *O. oryzae* and *O. fluvialis*. These probes detected changes in the repetitive sequence structure between species and constitute the 1st genetic markers for distinguishing between field isolates of *O. oryzae* and related species of *Orseolia*. These are useful in identifying and eradicating alternative hosts and detecting early-season outbreaks of *O. oryzae* from light traps collections (Ehtesham *et al.*, 1995).

Five biotypes of rice GM have been identified in India, with the Manipur population being biotype 3 (the Ranchi biotype). However, since 1991 a new pattern of reaction has been observed among differential rice varieties. A standard set of 10 differentials in four groups was evaluated in the wet seasons of 1991-94 against the GM population of Iroisemba, Manipur. GM incidence was recorded at 50 days after transplanting. Only group I varieties (W1263 and ARC6605) showed a resistant (R) reaction. All other varieties in the other 3 groups were susceptible (S). This new R-S-S-S type of response has not been reported previously in India and it is proposed that the Iroisemba population be considered a distinct biotype, designated 3M. In supplementary studies this biotype did not mate with any of the other biotypes (Singh, 1996).

Table 2.1 The number of rice gall midge biotypes reported from different countries

Country	Biotypes reported	References
India	5	Kalode and Bentur, 1989 Nair and Devi, 1994 Anonymous, 1992
China	4	Lai *et al.*, 1984 Tan *et al.*, 1993
Srilanka	2	Anonymous, 1981
Thailand	1	Anonymous, 1981
Indonesia	1	Anonymous, 1981

(Sardesai *et al.*, 2001)

2.2.4 Biotype Identification through Molecular techniques

Scientists have identified an AFLP marker SA598 that is linked to Gm7, a gene conferring resistance to biotypes 1, 2 and 4 of the gall midge. A set of PCR primers specific to an RFLP marker, previously identified to be linked to another gall midge resistance gene Gm2, also amplified a 1.5-kb (F8LB) fragment that is linked to Gm7. Gm7 is a dominant gene and non-allelic to Gm2. Hybridization experiments with clones from a YAC library of *Nipponbare*, a *japonica* variety, a BAC library of IR-BB21, an *indica* variety and cosmid clones encompassing Gm2 from Phalguna, an *indica* variety, with F8LB and SA598 as probes revealed that Gm7 is tightly linked to Gm2 and is located on chromosome 4 of rice. SA598 was sequenced and the sequence information was used to design sequence-characterized amplified region (SCAR) primers. The potential use of these SCAR primers in marker-aided selection of Gm7 in a rice breeding programme has been demonstrated (Sardesai *et al.*, 2002).

A PCR-based assay that distinguished five different biotypes of the Asian gall midge, a major insect pest of rice was developed by Behura et al. (1999). A total of 400 random primers were screened using RAPDs. Five diagnostic PCR products were isolated, cloned, sequenced and converted to sequence characterized amplified regions (SCARs). Primers specific to these SCARs were able to amplify specific DNA fragments from genomic DNAs of five biotypes of gall midge in a multiplexed-PCR-based assay. The amplified DNA fragments were used as diagnostic markers to identify different biotypes of gall midge. The SCAR primers were also capable of differentiating the Asian from the African rice gall midge as well as detecting a variant of biotype 5, which caused an outbreak in Kerala. Unlike the use of plant host differentials and midge feeding behaviour for identifying biotypes, this assay is fast, reliable and unaffected by environmental factors.

Amplified fragment length polymorphism (AFLP) analysis was used to assess the biodiversity of the Asian rice gall midge. Larvae and pupae were collected at 15 locations in five Asian countries and preserved in 95% ethanol for storage, shipment and DNA extraction using cetyltrimethylammonium bromide (CTAB). Cluster analysis performed by the unweighted pair-group method (UPGMA), separated the populations into two distinct groups. Group I included two populations from Guangdong province of southern China and one each from Laos and Imphal in North Eastern India, while group was comprised of eleven populations from elsewhere in India (Assam, Orissa, Madhya Pradesh, Andhra Pradesh and Kerala) and from Nepal and Sri Lanka. AFLP analysis provided insight into the origins of gall midge biotypes. In 1992, the prevailing biotype in Imphal changed from Indian biotype 3 to a new biotype 3M. Workers data show that biotype 3M belongs to group I and did not arise by a recent mutation from biotype 3, which belongs to group II. By contrast, Indian biotypes 2 and 4 are likely to have diverged through recent mutation and selection, as are Chinese biotypes 1 and 4. The almost simultaneous emergences of new biotypes in Kerala and Sri Lanka during 1985-88 were most probably coincidental, because these biotypes are not closely related. AFLP fingerprints were also able to detect sexual dimorphism in the DNA of adult gall midges and to distinguish gall midge from its major parasite *Platygaster oryzae* (Katiyar *et al.,* 2000).

In an effort to study genome diversity within and between the Indian biotypes of the Asian rice GM, scientists made use of mariner transposable element integration site polymorphisms. Using degenerate primers, the design of which is based on mariner sequences, they have amplified approximately 450-bp mariner sequence from the rice gall midge (biotypes 1, 2, 4 and 5). The mariner sequence showed homology with that of a mariner element isolated from the Hessian fly, *Mayetiola destructor* (Say.) a major dipteran pest of wheat. Southern hybridization, using this mariner fragment as a probe, revealed that the mariner elements are moderately to highly repetitive in the rice gall midge genome. Results revealed biotype-specific polymorphisms in the regions flanking the mariner integration sites, suggesting that mariner elements in the rice gall midge may be fixed in a biotype-specific manner. The implications of these results are discussed in the context of biotype differentiation (Behura *et al.,* 2001). From the review of exhaustive literature on host plant resistance in rice gall midge certain facts can be deduced which are summarized below.

Since 1950s a large number of rice germplasm accessions have been field evaluated for gall midge resistance. However, this method suffers from inconsistency arising from non-uniformity and fluctuations in pest population. Hence, results need to be revalidated and retested. Further, field evaluation is limited to a season only in a year. So it takes at least two to three years to confirm the results. As an alternative, greenhouse screening methods were developed (Kalode *et al.*, 1977) using this method a large number of rice collections were evaluated from 1975 to 1985 and 118 source of resistance were identified. This forms 46 per cent of all the donors reported before 1990. The advantages of greenhouse screening are that year round screening is possible, uniform and high pest pressure and rapid confirmation of results. Maintaining more than one GM biotypes separately helped in recording differences in reaction of the same donor against different biotypes. A set of differential varieties are used for maintaining biotype cultures in separate chambers. Like - wise different sets of check lines are used in screening with different biotypes.

With the advent of high yielding varieties GM resistance breeding programme got a boost. In addition to Ptb18 and Ptb21, Leuang 152, Eswarakora, Siam 29 and their derivatives were used extensively as donors and a large number of breeding lines were developed and tested mainly at Cuttack, Warangal and Hyderabad, besides in pest endemic areas of Karnataka, Madhya Pradesh and Kerala. Since the release of Kakatiya in 1972, 56 varieties have been developed and released so far.

2.3. Identification of biotypes using standard rice differentials

Occurrence of gall midge biotypes in India was first suspected by Khan and Murthy (1955) even when no resistant varieties were developed. Subsequently Roy *et al.* (1969) observed differential reaction in some gall midge resistant donors / cultures at two of the pest endemic locations viz., Sambalpur in Orissa and Warangal in Andhra Pradesh presence of two biotypes was further confirmed by results of evaluation of rice cultivars in national and International testing programmes.

Fourteen differential rice cultivars under four major donor groups were evaluated. Three basic variations, which qualify to be called biotypes 1, 2 and 3 of *O. oryzae* were identified based on overall reaction patterns against Eswarakora and Siam 29 differential groups. Biotype 1 could not damage entries involving either Eswarakora or Siam 29. Biotype 2 was capable of damaging the group of Eswarakora and its derivatives but was not able to damage the group of Siam 29. Biotype 3 could damage the Siam 29 group while being incapable of doing so with the Eswarakora group (Kalode and Bentur, 1989).

Geographic distribution of these biotypes, then, was not in continuum. While populations at Hyderbad, Warangal and Maruteru in Andhra Pradesh, Sambalpur in Orissa and Raipur in Madhya Pradesh were grouped as biotype 1, populations at Cuttack and Bhubaneswar in Orissa State on the east coast, at Mangalore in Karnataka and Goa on the west coast and Sakoli in Maharastra in the central India were grouped as biotype 2. Gall midge populations at Ranchi in Bihar and Wangbal in Manipur belonged to biotype 3. As these reactions were based on field evaluation over the years, population at the test site was considered to be homogeneous.

Bio Type	Differential group I	II	III	IV
1	R	R	R	
2		R	R	
3	R		R	
4			R	
5	R	R		
6	R			

Figure 2 Current status of gall midge biotypes and their distribution in India

In field trials in Titabar, Assam in 1993-95, the susceptibility of various rice cultivars to *O.oryzae* was investigated. The infestations were recorded at 50 days after transplanting. Rice cultivars were classified into groups: I (W 1263 and ARC 6605), II (Phalguna and ARC 5984), III (CR-MR 1523, Velluthacheera, Aganni, Ptb 10 and T 1477) and IV (TN 1). These results were similar to those obtained in other areas where O. *oryzae* was designated as biotype 1 and it is concluded that *O. oryzae* in this area is also biotype 1(Hussain and Bora, 1996).

Regular monitoring biotypes since 1989 at different location with in this zone has consistently prevalence of biotype 4 displaying the defined pattern S-S-R-S reaction of the differential rice varieties in I-II-III-IV groups respectively. These results are in accordance with those obtained in green house test conducted by DRR (Anon, 2002a).

The updated reaction pattern of the standard set of differentials in four discrete groups against the six Indian biotypes of rice gall midge and geographical distribution of these populations is shown in Figure 2. Geographic distribution of these biotypes, then, was not in continuum. While populations at Hyderbad,Warangal and Maruteru in Andhra Pradesh, Sambalpur in Orissa and Raipur in Madhya Pradesh were grouped as biotype 1, populations at Cuttack and Bhubaneswar in Orissa State on the east coast, at Mangalore in Karnataka and Goa on the west coast and Sakoli in Maharastra in the central India were grouped as biotype2. Gall midge populations at Ranchi in Bihar and Wangbal in Manipur belonged to biotype 3. As these reactions were based on field evaluation over the years, population at the test site was considered to be homogeneous.

2.4 Biology of rice gall midge

2.4.1 Field biology

In connection with mass rearing of *O.oryzae* for rice varietal resistance, aspects of biology and behaviour of the gall midge that are relevant to continuous efficient rearing are described. The topic discussed includes oviposition, egg hatching, larval movements and developments, adult emergence, mating and sex ratio. The relations of some of these factors to the age of the food plant are described (Vreden and Arifin, 1977b).

Joshi *et al.* (1983) studied the biology of rice gall midge under field condition. The life cycle from oviposition to adult emergence required two to three weeks. Eggs are laids either on hairs of ligule or on leaf sheath. Egg period varies from three to four days. Maggot's period varies from six to thirty three days and pupal period varies from four to eight days and adult longevity varies from one to five days.

Development periods of different life cycle stages of gall midge studied during April (temperature ranging 27.19 to 41.0°C) and December (19.13 to 33.8°C) reflected the effects of ambient temperature. Life cycle was prolonged 1.7 times during December (28-33 days) in comparison to that during April (16-21 days). In earlier studies maintenance of 14-cm water around 25 days old plants after oviposition showed reduction in percentage plant damage. A study was conducted to know the possible courses of such reduction in plant damage. It was observed that percent hatching of eggs was not affected by complete immersion of the eggs in petridishes containing water though hatching was slightly delayed. In the second experiment restricting oviposition either to leaf blades or to basal leaf sheaths alone prior to plant submergence up to 14 cm water greatly reduced the extent of damage by the pest as compared to those plants having received the eggs on all parts. The reduction in damage in the earlier treatments might be due to possible dislodging of newly hatched maggots on their way of entry to apical buds (Harris and Gagne, 1982).

Studies on the rate, period and cycle of emergence and oviposition of African rice gall midge, kept in screenhouses revealed an endogenously entrained circadian rhythm. Emergence commenced 23 days after infestation (at 27±2°C and 70±12% relative humidity) at 1800 h and stopped at 2400 h daily for a five-day period of emergence. Each female mated once throughout life and oviposition occurred after mating between 1800 h and 2400 h daily. This six hour cycle of oviposition continued until the ovipositing female died (Omoloye and Odebiyi, 2001).

2.4.1.1 Seasonal Occurrence of gall Midge

Gall midge damage was noted only in crops planted during July to December with peak incidence in August-September planted crop (observed during October-November) at the stage of 45 DAT. Maximum larval and pupal parasitisation mainly by *platygaster sp.* and *Eurytoma setitibia* was observed in October (Prakasa Rao., 1982).

Prakasa Rao and Dani (1982) reported that the crop planted in August suffered high gall midge infestation (42.7%) at 60 DAT. Crops planted early or later than September recorded negligible gall midge infestation.

Prakasa Rao (1983) reported the data accumulated over the past 10 years showed that heavy gall midge incidence level were already reached in standing crops before the abundance of the peak of gall midge were detected at light trap and hence, light trap was of less value in detecting the build up of the pest incidence in fields.

2.4.1.2 Alternate host plants of gall midge

More than 20 species of grasses and wild rices have been reported in the past as hosts (Pathak and Heinrichs, 1982). Several of these grasses are weeds growing in and around rice fields appearance of galls in these weeds has probably led to many reports claiming the weeds to be alternate hosts of the rice gall midge. Critical studies on cross infestation (Sain and Kalode, 1988; Natarajan *et al.*, 1988) have not confirmed the role of many weeds as hosts. Forty-nine slender grain cultivars of rice were tested in Karnataka for susceptibility to attack by the rice gall midge.The percentage of hills showing galls ranged from 16.6 to 70.3 and the number of galls per m^2 from 9.5 to 65.5. All cultivars were susceptible to the parasite reared from the gall midge composed a species of *Platygaster oryzae*(Cameron) and *Neanastatus grallarius* (Masi) which together parasitized more than 50% of the species of *Gyrocompa*; *Gelis areatolpaz*) and unidentified ceratopoganids (Rai *et al.*, 1976).

A serious outbreak of *O.oryzae* occurred in the West Godavari District of Andhra Pradesh in 1989. Crops planted early (up to the end of December 1988) suffered no damage or less than 10% silvershoots, with higher than expected yields. Some varieties, although planted late, were also not attacked. The factors thought to have caused the outbreak were late planting of a susceptible genotype and unusually heavy mist every day from 5 to 30 February (Rao and Rao, 1989).

Fourteen grasses that have been reported in the literature as food plants for the rice pest GM were screened in India as alternative hosts for the Cecidomyiid. *O. oryzae* could develop only on *Leersia hexandra* (Linn.), but development on this grass under field conditions was negligible, indicating that it does not play an important role in carry-over of the pest (Natarajan *et al.*, 1987).

Field studies conducted during the wet season in India, during 1983-85, identified the platygasterid *P. oryzae* and the eupelmid *N. grallarius* [*N. cinctiventris*] as parasitoids of the cecidomyiid *O.oryzae*. The predominant parasitoid was *P. oryzae*, which became active in the second week of September when host infestation was the lowest (5.5%), 25-30 days after transplanting. The peak level of parasitoid activity by *P. oryzae* occurred during the first week of December, resulting in heavy mortality (85%) during this month. The level of infestation by *O. oryzae* and the level of parasitism by *P. oryzae* were positively correlated between the second week of September and the first week of November; However, the reverse trend was observed from then until the end of December (Chandrakar *et al.*, 1989).

Eighteen grasses were screened for the development of *O. oryzae* in laboratory and net-house studies in Orissa in 1979-85. None of the grasses supported development of the pest. In the field, adult emergence was negligible (6.8%) on *Leersia hexandra* compared with rice (73.6%). Eight species of cecidomyiids were reared from rice and nine species of grasses found in and around rice fields. The cecidomyiids reared from the test grasses, except *L. hexandra*, were unable to develop on the susceptible rice cultivar, Jaya. In *O.*

oryzae and *Mnesithea laevis*, the presence of the host plant or leaf extract of the host plant attracted the females to oviposit. Morphological differences between different cecidomyiid species are described. The galls formed by different cecidomyiid species also differed morphologically (Natarajan *et al.*, 1981).

In Guangdong, China, *O.oryzae* produced eight to nine generations annually. Under optimum temperature (25-28°C) and humidity (90% RH), despite the influence of natural enemies, the reproductive rate of the second-sixth generations on rice seedlings was 25.2-35.3 times on average, with the maximum more than 50 times. From the third generation the reproductive rate increased rapidly in each generation. The entire vegetative growing stage of rice was suitable for population growth. The greatest reproductive rate was observed on the seventh day of the seedling stage and in the middle and last stages of tillering. Humidity was the main factor influencing the reproduction of the cecidomyiid. At an average humidity of more than 78%, at the early to middle stages of rice tillering, the rate of reproduction increased by more than seven times from the previous generation to the following generation (Pan *et al.*, 1993).

The most important factor affecting the occurrence of rice GM in Wuping County, Fujian, China in 1993 were high density of overwintering populations, mild weather and a decrease in natural enemy density (Lan, 1994).

Infestation of paddy GM was studied on rice variety Sakoli-6 (Nagpur-27 X IR-8) in Maharashtra, during *kharif* 1983. The infestation was severe in the plots treated with nitrogen and lime alone or in combination. The intensity of infestation decreased with a more balanced nutritional supply to the plants and the lowest infestation was noted with the application of NPK at 100:50:50 kg/ha (Wankhade, 1994).

The pest was studied in Nigeria during the 1989 rainy season. In general, damage on ratoons was higher the occurrence of *O.oryzivora* on 33 Asian rice varieties resistant to than on the main crop, except for ARC5988, ARC14421, PTB18 and Warangal Culture 1251. Dissection of galls and ratoons revealed pupae and some diapausing larvae. The findings suggest that ratoons and volunteer plants may play a role in survival of the pest until the next rainy season (Joshi *et al.,* 1990).

2.4.1.3 Natural enemies of gall midge

Galls produced by GM were collected from rice at 18 sampling sites in five districts in the wet zone and three sites in the intermediate zone in paddy fields in Sri Lanka when plants were in the vegetative growth stage between 14 June and 5 July 1989. Predators and parasitoids were recorded and reared in the laboratory to the adult stage. Five hymenopterous parasitoids were collected: *P. oryzae, P.foersteri* (Gahan.), *Nanastatus cinctiventris* (G.) *Obtusiclava oryzae* S.Rao and *Eurytoma sp.*(A.) One predator, the carabid *Ophionea indica* was collected. Galls containing *P. oryzae* were found most frequently (13.5% of galls), followed by *N. cinctiventris* (8.7%) (Kobayashi *et al.,* 1990).

Hymenopterous parasitoid species and their parasitism were investigated on ratoon rice plants in paddy fields in the period of early to middle October 1990, immediately before the Maha rainy season in Sri Lanka. The following five species were observed in the galls of the cecidomyiid *Odorize* on secondary tillers from rice stubbles; *Eurytoma* sp., *Neanastatus cinctiventris, Obtusiclava oryzae*, *P. oryzae* and *P. foersteri. P. oryzae* and *N.cinctiventris* were the most abundant among these species. The highest percentage parasitism of *P. oryzae*, 68.2, was recorded at a sampling site in Mawatura, Nuwara Eliya District. It is concluded that these parasitoids pass through the season, even though rice plants are not cultivated, mainly in the galls on secondary tillers which sprout from rice stubbles (Kobayashi *et al.*, 1991).

Sain and Kalode (1992) carreid out studies on the population dynamics of the rice pest *O.oryzae* at Rajendranagar, Andhra Pradesh, over four years and showed that the pest appeared in late August, Its incidence reached a peak in October and declined by December. The activity of its parasitoids (*Platygaster oryzae, Platygaster* sp., *Propicroscytus mirificus* and *Eurytoma* *setitibia*) closely followed that of the host, increasing slowly to reach a peak in October-November.

Hymenopterous parasitoids and parasitism rates of *O.oryzae* were investigated in paddy fields of 11 districts in Sri Lanka, including three districts in the dry zone, from late December 1991 to mid-January 1992 during the Maha monsoon season. The same surveys were conducted during the Yala monsoon season in 1989 and the dry season just before the Maha season in 1990. The following species were collected during the current and previous surveys: *Platygaster oryzae*; *P. foersteri*; *Neanastatus cinctiventris* and *Obtusiclava oryzae*. *P.oryzae* was widely distributed throughout all the climatic zones, with the mean value of 21% parasitism being the greatest among the four species. Mean parasitism by *P.foersteri* was about one per cent. Parasitism by these two species decreased from the wet zone to the dry zone, parasitism by *P. oryzae* being about 31, 20 and 3% in the wet, intermediate and dry zones, respectively (Kobayashi and Kudagamage, 1994).

Populations of *Ophionea indica* larvae inhabiting the gall cavities resulting from infestation with *O. oryzae* were investigated in the paddy fields of Sri Lanka. The surveys were conducted three times from 1989 to 1992 during the Yala and Maha (monsoon seasons) and early Maha (dry season) seasons. In the Yala season, the population was high in the wet zone where a mean value of 3.0 larvae/100 galls was observed, while only 0.6 larvae/100 galls were recorded in the intermediate zone. These results suggest that the population density of the predatory larvae is high in the wet zone in the monsoon seasons. The predators seems to aggregate in the paddy fields where the rice gall midge pupae were abundant, because marked differences in larval catches were observed in the same district (Kobayashi *et al.*, 1995).

Populations of larvae and pupae of *O.oryzivora* and two parasitoids, *Platygaster diplosisae* and *Aprostocetus procerae*, were monitored during 1992-93 in irrigated rice fields (cv. ITA 123) at Karfiguela, Burkina Faso. Insect populations in the wet season developed through three phases; initial slow increase, followed by rapid increase coinciding with maximum tillering and a declining phase (Nacro *et al.*, 1995).

Host range experiments and field sampling in Nigeria produced no evidence that African rice gall midge, *O. oryzivora*, can develop on plants other than *Oryza* species. Sampling in three outbreak areas during 1994 showed that the insect's annual cycle varied according to the agro ecological zone and rice-cropping pattern. In the humid forest zone, *O.oryzivora* persisted through the short dry season on ratoons of cultivated rice at a rain fed site and on dry season rice crops at an irrigated one. Uncultivated wetland, irrespective of the time of year or the hosts involved. From gall dissections, the parasitoids *Aprostocetus procerae* (Risbec) and *Platygaster diplosisae* Risbec caused over 30% mortality at some sites by October but generally increased too late to prevent crop damage (Williams *et al.*, 1999).

Field sampling of grasses growing in and near rice fields at 12 sites in Nigeria during April / May 1994 recorded the presence of galls on *Pasphalum scrobiculatum* at densities of up to 10.9 galls per m2. These galls were induced by *Orseolia bonzii* Harris, sp. nov., which is described. This species is morphologically close to, but distinct from, the African rice gall midge, *O.oryzivora* with which it has been confused in earlier studies of that pest species. In host-transfer experiments *O. bonzii* did not transfer to rice. . Six hymenopterous parasitoids were reared from galls of *O. bonzii* and the most abundant of these were *Platygaster diplosisae* Risbec, *Aprostocetus* near *procerae* (Risbec) and *Neanastatus* near *cinctiventris* Girault. Host-transfer experiments with the Platygaster and *Aprostocetus* species from *O. bonzii* on *Pasphalum* indicated that the *Platygaster* may not transfer onto *O. oryzivora* on rice, whereas the *Aprostocetus* does (Harris *et al.*, 1999).

Table 2.4.1.3 Important natural enemies recorded for rice gall midge in India

Parasites	Stage
Platygaster oryzae	Egg / larva
P. foersteri	Egg / larva
Neamastatus grallarius	Pupa
Obtusiclava oryzae	Larva / pupa
Eurytoma spp	Larva / pupa
Predators	
Ophionea indica	Pupa
Paederus fusipes	Pupa
Amblyseius imbricatus	Egg

2.4.2 Laboratory biology

Methods are described by which *O. oryzae* was reared in large numbers on rice in the laboratory. The highest rate of production per cage was obtained with 30 males and 30 females confined on 1600 seedlings of two weeks old. Since most of the adult females emerged in the early evening. Mating and ovipositon took place immediately, afterwards transfer the midges to new plants had to be carried out. B/w 18.00 and 21.00 h midge development was not infleunced by the application N, P, K. Nitrogen alone rearing output was reduced by damage to the food plant or by *N.lugens* (Arifin and Vreden, 1977).

Adult flies of rice gall midge are mosquito - like, pink (female) to brownish (male) bodied which live for only one to two days. Flies emerged during early morning hours of the day and mate before day break. Unmated female emit strong sex pheromone that attracts male and ensures mating (Sain and Kalode. 1985). Female mate only once and lay about 100 -150 eggs on the plant. The egg hatch on the 4th day and newly hatched maggot crawl down the space between leaf sheath to reach apical meristem to start feeding. High humidity and presence of thin film of water on the plant surface facilitate maggot establishment in the plant.

2.5 Morphometrics of rice gall midge

Prakasa Rao, (1983) studied morphological differences of midges which includes the antennal horns of the pupae of rice gall midge, *Phasphalum distichum* midge and *Cynodon dactylon* midge are bifid but in the latter two, the length of the two arms are uneven and the abdominal tergal spines of the pupa of rice gall midge are arranged in single row with many spines and there is no pigmentation in 8-9 segments of pupae reared form *Oryza sativa* L. The abdominal colour of all grass midges was orange as that of rice. The forewing, haltere, fore-femur and fore tebia of the adult rice and grass midge was smaller in male midges than in female midges.

Natarajan *et al.* (1981) used the characters of apical horns of gall midge pupae to distinguish the *Mnesithea laevis* (Swartz) midge from rice midge. Gagne (1985) described this *M. laevis* midge as a new species (*Orseolia mnesitheae* Gagne). The ovipositional preference of this midge reported by Gagne lends further support to treat this midge distinct form rice gall midge.

Pupation of rice gall midge takes place inside the gall. The male and female pupae can be easily separated by their size and colour of the abdomen (Panda and Mohanty, 1970). Male pupae are small and brown. While the females are larger and pinkish.

MATERIAL AND METHODS

CHAPTER III

MATERIAL AND METHODS

In this Chapter, the materials used and the methods deployed for the investigation on rice gall midge have been described.

3.1. Field screening

Field screening for gall midge resistance was undertaken at Agricultural Research Station, Kankanady, University of Agricultural Sciences, Mangalore (13°N latitude 75°E longitude and 30 m AMSL) and at the Zonal Agricultural Research Station, V.C.Farm, Mandya (12° 32' N latitude, 76° 53' E longitude and 690 m AMSL), Karnataka where persistent occurrence of gall midge in abundance have been previously recorded. Field screening was conducted during *Kharif* (June-October) and summer (February-May) seasons 2003 and 2004 utilizing a variable number of rice accessions. Mangalore is located in the Coastal zone of Karnataka which is the **hot spot** for midge populations. Mandya is in Southern Karnataka and lies in the Cauvery command area, where irrigation is through canal water and gall midge is becoming an important constraint for increasing rice production. The area is fed by the Cauvery river water. Apart from field screening at the above two Research Stations, rice fields of farmers cultivating different rice varieties were visited and scored for gall midge infestation. Five metre square quadrates were randomly selected in the fields and all paddy hills within the quadrate were screened for gall midge resistance.

Selected rice accessions were planted in fields with Randomized complete block design. Each entry was replicated thrice in rows of 15 clumps. Spacing of 25 cm between rows and 20 cm between hills was maintained. There was one seedling/hill. After every ten rows of test entries, a row of susceptible check entry was planted. In Mandya and Mangalore TN-1 was choosen as susceptible check. To provide high humidity, water level at four-inch height was uniformly maintained in the field. Excessive nitrogenous fertilizers (@ additional 100 gm urea/100 m2 area) was applied. This was done to help increase gall midge population. For evaluating the rice entries against gall midge attack, the method of field screening developed by Prakasa Rao (1975) was used. The silver shoots were recorded twice at 30 and 50 days after transplanting. Data on total number of hills and number of infested and healthy hills were recorded. At both locations, abundant populations of gall midge occurred. The percentage of hills and tillers damaged was recorded and results converted to 0-9 scale.

$$\% \text{ damaged plants} = \frac{\text{No.of infested plants}}{\text{Total no.of plants}} \times 100$$

$$\% \text{ Silver shoots} = \frac{\text{Number of infested tillers}}{\text{Total number of tillers}} \times 100$$

The percentage of infested plants was converted to a 0-9 scale using the Standard Evaluation Score (SES) for rice (IRRI scale).

Scale	Plants with galls
0	None
1	Less than 1%
3	1-5%
5	6-15%
7	16-50%
9	51-100%

The accessions were raised following recommended package of practice (UAS, 2002). The field screening provided natural infestation conditions with a genetically heterogeneous gall midge population.

Six released varieties and six elite rice genotypes were tested at V.C. farm, Mandya, the varieties and genotypes were planted in two rows, each of ten meter row length, observations were recorded on per cent damaged plants (DP) and per cent silver shoots (SS) at 30 and 50 DAT.

3.2 Laboratory Screening

The laboratory screening was done at ARS, Kankanady, Mangalore during December, 2003. The method followed by Arifin and Vreden, (1977) was used. Plastic seed boxes of (60 x 45 x10 cm) was selected and filled with fertile soil. Four rice cultivars *viz.,* Jaya, Jyothi, Phalguna and MO-4 along with Savithri a rice genotype and TN -1, a susceptible check were sown at 15 cm long rows and maintained 15 plants per row. Ten days after sowing placed the boxes in shallow iron tray measuring 123 x 85 x 21 cm and covered the tray with nylon mesh of 150 x 100 x 100 cm (Plate 1). Twenty days old seedlings were infested with wild caught 0-1 day old male and females adults midges of six pairs were released into the box. After two days of infestation, spray the plant with water by using hand sprayer at 2-3 hour interval a day for two days and then filled the water in iron tray and increase the water level upto three cm from the base of the plant there by facilitating egg hatching and preventing the parasitization. Per cent DP and SS were recorded at 30 and 50 days after infestation.

$$\% \text{ damaged plants} = \frac{\text{Number of plants infested}}{\text{Total No.of plants}} \times 100$$

$$\% \text{ Silver shoots} = \frac{\text{Number of tillers infested}}{\text{Total number of tillers}} \times 100$$

The percentage of infested plants was converted to a 0-9 scale using the Standard Evaluation Score (SES) for rice.

3.3 Identification of biotypes using standard rice differentials

A set of 14 differential rice cultivars were field evaluated at Agricultural Research Station, Kankanady, Managalore and ZARS Mandya during the wet season *(Kharif)* in 2003. The method followed by Kalode and Bentur (1989) was used. Based on the resistant donor parent involved the cultivars were grouped

Plate 1 Experimental set up for screening rice varieties in laboratory

into four main differential groups, viz., Group I, Group II, Group III and TN1 as susceptible check variety included in group IV.

As this screening was conducted at Kankanady, Mangalore and Mandya which have been designated as **hot spot** for rice gall midge (RGM), the test was valid as there was adequate GM population in the field. Each entry was replicated four times. The test cultivars and the susceptible controls were evaluated in terms of percent plants and/or tillers damage from 20 hills. Each entry was rated either resistant (R) with less than 10% damage or susceptible (S) with more than 10 per cent damage. Overall performance of each group of differentials was made out to characterize differences in biotype reaction. Percent DP and percent SS were recorded at 30 and 50 DAT.

3.4 Biology of rice Gall midge

3.4.1 Field biology

Observations on biology of RGM were recorded at ARS, kankanady, Mangalore during wet season (*Kharif*) July to November. Blocks of rice cultures were maintained at field conditions. These rice accessions were naturally infested by the GM. Clumps showing silver shoots were enclosed in a nylon mesh chamber, which conveniently housed the rice clumps without affecting the plant growth and growth and development of insects. In a block, ten such chambers were maintained and in all ten rice clumps of Jaya variety were utilized for the purpose. A method followed by Joshi et al. (1983) was used. Records were maintained on adult emergence, oviposition, larval duration, pupal duration and adult longevity. To confirm field observations twelve uninfested clumps of Jaya variety were enclosed in Nylon mesh chamber (50x40x60 cm) and one pair of adults were released. Records on different life cycle stages were maintained as previously mentioned. The data on weather parameters during the period of study was collected and their influence on the life cycle of GM was determined. Besides this, a survey was conducted in farmers fields in coastal region (in and around Mangalore) and in Cauvery command area (in and around Mandya) and observations on alternate hosts of GM, natural enemies, survival of the pest during off season, light trap catches were recorded at weekly intervals during the peak activity of the pest.

3.4.2 Biology of gall midge in laboratory

In laboratory, one pair of wild caught males and females of rice GM were enclosed in an oviposition cage measuring (75x75x85 cm.) containing potted 20 days old rice seedlings of Jaya, ten such pots (15x15 cm) were maintained separately, after 24 hours of infestation count the number of eggs laid by each female until the death of the female. Everyday adults were provided with fresh potted seedlings of Jaya variety for oviposition. After two days, the potted plants with eggs were transferred to a cage, made of wood and wire mesh (77.5 x 60 x 75 cm.). High humidity was maintained inside the cage by spraying water with hand sprayer every two hour during the day. The seedlings were maintained in this condition for four days, as moisture is necessary for egg hatching, larval feeding and growth. (Date records were maintained on toal number of eggs laid by each female, incubation period of eggs, total maggot period,pupal duration and adult longevity).

After four days the cage is placed in a metallic tray (123 x 85 x 21 cm) filled with water upto three cm. This is done in order to facilitate optimum humidity and prevent parasitization and predation of GM life stages.

When galls are observed on shoots the potted seedling is transferred to adult emergence cage, adults are collected every day b/w 1800 and 2100 h. A zero watt red bulb was provided in the cage to concentrate spots for adult collections using aspirator.

3.4.3 Monitoring adults of rice gall midge

Adequate population of GM under natural conditions is a pre-requisite for conducting valid field screening trials. In order to determine the adult density of rice gall midge (RGM) 250-watt mercury vapour lamp was used. This light trap was placed at one end of the cultivated paddy fields in an elevated spot and was covered by a metallic zinc sheet over head. The temperature, relative humidity and rainfall data was also collected during the period of adult gall midge collection.

3.5 Morphometrics of life stages of gall midge

During surveys for rice GM and during field screenings, samples of different stages of rice gall midge were collected in glass vials (7 x 1 cm) with alcohol (95%). Each vial was numbered and against each number detail on rice variety, location, date of sampling and insect stage was maintained separately. These insect samples were maintained in a dry freeze.

At the time of recording measurements, samples were brought to laboratory and contents of each vial were poured in a cavity block and using a binocular microscope, measurements were recorded in eye piece calibrated ocular micrometer was inserted and each division on ocular micrometer corresponded to 0.14mm at 0.7 resolution. The parameters selected for measurements are length, breadth of egg, pupae and adult; in pupae antennal horne and abdominal spines were also observed.

Observations recorded on collection of gall midges to light traps. The relation ship between the gall midge adult light trap catches and weather parameters was determined by correlation analysis (Sunderaraj *et al.*, 1972).

EXPERIMENTAL RESULTS

CHAPTER IV

EXPERIMENTAL RESULTS

The results of different investigations carried out on rice gall midge *Orseolia oryzae* in Mangalore, Mandya and surrounding areas in Karnataka conducted during 2003 and 2004 are presented in this Chapter.

4.1 Field screening

Twenty-five rice germplasm accessions were screened during *kharif* (June to October) 2003 at Agricultural Research Station, Kankanady, Mangalore. The Agricultural Research Station Farm represented both low land and midland farming situations. So, TN-1 and MO4 were included as check. At 30 days after transplantation (DAT) the accessions were scored for per cent silvershoots (SS) and per cent damaged plants (DP). All the accessions were free from gall midge infestation at 30 DAT. At 50 DAT GM infestation ranged from zero in MO4, IET 17515, IET 17248 and IET 16935 to 17.59 per cent in Pusabasmati. Statistical data showed significant differences at 5% in GM infestation among the accessions. Thus, Savithri, Pusabasmati, Pooja, Salivahana, CSR13 and Govinda recorded significantly higher infestation than other varieties compared to 31.25 percent silver shoots recorded in susceptible check TN-1 (Table 1 and 4a).

The same (as above) twenty-five rice germplasm accessions were screened under field conditions at Zonal Agricultural Research Station, V.C. Farm, Mandya during *Kharif* 2003. Due to long dry spell and drought - like situation with delayed scanty rains (Table 20 and Appendix II). The area under rice cultivation was drastically reduced, the growth of the paddy plant at several places suffered due to lack of moisture and as a result population build up of gall midge under field conditions was hindered. At 30 DAT none of the accessions recorded gall midge infestation. At 50 DAT, only twelve accessions recorded gall midge infestation. Only eight accessions recorded more than one per cent infestation on silver shoot basis (Table 2 and 4a) including susceptible check TN-

Table 1 Response of rice germplasm accessions to gall midge during *kharif*, 2003 at Mangalore

Sl. No	Accessions	Infestation (%) at 30 DAT			Infestation (%) at 50DAT		
		DP	SS	Score	DP	SS	Score
1	IET 17114	0.00	0.00	0	1.66	0.23	3
2	17116	0.00	0.00	0	3.33	0.83	3
3	17248	0.00	0.00	0	0.00	0.00	0
4	17439	0.00	0.00	0	1.66	0.66	3
5	17249	0.00	0.00	0	3.33	1.38	3
6	17441	0.00	0.00	0	1.66	0.71	3
7	17115	0.00	0.00	0	1.66	0.23	3
8	17079	0.00	0.00	0	1.66	0.55	3
9	17247	0.00	0.00	0	3.33	0.55	3
10	16708	0.00	0.00	0	1.66	0.33	3
11	17515	0.00	0.00	0	0.00	0.00	0
12	17048	0.00	0.00	0	0.00	0.00	0
13	17512	0.00	0.00	0	1.66	0.37	3
14	16935	0.00	0.00	0	0.00	0.00	0
15	459 (Tulasi)	0.00	0.00	0	20.00	8.33	7
16	463 (Savithri)	0.00	0.00	0	26.66	21.66	7
17	451 (Pusa basmati)	0.00	0.00	0	30.00	17.59	7
18	464 (Pooja)	0.00	0.00	0	28.33	16.33	7
19	457 (Govinda)	0.00	0.00	0	25.00	11.81	7
20	460 (CSR 13)	0.00	0.00	0	26.66	11.83	7
21	465 (Salivahana)	0.00	0.00	0	21.66	16.19	7
22	449 (Dubaraj)	0.00	0.00	0	23.33	16.33	7
23	IET 17430	0.00	0.00	0	1.66	0.41	3
24	TN1(Check)	0.00	0.00	0	56.66	31.25	9
25	MO4 (Check)	0.00	0.00	0	0.00	0.00	0

DP = Damaged plants
SS = Silver shoots

Table 2 Response of rice germplasm accessions to gall midge during *kharif*, 2003 at Mandya

Sl. No	Accessions	Infestation (%) at 30 DAT			Infestation (%) at 50DAT		
		DP	SS	Score	DP	SS	Score
1	IET 17114	0.00	0.00	0	0.00	0.00	0
2	17116	0.00	0.00	0	0.00	0.00	0
3	17248	0.00	0.00	0	0.00	0.00	0
4	17439	0.00	0.00	0	1.66	0.23	3
5	17249	0.00	0.00	0	0.00	0.00	0
6	17441	0.00	0.00	0	1.66	0.47	3
7	17115	0.00	0.00	0	0.00	0.00	0
8	17079	0.00	0.00	0	3.33	0.83	3
9	17247	0.00	0.00	0	3.33	0.74	3
10	16708	0.00	0.00	0	0.00	0.00	0
11	17515	0.00	0.00	0	0.00	0.00	0
12	17048	0.00	0.00	0	0.00	0.00	0
13	17512	0.00	0.00	0	5.00	1.90	3
14	16935	0.00	0.00	0	0.00	0.00	0
15	459(Tulasi)	0.00	0.00	0	10.00	4.37	5
16	463(Savithri)	0.00	0.00	0	5.00	1.48	3
17	451(Pusa basmati)	0.00	0.00	0	8.33	2.91	5
18	464(Pooja)	0.00	0.00	0	18.33	7.38	7
19	457(Govinda)	0.00	0.00	0	0.00	0.00	0
20	460(CSR 13)	0.00	0.00	0	8.33	3.12	5
21	465(Salivahana)	0.00	0.00	0	0.00	0.00	0
22	449(Dubaraj)	0.00	0.00	0	11.66	3.80	5
23	IET17430	0.00	0.00	0	1.66	0.47	3
24	TN1(Check)	0.00	0.00	0	48.33	20.18	7
25	MO4 (Check)	0.00	0.00	0	0.00	0.00	0

DP = Damaged plants
SS = Silver shoots

1. The highest per cent silver shoot was recorded in TN-1 that is (20.18) and Phalguna recorded zero per cent silver shoots as resistant check. IET 17114, IET 17116, IET 17248, IET 17249, IET 17115, IET 16708, Govinda, IET 17515, IET 17048, IET 16935, and Salivahana recorded zero per cent SS at 50 DAT. Therefore, no logical inference could be deduced from the results of screening trial at Mandya during *Kharif*, 2003.

During *Kharif*, 2004 another set of 25 rice accessions with MO4 as a check were field evaluated at Agricultural Research Station, Kankanady, Mangalore. An observation on gall midge infestation was limited to 30 days after transplanting only. The per cent silver shoots ranged from 0 to 2.5 in IET 17247. MO4 recorded 0.41 SS compared to 3.00 in TN-1(Table 3). Further observations are required to assess the reaction of rice accessions to gall midge damage.

Another field screening trial using 25 rice accessions was conducted at ZARS, V.C. Farm, Mandya during *Kharif*, 2004. None of the entries at 30 DAT recorded any infestation by gall midge (Table 4).

Apart from the field screening, farmer's fields were visited during *Kharif*, 2003 in and around Mangalore, where Jaya, Jyothi, Mahaveer, Shakthi, Nethra varieties were cultivated by the farmers. At a place called Jellygudde, Jaya recorded 5.8 per cent DP with 2.66 per cent SS and Jyothi recorded 5.26 per cent DP with 0.8 per cent SS at 40 DAT. Whereas Mahaveera recorded 3.59 per cent DP and 0.75 per cent SS (Table 4b).

In Mandya region, Jaya and IR 64 varieties were grown during *Kharif*, 2003 and 2004. IR 64 recorded 4.69 per cent DP with 0.38 per cent SS where as Jaya recorded 9.03 per cent DP with 1.14 per cent SS (Table 4b).

In addition to field screening trials conducted as presented above, six rice released varieties and six elite rice genotypes were screened for GM infestation

Table 3 Response of rice germplasm accessions to gall midge during *kharif*, 2004 at Mangalore

Sl. No	Accessions	Infestation (%) at 30 DAT		
		DP	SS	Score
1	IET 18470	0.00	0.00	0
2	18472	1.66	0.55	3
3	18477	3.33	1.25	3
4	18479	0.00	0.00	0
5	18480	1.66	0.83	3
6	18494	0.00	0.00	0
7	18495	3.33	1.33	3
8	17501	3.33	2.08	3
9	17898	5.00	2.00	3
10	18218	3.33	1.25	3
11	18221	0.00	0.00	0
12	18224	0.00	0.00	0
13	18232	1.66	0.66	3
14	18238	0.00	0.00	0
15	18240	0.00	0.00	0
16	18244	1.66	1.25	3
17	17431	0.00	0.00	0
18	17457	0.00	0.00	0
19	17519	1.66	0.66	3
20	17910	0.00	0.00	0
21	17918	0.00	0.00	0
22	17247	3.33	2.50	3
23	17205	0.00	0.00	0
24	TN-1(Check)	6.66	3.00	5
25	MO-4(Check)	1.66	0.41	1

DP = Damaged plants

SS = Silver shoots

Table 4 Response of rice germplasm accessions to gall midge during *kharif*, 2004 at Mandya

Sl. No	Accessions	Infestation (%) at 30 DAT		
		DP	SS	Score
1	IET 18470	0.00	0.00	0
2	18472	0.00	0.00	0
3	18477	0.00	0.00	0
4	18479	0.00	0.00	0
5	18480	0.00	0.00	0
6	18494	0.00	0.00	0
7	18495	0.00	0.00	0
8	17501	0.00	0.00	0
9	17898	0.00	0.00	0
10	18218	0.00	0.00	0
11	18221	0.00	0.00	0
12	18224	0.00	0.00	0
13	18232	0.00	0.00	0
14	18238	0.00	0.00	0
15	18240	0.00	0.00	0
16	18244	0.00	0.00	0
17	17431	0.00	0.00	0
18	17457	0.00	0.00	0
19	17519	0.00	0.00	0
20	17910	0.00	0.00	0
21	17918	0.00	0.00	0
22	17247	0.00	0.00	0
23	17205	0.00	0.00	0
24	TN1(Check)	0.00	0.00	0
25	Phalguna (Check)	0.00	0.00	0

DP = Damaged plant

SS = Silver shoot

Table 4a Number of rice accessions showing incidence of silver shoots during *kharif* 2003

Number of accessions producing silver shoots

Mangalore

Incidence (%)	30 DAT	50 DAT
0	25	5
1-5	0	11
5.1-10	0	1
10.1-20	0	6
> 20	0	2
Total	25	25

Mandya

Incidence (%)	30 DAT	50 DAT
0	25	12
1-5	0	11
5.1-10	0	1
10.1-20	0	0
> 20	0	1
Total	25	25

Table 4b Gall midge infestation in farmer's field at Mangalore and Mandya during *kharif* 2003

Location	Variety	Infestation at 40 DAT		Score
		DP(%)	SS(%)	
Mangalore				
Jelligudde	Jaya	5.8	2.66	5
Pumpwell	Jyothi	5.26	0.80	5
	Mahaveera	3.59	0.75	3
Mandya				
Shivapura	IR 64	4.69	0.38	3
	Jaya	9.03	1.14	5

Table 5 Gall midge Incidence on elite genotypes at Mandya during February to May 2004

Sl. No	Released varieties	Infestation (%) at 30 DAT			infestation (%) at 50 DAT		
		DP	SS	Score	DP	SS	Score
1	Jaya	3.5	2.62	3	6.66	4.99	5
2	BR – 2655 (GOT)	2.1	1.57	3	3.45	2.58	3
3	IET – 7575	1.80	1.34	3	3.33	2.49	3
4	IET – 8116	0.00	0.00	0	0.20	0.14	1
5	KMP – 101 (Tanu)	0.00	0.00	0	0.00	0.00	0
6	Mandya Vijaya (GOT)	0.51	0.38	1	1.20	0.84	3
	Elite rice genotype						
1	IET 16350	0.0	0.0	0.0	0.0	0.0	0
2	IET 16347	0.0	0.0	0.0	0.0	0.0	0
3	IET 16348	0.0	0.0	0.0	0.0	0.0	0
4	IET 17616	0.0	0.0	0.0	0.0	0.0	0
5	IET 15297	0.0	0.0	0.0	0.0	0.0	0
6	IET 15924	0.0	0.0	0.0	0.0	0.0	0

DP = Damaged plants SS = Silver shoots

at V.C. Farm, Mandya during summer 2004. Data is presented in Table 5. At 30 DAT, Jaya, BR 2655 and IET 7575 recorded a GM score of 3; Mandya Vijaya recorded a GM score of 1. At 50 DAT Jaya recorded a GM Score of 5 which was maximum score recorded for any of the rice genotype tested. BR-2655 and IET 7575 maintained the GM damage score of 3 at 50 DAT, IET 8116 recorded GM damage score of 1 at 50 DAT. Mandya vijaya recorded a damage score of 3 at 50 DAT and KMP-101 recorded Zero infestation at 50 DAT. Where as none of the elite rice genotypes recorded a silver shoots at 30 and 50 DAT. Thus, it may be concluded that some of the seed production plots of elite rice genotypes were found vulnerable to GM damage. Hence, precautionary measures and plant protection practices need to be executed while raising seed production in bulk of the above elite rice genotypes and released rice varieties.

4.2 Laboratory screening

The reaction of four commonly cultivated rice varieties in coastal region, one susceptible check, TN-1 and one rice accession Savithri were tested in laboratory against gall midge populations during December 2003 and January 2004. The onion shoots from TN-1 were field collected and maintained in laboratory under high humidity condition for adult emergence. No attempt was made to genetically characterize the gall midge populations.

Adults from the light trap catches were collected in glass vials using aspirator. Ten clumps were randomly chosen in a plastic tray and they were covered with nylon mesh. Ten clumps of each variety of 20 days old seedlings were infested by releases six pairs of adults later the per cent damaged plants and silver shoots were recorded at 30 and 50 Days after infestation (DI). Data is presented in Table 6.

All the six rice genotypes were found susceptible to gall midge populations at 30 days after infestation. The per cent damaged plants (D.P) varied from 7 in Phalguna to 25 in TN-1 and the per cent silver shoot (SS) varied from 3.11 to 11.11 respectively.

Table 6 Screening of rice genotypes for gall midge damage under laboratory conditions at Mangalore

Sl. No	Genotypes/ cultivar	Infestation(%) at			
		30 DAT		50 DAT	
		DP	SS	DP	SS
1	Jaya	19	8.44	59	38.77
2	Jyothi	15	6.66	55	36.14
3	MO4(Bhadra)	9	4.00	15	9.85
4	Phalguna	7	3.11	16	10.51
5	Savithri	12	5.33	59	38.77
6	TN -1 (Check)	25	11.11	65	42.71

DP = Damaged plants SS = Silvershoots

At 50 DAT per cent damage plants varied from 15 to 65. The per cent silver shoot varied form 9.85 in MO4 to 38.77 in Jaya compare to 42.71 in susceptible check TN-1. This data indicated that Jaya was the most susceptible and that the population of gall midge was derived from the same genotype. Jaya, Jyothi and Savithri were also highly susceptible. MO4 and Phalguna showed about 10% SS damage under laboratory condition (Table 6). However, under field condition they may be Susceptible in view of occurrence of genetically mixed gall midge populations.

4.3 Reaction of differentials to gall midge infestation

A set of fourteen differentials belonging to four groups were screened in field at Agricultural Research Station, Kankanady, Mangalore, during *kharif*, 2003. Group I included two differentials viz., W1263 and ARC6605, group II included three differentials viz., Phalguna, ARC 5984 and Bhumamsan, group III included eight differentials viz., CR-MR1523, Velluthacheera, Aganni, RP-2068-18-3-5, Abhaya, T1477, INRC 202 and INRC 1997 and group IV included TN-1 as susceptible check, as it was showing susceptibility to all the biotypes of gall midge.

A fairly good level of infestation by gall midge was observed in the test plots at Mangalore. All the fourteen differentials showed infestation of the gall midge. However, CR-MR1523, Velluthacheera, RP-2068-18-3-5 and T-1477 of group III showed less than eight per cent silver shoot at 50 DAT. This low level of infestation needs to be further confirmed both under field conditions and laboratory. These are resistant donors and under field conditions they may show higher level of infestation in view of the genetically mixed populations, the reaction under field conditions cannot be regarded as susceptible (Table7).

In Group I W1263 and ARC 6605 recorded 16.43 and 22.92 per cent silver shoot at 50 DAT. Similarly in-group II Phalguna, ARC 5984 and Bhumansan recorded 23.85, 19.31 and 24.02 per cent silver shoot at 50 DAT. In group III of eight differentials four were damaged by gall midge more than 10% and the per cent S.S. varied in these four differentials from 11.79 to 20.97 at 50 DAT (Table 7). Surveys conducted in different parts of Coastal Karnataka during 2003-2004. Suggested that, under these conditions most rice cultivars commonly cultivated in Coastal Karnataka were highly susceptible to rice gall midge populations. Group IV TN1 recorded 32.63 per cent silvershoot at 50 DAT, as it is potentially susceptible to all the biotypes. This screening trial showed that in Mangalore genetically mixed populations of rice gall midge are prevaled.

Geographic distribution of these biotypes, then, was not in continuum. While populations at Hyderbad, Warangal and Maruteru in Andhra Pradesh, Sambalpur in Orissa and Raipur in Madhya Pradesh were grouped as biotype 1, populations at Cuttack and Bhubaneswar in Orissa State on the east coast, at Mangalore in Karnataka and Goa on the west coast and Sakoli in Maharastra in the central India were grouped as biotype 2. Gall midge populations at Ranchi in Bihar and Wangbal in Manipur belonged to biotype 3 (Kalode and Bentur, 1989). As these reactions were based on field evaluation over the years, population at the test site was considered to be homogeneous.

Phalguna is a resistant donor for biotype 2 and ARC 5984 is a resistant donor for biotype 2 and RP 2068-18-3-5 as a resistant donor for biotype 3 all the resistant donors were found infested with the GM populations. This observation indicated presence of genetically mixed populations at Kankanady and further observations are required to confirm the genetic status of the GM populations and also the host plant interaction.

The reaction of rice differentials to gall midge populations was field tested simultaneously at ZARS, V.C. Farm, Mandya (Table 8). The 14 differentials belonged to the same four groups identified at Mangalore (Table 7 and 8). Interestingly only TN-1 the susceptible check was vulnerable to damage by gall midge populations in Mandya, which is in the Cauvery Command area. This

Table 7 Reaction of standard rice differentials for gall midge incidence at Mangalore during *kharif*, 2003

Group	Entry No	Differential	Infestation(%) at 30 DAT DP	30 DAT SS	50 DAT DP	50 DAT SS
I	1	W 1263	11	4.89	25	16.43
	2	ARC 6605	10	4.62	47	22.92
II	3	Phalguna	9	6.50	35	23.85
	4	ARC 5984	8	5.80	34	19.31
	5	Bhumansan	5	4.50	28	24.02
III	6	CR-MR 1523	5	2.52	10	7.50
	7	Velluthacheera	4	2.70	9	5.69
	8	Aganni	11	5.39	29	20.97
	9	RP 2068-18-3-5	3	2.39	2	1.29
	10	Abhaya	5	3.40	20	18.18
	11	T 1477	4	1.86	7	4.61
	12	INRC 202	7	3.36	19	12.63
	13	INRC 1997	3	1.44	14	11.79
IV	14	TN-1	13.1	7.80	54.3	32.63

TP = Total plants DP = Damaged plant

TT = Total tilters SS = Silver shoots

Table 8 Reaction of standard rice differentials for gall midge incidence at Mandya during *kharif*, 2003

Group	Entry No	Differential	Infestation(%) at			
			30 DAT		50 DAT	
			DP	SS	DP	SS
I	1	W 1263	0.00	0.00	0.00	0.00
	2	ARC 6605	0.00	0.00	0.00	0.00
II	3	Phalguna	0.00	0.00	0.00	0.00
	4	ARC 5984	0.00	0.00	0.00	0.00
	5	Bhumansan	0.00	0.00	0.00	0.00
III	6	CR-MR 1523	0.00	0.00	0.00	0.00
	7	Velluthacheera	0.00	0.00	0.00	0.00
	8	Aganni	0.00	0.00	0.00	0.00
	9	RP2068-18-3-5	0.00	0.00	0.00	0.00
	10	Abhaya	0.00	0.00	0.00	0.00
	11	T 1477	0.00	0.00	0.00	0.00
	12	INRC 202	0.00	0.00	0.00	0.00
	13	INRC 1997	0.00	0.00	0.00	0.00
IV	14	TN-1	15.50	12.71	58.00	34.85

TP = Total plants DP = Damaged plant

TT = Total tilters SS = Silver shoots

indicated that the presence of only one GM biotype1 under the conditions of Mandya displaying R-R-R-S pattern of differential reaction.

4.4 Biology of rice gall midge

4.4.1 Field biology

Field observations in rice fields during July to August 2003 revealed presence of gall midge eggs at lower surface of paddy leaves. Eggs were laid parallel to the midrib either singly or in groups. When in groups the eggs were glued parallel to each other. In each group 2-4 eggs were found. Freshly laid eggs were tubular, with light pink shade (Plate 2). However, in Mandya the gall midge eggs were light pink, shiny, transluscent laid in groups on the under side near the base of the rice leaves. The incubation period lasted for 2.2 to 3.5 days under conditions of Mangalore, when temperature, relative humidity fluctuated between 28^0 – 30^0C and 90-92% RH (Table 9 and Appendix I). Newly hatched maggots moved between leaf sheath until it reached a growing point of apical or lateral buds. The newly hatched maggots were greyish with a pointed anterior end. The maggot fed inside the developing bud. The presence of an active maggot at the meristem stimulated the formation of a gall and suppressed the growth cone. When fully fed the third instar maggot moult into pupa. The total maggot period lasted on an average 8.0 to 11.5 days. The pupal period lasted on an average between 4.0 to 5.5 days (Table 9 and Figure3).

Pupation took place inside the gall, the male and female pupae could be easily distinguished by their size and the colour of the abdomen. Male pupae were small and brown. Female pupae were pink and large (Plate 3).

The pupae have several rows of abdominal spines enabled it to move up to the tip of the gall before adult emergence. The pupa made a hole at the gall tip with its spines through which the adult midge emerged. Adult emergence was observed between 19.00 h to 5.30 h in the morning. The adult male lived for one to two days and the female on an average lived for two to three days. Each female laid 188-208 eggs under field conditions of Mangalore during August

Plate 2 Eggs of rice gall midge

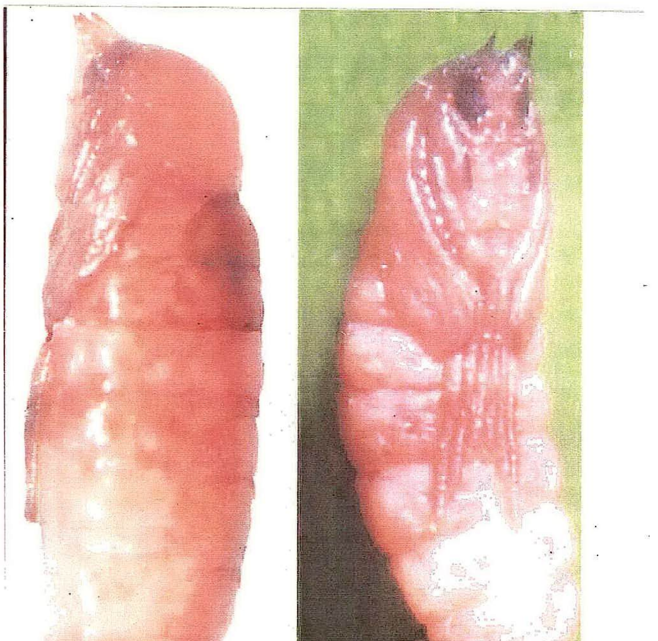

Plate 3 Dorsal and ventral view of rice gall midge pupae

Table 9 Field Biology of rice gall midge *Orseolia oryzae* at Mangalore

Life Stages	Range (Days)		Mean
Egg	2.2	3.5	2.84
Larval Instars (I,II & III)	8.0	11.5	9.75
Pupa	4.0	5.5	4.75
Total Developmental period	16.5	23.5	20.0
Fecundity /female	188	208	198.0
Adult longevity			
Male	1.0	2.0	1.5
Female	2.0	3.0	2.5

* Mean of 10 observations

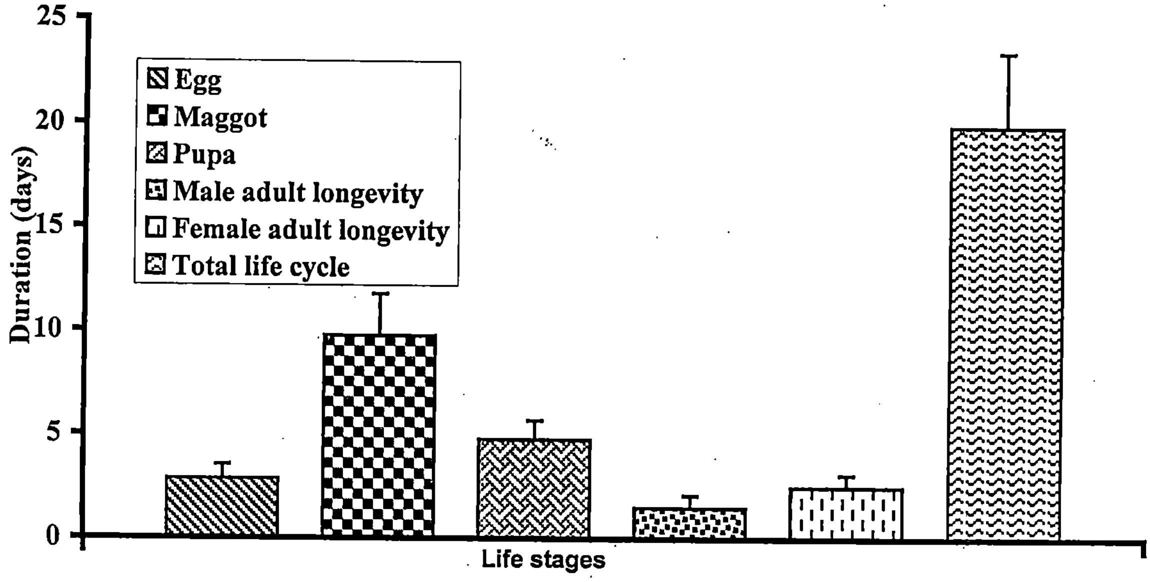

Figure 3 Field biology of rice gall midge *Orseolia oryzae* at Mangalore

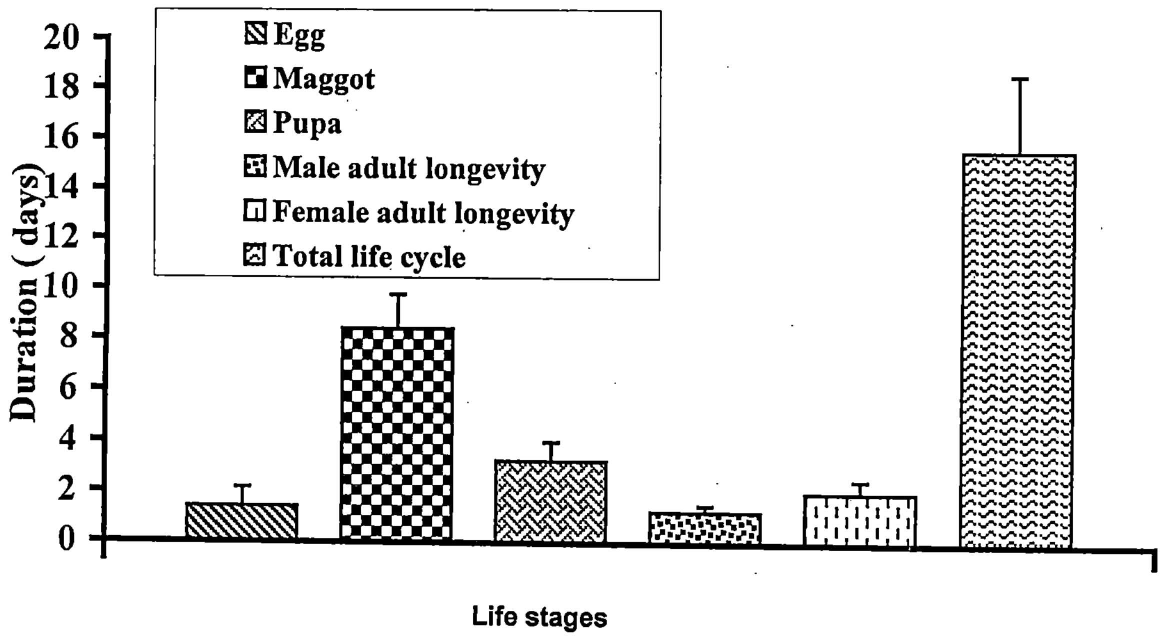

Figure 4 Biology of rice gall midge *Orseolia oryzae* in laboratory at Mangalore

2003. Adult copulated soon after the emergence and within 6h of emergence females were observed laying eggs. The total life cycle under field conditions varied from 16.5 to 23.5 days in Mangalore (Table 9 and Figure 3). An interesting feature in the biology of gall midge observed was a female laid eggs of only one sex; either male or female.

4.5 Biology of *Orseolia oryzae* under laboratory condition

To confirm field observations on the life stages and life cycle of rice gall midge biology of the insect pest was also studied under laboratory conditions in Mangalore. The incubation period of eggs on an average varied from 1.5 to 3.0 days, when temperature fluctuated between 32^0-34^0C and relative humidity touched almost 100% under caged condition (Table 10 and Figure 4). Eggs were laid in clusters under laboratory conditions on underside of the leaf sheath. Freshly laid eggs were tubular with pink shade (Plate 2). Before hatching egg colour changes to dark brown, on hatching the tiny young maggots moved down between leaf sheath and attacked the lateral buds.

In this congenial microclimatic condition, maggot grew up fast and completed development within 7.0 to 9.75 days. The maggot were grey white having 13 segments and were surrounded by the hallow chamber called "gall".As the larva continued feeding inside the gall, the gall enlarged and the whole tiller gave the appearance of an onion shoot(Plate 6). Pupation occurred inside the gall (Plate 5) and the pupal period, on an average inside the cage varied from 2.5 to 4.0 days. Adult longevity in male Spanned between 1 to 1.5 days. In female the corresponding value on an average was between 1.5 to 2.5 days. On an average a female laid 90-115 eggs, which was smaller than that laid under field conditions the total life cycle of the midge required shorter time of 12.5 to 18. 5 days.

Table 10 Biology of rice gall midge *Orseolia oryzae* **in laboratory at Mangalore**

Life stages	**Range(days)**		*** Mean**
Egg	1.5	3.0	2.25
Larval Instars (I,II & III)	7.0	9.75	8.37
Pupa	2.5	4.0	3.25
Total Developmental period	12.5	18.50	15.5
Fecundity /female	90.0	115.00	102.5
Adult longevity			
Male	1.0	1.5	1.25
Female	1.5	2.5	2.0

* Mean of 10 observations

Plate 6 General view of well formed gall under field condition

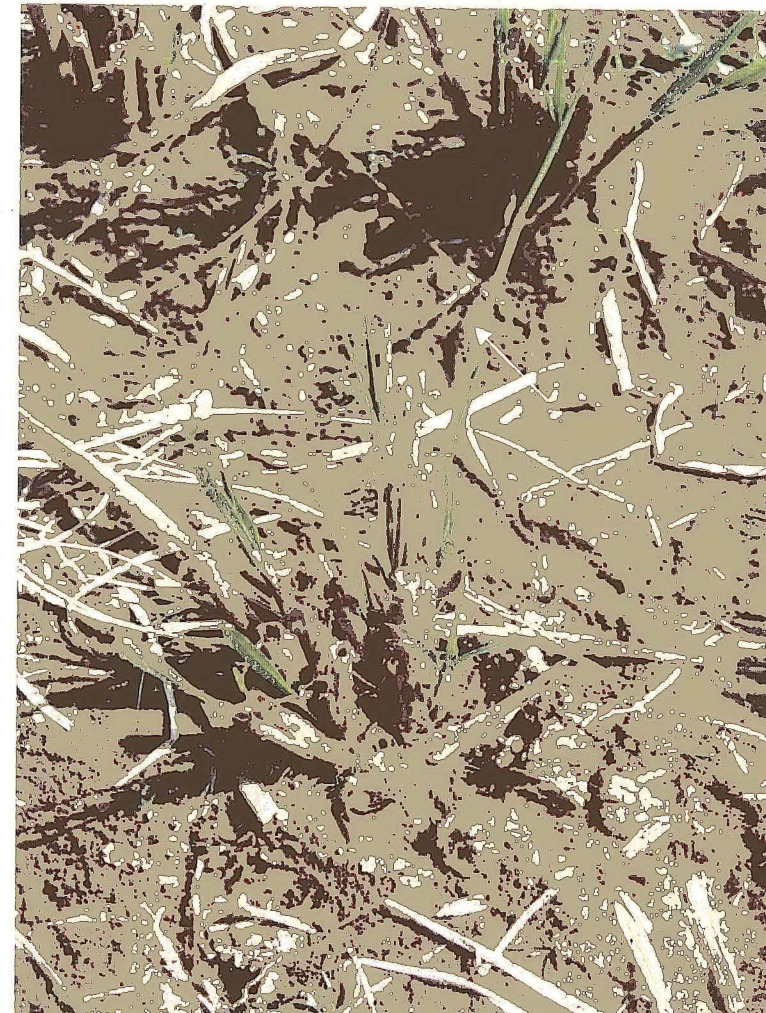

Plate 7 Gall found on sprouts of ratoon rice stubbles left over after harvest during off season

Table 11 Seasonal occurrence of rice gall midge at Mangalore

+ = Abundant population (>5/day/trap)
+ = Negligible population (<1/day/trap)
+ = Minimum population (1-5/day/trap)
- = No population (Zero/day/trap)

+	-	-	+	+	+	+	+	+	+	+	+
Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.

Table 12 Seasonal occurrence of rice gall midge at Mandya

✚ = Abundant population (>5/day/trap)
✙ = Negligible population (<1/day/trap)
+ = Minimum population (1-5/day/trap)
- = No population (Zero/day/trap)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
+	+	-	✙	+	✙	-	-	✚	✚	✚	✚

4.4.2 Alternate host plants of rice Gall midge

Six species of plants in and around cultivated paddy fields at Kankanady, Mangalore were examined for rice gall midge life stages throughout the year. The rice gall midge population was also monitored for presence or absence throughout the year. Observations were recorded on cultivated paddy crop during 2003 and 2004 (upto August 2004) revealed that gall midge was not present on cultivated paddy crop during February and March at Mangalore (Table 11 and 13). Negligible GM infestation (less than 1%) was found during April and May both the years.

At V.C. Farm, Mandya, nine species of plants in and around cultivated paddy fields were examined for rice gall midge life stages throughout the year. The rice gall midge populations were also monitored for presence or absence throughout the year on cultivated paddy crop. Observations recorded during 2003 and 2004 (upto August 2004) revealed that gall midge was not present on cultivated paddy crop during March, July and August (Table 12 and 14). However, negligible infestation (less than 5%) of cultivated paddy crop by gall midge was observed during these three months. The area under cultivated rice was highly limited and it occupied a very small area. However continuous monitoring of gall midge populations at monthly intervals during 2003 and 2004 revealed that, sprouts from left over rice stubbles (Table 13 and 14 and Plate 7) after harvest of the paddy crop contained GM infestation during 2003 and 2004

Further observations in left over stubbles after harvest of paddy crop. Jaya paddy cultivar and CTH-1 rice genotype were recorded for the presence or absence of rice gall midge. The data revealed that gall midge population was found surviving on sprouts of rice stubbles (Table 15 and Plate 7). The two genotypes were infested with gall midge. Thus also detected (41.2%) Silver shoots in Jaya cultivar and (25.5%) Silver shoots in CTH-1 rice genotype in high proportion of stubbles.

Table 13 Occurrence of rice gall midge on alternate host plants in Mangalore

Sl. No	Plants observed	Date of observation	No of clumps/plants scored	Life stages of RGM
1	*Cynodon dactylon*	4.2.2004	205	A
2	*Panicum repens*	14.2.2004	108	A
3	*Brachieria* Sp.	24.2.2004	98	A
4	*Echinochloa* Sp.	5.3.2004	27	A
5	*Oryza* species	15.3.2004	15	A
6	*Chloris barbata*	25.3.2004	58	A
7	Ratoon rice stubbles	26.3.2004	110	P

A = Absent, P = Present

Table 14 Occurrence of rice gall midge on alternate host plants in Mandya

Sl. No	Plants observed	Date of observations	No. of clumps/plant scored	Life stages of Rice Gall midge
1	*Eleucine indica*	14.11.2003	55	A
2	*Echinochloa crusgali*	18.11.2003	47	A
3	*Chloris barbata*	23.11.2003	95	A
4	*Cynodon dactylon*	8.12.2003	165	A
5	*Cyperus rotendus*	23.12.2003	185	A
6	*Cynodon creveatum*	25.12.2003	255	A
7	*Imperata cylindrica*	28.12.2003	170	A
8	*Eragrastis* sp.	31.12.2003	87	A
9	*Brachieria* sp.	2.1.2004	93	A
10	Ratoon rice stubbles	4.1.2004	150	P

A = Absent ,   P = Present

Table 15 Occurrence of gall midge on ratoon stubbles of different rice varieties during January 2004 at Mandya

CTH -1			JAYA		
Total No. of sprouts	No. of GM affected sprouts	SS(%)	Total No. of sprouts	No. of GM affected sprouts	SS(%)
7	3	42.85	8	3	37.50
6	2	33.33	7	3	42.85
5	0	0.00	6	3	50.00
4	1	25.00	5	3	60.00
6	2	50.00	7	0	0.00
5	0	0.00	4	2	50.00
5	3	60.00	6	2	33.33
7	0	0.00	5	0	0.00
6	0	0.00	4	2	50.00
4	2	50.00	7	2	28.57
7	2	28.57	6	2	33.33
6	2	33.33	5	2	40.00
5	0	0.00	4	1	25.00
4	1	25.00	4	0	0.00
5	0	0.00	7	2	28.57
4	0	0.00	6	4	66.66
6	2	33.33	5	3	60.00
5	0	0.00	5	0	0.00
5	2	40.00	4	3	75.00
4	2	50.00	6	3	50.00
6	3	50.00	5	2	40.00
5	2	40.00	8	4	50.00
			9	3	33.33
			7	4	57.14
			4	4	100.00
			4	1	25.00
			5	3	60.00
					1071.28
Mean±SD		**25.5±21.00**			**41.20±0.23**
	N=22		**N= 26**		

SS = Silver shoots, N = Sample size

At Kankanady, Mangalore also GM infestation was detected on stubbles of Jaya cultivar during off-season that is during April 2004. This suggested that rice stubbles served as an important host for multiplication and perpetuation of rice gall midge populations. Destruction of rice stubbles or deep ploughing after the harvest of the paddy crop will adversely affect gall midge population. So destruction of rice stubbles during off-season may form an important tool for the management of the pest in Karnataka.

The percentage of silver shoots on stubbles of CTH-1 cultivar varied form 0 to 50 per cent with an average of 25.5 per cent, while the percentage of silver shoots on Jaya rice genotypes varied form 0 to 100% with an average 41.20 SS were (Table 15).

4.4.3 Monitoring adults of rice gall midge

Maximum numbers of adult gall midge were trapped during September 2003 again during August 2004 at Mangalore (Table 19 and Figure 5). The light trap catches did not indicate a definite trend in the numbers of adult rice gall midge. However, the presence or absence of adult gall midge in the field could be detected from this data. No gall midge adult was trapped during February and March 2004 in Mangalore, because during this time the paddy crop in most areas is not available and the gall midge population was found on stubbles left over after the harvest of the paddy crop. This observation corroborates with our earlier observations on gall midge presence or absence data (Table 11). Further during April and May only a very small number mean 2.5 to 1.45 of adult midges were trapped in the light trap. This observation again agrees with the data in (Table 11). Where, negligible gall midge infestation found on the standing paddy crop (Table 19 and 20).

The adult gall midge population was also monitored at V.C. Farm, Mandya. The same type of light trap set up which was used at V.C. Farm Mandya. Data is presented in Table 20 and Figure 6 along with the

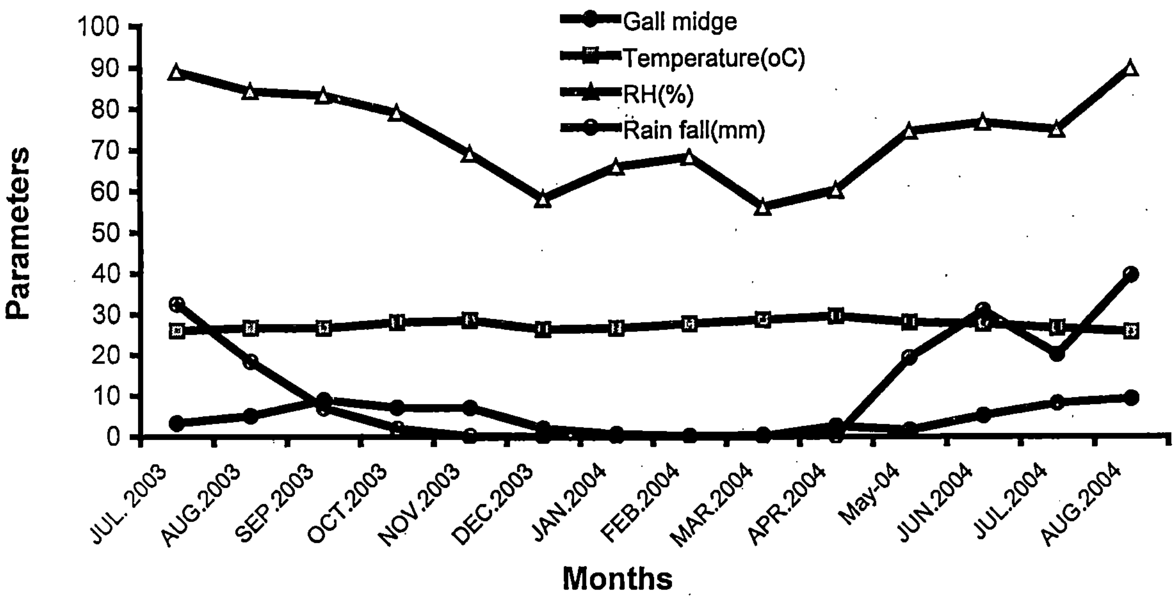

Figure 5 Light trap collections of gall midge in relatioin to weather parameters at Mangalore from july 2003-August 2004

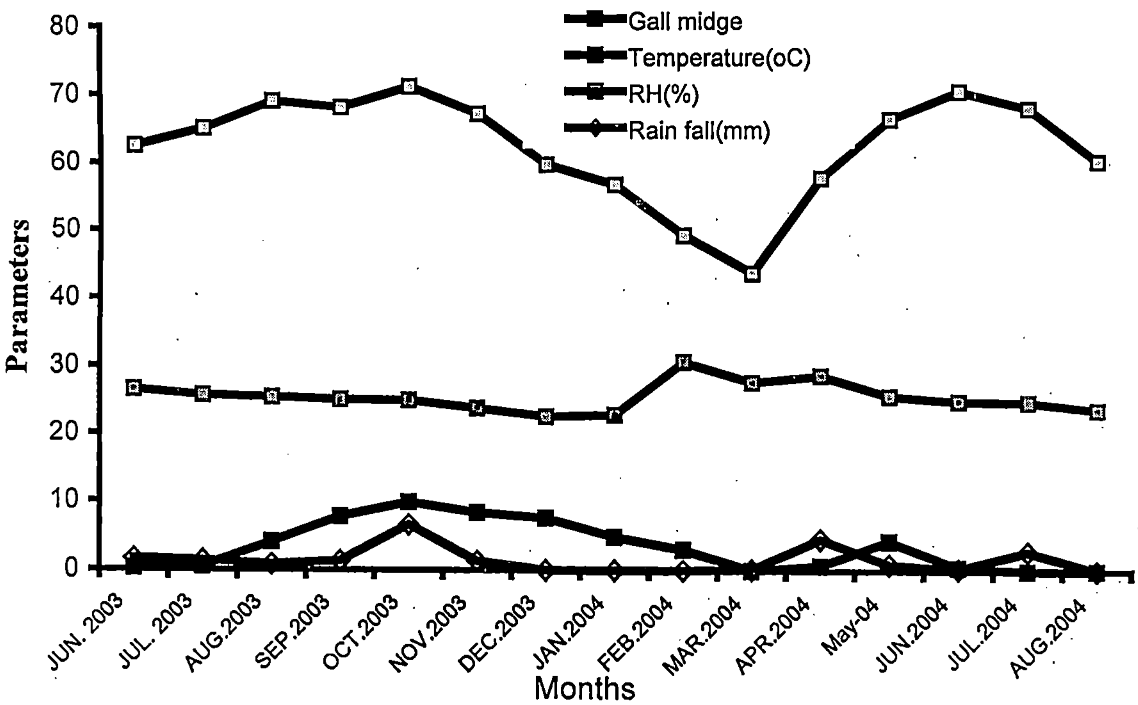

Figure 6 Light trap collection of gall midge in relation to weather parameters at Mandya

meteorological data. The maximum number 9.8 per month of adult gall midges were trapped during October 2003. No adult gall midge was trapped during March, July and August.2004. This data is in agreement with the observations recorded in (Table 12) where, the gall midge infestation was not detected on cultivated paddy crop during March, July and August 2004.

Further insight into the data revealed that on an average 0.23, 0.45 and 2.25 per month adult gall midges were trapped during June, July and August 2003, respectively. In April and June 2004 only 0.7 and 0.46 adults per month were trapped. These data confirmed that a very low population of gall midge occurred during the above months. These findings also are in agreement with the observations recorded on the presence or absence of rice gall midge at V.C. Farm, Mandya (Table 12), where negligible infestation of gall midge was detected on cultivated paddy crop.

Correlation of weather parameters with adult gall midge light trap catches (Pooled data) during 2003-2004 at Mangalore revealed that, maximum temperature was negatively and significantly correlated with adult catches. While, minimum temperature was positively correlated. Relative humidity at morning and afternoon and rainfall was positively and significantly correlated with adult GM catches to light trap at Mangalore (Figure7).

Simillarly at Mandya both maximum and minimum temperatures were negatively correlated with GM catches to light trap. While relative humidity at morning and afternoon and rainfall were positively and significantly correlated with gall midge catches (Figure 8).

4.4.4 Natural enemies of rice gall midge

At Kankanady, Mangalore 50 to 80 silver shoots affected by gall midge were randomly sampled throughout the year at monthly intervals during 2003 and 2004 (upto August 2004) and examined for natural enemies under laboratory

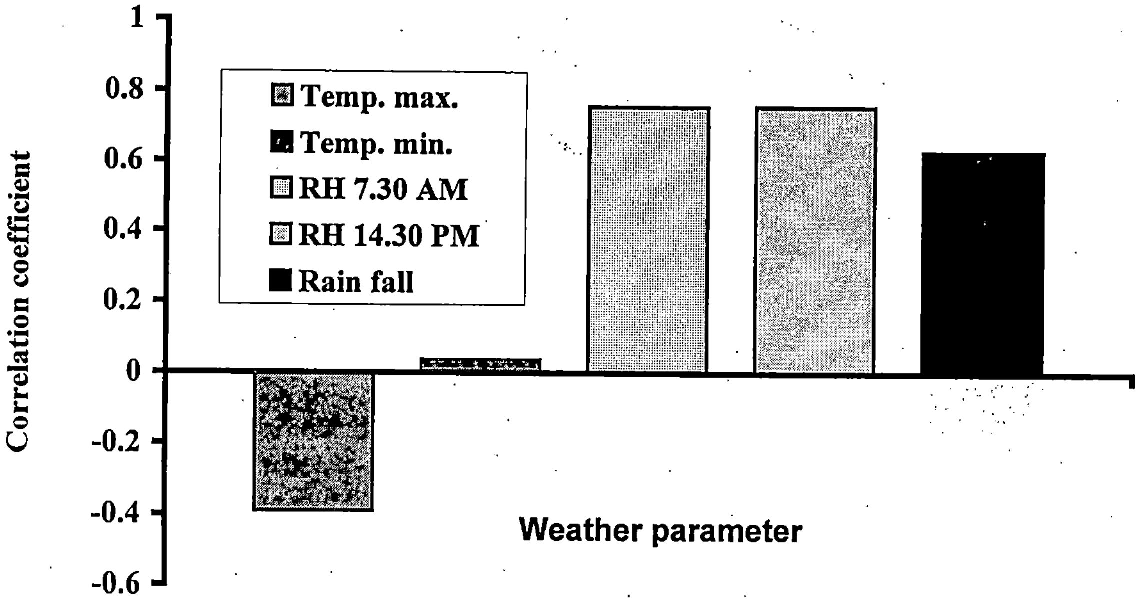

Figure 7 Correlation of weather parameters and gall midge light traps catches during 2003-2004 at Mangalore.

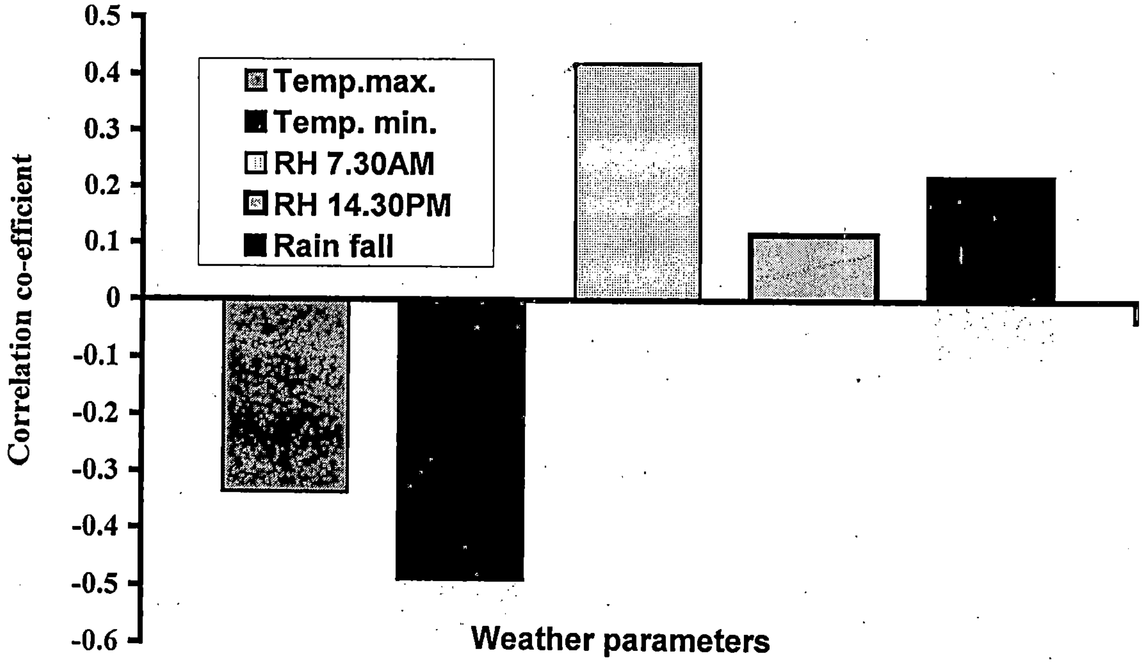

Figure 8 Correlation of weather parameters and gall midge catches of light trap during 2003-2004 at Mandya

Table 16 Parasitization of gall midge by Platygaster *oryzae at Mangalore*

Sl. No	Rice variety	Parasitoid	Date of observation	n = sample size No. of galls observed	% Parasitization
1	Jaya	*Platygaster oryzae*	10-10-2003 16-10-2003	50 55	10.00 7.27
2	Jyothi	*Platygaster oryzae*	22-10-2003 2-11-2003	80 62	10.00 11.29
3	IET 17115	*Platygaster oryzae*	11-11-2003 20-11-2003	80 70	13.75 15.71
4	IET 17247	*Platygaster oryzae*	26-11-2003 3-12-2003	75 50	9.33 10.00
5	Phalguna	*Platygaster oryzae*	10-12-2003 22-12-2003	60 50	11.66 12.00
Mean ±SD					**11.10±2.25**

Table 17 Parasitization of gall midge by *Platygaster oryzae at Mandya*

Sl. No	Rice variety	Parasitoid	Date of observation	N = sample size	% Parasitism
1	IET 17116	*Platygaster oryzae*	28.12.2003 2.1.2004	80 100	10.00 19.00
2	Jaya	*Platygaster oryzae*	25.12.2003 3.1.2004	50 65	24.00 20.00
3	Pooja	*Platygaster oryzae*	7.1.2004 15.1.2004	50 55	14 .00 21.81
4	CSR 13	*Platygaster oryzae.*	22.1.2004 28.1.2004	55 60	20.00 20.00
Mean±SD					**18.60± 4.19**

Plate 8 Adult parasitoid of rice gall midge *Platygaster oryzae* (Cameron) (Platygasteridae : Hymenoptera).

Plate 9 Cocoons of *Platygaster oryzae* (Cameron) on maggot of rice gall midge

conditions. Observations revealed that the gall midge was parasitized during October, November and December 2003. The per cent parasitization varied from 7.27% to 15.71% (Table 16). The parasitoid was identified as *Platygaster oryzae* (Plate 8 and 9). The GM population infesting Jaya, Jyothi, Phalguna, IET 17115 and IET 17247 paddy accessions were found infested with with parasitoid. These priliminary results indicated that one of the factors for the reduction in GM population in Mangalore could be due to natural enemies. The parasitoid predominantly included the *Platygaster oryzae* (Platygasteridae : Hymenoptera).

At V.C. Farm, Mandya 50-100 silver shoots affected by gall midge were randomly sampled throughout the year at monthly intervals during 2003 and 2004 (upto August 2004) and examined for natural enemies under laboratory conditions. Observations revealed that gall midge was parasitized during December 2003 and January 2004. The per cent parasitization varied from 10 to 24 (Table 17). The parasite was identified as *Platygaster oryzae*. The GM population infesting IET 17116, Jaya, Pooja and CSR 13 paddy accessions were found infested with paratisoid *P. oryzae*. However, further studies are required to document more natural enemies including predators on gall midge.

From the results presented on natural enemies of rice gall midge, it may be concluded that *Platygaster oryzae* is predominant parasitoid affecting rice gall midge (RGM) populations in Mangalore (Coastal area) and Mandya (Cauvery command area in Southern Karnataka).

4.6 Morphometrics of rice gall midge populations

Under natural conditions, the gall midge populations may exhibit variation in their genetics and may also respond differently to the same rice cultivar or accession. Workers have deployed molecular techniques and reaction to the host plant as the basis for differentiating naturally occurring rice gall midge populations. An attempt was made to determine the morphometrics of life stages of rice gall midge and to know the exhibited genetic differences in terms of morphological /anatomical characteristics.

Samples of egg, pupae and adults were collected on Jaya rice cultivar at Kankanady, Mangalore, the data is presented in Table 18. On Jaya cultivar egg on an average measured 0.80 x 0.2 mm, while pupae measured 3.48 x 1.02 mm in male, 4.44 x 1.03 in female. Therefore female pupae were larger than male pupae.

Similarly the adult male on Jaya cultivar on an average measured 4.22 x 0.67 mm in male and 4.47 x 0.70 mm in female (Plate 4). The forewing in male measured 1.98 x 0.95 (length x breadth) in mm and female measured 2.10 x 0.98mm.

On Jyothi cultivar egg on an average measured 0.90 x 0.22 mm, the male pupae measured 3.48 x 1.01 mm and female pupae measured 4.45 x 1.03 and adult male measured on an average 4.24 x 0.67 mm and female measured 4.49 x 0.72 mm and forewing of male measured on an average 2.00 x 0.95 mm and 2.02 x 0.99 mm in female forewing, respectively.

The rice gall midge life stages did not exhibit much variation in morphometrics and under field condition observations showed that both Jaya and Jyothi cultivar were susceptible to gall midge infestations. When different life stages of gall midge examined under stereobinocular microscope, no striking differences in their morphological parameters like size and colour.

Phalguna is another paddy cultivar commonly cultivated in coastal Karnataka. The egg on an average measured 0.8 x 0.2 mm. The male pupae on an average measured 3.54 x 1.10 mm and female pupae on an average measured 4.26 x 1.14 mm and male adults measured on an average 4.16 x 0.58 mm and female adult measured 4.35x0.62mm, the forewing of male on an

Plate 4 Adult gall fly

Plate 5 Cross section of the gall contains pupa of paddy gall midge

Table 18 Morphometrics of Rice gall midge populations collected during 2003 and 2004

Location	Varieties	Insect life stages and their body measurements (mm)													
		Egg (*Mean±SD)		Pupae (*Mean±SD)				Adult (*Mean±SD)				Forewings of Adults (*Mean±SD)			
				Male		Female		Male		Female		Male		Female	
		(L)	(B)	(L)	(B)	(L)	(B)	(L)	(B)	(L)	(B)	(L)	(B)	(L)	(B)
Mangalore	Jaya	0.80± 0.008	0.20± 0.007	3.48± 0.004	1.02± 0.04	4.44± 0.005	1.03± 0.002	4.22± 0.005	0.67± 0.007	4.47±0 .007	0.70± 0.008	1.98± 0.004	0.95± 0.005	2.10± 0.008	0.98± 0.003
	Jyothi	0.90± 0.008	0.22± 0.004	3.48± 0.004	1.01± 0.00	4.45± 0.005	1.03± 0.002	4.24± 0.006	0.67± 0.005	4.49±0 .004	0.72± 0.005	2.02± 0.05	0.95± 0.003	2.12± 0.003	0.99± 0.003
	Phalguna	0.8± 0.006	0.20± 0.008	3.54± 0.06	1.10± 0.003	4.26± 0.005	1.14± 0.006	4.16± 0.005	0.58± 0.005	4.35±0 .005	0.62± 0.005	2.01± 0.005	0.88± 0.004	2.06± 0.005	0.90± 0.005
Mandya	TN1	0.81± 0.008	0.21± 0.007	3.72± 0.003	1.03± 0.002	4.48± 0.004	1.05± 0.005	4.49± 0.004	0.72± 0.004	4.55±0 .005	0.74± 0.005	2.05± 0.005	0.98± 0.003	2.12± 0.005	0.92± 0.005
	IET15164	0.82± 0.00	0.23± 0.00	3.85± 0.004	1.12± 0.005	4.52± 0.05	1.08± 0.004	4.5± 0.005	0.84± 0.005	4.55±0 .005	0.78± 0.006	2.08± 0.004	1.01± 0.005	2.17± 0.005	0.99± 0.002

*Mean of fifteen samples / life stage /variety average measured 2.01 x 0.88 mm, while fore wing of female on an average measured 2.06x0.90mm. Even these measurements did not exhibit distinct difference from the measurement on Jaya and Jyothi and when the life stages of gall midge collected on Phalguna were examined under stereo binocular microscope did not exhibit much difference in size, colour and other morphological features.

In Mandya different life stages of rice gall midge were collected on two accessions viz., IET 15164 and TN-1. The eggs on IET 15164 on an average measured 0.82 x 0.23 mm, the male pupae on an average measured 3.85 x 1.12 mm and the female pupae on an average measured 4.52 x 1.08 mm. While the male adult midge on an average measured 4.5 x 0.84 mm and in female adult on an average measured 4.55 x 0.78 mm and fore wing of male fly on an average measured 2.08 x 1.01 mm and female forewing measured on an average 2.17 x 0.99 mm.

On TN-1 eggs on an average measured 0.81 x 0.21 mm, the pupae of male and female midges on an average measured 3.72 x 1.03 mm and 4.48 x 1.05 mm respectively. The adult on an average measured 4.49 x 0.72 mm and 4.55 x 0.74 mm in male and females respectively. Forewing of male on an average measured 2.05 x 0.98 mm and 2.12 x 0.92 mm in female midge. These measurements revealed that gall midge life stages sampled in Mandya were larger in size (Table 18) and gall midge population from Mandya generally carried light pink shade wings.

Table 19 Monthly mean light trap collections of gall midge in relation to weather parameters at Mangalore

Month	Gall midge (no.)	Temperature (^{0}C)	Relative humidity (%)	Rain fall (mm)
July 2003	3.20	26.00	89.00	32.45
August 2003	5.00	26.69	84.33	18.39
September 2003	8.90	26.67	83.28	6.96
October 2003	7.00	28.00	79.00	1.85
November 2003	6.96	28.50	69.00	0.00
December 2003	1.77	26.23	58.00	0.00
January 2004	0.48	26.58	65.75	0.00
February 2004	0.00	27.67	68.12	0.00
March 2004	0.00	28.61	56.60	0.22
April 2004	2.50	29.51	60.06	0.13
May 2004	1.45	27.95	74.23	19.31
June 2004	5.10	26.55	76.38	30.76
July 2004	8.10	26.19	74.63	20.10
August 2004	9.20	25.66	89.25	39.35

Table 20 Monthly mean light trap collections of gall midge in relation to weather parameters at Mandya

Month	Gall midge (no.)	Temperature (^{0}C)	Relative humidity (%)	Rain fall (mm)
June 2003	0.23	26.50	62.50	1.62
July 2003	0.45	25.65	65.00	1.32
August 2003	2.25	25.35	69.00	0.82
September 2003	7.70	25.00	68.00	1.62
October 2003	9.80	24.90	71.00	6.55
November 2003	8.30	23.70	67.00	1.27
December 2003	7.50	22.55	59.50	0.00
January 2004	4.80	22.75	56.50	0.00
February 2004	3.00	30.50	49.00	0.00
March 2004	0.00	27.55	43.50	0.16
April 2004	0.70	28.50	57.55	4.50
May 2004	4.20	25.50	66.00	0.90
June 2004	0.46	24.74	70.08	0.23
July 2004	0.00	24.60	66.50	2.74
August 2004	0.00	23.45	59.76	0.00

DISCUSSION

CHAPTER V
DISCUSSION

In this Chapter results obtained on host plant interaction, biology and morphometrics of rice gall midge has been discussed with the findings of earlier workers on rice gall midge.

5.1 Field Screening

Screening of 25 rice germplasm accessions at Kankanady, Mangalore, revealed that gall midge infestation began building up only after 30 DAT. At 50 DAT the rice accession showed statistically significant difference in gall midge infestation at 5%. Pusa basmati recorded 17.59 percent gall midge infestation compared to MO4 which recorded Zero percent infestation.

Field screening showed differential reaction to gall midge populations between Mandya and Mangalore. This may be due to variations in climatic conditions and occurrence of genetically different gall midge populations.

A number of workers have field screened rice germplasms against gall midge populations through which several important sources of resistance have been identified. This method suffers from inconsistency arising from non-uniformity and fluctuations in pest pressure, hence results of field screening need to be revalidated through repeated tests. Further, field screening takes at least two to three years for the confirmation of the results (Bentur *et al.*, 2003). However, the present study rice germplasms were screened in two locations for two years, which are hot spots for gall midge.

5.2 Laboratory Screening

Selected rice genotypes (six) were tested in laboratory. All the four cultivars were found susceptible. Bhadra(MO4) and Phalguna were relatively less susceptible under artificial infestation conditions as probably the plants were exposed to only one genetically determined GM populations under laboratory conditions. However, genetically diversified populations of GM are encountered in the field. A total of 2256 germplasm accessions, 3000 advanced generation breeding lines and 150 released varieties of rice were screened for resistance to *O. oryzae.* In the greenhouse among these 15 germplasm accessions and 50 breeding lines were resistant, Antibiosis was the predominant resistant mechanism (Sain and Kalode, 1994).

5.3. Reaction of differentials to gall midge infestation

Fourteen rice differentials belonging to four groups were screened under field conditions at kankanady, Mangalore. All the fourteen differentials were found susceptible to mixed gall midge populations (Table 7) based on criteria that if a rice differential recorded more than 10% infestation it is considered as susceptible. The per cent infestation in fourteen differentials in III group varied from 11.79 to 20.97 at 50 DAT. Maximum infestation was recorded in TN-1 (32.63% SS), susceptible check in 1V group and minimum infestation was in III group of RP2068-18-3-5 (1.29%SS).

Rice gall midge biotypes was first suspected by Khan and Murthy (1955) even when no resistant varieties were developed. Subsequently Roy *et al.* (1969) observed differential reaction in some gall midge resistant donors/cultures at two of the pest endemic locations Viz, Sambalpur in Orissa and Warangal in Andhra Pradesh. Initially, the differentials selected for this purpose were varying and chosen at random. Based on the summary of results of 13 years of data three distinct gall midge biotypes were characterized (Bentur and Kalode, 1989). Further, it was found that five differentials in three groups were adequate enough to distinguish these biotypes.

Subsequent to the report of evolution of a new virulent biotype in North Coastal district of Andhra Pradesh (Bentur *et al.*, 1987). A third group of differential was found essential to distinguish the then prevalent four biotypes. Continued monitoring of gall midge biotypes using these differentials helped to detect emergence of new biotypes from other areas of the country. These differentials were good enough to characterize biotype 5 and 6 also. Based on the additional information on genetics of some of the resistant donor parents and the reaction pattern of these against the biotypes, more and more differentials are being added. The reaction of differentials to rice gall midge populations as follows:

If R- R- R- S patterns of reaction biotype 1 is Prevalent
If S - R -R -S pattern of reaction biotype 2 is Prevalent
If R - S - R –S Pattern of reaction biotype 3 is Prevalent
If S - S - R –S pattern of reaction biotype 4 is Prevalent
If R - R -S- S pattern of reaction biotype 5 is Prevalent
If R - S - S – S Pattern of reaction biotype 6 is Prevalent

However, in the present study S –S –S –S reaction pattern was obtained, indicating that fourteen differentials belonging to four groups did not exhibit any definite reaction pattern by which a biotype population could be characterized. The reaction pattern showed that genetically mixed biotype populations of rice gall midge is prevalent at Kankanady, Mangalore. Consistency of this reaction pattern to rice differentials in necessary to identify the rice gall midge biotypes. Screening with additional sources of resistance donors may bringout identity of individual biotypes.

The differentials in this study have been grouped mainly on the basis of the reaction pattern observed against different biotypes. Genetic characterization of other differentials is thus imperative since it may bring out further diversity within and among the groups based on the genetics of resistance known against some of the differentials. It is apparent that virulence in these biotypes is closely associated with resistance genes.

A set of same fourteen differentials were screened against rice gall midge population at V.C farm, Mandya. Only TN-1, the susceptible check was found susceptible recording 34.85% SS at 50 DAT (Table 8). All the other rice differentials tested did not record any gall midge infestation at both 30 and 50 DAT. The fourteen differentials in four groups because of no infestation in first three groups, the differential reaction pattern was R – R – R – S indicating that biotype1 is prevalent. This is because the differentials belonging to first three groups were resistant and only susceptible check was susceptible. However, continued monitoring of gall midge biotypes using these additional differentials is necessary to detect emergence of new biotypes in Cauvery command area. Observations and interactions with rice growers revealed that a majority of farmers are currently cultivating rice cultivars are susceptible to gall midge. For example, Jaya, Mandya Vijaya and KMP- 101 which has been found susceptible to rice gall midge. So, there is no evolution of new biotypes in rice gall midge in Cauvery command area.

5. 4 Biology of rice gall midge

Eggs: In the present study the eggs were mainly found underside of the leaf blade towards basal part. Eggs were laid singly or in-groups of two to four arranged parallel to each other. Similar observations were earlier recorded by Sontakay (1941) and Yen *et al.* (1941).

Maggots: The maggots had three instars. In field the maggot period varied from 8 to 11.5 days and in laboratory condition maggot period varied from 7 to 9.75 days (Tables 9and 10). Larval period in rice gall midge varies from 6 to 33 days (Sontakay, 1941; Huang, 1957; Fernando, 1962). Maggot lacerates meristem tissue with pharyngeal spatula and feed on the oozing cell sap. Laceration and secretion of saliva results in hypertrophy and hyperplasia of cells and lead to development of a gall chamber surrounding the maggot.

Pupae: The pupal period under field conditions varied from 4 to 5.5 days and under laboratory conditions from 2.5 to 4.0days (Tables 9 and 10). The pupal period of rice gall midge in rice varieties varied from 2 to 8 days (Murthy, 1958).

Adults: Under field conditions total life cycle varied from 16.5 to 23.5 days with fecundity per female varying from 188 to 208 eggs. Corresponding figures under laboratory conditions were 12.5 to 18. 5 and 90 to 115 eggs respectively (Table 9 and 10). This indicated that the insect completed life cycle early, being less fecund, this may be due to relatively higher temperature and under confined conditions insects were induced to complete the life cycle early and there by lay less number of eggs. The egg laying capacity of female gall midge varies greatly and could be from 100 to 400eggs (Yen, *et al*, 1941; wong *et al*, 1956). The rice gall midge produces monogenous progeny where in, all offspring's of a single female are of one sex only (Sain and Kalode, 1988). An interesting feature of the gall midge life cycle is the existence of a female biased sex ratio in the population with the ratio of male producing females and female producing females being 1:1.32 (Panda and Mohanty, 1970).

5. 4.1 Alternate host plants

In the present study the gall midge population was not found on cultivated rice and plants present surrounding the paddy fields during February and March 2004 at Kankanady, Mangalore (Table 11). Similarly, in Mandya the gall midge populations were not found on cultivated rice and weeds surrounding the plot during March, July and August 2004. Negligible infestation of rice gall midge was recorded during April and May in Mangalore during 2004 and during April, May, June and September in Mandya. At both the locations rice stubbles left over after harvest of the paddy crop served as alternate host on which the population survived and multiplied during the off season on stubbles of Jaya and CTH–1, 41.2 % SS and 25.5% SS were recorded, respectively at Mandya (Table 15). Therefore in Coastal Karnataka and Cauvery Command area destruction of stubbles is important for managing the pest on cultivated rice. Prakasa Rao (1983) reported 28 grasses as weed hosts of the Asian rice gall midge, *O. oryzae.* There are contradictory reports on the host range of this pest (Israel *et al.*, 1970; Natarajan *et al.*, 1981; Gagne, 1985).

Many of the weed hosts reports for this pest are based perhaps on mere presence of galls on these grasses. Eighteen grasses were screened for the development of rice gall midge at Cuttack, but none of them supported its development (Natarajan *et al.*, 1988). In the present study also RGM population could not be detected on six monocot weed plants in Mangalore and nine monocot weed plants in Mandya (Tables 13 and 14).

A comprehensive study made by Descamps (1956) reveals that after harvest of the rice crop, the pest infests wild rice; *Oryza barthii*, which grows abundantly in and around water. As it dries up in summer most of the larvae enter diapause in the buds of the plants. Under favorable moisture conditions, development may continue throughout, otherwise the diapause continues for many months. Wong et al. (1956) have reported that larvae overwintering in stubbles from November to April and then pupate. In the present study also the GM population was found in stubbles during off-season at both Mangalore and Mandya.

5.4.2 Monitoring of adult rice gall midge

Maximum number of adult gall midge were trapped during July and September although at Mangalore, the light trap catches did not indicate the definite trend in the emergence of adult rice gall midge. No gall midge adult was trapped during February and March 2004 (Table 19 and Figure 5). At VC farm Mandya, maximum adult gall midges were trapped during October 2003 (Table 20 and Figure 6).

Prakasa Rao and Dani (1982) reported that the crop planted in August suffered high gall midge infestation (42.7%) on 60 DAT. Crops planted early or later than September recorded negligible gall midge infestation.

Correlation of weather parameters at Mangalore and Mandya conditions indicated that, temperature is inversely proportional to GM adult catches. Where as relative humidity and rain fall are directly proportional to gall midge catches and their outbreaks. This indicated that, this pest required high moisture and humidity for egg hatching and Maggot movement to the growing leaf primordium and population increased rapidly.

Prakasa Rao (1983) reported the data accumulated over the past 10 years showed that heavy gall midge incidence level were already reached in standing crops before the abundance of the peak of gall midge were detected at light trap and hence, light trap was of less value in detecting the buildup of the pest incidence in fields.

Certainly there may be other parasitoids and predators affecting mortality of the gall midge populations under natural conditions to get a comprehensive picture on natural enemy complex. Further systematic studies are required and there is an urgent need to utilize natural enemies for the management of the pest.

5.4.3 Natural enemies

Monthly observations at Kankanady, Mangalore revealed that rice gall midge egg/larva was parasitized by *platygaster oryzae*, platygasteridae; Hymenoptera. During October, November and December 2003 the percent parasitization on rice cultivars varied from 7.27 to 15.71 (Table 16). Under Mandya conditions the RGM egg/larva was found parasitized during December 2003 and January 2004 only (Table 17). The percent parasitization varied from 10 to 24%. Thus, at both locations the percent parasitization by parasitoid coincided almost with the developing or peak population of the pest (Tables 16, 17, 19 and 20), Kobayashi and Kudagamage (1994) reported *P. oryzae* was widely distributed throughout all the climatic zones and the mean value of 21% for the percentage of parasitism, which was the highest among the four species of parasitoids. (Kobayashi *et al.*, 1991) recorded more than 95% of gall midge larvae are parasitized by *Platygaster* sp. late in the rice growing season.

5.5 Morphometrics of rice gall midge

Preliminary observations on morphometrics of RGM life stages (Table 18) indicated that, the variations in morphometrics was not helpful in reflecting genetic status of RGM population. The differences in morphological parameters were not very much different either. Studies on RGM morphometrics are meagre because of obvious reasons firstly they arecumbersome, laborious and time consuming.

Pupation of rice gall midge takes place inside the gall. The male and female pupae can be easily separated by their size and colour of the abdomen (Panda and Mohanty, 1970). Male pupae are small and brown. While the females are larger and pinkish. Jaya, Jyothi and Phalguna are the common paddy cultivars cultivated in Coastal Karnataka and found susceptible to gall midge infestation (These cultivars showed same type of response to the host plant interaction and so the life stages of gall midge developing on these three cultivars may not exhibit variation in observable morphological features.

Natarajan *et al.* (1981) used the characters of apical horns of gall midge pupae to distinguish the *Mnesithea laevis* (Swartz) midge from rice midge. Gagne (1985) described this *M. laevis* midge as a new species (*Orseolia mnesitheae* Gagne). The ovipositional preference of this midge reported by Gagne lends further support to treat this midge distinct form rice gall midge.

Prakasa Rao, (1983) studied morphological differences of midges which includes the antennal horns of the pupae of rice gall midge, *Phaspalum distichum* midge and *Cynodon dactylon* midge are bifid but in the latter two, the length of the two arms are uneven and the abdominal tergal spines of the pupa of rice gall midge are arranged in single row with many spines and there is no pigmentation in 8-9 segments of pupae reared form *Oryza sativa* L. The abdominal colour of all grass midges was orange as that of rice. The forewing, haltere, fore-femur and fore tebia of the adult rice and grass midge was smaller in male midges than in female midges. However, more samples need to be examined to document morphological differences consistently across different seasons and rice accessions. From these preliminary data no definite inference could be deduced on morphometrics vis-à-vis genetic status of rice gall midge populations sampled.

SUMMARY

CHAPTER VI

SUMMARY

The results of studies conducted on rice gall midge in Mangalore, Mandya and surrounding areas during 2003-2004 are summarized in this chapter.

The rice gall midge is increasing in severity in rice cultivated tracts of Karnataka and many of the commonly cultivated rice varieties like Mahaveera, Bhadra(MO4), Phalguna, Shakthi, Jyothi, Jaya, CTH-1 and KMP-101etc, are becoming increasingly susceptible. Midge populations comprising newer biotypes are being suspected both in coastal and Cauvery command area. This is for the first time that studies embracing field and laboratory screening, rice differential reaction, biology and morphometrics were taken up on rice gall midge.

Twenty-five rice germplasm accessions were screened during *Kharif* 2003 and another 25 during kharif 2004 (up to August only), at Kankanady, Mangalore and simultaneously at V.C, farm, Mandya. Field Screening was done with MO-4 and TN –1 as resistant.and susceptible check at Mangalore and Phalguna and TN-1is resistant and susceptible, check respectively. At V.C. Farm, Mandya observations were recorded at 30 DAT and 50 DAT. The highest silver shoots (20.18%) were recorded in TN-1 and phalguna was free from gall midge infestation. No logical inference could be deduced from the result of screening trials at Mandya; in view of the low midge infestation both the years. At Kankanady, Mangalore Pusabasmati recorded 17.59 per cent GM infestation compared to MO-4, which was free from infestation.

Four commonly cultivated rice varieties and one rice entry with susceptible Check TN_1 were evaluated at laboratory condition during December 2003 at A.R.S Kankanady, Mangalore. All the six rice genotypes were found susceptible to gall midge populations at 30 days after infestation. The percent damaged plants varied from 7 in phalguna to 25 in TN-1.

A set of fourteen rice differentials belonging to four groups were screened under field conditions at A.R.S. Kankanady, Mangalore and ZARS, V.C farm, Mandya during *Kharif* 2003. Differentials receiving less than 10% were regarded as resistant and more than 10% were regarded as susceptible (S). So the differentials followed the S-S-S-S pattern at Mangalore and R-R-R-S reaction pattern at V.C farm Mandya. This indicated that at Mangalore genetically mixed populations of rice gall midge biotypes are prevalent. It is imperative that screening with more number of differentials is necessary to identify and detect biotypes in gall midge populations. At Mandya the differentials followed R-R-R-S reaction pattern indication that biotype1 is prevalent under condition of Mandya. However further screening trials involving more number of differentials are necessary to confirm the biotypes in the populations of rice gall midge at Mandya.

The rice gall midge under Mangalore conditions completed life cycle on Jaya, on an average 20±3.75 days with egg, larval, pupal periods and adult longevity extending up to 2.84±0.68, 9.75±2.02, 4.75±0.92 and 2.5±0.60, days, respectively. Under laboratory conditions the insect completed life cycle on an average on Jaya 15.5±3.0 days with egg, larval, pupal period and adult longevity on an average 2.25±0.75, 8.37± 1.37, 3.25±0.75 and 2.0±0.5 days, respectively.

The gall midge population during the off season (February and March at Mangalore and March, July, August at Mandya 2004) survived on sprouts from the rice stubbles left over after the harvest of the paddy crop. Therefore destruction of rice stubbles during the off-season in Coastal Karnataka and Cauvery command area would reduce the midge infestation on rice. None of the plants growing wild around the plots served as alternate hosts for the pests at both the locations.

Monitoring of rice gall midge adults at Mangalore and Mandya revealed that adults did not followed a definite trend in their emergence pattern at both the locations viz., Mangalore and Mandya. However, maximum adults were trapped during September and July at Mangalore. While the maximum number of adults were trapped during October at Mandya. Observations on monitoring of adults population showed that light trap was of less value in detecting build up of pest infestation in the rice fields as high infestation levels in standing crop was not reflected in trap catches.

Observations on natural enemies of rice gall midge at Mangalore and Mandya revealed that *Platygaster oryzae* parasitoid was the dominant species. The natural enemies were noticed only after the heavy midge infestation, when the crop was maturing. The percent parasitization from natural enemies varied from 7.27 to15.71% in Mangalore and 10 to 24% in Mandya, respectively.

The rice gall midge life stages did not exhibit much variation in morphometrics, when different life stages of rice gall midge were examined under stereo binocular microscope. Morphometrics may not be a good indicator of genetic variation occurring in rice gall midge populations.

Future line of work

- It is evident from the foregoing account that the intimate and intricate relationship between the insect and the plant needs to be better understood to develop durable gall midge resistant varieties
- Gall midge populations have already overcome the resistance against all these three sources in different parts of the country and also showed high frequency of virulent individuals in other regions. Hence, we need to look for the new sources of resistances and screen genotypes against the existing ones.
- Development of gene tags and markers linked to the genes against the many of the known gall midge resistant genes will help in marker aided selections for pyramiding or more genes in breeding programmes.
- For identification of biotypes, use of molecular markers like RAPD, AFLP, PCR or Finger printing technique may be needed to identify the biotypes within short period of time in these regions.
- To study the morphometrics of rice gall midge more samples need to be collected across the several varieties and several locations.
- At regional level, further details on bio-ecology are required to standardize cultural operations that would facilitate suppression of gall midge populations.

REFERENCES

CHAPTER VII

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* Originals not seen

APPENDCES

Appendix I Weekly mean weather parameters at Mangalore

Month	Week	Temperature (°C)		R.H(%)		Rain fall (mm)
		Max.	Min.	7.30AM	14.30PM	
July 2003	1	27.10	20.50	92.00	84.00	45.57
	2	24.20	22.70	90.00	88.00	40.55
	3	25.10	23.00	89.00	83.00	21.02
	4	23.90	22.50	91.00	81.00	22.68
August 2003	1	30.98	23.49	94.30	83.10	25.97
	2	30.99	24.56	90.50	79.20	17.35
	3	29.75	22.84	92.80	82.50	17.30
	4	28.68	23.21	94.00	85.00	12.97
September 2003	1	29.87	22.39	87.00	81.00	17.52
	2	30.19	23.14	91.00	78.00	06.42
	3	31.06	23.01	90.30	79.50	02.45
	4	31.42	23.23	84.40	67.80	01.48
October 2003	1	31.40	23.56	90.00	81.00	05.60
	2	31.85	23.50	87.00	82.00	01.35
	3	31.96	23.50	83.00	80.00	00.46
	4	31.43	23.10	88.00	67.00	00.00
November 2003	1	32.29	24.15	85.00	68.00	00.00
	2	33.85	23.25	89.00	72.00	00.00
	3	33.68	23.75	75.00	62.00	00.00
	4	33.10	24.53	72.00	61.00	00.00
December 2003	1	34.50	19.84	70.00	59.00	00.00
	2	33.15	18.95	69.00	53.00	00.00
	3	33.60	18.86	60.00	50.00	00.00
	4	33.40	20.30	78.00	50.00	00.00
January 2004	1	32.50	19.85	77.00	52.00	00.00
	2	33.10	20.54	79.00	51.00	00.00
	3	31.30	21.65	74.00	49.00	00.00
	4	32.45	21.30	79.00	65.00	00.00
February 2004	1	33.25	21.30	79.00	65.00	00.00
	2	32.95	20.85	74.00	60.00	00.00
	3	33.40	23.35	75.00	62.00	00.00
	4	33.10	23.21	70.00	60.00	00.00
March 2004	1	33.31	23.61	60.00	55.00	00.00
	2	33.75	23.85	65.00	50.00	00.00
	3	33.26	24.10	52.00	52.00	00.00
	4	33.09	23.95	63.00	51.00	00.88
April 2004	1	34.78	25.15	65.00	50.00	00.52
	2	33.98	25.98	67.00	55.00	00.00
	3	33.58	23.18	69.00	53.00	00.00
	4	34.50	24.98	67.75	53.75	00.00
May 2004	1	33.14	25.00	70.37	60.25	17.10
	2	32.95	24.97	81.37	68.25	20.22
	3	31.58	22.19	90.75	77.12	31.75
	4	32.10	21.90	78.40	67.40	08.20

June 2004	1	30.45	24.81	83.75	71.12	69.50
	2	30.45	24.60	81.12	71.12	28.00
	3	32.16	24.91	73.00	66.12	03.15
	4	30.30	22.75	93.16	71.66	22.40
July 2004	1	33.46	22.92	84.00	74.25	10.77
	2	30.19	20.95	85.25	81.25	24.00
	3	31.50	21.97	92.12	83.75	16.55
	4	29.95	21.81	88.20	84.28	29.11
August 2004	1	30.20	22.20	95.00	86.25	45.52
	2	30.30	22.10	92.50	84.25	36.90
	3	29.45	21.00	93.00	85.00	40.00
	4	28.90	21.10	94.00	84.00	35.00

Appendix II Weekly mean weather parameters at Mandya

Month	Week	Temperature (°C)		R.H(%)		Rain fall
		Max.	Min.	7.30AM	14.30PM	(mm)
June 2003	1	34.00	21.28	81.00	53.00	05.31
	2	34.15	21.78	74.28	46.71	00.00
	3	30.50	20.00	69.14	50.14	01.18
	4	30.32	19.92	78.71	49.14	00.45
July 2003	1	30.00	21.90	76.00	54.71	00.00
	2	30.07	22.85	73.71	45.57	00.00
	3	27.57	22.07	80.57	58.57	00.51
	4	28.92	22.85	78.14	53.14	04.31
August 2003	1	28.57	21.92	79.57	62.57	00.28
	2	29.57	23.14	78.28	57.00	00.25
	3	28.71	2178	75.28	54.85	02.65
	4	27.64	22.28	85.28	57.85	00.45
September2003	1	28.57	21.57	84.85	59.14	00.00
	2	28.42	21.00	79.57	58.00	00.45
	3	28.78	21.21	78.71	55.14	03.94
	4	28.97	21.42	78.28	53.28	00.25
October 2003	1	28.57	22.07	78.85	61.00	11.72
	2	27.21	21.85	85.57	60.14	06.54
	3	28.14	21.35	83.57	64.42	09.74
	4	28.35	21.28	85.57	57.00	00.08
November 2003	1	29.21	21.35	80.42	57.00	00.00
	2	27.21	18.85	84.00	51.14	05.45
	3	27.92	20.28	80.85	53.00	00.00
	4	27.85	17.35	80.71	51.71	00.00
December 2003	1	28.14	19.78	81.14	38.85	00.00
	2	27.35	15.64	75.57	40.45	00.00
	3	27.64	17.28	79.28	39.42	00.00
	4	29.35	16.42	79.00	36.71	00.00
January 2004	1	27.57	18.64	77.57	48.14	00.00
	2	27.78	15.14	75.42	35.00	00.00
	3	28.50	15.92	64.71	34.28	00.00
	4	28.00	18.64	67.57	39.42	00.00
February 2004	1	30.85	20.35	68.71	40.42	00.00
	2	30.42	17.78	65.42	37.00	00.00
	3	30.60	17.24	52.85	39.14	00.00
	4	31.35	17.42	54.85	35.00	00.00
March 2004	1	34.00	18.71	77.57	44.57	00.00
	2	33.78	19.41	63.42	36.28	00.00
	3	34.50	20.92	70.14	38.57	00.00
	4	34.78	23.88	75.28	48.00	00.00
April 2004	1	31.50	21.78	79.42	57.14	14.81
	2	33.28	23.71	80.28	51.42	00.00
	3	35.00	25.21	79.57	58.42	00.57
	4	33.14	24.92	75.42	55.85	03.22

May 2004	1	29.71	22.14	81.42	52.14	15.71
	2	30.07	22.14	79.14	55.00	03.68
	3	28.21	22.00	85.85	51.00	05.88
	4	29.04	21.52	81.57	49.31	08.61
June 2004	1	28.17	21.12	82.00	51.00	00.00
	2	29.28	21.00	83.00	59.00	00.31
	3	28.00	20.50	80.00	60.00	00.00
	4	30.10	20.00	84.00	61.00	00.57
July 2004	1	28.92	21.78	87.57	46.00	00.97
	2	28.35	21.14	86.42	47.70	10.00
	3	28.78	21.57	89.90	747.00	01.17
	4	28.50	22.21	85.00	53.57	00.00
August 2004	1	29.57	22.50	83.00	48.00	00.00
	2	28.70	23.10	82.00	50.00	00.00
	3	28.95	23.00	83.10	44.00	00.28
	4	29.75	22.10	82.00	46.00	00.11