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Abstract

Orseolia oryzae, the rice gall midge is a major pest of rice in many areas of tropical Asia and is becoming an important pest in Africa. A chronological review of the progress made in various national programs on varietal resistance, sources of resistance and breeding for resistance is given. Many resistant varieties have been identified and have been utilized in breeding programs to develop high yielding varieties with multiple resistance to the gall midge and other insect pests and diseases. Mechanisms and inheritance of resistance in rice varieties are discussed. Rice varieties resistant in various countries and sources of resistance used in breeding programs are listed. Biotype variations in different countries and within the countries are revealed and a preliminary classification of gall midge biotypes based on varietal reactions is proposed.

Résumé

Variétés de riz résistantes à Orseolia oryzae
et mécanismes de résistance

Orseolia oryzae ("rice gall midge") est un parasite important du riz en Asie tropicale qui commence à se développer en Afrique. Une revue chronologique des travaux effectués sur la resistance variétale du riz a O. oryzae et ses mécanismes indique que de nombreuses variétés résistantes out été découvertes et utilisées pour des croisements génétiques. Des variétés à haut niveau de production présentant une résistance multiple à O. oryzae ainsi qu' à d'autres parasites ont été obtenues. Une liste des variétés parentales résistantes et des variétés utilisées pour les croisements génétiques est donnee. Les mecanismes et les caractères génétiques de la résistance à O. oryzae sont discutés. Differents biotypes d O. oryzae ont été distingués suivant les régions et une classification préliminaire fondée sur la susceptibilité et la résistance de différentes variétés de riz est proposée.

RESISTANCE TO THE RICE GALL MIDGE, *ORSEOLIA ORYZAE* IN RICE

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The gall midge, *Orseolia oryzae* (Wood-Mason) (Diptera:Cecidomyiidae) is a major rice pest in certain regions of Asia and occurs in Africa. It can cause severe crop losses by producing a gall called "silver shoot" that prevents panicle production. The gall midge was first reported as a rice pest in Bihar, India in 1880 (Reddy 1967). Its distribution is limited to the area between 10^{O} south and 24^{O} north latitude (Hidaka 1974) (Fig. 1). In Asia it has been reported from Bangladesh, Burma, Cambodia, China, India, Indonesia, Laos, Nepal, Pakistan, Papua (New Guinea), Sri Lanka, Thailand, and Vietnam (Barnes 1956, Anonymous 1963, Grist & Lever 1969, Mani 1973, Hill 1975). Gall midge occurrence has not been recorded in the Philippines or Malaysia. In Indonesia it is a pest in Java but it is not known to occur in Sulawesi. In Africa it occurs in Sudan, Cameroons, Mali, Upper Volta, Ivory Coast, Senegal, Guinea Bissau, and Nigeria (Anonymous 1963, Grist & Lever 1969, Hill 1975, Enyi, personnal communication).

The gall midge is primarily a pest of lowland irrigated rice, but it has been reported on upland rice in China(Li & Chiu 1951) and on deep water rice as well (Venu Gopal 1975). In addition to *Oryza sativa* it also attacks wild rice species (Reddy 1967, Israel et al., 1961, Israel et al., 1963) and weeds (Israel et al., 1970).

The gall midge recurs after the dry season from the diapausing larvae in underground dormant grass buds. Overwintering of larvae in rice stubbles

(Yen et al., 1941), regenerated rice plants (Li & Chiu 1951), and grasses (Huang 1957) has also been reported. The gall midge may complete a few generations on grasses before rice is planted. Adult flies emerge with the onset of the monsoon rains or favorable moisture conditions (Ramchandra Rao 1924, Descamps 1956). Females lay eggs on leaves or leaf sheaths of newly transplanted rice. On hatching the larvae move down the leaf sheaths and into the plants until they reach the growing points where they feed at the bases of the plants. A life cycle is completed in about 25 days (Reddy 1967).

Gall formation results from 1) the suppression of leaf primordial differentiation at the growth cone and 2) the development of the radial ridges from the innermost leaf primordium followed by an elongation of the leaf sheath (Perera & Fernando 1970). It is not clear whether feeding activity or secretion of a substance by the maggot stimulate growth of the leaf sheath to form a gall. Profuse tillering occurs under early infestation but the new tillers often become infested too. Excessive stunting occurs and few panicles are produced under severe infestation.

The severity of gall midge damage appears to have increased in the last decade. In India it was formerly a pest only in the wet season crop but recently it has also been observed in the winter crop (Kalode & Kasiviswanathan 1976). In Thailand Hidaka (personal communication) reported that the gall midge, which was formerly a pest in the Northeast, is now a pest in the Central Plains as well. The high degree of gall midge susceptibility of high yielding varieties such as IR8, Jaya, and Padma has been a limiting factor to the widespread cultivation of these varieties in some states in India (Misra & Kulshreshtha 1971).

Control of the gall midge has emphasized time of planting to avoid infestations, and insecticides when infestations occur. Neither method has been entirely satisfactory. There has been a great need to develop resistant rice varieties because of the importance of gall midge and the difficulty in controlling it with insecticides. This paper discusses the status of the development of gall midge resistant varieties.

Varietal Resistance

Resistance sources

Early observations on differences in varietal reactions to the gall midge were reported by Nguyên (1922) in Vietnam, Li & Chiu (1951) in China, and Hegdekatti (1927) in India, although differences were not distinct.

National rice improvement programs in Bangladesh, India, Indonesia, Sri Lanka, and Thailand are currently screening germplasm for resistance to the gall midge and have identified about 170 resistant varieties (Table 1). Studies on varietal resistance in India began in the 1950s (Shastry & Seshu 1971). These studies have been reviewed by Shastry et al., (1972) and Prakasa Rao et al., (1974). Field screening of 3600 varieties of the National Germplasm Collection of Rice at the Central Rice Research Institute (CRRI) at Cutttack, India began in 1948. Through the initial field screening program, 246 resistant varieties were identified. Retesting resulted in the selection of the Indian varieties Ptb 18, Ptb 21, Ptb 27, Peykeo E.53, and Peykeo P.129, and the Thai variety Leuang 152. Screening at Warangal resulted in the identification of Eswarakora, HR 12, HR 42, and MR 63 as resistant donors

(Venkataswamy 1966). Studies conducted from 1954-1964 at Warangal in Andhra Pradesh, a "hot spot" for the gall midge, confirmed the resistance of Eswarakora, HR 42, HR 63, Ptb 18, Ptb 21 and Siam 29. Between 1968 and 1970, the All-India Coordinated Rice Improvement Project (AICRIP) screened germplasm from India and germplasm from the International Rice Research Institute (IRRI) collection at the Warangal Rice Research Station in Andhra Pradesh. Two varieties from the Jeypore Botanical Survey, JBS 446 (Desi Bayahunda) and JBS 673 (Ratnachudi) were resistant. In the same evaluation, 44 ARC (Assam Rice Collection) varieties were resistant. Of 3804 IRRI germplasm collection varieties tested, Ptb 10 and AC 1423 from India and DNJ 45 and DV 12 from East Bengal were resistant (Shastry & Seshu 1971).

During 1968-1970, resistant varieties that had been identified in India were provided to the national programs in Indonesia, Sri Lanka, Thailand, and to two international institutes, IRRI, and the International Institute of Tropical Agriculture (IITA). Field tests begun in Thailand in 1969 confirmed the resistance of Eswarakora and some Eswarakora derivatives. Muey Nawng 62M was found to be only moderately resistant in the north but resistant in the northeast (Pongprasert et al., 1972). Muey Nawng 62M had been recommended for endemic gall midge areas of the north in 1961 (Weerapat et al., 1974).

The Indonesian program has evaluated more than half of the 6,000 local varieties (Vreden & Arifin 1977). Varieties previously reported to be resistant, Leri, Gama 61, Jimbruk, Gundil Sempol, Gundul, and PS putih, were found to be susceptible upon re-evaluation. No resistant varieties have thus far been identified from the Indonesian collection. Bangladesh conducted field tests from 1970-1977 but populations have not been high enough to provide sufficient pressure for good evaluation (Alam et al., 1979).

With the development of a mass-rearing technique by Leuamsang et al., (1968) in Thailand and Perera & Fernando (1969) in Sri Lanka, screening is no longer dependent on field populations. Thus the evaluation program has been accelerated. CRRI and AICRIP in India (Kalode et al., 1977) and the Central Research Institute for Agriculture (CRIA) in Indonesia (Arifin & Vreden 1977) have active mass-rearing and greenhouse screening programs.

Although in wild rice no highly resistant type has been found, evaluation at CRRI indicated that species under section Sativa were generally more susceptible than species under section Officinalis or Granulata (Israel et al., 1961, 1963). Israel et al., (1963) also observed that in Oryza australiensis the gall does not emerge and remains ill formed. Israel et al., (1961, 1963) found lower incidence of gall midge in the tetraploid strains than in the diploid strains of Seta, Indrasail, GEB 24, and S.R. 26B.

Biotypes

For many years there has been some indication that the differential varietal reactions from country to country, and even within a country, may be due to the existence of biotypes of gall midge. Possibly the first recorded evidence of this was when Khan & Murthy (1955) found in South India at Nizamabad that HR 14 was consistently less susceptible than HR 8 while Israel & Vedamoorthy (1953) about 1,200 km to the northeast at Cuttack, had conflicting results. Later simultaneous testing at Cuttack and Sambalpur, India indicated differential reactions between the two locations for some cultures (Roy et al., 1971).

To clarify the differential reactions in various Indian locations, a gall midge biotype study was initiated in which the same varieties were evaluated at 11 locations (AICRIP 1978). The results confirmed previous years' results that indicated some varieties tested at Andhra Pradesh and Madhya Pradesh gave distinctly different reactions to the gall midge than the same varieties tested at Orissa.

The fact that Muey Nawng 62M was highly resistant in northeastern Thailand but not in the northern part indicates a possibility of biotypes within the country (Pongprasert et al., 1972) but this has not been confirmed. Fernando (1972) indicated that certain varieties resistant in Cuttack (India) are susceptible in Sri Lanka.

Further evidence on differential reactions throughout Asia was obtained with the establishment by IRRI of the International Rice Gall Midge Nursery (IRGMN) in 1975. After several years of growing the nursery at various locations within Indonesia, India, Sri Lanka and Thailand it became evident that there were several types of differential reactions, indicating the possibility of biotypes. As most of the cooperating countries have greenhouse screening facilities at one or more locations, differential reactions are not attributed to environmental variability.

When in 1978 it became evident that a study specifically aimed at the biotype problem should be established, IRRI developed a collaborative program with national scientists in India, Indonesia, Sri Lanka and Thailand. Results of two years studies conducted in greenhouses at most locations indicate the possibility of four biotypes in Asia as based on reactions of differential varieties (Table 2).

Caution must be taken in the interpretation of field data when determining resistance to biotypes (Prakasa Rao et al., 1974). He found that antibiosis did not function in killing parasitized maggots and that as a result, silver shoots were formed even in resistant varieties. Thus he concluded that antibiosis of resistant varieties functioned only against unparasitized gall midge maggots, killing them before they caused silver shoot formation.

Hidaka et al., (1977) studied morphological variations in gall midge adults that were collected from India and Thailand. Gall midges collected at Cuttack and Chakoli (India) were distinctly smaller in body size than those collected from Phrae, Thailand and their abdomens were covered with minute hairs, considerably smaller than abdominal hairs on the Thailand specimens. This morphology study has been expanded to include gall midge adults from Sri Lanka and Indonesia.

The senior author, on a recent trip to gall midge infested areas in India and Thailand, heard reports of an increasing susceptibility of varieties that had been released for gall midge resistance. This would be similar to the selection in the United States of biotypes of Hessian fly (Gallun 1977) which belongs to the same family as the gall midge.

Mechanisms of Resistance

There are few reports on the mechanisms of resistance to rice gall midge. In early studies gall midge resistance was reported to be associated with biophysical characters such as purple pigmentation and scent (CRRI 1952), hairiness of the leaf (Israel et al., 1961, Krishnamurthy Rao & Krishnamoorthy 1964, Venkataswamy 1966) and compactness of the leaf sheath (Roy et al., 1969 , Rao et al., 1971). Rao et al., (1971) concluded that the smaller interspaces in the resistant varieties prevented gall midge larvae from reaching the primordium. Later studies indicated that neither hairiness nor physical factors were the cause of resistance (Shastry et al., 1972, Prakasa Rao 1972, and Kalode 1973).

Work on ovipositional preference indicated no difference in the number of eggs laid on resistant and susceptible varieties (AICRIP 1969, Hidaka 1971). Kalode et al., (1977) observed that more adults were attracted to susceptible varieties than to resistant varieties. Later Kalode (1979) observed apparent differences in the total number of eggs on resistant and susceptible varieties, but there was no difference in percentage of hatching of the eggs.

Apparently the nature of varietal resistance in rice to the gall midge is of antibiosis type as the larvae do not molt beyond the first instar. Studies conducted by Modder & Alagoda (1971) and Hidaka & Vungsilabutr (1971) showed that in the resistant variety W1263, first instar larvae entered the shoot apices but failed to transform into the second instar. The larvae continued feeding for many days and finally died whereas larvae feeding on IR8, a susceptible variety, developed normally. Evidence indicated nutrition was adequate in both varieties. Molting inhibition was presumed to be caused by either the presence of a specific factor which prevents molting or the absence of a factor essential to molting.

Very little is known about the chemical nature of gall midge resistance. Guru & Roy (1974) studied the biochemical differences in rice varieties and correlated amino acid content with the degree of gall midge resistance. Increase in the phenolic contents of the growing points in a resistant variety during early infestation and phenolic reduction in a suscepitble variety were also reported (CRRI 1975). Balasubramanian & Purushothaman (1971) suggested the use of auxin level as the expression of relative resistance. They reported the presence of more tryptophan and indole acetic acid in galled tissues than in healthy ones, thus indicating changes in the auxin level.

Panda (1978a) induced gall midge resistance in the rice plant by applying chelated boron and zinc to seeds prior to planting and by spraying plants in the field. Gall midge incidence was decreased from 55% in the untreated plots to 5% in the treated plots. According to Panda (1978b), silicic acid which is converted to soluble polymeric forms inhabits normal protein synthesis in gall midge larvae.

Inheritance of Resistance

Most of the studies on inheritance of resistance have been conducted at CRRI in Cuttack, and AICRIP headquarters in Hyderabad, India. Work in India has been reported by Shastry and Seshu (1971), Shastry et al., (1972), Satyanarayanaiah & Reddi (1972), Prakasa Rao et al., (1974), Seshu et al., (1974), Sastry et al., (1975), Prasad et al., (1975), Sastry et al., (1976), and Roy et al., (1978).

Narasimha Rao (1970) conducted the first genetic studies of gall midge resistance at Warangal in 1969 (Shastry et al., 1972). Two crosses were studied; IR8 x W1263 (strain of MTU 15/Eswarakora) and IR8 x Ptb 21. He reported that in W1263 and Ptb 21, two and four genes governed resistance, respectively with susceptibility dominant but suppressed by a dominant inhibitory gene. Satyanarayanaiah & Reddi (1972), conducting inheritance studies at the same location as Narashimha Rao (1970), and Venkataswamy (1974) reported that resistance in W1263 was governed by a single dominant gene. Further studies at CRRI indicated W1263 and W12708 had three recessive genes for resistance but presence of the dominant inhibitor gene was not confirmed

(Sastry & Prakasa Rao 1973, Sastry et al., 1975, Sastry et al., 1976).

Khamboonruang (1973) studied the inheritance of resistance in Muey Nawng 62M and W1263 and concluded that resistance was simply inherited and appeared to be recessive. W1263 conveyed a higher degree of resistance to its progeny than did Muey Nawng 62M (Weerapat et al., 1974). As indicated above, various workers have reported resistance to gall midge to be controlled by from one to four genes. Prasad et al., (1975), in an attempt to clarify the discrepancies of various authors, studied the cytoplasmic influence on gall midge resistance. Their results supported those of Satyanarayanaiah & Reddi who reported a single gene for resistance in W1263.

Brown furrow color in the glumes has been reported to be linked with one of the genes governing gall midge resistance (Sastry & Prakasa Rao 1973). This could be utilized in a breeding program to combine gall midge resistance with other desirable characters.

Breeding for Resistance

Breeding for resistance to the gall midge is being conducted in India, Indonesia, Philippines (IRRI), Sri Lanka, and Thailand. Various sources of resistance are being utilized (Table 3). Breeding for resistance was first conducted in India and the Indian program continues to be the most active. Details of the Indian program have been reported by Roy et al.,(1969, 1971), Shastry & Seshu (1971), Shastry et al.,(1972), Prakasa Rao (1974), Prakasa Rao et al., (1974), Khush (1977) and Roy et al., (1978).

At CRRI, in 1964 resistant donors Ptb 18 and Ptb 21 were crossed with a local type GEB 24 which was extensively grown in India and preferred for its cooking quality. The crosses resulted in several CR56 selections that were not only highly resistant to the gall midge but had other desirable agronomic characters (Prakasa Rao et al., 1974). Crosses of Ptb 18/Ptb 21 yielded highly resistant CR55 selections. Simultaneously crosses between Eswarakora and MTU 15 at the Warangal Station resulted in the resistant selections W1252, W1253, W1257 and W1263 (Venkataswamy 1969). However, these being tall varieties and not suitable as commercial varieties, they were used as donors (Roy et al., 1971).

With the advent of the high-yielding semidwarf varieties such as IR8, hybridization programs at CRRI, Warangal, and AICRIP (Hyderabad) were initiated to incorporate gall midge resistance into these improved plant types utilizing Ptb 18, Ptb 21, Eswarakora, Siam 29, and CR55 and CR56 series, and Warangal cultures, W1251, W1253, W1257 and W1263) as resistance donors (Shastry et al., 1972, Seshu et al., 1974, and Prakasa Rao et al., 1974). Selections from these crosses were field evaluated at Warangal and CRRI. Selected lines were further tested in farmers' fields in the AICRIP multilocation tests. Based on regional performance, CR93-4-2 (CR55-12/IR8) was released in Orissa State as Shakti, and RPW6-13 (IR8/Siam 29) as Vikram in Karnataka (Roy et al., 1978). The resistant variety Kakatiya (IR8/W1263) was released in Andhra Pradesh (Seshu et al., 1974). Recently two varieties from the cross IR8/Siam 29 were released — Phalguna (RP-17) in Andhra Pradesh and Karnataka; Surekha (W13400) for cultivation in the Central Plains of Andhra Pradesh (Kalode 1979).

Currently, gall midge resistance breeding is being conducted at several locations in India. Donor sources most commonly used are OB677 (IR8/Ptb 18//Eswarakora/IR8), W1263, Siam 29, Leuang 152, Ptb 10, Ptb 18, Ptb 21, W12708 and Eswarakora. In the 1978 AICRIP trials conducted at 10 locations throughout India, the elite gall midge-resistant breeding lines

OR132-3-1 and RP825-71-4-11, both having Ptb 21 as a donor parent, were the highest yielders. Many of the gall midge cultivars have multiple resistance to insects and diseases. The four Warangal selections W1252, W1253, W1257, and W1263 are resistant to the gall midge, thrips, stem borers and leafhoppers (Shastry et al., 1972). Saivaraj et al., (1979) reported resistance to the gall midge and leaf folder, Cnaphalocrosis medinalis, in Warangal and CRRI cultures having W12708 and Leuang 152 as donor parents. Kalode et al., (1977) reported 13 local varieties with resistance to the brown planthopper, Nilaparvata lugens, whitebacked planthopper, Sogatella furcifera, and the gall midge. Sastry and Prakasa Rao (1976) and Prasad et al., (1977) reported that CR cultures (CR57-MR1523, CR94-MR1550, CR188, CR189, CR190, CR191 and CR200) from CRRI carried multiple resistance to gall midge and other major insects and diseases.

The Thailand breeding program began in 1967 when the Warangal cultures W1240, W1256, W1259, W1262, and W1263 were received from India (Pongprasert et al., 1972). After field tests indicated high resistance levels, crosses were made with local and improved plant-type varieties. Progenies were field tested for resistance and resistant lines were selected. The first resistant variety RD4 was released in 1973 (Weerapat et al., 1974). Yields under heavy gall midge infestation were twice that of RD1, a susceptible variety. The need for a nonglutinous gall midge-resistant variety prompted the release of RD9 ((Anonymous 1977). Both RD4 and RD9 have multiple resistance to insects and diseases.

The breeding program in Sri Lanka began in 1969 and is conducted at two locations, Gannoruwa and Batalagoda. The approach at Batalagoda initially involved the use of Indian breeding lines having Ptb 18 and

Eswarakora as donor parents (Weeraratne et al., 1974).. At Gannoruwa, W1263 was selected as the major donor parent. Recurrent parents used in the breeding program were recommended susceptible varieties and susceptible elite breeding material such as Bg11-11, Bg34-6, Bg34-8, Bg90-2, Bg94-1 and H4. The current breeding program utilizes OB678 (IR8/Ptb 18//Eswarakora /IR8), as the major donor source. Of the breeding lines developed, Bg 400-1, Bg 276-5 have been recommended for cultivation.

Resistant breeding lines from India and IRRI are used in the breeding program in Indonesia. Because Eswarakora and Ptb derivatives are susceptible to the Indonesian biotype, breeding lines with resistance from Siam 29 and OB677 are used particularly IR4744 (Harahap et al., 1977). No resistant varieties have so far been released from the Indonesian breeding program. CPA6805-22, CPA6809-74 and BKN6805-7 are the most promising lines having multiple resistance (Anonymous 1978).

The IRRI program has utilized Ptb 18, CR94-14 (Ptb 18/Ptb 21), Eswarakora, OB677 and RPW6-13 (IR8/Siam 29) as source of resistance. Selections with multiple resistance to other insects and diseases were screened in cooperation with CRRI scientists. IR2070-747-6-3 was named IR32 in 1975 and IR2071-625-1-252 was named IR36 in the Philippines in 1976 (Khush 1977).

To accelerate the breeding of gall midge-resistanct varieties, in 1975 IRRI established the International Rice Gall Midge Nursery (IRGMN) as one of the nurseries in the International Rice Testing Program (IRTP) (Anonymous 1975). The 1979 IRGMN consists of 104 entries from national programs and the IRRI breeding program. As one of the IRTP nurseries it is being evaluated in Africa, Bangladesh, India, Indonesia, Sri Lanka, and Thailand.

Tests are conducted in the greenhouse and in the field. The International Collaborative Study on Gall Midge Biotypes was developed to clarify the differential reactions first observed in the IRGMN.

Conclusions

Significant advances have been made in the development of gall midge-resistant rice varieties in Asia. Gall midge resistant varieties have higher yields when they are grown under conditions of gall midge infestation. Still much more needs to be done. It has been difficult to provide farmers with varieties that have acceptable grain quality and multiple resistance to the gall midge and other insects. However, recently released varieties are more acceptable than those released earlier.

The genetics of resistance have received low research priority in recent years. There are still contradictory views on the inheritance of resistance in varieties that have been studied, and the genetics of many resistant varieties are yet to be determined. New resistance sources should be included in the various breeding programs. Identification of the resistance genes and the development of isogenic lines is necessary to properly classify the biotypes. Studies should be conducted to confirm the observations that currently grown resistant varieties are becoming susceptible due to an increase in the population of virulent biotypes in India and Thailand. If biotype shifts occur, as happened with the brown planthopper, consideration must be given to identifying appropriate breeding methods to cope with the problem.

Excellent programs for the development of varietal resistance as a pest management component in the control of gall midge have been established in Asia. Utilization of the resistant varieties, in combination with chemical, cultural and biological control, can be expected to provide effective and economic control of the gall midge.

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Table 1. Rice varieties reported as having resistance to the gall midge, Orseolia oryzae in various screening programs (1957-1979).

Variety	Origin[a]	Type of test[b]	Reference
AC 355, 1368	India	F	Prakasa Rao (1971)
AC 1423	India	F	Shastry & Seshu (1971)
ADR 52	India	F	Shastry et al. (1970)
ARC 5810	India	F	Shastry et al. (1970)
ARC 5833, 5834	India	GH	Kalode (1979)
ARC 5838, 5842,	India	F	Shastry et al. (1970)
ARC 5848, 5911, 5912, 5918, 5939	India	GH	Kalode (1979)
ARC 5947A, 5949, 5951	India	F	Shastry et al. (1970)
ARC 5959	India	F	CRRI (1974)
ARC 5984	India	F	Shastry et al. (1970)
ARC 5987	India	F	CRRI (1974)
ARC 5988, 6001	India	GH	Kalode (1979)
ARC 6010, 6014, 6087	India	F	Shastry et al. (1970)
ARC 6103	India	GH	Kalode (1979)
ARC 6136, 6140	India	F	Shastry et al. (1970)
ARC 6157	India	GH	Kalode (1979)

Table 1 (Cont'd.)

Variety	Origin[a]	Type of test[b]	Reference
ARC 6158, 6163, 6202, 6210, 6221, 6232, 6234, 6238, 6557, 6605A	India	F	Shastry et al. (1970)
ARC 6606, 6607, 6618, 6619	India	GH	Kalode (1979)
ARC 6631	India	F	Shastry et al. (1970)
ARC 6632	India	F	CRRI (1974)
ARC 7004, 7077, 7138, 7213	India	F	Shastry et al. (1970)
ARC 7255, 7292, 7293	India	GH	Kalode (1979)
ARC 7308, 7316, 7317, 7318, 7329	India	F	Shastry et al. (1970)
ARC 10040, 10227	India	GH	Kalode (1979)
ARC 10272, 10295	India	F	Shastry et al. (1970)
ARC 10331	India	GH	Kalode (1979)
ARC 10345	India	F	Shastry et al. (1970)
ARC 10360, 10377	India	GH	Kalode (1979)
ARC 10395	India	F	Shastry et al. (1970)
ARC 10460	India	GH	Kalode (1979)
ARC 10494, 10534	India	F	Shastry et al. (1970)
ARC 10557	India	GH	Kalode (1979)
ARC 10654	India	F	Shastry et al. (1970)
ARC 10659, 10660	India	GH	Kalode (1979)

Table 1 (Cont'd.)

Variety	Origin [a]	Type of test [b]	Reference
ARC 10817	India	F	Shastry et al. (1970)
ARC 10932-2	India (Indonesia)	F	Soehardjan et al. (1977)
ARC 10963, 11210, 11307	India	F	Shastry et al. (1970)
ARC 11704	India	GH	Kalode et al. (1977)
ARC 13500, 13516, 13564, 13902, 13929, 14148, 14378, 14421, 14549, 14725, 14748, 14787, 15067, 15151, 15159, 15905, 17789, 18595, 18596, 18601	India	F	CRRI (1974)
Bainsa	India	F	Sen (1957)
Chemban, Chennellu, Chenni Nayakan	India	GH	Kalode et al. (1977)
Dahanala-37	India	F	CRRI (1964)
DNJ-45	India	F	Shastry and Seshu (1971)
Dok Putdor	Thailand	F	Kovitvadhi (1963)
DV-12	India	F	Shastry and Seshu (1971)
Eswarakora	India	F	Venkataswamy (1966)
Hochin	India	F	CRRI (1964)
HR 14	India	F	Khan & Murthy (1955)
HR 42, HR 63	India	F	Krishnamurthy Rao & Krishnamoorthy (1964)

Table 1 (Cont'd.)

Variety	Origin[a]	Type of test[a]	Reference
JBS 446 (Desi Bayahunda)	India	F	Shastry & Seshu (1971)
JBS 673 (Ratnachudi)	India	F	Bhat et al. (1958)
JBS 990, 1224	India	F	Seshu et al. (1974)
Kurutha Vellathan	India	GH	Kalode et al.(1977)
Kalijira	India (Bangladesh)	F	BRRI (1979)
Leuang 152	Thailand (India)	F	Rao et al. (1969)
MGL 5	India	F	Pai and Rao (1958)
MNP 7, 14, 14-A, 15, 30, 62, 336, 380B, 448, 457	India	F	Seshu et al. (1974)
MNP 471	India	F	Shastry & Prakasa Rao (1976)
MNP 753, 800, 837	India	F	Seshu et al. (1974)
Muey Nawng Fang, Muey Nawng 62, Muey Nawng 62M	THailand	F	Kovitvadhi (1963)
Muey Nawng 6	Thailand	F	Ou & Kanjanasoon (1961)
Neto	India	F	Sen (1957)
Nizersail	(Indonesia)	F	Anonymous (1976)
Pandi, Parakulam	India	GH	Kalode et al. (1977)
Peykeo E 53, Peykeo P 129	India	F	CRRI (1963)
Ptb 10	India	F	Thomas & Chacko (1968)

Table 1 (Cont'd.)

Variety	Origin[a]	Type of test[b]	Reference
Ptb 12	India	GH	Kalode et al. (1977)
Ptb 18	India	F	CRRI (1965)
Ptb 19	India	GH	Kalode et al. (1977)
Ptb 21	India	F	CRRI (1965)
Ptb 27	India	F	CRRI (1963)
Ptb 28, 32	India	F	Khush (1977)
Siam 29	Thailand (India)	F	Roy et al. (1971)
T10, 16	India	GH	Kalode et al. (1977)
T405, 1162	India	GH	Kalode et al. (1979)
T1421, 1425, 1426, 1432	India	GH	Kalode et al. (1977)
T1426	India	GH	Kalode (1979)
T1471	India	GH	Kalode et al. (1977)
T1479, 2587	India	GH	Kalode (1979)
Vella Chenipan, Vellathil Cheera, Velutha Chera	India	GH	Kalode et al. (1977)
710	India	GH	Kalode et al. (1977)

Table 1 (Cont'd.)

Variety	Origin[a]	Type of test[b]	Reference
	WILD RICE SPECIES		
O. brachyantha, coarctata, eichingiri, granulata, ridleyi	(India)	F	Israel et al. (1963)

[a]Name given in parenthesis where resistance identified.

[b]GH = greenhouse; F = field

Table 2. Gall midge biotype classification based on the reaction of differential varieties.[1]

Thailand	* Eswarakora derivatives resistant * Leuang 152, Siam 29, OB677, and PTB derivatives susceptible
Indonesia biotype	* Leuang 152, Siam 29 and OB677 derivatives resistant * Eswarakora and PTB derivatives susceptible
India (Orissa) and Sri Lanka biotype	* Leuang 152, Siam 29, OB677 and PTB derivatives resistant * Eswarakora derivatives susceptible
India (A.P.) biotype	* Leuang 152, Siam 29, OB677, Eswarakora and PTB derivatives resistant

[1]Summarized by D.V. Seshu, IRRI, as based on reports of the International Rice Gall Midge Nursery (1976-78) and International Collaborative Studies on Gall Midge Biotypes (1977-78) between IRRI and national programs in India, Indonesia, Sri Lanka, and Thailand.

Table 3. Sources of resistance used in developing gall midge-resistant rice varieties and breeding lines in various countries (1964-1978).

India		Indonesia	Philippines (IRRI)	Sri Lanka	Thailand
ARC 5833	ARC 15334	ARC 6650	Ptb 18	Eswarakora	Eswarakora
ARC 5984	ARC 15905	OB 677	Ptb 21	Leuang 152	Muey Nawng 62M
ARC 5959	Eswarakora	Ptb 18	Siam 29	OB 677	
ARC 6158	JBS 446	Siam 29	Eswarakora	OB 678	
ARC 6221	JBS 673		OB 677	Ptb 18	
ARC 6632	Leuang 152			Ptb 21	
ARC 13516	MNP 30			Siam 29	
ARC 14421	MNP 471				
ARC 14375	OB 677				
ARC 14748	Ptb 10				
ARC 14787	Ptb 18				
ARC 15315	PTB 21				
	Siam 29				
	W1263				
	W12708				

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Keywords: rice Oryza sativa, host plant resistance, sources of resistance, plant breeding, multiple pest resistance, proposed classification of biotypes