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Orseolia and rice: Cecidogenous interactions

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Abstract. The active substance, cecidogen secreted from the saliva of gall midge larva and the larval feeding on the meristematic tissue of terminal and auxillary shoot apices in rice plant are responsible for gall formation (silver-shoot) in rice. Gall midge occurs in many of the rice growing areas and causes considerable yield loss even up to 70% in kharif crop. Many resistant varieties are being cultivated but the occurrence of biotypic variation of the insect limits their extensive use. Integrating chemical and genetic resistance appeared feasible to check the pest. Seasonal occurrence, host variation, resistance mechanism, biological, cultural and chemical control methods are reviewed and future lines of research on this important pest have also been discussed.

Keywords: Rice gall midge; biotype; resistance mechanism; control methods.

1. Introduction

Feeding of *Orseolia oryzae* (Wood-Mason) larva, upon the meristematic tissues of the growing terminal or auxiliary shoot apices of the rice plant, produces gall. The rice gall formation results from the suppression of leaf primordial differentiation at the growth cone and the development of the radial ridges from the inner most leaf primordium followed by the elongation of the leaf sheath (Perara and Fernando 1970; Hidaka 1974; Kalode 1980; Chiu-Shin-Foon 1980). The ridge of the tissue grows and fuses forming the primordial gall that encloses the first instar *O. oryzae* maggot. It is suspected that the feeding by the maggot and irritation on the attacked portion (meristematic tissue) are responsible for gall formation (Reddy 1967). The salivary secretion of the larva contains an active substance called cecidogen which causes abnormal proliferation of cells at the site of feeding (Chiu-Shin-Foon 1980). The gall elongates in correspondence with the larval development and when the visible gall midge attack, symptom known as 'silver shoot' appears, the insect is in the pupal stage and ready for emergence. The length and size of the gall varies with the age of the plant or the sex of the pupa it contains. The silver shoot with parasitised maggot is bigger in diameter and appears later than the silver shoot with unparasitized midge.

Gall midge occurs as a pest in many parts of Asia (Bangladesh, Burma, Cambodia, China, India, Indonesia, Laos, Nepal, Pakistan, Papua, Sri Lanka, Thailand and Vietnam) (Heinrichs and Pathak 1981) and in Africa. In India, it is reported to occur in Assam, Andhra Pradesh, Bihar, Karnataka, Kerala, Maharashtra, Manipur, Madhya Pradesh, Tamil Nadu and parts of Uttar Pradesh and West Bengal (Mathur and Rajamani 1979). Though gall midge is primarily considered as a pest of wetland (lowland) irrigated rice (Anonymous 1981; Heinrichs and Pathak 1981) it has been reported to occur in dryland rice in China (Li and Chiu 1951) and in deep water rice. In India, usually it occurs as a pest during the wet season, but it has also been observed to occur during the winter season and progressively increasing in incidence (Kalode and Kasiviswanathan 1976). Although gall formation usually occurs during the vegetative

(tillering) period of the plant, galls are occasionally seen during flowering stages (Rajamani *et al* 1979) and on parts of the panicles (reproductive shoot apices, Fernando cited by Hidaka 1974). The rice plants do not bear panicles when attacked during vegetative phase. The panicles are not able to come out of the boot leaf or are highly deformed when the plant is attacked in reproductive phase.

Depending on the severity of attack, the yield loss ranges between 3 and 70% and complete yield loss is not uncommon in highly susceptible varieties in certain years (Chatterji *et al* 1976). Profuse tillering occurs under early infestation but the new tillers too often become infested. It has been estimated that every unit per cent increase in gall midge incidence enhances the yield loss by 0.4 to 0.5% (Reddy 1967; Hidaka 1974; Premchand and Acharya 1982).

2. Breeding and biotype

Field screening for resistance to gall midge was initiated as early as 1950 (Reddy 1967). Several resistant donors were identified from the National Germplasm Collection. However only a few of them *i.e.* Eswarakora, W 1263, Ptb. 10, Ptb. 18, Ptb. 21, Siam 29, Leuang 152 and OB 677 were utilised for resistance breeding as these donors possessed higher and consistant resistance to gall midge and moderate resistance to other pests too. As a result of active breeding programme, six resistant varieties, Shakti and Samalei in Orissa, Kakatiya, Surekha and Phalguna in Andhra Pradesh and Vikram in Karnataka were released for general cultivation (Seshu *et al* 1974; Roy *et al* 1978; Mathur and Rajamani 1979; Kalode 1980) and several other materials are in advanced testing and pre-release stage.

Susceptibility of such resistant varieties in certain localities has also been reported (Pathak and Heinrichs 1981; Venugopala Rao *et al* 1982), indicating the selection of new biotypes. In fact biotype occurrence was suspected much earlier even when the screening varieties for gall midge resistance was undertaken. Khan and Murty (1955) for the first time reported that some varieties were recorded to be less susceptible in Andhra Pradesh, contrary to the observations made by Israel and Vedamoorthi (1953) at Cuttack in the state of Orissa. Subsequently varietal reaction in terms of severity of the incidence in some gall midge resistant varieties were observed in the states of Andhra Pradesh and Orissa (Shastry *et al* 1972) and even within the state of Orissa (Roy *et al* 1969, 1971; Chatterji *et al* 1975). Later Panda (1978) noticed that Shakti, the resistant variety released in Orissa, had high incidence of gall midge in certain parts of Orissa. He attributed this to either breakdown of resistance due to high population pressure prevailing in this location or occurrence of biotype. Recently increased incidence of gall midge in Ptb group under field condition was also observed at Cuttack (Rajamani and Mathur 1981).

The coordinated gall midge biotype study conducted at various centres in India confirmed the existence of biotypes which were classified as Andhra Pradesh, Orissa, Madhya Pradesh and Manipur (Kalode 1980) and Bihar biotypes (Shaw *et al* 1981). Since the Bihar biotype differed only in one reaction as compared to Thailand biotype (Eswarakora being resistant in Thailand and moderately resistant in Bihar (Ranchi)) Rajamani and Mathur (1981) suggested that for biotypic studies the classification should be based on resistance or susceptibility and not intermediate reactions which will create difficulties in the nomenclature. Similarly the results of International Rice

Testing Programme (Anonymous 1981) also indicated eight biotypes of gall midge which were named as China, India (AP), India (Bihar), India (Orissa), India (Raipur), Indonesia, Sri Lanka and Thailand biotypes (table 1).

Biotype of an organism is similar in their morphology and differ only in their physiological ability to damage particular resistant varieties. However, morphological variations in gall midge collected from different geographical regions were reported (Hidaka *et al* 1977; Hidaka and Ya-Klai 1979). Recently, it has been reported that the African midge is a distinctly different species of *Orseolia* (Harris and Gagne 1982). This suggests the need of further taxonomic studies on rice gall midges in different localities.

Table 1. Gall midge biotype classification by varietal reaction (Anonymous 1981).

Biotype	Reaction
China biotype	Eswarakora, Leuang 152 and OB 677 derivatives resistant Siam 29 derivatives moderately resistant Muey Nawng 62 M and Ptb derivatives susceptible
Indonesia biotype	Leuang 152, Siam 29, Muey Nawng 62 M and OB 677 derivatives resistant Eswarakora and Ptb derivatives susceptible
Thailand biotype	Eswarakora derivatives resistant Muey Nawng moderately resistant Leuang 152, Ptb, Siam 29 and OB 677 derivatives susceptible
Sri Lanka biotype	Leuang 152, Ptb, Siam 29 and OB 677 derivatives resistant
India (Raipur biotype)	Leuang 152, Eswarakora, Siam 29 and OB 677 derivatives resistant Ptb derivatives and Muey Nawng 62 M susceptible
India (Andhra Pradesh biotype)	Leuang 152, Ptb, Eswarakora, Siam 29, and OB 677 derivatives resistant Muey Nawng 62 M susceptible
India (Orissa biotype)	Leuang 152, Ptb, Siam 29 and OB 677 derivatives resistant Muey Nawng 62 M moderately resistant Eswarakora derivatives susceptible
India (Bihar biotype)	Eswarakora derivatives moderately resistant Leuang 152, Ptb, Siam 29, Muey Nawng 62 M and OB 677 derivatives susceptible
Gall midge biotype in India (AICRIP 1982)	
Andhra biotype Madurai biotype Raipur biotype	Siam 29, Leuang 152, Ptb and Eswarakora derivatives resistant
Orissa biotype	Eswarakora derivatives susceptible, others resistant
Bihar, Manipur biotype	Siam 29, Leuang 152 derivatives susceptible, others resistant

Biotypic variation had made the rice improvement programme a bit complex and difficult. Information on how soon a biotype selection takes place is lacking.

3. Inheritance of resistance

Contradicting reports on the inheritance of resistance are available. Crosses made with W 1263 and IR 8 and Ptb 21 × IR 8 indicated that two genes were responsible in the former cross and four genes in the latter cross (Narasimha Rao 1970; Shastry *et al* 1972). In addition, susceptibility is inhibited by one dominant inhibitor gene. However, later workers did not find any inhibitory gene over susceptibility (Sastri and Prakasa Rao 1973; Sastri *et al* 1975, 1976). Only one dominant gene governing resistance has been reported (Satyanarayanaiah and Reddy 1972; Venkataswamy 1974). Even cytoplasmic influence in the expression of resistance was reported (Prasad *et al* 1975).

Hidaka (1974) observed environmental influence in crosses with W 1263 and Muey Nawng 62 M in Thailand which indicates that apparently no true resistant variety exists in that region. Genetics of resistance in case of many resistant varieties has to be taken up in view of the biotypic variations in many regions.

4. Mechanism of resistance

Earlier workers attributed morphological characters, purple colour, scent possessed by the varieties (CRRI 1953; Israel *et al* 1961) and hairiness in the leaves (Krishnamoorthy Rao and Krishnamoorthy 1974; Venkatasamy 1966) to the resistance of rice varieties to gall midge. Israel *et al* (1964) observed increased presence of lignified sclerenchymatous patches below the epidermis in the leaf sheaths of resistant varieties as compared to the susceptible ones. In addition, Rao *et al* (1971) reported that the resistant cultivars are characterized by compact leaf sheaths which prevent entry of newly hatched maggot to the feeding primordium. However, later studies confirmed that the hairiness or physical characters have little relation with resistance, as there was no ovipositional preference among the varieties and the earlier mentioned characters offer no resistance to the entry of newly hatched maggots into the host tissue (Modder and Alagoda 1972; Shastry *et al* 1972; Prakasa Rao 1972; Hidaka *et al* 1974; Kalode 1980). The nature of resistance that operates in rice varieties to gall midge is now considered to be due to antibiosis (AICRIP 1969; Narasimha Rao 1970; Prakasa Rao 1971; Fernando 1972; Pongprasert *et al* 1972; Kalode *et al* 1977; Heinrichs and Pathak 1981). The first instar larvae are either killed upon feeding or fail to transform into second instar (Prakasa Rao 1971; Modder and Alagoda 1972; Hidaka *et al* 1974; Chiu-Shin-Foon 1980; Kalode 1980). However, low percentage (3%) of adult emergence (Hidaka *et al* 1974) and silver shoots, harbouring varying proportions of larval and pupal population (Padhi and Prakasa Rao 1978), under field conditions have also been reported to be associated with rice varieties resistant to rice gall midge.

Induced resistance against rice gall midge was attempted by applying silica fertilizers (Hidaka 1974) or chelated boron and zinc to rice plants (Panda 1978). Gall midge incidence decreased by 50% by the latter method. This method has yet not been taken up on field scale.

The resistant varieties exhibit more of phenols and amino acids and less of sugars in

the growing apices (Guru and Roy 1974; Peraiah and Roy 1979; Vidyachandra *et al* 1981). Higher phenol accumulates in the growing tissues of resistant variety upon feeding by the gall midge (CRRI 1975). Due to the accumulation of phenols necrotic brown spot is formed in the tissue (CRRI 1976; Wickeramasinghe 1979). Hidaka and Ya-Klai (1979) detected seven amino acids in the gall midge infested plants, but only 5 in the healthy tissue. On the other hand, Balasubramaniam and Purushothaman (1976) noticed 11 amino acids in the galled tissue and 15 in the healthy tissues. Increased nitrogen application enhances the concentration of amino acids in plants, which favours the gall midge multiplication (Regupathy and Subramanian 1972). This perhaps indicates the role of amino acid in the susceptibility of the plants. Modder and Alegoda (1972) however felt that there is lack of moulting hormone in the resistant varieties. Since antibiosis is essentially biochemical in nature, more qualitative work on the biochemical basis of resistance has to be undertaken to get a clear understanding.

5. Chemical control

Method of application of insecticide is an important phenomenon for gall midge control as the infestation starts appearing right from the seed bed and continues till the tillering period and once the infestation has established, any amount of insecticidal application does not bring down the infestation. Therefore, prophylactic application is generally recommended for its control especially in the pest endemic area and late planted conditions (Chatterji *et al* 1976; Kalode 1976; Kulshreshtha *et al* 1978; Mathur and Rajamani 1979). Kulshreshtha *et al* (1980) recommended less than 5% gall midge damage to be economic threshold in endemic areas. Seedling root dip prior to planting with chlorpyrifos, isofenphos or chlorfenvinphos at 0·02 to 0·04% concentrations for 12 hr dipping was advocated under transplanted conditions. The effectiveness of this treatment persisted atleast for 30 days in the main field (Kulshreshtha and Rajamani 1973; Kalode 1980; Rajamani *et al* 1980; Misra *et al* 1981). The dipping period can be conveniently reduced to 3 to 4 hr if urea (1%) is added (Rajamani and Mathur 1981) or even to 1 to 2 min if phosphate slurry is added to the insecticide (Kalode *et al* 1982). However, under direct seeded condition, sprouted seed treatment with chlorpyrifos emulsion (Kalode *et al* 1982) or with isofenphos (CRRI 1980) also remained effective for 30 days.

Frequent rains, favourable for gall midge multiplication during *kharif* season, reduce the effectiveness of the foliar sprays which remained only partially effective even if applied very often (Kalode 1980). Granular application of diazinon, mephosfolan and phorate is effective for its control in the medium land situation, where water control is possible. Application of these insecticides in the seed bed also prevents initial build up. In the waterlogged fields insecticide application in the root zone immediately after planting or incorporating the insecticide at the final puddling afforded control for a longer period (Kulshreshtha *et al* 1978; CRRI 1979–1981).

Similarly under upland or direct seeded conditions seeds or sprouted seeds treated with insecticides remained effective for 30 days after seeding (CRRI 1980; Kalode *et al* 1982). Interestingly Rajamani *et al* (1982), observed that when application was made in the root zone, carbofuran controls the gall midge, while the same applied in the standing water does not control. Another insecticide, evisect has been reported to enhance the gall midge multiplication in the field as well as in the net house (Rajamani

et al 1982; CRRI 1982). The phenomenon of increased activity of the gall midge with the application of insecticides has come to light rather recently and requires further detailed studies for a better understanding.

6. Biological control

A large natural enemy complex (11 parasites and 8 predators) is operating against the gall midge (Kalode 1980) of which the egg/larval parasite, *Platygaster oryzae* Cameron accounts for 90% parasitism (Mathur and Rajamani 1979). The percentage parasitism by *P. oryzae* increases with the build-up of the pest population, continues beyond the peak midge incidence and suppresses the population in the season (Prakasa Rao 1971). Since the parasite activity gradually increases in the field and takes time to overcome the pest population, in spite of high parasitism late in the crop season the damage to the crop is inflicted by the pest each year.

Rice damage is reported to be reduced when parasitism reaches 50% at an early stage of infestation and chemical control during this period is best avoided (Kulshreshtha 1979). Biological control efforts to-date are limited only to record the periodical occurrence of natural enemies and understanding their population fluctuation. Inundative release of the parasites early in the season, affords great scope for the gall midge management. Field trial on this line is yet to be taken up, when mass multiplication of gall midge parasite in the laboratory becomes possible.

7. Forecasting of gall midge

Depending on the rainfall pattern during April and May, it is possible to forecast the occurrence of gall midge in the ensuing *kharif* season. If the pre-monsoon showers exceed more than 150 mm during these months, the gall midge activity starts in the activated stubbles and self sown rices and regular infestation occurs, when the paddy is transplanted in the month of July. If the pre-monsoon rains fail to occur and the monsoon rains start in June–July, early planted crop in July normally escapes from the severe infestation and only the late planted crop (August) suffers serious damage (Kulshreshtha *et al* 1978). Depending on the monsoon pattern in an area, the shift of transplanting time and the right choice of varieties would help in escaping from infestation especially in the vulnerable stage of the crop growth (Mathur 1978). It can also help decide upon the prophylactic chemical control measures to be applied to the crop.

8. Cultural control

According to the pre-monsoon shower, planting schedules may suitably be adjusted to avoid peak period of gall midge attack (Mathur and Rajamani 1979). Early planted crop with early maturing varieties normally escapes from the severe gall midge infestation, which can be adopted whenever it is possible (Reddy 1967). Closer spacing in planting, which favours the gall midge multiplication in the field, should be avoided (Prakasa Rao 1975). Similarly, susceptibility of rice cultivars to gall midge increases

with enhanced nitrogen application (Israel and Prakasa Rao 1968; Regupathy and Subramanian 1972; Narayanan *et al* 1973) and higher nitrogen also favours increased tillering of the variety and increased number of tillers favour high incidence of the pest (Ramasubbaiah *et al* 1977). Judicial application of nitrogen especially in the initial tillering period of the crop would minimise the incidence of gall midge.

The gall midge is essentially a monsoon pest. Continuous water stand in the field which provides higher humidity is necessary for multiplication. Alternate drying and wetting the field minimises gall midge activity (Prakasa Rao 1971).

Although many hosts are reported to act as alternate host (Reddy 1967; Heinrichs and Pathak 1981), only a very few, *Leersia hexandra* and the wild rice, *Oryza barthii*, serve as alternate host in Orissa (CRRI 1982; Natarajan *et al* 1983). Rice stubbles and self sown rices are the main source of carry-over of the pest incidence. Removal of the alternate hosts and destruction of stubbles especially in the off season are recommended to prevent the carryover of the gall midge population. However in double cropped situations *L. hexandra* does not seem to play a significant role in the carry-over of the pest during no rice period (Natarajan *et al* 1983).

9. Integrated pest management

Integrated pest management of rice gall midge was attempted in early 1970, utilising all the possible control methods. Field trial with the parasitic nematode, DD 136, or microbial agent, *Bacillus thuringensis* did not afford any control of this internal feeder (CRRI 1971; 1972) and only integrating genetic resistance in the varieties and need-based insecticidal application affords effective control of the insect (Kulshreshtha and Rajamani 1976). Kalode (1980) later advocated that gall midge resistant cultivars do not require any insecticidal protection for gall midge control as the genetic base in the resistance is high.

Mohan Rao *et al* (1982) claimed that the number of insecticidal sprays has been considerably reduced in some of the gall midge endemic areas by utilising integrated control methods like conservation of the natural enemies, suitable planting time and varieties. Since a high level of resistance against gall midge is available, these varieties do not require any control measures if the variety becomes acceptable to the farmers. However, much more work is required to devise control measures for areas where real resistance against gall midge is not available and relatively susceptible varieties need to be cultivated.

10. Future research priorities

Rice gall midge ecology has to be studied further in detail to understand the factors responsible for its outbreaks. Proper classification of biotypes of rice gall midge has to be made along with its distribution to help breeders in developing resistant varieties for each biotype area. The reasons for breaking down of resistance to gall midge needs attention and possibility of biotype shift examined. Knowledge on the rate at which biotypes can be selected on the various resistant sources will be required to help varietal releases for an area. New resistance sources have to be identified and increased emphasis has to be placed on genetics of resistance keeping the biotypes in view. It is

also necessary to understand if the rice gall midge reared on different hosts have any biological differences. Efforts have to be made to introduce effective natural enemies against rice gall midge to improve level of natural control at all stages of pest development. Little information is available on the predators of the rice gall midge and behaviour of the dominant parasitoids. Large scale multiplication of midges without resorting to rice plant is still not possible and methods are required to be developed.

A long term research programme is required to establish a forecasting system for rice gall midge taking into account varieties cultivated, planting date, rainfall pattern, damaged tillers, population density, natural enemies and mode of carry-over of the insect in an area. Reasons for lower occurrence of rice gall midge in certain areas as compared to others where higher populations are obtained has to be investigated to help develop sound management practices.

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