MECHANISMS OF RESISTANCE IN WILD RICES (*Oryza* spp.) TO YELLOW STEM BORER *Scirpophaga incertulas* (Walker) (Pyralidae : Lepidoptera)

Thesis submitted in part fulfilment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY** (Agriculture) in Agricultural Entomology to the Tamil Nadu Agricultural University, Coimbatore

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CERTIFICATE

This is to certify that the thesis entitled "**MECHANISMS OF RESISTANCE IN WILD RICES (*Oryza* spp.) TO YELLOW STEM BORER *Scirpophaga incertulas* (Walker) (Pyralidae : Lepidoptera)**" submitted in part fulfilment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY (AGRICULTURE) IN AGRICULTURAL ENTOMOLOGY**, to the Tamil Nadu Agricultural University, Coimbatore is a record of **bonafide** research work carried out by **Y.S. JOHNSON THANGARAJ EDWARD** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

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ABSTRACT

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(Pyralidae : Lepidoptera)

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Twenty four wild rice accessions belonging to six species *viz.*, *Oryza australiensis, O. latifolia, O. minuta, O. nivara, O. officinalis* and *O. punctata* were screened for their resistance to the rice yellow stem borer, *Scirpophaga incertulas* (Walker) at tillering and booting stage. Fourteen wild rice accessions were found resistant at tillering stage and eight accessions were found resistant at booting stage.

The wild rice accessions differed in their susceptibility to yellow stem borer at tillering and booting stage. The wild rice accessions *O. australiensis* (103318 and 101144), *O. latifolia* (101443, 102481), *O. officinalis* (100948 and 100947), *O. minuta* (101092) and *O. punctata* (100954) were resistant at both tillering and booting stage. The wild rice accessions *O. latifolia* (100966), *O. minuta* (101079, 101086, 101096 and 101128) and *O. punctata* (101417) were resistant at tillering stage and susceptible at booting stage.

The weight gained by third instar larvae after 48 and 96 h of feeding in callus of resistant wild rices was significantly reduced. There was no significant difference in the number of egg masses laid by yellow stem borer on the accessions with varying levels of resistance. There was no marked difference in the number of larvae oriented towards different accessions even 12 h after release in a free choice test.

Significantly lower percentage of larvae entered the lumen of the resistant wild rice accessions tested. However there was no significant difference in the place of larval entry into the lumen in different accessions. The distance tunnelled by the larvae, 5 days after release was significantly reduced in the resistant wild rice accessions. The larvae exhibited an extended larval period and reduced percentage of pupation in the resistant wild rice accessions. The percentage of adult emergence was greatly reduced when the larvae were reared on the resistant wild rice accessions.

The adult females and males emerged from the resistant wild rice accessions lived for a shorter period and laid less number of smaller egg masses containing less number of eggs than the adults emerged from susceptible IR 62. The larval, pupal and adult male and female weights were significantly reduced when developed on the resistant wild rice accessions. The length and width of the mandibles were significantly reduced when fed on the resistant wild rice accessions. There was marked wear in the mandibles of the larvae fed on the resistant wild rice accessions.

The steam distillate and cuticular wax extract of resistant wild rice accessions did not influence the oviposition of adult females and the orientation response of neonate larvae. But they decreased the survival of neonate larvae feeding on the susceptible IR 62 plants smeared with extract and reduced the deadheart / whitehead damage.

The amylase, invertase, protease and lipase activity in the gut of the yellow stem borer larvae was greatly reduced when fed on the resistant wild rice accessions.

The lumen diameter and the length of ligule were not found to have any significant role in resistance. However the length of trichome and their distribution were found to be positively correlated with resistance.

The total nitrogen content in the leaf sheath did not vary with level of resistance in the accessions tested. However the resistant wild rice accessions recorded high content of crude silica, cellulose and lignin.

The increase in the total protein and free amino acid content was not much pronounced in different accessions. The yellow stem borer infestation resulted in an increase in the phenol and OD phenol content, which was more pronounced in the resistant wild rice accessions.

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INTRODUCTION

Rice is the staple food in Asia. More than 100 insect species take serious toll of rice production of which stem borers are of major economic importance. The stem borers are constant menace to rice infesting the crop from seedling to maturity and account for a larger share of crop loss. Though changes in the status of stem borers were observed among different species, the yellow stem borer, *Scirpophaga incertulas* (Walker) still continues to be the predominant species in different temperate and tropical countries (Kalode, 1974; CAB, 1980; Pathak and Dhaliwal, 1981). Periodic flooding of irrigated rice fields ensures the supremacy of *S. incertulas* in tropical Asia. Yellow stem borer is serious in all the systems of rice cultivation like rainfed, irrigated and deep water system of cultivation. It was responsible for a steady annual loss of 5 to 10 per cent of the rice crop, with occasional localised outbreaks damage up to 60 per cent (Singh and Pandey, 1997). In addition to the direct damage to the crop, the larvae also transmits the bacteria, *Erwinia chrysanthemi* causing bacterial foot rot disease in rice (Hossain and Mew, 1989).

Application of insecticides against stem borers was sometimes prophylactic in nature and often it was found uneconomical since the pest density tended to fluctuate in time and space. Also the practical means of controlling borers through insecticides can provide only temporary control; besides they are not ecologically safer. In view of the above problems, the use of resistant varieties in the control of stem borers is receiving increasing attention. During last 35 years, extensive screening of local and introduced rice germplasms for resistance to yellow stem borer has been done in several countries and sources of resistance have been identified (Khan *et al.*, 1991). Difference in resistance to stem borer among varieties are only quantitative. Very high levels of resistance have not been found and there is continuous variation for this trait among rice varieties, from highly susceptible to moderately resistant. Even varieties classified as resistant suffer some damage under high insect population. However, several wild rices have high levels of resistance to stem borers (Khan *et al.*, 1991).

The wild *Oryza* species represent a rich, largely untapped source of resistance to biotic as well as abiotic stresses. As the genetic variability for disease and insect resistance within cultivated rice is used up and overcome by new insect biotypes, the wild species is increasing in importance as a germplasm source. The counter strategy against the pests involved breeding of varieties, with genes for resistance to pests taken from wild relatives of the rice and its traditional cultivars. Though the cultivated and wild rices are of different genome, recent developments in plant breeding techniques permit such hybridisation.

Understanding the bases of resistance and the biological activity of allelochemicals involved can facilitate breeding programmes aimed at transferring resistant factors to cultivated crops. Such knowledge will also ensure that resistant varieties do not adversely affect other biological control agents regulating the pest (Kauffman and Kennedy, 1989).

Hence, the present study was undertaken with the following objectives.

(i) to identify the wild rice species accessions resistant to the yellow stem borer, *S. incertulas*

(ii) to identify the mechanism of resistance involved in the wild rice accessions to *S. incertulas* and

(iii) to investigate the biochemical and morphological bases of resistance.

REVIEW OF LITERATURE

CHAPTER II
REVIEW OF LITERATURE

2.1. Taxonomy

The yellow stem borer, *Scirpophaga incertulas* (Walker) belongs to the subfamily Schoenobiinae under the family Pyralidae. Walker (1863a,b) described the males of yellow stem borer as *Chilo incertulas* and females as *Tipanaea bipunctifera*. It has the following synonyms.

Catagla (?) *admotella* Walker (1863c)

Schoenobius punctellus Zeller (1863)

Schoenobius minutellus Zeller (1863)

Chilo gratiosellus Walker (1864)

Apurima gratiosella Butler (1880)

Schoenobius incertulas Hampson (1896)

Schoenobius bipunctifer Hampson (1896)

Tryporyza incertulas Common (1960)

Finally, the name was changed to *Scirpophaga incertulas* by Leuvanich (1981). Besides the description of the male and female moths by various workers, Walker (1863c) described the immature stages also.

2.2. Distribution

Yellow stem borer is the most destructive rice borer in the Oriental region. It has been reported from Afghanistan, Nepal, India, Sri Lanka, Bangladesh, Myanmar, Vietnam, Thailand, Malaysia, Singapore, Indonesia, Philippines, Hong Kong, Taiwan-China, Main land-China, Japan and Pakistan (CAB, 1980).

2.3. Alternate host plants

The yellow stem borer is a major pest of rice and *Oryza sativa* (Family: Poaceae) is the primary host. It was also found to feed on other plants belonging to the families Cyperaceae and Poaceae. It was repoted to feed on sugarcane, wheat and maize (Ghai *et al.* 1979; Singh, 1971). Balasubramanian *et al.* (1994) listed 14 species as alternate hosts to yellow stem borer. A complete list of alternate hosts reported by several workers is listed below.

Family	Scientific name	Country	Reference
Cyperaceae	*Cyperus compactus* Retz.	Indonesia	Soehardjan and Soegiarto (1975)
	Cyperus compressus L.	Indonesia	Soehardjan and Soegiarto (1975)
	Cyperus difformis L.	Indonesia	Soehardjan and Soegiarto (1975)
	Cyperus dubius Rottb. [= *Cyperus kyllingaeoides]*	Indonesia	Soehardjan and Soegiarto (1975)
	Cyperus elatus L.	Indonesia	Soehardjan and Soegiarto (1975)
	Cyperus iria L.	Indonesia	Soechardijan and Soegiarto (1975)
	Cypeprus rotundus L.	India, Indonesia	Arvind (1987) Soehardjan and Soegiarto (1975)
	Cyperus spp.	Philippines	Otanes and Sison (1941)
	Fimbristylis littoralis Gaudich [=*Fimbristylis milliace* (L.) Vahl].	Indonesia	Soehardjan and Soegiarto (1975)
	Scirpus grossus Lf.	Malaysia	Yunus (1967), Singh (1971)
	Scirpus juncoides Roxb.	Indonesia	Soehardjan and Soegiarto (1975)
Poaceae	*Andropogon odoratus* Auct.ex Steud.	India	Kasargode and Despande (1915), Fletcher and Ghosh (1920), Manickavasagar and Miyashita (1959), Banerjee and Pramanik (1967), Zaheruddeen and Prakasa Rao (1983c)

Axonopus compressus (Sw.) P. Beauv.	Indonesia	Soehardjan and Soegiarto (1975)
Brachiaria miliiformis (Presl) A. Chase	Indonesia	Soehardjan and Soegiarto (1975)
Brachiaria mutica (Forssk.) Stapf	Indonesia	Soehardjan and Soegiarto (1975)
Coix lachryma-jobi L.	India	Kasargode and Despande (1915), Fletcher and Ghosh (1920), Manickavasagar and Miyashita (1959), Banerjee and Pramanik (1967), Zaheruddeen and Prakasa Rao (1983c)
Cynodon dactylon (L. C. Rich.) Pers	India	Arvind (1987)
	Indonesia	Soehardjan and Soegiarto (1975)
Digitaria sanguinalis (L.) Scop.	Indonesia	Soehardjan and Soegiarto (1975)
Echinochloa colona (L.) Link	Indonesia	Soehardjan and Soegiarto (1975)
	Malaysia	Yunus (1967), Singh (1971)
Eleusine indica (L.) Gactin.	Malaysia	Yunus (1967), Singh (1971)
Eragrostis unioloides (Retz.) Nees ex. Steud.	Indonesia	Soehardjan and Soegiarto (1975)
Eriochloa procera (Retz.) C.E. Hubb. [=*Eriochloa annulata* Kunth]	Malaysia	Yunus (1967), Singh (1971)
Ischaemum aristatum L.	India	Kasargode and Despande (1915), Fletcher and Ghosh (1920), Manickavasagar and Miyashita (1959), Banerjee and Pramanik (1967), Zaheruddeen and Prakasa Rao (1983c)
Ischaemum timorense Kunth	Malaysia	Yunus (1967)
Leersia hexandra Sw.	Indonesia	Soehardjan and Soegiarto (1975)

Leptochloa chinensis (L.) Nees	The Phillipines	Catindig *et al.* (1988)
Leptochloa panicoides (Presl) Hitch.	India	Zaheruddeen and Prakasa Rao (1983b, c, d)
Monochoria vaginalis (Burm.f.) Presl	Indonesia	Soehardjan and Soegiarto (1975)
Oryza latifolia Desv.	India	Zaheruddeen and Prakasa Rao (1983a, b, c)
Oryza nivara Sharma and Shastry	India	Zaheruddeen and Prakasa Rao (1983a, b, c)
Oryza perennis Moench	Madagascar	Appert (1967)
Oryza rufipogon Griff.	India	Zaheruddeen and Prakasa Rao (1983a, b, c)
Panicum auritum Presel	Malaysia	Yunus (1967), Singh (1971)
Panicum repens L.	Malaysia	Yunus (1967), Singh (1971)
Paspalum punctatum Burm.	Malaysia	Yunus (1967), Singh (1971)
Paspalum scrobiculatum L. [=*Paspalum orbiculare* Forst.] [=*Paspalum commersoni* Lam.]	Indonesia Malaysia	Soehardjan and Soegiarto (1975) Yunus (1967), Singh (1971)
Polytrias amaura (Buse) O. Ktze.	Indonesia	Soehardjan and Soegiarto (1975)
Saccharum officinarum L.	India	Ghosh (1921), Fletcher (1928), Ghai *et al.* (1979)
	Malaysia	Yunus (1967), Singh (1971)
Sacciolepis myosuroides (R.Br.) A. Camus	Malaysia	Yunus (1967), Singh (1971)
Sacciolepsis myurus (Lam.) A. Chase [=*Hymenachae myurus* (Lann).Beauv]	Malaysia	Yunus (1967), Singh (1971)
Setaria barbata (Lam.) Kunth	Indonesia	Soehardjan and Soegiarto (1975)

Setaria pumila (Poir.) Roem. And Schult [=*Setaria rebiginosa* (Steud.) Miq.]	Malaysia	Yunus (1967), Singh (1971)
Tristachya leucothrix Nees [=*Anthistiria ciliata*]	India	Kasargode and Despande (1915), Fletcher and Ghosh (1920), Manickavasagar and Miyashita (1959), Banerjee and Pramanik (1967), Zaheruddeen and Prakasa Rao (1983c)
Triticum sp.	Myanmar	Banerjee and Pramanik (1967), Manickavasagar and Miyashita (1959)
Vetiveria odorata Virey	Malaysia	Yunus (1967), Singh (1971)
Zea mays L.	Malaysia	Yunus (1967), Singh (1971)

2.4. Host plant resistance

During the past 30 years, extensive screening of local and introduced germplasm for resistance to yellow stem borer has been done in several countries. Screening for yellow stemborer began at IRRI in1972 and more than 1000 germplasm entries were screened during 1972 (Akinsola, 1973) and more than 39,000 varieties were screened so far. Difference in resistance among varieties are only quantitative and very high levels of resistance have not been found and there is continuous variation for this trait among rice varieties from highly susceptible to moderately resistant. Even varieties classified as resistant suffer some damage under high insect populations (Khan *et al.*, 1991).

In India, screening for stem borers started in 1937 itself when 1000 varieties were screened in the field against combined infestation of borer species and CO 19, CO 25, ADT 1, ADT 25, ASD 2, ASD 8, MTU 15, China 47 and Chautukalu were found resistant (Pawar *et al.*, 1959). Shastry *et al.* (1971) screened 1456 Assam Rice Collections (ARC) at the deadheart and whitehead stage for damage by yellow stemborer and six varieties ARC 5920, ARC 6184, ARC 7098, ARC 10443, ARC 10958 and ARC 11537 were found to be resistant at both stages. The varieties / breeding lines reported to be resistant to yellow stem borer by several workers in different countries are given in appendix 1.

Several wild rice accessions were screened at IRRI between 1976 and 1981 and resistance in 20 accessions was recofirmed. These accessions of wild rices *O. punctata*, *O. officinalis*, *O. minuta*, *O. eichingeri* and *O. latifolia* have the highest level of resistance so far obtained with rating of 3 or less on a 0-9 scale (Chaudhary *et al.*, 1984). In India, Padhi and Prakasa Rao (1978) screened 14 wild species against yellow stem borer and found that *O. tisseranti*, *O. ridleyi* and *O. perrieri* were resistant at deadheart stage. The list of wild rice accessions reported as resistant is given below.

Wild rice species	**Accession number**	**Origin**	**Reference(s)**
O. alta Swallen	100161	Brazil	Khan *et al.* (1991)
O. alta	100888	Latin America	Khan *et al.* (1991)
O. alta	100952	Latin America	Khan *et al.* (1991)
O. alta	100967	Surinam	Khan *et al.* (1991)
O. alta	101395	Latin America	Khan *et al.* (1991)
O. australiensis Domin	101144	Australia	Khan *et al.* (1991)
O. australiensis	103303	Australia	Khan *et al.* (1991)
O. australiensis	103318	Australia	Khan *et al.* (1991)
O. australiensis	105165	Australia	Khan *et al.* (1991)
O. barthii A. Chev.	100122	Gambia	Khan *et al.* (1991)
O. brachyantha A. Chev. et Roehr.	100115	Guinea	Khan *et al.* (1991)
O. brachyantha	101231	Sierra Leone	Khan *et al.* (1991)
O. brachyantha	101232	Sierra Leone	Khan *et al.* (1991)
O. brachyantha	101233	Sierra Leone	Khan *et al.* (1991)
O. brachyantha	101234	Sierra Leone	Khan *et al.* (1991)
O. brachyantha	101235	Sierra Leone	Khan *et al.* (1991)
O. brachyantha	101236	Mali	Khan *et al.* (1991)
O. brachyantha	105150	Sierra Leone	Khan *et al.* (1991)
O. brachyantha	105151	Sierra Leone	Khan *et al.* (1991)
O. brachyantha	105152	Sierra Leone	Khan *et al.* (1991)
O. eichingeri A. Peter	101418	Uganda	IRRI (1981a), Khan *et al.* (1991)
O. eichingeri	101421	Uganda	IRRI (1981a), Khan *et al.* (1991)
O. eichingeri	101422	Uganda	IRRI (1981a), Chaudhary *et al.* (1984)
O. eichingeri	101424	Uganda	IRRI (1981a), Khan *et al.* (1991)
O. eichingeri	101425	Uganda	Khan *et al.* (1991)

O. eichingeri	101426	Uganda	IRRI (1981a) Khan *et al.* (1991)
O. eichingeri	101430	Uganda	IRRI (1981a), Chaudhary *et al.* (1984)
O. eichingeri	105159	Uganda	Khan *et al.* (1991)
O. eichingeri	105163	Uganda	Khan *et al.* (1991)
O. eichingeri	105181	Uganda	Khan *et al.* (1991)
O. glumaepatula Steud.	100894	America	Khan *et al.* (1991)
O. grandiglumis (Doell) Prod.	105144	Brazil	Khan *et al.* (1991)
O. grandiglumis	105155	Brazil	Khan *et al.* (1991)
O. latifolia Desv.	100170	Costa Rica	Khan *et al.* (1991)
O. latifolia	100171	Guatemala	Khan *et al.* (1991)
O. latifolia	101443	Mexico	IRRI (1981a), Chaudhary *et al.* (1984), Khan *et al.* (1991)
O. latifolia	102481	Nicaragua	IRRI (1981a), Chaudhary *et al.* (1984)
O. latifolia	105141	Costa Rica	Khan *et al.* (1991)
O. latifolia	105142	Costa Rica	Khan *et al.* (1991)
O. latifolia	100966	Panama	IRRI (1981a), Chaudhary *et al.* (1984)
O. longistaminata A. Chev. et. Roehr.	101754	Senegal	Khan *et al.* (1991)
O. longistaminata	101383	Mali	Khan *et al.* (1991)
O. malampuzhaensis Krish. et. Chand.	100957	India	Khan *et al.* (1991)
O. meridionalis Ng	103317	Australia	Khan *et al.* (1991)
O. meridionalis	103321	Australia	Khan *et al.* (1991)
O. minuta J.S. Presl. ex. C.B. Pres.	101080	Philippines	Khan *et al.* (1991)
O. minuta	101083	Philippines	Khan *et al.* (1991)
O. minuta	101086	Philippines	IRRI (1981a), Chaudhary *et al.* (1984), Khan *et al.* (1991)
O. minuta	101089	Philippines	IRRI (1981a), Khan *et al.* (1991)
O. minuta	101092	Philippines	IRRI (1981a), Khan *et al.* (1991)
O. minuta	101094	Philippines	IRRI (1981a), Khan *et al.* (1991)
O. minuta	101096	Philippines	IRRI (1981a), Khan *et al.* (1991)
O. minuta	101128	Philippines	IRRI (1981a), Khan *et al.* (1991)
O. minuta	104676	Philippines	Khan *et al.* (1991)
O. minuta	105124	Philippines	Khan *et al.* (1991)

O. minuta	105125	Philippines	Khan *et al.* (1991)
O. minuta	105126	Philippines	Khan *et al.* (1991)
O. minuta	105130	Philippines	Khan *et al.* (1991)
O. nivara Sharma et Shastry	103419	Sri Lanka	Khan *et al.* (1991)
O. nivara	103830	Bangladesh	Khan *et al.* (1991)
O. nivara	103837	Bangladesh	Khan *et al.* (1991)
O. nivara	103838	Bangladesh	Khan *et al.* (1991)
O. nivara	103839	Bangladesh	Khan *et al.* (1991)
O. nivara	103840	Bangladesh	Khan *et al.* (1991)
O. nivara	103841	Bangladesh	Khan *et al.* (1991)
O. nivara / O. rufipogon	103814	China	Khan *et al.* (1991)
O. nivara / O. sativa	103842	Bangladesh	Khan *et al.* (1991)
O. officinalis Wall ex. Watt	100925	Myanmar	Khan *et al.* (1991)
O. officinalis	100947	India	IRRI (1981a), Khan *et al.* (1991)
O. officinalis	100948	India	IRRI (1981a), Khan *et al.* (1991)
O. officinalis	100953	Philippines	Khan *et al.* (1991)
O. officinalis	101151	Brunei	Khan *et al.* (1991)
O. officinalis	101999	Sri Lanka	Khan *et al.* (1991)
O. officinalis	102382	Indonesia	IRRI (1981a)
O. officinalis	102383	Indonesia	Khan *et al.* (1991)
O. officinalis	103285	Indonesia	Khan *et al.* (1991)
O. officinalis	103286	Indonesia	Khan *et al.* (1991)
O. officinalis	105098	Brunei	Khan *et al.* (1991)
O. officinalis	105100	Brunei	Khan *et al.* (1991)
O. officinalis	105112	Philippines	Khan *et al.* (1991)
O. officinalis	105113	Philippines	Khan *et al.* (1991)
O. officinalis	105174	Malaysia	Khan *et al.* (1991)
O. officinalis	105178	Philippines	Khan *et al.* (1991)
O. officinalis	105220	Indonesia	Khan *et al.* (1991)
O. punctata Kotschy ex. Steud.	100125	Africa	Khan *et al.* (1991)
O. punctata	100126	Africa	Khan *et al.* (1991)
O. punctata	100884	Africa	Khan *et al.* (1991)
O. punctata	100937	Ghana	Khan *et al.* (1991)
O. punctata	100954	Africa	Khan *et al.* (1991)
O. punctata	101167	Malaysia	IRRI (1981a), Chaudhary *et al.* (1984)
O. punctata	101389	Africa	Khan *et al.* (1991)
O. punctata	101417	Kenya	Chaudhary *et al.* (1984), Khan *et al.* (1991)
O. punctata	101434	Tanzania	Khan *et al.* (1991)
O. punctata	101439	Ghana	IRRI (1981a), Chaudhary *et al.* (1984)
O. punctata	103887	Tanzania	Khan *et al.* (1991)

O. punctata	105153	Nigeria	Khan *et al.* (1991)
O. punctata	105154	Nigeria	Khan *et al.* (1991)
O. punctata	105158	Kenya	Khan *et al.* (1991)
O. rhizomatis Vaughan	103417	Sri Lanka	Khan *et al.* (1991)
O. ridleyi Hook. f.	100821	Southeast Asia	Khan *et al.* (1991), Padhi and Prakasa Rao (1978), Caballero *et al.* (1988b)
O. ridleyi	100820	Southeast Asia	Khan *et al.* (1991)
O. rufipogon Griff.	100926	Myanmar	Khan *et al.* (1991)
O. rufipogon	101186	Taiwan-China	Khan *et al.* (1991)
O. rufipogon	103823	China	Khan *et al.* (1991)
O. rufipogon	103844	Bangladesh	Khan *et al.* (1991)
O. rufipogon	103849	India	Khan *et al.* (1991)
O. rufipogon / O. nivara	104056	China	Khan *et al.* (1991)
O. sativa / O. nivara	104436	Thailand	Khan *et al.* (1991)
O. sativa / O. nivara	104448	Thailand	Khan *et al.* (1991)
O. sativa / O. nivara	104464	Thailand	Khan *et al.* (1991)
O. sativa / O. nivara	104475	Thailand	Khan *et al.* (1991)
O. sativa / O. nivara	104481	Thailand	Khan *et al.* (1991)
O. spontanea Roschev.	103826	Bangladesh	Khan *et al.* (1991)
O. spontanea	103832	Bangladesh	Khan *et al.* (1991)
O. spontanea	103833	Bangladesh	Khan *et al.* (1991)

2.5. Use of tissue culture for evaluating insect resistance

The use of plant tissue culture as an alternate method to evaluate resistance of crops against insect attack opens a new avenue to study and understand the nature and causes of resistance. The pioneering research of Williams *et al.* (1983) demonstrated that south western corn borer, *Diatrae grandiosella* (Dyar) larvae can be fed on callus initiated from corn genotypes and that larvae develop differently when fed on callus from genotypes with different levels of resistance. In subsequent studies, the larval growth of *D. grandiosella* on callus was correlated to leaf feeding under field conditions. Similar experiments had been conducted with other insect pests of corn including the fall armyworm (Williams *et al.*, 1985), the corn ear worm, *Heliothis zea* (Boddie) (Williams *et al.*, 1987a), the sugarcane borer, *Diatrae saccharalis* (F.) and the European corn borer, *Ostrinia nubilalis* Hubner (Williams *et al.*, 1987b).

Caballero *et al.* (1988b) reported that the development of the yellow stem borer, *S. incertulas*, striped stem borer, *Chilo suppressalis* Walker and the leaffolder, *Cnaphalocrocis medinalis* Guenee on callus of susceptible Rexoro was normal and similar to their development on rice foliage. But the callus from resistant wild rices affected the growth and development.

2.6. Mechanism of resistance

Complex factors like behavioural and metabolic processes of the insect and phenotypic characters of the plant are involved in resistance to stem borer which were well documented (Israel, 1967; Munakata and Okamoto, 1967; Pathak *et al.*, 1971 and Padhi, 1980). Biochemical basis of resistance and general association between several morphological and anatomical characters of the rice plant and its influence on resistance have been reported by CRRI (1971), Akinsola (1973) and Padhi (1980).

Differences in non-preference for oviposition by *S. incertulas* were not distinct in screen house tests (Khan *et al.*, 1991). The moths freely oviposited on the frames of the cages and between the plant surfaces (Chandramohan, 1983). Agus (1974) also reported ovipositional non-preference of adult yellow stem borer. Manwan (1975) reported that the plant characters did not influence the oviposition by adults. Islam (1991) observed that the leaf blade width and foliar colour did not have any influence on the ovipositional preference. However, taller denser canopies were preferred for oviposition in the field. He also reported that the accession DWC-B-184, which was less preferred in the field, had about the same number of egg masses as the highly preferred entries in the screen house. Prakasa Rao (1972a, 1980) and Padhi (1980) reported that there was ovipositional preference in the field and moths alighted in the field during day time on susceptible accessions with high chlorophyll content.

The adverse effects of the resistant rice accessions on the survival and development of the larvae are important factors in varietal resistance. Larvae cultured on W 1263, IR 20, IR 26 and IR 1820-52-2 gained less body weight with prolonged larval growth as compared to those on the susceptible Rexoro indicating the antibiosis effect of the resistant sources (Manwan, 1975). Padhi and Chatterji (1985) reported that the variety TKM 6 showed highest antibiosis followed by MR 1526, Ptb 18 and RPW 6-13 by decreased survival of the larvae. The weight and percentage survival of larvae and pupae decreased, whereas the duration of the larval period increased on IR 198007-21-2-2, a resistant breeding line, compared with that on Basmati 370, a susceptible variety (Marwat, 1992). Riaz *et al.* (1993) studied the mechanism of resistance in rice varieties to yellow stem borer and reported that TKM 6 and Basmati 385 exhibited nonpreference and antibiosis, whereas line 4321 showed preference and antibiosis. Padhi and Prakasa Rao (1978) reported antibiosis in wild rices. *O.tisseranti, O.ridleyi, O.perreiri, O.officinalis* and *O.minuta* were highly antibiotic in nature, either killing larvae or preventing them from establishing inside the tillers.

According to Patanakamjorn and Pathak (1967) and Pathak (1972) varieties with tight leaf sheath which completely covered the internode were resistant to yellow stem borer. Shiraki (1917) and Van der Goot (1925) observed that the awnless varieties were susceptible to the attack by *S. incertulas*. Pawar *et al.* (1959) reported that varieties with thin culm are resistant. Seko and Kato (1950a,b) concluded that varieties with thin lumen offered resistance to larval movement and are found to be resistant to yellow stem borer. Plants with thin lumen, closely spaced vascular bundles, lignified sclerenchyma tissues with poor air space between paranchymatous cells with larger and more spicules in the epidermis and ridged stem surface were reported to be resistant (Van and Guan, 1959; Richharia, 1963; Israel, 1967; Chaudhary *et al.*, 1984). Israel *et al.* (1961) observed four to five layers of broad and thick sclerenchymatous hyperdermis in the resistant TKM 6, SLO 12 and MTU 15. Van and Guan (1959) reported that the thick layer of sclerenchymatous tissue conferred resistance in *O. ridleyi* to yellow stem borer.

Pathak (1964) observed no influence of cell wall thickness in the resistance to yellow stem borer, and reported that tall plants with bigger stems and wider leaves were found to be susceptible. He also reported that hairy leaf surface and stems with thick layers of lignified tissues with shorter distance between vascular bundles offered resistance.

Generally, scented rice varieties were found to be susceptible to yellow stem borer. Infestation was higher in the scented variety HR-22 than in other non-scented varieties included in the tests (Khan and Murthy, 1955; Banerjee, 1951). These studies also showed that scent alone did not especially attract the borers. Ghosh (1960) reported that highly susceptible varieties such as ASSAM-IV, HBJ Boro-II were scented, taller and have higher water content. Subba Rao and Perraju (1976), Ghosh (1960, 1962) and Marwat and Baloch (1985) also reported that high water content make the variety susceptible. Varieties with low nitrogen, low sodium and high potassium were reported to be resistant (Subba Rao and Perraju, 1976). Saroja and Raju (1981) reported high nitrogen content in the susceptible varieties and Tsutsui *et al.* (1957) reported high starch content in the susceptible varieties.

High silica content interfered with larval feeding and caused wearing of the mandible of the young larvae. Due to the high silica content in resistant accessions, the larvae died without being able to bore inside the stem (Israel and Kalode, 1966; Subbanna, 1971; Subba Rao and Perraju, 1976). High silica content and nitrogen indirectly influenced the cellulose metabolism of larvae and decreased the gain in body weight (Panda *et al.*, 1975). Sasamoto (1961) recorded an increase in the percentage of total silica in rice plants when grown in a soil treated with silica gel or slag material and a parallel decrease in their susceptibility. Djamin and Pathak (1967) investigated 20 varieties with different levels of susceptibility. These varieties varied significantly in their silica content with higher SiO_2 content in Yabami Montakhab, a resistant variety.

Further more, silica content showed a highly significant negative correlation with percentage of deadheart (Pathak *et al.*, 1971). Chandramohan and Chelliah (1983, 1984) and Marwat and Baloch (1985) also observed high silica content in resistant varieties. However Pathak *et al.* (1971) concluded that silica plays only limited role in borer resistance since they bore mostly through the nodes which have less silica content.

2.7. Role of steam distillate extract on resistance

The contribution of both volatile and nonvolatile chemicals of host plants has been recognised as important in insect plant interactions. The effect of steam distillate extract of resistant rice accessions was demonstrated on leaffolder, brown planthopper and whitebacked planthopper. The steam distillate extract from TKM 6, Darukasail, IR 5865 and Kataribhog caused 39 to 46 per cent mortality of larvae of *C. medinalis* compared to 9 per cent in IR 36 (Medina and Heinrichs, 1986). Medina and Tyron (1986) reported that the extract of TKM 6 significantly reduced the hatching of eggs. They also reported that the extracts of Darukasail, Kataribhog and TKM 6 caused 32 to 36 per cent larval mortality, as compared with two per cent mortality of larvae that had fed on leaves dipped in solvent only. When steam distillates of resistant *O. punctata* and *O. officinalis* were sprayed on susceptible plants there was a significant reduction in the leaf area fed and per cent weight gained (Villanueva and Khan, 1988; Velusamy *et al.*, 1990). The resistant plant extracts also reduced the egg hatchability (Medina and Tyron, 1986). In bioassays, the application of extracts of resistant IR 2035-117-3 or moderately resistant Podiwi A8 to susceptible plants significantly reduced the ingestion and assimilation of food by whitebacked planthopper, *Sogatella furcifera* (Hovarth) as compared to application of acetone or TN 1 extracts (Khan and Saxena, 1985). Topical application of the steam distillate extracts from resistant rice plants reduced the survival of the brown planthopper, *Nilaparvata lugens* (Stal) females (Saxena and Okech, 1985).

2.8. Role of cuticular wax extract on resistance

The chemical characteristics of plant cuticular wax can affect many aspects of insect behaviour such as orientation, movement, oviposition and feeding (Bernays *et al.*, 1976; Chapman and Bernays, 1989; Espelie *et al.*, 1991). Variation in the chemical composition of cuticular lipids may result in variable resistance due to non-acceptance (Elgenbrode *et al.*, 1991). Larval feeding of *C. medinalis* on leaf cuts from a susceptible plant impregnated with the antifeedant activity was concentrated in the methanol extract (Caballero *et al.*, 1988a).

Bharadwaj and Weaver (1987) observed that the average weight was more on water washed plants than unwashed when *H. zea* larvae fed on terminals of a resistant cotton variety, PD 695. Mitchell *et al.* (1990) also reported that methylene chloride extract of flower buds of the variety, Mc Nair 220 stimulated oviposition by *Heliothis virescens* (F.). The insecticidal properties of surface wax was also reported by Thayumanavan (1994).

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

3.1. Identification of resistant sources

3.1.1. Preliminary screening at tillering stage

Twenty four wild rice accessions belonging to six species listed below were screened for their resistance to the rice yellow stem borer, *Scirpophaga incertulas* (Wlk.). Cultivar W 1263 served as resistant check and IR 62 as susceptible check.

Wild rice accessions screened for resistance to rice yellow stem borer, S. *incertulas*

Oryza spp.	Origin	Accession number
O. australiensis	Australia	101144
	Vietnam	101397
	Australia	103318
O. latifolia	Gautemala	100963
	Gautemala	100964
	Panama	100966
	Mexico	101443
	Nicaragua	102481
O. minuta	Philippines	101079
	Philippines	101082
	Philippines	101086
	Philippines	101092
	Philippines	101096
	Philippines	101126
	Philippines	101128
	Japan	101387
O. nivara	India	100897
O. officinalis	India	100947
	India	100948
	Ghana	101412
O. punctata	Ghana	100937
	Africa	100954
	Ghana	101409
	Kenya	101417

Twenty five days after sowing, the test accessions were planted in 10 cm diameter mud pots at the rate of one seedling per pot. Forty five days after seeding they were infested with neonate larvae of yellow stem borer with camel hair brush in the top most leaf auricle at the rate of two larvae per tiller. The pots were covered with polyester film cages and kept in a galvanised iron tray (90 x 60 x 15 cm) filled with water. Ten pots constituted a replication and three replications were maintained for each accession.

The accessions were rated after 21 days after releasing larvae based on the development of deadheart symptom as per Heinrichs *et al.* (1985a). The deadhearts in the test entries were corrected to the level of infestation as follows.

$$\text{Corrected deadheart (\%)} = \frac{\text{Per cent deadheart in test entry}}{\text{Per cent deadheart in susceptible check}} \times 100$$

The corrected deadheart was transformed to a 0-9 scale.

Scale	Corrected deadheart (%)	Rating
0	No damage	Highly resistant
1	1-20	Resistant
3	21-40	Moderately resistant
5	41-60	Moderately susceptible
7	61-80	Susceptible
9	81-100	Highly susceptible

3.1.2. Preliminary screening at panicle initiation stage

The experiment was conducted as above by infesting the plants of different accessions with two neonate larvae in the auricle of the flag leaf at booting stage. Rating was done based on the whitehead symptom developed. The whitehead percentage was worked out and was corrected based on the level of infestation.

$$\text{Corrected whitehead (\%)} = \frac{\text{Whitehead (\%) in test entry}}{\text{Whitehead (\%) in susceptible check}} \times 100$$

The corrected whitehead (%) was transformed to a 0-9 scale (Heinrichs *et al.*, 1985a).

Scale	Corrected deadheart (%)	Rating
0	No damage	Highly resistant
1	1-10	Resistant
3	11-25	Moderately resistant
5	26-40	Moderately susceptible
7	41-60	Susceptible
9	61-100	Highly susceptible

3.2. Screening the callus of different accessions for yellow stem borer resistance

3.2.1. Tillering stage

The callus was developed from leaves of 45 days old plants of wild rice accessions viz., *O. minuta* (101092, 101126), *O. officinalis* (100948, 101412), *O. punctata* (100954, 101409), and *O. sativa* (W 1263, IR 62) using Murashige and Skoog (MS) medium (Murashige and Skoog, 1962). Each litre of medium was supplemented with 2 mg of kinetin and 30 g of sucrose and the callus were obtained. About 200 mg of callus were placed in a 5 cm diameter petridish. Callus in each petridish was infested with 3 neonate larvae and incubated at 26 ± 1°C at 12 h dark and 12 h light. The experiment was replicated four times. The neonate larvae were not able to feed on the callus. Hence the experiment was repeated with the preweighed third instar larvae reared on IR 62 plants. The weight gained after 48 and 96 h of feeding was observed.

3.2.2.2. Panicle initiation stage

The callus was developed from the leaves of different accessions at the panicle initiation stage and the experiment was repeated to assess the level of resistance at the panicle initiation stage.

3.3. Confirmatory screening

3.3.1. Tillering stage

For each species, one resistant and one moderately susceptible accession *viz.*, *O. australiensis* (103318, 101397), *O. minuta* (101092, 101126), *O. latifolia* (101443, 100963), *O. officinalis* (100948, 101412) and *O. punctata* (100954, 101409) were selected for confirmatory screening for resistance to yellow stem borer. The accessions were screened as per the methodology described earlier, with 20 tillers per replication in four replications with resistant check W 1263 and susceptible check IR 62 and were scored as per Heinrichs *et al.* (1985a).

3.3.2. Panicle initiation stage

The ten accessions mentioned above were screened at the booting stage along with W 1263 and IR 62 as resistant and susceptible checks. They were scored for their resistance to confirm the results of the preliminary screening. The experiment was conducted with four replications.

3.4. Mechanism of resistance

3.4.1. Ovipositional preference

3.4.1.1. Tillering stage

Forty five day old seedlings of different accessions *viz.*, *O. australiensis* (103318, 101397), *O. minuta* (101092, 101126), *O. latifolia* (101443, 100963), *O. officinalis* (100948, 101412), *O. punctata* (100954, 101409) and *O. sativa* (W 1263, IR 62) grown in 10 cm diameter mud pots were thinned to three tillers and were arranged along the circumference of a circle inside a cage and fifty newly mated adult females were released in the centre. The number of egg masses laid in each accession was counted after 5 days.

3.4.1.2. Panicle initiation stage

The experiment was repeated with plants at the booting stage and ovipositional preference of yellow stem borer at the panicle initiation stage was studied.

3.4.2. Orientation behaviour of first instar larva

3.4.2.1. Tillering stage

Forty five day old seedlings of selected wild rice accessions *O. australiensis* (103318, 101397), *O. minuta* (101092, 101126), *O. latifolia* (101443, 100963), *O. officinalis* (100948, 101412), *O. punctata* (100954, 101409) along with W 1263 and IR 62, grown in 10 cm diameter mud pots were inserted through holes of 2.0 cm diameter bored equidistantly in a circle along with circumference of a plywood lid covering the galvanised iron tray (60 x 45 x 10 cm). The top surface of the lid was painted white. The remaining portion of the holes after the insertion of plants were plugged with cotton in such a way that the bottom portion of the plant above the lid faced the inner side. The lid was supported with two bamboo stakes on either side. The whole contraption was covered up to lid with wire mesh cage (60 x 50 x 60 cm) after introducing 150 neonate larvae in the centre. The experiment was repeated four times with five such observations per replication (Plate 1). The number of larvae oriented and settled in each accession was observed 3, 6 and 12 h after release.

3.4.2.2. Panicle initiation stage

The experiment was conducted in four replications with the plants in 10 cm diameter mud pots at booting stage as described above and the orientation response of the neonate larvae towards the different accessions was assessed.

Plate 1. Experimental set up for assessing orientation response of larvae

3.4.3. Ability of larva to enter the stem

3.4.3.1. Tillering stage

The ability of the first instar larva of yellow stem borer to enter the stem of selected accessions was assessed. Forty five day old plants in 10 cm diameter mud pots were thinned to five tillers per pot. Two pots constituted one replication and four replications were maintained for each accession. Neonate larvae were released at the rate of one per tiller in the top most leaf auricle using a camel hair brush. Five days after infestation, the plants were carefully examined in the leaf sheath and lumen . The place of entry of the larva into the stem i.e., the distance from the node, place of larva in the stem, i.e., the distance from the place of entry and the number of larvae that successfully entered the stem were observed after split opening the stem.

3.4.3.2. Panicle initiation stage

The plants in mud pots at booting stage were also infested with neonate larva at the auricle of flag leaf and the ability of the larva to enter the stem of selected accessions at the panicle initiation stage was studied.

3.4.4. Biology of yellow stem borer on different accessions

3.4.4.1. Tillering stage

Sufficient seedlings (45 day old) of test accessions *viz*., *O. australiensis* (103318, 101397), *O. minuta* (101092, 101126), *O. latifolia* (101443, 100963), *O. officinalis* (100948, 101412), *O. punctata* (100954, 101409) in 10 cm diameter mud pots were infested with one neonate larva per tiller in the top most leaf auricle with camel hair brush and were maintained in galvanised iron trays (90 x 60 x 15 cm) filled with water. Cultivar W 1263 served as resistant check and IR 62 served as susceptible check.

3.4.4.1.1. Larval period

Twenty five days after release of the larvae, the test accessions were dissected every day and observed for the presence of larva and pupa. The mean number of larval days was arrived by observing 10 larvae for each accession for each day in four replications.

3.4.4.1.2. Pupal period

The pupae recovered from the previous larval observations kept in a petridish were incubated at 26 ± 1°C till the emergence of adult. Ten pupae were observed for each replication for each accession and the mean pupal period was worked out.

3.4.4.1.3. Percentage of adult recovery

The experiment was replicated four times with ten tillers for each replication. Ten days after the larval release, individual pots were covered with polyester film cages. The total number of moths emerged in each accession was recorded and the percentage of adult recovery was worked out.

3.4.4.1.4. Adult longevity

Ten pairs of freshly emerged adults from each test accession were caged separately in 45 days old susceptible IR 62 plants in 10 cm diameter mud pots and were observed daily for the survival of moth. Mean longevity of the males and females were worked out. Four replications were maintained for each accession.

3.4.4.1.5. Fecundity

The total number of egg masses in the above experiment was counted after the death of females and the mean number of egg masses per female was worked out.

3.4.4.1.6. Egg mass size

The size of ten egg masses from each replication was assessed by measuring the length and width of each egg mass and the mean value was worked out.

3.4.4.1.7. Number of eggs per egg mass

The number of eggs per egg mass was calculated using the formula developed by Romena *et al.* (1997).

No. of eggs per egg mass = (19.88 x length of egg mass in mm) + (16.44 x width of egg mass in mm) – 56.96

The number of eggs present in ten egg masses in each replication was calculated and the mean was worked out.

3.4.4.2. Panicle initiation stage

The experiment was conducted using the plants of different test accessions by infesting with neonate larvae at the booting stage and observing the biology of yellow stem borer as above.

3.4.5. Growth and development of yellow stem borer on different accessions

3.4.5.1. Tillering stage

Forty five day old seedlings of each test accession were infested with neonate larvae at the rate of one per tiller in the top most leaf auricle and sufficient number of seedlings in 10 cm pots were maintained in galvanised iron trays (90 x 60 x 15 cm) filled with water.

3.4.5.1. Larval weight

After 10, 20 and 30 days of release of larvae the test accessions were dissected out and the larvae were recovered. Ten larvae were recovered from each accession per replication from four replications for each period. The larvae were weighed individually in a top pan balance and the mean larval weight was estimated for each period.

3.4.5.1.2. Pupal weight

The silken covering of the fresh pupae were removed and weighed individually in a top pan balance. Ten pupae per replication from each test accession were observed and four replications were maintained for each accession.

3.4.5.1.3. Adult weight

Ten freshly emerged female and male moths from different test accessions per replication were weighed individually in a top pan balance and the mean weight was worked out. The experiment was replicated four times.

3.4.5.2. Panicle initiation stage

The experiment was conducted at booting stage of each test accession and the influence of the test accessions at the booting stage on the growth parameter of yellow stem borer was studied at the panicle initiation stage.

3.4.6. Effect of feeding on different accessions on the mandibles of yellow stem borer larva

3.4.6.1. Tillering stage

Forty five day old seedlings of different test accessions in 10 cm diameter mud pots were infested with one neonate larva per tiller at the top most leaf axis and was maintained in galvanised iron trays (90 x 60 x 15 cm) filled with water. After 15 and 30 days of infestation, ten larvae were recovered per replication and the mandibles were dissected out and observed under light microscope. The length and breadth of the mandibles were measured using an ocular micrometer and the mean was worked out. The wear and tear of the mandibles of the yellow stem borer larvae fed on different test accessions was also observed. The experiment was replicated four times.

3.4.6.2. Panicle initiation stage

The experiment was repeated using the plants of test accessions at the booting stage and the effect of the test accessions at booting stage on the mandible was observed as described above.

3.5. Evaluation of rice plant volatiles

3.5.1. Tillering stage

3.5.1.1. Steam distillation and extraction of rice plant volatiles

Rice plant volatiles were extracted as steam distillates following the method described by Saxena and Okech (1985). Leaf sheaths from 45 day old plants of *O. minuta* (101092), *O. officinalis* (100948) and *O. punctata* (100954) were collected and ground with an electric grinder. Two hundred gram of ground sample was steam distilled for 3 h during which approximately 200 ml of distillate was collected. The distillate was then partitioned with diethyl ether (300 ml of distillate : 100 ml of diethyl ether) by thoroughly shaking the mixture in a separating funnel for 5 minutes. Diethyl ether extracted the essential oil and other volatiles, and the ether mixture settled above the water layer in the funnel. The water layer was discarded and the extract was pooled in a 500 ml beaker to which 100 g of anhydrous sodium sulphate was added. The resultant mixture was kept inside a fume hood to evaporate excess ether until the remaining volume was approximately 25 ml. The beaker was then covered with aluminium foil and held over night to allow sodium sulphate to absorb traces of water from the extract. The extract was evaporated further to 10 ml and decanted into a preweighed glass vial, which was then covered with perforated aluminium foil and placed inside a desiccator. Ether was evaporated under vacuum, leaving behind a yellow oily odorous residue. The vial was reweighed and the residue dissolved in acetone to desired concentrations.

3.5.1.2. Effect of steam distillate extract on the ovipositional behaviour of yellow stem borer

Three tillers of 45 day old susceptible IR 62 plants grown in 10 cm diameter pots were smeared uniformly all over with 500, 1000 and 2000 ppm concentrations of extract from the resistant test accessions. Acetone treated IR 62 and 45 day old seedlings of the resistant accessions were used as control. All the plants were placed inside a cage along the circumference. The ovipositional preference was studied by releasing 50 newly mated female moths and counting the number of egg masses laid after 5 days.

3.5.1.3. Effect of steam distillate extract on orientation response of first instar larva

Thirty minutes before exposure to larvae, the IR 62 plants were treated with volatiles as described above and the orientation and settling behaviour of first instar larva of yellow stem borer was assessed along with the acetone treated IR 62 and resistant wild rice accessions as check as detailed in section 3.4.2.1.

3.5.1.4. Toxicity of steam distillate extract to first instar larva

The bioassay of the steam distillate was conducted with IR 62 plants treated with the volatiles. The plants were treated with volatiles as described above and the treated and control plants were infested with one neonate larva per tiller. Ten tillers were taken per replication and four replications were maintained. The number of surviving larvae were counted 3 and 5 days after release by carefully examining the leaf sheath and lumen, and the percentage of larval survival was worked out.

In another set of experiment, the deadheart symptom expressed was counted 25 days after release of the larvae and the percentage was worked out.

3.5.1.5. Topical assay of steam distillate extract

The steam distillate extract from the resistant accessions in acetone were prepared at concentrations of 500,1000 and 2000 ppm. One μl of the extract was applied to the thoracic dorsum of each third instar larva using a top syringe with guided plunger. Larvae treated with acetone alone served as control. For each replication 20 larvae were treated and four replications were maintained. The treated larvae were released into cut stems of IR 62 plants. Mortality was observed 3 and 5 days after treatment.

3.5.2. Panicle initiation stage

The steam distillation was done as above with the leaf sheath of different test accessions at the booting stage and the experiment was conducted to assess the effect of the extract from leaf sheath at booting stage.

3.6. Evaluation of cuticular wax from resistant accessions

3.6.1. Tillering stage

3.6.1.1. Extraction of cuticular wax from leaf sheath

The cuticular wax from the leaf sheath of forty five day old seedlings were extracted following the method of Jackson *et al.* (1984).

Fresh leaf sheaths (100 g) of different accessions were washed thoroughly with 500 ml of hexane and chloroform for 30 seconds. The filtrate was then kept inside the funnel hood to evaporate up to 15 ml and decanted into a preweighed glass vial and again allowed for evaporation, leaving behind a yellow residue. The vial was reweighed. The residue was diluted with 0.025 per cent Triton X 100 in distilled water and Triton X 100 : Acetone (1:3) and sprayed at 500, 1000 and 2000 ppm.

3.6.1.2. Effect of cuticular wax extract on the ovipositional behaviour of yellow stem borer

Three tillers of 45 day old susceptible IR 62 plants grown in 10 cm diameter pots were smeared uniformly all over with 500, 1000 and 2000 ppm concentration of extract from the resistant test accessions. Acetone treated IR 62 and 45 days old seedlings of the resistant accessions were used as control. All the plants were placed inside a cage along the circumference. The ovipositional preference was assessed by releasing 50 newly mated female moths and counting the number of egg masses laid after 5 days.

3.6.1.3. Effect of cuticular wax extract on the orientation response of first instar larva

Thirty minutes before exposure to larvae, the IR 62 plants were treated with extract as above and the orientation and settling behaviour of first instar larva of yellow stem borer was assessed along with the acetone treated IR 62 and resistant accession as check as detailed in section 3.4.2.1.

3.6.1.4. Toxicity of cuticular wax extract to first instar larva

The bioassay of the cuticular wax extract was conducted with IR 62 plants treated with the extract as detailed in section 3.5.1.4.

In another set of experiment, the deadheart symptom expressed was counted 25 days after release of the larvae and the percentage was worked out.

3.6.1.5. Topical assay of cuticular wax extract

The assay was conducted as detailed in section 3.5.1.5 with the wax extract.

3.6.2. Panicle initiation stage

The cuticular wax was extracted as above from the leaf sheath of different test accessions at the booting stage and the experiment was conducted to assess the effect of cuticular wax from leaf sheath at booting stage.

3.7. Effect of feeding on different accessions on the enzyme activity of yellow stem borer larva

The alimentary canal of the 30 day old larva that fed on different accession *viz.*, *O. minuta* (101092, 101126), *O. officinalis* (100948, 101412), *O. punctata* (100954, 101409) at the tillering stage was dissected free of adhering fat bodies and other tissue debris under ice cold distilled water. The midgut was then severed and removed. The gut portion was opened longitudinally and brushed out so as to remove as much as possible of the gut debris and symbionts if any. The midguts were then homogenized (3 midguts for each observation) in ice cold distilled water (volume adjusted to 30 times the weight of midgut). The resultant homogenate was centrifuged at 500 rpm for 15 minutes and the supernatant was used for enzyme assay. Larvae reared on W 1263 and IR 62 served as control.

3.7.1. Determination of enzyme activity

3.7.1.1. Tillering stage

3.7.1.1.1. Amylase

Amylase activity was determined based on the method of Ishaaya and Swiriski (1970) using 3,5-dinitro salicylic acid reagent.

3.7.1.1.2. Invertase

The invertase activity was assessed by following the method of Ishaaya and Swiriski (1970) was followed.

3.7.1.1.3. Protease

The protease activity was estimated by casein digestion method at an absorbancy of 289 mμ as described by Ishaaya *et al.* (1971).

3.7.1.1.4. Lipase activity

The lipase activity was determined by the method described by Sadasivam and Manickam (1996).

3.7.2. Panicle initiation stage

The enzyme homogenate was prepared from 30 day old larva that fed on different accessions at the booting stage and the enzyme assay was done as described earlier.

3.8. Plant biophysical characters associated with resistance

3.8.1. Tillering stage

3.8.1.1. Hairiness of leaf sheath

Leaf sheath samples were drawn from 45 day old plants of *O. minuta* (101092, 101126), *O. officinalis* (100948, 101412), *O. punctata* (100954, 101409) and *O. sativa* (W 1263 and IR 62). Twenty samples were drawn from each accession. The samples were cut into one square centimeter size and boiled in 20 ml of water in small glass vials for 15 minutes in hot water bath at 85°C. The water was then removed and 20 ml of 90 per cent ethyl alcohol was added and the leaves were boiled for 20 minutes at 80°C. The alcohol was then removed and the boiling process with alcohol was repeated to remove the chlorophyll completely from the leaves. Alcohol was then poured off and 90 per cent lactic acid was added, the vials were stoppered and heated at 85°C for 30 minutes to clear the sample. The samples were then cooled, mounted on clean glass slides using a drop of lactic acid and observed under microscope. The length of trichomes and the number of trichomes per cm^2 were measured using an ocular micrometer.

3.8.1.2. Lumen diameter

The lumen diameter of different accessions at the tillering stage was recorded using a travelling microscope.

3.8.1.3. Ligule length

The ligule length of different accessions from the top most leaf at the tillering stage was recorded using a travelling microscope.

3.8.2. Panicle initiation stage

The samples were drawn from the plants of different accessions at the booting stage and the various plant characters were recorded as described earlier.

3.9. Plant biochemical character associated with resistance

3.9.1. Tillering stage

The leaf sheath samples were taken from 45 day old seedlings of different accessions *viz., O. minuta* (101092, 101126), *O. officinalis* (100948, 101412), *O. punctata* (100954, 101409) and *O. sativa* (W 1263 and IR 62) and the following biochemical constituents were estimated.

3.9.1.1. Silica content

The crude silica content was estimated by the method described by Yoshida *et al.* (1976).

3.9.1.2. Nitrogen content

The total organic nitrogen in the leaf sheath of different accessions was estimated by the method described by Yoshida *et al.* (1976).

3.9.1.3. Cellulose

The cellulose content in different accessions was determined by the method of Sadasivam and Manickam (1996) using anthrone reagent.

3.9.1.4. Lignin content

The acid detergent lignin content in the test accessions was estimated by the method described by Sadasivam and Manickam (1996).

3.9.2. Panicle initiation stage

The leaf sheath samples were taken from the accessions at booting stage and the biochemical constituents were analysed as above to assess their role in conferring resistance.

3.10. Changes induced in the biochemical constituents due to feeding by stem borer larva

3.10.1. Tillering stage

Leaf sheath samples from 45 day old plants of *O. minuta* (101092, 101126), *O. officinalis* (100948, 101412), *O. punctata* (100954, 101409) and *O. sativa* (W 1263 and IR 62) were drawn before infestation and 48 h after infestation by the first instar larva. The changes induced due to feeding by the larvae were assessed by analysing the samples for the biochemical constituents.

3.10.1.1. Total protein

The total protein content was estimated by the method of Lowry *et al.* (1951).

3.10.1.2 Total free amino acids

The total free amino acids in different accessions were estimated by the method described by Spies (1955a).

3.10.1.3. Total phenols

The total phenol content was estimated by employing the method developed by Spies (1995b).

3.10.1. 4. Orthodihydroxy phenols

The orthodihydroxy phenols content in different accessions were estimated by the method of Johnson and Schall (1957).

3.10.2. Panicle initiation stage

The leaf sheath samples from the plants of different accessions at booting stage were drawn and the changes in the biochemical constituents induced due to feeding by larvae were assessed as described above.

3.11. Statistical analysis

The data on percentage were transformed into corresponding angle arc sine values or square root [$\sqrt{(X=0.5)}$] values (Snedecor and Cochron, 1967). Duncan's mutiple range test (DMRT) was applied for comparing means (Duncan, 1955).

EXPERIMENTAL RESULTS

CHAPTER IV

EXPERIMENTAL RESULTS

4.1. Identification of resistant sources

A total of twenty four accessions belonging to six wild rice species *viz.*, *O. australiensis, O. latifolia, O. minuta, O. nivara, O. officinalis* and *O. punctata* were screened for their resistance to the rice yellow stem borer, *Scirpophaga incertulas* at tillering and panicle initiation stage under screen house conditions and the results are presented.

4.1.1. Tillering stage

It is evident from Table 1 that significant differences in the percentage of deadheart were recorded among different accessions of wild rice species. The percentage of deadheart varied from 3.33 to 73.33 in different accessions, resistant and susceptible check tested. The accessions *O. minuta* (101092) recorded the minimum damage of 3.33 per cent followed by *O. latifolia* (101443) and *O. officinalis* (100948) with 6.67 per cent damage. The deadheart symptom produced was less than the resistant check (26.67 per cent) in 15 wild rice accessions. All the accessions screened recorded significantly less damage than the susceptible check IR 62 (73.33%).

Of the 24 wild rice accessions tested, 14 (58.33%) were resistant to yellow stem borer at tillering stage (Table 1). Of the eight *O. minuta* accessions tested, five were resistant. The only accession of *O. nivara* tested was susceptible with a damage score of 5.67. Two accessions each of *O. latifolia, O. officinalis* and *O. punctata* and one accession of *O. australiensis* were resistant with a mean damage score of 3 or less. The accessions, *O. minuta* (101092), *O. latifolia* (101443) and *O. officinalis* (100948) were found to be highly resistant with a mean damage score of one. The resistant check W 1263 recorded a damage score of 3.67.

Table 1. Preliminary screening of wild rice accessions for resistance to rice yellow stem borer, *Scirpophaga incertulas* at tillering stage

Oryza species	Accession Number	Deadheart (%)*	Damage rating*
O. australiensis	101144	23.33(28.77) cd	3.67 cd
	101397	36.67 (37.21) b	5.00 bc
	103318	13.33 (21.14) ef	1.67 ef
O. latifolia	100963	43.33 (41.14) b	5.67 b
	100964	40.00 (39.13) b	5.00 bc
	100966	16.67 (23.85) de	2.33 def
	101443	6.67 (12.39) fg	1.00 f
	102481	20.00 (26.55) cde	3.00 de
O. minuta	101079	16.67 (23.85) de	2.33 def
	101082	36.67 (37.21) b	5.00 bc
	101086	20.00 (26.55) cde	3.00 de
	101092	3.33 (6.36) g	1.00 f
	101096	23.33 (28.77) cd	3.00 de
	101126	40.00 (39.13) b	5.67 b
	101128	16.67 (23.85) de	2.33 def
	101387	36.67 (37.21) b	5.00 bc
O. nivara	100897	43.33 (41.14) b	5.67 b
O. officinalis	100947	16.67 (23.85) de	2.33 def
	100948	6.67 (12.39) fg	1.00 f
	101412	43.33 (41.14) b	5.67 b
O. punctata	100937	20.00 (26.06) cde	3.00 de
	100954	13.33 (21.14) ef	1.67 ef
	101409	40.00 (39.13) b	5.67 b
	101417	16.67 (23.85) de	2.33 def
O. sativa W 1263	Resistant check	26.67 (30.98) c	3.67 cd
IR 62	Susceptible check	73.33 (58.98) a	9.00 a

*Mean of three replications.
Figures in parentheses are arcsine transformed values.
In a column, means followed by same letters are not significantly different by DMRT ($p = 0.05$).

4.1.2. Panicle initiation stage

The percentage whitehead damage and damage rating are presented in Table 2. The minimum damage of 3.33 per cent whitehead was recorded in *O. australiensis* (103318), *O. minuta* (101092) and *O. officinalis* (100948). The susceptible check IR 62 registered 66.67 per cent whitehead. Among the different wild *Oryza* species screened, only *O. nivara* recorded more than 26.67 per cent damage.

Of the 24 wild rice accessions screened, eight (33.33%) were resistant to *S. incertulas* at booting stage (Table 2). Only one accession of *O. minuta* was found resistant at booting stage among eight accessions tested. Two accessions from *O. australiensis* (101144,103318), *O. latifolia* (101443, 102481) and *O. officinalis* (100947, 100948) and one from *O. minuta* (101092) and *O. punctata* (100954) recorded a damage score of 3 or less, as against 3.67 in the resistant check W 1263 (Table 2). Except *O. nivara* all other accessions registered a damage score of less than 7.

The wild rice accessions differ in their susceptibility to yellow stem borer at the tillering and panicle initiation stage. Of the eight *O.minuta* accessions tested, five (62.5%) were found to be resistant at the tillering stage and one (12.5%) at booting stage. The wild rice species *O. latifolia* (100966), which was found resistant at tillering stage, was found susceptible at panicle initiation stage. Similar observation was recorded in case of wild rice species *O. minuta* (101079, 101086, 101096 and 101128) and *O. punctata* (101417).

4.2.2. Screening the callus of different accessions for resistance

4.2.2.1. Tillering stage

The weight gained by third instar larva after 48 and 96 h of feeding in callus of different accessions developed from leaves at tillering stage is presented in Table 3 (Plate 2). The weight gained was 41.24 and 82.42 per cent in the susceptible IR 62 callus 48 and 96 h after feeding respectively, whereas it was only 14.72 and 30.34 per cent in the callus of

Table 2. Preliminary screening of wild rice accessions for resistance to rice yellow stem borer, *Scirpophaga incertulas* at booting stage

Oryza species	Accession Number	Whitehead (%)*	Damage rating*
O. australiensis	101144	10.00 (18.43) de	3.00 fg
	101397	20.00 (26.06) bcd	5.00 cde
	103318	3.33 (6.36) f	1.67 g
O. latifolia	100963	23.33 (28.77) bcd	5.00 cde
	100964	13.33 (21.14) cde	3.67 defg
	100966	20.00 (26.55) bcd	5.67 bcd
	101443	6.67 (12.39) ef	2.33 fg
	102481	6.67 (12.39) ef	2.33 fg
O. minuta	101079	16.67 (23.85) bcde	4.33 cdef
	101082	16.67 (23.85) bcde	4.33 cdef
	101086	16.67 (23.85) bcde	4.33 cdef
	101092	3.33 (6.36) f	1.67 g
	101096	16.67 (23.85) bcde	4.33 cdef
	101126	23.33 (28.77) bcd	5.67 bcd
	101128	16.67 (23.85) bcde	4.33 cdef
	101387	16.67 (23.85) bcde	4.33 cdef
O. nivara	100897	33.33 (35.20) b	7.00 ab
O. officinalis	100947	10.00 (18.43) de	3.00 efg
	100948	3.33 (6.36) f	1.67 g
	101412	23.33 (28.77) bcd	5.67 bcd
O. punctata	100937	13.33 (21.14) cde	3.67 defg
	100954	10.00 (18.43) de	3.00 efg
	101409	26.67 (30.77) bc	6.33 bc
	101417	16.67 (23.85) bcde	4.33 cdef
O. sativa	W 1263	13.33 (21.14) cde	3.67 defg
	IR 62	66.67 (54.76) a	9.00 a

* Mean of three replications.
Figures in parentheses are arcsine transformed values.
In a column, means followed by same letters are not significantly different by DMRT ($p = 0.05$).

Table 3. Screening the callus of wild rice accessions against rice yellow stem borer

Oryza species	Accession number	Tillering stage*		Booting stage*	
		Per cent weight gained by the larva		Per cent weight gained by the larva	
		48 h after feeding	96 h after feeding	48 h after feeding	96 h after feeding
O. minuta	101092 (R)	14.72 (22.53) e	30.34 (33.40) c	15.25 (22.96) f	28.18 (32.05) d
	101126 (MS)	26.24 (30.80) bc	48.17 (43.93) bc	26.21 (30.75) b	46.15 (42.77) bc
O. officinalis	100948 (R)	16.28 (23.74)de	33.45 (35.28) c	16.52 (23.95) ef	30.20 (33.29) d
	101412(MS)	24.56 (29.67) bc	52.28 (46.29) b	24.18 (29.44) bc	50.78 (45.43) b
O. punctata	100954 (R)	18.12 (25.16) d	34.49 (35.94) c	19.21 (25.96) de	36.18 (36.90) cd
	101409 (MS)	27.15 (31.39) b	54.12 (47.40) b	23.18 (28.75) bc	51.17 (45.65) b
O. sativa W 1263	R check	23.18 (28.76) c	46.15 (42.77) b	21.28 (27.45)cd	44.12 (41.59) bc
IR 62	S check	41.24 (39.94) a	82.42 (65.30) a	40.21 (39.32) a	80.18 (64.08) a

* Mean of four replications.
Figures in parentheses are arcsine transformed values.
In a column, means followed by same letters are not significantly different by DMRT ($p = 0.05$).

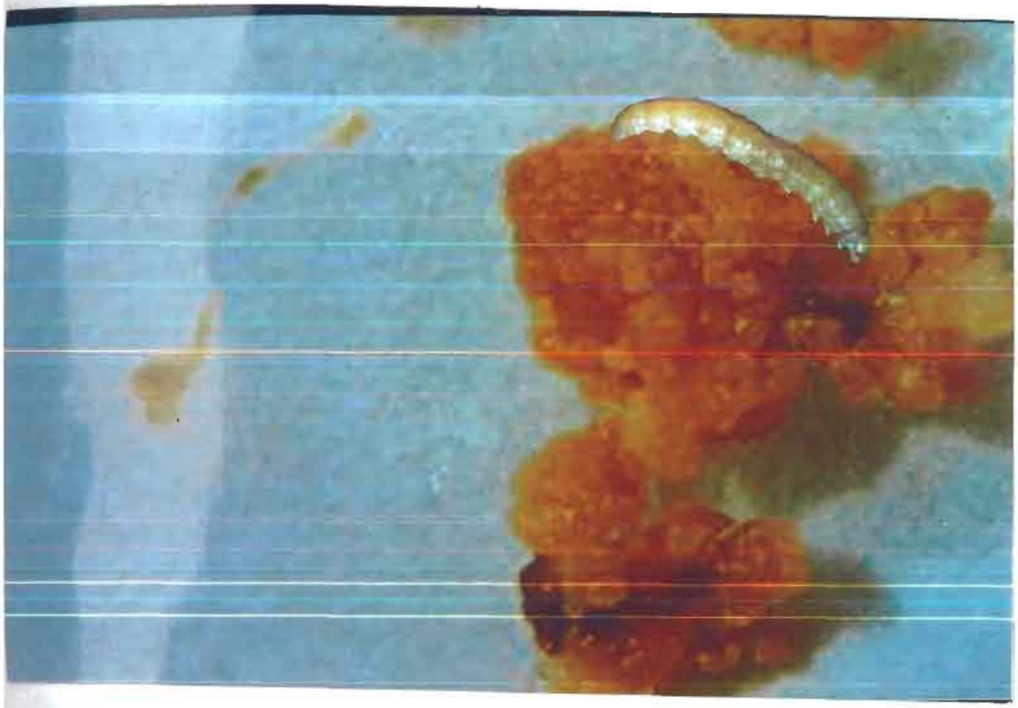


Plate 2. Yellow stem borer larva feeding on IR 62 callus

the resistant *O. minuta* (101092). All the three resistant wild rice accessions tested had registered significantly less weight gain than resistant and susceptible check. The weight gained by the larva 96 h after feeding from the resistant check W 1263 was on par with the weight gained in the moderately susceptible wild rice accessions. The weight gained by the larva after 96 h of feeding ranged from 30.34 per cent in *O. minuta* (101092) to 82.42 per cent in IR 62.

4.2.2.2. Panicle initiation stage

The weight gained by larva after 48 h of feeding in callus developed from leaves at booting stage ranged from 15.25 per cent in *O. minuta* (101092) to 40.21 per cent in IR 62 (Table 3). The per cent weight gain was only less than 20 per cent in all the wild resistant accessions tested and was 21.28 in the resistant check W 1263.

The difference in the weight gain was more pronounced during 96 h after feeding than at 48 h. There was nearly 3 fold increase in the weight gained by larva when fed on IR 62 callus than when fed on callus from resistant wild rice accessions. The weight gain was only 51.17 per cent even in the moderately susceptible wild rice accession *O. punctata* (101409) as against 80.18 per cent in the susceptible check IR 62.

4.3. Confirmatory screening

Two accessions one found to be highly resistant at both tillering and panicle initiation stage and other one found to be moderately susceptible at both stages from *O. australiensis, O. minuta, O. latifolia, O. officinalis* and *O. punctata* were screened again and the results are presented.

4.3.1. Tillering stage

The deadheart percentage ranged from 7.50 to 15.00 among the resistant accessions and 37.50 to 42.50 among the moderately susceptible accessions as against

27.50 in the resistant check W 1263 and 75.00 in the susceptible check IR 62 (Table 4). The damage was minimum (7.50%) in *O. latifolia* (101443) which was on par with all other resistant wild rice accessions tested.

The mean damage score ranged between 1.00 and 2.00 among the resistant wild rice accessions as against 3.50 in the resistant check W 1263, indicating high level of resistance in the wild rice accessions.

4.3.2. Panicle initiation stage

The whitehead damage was less than 8.00 per cent in all the resistant wild rice accessions tested and was 12.50 per cent in the resistant check W 1263. The damage was high (75.00 %) in the susceptible check IR 62.

All the accessions found resistant in the preliminary screening had registered a mean damage score of 2.50 or less confirming their resistance. The resistant check W 1263 registered a mean damage score of 3.50 which was on par with the resistant wild rice accessions *O. australiensis* (103318), *O. minuta* (101092), *O. officinalis* (100948) and *O. punctata* (100954) (Table 4).

4.4. Mechanism of resistance

4.4.1. Ovipositional preference

The mean number of egg masses laid in free choice test in different accessions at tillering stage is presented in Table 5. The number of egg masses laid in different accessions ranged from 11.00 in IR 62 to 17.25 in *O. minuta* (101092). There was no significant difference in the number of egg masses laid in the susceptible check IR 62 and resistant check W 1263.

The number of egg masses laid in different accessions at booting stage tested under free choice test varied between 11.50 in *O. latifolia* (100963) and 17.50 in

Table 4. Confirmatory screening of wild rice accessions for resistance to rice yellow stem borer

Oryza species	Accession number	Tillering stage*		Booting stage*	
		Deadheart (%)	Damage rating	Whitehead (%)	Damage rating
O. australiensis	103318 (R)	15.00 (22.49) d	2.00 d	5.00 (9.42) de	2.00 cd
	101397 (MS)	40.00 (39.15) bc	4.50 bc	17.50 (24.52) bc	4.50 b
O. minuta	101092 (R)	12.50 920.46) d	1.00 d	5.00 (9.42) de	2.00 cd
	101126 (MS)	42.50 (40.59) b	5.50 b	20.00 (26.18) bc	5.00 b
O. latifolia	101443 (R)	7.50 (13.92) d	1.00 d	2.50 (4.92) e	1.50 d
	100963 (MS)	42.50 (40.66) b	5.00 b	17.50 (24.52) bc	4.50 b
O. officinalis	100948 (R)	10.00 (15.96) d	1.00 d	7.50 (13.92) cde	2.50 cd
	101412 (MS)	40.00 (39.15) bc	5.50 b	20.00 (26.55) b	5.00 b
O. punctata	100954 (R)	10.00 (15.96) d	1.50 d	7.50 (13.92) cde	2.50 cd
	101409 (MS)	37.50 (37.65) bc	5.00 b	20.00 (26.18) bc	5.00 b
O. sativa W 1263	R check	27.50 (31.54) c	3.50 c	12.50 (20.46) bcd	3.50 bc
IR 62	S check	75.00 (60.09) a	9.00 a	75.00 (60.09) a	9.00 a

* Mean of four replications.
Figures in parentheses are arcsine transformed values.
In a column, means followed by same letters are not significantly different by DMRT ($p = 0.05$).

Table 5. Ovipositional preference of rice yellow stem borer on wild rice accessions in free choice test

Oryza Species	Accession number	Number of egg masses laid*	
		Tillering stage	Booting stage
O. australiensis	103318 (R)	13.75 cde	15.00 abcd
	101397 (MS)	14.5 bcde	15.25 abc
O. minuta	101092 (R)	17.25 a	16.00 ab
	101126 (MS)	13.00 def	17.00 ab
O. latifolia	101443 (R)	15.25 abcd	13.25cde
	100963 (MS)	16.00 abc	11.50 e
O. officinalis	100948 (R)	14.50 bcde	12.50 de
	101412 (MS)	12.75 def	14.50 bcd
O. punctata	100954 (R)	17.00 ab	17.00 ab
	101409 (MS)	13.00 def	17.50 a
O. sativa W1263	R check	12.00 ef	14.50 bcd
IR 62	S check	11.00 f	17.25 a

* Mean of four replications.
In a column, means followed by same letters are not significantly different by DMRT ($p = 0.05$).

O. punctata (101409) (Table 5). There was no marked difference among the number of egg masses laid in different accessions. The maximum number of egg masses was laid in *O. punctata* (101409) which was statistically on par with the susceptible check IR 62.

4.4.2. Orientation and settling behaviour of first instar larva

4.4.2.1. Tillering stage

The yellow stem borer larva did not show any preference towards the rice accessions. Three hours after release, the number of larvae oriented and settled among the different accessions ranged from 2.1 to 3.2 (Table 6). The number of larvae settled was more in *O. minuta* (101092), a resistant accession which was on par with the susceptible check IR 62 and seven other accessions tested with varying levels of resistance.

The percentage of larvae oriented and settled among different accessions 3 h after release ranged from 1.40 to 2.13. Laval orientation was minimum (1.40 %) towards *O. australiensis* (103318) which was statistically lower than the susceptible check (1.87%) but was on par with *O. australiensis* (101397), *O. officinalis* (101412) and *O. punctata* (101409) which were found to be susceptible.

A similar trend was observed 6 and 12 h after release also. The percentage of larvae settled after 6 h in different accessions ranged from 4.13 to 5.47. The resistant accession *O. australiensis* (103318) which attracted less number of larvae was on par with the susceptible check IR 62 and the resistant check W 1263 (Table 6). Even 12 h after release when more than 90 per cent of the larvae released settled in different accessions, there was no marked difference in the number of larvae settled among the different accessions.

4.4.2.2. Panicle initiation stage

No larval preference towards different accessions at the panicle initiation stage was observed (Table 7). The moderately susceptible accession *O. officinalis* (101412) which was found to be less attractive to the first instar larva was on par with resistant

Table 6. Orientation response of the first instar larva of rice yellow stem borer towards wild rice accessions at tillering stage

Oryza Species	Accession number	Number of larvae settled after *					
		3 h		6 h		12 h	
		Number	Percentage	Number	Percentage	Number	Percentage
O. australiensis	103318 (R)	2.1 d	1.40 (1.38) d	6.2 d	4.13(2.15) d	10.2 c	6.80 (2.70) c
	101397 (MS)	2.8 abc	1.87 (1.54) abc	7.80 ab	5.20(2.39) ab	12.4 abcd	8.27 (2.95) abc
O. minuta	101092 (R)	3.2 a	2.13 (1.62) a	8.2 a	5.47(2.44) a	11.8 abc	7.87 (2.89) abc
	101126 (MS)	2.4 bcd	1.60 (1.45) bcd	6.9 bcd	4.60(2.26) bcd	10.4 c	6.93 (2.72) c
O. latifolia	101443 (R)	2.7 abc	1.80 (1.52) abc	8.2 a	5.47(2.44) a	12.2 abc	8.13 (2.94) abc
	100963 (MS)	2.3 cd	1.53 (1.43) cd	6.5 cd	4.33(2.20) cd	12.4 abc	8.27 (2.95) abc
O. officinalis	100948 (R)	3.1 a	2.07 (1.60) a	7.8 ab	5.20(2.39) ab	13.2 a	8.80 (3.05) a
	101412 (MS)	2.9 ab	1.93 (1.56) ab	8.2 a	5.47(2.44) a	12.8 ab	8.53 (3.01) ab
O. punctata	100954 (R)	2.4 bcd	1.60 (1.45) bcd	7.4 abc	4.93(2.33) abc	11.2 abc	7.47 (2.82) abc
	101409 (MS)	2.7 abc	1.80 (1.52) abc	8.2 a	5.47(2.44) a	10.8 bc	7.20 (2.77) bc
O. sativa W 1263	R check	2.4 bcd	1.60 (1.45) bcd	6.8 bcd	4.53(2.24) bcd	10.9 bc	7.27 (2.78) abc
IR 62	S check	2.8 abc	1.87 (1.54) abc	7.2 abcd	4.80(2.30) abcd	11.4 abc	7.60(2.84) abc

* Mean of four replications.
Figures in parentheses are square root transformed values.
In a column, means followed by same letters are not significantly different by DMRT ($p = 0.05$).

Table 7. Orientation response of the first instar larva of rice yellow stem borer towards wild rice accessions at booting stage

Oryza Species	Accession number	Number of larvae settled after *					
		3 h		6 h		12 h	
		Number	Percentage	Number	Percentage	Number	Percentage
O. australiensis	103318 (R)	2.8 abc	1.87 (1.54) ab	7.2 bc	4.80 (2.30)bc	12.8 abcd	8.53 (3.00) abcd
	101397 (MS)	2.9 ab	1.93 (1.56) ab	8.2 abc	5.47 (2.44) abc	10.4 f	6.93 (2.73) f
O. minuta	101092 (R)	3.1 ab	2.07 (1.60) ab	6.8 c	4.53 (2.24) c	11.8 cdef	7.87 (2.89) cdef
	101126 (MS)	2.9 ab	1.93 (1.56) ab	8.4 ab	5.60 (2.46) abc	12.2 bcdef	8.13 (2.93) bcdef
O. latifolia	101443 (R)	3.2 a	2.13 (1.62) a	6.9 bc	4.60 (2.26) bc	14.2 a	9.47 (3.15) a
	100963 (MS)	3.0 ab	2.00 (1.58) ab	7.2 bc	4.80 (2.30) bc	13.8 ab	9.20 (3.11) ab
O. officinalis	100948 (R)	2.8 abc	1.87 (1.54) ab	9.0 a	6.00 (2.55) a	13.6 abc	9.07 (3.09) abc
	101412 (MS)	2.4 c	1.60 (1.45) c	8.3 abc	5.53 (2.46) abc	12.6 abcde	8.40 (2.98) abcde
O. punctata	100954 (R)	2.9 ab	1.93 (1.56) ab	7.4 abc	4.93 (2.33) abc	12.4 abcde	8.27 (2.96) abcde
	101409 (MS)	2.8 abc	1.87 (1.54) ab	6.9 bc	4.60 (2.26) bc	11.8 cdef	7.87 (2.89) cdef
O. sativa W 1263	R check	3.1 ab	2.06 (1.60) ab	6.8 c	4.53 (2.24) c	10.8 ef	7.20 (2.77) ef
IR 62	S check	2.7 bc	1.80 (1.52) bc	7.1 bc	4.73 (2.28) bc	11.3 def	7.53 (2.83) def

* Mean of four replications.
Figures in parentheses are square root transformed values.
In a column, means followed by same letters are not significantly different by DMRT ($p = 0.05$).

accession *O. australiensis* (103318) also. The susceptible check (IR 62) which attracted 2.7 larvae was on par with all the resistant accessions tested except *O. latifolia* (101443). The percentage of larva settled among different accessions ranged from 1.60 per cent in *O. officinalis* (101412) to 2.13 per cent in *O. latifolia* (101443).

No wide variation in number of larvae settled in different accessions was observed 6 h after release. Six per cent of the larvae settled in *O. officinalis* (100948), a resistant accession which was significantly more than that settled in the susceptible check IR 62 (4.73 %). The same trend was observed after 12 h of release also. The number of larvae settled in different accessions ranged from 10.4 (6.93 %) in *O. australiensis* (101397), a susceptible accession to 14.2 (9.47 %) in *O. latifolia* (101443), a resistant accession.

4.4.3. Ability of larva to enter the stem

4.4.3.1. Tillering stage

4.4.3.1.1. Per cent larvae entering stem

A wide variation was observed in the percentage of larvae entering the lumen of different accessions tested (Table 8). The per cent larvae entered the lumen of different accessions at tillering stage ranged from 32.50 in the resistant accessions *O. minuta* (101092) and *O. officinalis* (100948) to 90.00 in the susceptible check IR 62. Significantly lower percentage of larvae entered the lumen of all the resistant accessions tested including the resistant check W 1263.

4.4.3.1.2. Place of entry into the stem

The distance from the place of entry of the larva from the node varied from 2.23 mm to 3.20 mm among different accessions tested at the tillering stage. The distance was highest (3.20 mm) in *O. minuta* (101092), a resistant accession which was on par with the susceptible check IR 62 (2.85 mm) (Table 8).

Table 8. Ability of the first instar larva of rice yellow stem borer to enter the stem of wild rice accessions

Oryza Species	Accession number	Tillering stage*			Booting stage*		
		Per cent larvae entering the lumen of stem	Place of entry (Distance from node) (mm)	Position of larva in the stem (Distance from entry) (mm)	Per cent larvae entering the lumen of stem	Place of entry (Distance from node) (mm)	Position of larva in the stem (Distance from entry) (mm)
O. australiensis	103318 (R)	35.00 (36.14) c	2.60 bc	7.15 c	30.00 (33.04) d	2.55 def	6.13 e
	101397 (MS)	65.00 (53.76) b	2.80 ab	10.63 b	55.00 (47.93) b	3.00 abc	9.20 b
O. minuta	101092 (R)	32.50 (34.70) c	3.20 a	6.95 c	27.50 (31.54) d	3.05 ab	7.18 de
	101126 (MS)	60.00 (50.81) b	2.90 ab	10.88 b	45.00 (42.10) bc	2.98 abcd	8.63 bc
O. latifolia	101443 (R)	35.00 (36.21) c	2.55 bc	6.15 c	37.50 (37.71) cd	2.63 cdef	7.30 de
	100963 (MS)	57.50 (49.31) b	2.80 ab	9.55 b	50.00 (44.98) b	3.13 a	9.30 b
O. officinalis	100948 (R)	32.50 (34.70) c	3.13 a	7.33 c	30.00 (33.04) d	2.70 bcdef	6.63 de
	101412 (MS)	60.00 (50.81) b	2.95 ab	9.13 b	52.50 (46.42) b	2.80 abcde	9.13 b
O. punctata	100954 (R)	37.50 (37.71) c	2.23 c	6.63 c	32.50 (34.70) d	2.45 ef	6.98 de
	101409 (MS)	55.00 (36.21) c	2.55 bc	10.05 b	50.00 (44.98) b	2.63 cdef	9.55 b
O. sativa W 1263	R check	35.00 (36.21) c	2.38 c	10.00 b	32.50 (34.70) d	2.30 f	7.70 cd
IR 62	S check	90.00 (74.01) a	2.85 ab	20.38 a	87.50 (71.98) a	2.55 def	17.55 a

* Mean of four replications.
Figures in parentheses are arcsine transformed values.
In a column, means followed by same letters are not significantly different by DMRT ($p = 0.05$).

4.4.3.1.3. Position of the larva inside the stem

The distance tunneled by the larva inside the stem was 20.38 mm in the susceptible check IR 62 which was nearly 3 fold more than in the resistant wild rice accessions tested and 2 fold more than in the resistant check W 1263 (10.00 mm). The distance tunneled by the larva five days after release was significantly lower in the resistant wild accessions tested than in the resistant check W 1263 (Table 8).

4.4.3.2. Panicle initiation stage

4.4.3.2.1. Per cent larvae entering stem

The percentage of larvae that entered the lumen of the stem varied significantly among the accessions tested at panicle initiation stage also (Table 8). Only 30 per cent of the larvae successfully entered the lumen of the resistant accessions *O. australiensis* (103318) and *O. officinalis* (100948) as against 87.50 per cent in the susceptible check IR 62. In the resistant check W 1263, 32.50 per cent larvae entered the lumen.

4.2.3.2.2. Place of entry into the stem

There was only minimum variation in the place of entry of the larva into the stem. The distance from the place of entry and the internode varied from 2.30 mm in W 1263, the resistant check to 3.05 mm in *O. minuta* (101092), a resistant accession, while it was intermediate in the susceptible check IR 62 (2.55 mm) (Table 8).

4.4.3.2.3. Position of the larva inside the stem

The place of larva inside the stem, 5 days after release varied significantly among the accessions tested (Table 8). The larva tunneled to a distance of 17.55 mm in the susceptible check IR 62 which was significantly higher than other accessions tested. The distance bored was significantly low (6.13 to 7.30 mm) among the resistant accessions tested.

4.4.4. Biology of yellow stem borer on different accessions

4.4.4.1. Tillering stage

4.4.4.1.1. Larval period

The larval period of yellow stem borer ranged from 35.3 to 46.2 days in different accessions tested. The larval period was shortest in the susceptible check IR 62. The larvae reared in the susceptible check IR 62 pupated 10.9 days earlier than the larvae reared on the resistant accession *O. minuta* (101092) (Table 9). The larval stage was prolonged by 10.5, 9.9, 9.4 and 8.6 days than the susceptible check in the other resistant accessions *O. australiensis* (103318), *O. punctata* (100954), *O. officinalis* (100948) and *O. latifolia* (101443) respectively.

4.4.4.1.2. Pupal period

The pupal duration in different accessions ranged from 8.5 to 10.9 days. The pupal period was minimum in the susceptible check IR 62 which was on par with all the accessions tested except *O. minuta* (101092) and *O. punctata* (100954).

4.4.4.1.3. Adult emergence

The percentage of adult emergence was significantly low on all resistant accessions tested (Table 9). In the susceptible check IR 62, 67.50 per cent of larva completed its life cycle. The per cent adult emergence among other resistant and moderately susceptible accessions ranged from 15.00 to 25.00 per cent. A maximum of only 10.00 per cent of the larva released was able to complete its life cycle in the resistant wild accessions tested (Table 9).

4.4.4.1.4. Adult longevity

Longevity of adult yellow stem borer significantly varied among different accessions at the tillering stage (Table 9). Adult female and male lived longer on the susceptible check IR 62 (5.1 and 4.9 days respectively). The lowest adult female

Table 9. Biology of rice yellow stem borer on wild rice accessions at tillering stage

Oryza species	Accession number	Larval period* (days)	Pupal period* (days)	Adult emergence (%)*	Adult longevity (days)*	
					Female	Male
O. australiensis	103318 (R)	45.8 ab	10.2 abc	7.5 (13.92) cd	2.8 def	2.2 d
	101397 (MS)	40.2 abcd	9.1 bc	20.0 (26.55) bc	3.8 b	3.2 bc
O. minuta	101092 (R)	46.2 a	10.4 ab	10.0 (18.43) bcd	2.9 def	2.2 d
	101126 (MS)	39.8 abcd	9.3 abc	22.5 (27.84) bc	3.2 cd	3.4 bc
O. latifolia	101443 (R)	43.9 abc	10.2 abc	7.5 (13.92) cd	2.4 f	1.9 d
	100963 (MS)	38.9 bcd	8.9 bc	25.0 (29.88) b	3.8 b	3.4 bc
O. officinalis	100948 (R)	44.7 abc	9.7 abc	5.0 (9.42) d	2.8 ef	1.9 d
	101412 (MS)	39.1 abcd	8.6 c	17.5 (24.15) bc	3.2 cd	3.5 b
O. punctata	100954 (R)	45.2 abc	10.9 a	10.0 (15.96) cd	2.4 f	2.1 d
	101409 (MS)	38.3 cd	9.3 abc	15.0 (22.49) bcd	3.6 bc	3.3 bc
O. sativa W 1263	R check	40.2 abcd	9.2 abc	12.5 (17.99) bcd	3.1 cde	2.5 cd
IR 62	S check	35.3 d	8.5 c	67.5 (55.64) a	5.1 a	4.9 a

* Mean of four replications.
Figures in parentheses are arcsine transformed values.
In a column, means followed by same letters are not significantly different by DMRT ($p = 0.05$).

longevity of 2.4 days was recorded in *O. latifolia* (101443) and *O. punctata* (100954) which was 50 per cent below than the susceptible check. The males emerged from different accessions lived for 2.8 days on an average. The longevity was less than the average in all the resistant accessions tested.

4.4.4.1.5. Number of egg masses laid

The number of egg masses laid by the female moths emerged from different accessions ranged from 1.6 to 4.8 (Table 10). The females that emerged from the resistant accessions laid fewer egg masses than the females emerged from susceptible accessions. Yellow stem borer moth laid 1.6 egg masses per female when developed from the accessions *O. punctata* (100954) which was 3 times less than the moths emerged from IR 62. The fecundity of moth emerged from other resistant accessions were 1.8, 2.0, 2.1 and 2.3 respectively in case of *O. officinalis* (100948), *O. latifolia* (101443), *O. australiensis* (103318) and *O. minuta* (101092).

4.4.4.1.6. Size of the egg mass

The size of the egg mass was greatly influenced by the different host plants with varying levels of resistance. The mean length and breadth of the egg mass was 11.95 and 5.45 mm respectively when laid by the females emerged from the susceptible IR 62 (Table 10). Significant reduction in size was noticed in the resistant accessions. The minimum biometric variation was recorded in *O. australiensis* (103318) which was only 5.80 mm and minimum width was observed in *O. latifolia* (101443) (2.95 mm). Resistant check W 1263 had registered a mean egg mass length of 8.45 mm and width of 3.70 mm.

4.4.4.1.7. Number of eggs per egg mass

There was a great deal of variation in the number of eggs per egg mass in smaller egg mass laid by the female moths developed from the resistant accessions. In resistant

Table 10. Biometric observation of egg mass laid by yellow stem borer moth developed on wild rice accessions at tillering stage

Oryza species	Accession number	Number of egg masses/ female*	Length of egg mass (mm)*	Width of egg mass (mm)*	Number of eggs per egg mass*
O. australiensis	103318 (R)	2.1 fg	5.80 d	3.13 ef	110.75 (10.52) d
	101397 (MS)	3.6 b	9.83 b	5.03 ab	221.00 (14.86) ab
O. minuta	101092 (R)	2.3 ef	6.35 d	3.55 def	127.75 (11.25) cd
	101126 (MS)	3.0 cd	8.10 bc	4.00 cde	169.75 (12.99) bc
O. latifolia	101443 (R)	2.0 fgh	6.15 d	2.95 f	114.00 (10.66) d
	100963 (MS)	3.2 bc	9.10 b	4.33 bcd	195.00 (13.94) b
O. officinalis	100948 (R)	1.8 gh	6.13 d	3.10 ef	116.00 (10.64) d
	101412 (MS)	2.9 cd	9.13 b	4.50 abcd	198.50 (14.08) b
O. punctata	100954 (R)	1.6 h	6.68 cd	3.35 ef	130.75 (11.42) cd
	101409 (MS)	3.1 c	9.08 b	4.58 abc	198.50 (14.08) b
O. sativa W 1263	R check	2.6 de	8.45 b	3.70 cdef	171.75 (13.10) bc
IR 62	S check	4.8 a	11.95 a	5.45 a	270.00 (16.41) a

* Mean of four replications.
Figures in parentheses are square root transformed values.
In a column, means followed by same letters are not significantly different by DMRT ($p = 0.05$).

accessions, less than 130 eggs were present in an egg mass as against 270 eggs per egg mass in the susceptible IR 62. The average number of eggs per egg mass in moderately susceptible wild rice accessions ranged from 169.75 to 221.00 (Table 10).

4.4.4.2. Panicle initiation stage

4.4.4.2.1. Larval period

The larval period was completed early (32.4 days) when grown on the susceptible check IR 62. It took 43.5 days for the larvae to pupate when reared on the resistant *O. minuta* (101092) (Table 11). The larval period was extended to more than 40 days when reared on the resistant wild rice accessions, where as it was only 37.2 days in the resistant check W 1263. The larval period ranged from 35.1 to 38.4 days among the moderately susceptible wild rice accessions tested.

4.4.4.2.2. Pupal period

The pupal period of yellow stem borer varied from 8.5 to 10.6 days among different accessions (Table 11) with a mean of 9.5 days. The pupal period was extended to more than 10 days in all the resistant wild rice accessions tested as against 8.9 days in the resistant check W 1263.

4.4.4.2.3. Adult emergence

The mean percentage of larvae entering into adult stage ranged from 5.00 to 70.00 per cent among different accessions (Table 11). The percentage of adult emergence was minimum (5.00%) in *O. australiensis* (103318), *O. latifolia* (101443) and *O. officinalis* (100948). In the resistant check W 1263, 12.50 per cent of the larvae released emerged into adults. A maximum of 20.00 per cent survival was observed in other moderately susceptible wild rice accessions tested, as against 70.00 per cent in the susceptible check IR 62.

Table 11. Biology of rice yellow stem borer on wild rice accessions at booting stage

Oryza species	Accession number	Larval period (days)*	Pupal period (days)*	Adult emergence (%)*	Adult longevity (days)*	
					Female	Male
O. australiensis	103318 (R)	42.2 ab	10.1 abc	5.0 (9.42) c	2.6 ef	2.2 d
	101397 (MS)	38.4 abc	9.2 abc	17.5 (24.52) b	3.1 cd	3.3 bc
O. minuta	101092 (R)	43.5 a	10.2 abc	10.0 (18.43) bc	2.4 f	2.1 d
	101126 (MS)	36.4 abc	8.9 abc	20.0 (26.55) b	3.6 b	3.4 b
O. latifolia	101443 (R)	40.5 ab	10.4 ab	5.0 (9.42) c	2.6 ef	1.9 d
	100963 (MS)	35.8 abc	9.2 abc	20.0 (26.18) b	3.2 cd	3.5 b
O. officinalis	100948 (R)	43.1 ab	9.8 abc	5.0 (9.42) c	2.3 f	2.0 d
	101412 (MS)	37.2 abc	8.7 bc	20.0 (26.18) b	3.1 cd	3.4 b
O. punctata	100954 (R)	41.8 ab	10.6 a	10.0 (18.43) bc	2.5 f	2.1 d
	101409 (MS)	35.1 bc	9.1 abc	15.0 (22.49) b	3.4 bc	3.5 b
O. sativa W 1263	R check	37.2 abc	8.9 abc	12.5 (20.46) b	2.9 de	2.6 cd
IR 62	S check	32.4 c	8.5 c	70.0 (56.92) a	5.0 a	4.7 a

* Mean of four replications.
Figures in parentheses are arcsine transformed values.
In a column, means followed by same letters are not significantly different by DMRT ($p = 0.05$).

4.4.4.2.4. Adult longevity

Adult life span of both the sexes extended longer when they developed on the susceptible check IR 62 (5.0 and 4.7 days respectively) (Table 11). The females developed from resistant accessions lived for shorter period which ranged from 2.3 to 2.6 days. In case of male, the adult longevity was 4.7 days in the susceptible check IR 62 which was significantly higher from other accessions tested. The shorter adult male longevity of 1.9 days was recorded in the resistant wild rice accession *O. latifolia* (101443).

4.4.4.2.5. Number of egg masses laid

The number of egg masses laid by adult females from different accessions tested is presented in Table 12. The females emerged from the susceptible check IR 62 laid on an average of 4.4 egg masses which was 210 per cent more than the number of egg masses laid by the females developed from the resistant wild rice accessions *O. australiensis* (103318) and *O. officinalis* (100948). The females emerged from the resistant check W 1263 laid on an average of 2.6 egg masses only.

4.4.4.2.6. Size of the egg mass

The females emerged from the resistant wild accessions laid small, subsized egg masses (Table 12). The length of egg mass laid by female emerged from resistant wild rice accession *O. latifolia* (101443) was minimum (6.30 mm) as against 12.33 mm in the susceptible check IR 62. The width of the egg mass ranged from 2.93 mm in the resistant *O. latifolia* (101443) to 5.90 mm in the susceptible IR 62. The width of the egg mass laid by the females emerged from W 1263, the resistant check was 4.23 mm which was 1.67 mm less than the egg mass laid by the females developed from the susceptible check IR 62 (5.90 mm).

4.4.4.2.7. Number of eggs per egg mass

The number of eggs per egg mass significantly differed among different accessions. The average eggs per egg mass was 184.52. Females emerged from the susceptible check

Table 12. Biometric observation on the egg mass laid by yellow stem borer moth developed on wild rice accessions at booting stage

Oryza species	Accession number	Number of egg masses/ female*	Length of egg mass (mm)*	Width of egg mass (mm)*	Number of eggs per egg mass*
O. australiensis	103318 (R)	2.1 ghi	6.40d	3.18f	122.25 (11.04)f
	101397 (MS)	3.2 bc	10.05b	5.05b	225.75 (14.99)bcd
O. minuta	101092 (R)	2.0 ghi	6.45d	3.18f	123.25 (11.10)f
	101126 (MS)	3.1 bcd	10.05b	5.00bc	225.25 (15.00)bc
O. latifolia	101443 (R)	2.4 fgh	6.30d	2.93f	116.50 (10.75)f
	100963 (MS)	2.8 bcde	10.23b	4.98bcd	228.25 (15.12)b
O. officinalis	100948 (R)	2.1 ghi	6.43d	3.15f	122.75 (11.07)f
	101412 (MS)	2.9 bcde	10.33b	5.33ab	235.75 (15.35)b
O. punctata	100954 (R)	2.4 fgh	6.50d	3.18f	124.25 (11.15)f
	101409 (MS)	3.2 bc	10.17b	5.13ab	229.75 (15.12)b
O. sativa W 1263	R check	2.6 ef	8.50c	4.23cde	181.50 (13.48)ce
IR 62	S check	4.4 a	12.33a	5.90a	285.00 (16.86)a

* Mean of four replications.
Figures in parentheses are square root transformed values.
In a column, means followed by same letters are not significantly different by DMRT ($p = 0.05$).

IR 62 registered an average of 285.00 eggs per egg mass. The number of eggs per egg mass was very low (116.50) in egg mass laid by females emerged from the resistant *O. latifolia* (101443) followed by *O. australiensis* (103318) (Table 12).

4.4.5. Effect of different resistant accessions on the larval, pupal and adult weight

4.4.5.1. Tillering stage

4.4.5.1.1. Larval weight

The weight of the larvae reared on different test accessions ranged from 7.82 to 18.28 mg 10 days after feeding on the seedlings of different accessions in tillering stage (Table 13). All the accessions tested recorded significantly low larval weight indicating antibiosis mechanism. The larval weight gained on the wild resistant accessions was significantly less 10 days after feeding than in the resistant check W 1263.

Significant difference was observed in the larval weight after 20 days of feeding in different accessions. The larval weight was minimum (16.09 mg) in the resistant wild rice accession *O. punctata* (100954) which was on par with other resistant wild rice accessions and significantly less than the resistant check W 1263.

The larval weight after 30 days of feeding ranged from 33.24 to 58.12 mg in different accessions (Table 13). All the resistant rice accessions tested recorded significantly lower larval weight 30 days after feeding. The average weight of larvae was 58.12 mg, 30 days after feeding in the susceptible check IR 62 which was 178 per cent more than when fed on the resistant *O. latifolia* (101443)

4.4.5.1.2. Pupal weight

The pupal weight of yellow stem borer developed from different test accessions varied from 11.00 mg in *O. australiensis* (103318) to 24.14 mg in the susceptible check IR 62. Robust pupae were recovered from the susceptible check as against under sized

Table 13. Larval, pupal and adult weights of rice yellow stem borer developed from wild rice accessions at tillering stage

Oryza species	Accession number	Larval weight (mg)*			Pupal weight* (mg)	Adult Weight (mg)*	
		10 days after feeding	20 days after feeding	30 days after feeding		Female	Male
O. australiensis	103318 (R)	7.82 d	16.28 e	36.12 d	11.00 d	8.17 d	5.55 c
	101397 (MS)	12.30 c	25.02 bc	42.85 bc	17.91 bc	15.78 b	12.03 b
O. minuta	101092 (R)	9.30 d	19.25 de	35.27 d	11.52 d	8.80 d	5.38 c
	101126 (MS)	14.27 b	29.08 a	44.23 bc	18.58bc	16.21 b	11.50 b
O. latifolia	101443 (R)	8.12 d	16.80 e	33.24 d	11.28 d	8.70 d	5.45 c
	100963 (MS)	13.2 bc	25.80 b	43.24 bc	19.10 b	15.12 b	12.13 b
O. officinalis	100948 (R)	8.05 d	17.21 e	35.82 d	10.92 d	9.20 d	5.28 c
	101412 (MS)	14.06 b	24.07 bc	45.20 bc	17.82 bc	15.27 b	12.13 b
O. punctata	100954 (R)	7.92 d	16.09 e	34.26 d	11.48 d	8.98 d	5.85 c
	101409 (MS)	13.98 b	25.21 bc	43.48 bc	18.32 bc	15.70 b	12.07 b
O. sativa W 1263	R check	12.15 c	22.03 cd	38.52 cd	15.23 c	13.23 c	10.58 b
IR 62	S check	18.28 a	30.20 a	58.12 a	24.14 a	21.18 a	15.33 a

* Mean of four replications.
In a column, means followed by same letters are not significantly different by DMRT ($p = 0.05$).

pupae from the resistant wild accessions (Plate 3). The pupae developed from resistant wild accessions weighed less than 50 per cent of the weight of the pupae developed from the susceptible check IR 62.

4.4.5.1.3. Adult weight

There was wide variation in the weight of the adults emerged from different test accessions. The female weight ranged from 8.17 mg in the resistant *O. australiensis* (103318) to 21.18 mg in the susceptible check. In case of males, the weight ranged from 5.28 mg in *O. officinalis* (100948) to 15.33 mg in the susceptible check IR 62. The weight of the adults emerged from the resistant wild rice accessions were significantly different from other accessions tested (Table 13).

4.4.5.2. Panicle initiation stage

4.4.5.2.1. Larval weight

The larva gained a weight of 6.20, 14.12 and 31.18 mg after 10, 20 and 30 days of feeding in the resistant accession *O. australiensis* (103318) as against 18.72, 36.18 and 56.18 mg respectively in the susceptible check IR 62(Table 14). There was nearly three fold reduction in the larval weight 10 days after feeding in the resistant accessions compared to susceptible check, indicating the difficulty encounted by early instar larva in nutritional assimilation from resistant wild rice accessions. After 20 days of feeding by the larvae in the resistant check W 1263, the weight gained was on par with the moderately susceptible wild accessions but weight gained after 30 days of feeding was significantly reduced in W 1263.

4.4.5.2.2. Pupal weight

The weight of the pupae developed from different accessions tested ranged from 10.28 mg to 25.01 mg (Table 14). The pupal weight was significantly reduced when fed on the resistant accessions (10.28 to 12.04 mg) than on the resistant check W 1263 (16.05 mg).

IR 62 *O. offcinalis* (100948)

Plate 3 . Effect of wild rice on the pupa of yellow stem borer

Table 14. Larval, pupal and adult weights of rice yellow stem borer developed from wild rice accessions at booting stage

Oryza species	Accession number	Larval weight (mg)*			Pupal weight* (mg)	Adult Weight (mg)*	
		10 days after feeding	20 days after feeding	30 days after feeding		Female	Male
O. australiensis	103318 (R)	6.20 e	14.12 c	31.18 f	11.24 c	8.02 d	5.48 c
	101397 (MS)	11.82 c	24.05 b	38.29 cde	18.01 b	14.18 c	11.65 b
O. minuta	101092 (R)	8.21 d	18.62 c	34.18 ef	12.02 c	8.52 d	5.15 c
	101126 (MS)	12.52 bc	26.02 b	45.12 b	18.51 b	16.52 b	11.33 b
O. latifolia	101443 (R)	7.27 de	15.12 c	32.57 ef	11.58 c	9.35 d	5.68 c
	100963 (MS)	11.15 c	24.28 b	43.72 bc	19.21 b	15.72 bc	11.95 b
O. officinalis	100948 (R)	8.10 d	16.51 c	35.16 ef	10.28 c	8.76 d	5.30 c
	101412 (MS)	13.28 b	26.20 b	44.12 bc	18.05 b	16.01 bc	11.48 b
O. punctata	100954 (R)	8.10 d	16.20 c	36.18 def	12.04 c	8.32 d	5.45 c
	101409 (MS)	12.00 bc	24.38 b	42.18 bcd	18.02 b	15.25 bc	12.05 b
O. sativa W 1263	R check	11.15 c	22.52 b	36.18 def	16.05 b	14.21 c	10.48 b
IR 62	S check	18.72 a	36.18 a	56.18 a	25.01 a	22.05 a	15.10 a

* Mean of four replications.
In a column, means followed by same letters are not significantly different by DMRT ($p = 0.05$).

The pupal weight developed from the moderately susceptible wild rice accessions were significantly lower (18.01 to 18.51 mg) than the pupae developed from the susceptible check IR 62 (25.01 mg).

4.4.5.2.3. Adult weight

The adult female and male weight significantly differed when emerged from different accessions tested (Table 14). The mean female and male weight recorded were 13.78 and 9.25 mg respectively. The adult females and males emerged from the resistant wild rice accession recorded lesser weight. The adult females developed from the resistant wild accession *O. australiensis* (103318) recorded minimum weight of 8.02 mg. In case of males, the lowest weight (5.15 mg) was recorded from the resistant wild rice accession *O. minuta* (101092).

4.4.6. Effect of feeding on different accessions on the mandibles of yellow stem borer larva

4.4.6.1. Tillering stage

There was wide variation in the length and width of the mandibles 15 days after feeding in different test accessions (Table 15). In the resistant wild rice accessions, the length of the mandible ranged from 185μ in *O. australiensis* (103318) to 197μ in *O. minuta* (101092). The width of the mandible was lowest in the resistant wild accession *O. officinalis* (100948) (112μ), 15 days after feeding which was significantly less than the resistant check W 1263 (142μ). The maximum length of 272μ and width of 208μ was observed in the larvae fed on the susceptible check IR 62.

The length and width of the mandibles varied from 360 to 653μ and 239 to 412μ respectively among different accessions tested 30 days after feeding. The length and width of the mandibles of the larvae reared on the resistant wild rice accessions were significantly reduced than from the mandibles of the larvae reared on other accessions.

Table 15. Effect of feeding on the wearing of mandibles of rice yellow stem borer larvae in different wild rice accessions at tillering stag

Oryza species	Accession number	15 days after feeding*		30 days after feeding*	
		Length (μ)	Width (μ)	Length (μ)	Width (μ)
O. australiensis	103318 (R)	185 f	124 e	360 f	252 ef
	101397 (MS)	243 b	162 bc	535 b	364 c
O. minuta	101092 (R)	197 def	114 e	372 f	248 ef
	101126 (MS)	208 de	152 cd	474 d	372 bc
O. latifolia	101443 (R)	186 f	120 e	364 f	268 e
	100963 (MS)	228 bc	172 b	496 cd	390 b
O. officinalis	100948 (R)	192 ef	112 e	385 f	239 f
	101412 (MS)	235 b	168 b	517 bc	368 bc
O. punctata	100954 (R)	189 f	119 e	368 f	242 f
	101409 (MS)	241 b	174 b	532 b	379 bc
O. sativa W 1263	R check	212 cd	142 d	438 e	325 d
IR 62	S check	272 a	208 a	653 a	412 a

* Mean of four replications.
In a column, means followed by same letters are not significantly different by DMRT ($p = 0.05$).

There was marked wear and tear in the mandibles of the larvae that fed on the resistant accessions which was well expressed in the larvae fed on the resistant wild rice accession *O. officinalis* (100948) (Plate 4).

4.4.6.2. Panicle initiation stage

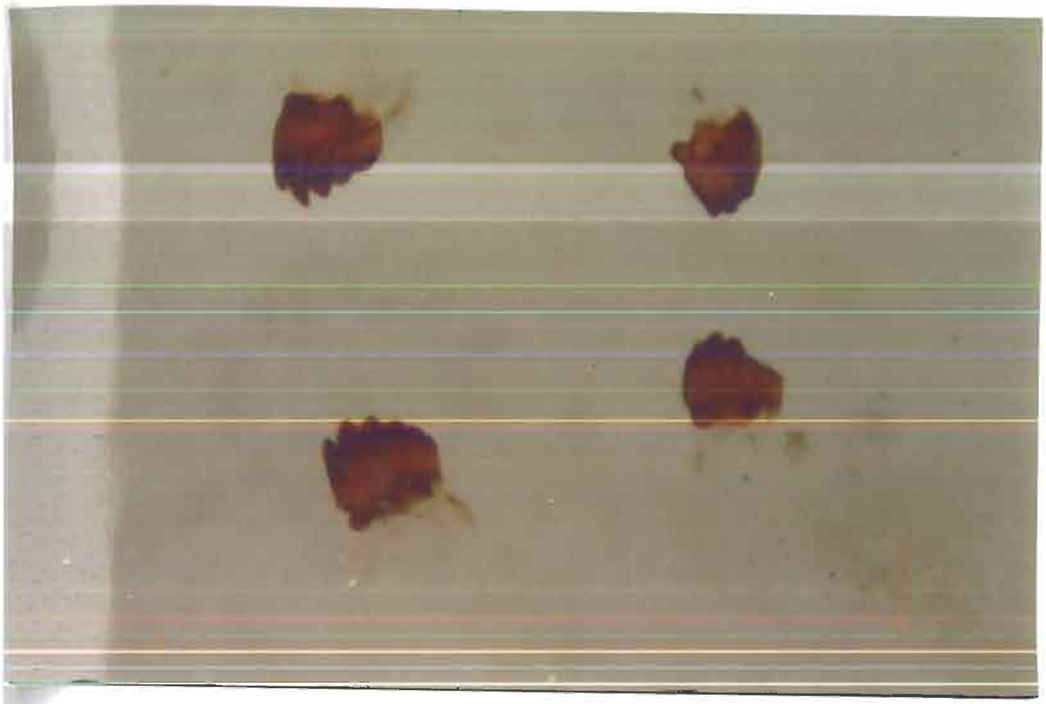
Significant difference was observed in the size of the mandibles of the larvae fed on different accessions at the booting stage (Table 16). During the first observation, the length of the mandible was 272μ in the susceptible check IR 62 which was 87μ more than the length of the mandibles from the larvae fed on the resistant *O. australiensis* (103318). Similarly 96μ reduction in the width of the mandibles was observed when the larvae fed on the resistant *O. officinalis* (100948) which was found to be severely worn out due to feeding.

The length of the mandibles ranged from 360 to 385μ among the larvae, after 30 days of feeding on the resistant wild rice accessions and 474 to 535μ among the larvae fed on moderately susceptible wild rice accessions. Maximum width of the mandible (412μ) was observed from the larvae fed on the susceptible check with sharp teeth and minimum width of 239μ was observed in the larva fed on the resistant wild rice accession *O. officinalis* (100948) with worn out blunt teeth. The length of the mandible after 30 days of feeding was 438μ in the resistant check W 1263 and 653μ in the susceptible check IR 62.

4.5. Evaluation of rice plant volatiles

4.5.1. Effect of steam distillate extract on the ovipositional behaviour of yellow stem borer

The number of egg masses laid in the susceptible check IR 62 plants sprayed with steam distillate of resistant wild rice accessions in a free choice test are presented in Table 17. The acetone control plant received 15.25 egg masses which was on par with the egg masses received by the plants treated with even 2000 ppm of steam distillate of *O. minuta* (101092) and *O. punctata* (100954) extracted at tillering stage. In case of plants sprayed



IR 62 *O. offcinalis* (100948)

Plate 4. Effect of wild rice on the mandibles of yellow stem borer larvae

Table 16. Effect of feeding on the wearing of mandible of rice yellow stem borer larvae in different wild rice accessions at booting s

Oryza species	Accession number	15 days after feeding*		30 days after feeding*	
		Length (μ)	Width (μ)	Length (μ)	Width (μ)
O. australiensis	103318 (R)	185 f	124 e	360 f	252 ef
	101397 (MS)	243 b	162 bc	535 b	364 c
O. minuta	101092 (R)	197 def	114 e	372 f	248 ef
	101126 (MS)	208 de	152 cd	474 d	372 bc
O. latifolia	101443 (R)	186 f	120 e	364 f	268 e
	100963 (MS)	228 bc	172 b	496 cd	390 b
O. officinalis	100948 (R)	192 ef	112 e	385 f	239 f
	101412 (MS)	235 b	168 b	517 bc	368 bc
O. punctata	100954 (R)	189 f	119 e	368 f	242 f
	101409 (MS)	241 b	174 b	532 b	379 bc
O. sativa W 1263	R check	212 cd	142 d	438 e	325 d
IR 62	S check	272 a	208 a	653 a	412 a

* Mean of four replications.
In a column, means followed by same letters are not significantly different by DMRT ($p = 0.05$).

Table 17. Effect of steam distillate extract of wild rice accessions on the ovipositional preference of rice yellow stem borer

Oryza species accession / concentration of steam distillate sprayed on IR 62	Number of egg masses laid*	
	Tillering stage	Booting stage
O. minuta (101092) -plant	16.25 a	15.25 a
500 ppm on IR 62	17.00 a	16.75 a
1000 ppm on IR 62	18.50 a	18.00 a
2000 ppm on IR 62	15.00 a	16.25 a
O. officinalis (100948) - plant	14.75 a	14.50 a
500 ppm on IR 62	16.75 a	18.25 a
1000 ppm on IR 62	18.00 a	17.00 a
2000 ppm on IR 62	17.25 a	16.75 a
O. punctata (100954) - plant	16.75 a	16.25 a
500 ppm on IR 62	16.50 a	15.50 a
1000 ppm on IR 62	15.50 a	15.00 a
2000 ppm on IR 62	14.75 a	14.75 a
Acetone control on IR 62	15.25 a	15.75 a

* Mean of four replications.
In a column, means followed by same letters are not significantly different by DMRT ($p = 0.05$).

with *O. minuta* (101092) extracts, the plants sprayed with 1000 ppm received 18.50 egg massess, 2000 ppm received 15.00 egg masses and 500 ppm received 17.00 egg masses indicating the insignificance of the volatiles on the egg laying by yellow stem borer.

The number of egg masses laid by yellow stem borer moths in a free choice test ranged from 15.00 to 18.25 in IR 62 plants sprayed with different concentration of steam distillate of resistant wild rice accessions extracted at booting stage (Table 17). The acetone treated control plant received 15.75 egg masses which was on par with plants treated with *O. minuta* (101092) extract at 500 and 2000 ppm, *O. officinalis* (100948) extract at 1000 and 2000 ppm and *O. punctata* (100954) extract at 500, 1000 and 2000 ppm indicating the insignificant role of the volatile in the ovipositional behaviour of yellow stem borer.

4.5.2. Effect of steam distillate extract on the orientation response of first instar larva

The first instar larva did not show any preference towards the plants sprayed with the steam distillate extract from resistant plants at tillering stage (Table 18). Three hours after the release of the larvae, the number of larvae oriented and settled among the plants treated with volatiles and the control ranged from 2.50 to 3.30 which were statistically similar. The percentage of the larvae oriented and settled in different accessions ranged from 1.67 to 2.20, three hours after release.

The number of larvae oriented and settled after 6 h of release ranged from 7.70 in *O. officinalis* (100948) extract 500 ppm treated IR 62 plants to 9.35 in *O. punctata* (100954) plant. No significant difference was observed in the number of larvae oriented and settled among different treatments. The percentage of larvae oriented and settled among IR 62 plants 12 h after release ranged from 6.10 in *O. minuta* (101092) steam distillate 2000 ppm treated plants to 8.30 in *O. officinalis* (100948) extract 500 ppm treated plants (Table 18).

Table 18. Preference of the first instar larva of rice yellow stemborer towards IR 62 plants sprayed with steam distillate extract of wild rice accessions at tillering stage

Oryza species accession / concentration of steam distillate sprayed on IR 62	Larvae settled after*					
	3 h		6 h		12 h	
	Number	Percentage	Number	Percentage	Number	Percentage
O. minuta (101092) - Plant	3.15 a	2.10 (1.60) a	8.85 a	5.90 (2.52) a	11.60 a	7.73 (2.86) a
500 ppm on IR 62	2.95 a	1.97 (1.56) a	7.75 a	5.17 (2.37) a	11.45 ab	7.63 (2.85) a
1000 ppm on IR 62	2.60 a	1.73 (1.48) a	8.65 a	5.77 (2.50) a	1.45 ab	7.63 (2.85) a
2000 ppm on IR 62	3.05 a	2.03 (1.58) a	7.90 a	5.27 (2.40) a	9.15 b	6.10 (2.56) b
O. officinalis (100948) - Plant	3.30 a	2.20 (1.64) a	8.60 a	5.73 (2.49) a	11.95 ab	7.97 (2.90) a
500 ppm on IR 62	2.95 a	1.97 (1.55) a	7.70 a	513 (2.37) a	13.50 a	8.30 (2.98) a
1000 ppm on IR 62	2.80 a	1.87 (1.52) a	8.35 a	5.67 (2.46) a	10.55 ab	7.03 (2.74) ab
2000 ppm on IR 62	2.70 a	1.80 (1.50) a	9.15 a	6.10 (2.57) a	1040 ab	6.93 (2.72) ab
O. punctata (100954) - Plant	2.80 a	1.87 (1.53) a	9.35 a	6.23 (2.59) a	11.10 ab	7.40 (2.80) ab
500 ppm on IR 62	2.50 a	1.67 (1.46) a	9.00 a	6.00 (2.55) a	10.55 ab	7.03 (2.74) ab
1000 ppm on IR 62	2.70 a	1.80 (1.51) a	9.20 a	6.13 (2.57) a	9.80 ab	6.53 (2.64) ab
2000 ppm on IR 62	2.80 a	1.87 (1.53) a	8.85 a	5.90 (2.53) a	10.80 ab	7.20 (2.79) ab
Acetone control (IR 62)	2.55 a	1.70 (1.48) a	8.05 a	5.37 (2.42) a	12.15 ab	8.10 (2.94) a

* Mean of four replications
Figures in parentheses are square root transformed values
In a column, means followed by same letters are not significantly different by DMRT (P=0.05)

The number of first instar larvae oriented and settled 3 h after release was high (3.40) in IR 62 plants sprayed with 1000 ppm steam distillate extract of *O. minuta* (101092) extracted at booting stage which was statistically on par with all other treatments. The percentage of larvae oriented and settled among plants treated with volatiles of resistant wild rice accessions varied from 1.67 to 2.27 (Table 19).

No significant difference was observed in the number of larvae oriented and settled among IR 62 plants treated with steam distillate extract of resistant wild rice accessions sprayed at 500, 1000 and 2000 ppm 6 h after release. The number of larvae oriented and settled was more in *O. minuta* (101092) plant 12 h after release, which was on par with the IR 62 plants treated with acetone alone (10.50).

4.5.3. Toxicity of the steam distillate extract to first instar larva of yellow stem borer

The percentage of larvae survived after 3 and 5 days of feeding in the susceptible IR 62 plants sprayed with the steam distillate extract of resistant wild rice accessions extracted at tillering stage are presented in Table 20. The steam distillate at 2000 ppm was found to be highly detrimental to the first instar larvae. Only 45 per cent of the larvae released survived after 3 days of feeding in *O. punctata* (100954) steam distillate (2000 ppm) sprayed plants as against 87.50 per cent survival in the acetone treated plants. The toxicity decreased as the concentration of the distillate was reduced. Even at 500 ppm concentration, there was more than 25 per cent mortality as against only 12.50 per cent mortality in the acetone treated plants.

The mortality of the first instar larvae was more than 50 per cent 5 days after feeding on plants sprayed with 2000 ppm of steam distillate extract of resistant wild rice accessions. The *O. punctata* (100954) steam distillate extract was found to be highly toxic with 55.0 and 60.0 per cent mortality of larva 5 days after feeding on plants sprayed at a concentration of 1000 ppm and 2000 ppm respectively.

Table 19. Preference of the first instar larva of rice yellow stem borer towards IR 62 plants sprayed with steam distillate extract of wild rice accessions at booting stage

Oryza species accession / concentration of steam distillate sprayed on IR 62	Larvae settled after*					
	3 h		6 h		12 h	
	Number	Percentage	Number	Percentage	Number	Percentage
O. minuta (101092) - Plant	2.50 a	1.67 (1.46) a	8.40 a	5.60 (2.46) a	12.75 a	8.50 (2.99) a
500 ppm on IR 62	3.05 a	2.03 (1.59) a	8.60 a	5.73 (2.49) a	11.65 ab	7.67 (2.87) ab
1000 ppm on IR 62	3.40 a	2.27 (1.64) a	9.25 a	6.17 (2.57) a	10.03 ab	6.68 (2.68) ab
2000 ppm on IR 62	2.90 a	1.93 (1.55) a	8.30 a	5.53 (2.45) a	9.05 a	6.03 (2.55) b
O. officinalis (100948) - Plant	3.30 a	2.20 (1.63) a	8.85 a	5.90 (2.53) a	10.15 ab	6.77 (2.69) ab
500 ppm on IR 62	2.70 a	1.80 (1.51) a	8.15 a	5.43 (2.43) a	10.25 ab	6.83 (2.71) ab
1000 ppm on IR 62	2.75 a	1.83 (1.52) a	9.35 a	6.23 (2.59) a	9.95 a	6.63 (2.67) ab
2000 ppm on IR 62	2.65 a	1.77 (1.50) a	8.45 a	5.63 (2.47) a	10.15 ab	6.77 (2.69) ab
O. punctata (100954) - Plant	2.60 a	1.73 (1.48) a	8.15 a	5.43 (2.43) a	11.30 ab	7.53 (2.83) ab
500 ppm on IR 62	2.70 a	1.80 (1.51) a	8.00 a	5.33 (2.41) a	10.25 ab	6.83 (2.70) ab
1000 ppm on IR 62	2.80 a	1.87 (1.53) a	8.45 a	5.63 (2.47) a	10.60 ab	7.07 (2.75) ab
2000 ppm on IR 62	2.95 a	1.97 (1.57) a	8.80 a	5.87 (2.52) a	10.25 ab	6.83 (2.71) ab
Acetone control (IR 62)	2.55 a	1.70 (1.47) a	8.40 a	5.60 (2.46) a	10.50 ab	7.00 (2.72) ab

* Mean of four replications
Figures in parentheses are square root transformed values
In a column, means followed by same letters are not significantly different by DMRT (P=0.05)

Table 20. Effect of steam distillate extract of wild rice accessions on larval survival and deadheart formation by yellow stem borer

Oryza species accession / concentration of steam distillate sprayed on IR 62	Larval survival (%)*		Deadheart (%)*
	After 3 days	After 5 days	
O. minuta (101092) - plant	40.0 (39.15) efgh	37.5 (37.71) ef	10.0 (18.43) e
500 ppm on IR 62	70.0 (56.92) b	70.0 (56.92) b	62.5 (52.32) ab
1000 ppm on IR 62	50.0 (44.98) edef	50.0 (44.98) cd	40.0 (39.15) cd
2000 ppm on IR 62	52.5 (46.42) ed	45.0 (42.10) de	35.0 (36.21) d
O. officinalis (100948) - plant	35.0 (36.21) h	32.5 (34.70) f	10.0 (15.95) e
500 ppm on IR 62	75.0 (60.09) b	72.5 (58.43) b	60.0 (51.03) ab
1000 ppm on IR 62	60.0 (50.81) c	57.5 (49.31) c	52.5 (46.42) bd
2000 ppm on IR 62	55.0 (47.86) cd	42.5 (40.66) def	32.5 934.55) d
O. Punctata (100954) - plant	35.0 (36.21) h	37.5 (37.71) ef	7.5 (13.92) e
500 ppm on IR 62	70.0 (56.77) b	72.5 (58.43) b	62.5 (52.25) ab
1000 ppm on IR 62	50.0 (44.98) cdef	45.0 (42.10) de	37.5 (37.71)
2000 ppm on IR 62	45.0 (42.10) def	40.0 (39.15) def	30.0 (33.04) d
Acetone control (IR 62)	87.50 (71.98) a	85.0 (69.95) a	70.0 (56.92) a

* Mean of four replications
Figures in parentheses are arcsine transformed values
In a column, means followed by same letter are not significantly different by DMRT (P=0.05)

There was more than 50 per cent reduction in the deadheart symptom produced in the IR 62 plants when sprayed with steam distillate extract *O. minuta* (101092), *O. officinalis* (100948) and *O. punctata* (100954) at 2000 ppm. Significantly lesser deadheart was produced when sprayed at 1000 ppm also. However, at 500 ppm the dead heart symptom produced were on par with the acetone treated control.

The steam distillate extract of leaf sheath of resistant wild rice accessions at booting stage was found to be highly toxic to the first instar larvae of yellow stem borer (Table 21). Only fifty or less per cent of the larvae released survived on the IR 62 plants sprayed with steam distillate extract of wild rice accessions at 2000 ppm, 3 days after feeding. In case of the accession *O. punctata* (100954), the effect was pronounced even at 1000 ppm with 50 per cent mortality after 3 days of feeding. After 5 days of feeding, the larval survival was significantly reduced at all the concentrations (500, 1000 and 2000 ppm) tested than the acetone treated control. At 2000 ppm concentration, the steam distillate extract caused significantly similar mortality caused in the wild rice accessions plants.

The whitehead damage recorded was only 30.0 and 32.5 per cent in the IR 62 plants sprayed with steam distillate extract of the resistant *O. punctata* (100954) and *O. minuta* (101092) at 2000 ppm as against 62.5 per cent in the acetone treated control. All the plants sprayed with 1000 or 2000 ppm of steam distillate extract of resistant wild rice accessions produced significantly lesser whitehead than the plants sprayed with acetone (Table 21).

4.5.4. Contact toxicity of steam distillate extract to larva of yellow stem borer

The mortality of the 10 day old yellow stem borer larvae was not significantly influenced by the topical application of the steam distillate extract of resistant wild rice accessions. Mortality of larvae ranged from 0.00 to 3.75 per cent when treated with different concentration of steam distillate extract of resistant wild rice accessions extracted at both tillering and booting stage 3 and 5 days after application (Table 22).

Table 21. Effect of steam distillate extract of wild rice accessions on the larval survival and whitehead formation by yellow stem borer

Oryza species accession / concentration of steam distillate sprayed on IR 62	Larval survival (%)*		Whitehead (%)*
	After 3 days	After 5 days	
O. minuta (101092) - plant	45.0 (42.10) d	42.5 (40.66) d	7.5 (13.92) e
500 ppm on IR 62	75.0 (60.09) b	72.5 (58.43) b	55.0 (47.86) a
1000 ppm on IR 62	65.0 (53.76) c	62.5 (52.25) c	50.0 (44.98) ab
2000 ppm on IR 62	50.0 (44.98) d	47.5 (43.54) d	32.5 (34.70) cd
O. officinalis (100948) - plant	50.0 (44.98) d	45.0 (42.10) d	5.0 (9.41) e
500 ppm on IR 62	77.5 (62.12) b	72.5 (58.43) b	57.5 (49.37) a
1000 ppm on IR 62	60.0 (50.81) c	57.5 (49.31) c	47.5 (43.54) abc
2000 ppm on IR 62	50.0 (44.98) d	47.5 (43.54) d	35.0 (36.21) bcd
O. punctata (100954) - plant	47.5 (43.54) d	40.0 (39.22) d	7.5 (13.92) e
500 ppm on IR 62	75.0 (60.09) b	72.5 (58.43) b	55.5 (47.86) a
1000 ppm on IR 62	50.0 (44.98) d	47.5 (43.54) d	35.0 (36.21) bcd
2000 ppm on IR 62	42.5 (40.66) d	42.5 (40.66) d	30.0 (33.04) d
Acetone control (IR 62)	92.5 (76.04) a	90.0 (74.04) a	62.5 (52.32) a

* Mean of four replications
Figures in parentheses are arcsine transformed values
In a column, means followed by same letter are not significantly different by DMRT (P=0.05)

Table 22. Effect of topical application of steam distillate extract of wild rice accessions on the larva of rice yellow stem borer

Oryza species accession/ concentration of steam distillate		Extract from plants at tillering stage*		Extract from plants at booting stage*	
		Mortality (%) after 3 days	Mortality (%) after 5 days	Mortality (%) after 3 days	Mortality (%) after 5 days
O. minuta (101092) -	500 ppm	2.50 (1.53) a	2.50 (1.53) a	1.25 (1.12) a	1.25 (1.12) a
	1000 ppm	2.50 (1.53) a	2.50 (1.53) a	1.25 (1.12) a	1.25 (1.12) a
	2000 ppm	2.50 (1.53) a	2.50 (1.53) a	2.50 (1.53) a	2.50 (1.53) a
O. officinalis (100948) -	500 ppm	1.25 (1.12) a	2.50 (1.53) a	1.25 (1.12) a	1.25 (1.12) a
	1000 ppm	1.25 (1.12) a	1.25 (1.12) a	1.25 (1.12) a	1.25 (1.12) a
	2000 ppm	3.75 (1.94) a	3.75 (1.94) a	2.50 (1.53) a	2.50 (1.53) a
O. punctata (100954) -	500 ppm	1.25 (1.12) a	1.25 (1.12) a	1.25 (1.12) a	1.25 (1.12) a
	1000 ppm	0.00 (0 .71) a	0.00 (0 .71) a	1.25 (1.12) a	2.50 (1.53) a
	2000 ppm	3.75 (1.94) a	3.75 (1.94) a	2.50 (1.53) a	2.50 (1.53) a
Acetone control		1.25 (1.12) a	1.25 (1.12) a	1.25 (1.12) a	1.25 (1.12) a

* Mean of four replications.
Figures in parentheses are arcsine transformed values.
In a column, means followed by same letters are not significantly different by DMRT ($p = 0.05$).

4.6. Evaluation of cuticular wax

4.6.1. Effect of cuticular wax on the ovipositional behaviour of yellow stem borer

The number of egg masses laid in a free choice test revealed no significant influence of cuticular wax on the oviposition of yellow stem borer (Table 23). The number of egg masses laid ranged from 10.75 to 14.00 on IR 62 plants sprayed with different concentrations of cuticular wax extracted at tillering stage. However they did not vary statistically.

The number of egg masses received by IR 62 plants treated with the cuticular wax of resistant wild rice accessions extracted at booting stage at 500, 1000 and 2000 ppm was presented in Table 23. There was no significant difference among the number of egg masses laid on IR 62 planted treated with the extract.

4.6.2. Effect of cuticular wax extract on the orientation response of first instar larva

There was no significant difference in the number of larvae oriented and settled in IR 62 plants sprayed with cuticular wax of resistant wild rice accessions, *O. minuta* (101092), *O. officinalis* (100948) and *O. punctata* (100954) at 500, 1000 and 2000 ppm extracted from leaf sheath at tillering stage (Table 24). The number of larvae oriented and settled among different treatment ranged from 2.35 to 2.75, 7.55 to 10.60 and 10.00 to 12.70, 3, 6 and 12 h after release respectively. The percentage of larvae oriented and settled among different accessions even after 12 h of release, when more than 90 per cent of the larvae settled in different treatments did not vary statistically (Table 24).

The percentage of larvae oriented and settled on IR 62 plants sprayed with cuticular wax of *O. minuta* (101092), *O. officinalis* (100948) and *O. punctata* (100954) extracted at booting stage varied from 1.73 to 2.20, 4.87 to 6.33 and 6.30 to 8.57 per cent respectively 3, 6 and 12 h after release (Table 25). No significant difference in the number of larvae oriented and settled even after 12 h of release was observed indicating that the cuticular wax had no effect on the preference of first instar larva.

Table 23. Effect of cuticular wax extract of wild rice accessions on the ovipositional preference of rice yellow stem borer

Oryza species accession/ concentration of cuticular wax extract sprayed on IR 62	Number of egg masses laid*	
	Tillering stage	Booting stage
). *minuta* (101092) -plant	10.50 a	12.00 a
500 ppm on IR 62	10.75 a	11.00 a
1000 ppm on IR 62	11.50 a	12.00 a
2000 ppm on IR 62	11.75 a	12.25 a
). *officinalis* (100948) - plant	11.00 a	11.75 a
500 ppm on IR 62	11.75 a	12.25 a
1000 ppm on IR 62	11.25 a	12.75 a
2000 ppm on IR 62	11.00 a	13.25 a
). *punctata* (100954) - plant	11.50 a	12.25 a
500 ppm on IR 62	12.25 a	13.25 a
1000 ppm on IR 62	12.75 a	14.50 a
2000 ppm on IR 62	14.00 a	11.50 a
Triton X 100 : Acetone (1:3) control on IR 62	11.75 a	11.00 a

* Mean of four replications.
In a column, means followed by same letters are not significantly different by DMRT (p = 0.05).

Table 24. Preference of the first instar larva of rice yellow stem borer towards IR 62 plant sprayed with cuticular wax extract of wild rice accessions at tillering stage

Oryza species accession/ concentration of cuticular wax extract sprayed on IR 62	Larvae settled after*					
	3 h		6 h		12 h	
	Number	Percentage	Number	Percentage	Number	Percentage
O. minuta (101092) -plant	2.45 a	1.63 (1.45) a	8.40 ab	5.60 (2.46) ab	10.60 a	7.07 (2.73) a
500 ppm on IR 62	2.65 a	1.77 (1.50) a	8.50 ab	5.67 (2.48) ab	12.05 a	8.03 (2.92) a
1000 ppm on IR 62	2.35 a	1.57 (1.43) a	8.65 ab	5.77 (2.50) ab	12.05 a	8.03 (2.91) a
2000 ppm on IR 62	2.40 a	1.60 (1.44) a	8.90 ab	5.93 (2.53) ab	10.00 a	6.67 (2.67) a
O. officinalis (100948) - plant	2.45 a	1.63 (1.46) a	7.55 b	5.03 (2.34) b	12.05 a	8.03 (2.92) a
500 ppm on IR 62	2.75 a	1.83 (1.51) a	8.50 ab	5.67 (2.47) ab	12.70 a	8.47 (2.99) a
1000 ppm on IR 62	2.45 a	1.63 (1.45) a	8.35 ab	5.57 (2.45) ab	11.05 a	7.37 (2.79) a
2000 ppm on IR 62	2.75 a	1.83 (1.51) a	9.40 ab	6.27 (2.60) ab	11.55 a	7.70 (2.85) a
O. punctata (100954) - plant	2.40 a	1.60 (1.43) a	9.25 ab	6.17 (2.58) ab	11.60 a	7.73 (2.86) a
500 ppm on IR 62	2.60 a	1.73 (1.48) a	8.75ab	5.83 (2.50) ab	10.55 a	7.03 (2.74) a
1000 ppm on IR 62	2.70 a	1.80 (1.49) a	7.95 ab	5.30 (2.40) ab	10.40 a	6.93 (2.72) a
2000 ppm on IR 62	2.50 a	1.67 (1.47) a	8.95 ab	5.97 (2.53) ab	11.40 a	7.60 (2.84) a
Triton X 100 : Acetone (1:3) control on IR 62	2.40 a	1.60 (1.44) a	10.60 a	7.07 (2.75) a	11.35 a	7.57 (2.84) a

* Mean of four replications.
Figures in parentheses are square root transformed values.
In a column, means followed by same letters are not significantly different by DMRT ($p = 0.05$).

Table 25. Preference of the first instar larva of rice yellow stem borer towards IR 62 plant sprayed with cuticular wax extract of wild rice accessions at booting stage

Oryza species accession/ concentration of cuticular wax extract sprayed on IR 62	Larvae settled after *					
	3 h		6 h		12 h	
	Number	Percentage	Number	Percentage	Number	Percentage
O. minuta (101092) -plant	2.90 a	1.93 (1.55) a	8.35 a	5.57 (2.45) a	9.45 a	6.30 (2.60) a
500 ppm on IR 62	2.80 a	1.87 (1.52) a	8.70 a	5.80 (2.50) a	11.20 a	7.47 (2.81) a
1000 ppm on IR 62	2.95 a	1.97 (1.56) a	8.75 a	5.83 (2.51) a	10.80 a	7.20 (2.77) a
2000 ppm on IR 62	3.05 a	2.03 (1.58) a	7.30 a	4.87 (2.31) a	11.35 a	7.57 (2.83) a
O. officinalis (100948) - plant	2.40 a	1.60 (1.44) a	8.75 a	5.83 (2.51) a	11.00 a	7.33 (2.79) a
500 ppm on IR 62	2.70 a	1.80 (1.49) a	9.50 a	6.33 (2.60) a	10.20 a	6.80 (2.69) a
1000 ppm on IR 62	2.60 a	1.73 (1.49) a	8.75 a	5.83 (2.51) a	10.25 a	6.83 (2.70) a
2000 ppm on IR 62	3.30a	2.20 (1.64) a	8.50 a	5.67 (2.47) a	10.75 a	7.17 (2.76) a
O. punctata (100954) - plant	2.75 a	1.83 (1.51) a	8.35 a	5.57 (2.45) a	10.95 a	7.30 (2.78) a
500 ppm on IR 62	2.70 a	1.80 (1.50) a	8.65 a	5.77 (2.50) a	11.05 a	7.37 (2.80) a
1000 ppm on IR 62	2.60 a	1.73 (1.49) a	7.50 a	5.00 (2.34) a	11.65 a	7.77 (2.86) a
2000 ppm on IR 62	2.70 a	1.80 (1.51) a	7.80 a	5.20 (2.38) a	12.85 a	8.57 (3.00) a
Triton X 100 : Acetone (1:3) control on IR 62	2.60 a	1.73 (1.49) a	8.50 a	5.67 (2.47) a	10.50a	7.00 (2.73) a

* Mean of four replications.
Figures in parentheses are square root transformed values.
In a column, means followed by same letters are not significantly different by DMRT ($p = 0.05$).

4.6.3. Toxicity of cuticular wax extract to first instar larva of yellow stem boer

The survival of the larvae released on IR 62 plants treated with cuticular wax extracted from leaf sheath of resistant wild rices at 2000 ppm concentration was significantly lowered than the survival of larvae in the triton X 100 : acetone (1:3) treated plants (Table 26). The survival was lowest (65.0 %) in *O. officinalis* (100948) cuticular wax 2000 ppm treated plants as against 85.0 per cent in the triton X 100 : acetone (1:3) treated plants 3 days after feeding. After 5 days of feeding, the survival was reduced to 52.5 per cent in plants treated with 2000 ppm of the extract from all the three wild rice accessions *viz, O. minuta* (101092), *O. officinalis* (100948) and *O. punctata* (100954) as against 82.5 per cent in the triton X 100 : acetone (1:3) treated plants.

The deadheart symptom produced in cuticular wax sprayed plants varied significantly. At 2000 ppm concentration, the cuticular wax extracted from the resistant wild rice accessions *O. minuta* (101092) and *O. punctata* (100954) produced significantly less deadheart than IR 62 plants treated with triton X 100 : acetone (1:3) alone. However, at lower concentration the deadheart symptoms produced were statistically on par with the triton X 100 : acetone (1:3) control (Table 26).

Thirty five per cent mortality was observed 3 days after feeding in IR 62 plants sprayed with 2000 ppm of the cuticular wax of *O. minuta* (101092) and 32.5 per cent mortality was recorded in case of *O. officinalis* (100948) and *O. punctata* (100954) cuticular wax extract at 2000 ppm extracted at booting stage (Table 27). However the cuticular wax were not found to influence the larval survival at lower concentrations. After 5 days of feeding, the mortality was increased to 50.0 per cent in *O. officinalis* (100948) cuticular wax sprayed plants at 2000 ppm. After 5 days of feeding, the extracts were found to reduce the survival significantly than the triton X 100 : acetone (1:3) control at 1000 ppm itself.

Table 26. Effect of cuticular wax extract of wild rice accessions on the larval survival and deadheart formation by rice yellow stem borer

Oryza species accession/ concentration of steam distillate sprayed on IR 62	Larval survival (%)*		Deadheart (%)*
	After 3 days	After 5 days	
O. minuta (101092) -plant	42.5 (6.55) e	40.0 (6.34) e	7.5 (13.92) d
500 ppm on IR 62	77.5 (8.83) abc	67.5 (8.24) b	67.5 (55.26) abc
1000 ppm on IR 62	67.5 (8.24) cd	60.0 (7.76) bc	55.0 (47.86) bc
2000 ppm on IR 62	67.5 (8.24) cd	52.5 (7.27) cd	52.5 (46.42) c
O. officinalis (100948) - plant	47.5 (6.92) e	42.5 (6.55) de	7.5 (13.92) d
500 ppm on IR 62	80.0 (8.96) ab	70.0 (8.39) ab	70.0 (56.77) ab
1000 ppm on IR 62	75.0 (8.68) abcd	60.0 (7.76) bc	65.0 (53.76) abc
2000 ppm on IR 62	65.0 (8.09) d	52.5 (7.27) cd	60.0 (50.81) abc
O. punctata (100954) - plant	45.0 (6.74) e	42.5 (6.55) de	5.0 (9.41) d
500 ppm on IR 62	82.5 (9.10) a	70.0 (8.39) ab	62.5 (52.25) abc
1000 ppm on IR 62	75.0 (8.68) abcd	60.0 (7.76) bc	60.0 (50.81) abc
2000 ppm on IR 62	70.0 (8.39) bcd	52.5 (7.24) cd	55.0 (47.86) bc
Triton X 100 : Acetone (1:3) control on IR 62	85.0 (9.24) a	82.5 (9.10) a	72.5 (58.43) a

* Mean of four replications.
Figures in parentheses are arcsine transformed values.
In a column, means followed by same letters are not significantly different by DMRT ($p = 0.05$).

Table 27. Effect of cuticular wax extract of wild rice accessions on the larval survival and whitehead fomation by rice yellow stem borer

Oryza species accession/ concentration of cuticular wax extract sprayed on IR 62	Larval survival (%)*		Whitehead (%)*
	After 3 days	After 5 days	
O. minuta (101092) -plant	40.0 (6.36) d	37.5 (6.13) f	2.5 (4.90) d
500 ppm on IR 62	75.0 (8.68) ab	67.5 (8.24) ab	55.0 (47.86) ab
1000 ppm on IR 62	75.0 (8.68) ab	62.5 (7.93) bc	50.0 (44.98) abc
2000 ppm on IR 62	65.0 (8.09) b	55.0 (7.44) bcd	45.0 (42.10) bc
O. officinalis (100948) - plant	45.0 (6.74) cd	40.0 (6.34) ef	5.0 (9.41) d
500 ppm on IR 62	77.5 (8.82) ab	65.0 (8.06) b	52.5 (46.42) abc
1000 ppm on IR 62	75.0 (8.68) ab	60.0 (7.76) bc	42.5 (40.66) bc
2000 ppm on IR 62	67.5 (8.23) b	50.0 (7.09) cde	37.5 (37.65) c
O. punctata (100954) - plant	50.0 (7.09) c	45.0 (6.74) def	5.0 (9.41) d
500 ppm on IR 62	77.5 (8.82) ab	67.5 (8.23) ab	52.5 (46.42) abc
1000 ppm on IR 62	67.5 (8.23) b	62.5 (7.92) bc	45.0 (42.10) bc
2000 ppm on IR 62	67.5 (8.23) b	55.0 (7.41) bcd	42.5 (40.66) bc
Triton X 100 : Acetone (1:3) control on IR 62	87.5 (9.38)a	82.5 (9.11) a	62.5 (52.25) a

* Mean of four replications.
Figures in parentheses are arcsine transformed values.
In a column, means followed by same letters are not significantly different by DMRT ($p = 0.05$).

The whitehead damage recorded in cuticular wax sprayed plants differed significantly (Table 27). Only 37.5 per cent whitehead was recorded in IR 62 plants sprayed with cuticular wax from *O. officinalis* (100948) at 2000 ppm as against 62.5 per cent in the triton X 100 : acetone (1:3) treated plants.

4.6.4. Contact toxicity of cuticular wax to larva of yellow stem borer

The contact toxicity of cuticular wax assessed by topical application of cuticular wax on 10 day old larvae reared in IR 62 plants 3 and 5 days after application is presented in table 28. No significant difference in the mortality of larvae was observed indicating that the cuticular wax has to be ingested to express the toxicity.

4.7. Effect of feeding on different wild rice accessions on the enzyme activity of yellow stem borer larva

4.7.1. Tillering stage

4.7.1.1. Amylase

The amylase activity was more in the larvae of yellow stem borer when fed on the susceptible check IR 62 (195.2 µg/g of gut tissue). Less activity was detected in the larvae fed on the resistant wild rice accessions with minimum activity on *O. punctata* (100954) at tillering stage with 92.3 µg/g of gut tissue (Table 29).

4.7.1.2. Invertase

The invertase activity expressed in terms of glucose liberated per gram of gut tissue was more in the larvae fed on the susceptible check IR 62 at tillering stage (16.8 µg/g of gut tissue) and less in the larvae fed on the resistant wild rice accession *O. officinalis* (100948)(8.4 µg/g of gut tissue), indicating the nutritional inferiority of the accession.

Table 28. Effect of topical application of cuticular wax extract of wild rice accessions on the larva of rice yellow stem borer

Oryza species accession/ concentration of cuticular wax extract		Extract from plants at tillering Stage*		Extract from plants at booting Stage*	
		Mortality (%) after 3 days	Mortality (%) after 5 days	Mortality (%) after 3 days	Mortality (%) after 5 days
O. minuta (101092) -	500 ppm	2.50 (1.53) a	1.25 (1.12) a	2.50 (1.53) a	0.00 (0 .71) a
	1000 ppm	1.25 (1.12) a	2.50 (1.53) a	1.25 (1.12) a	0.00 (0 .71) a
	2000 ppm	2.50 (1.53) a	2.50 (1.53) a	2.50 (1.53) a	1.25 (1.12) a
O. officinalis (100948) -	500 ppm	1.25 (1.12) a	2.50 (1.53) a	1.25 (1.12) a	1.25 (1.12) a
	1000 ppm	0.00 (0 .71) a	1.25 (1.12) a	1.25 (1.12) a	0.00 (0 .71) a
	2000 ppm	2.50 (1.53) a	3.75 (1.94) a	2.50 (1.53) a	1.25 (1.12) a
O. punctata (100954) -	500 ppm	1.25 (1.12) a	1.25 (1.12) a	1.25 (1.12) a	1.25 (1.12) a
	1000 ppm	0.00 (0 .71) a	0.00 (0 .71) a	1.25 (1.12) a	0.00 (0 .71) a
	2000 ppm	1.25 (1.12) a	1.25 (1.12) a	2.50 (1.53) a	2.50 (1.53) a
Triton X 100 : Acetone (1:3) control		1.25 (1.12) a	0.00 (0 .71) a	2.50 (1.53) a	1.25 (1.12) a

* Mean of four replications.
Figures in parentheses are arcsine transformed values.
In a column, means followed by same letters are not significantly different by DMRT ($p = 0.05$).

Table 29. Effect of the wild rice accessions at tillering stage on the activity of digestive enzymes in rice yellow stem borer

Oryza species	Accession number	Amylase (μg/g of gut tissue)*	Invertase (μg/g of gut tissue)*	Protease (OB units/ g of gut tissue)*	Lipase (activity/ g of gut tissue)*
O. minuta	101092 (R)	120.2	11.3	150.4	438.7
	111126 (MS)	170.4	15.2	206.7	643.2
O. officinalis	100948 (R)	102.8	8.4	122.9	384.9
	101412 (MS)	158.2	12.5	186.3	602.3
O. punctata	100954 (R)	92.3	9.0	103.5	443.1
	101409 (MS)	139.7	13.8	152.6	584.3
O. sativa W 1263	R check	160.9	10.7	125.3	473.6
IR 62	S check	195.2	16.8	278.7	826.4

* Mean of four replications

4.7.1.3. Protease

The activity of protease enzyme ranged from 103.5 to 278.7 OD units/g of gut tissue in the larva fed with different accessions. In case of resistant accessions, there was more than fifty per cent reduction in the protease activity.

4.7.1.4. Lipase

The lipase activity was maximum (826.4 activity/g of gut tissue) in the susceptible check IR 62 which was 215 per cent more than the activity in the larva fed on the resistant wild rice accession *O. officinalis* (100948) and 173 per cent more than the activity in the larvae fed on the resistant check W 1263 (Table 29).

4.7.2. Panicle initiation stage

4.7.2.1. Amylase

The activity of the amylase varied from 76.3 μg/g of gut tissue in the larvae fed on the resistant wild rice accession *O. officinalis* (100948) to 180.1 μg/g of gut in the larvae fed on susceptible check IR 62 at the booting stage. The amylase activity of the larvae was reduced when fed on the resistant accessions (Table 30).

4.7.2.2. Invertase

The invertase activity was less than 10.0 μg/g of gut tissue in the larvae fed on the resistant accessions as against 14.5 in the susceptible check IR 62 indicating the nutritional superiority of IR 62 to yellow stem borer larva (Table 30).

4.7.2.3. Protease

The protease activity was highly reduced in the larva fed on the resistant wild rice accessions which was more pronounced in the larvae fed on *O. punctata* (100954) at the panicle initiation stage (Table 30). The protease activity ranged from 167.8 to 386.8 OD units/g of gut tissue in different accessions tested.

Table 30. Effect of the wild rice accessions at booting stage on the activity of digestive enzymes in rice yellow stem borer

Oryza species	Accession number	Amylase (μg/g of gut tissue)*	Invertase (μg/g of gut tissue)*	Protease (OB units/ g of gut tissue)*	Lipase (activity/ g of gut tissue)*
O. minuta	101092 (R)	108.3	9.2	207.2	627.2
	111126 (MS)	156.4	13.4	310.4	870.4
O. officinalis	100948 (R)	76.3	7.3	182.7	538.7
	101412 (MS)	134.5	11.4	284.3	789.2
O. punctata	100954 (R)	87.4	8.3	167.8	512.6
	101409 (MS)	112.8	12.7	217.2	820.4
O. sativa W 1263	R check	105.7	9.4	212.4	721.7
IR 62	S check	180.1	14.5	386.8	907.6

* Mean of four replications

4.7.2.4. Lipase

A high lipase activity of 907.6 activity/g of gut tissue was observed in the larva fed on the susceptible check IR 62 as against only 512.6 activity/g of gut tissue in the larvae fed on the resistant wild rice *O. punctata* (100954). The lipase activity of the larvae fed on resistant wild rice accessions were greatly reduced indicating their unpalatability (Table 30).

4.8. Plant biophysical characters associated with resistance

4.8.1. Tillering stage

4.8.1.1. Lumen diameter

The lumen diameter among the different accessions tested varied from 2.71 mm in *O. minuta* (101092) to 3.84 mm in *O. officinalis* (100948). The lumen diameter at tillering stage was found to be intermediate in both the resistant check W 1263 (2.82 mm) and susceptible check IR 62 (2.91 mm) indicating that the lumen diameter did not have a significant role in the resistance to yellow stem borer (Table 31).

4.8.1.2. Length of ligule

The length of the ligule was high in the resistant *O. minuta* (101092) (7.3 mm) at the tillering stage. However, it was only 2.8 mm in the resistant *O. officinalis* (100948) which is 1.8 mm less than in the susceptible check IR 62. The resistant check W 1263 had recorded an average ligule length of 5.7 mm at the tillering stage (Table 31).

4.8.1.3. Length of trichome

The mean length of trichome in the leaf sheath of different accessions at tillering stage ranged from 569.7 to 896.2μ (Table 31). Among the accessions, the length of trichome was high in *O. officinalis* (100948) (896.2μ) followed by *O. minuta* (101092) (832.1μ). The trichome was significantly shorter in the susceptible check IR 62 (569.7μ).

Table 31. Plant characters at tillering stage associated with resistance (Mean ± SD)*

Oryza species	Accession number	Lumen diameter (mm)	Length of ligule (mm)	Length of trichome (μ)	Distribution of trichome (No./cm^2)
O. minuta	101092 (R)	2.71 ± 0.18	7.3 ± 0.67	832.1 ± 56.2	312.8 ± 27.6
	111126 (MS)	2.76 ± 0.14	6.4 ± 0.81	791.4 ± 51.7	168.5 ± 21.2
O. officinalis	100948 (R)	3.84 ± 0.22	2.8 ± 0.17	896.2 ± 62.1	190.7 ± 20.8
	101412 (MS)	3.65 ± 0.31	2.2 ± 0.13	828.3 ± 50.2	148.4 ± 19.7
O. punctata	100954 (R)	3.42 ± 0.19	3.4 ± 0.20	821.7 ± 50.2	268.2 ± 20.4
	101409 (MS)	3.61 ± 0.22	2.8 ± 0.21	784.4 ± 48.3	228.5 ± 19.9
O. sativa W 1263	R check	2.82 ± 0.16	5.7 ± 0.48	758.2 ± 47.2	249.5 ± 20.8
IR 62	S check	2.91 ± 0.19	4.6 ± 0.46	569.7 ± 43.8	7.0 ± 2.1

* Mean of twenty observations

4.8.1.5. Distribution of trichome

The distribution of trichome was more in the resistant wild rice accession *O. minuta* (101092) (312.8/cm^2) followed by the resistant wild rice accession *O. punctata* (100954) (268.2/cm^2). In case of the resistant check W 1263, 249.5 trichomes were recorded per cm^2. The trichome distribution was sparse (7.0/ cm^2) in the susceptible check IR 62 (Table 31).

4.8.2. Panicle initiation stage

4.8.2.1. Lumen diameter

The lumen diameter recorded at the panicle initiation stage in different accessions is presented in Table 32. It varied from 2.82 in *O. minuta* (101092) to 3.92 in *O. officinalis* (100948). Lumen diameter was not found to be correlated with resistance to yellow stem borer.

4.8.2.2. Length of ligule

The ligule length varied from 2.6 mm to 7.6 mm at panicle initiation stage among different accessions tested. The length of ligule was found to be influenced by the species of the wild rice. Both resistant and susceptible *O. minuta* accessions had longer ligule where as it was short in *O. officinalis* (Table 32).

4.8.2.3. Length of trichome

The length of the trichome was more in the wild rice accession *O. officinalis* (100948) (891.7μ). It was minimum in the susceptible check IR 62 (528.6) and intermediate (768.2μ) in the resistant check W 1263 at panicle initiation stage. The length of the hair was also influenced by the species of wild rice accessions (Table 32).

4.8.2.5. Distribution of trichome

The number of trichome present per square centimetre varied significantly among accessions tested at booting stage (Table 32). The number of trichome present per cm^2 was 313.2 in the resistant wild rice accession *O. minuta* (101092). The trichome density was very high in the resistant check W 1263 (269.8/ cm^2) compared to the susceptible check IR 62 (16.7/ cm^2).

Table 32. Plant characters at booting stage associated with resistance (Mean ± SD)*

Oryza species	Accession number	Lumen diameter (mm)	Length of ligule (mm)	Length of trichome (μ)	Distribution of trichome (No./cm^2)
O. minuta	101092 (R)	2.82 ± 0.20	7.6 ± 0.78	812.1 ± 52.1	313.2 ± 28.4
	111126 (MS)	2.84 ± 0.26	6.2 ± 0.68	764.2 ± 56.7	179.8 ± 20.2
O. officinalis	100948 (R)	3.92 ± 0.22	2.9 ± 0.21	891.7 ± 67.2	210.9 ± 21.8
	101412 (MS)	3.84 ± 0.28	2.6 ± 0.19	812.4 ± 51.8	169.2 ± 20.6
O. punctata	100954 (R)	3.68 ± 0.32	3.2 ± 0.27	818.2 ± 50.2	287.9 ± 26.7
	101409 (MS)	3.72 ± 0.36	2.9 ± 0.24	768.3 ± 43.8	238.1 ± 22.3
O. sativa W 1263	R check	2.91 ± 0.18	5.4 ± 0.52	768.2 ± 48.4	269.8 ± 28.0
IR 62	S check	3.08 ± 0.24	4.2 ± 0.48	528.6 ± 38.4	16.7 ± 1.8

* Mean of twenty observations

4.9. Biochemical characters associated with resistance

4.9.1. Tillering stage

4.9.1.1. Total nitrogen

The total nitrogen content in the leaf sheath varied from 2.15 to 3.28 at the tillering stage (Table 33). It was low in the resistant wild rice accession *O. minuta* (101092) and high in the resistant wild rice accession *O. officinalis* (100948) and intermediate (2.78%) in the resistant check W 1263.

4.9.1.2. Crude silica

The crude silica content was more in all the wild rice accessions than the susceptible check IR 62. There was more than three fold increase in the silica content in the resistant wild rice accession *O. officinalis* (100948) (5.4%) over the susceptible check IR 62 (1.7%) (Table 33).

4.9.1.3. Cellulose

Among the accessions tested, the cellulose content was more in *O. officinalis* (100948) leaf sheath at tillering stage (512 mg/g) followed by *O. minuta* (101092) (482 mg/g) and *O. punctata* (100954) (460 mg/g). The cellulose content was minimum in the susceptible check IR 62 (298 mg/g). The resistant check W 1263 recorded 438 mg/g of cellulose.

4.9.1.4. Lignin

Maximum acid detergent lignin content of 512 mg/g in the leaf sheath at tillering stage was recorded in the resistant wild rice accession *O. officinalis* (100948). The lignin content in the resistant check (384 mg/g) was lower than that of the resistant wild rice accessions but higher than the moderately susceptible accessions (Table 33).

Table 33. Biochemical constituents of different wild rice accessions

Oryza species	Accession number	Tillering stage*				Booting stage*			
		Total nitrogen (%)	Crude silica (%)	Cellulose (mg/g)	Lignin	Total nitrogen (%)	Crude silica (%)	Cellulose (mg/g)	Lignin
O. minuta	101092 (R)	2.15	4.8	482	489	1.93	5.8	517	547
	111126 (MS)	2.20	2.4	417	362	2.04	3.2	432	406
O. officinalis	100948 (R)	3.28	5.4	512	512	2.92	6.9	537	582
	101412 (MS)	3.12	3.6	438	307	2.76	4.0	472	387
O. punctata	100954 (R)	2.24	4.6	460	467	2.02	5.4	482	515
	101409 (MS)	2.82	3.0	390	344	2.58	3.8	411	409
O. sativa W1263	R check	2.78	4.2	438	384	2.18	5.1	461	432
IR 62	S check	3.21	1.7	298	243	2.74	2.2	318	298

* Mean of four replications

4.9.2. Panicle initiation stage

4.9.2.1. Total nitrogen

The total nitrogen in the leaf sheath of different accessions tested at the booting stage ranged from 1.93 per cent in the resistant *O. minuta* (101092) to 2.92 per cent in the resistant *O. officinalis* (100948). It was 2.18 and 2.74 per cent respectively in the resistant check W 1263 and susceptible check IR 62 (Table 33).

4.9.2.2. Crude silica

The crude silica content was very high (6.9 %) at the booting stage in leaf sheaths of the resistant wild rice accession *O. officinalis* (100948) followed by 5.8 per cent in the resistant *O. minuta* (101092). The silica content was 5.1 per cent in the leaf sheaths of the resistant check W 1263 at booting stage as against only 2.2 per cent in the susceptible check IR 62.

4.9.2.3. Cellulose

The cellulose content recorded at the leaf sheaths of different accessions tested at booting stage is presented in table 33. It was high in the resistant wild rice accession *O. officinalis* (100948) (537 mg/g) and lowest in the susceptible check IR 62 (318 mg/g). The resistant check W 1263 was intermediate with 461 mg of cellulose/gram of fresh leaf sheath.

4.9.2.4. Lignin

The total acid detergent lignin in the leaf sheath of different accessions tested at the booting stage ranged from 298 mg/g in the susceptible check IR 62 to 582 mg/g in the resistant *O. officinalis* (100948) (Table 33). It was 432 mg/g in the resistant check W 1263 and was greater than the lignin content of the moderately susceptible accessions.

4.10. Changes induced in the biochemical constituents due to larval feeding

4.10.1. Total protein

At tillering stage, the protein content of the leaf sheath ranged from 5.6 to 7.6 mg/g among the accessions tested. The protein content was highest in the susceptible check IR 62 (7.6 mg/g) and was least in the resistant accession *O. punctata* (100954) (5.6 mg/g). Infestation by the larva increased the protein content in all the accessions tested. The per cent increase was high in the accession *O. minuta* (101092) (19.35%), followed by *O. officinalis* (100948) (15.00%) and low in the accession *O. minuta* (101126) (6.90%) (Table 34).

The protein content was high (9.6 mg/g) in the leaf sheath of susceptible check IR 62 and low (7.3 mg/g) in the resistant accession *O. punctata* (100954) at the panicle initiation stage. The per cent increase in the protein level due to infestation ranged from 4.17 to 10.96. The increase was found to be more in the resistant accessions than the susceptible accessions.

4.10.2. Total free amino acid

The free amino acid content in the leaf sheath samples of different accessions tested at tillering stage varied from 0.81 to 0.98 mg/g before infestation and 0.92 to 1.06 mg/g, 48 h after infestation (Table 35). The increase in the free amino acid level was more pronounced in the resistant accession *O. minuta* (101092) (13.58%) and least pronounced in the susceptible check IR 62 (8.16%) and intermediate in the resistant check W 1263 (10.84%).

At booting stage, there was an increase in the free amino acid content from the tillering stage. The amount of free amino acid ranged from 1.18 to 1.42 mg/g before infestation. Increase in the free amino acid content due to infestation was maximum in the resistant accession *O. officinalis* (100948) (16.15%) and minimum in the susceptible check IR 62 (9.86%).

Table 34. Changes induced in the protein content in wild rice accessions due to infestation by yellow stem borer

Oryza species	Accession number	Total protein content (mg/g of fresh leaf sheath)*					
		Tillering stage			Booting stage		
		Before infestation	48 h after infestation	Increase (%)	Before infestation	48 h after infestation	Increase (%)
O. minuta	101092 (R)	6.2	7.4	19.35	8.0	8.5	6.25
	111126 (MS)	5.8	6.2	6.90	7.6	8.0	5.26
O. officinalis	100948 (R)	6.0	6.9	15.00	7.7	8.4	9.09
	101412 (MS)	6.4	7.1	10.94	8.0	8.5	6.25
O. punctata	100954 (R)	5.6	6.3	12.50	7.3	8.1	10.96
	101409 (MS)	5.9	6.5	10.17	7.8	8.4	7.69
O. sativa W1263	R check	6.2	6.9	11.29	8.4	8.9	5.95
IR 62	S check	7.6	8.3	9.21	9.6	10.0	4.17

* Mean of four replications

Table 35. Changes induced in the free amino acid content in wild rice accessions due to infestation by yellow stem borer

Oryza species	Accession number	Total free amino acid content (mg/g of fresh leaf sheath)*					
		Tillering stage			Booting stage		
		Before infestation	48 h after infestation	Increase (%)	Before infestation	48 h after infestation	Increase (%)
O. minuta	101092 (R)	0.81	0.92	13.58	1.21	1.38	14.05
	111126 (MS)	0.92	1.00	8.70	1.18	1.31	11.02
O. officinalis	100948 (R)	0.83	0.94	13.25	1.30	1.51	16.15
	101412 (MS)	0.85	0.93	9.41	1.38	1.50	8.70
O. punctata	100954 (R)	0.87	0.96	10.34	1.23	1.37	11.38
	101409 (MS)	0.88	0.95	7.95	1.28	1.39	8.59
O. sativa W1263	R check	0.83	0.92	10.84	1.20	1.38	15.00
IR 62	S check	0.98	1.06	8.16	1.42	1.56	9.86

* Mean of four replications

4.10.3. Total phenols

The total phenol content in the leaf sheath of different accessions at the tillering stage ranged from 2.1 mg/g in the susceptible IR 62 to 2.6 mg/g in the resistant *O. punctata* (100954). The difference in the phenol content was more pronounced two days after infestation with 4.2 mg/g in the resistant *O. punctata* (100954) as against only 2.3 mg/g in the susceptible check IR 62 (Table 36).

At panicle initiation stage, a higher content of total phenol (3.7 mg/g) was recorded in the resistant accession *O. minuta* (101092) as against 2.7 mg/g in the susceptible check IR 62. In the resistant check W 1263, the total phenol content recorded was 3.1 mg/g. Yellow stem borer infestation resulted in an increase in the phenol content among the accessions by 24.32, 16.13 and 7.41 per cent in the resistant wild rice accession *O. minuta* (101092), resistant check W 1263 and susceptible check IR 62 respectively.

4.10.4. Ortho-di-hydroxy phenols (OD phenols)

The resistant wild rice accessions tested had a high amount of OD phenols (Table 37). It was 1.57 mg/g in case of *O. minuta* (101092) and 1.52 mg/g in *O. punctata* (100954). The per cent increase due to the infestation by yellow stem borer was as high as 54.14 and 53.95 per cent in the resistant *O. minuta* (101092) and *O. punctata* (100954) respectively as against only 22.73 per cent in the susceptible check IR 62.

At the booting stage, the OD phenol content varied from 1.62 mg/g in the susceptible check IR 62 to 2.01 mg/g in the resistant wild rice accession *O. minuta* (101092). After infestation, the OD phenol content was increased to 3.26 mg/g in *O. minuta* (101092), where as it was increased to only 1.98 mg/g in the susceptible IR 62. The per cent increase varied from 22.22 to 62.19 with 39.57 in the resistant check W 1263 (Table 37).

Table 36. Changes induced in the phenol content in wild rice accessions due to infestation by yellow stem borer

Oryza species	Accession number	Total phenol content (mg/g of fresh leaf sheath)*					
		Tillering stage			Booting stage		
		Before infestation	48 h after infestation	Increase (%)	Before infestation	48 h after infestation	Increase (%)
O. minuta	101092 (R)	2.4	3.8	58.33	3.7	4.6	24.32
	111126 (MS)	2.3	3.1	34.78	3.2	3.6	12.50
O. officinalis	100948 (R)	2.5	3.9	56.00	3.4	4.2	23.53
	101412 (MS)	2.2	2.7	22.73	3.0	3.4	13.33
O. punctata	100954 (R)	2.6	4.2	61.54	3.6	4.1	13.89
	101409 (MS)	2.3	2.7	17.39	3.5	3.8	8.57
O. sativa W1263	R check	2.2	2.8	27.27	3.1	3.6	16.13
IR 62	S check	2.1	2.3	9.52	2.7	2.9	7.41

* Mean of four replications

Table 37. Changes induced in OD phenol content in wild rice accessions due to infestation by yellow stem borer

Oryza species	Accession number	Total OD phenol content (mg/g of fresh leaf sheath)*					
		Tillering stage			Booting stage		
		Before infestation	48 h after infestation	Increase (%)	Before infestation	48 h after infestation	Increase (%)
O. minuta	101092 (R)	1.57	2.42	54.14	2.01	3.26	62.19
	111126 (MS)	1.52	1.83	20.39	1.92	2.42	26.04
O. officinalis	100948 (R)	1.46	2.18	49.32	1.94	3.08	58.76
	101412 (MS)	1.41	1.80	27.66	1.83	2.53	38.25
O. punctata	100954 (R)	1.52	2.34	53.95	1.97	3.19	61.93
	101409 (MS)	1.43	1.77	23.78	1.91	2.49	30.37
O. sativa W1263	R check	1.43	1.92	34.27	1.87	2.61	39.57
IR 62	S check	1.32	1.62	22.73	1.62	1.98	22.22

* Mean of four replications

DISCUSSION

CHAPTER V

DISCUSSION

The yellow stem borer, *Scirpophaga incertulas* (Walker) is a major pest of rice under all systems of cultivation like irrigated, rainfed and deep water. It attacks the crop from seedling to maturity and accounts for a larger share of crop loss. Use of insecticide against stem borer was prophylactic in nature and often it was found uneconomical since the pest density tends to fluctuate in time and space. Also the practical means of control of borer through insecticide can provide only temporary control, besides they are not ecologically safer. In view of the above problems, the use of resistant varieties in the control of yellow stem borer is receiving increasing attention. The wild rices represent a rich, largely untapped source of resistance to biotic as well as abiotic stresses. Hence, 24 wild rice accessions belonging to *O. australiensis, O. latifolia, O. minuta, O. nivara, O. officinalis* and *O. punctata* were screened for their resistance to yellow stem borer and detailed studies were conducted in selected accessions to understand the mechanism of resistance.

The wild rice accessions tested differed in their resistance to the yellow stem borer. The variation in the levels of resistance occurred even within the accessions of the same species. Among eight *O. minuta* accessions tested, five were resistant at the tillering stage. At tillering stage 14 wild rice accessions were found to be resistant. The maximum score of 5.67 was recorded in *O. nivara*. Differential susceptibility to yellow stem borer within the accessions of same species was earlier reported by Padhi and Prakasa Rao (1978) and IRRI (1981b). Similarly variation in the susceptibility to brown planthopper, *Nilaparvata lugens* (Stal) and whitebacked planthopper, *Sogatella furcifera* (Horvath) within the accessions of same species was reported by Velusamy (1988, 1989). The variation may be due to change in the genetic make up of the accessions which originated from different countries.

The wild rice accessions *O. minuta* (101092), *O. latifolia* (101443) and *O. officinalis* (100948) were found to be highly resistant at tillering stage and *O. australiensis* (103318) and *O. officinalis* (100948) were found to be highly resistant at panicle initiation stage. These accessions were reported to be resistant to yellow stem borer by earlier workers (IRRI, 1981a; Heinrichs *et al.*, 1985a; Khan *et al.*, 1991).

Of the eight accessions of *O. minuta* tested, five were found resistant at tillering stage, whereas only one was found resistant at panicle initiation stage. Similar observation was recorded among different accessions of *O. latifolia* and *O. punctata* as well. Differential susceptibility to yellow stem borer at tillering stage and panicle initiation stage was earlier reported by many workers in *O. sativa* cultivars. Singh and Pandey (1997) screened 41 accessions for resistance to yellow stem borer and found 6 accessions resistant at tillering stage and only one accession resistant at heading stage. The findings are in conformity with the findings of earlier workers (Pathak, 1964; Mathur and Chaturvedi, 1978; Srivastava, 1979; Chandramohan and Chelliah, 1983; Mann and Shukla, 1999) who reported that accessions resistant to yellow stem borer attack at vegetative stage are not necessarily resistant at heading stage. Observation at IRRI (Pathak *et al.,* 1971) during different seasons showed that some varieties resistant at the tillering stage were susceptible at the heading stage. These results indicated that resistance at tillering and heading stages is independent (IRRI, 1964) and the resistance may be controlled by minor gene (s) (Dutt *et al.*, 1980).

The percentage of weight gained by yellow stem borer larvae after 3 days of feeding on the callus of resistant accessions was significantly low compared to that fed on the susceptible accessions (Fig.1). The weight gained on the callus of resistant *O. minuta* (101092) was only 14.72 and 30.34 per cent as against 41.24 and 82.42 per cent on the callus of susceptible IR 62. The result obtained suggests that the callus can be utilised as

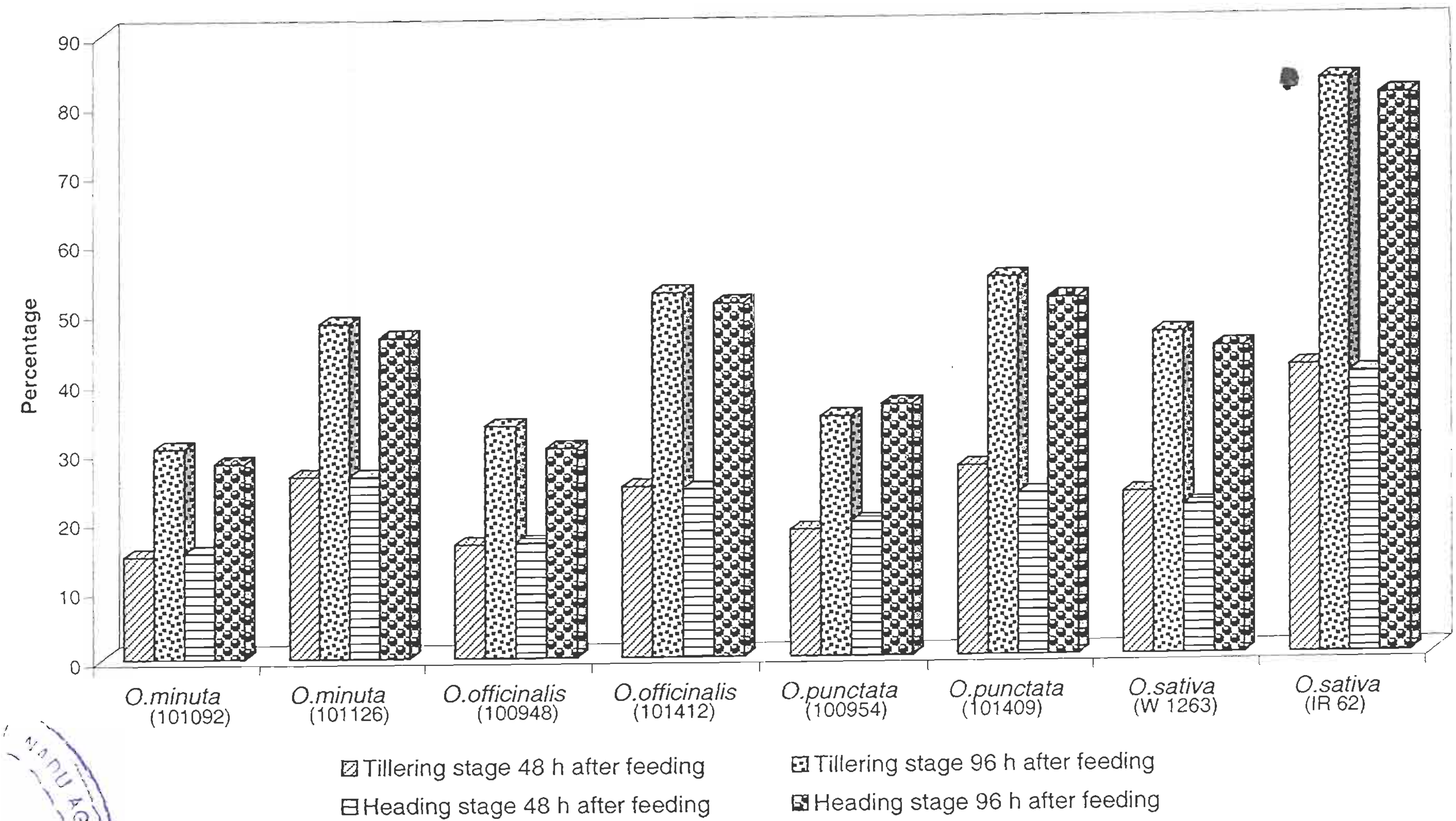


Fig. 1. Weight gained by yellow stem borer larvae on callus of different wild rice accessions

a tool for evaluating resistance to yellow stem borer. Williams *et al.* (1983) screened the callus of various genotypes of corn against south western corn borer, *Diatrea gradisella* (Dyer). Smaller larvae developed on calli of those genotypes which had relatively higher level of field resistance to leaf feeding when infested at whorl stage or to stalk tunneling when infested at anthesis. Similar trend in larval weight of fall armyworm on callus initiated from resistant and susceptible corn hybrids were observed by Williams *et al.* (1985). Caballero *et al.* (1988b) reported that yellow stem borer larvae failed to survive on the callus of resistant *Oryza ridleyi*, while development was normal on the callus of susceptible Rexoro.

In the present study, no significant differences were observed in the number of egg masses laid on accessions with varying levels of resistance in choice test. Khan *et al.* (1991) also reported that differences in nonpreference for oviposition by *S. incertulas* are not distinct in screen house tests. Manwan (1975) reported that the plant characters had no influence on the ovipositional preference by yellow stem borer moths. Islam (1991) reported that the leaf blade width and foliar colour had no effect on the preference of the moths but tall denser canopies attracted the female moths. Wicklund (1974) opined that even in monophagous insects, larval food suitability and adult ovipositional preference are determined by different gene complex leading to different behavioural drives and responses. This may be the possible reason for the ovipositional nonpreference of the moths. In studies on preference of yellow stem borer moths for shelter and oviposition, Prakasa Rao (1983) concluded that the gravid females of *S. incertulas* could and did oviposit normally even in the absence of a rice plant and on any other plant or nonplant surface, the relative nonpreference of moths for shelter and / or oviposition is therefore considered unstable for utilisation in resistance breeding.

No significant difference was observed in the number of larvae oriented towards different accessions in free choice test. The reason may be the absence of any volatile chemicals that attracts the larvae or the inability of sensory organs in the neonate larvae to discriminate the volatiles from the plants.

The percentage of larvae that successfully extended the lumen of the stem varied significantly among the different accessions tested (Fig.2). Similar observation was recorded by Chandramohan (1983), who concluded that the longer and denser spicule might have interfered with the initial larval establishment. The reason for the lower percentage of the larval entry may be due to the physical barriers like long and dense trichomes, increased deposit of silica in the hypodermis and the presence of more lignified tissues present in the resistant varieties which is evident from the present study by the increased trichome length and density as well as high silica and lignin content in the resistant accessions.

The larval period was extended more than 10 days in the resistant wild rice accession than the susceptible IR 62. The larval and pupal weights were greatly reduced when fed on the resistant wild rice accessions. Only less than 10 per cent of the larvae inoculated developed into adult as against nearly 70 per cent in the susceptible accessions. The adults emerged from the resistant accessions were undersized, weighing less than half of the adults emerged from susceptible accessions. The short lived adults emerged from the resistant accessions laid smaller egg masses containing lesser number of eggs. These observations indicate the operation of antibiosis mechanism of resistance in the accessions tested.

The larvae and pupae reared on IR 62 had higher weight than those reared on the resistant accessions (Fig.3) and the difference in weight gained was more evident even at 10 days after release. The larval weight after 30 days of feeding was only 33.24 mg

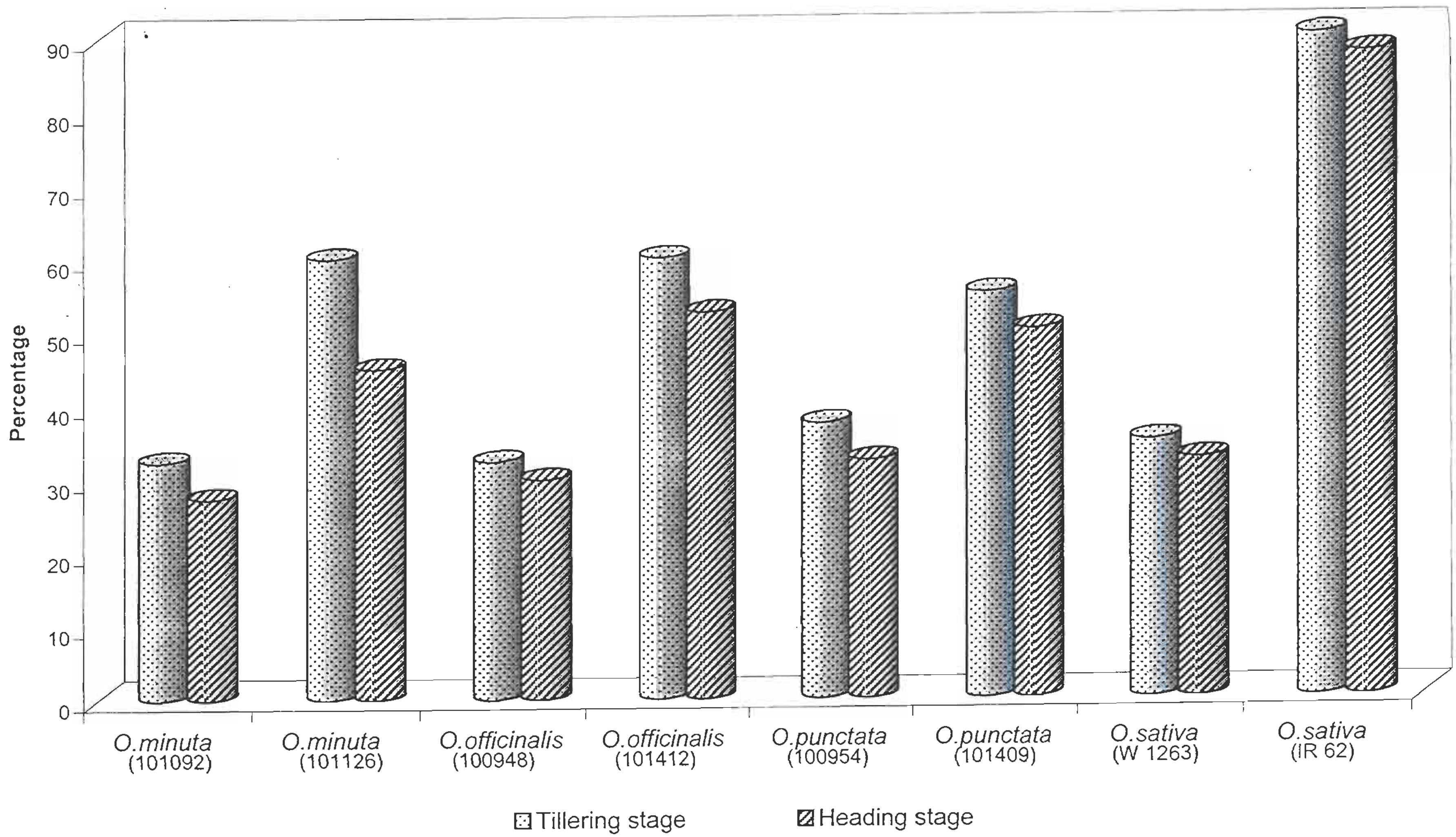


Fig. 2. Percentage of yellow stem borer larvae entered the lumen of different wild rice accessions

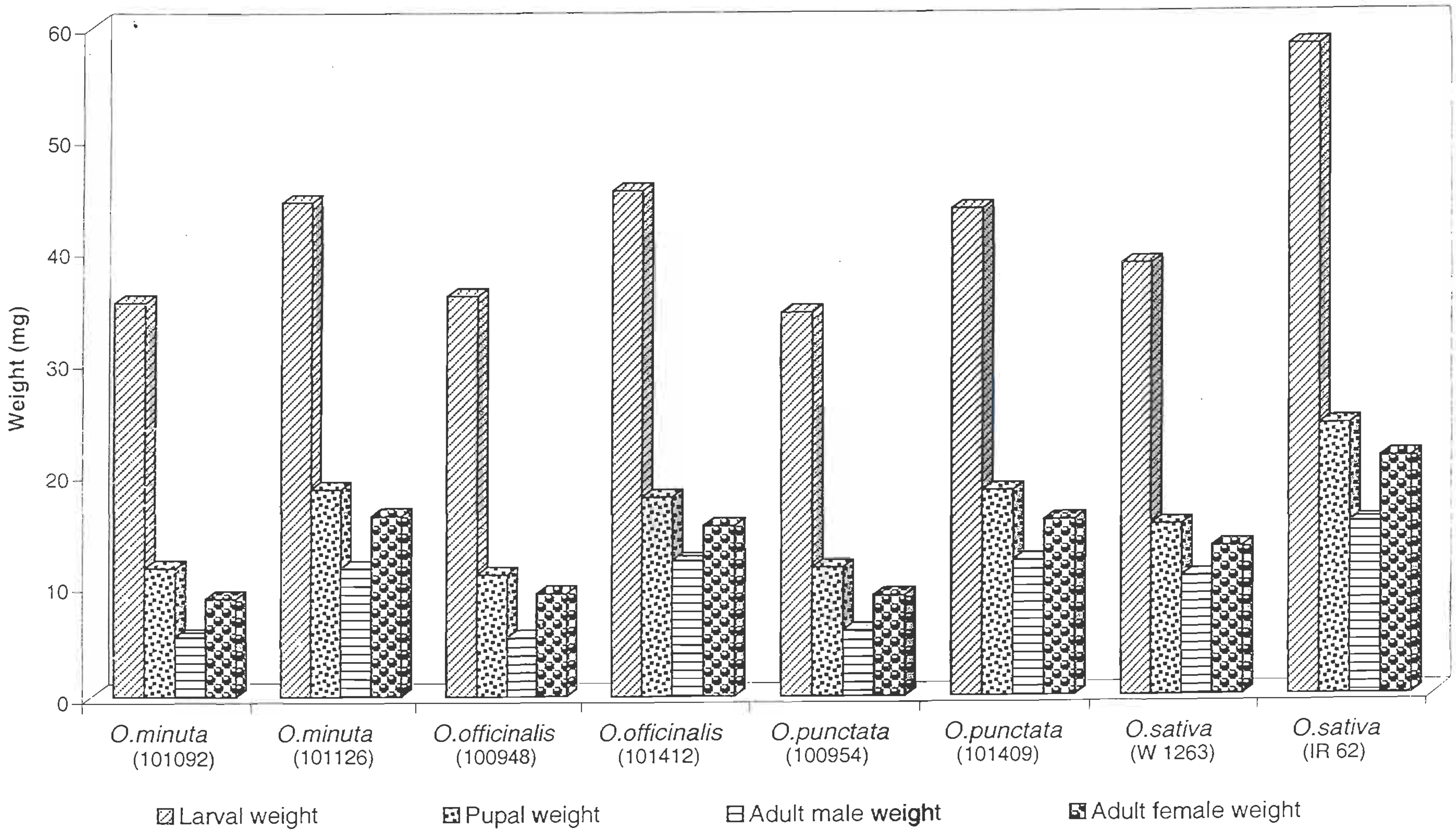


Fig. 3. Larval, pupal and adult weight of yellow stem borer developed from different wild rice accessions

on the resistant *O. latifolia* (101443) as against 58.12 mg in the susceptibe IR 62 at tillering stage. Similar weight gain of larvae in susceptible accessions were earlier reported by Pathak *et al.* (1971), Manwan and Vega (1975), Oliver and Gifford (1975) and CRRI (1976). Riaz *et al.* (1993) observed lower larval weight when fed on TKM 6 and Basmati 385 and concluded that antibiosis mechanism present in these varieties against yellow stem borer. Panda *et al.* (1975) reported that larvae were unable to utilise the starch of resistant plant because of the high silica content and low nitrogen level besides the thick stem with large lumen size aided the easy larval movement and provided more food by way of loose packing (Israel, 1967; Manwan, 1975; Catling and Islam, 1982).

Much of the food eaten by insects during larval stage was converted into fat or transferred to adult and converted into protein and lipid of the developing eggs (Gilmour, 1965; Matthews and Matthews, 1978). The transfer of lipid from immature stage to adult was poor in the resistant accessions and hence the adult females and males also weighed less. It is evident from the present study, the enzyme activities were very low when the larvae fed on the resistant accessions.

The larval and pupal periods were extended in resistant wild rice accessions (Fig. 4). The larvae took 46.2 days to pupate in the resistant wild rice accession *O. minuta* (101092) at tillering stage as against only 35.3 days in the susceptible IR 62. The increased developmental period in the resistant accessions might be attributed by the reduced activity of the larval digestive enzymes like amylase, invertase, protease and lipase observed when reared on the resistant accessions in the present study. The reduction in growth rate of the lepidopteran larvae observed in cotton by Ananthakrishnan *et al.* (1994) indicated that on the least preferred cultivar, reduction may be due to a lesser amount of proteins as well as reduced protease activity compared to the most preferred one. As a result of reduced protease activity, decrease in larval growth rate was observed. Intake of a protein

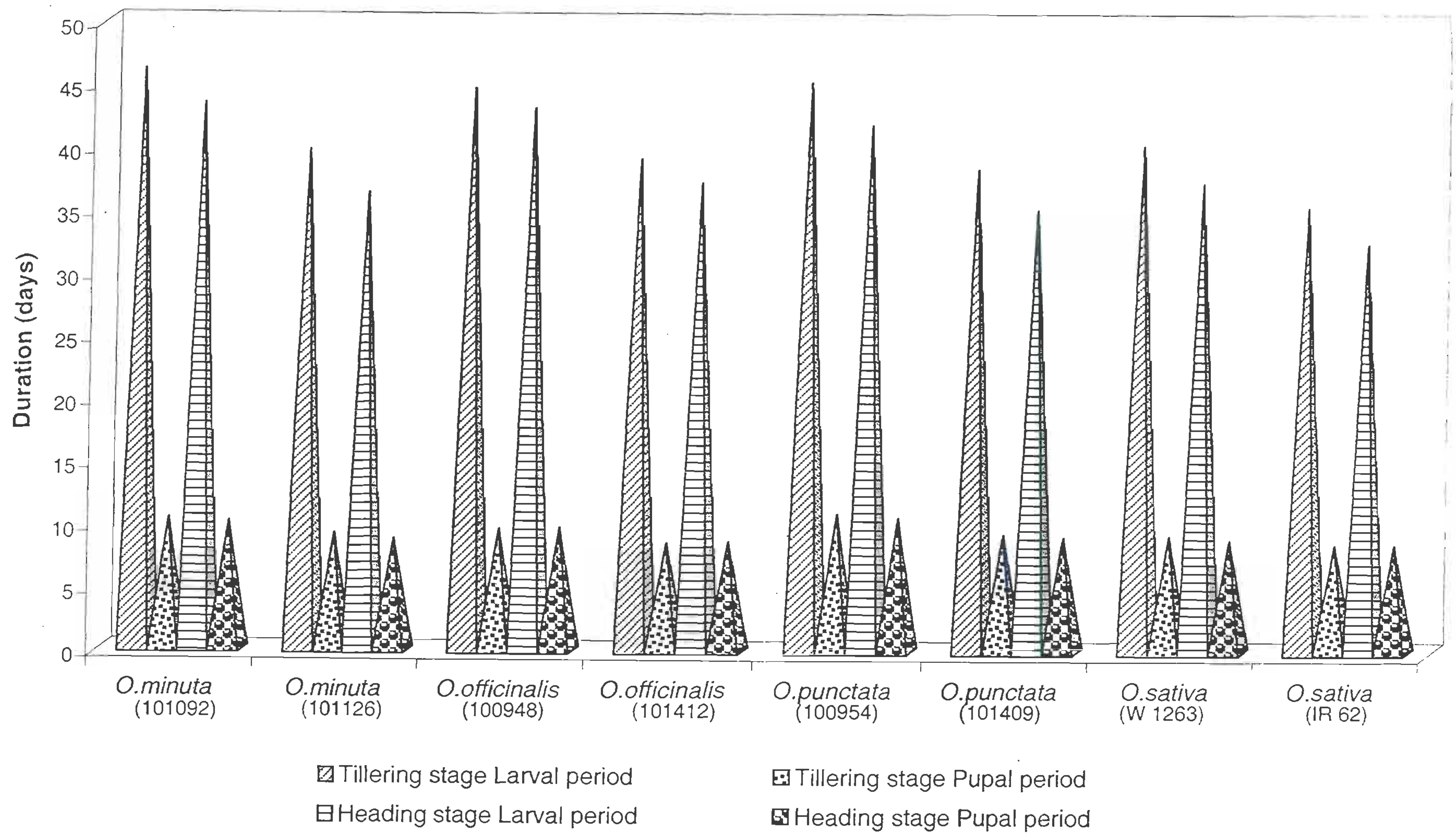


Fig. 4. Larval and pupal period of yellow stem borer developed on different wild rice accessions

rich diet influences the protease activity. Ishaaya *et al.* (1971) had shown that reducing protein content in an artificial diet from 7.6 to 3.6 per cent resulted in decrease of 75 per cent of proteolytic activity of the midgut wall with a similar decrease in larval weight. Varying levels of plant chemicals present in different cultivars have an impact on the performance of insect through enhancing or decreasing the digestive enzyme activity in the gut, which ultimately affects the assimilation efficiency, growth and subsequent allocation for reproduction (Ananthakrishnan *et al.*, 1994). Marwat (1992) observed increased larval period in IR 198007 - 21-2-2, a resistant variety compared with that of Basmati - 370, a susceptible variety and concluded that the antibiosis is the mechanism of resistance present in this variety against the attack of yellow stem borer.

The presence of antibiosis in some resistant varieties as demonstrated in feeding experiments was expressed in low survival and low growth rate of larvae (Pathak, 1964). Pathak *et al.* (1971) reported that resistant varieties lack a resistance factor in the apical portion of stem at heading and thus show high whiteheads. At 20-25 days after hatching, which is the usual growth duration of larvae on suitable hosts, larvae from susceptible varieties weighed almost twice as much as those reared on resistant varieties. Differences in pupal weight were also of same magnitude. Furthermore, the rate of larval growth was faster on susceptible varieties and pupation reached 69% in 30 days after infestation. On resistant varieties, only 20% had pupated 40 days after infestation (IRRI, 1964). In the present study also, only less than 10 per cent of the larvae developed into adults in the resistant wild rices as against nearly 70 per cent in the susceptible IR 62 (Fig. 5). The reason for the lower survival may be due to the difficulties encountered by the larvae in boring into the lumen as evidenced by lower percentage of larva entering the lumen of the resistant accessions in the present study or the presence of antibiotic compounds which may hinder the growth of the developing larvae.

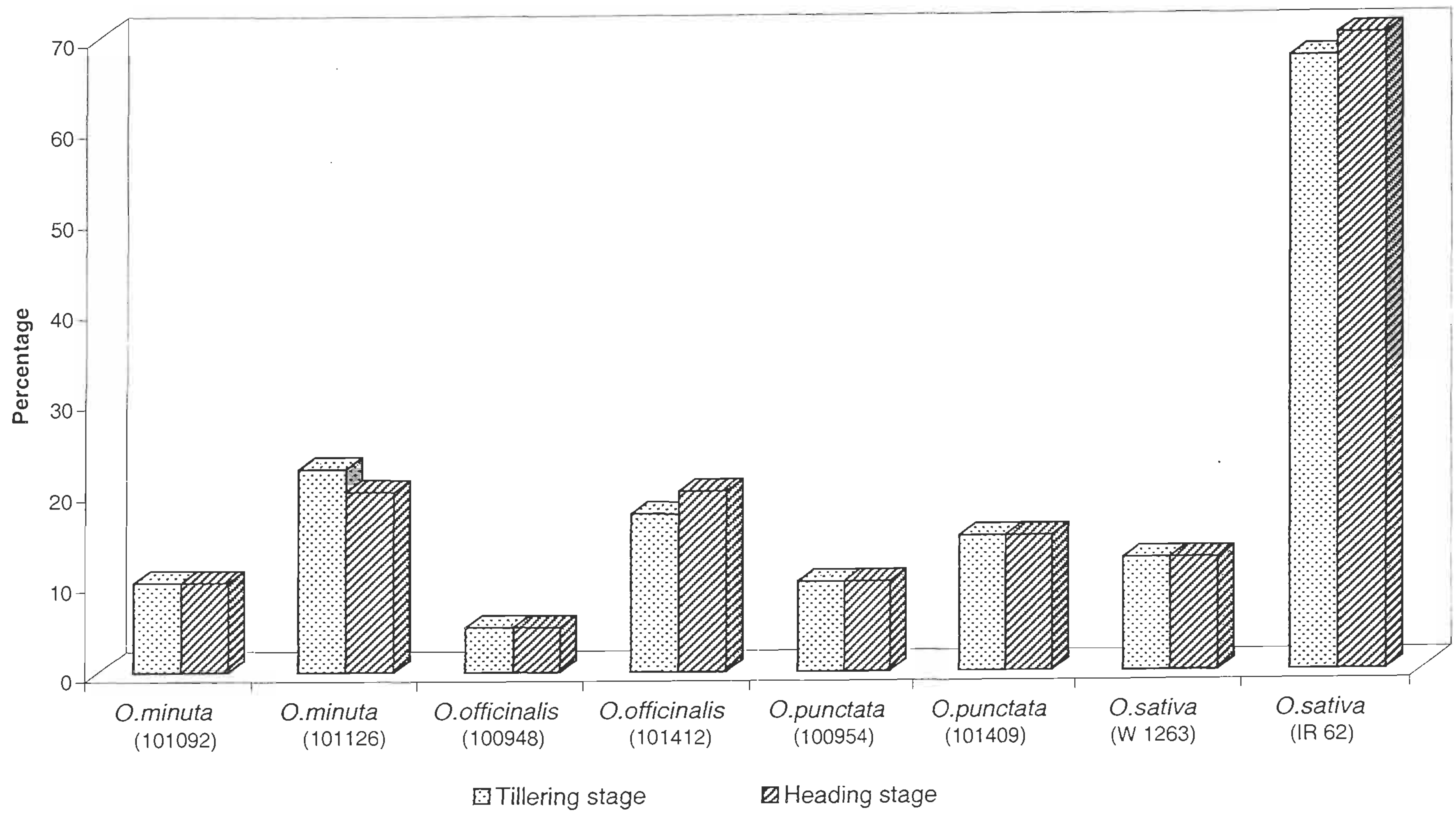


Fig. 5. Percentage of adult emergence from different wild rice accessions

Retardation of larval growth during feeding on resistant variety has also been reported from India (AICRIP, 1969). The use of a leaf-factor in a synthetic diet for striped stem borer hindered the larval development (Ishii *et al.*, 1962). In subsequent studies benzoic acid, salicylic acid and some fatty acids isolated from a resistant rice plant showed growth inhibitory effects on stem borer larvae (Munakata and Okamato, 1967). The variety TKM 6 showed highest antibiosis followed by MR 1526, Ptb 18 and RPW 6-13 where as W 1263, ARC 10443 and Ratna showed moderate degree of antibiosis in so far as the larval survival in different varieties was concerned (Padhi and Chatterji, 1985). Mishra *et al.* (1990) recorded lower larval length and larval weight on resistant as compared to susceptible varieties. Prakasa Rao (1983) observed antibiosis in varieties Ptb 18 and CR 44-98. Antibiosis has also been reported in wild rices. Padhi and Prakasa Rao (1978) observed that *O. tisseranti, O. ridleyi, O. perreiri, O. officinalis* and *O. minuta* were highly antibiotic in nature to yellow stem borer, either killing the larvae or preventing them from establishing inside the tillers.

The number of egg masses laid and the number of eggs present per egg mass was highly reduced in the adults developed from resistant accessions in the present study. The adult yellow stem borer moths has atrophied mouth part and no feeding was observed. The food eaten by the larval stage was converted into fat and transferred to adult and converted into protein and lipids of the developing eggs. The presence of some factors in the resistant accessions which hindered the normal feeding and assimilation of food and reduced the digestive enzyme activity might lead to decreased resource of food materials in the small females emerged from resistant accessions. This might be the reason for the decreased fecundity from the females emerged from resistant accessions.

The digestive enzyme activity was highly reduced in the larvae fed on the resistant accessions. The amylase, invertase, protease and lipase activities were more than 200 per cent in the gut of the larvae fed on the susceptible IR 62 than the larvae fed on the resistant *O. officinalis* (100948) (Fig.6). The significant positive correlation was observed between the enzyme activity and the level of infestation. In general, soluble carbohydrates and proteins are very efficiently utilised by the insect and most of the species desired the largest share of their nourishment from these nutrients (Ishaaya *et al.*, 1971) while the utilisation of these nutrients from the available food plants depends on the digestive enzymes. According to Hori (1969) certain plant compounds can activate or inhibit digestive enzymes, and the later in turn affect digestion and food utilisation.

The reason for the reduced enzyme activity may be due to the absence of phagostimulant or presence of some inhibitory compounds. Ananthakrishnan *et al.* (1994) observed that the enzyme activity in *Helicoverpa armigera* (Hubner) varied with different varieties of cotton. They also observed increase in the amylase, invertase, protease and lipase activity of *Spodoptera litura* Fab., *Earis vittella* Fab. and *Pectinophora gossypiella* (Saunders) larvae fed on the bolls of susceptible varieties of cotton. A significant positive relationship between concentrations of nutrients in the cultivars such as carbohydrates, proteins, lipids and activity of digestive enzymes such as intertase, amylase, sucrase, protease and lipase was obtained for the species studied, suggesting that the level of certain vital nutrients was important for larval growth which is enhanced by the efficient activity of these digestive enzymes upon their substrate.

Eventhough the steam distillate extract did not have any effect on the oviposition preference by the adult female moths and the orientation response of the first instar larvae, they are found to be toxic to the first instar larvae. High mortality was observed even 3 days after feeding by the first instar larvae on the susceptible IR62 plants sprayed with the extract from resistant accessions. This may be due to decreased feeding in the plants sprayed with extract. Ekambaram (1994) observed significant reduction in the leaf area consumed by the larvae of *Cnaphalocrocis medinalis* (Guenee) on plants of TN 1 treated with extracts of resistant *O. brachyantha.* He also observed that the food

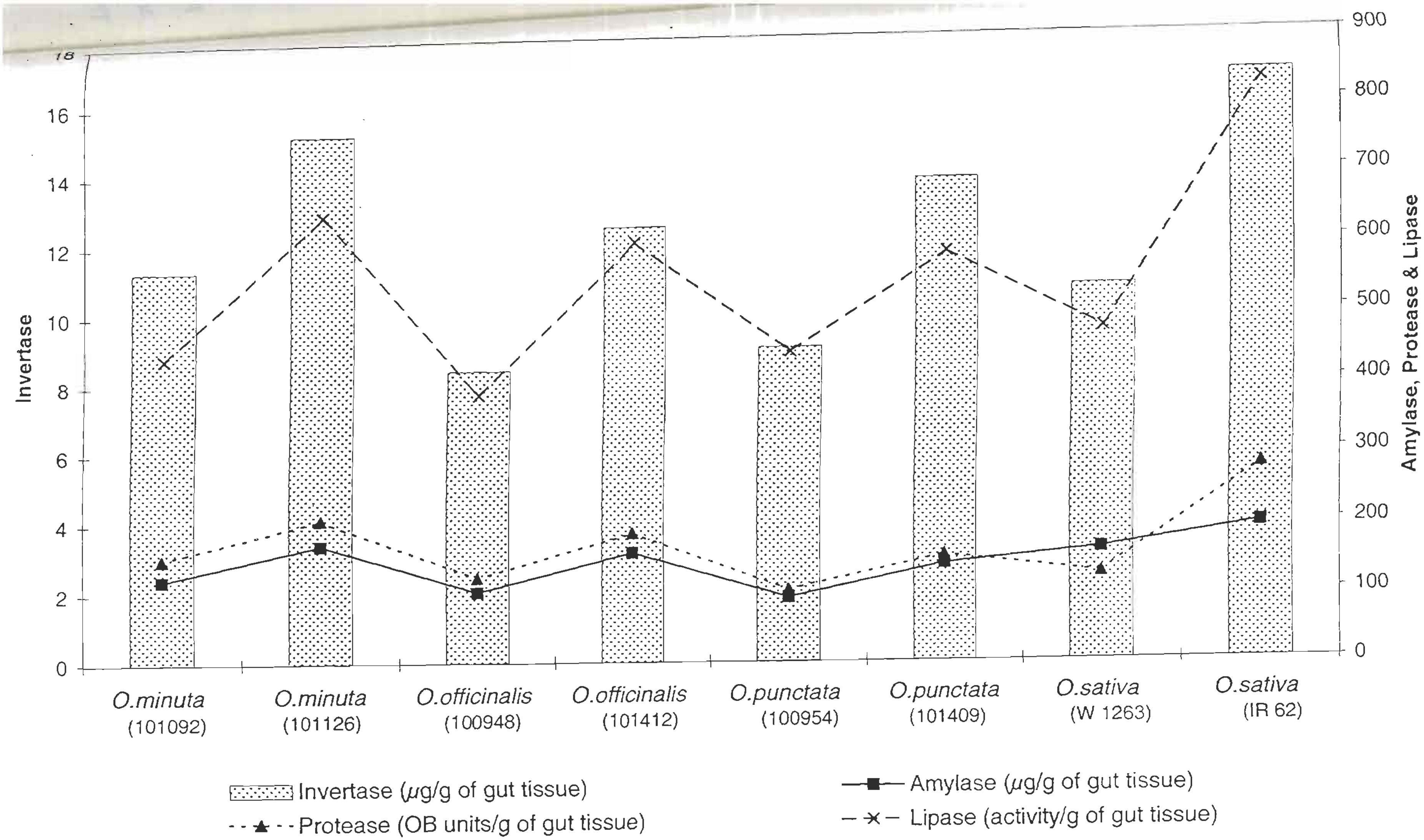


Fig. 6. Enzyme activity in the larvae of yellow stem borer fed on different wild rice accessions

ingestion and assimilation of larvae were higher in untreated plants of TN 1 than in the TN 1 plants treated with extracts of resistant wild *O. brachyantha*. Saxena and Okech (1985) observed significantly high mortality of first instar nymphs of *N. lugens* in TN 1 plants treated with extract of plants of the resistant varieties and concluded that the effect was due to the allelochemical present in the resistant varieties.

Mohite (1995) reported the toxicity of steam distillate extract of wild species of *Gossypium viz., G. raimondii, G. anomalum* and *G. davidsonii* to the neonate larvae of *Holicoverpa armigera* and concluded that the extracts may have higher concentration of allomones. Similar results were reported when steam distillate extracts of wild rice *Oryza officinalis* and *O. punctata* were treated on susceptible TN 1 variety against *C. medinalis* (Medina and Tryon, 1986; Velusamy *et al.,* 1990).

Eventhough, the exact identity of allelochemics in the resistant accessions was not known, the methodology of extraction suggests that a large group of compounds such as essential oils, particularly terpenoids, low molecular weight alcohols, aldehydes, fatty acids, esters, waxes etc., may be extracted (Bianchi *et al.*, 1979; Robinson, 1983).

Topical application of the extract to the larvae of yellow stem borer was not found to be toxic. Similar observation was recorded by Ekambaram (1994) in case of rice leaffolder, *C. mdeinalis*. The observation suggest that the allelochemical present in the extract has to be necessarily ingested to express toxicity.

The plant surface with which an insect pest first comes in contact plays an important role in insect plant interactions. Many herbivorous insects seem to be attracted to their potential host plant by visual, olfactory or tactile stimuli based on the physical and chemical characteristics of plant leaf surface. Leaf surface wax can affect insect behaviour such as orientation, movement, oviposition and feeding. However, the leaf cuticular wax extracts of resistant wild rice accessions do not have any influence on the ovipositional preference of the female moths and the orientation preference by the first instar larvae of yellow stem borer. However, at high concentration (2000 ppm) the extract of the resistant wild rice accessions sprayed on susceptible IR 62 caused significant mortality of neonate larvae of yellow stem borer. Mohite (1995) observed similar effect on neonate larvae of *H. armigera* by the leaf surface wax extract of wild species of *Gossypium*.

Insects possess intimate and subtle relationship with their host plants. Several studies have demonstrated the importance of plant chemical factors in determining the susceptibility or resistance of rice varieties to insect pests (Khan and Saxena, 1985; Saxena and Okech, 1985, Khan *et al.*, 1988).

Generally, antibiosis between crop plants and insect pests appeared to be due to the differences in chemical constituents of the plant (Pathak, 1975). Analysis of biochemical composition would help to understand why the accessions are differentially damaged and the causes of resistance.

There was not much difference in the total nitrogen content in the leaf sheath between resistant and susceptible accession and no significant correlation was obtained between the nitrogen content and the level of stem borer infestation.

Israel and Kalode (1966) and Saroja and Raju (1981) attributed low nitrogen content as the resistance factor for yellow stem borer. Chandramohan (1983) reported that the accession IR 13641-4 with high nitrogen content was equally resistant as that of CO 18 which had low nitrogen content. Though nitrogen content may influence the succulency of tissues, in the modern crop production technology, none of the high yielding varieties prove productive without proper nitrogen management. Hence, we cannot involve in a breeding programme incorporating low nitrogen response in view of resistance to stem borer, since it may result in decreased yield potential.

Norris and Kagon (1980) reported that deposition of cellulose and lignin as one of the resistant factors for stem borers. However, Chandramohan (1983) reported that few susceptible accessions had high cellulose and lignin content and vice versa with the resistant accessions. In the present study, the cellulose and lignin content at both vegetative and heading stage were more in resistant accessions (Fig.7 and 8) and were negatively correlated with the level of yellow stem borer infestation.

Lignins are phenolic polymers present in the cell walls of plants which are responsible together with cellulose, for the stiffness and rigidity of plant stems. Lignin acts as a physical barrier against invading pests and pathogens (Sadasivam and Manickam, 1996). Pathak (1964) and Israel (1967) also reported that stems with lignified scelrenchyma tissues were found to be resistant to stem borers of rice. Penetration of the stem and feeding of larvae were impaired by the structural characters of the plant. Accessions with thick layers of scelrenchymatous hypodermis or lignified tissues next to epidermis apparently resisted the larval boring (Van and Guan, 1959; Israel *et al.*, 1961).

In rice stem, the silica is localised mostly in hypodermis, the sclerenchymatous tissue and all along the cell walls of the parenchyma (IRRI, 1966). Accessions with high silica content had more silica cells in the hypodermis and the number of silica cells was negatively correlated with the percentage of deadheart produced (Djamin and Pathak, 1967). The resistance of wild rice accessions, *O. officinalis* (100948), *O. minuta* (101092) and *O. punctata* (100954) observed in the present study might be attributed due to the high percentage of crude silica, 2 to 3 fold more than the susceptible IR 62 (Fig.9). The role of silica content in imparting resistance to rice stem borers have been reported by earlier workers (Sasamoto, 1961; Pathak *et al.*, 1971; Subbanna (1971); Panda *et al.* 1975; Subba Rao and Perraju, 1976). Marwat and Baloch (1985) also observed a significant negative correlation with silica content and infestation by yellow stem borer.

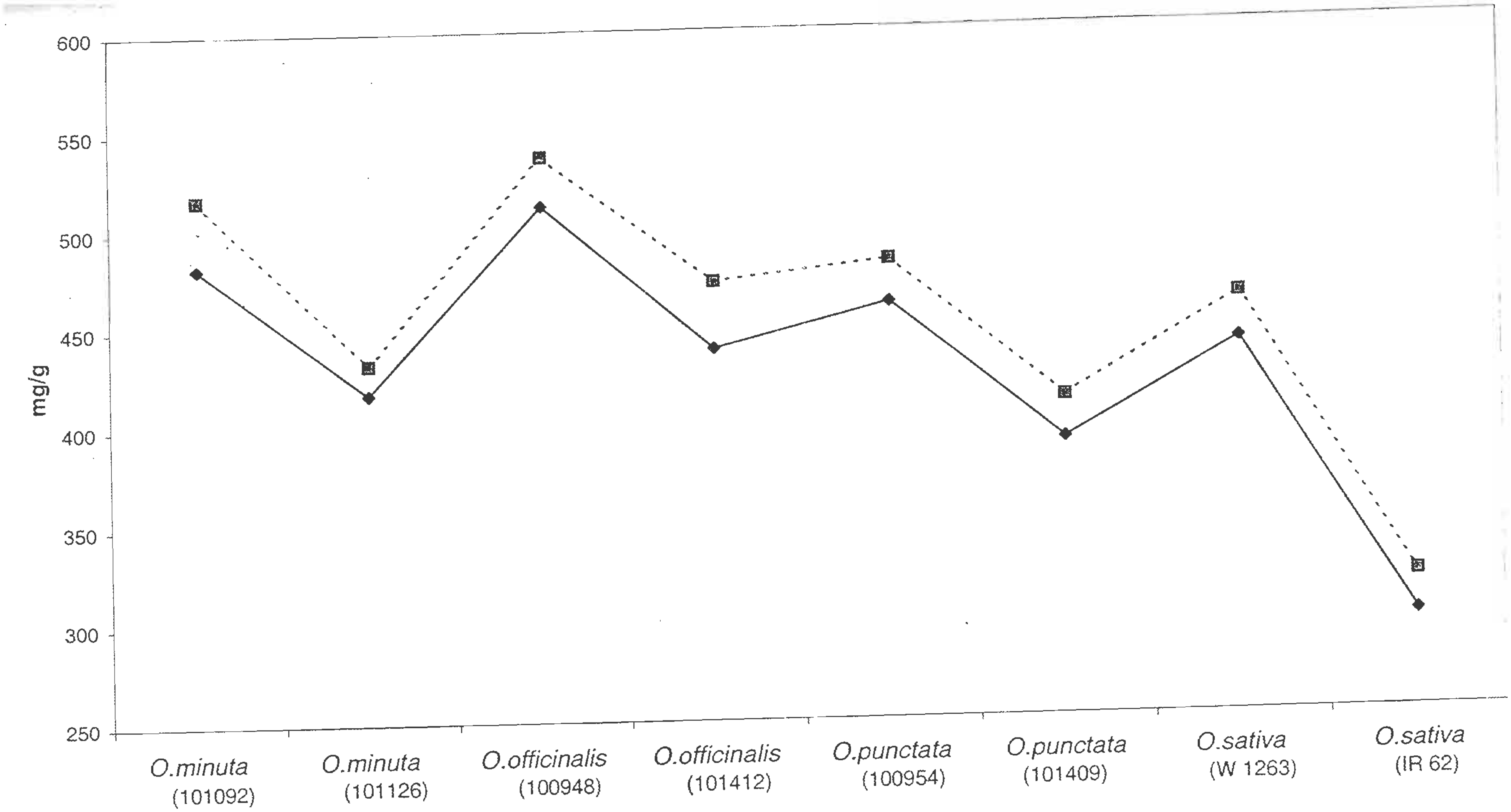


Fig. 7. Cellulose content of different wild rice accessions

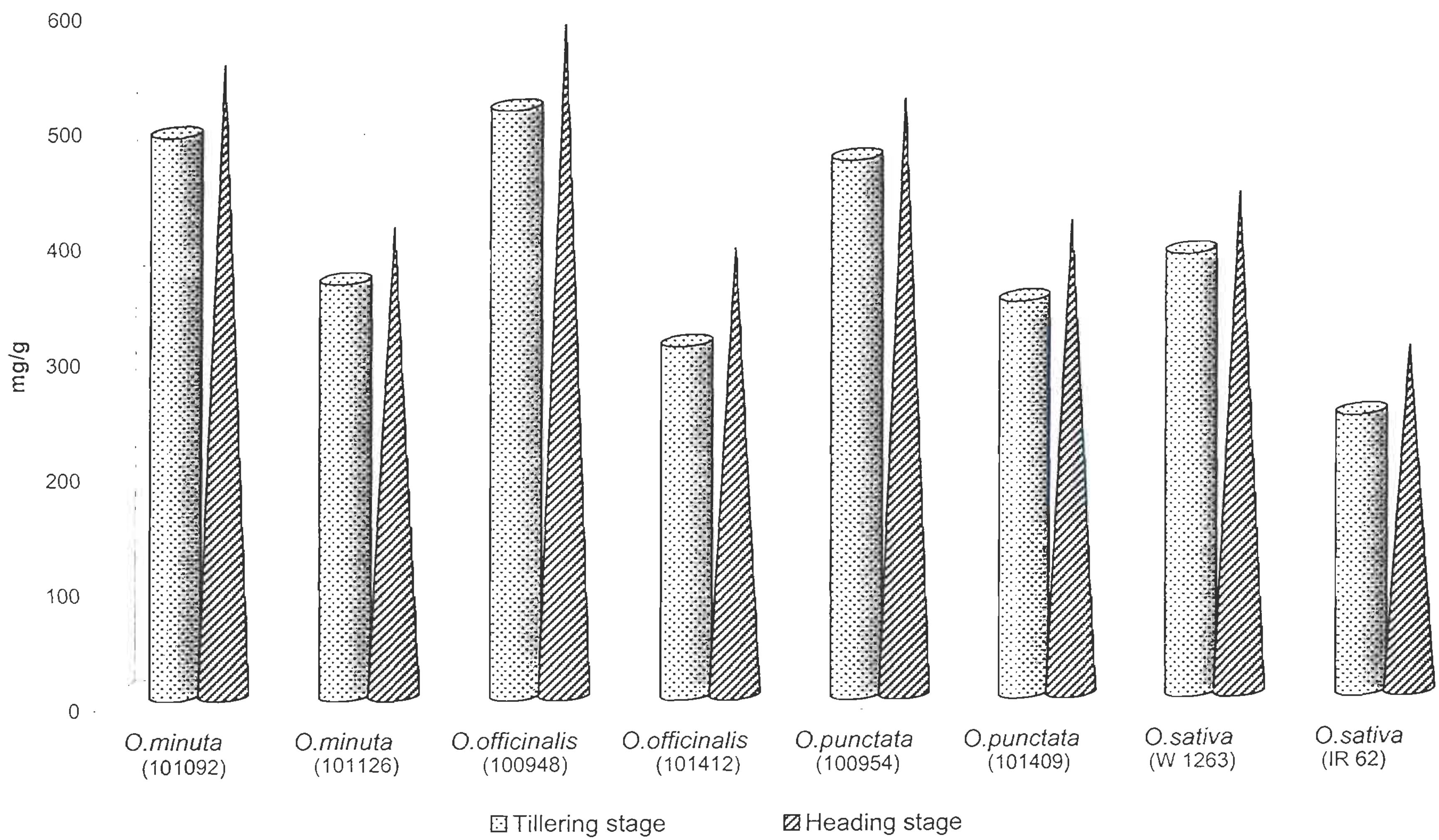


Fig. 8. Lignin content of different wild rice accessions

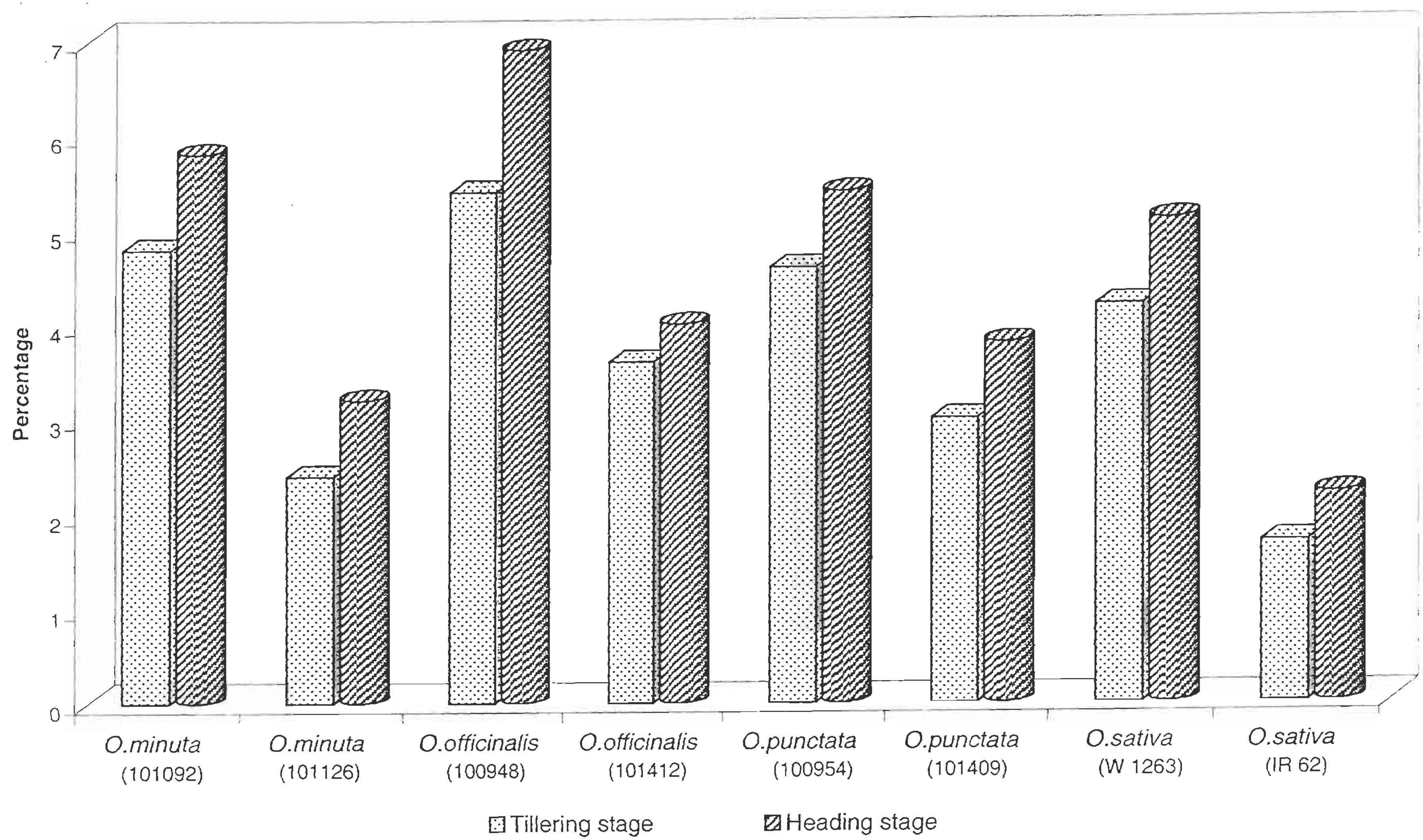


Fig. 9. Silica content of different wild rice accessions

The high silica content in the resistant accessions adversely interfered with larval feeding. The mandibles of the larvae that fed on the resistant *O. officinalis* (100948) with high silica content had worned out mandibles. Earlier, observations of mandibles of larvae feeding on the variety Yabami Montakhab, which has a high silica content (Hashida, 1964; Pathak *et al.*, 1971) confirmed that high silica content interfered with larval feeding. The mandibles of larvae feeding on Yabami Montakhab were worn-out, where as those of larvae feeding on the variety Sapan Kwai, which has a low silica content, were normal. Larvae with worn-out mandibles have low feeding efficiency and suffer high mortality (Sasamoto, 1961; Djamin and Pathak, 1967; Subba Roa and Perraju, 1976). Many of the larvae died without being able to bore inside the stems unlike the larvae on varieties with low silica content. In the present study also only about 30 per cent of the larvae entered the lumen of the resistant *O. officinalis* (100948) with high silica content as against around 90 per cent larvae entering the lumen of the susceptible IR 62 with low silica content.

In the rice stem, silica is deposited mostly in the epidermis, sclerenchymatous tissues, vascular bundle sheath and along the cell walls of the parenchymatous tissues. In the epidermis, it is primarily contained in silica cells. Generally, varieties with higher silica content had more silica cells in the epidermis and a negative correlation between the number of silica cells and percentage of deadheart caused by borers was recorded. A large number of silica cells in the epidermis might inhibit larvae from boring into the stem, whereas silica in other tissues might interfere with their feeding after they have entered the lumen (IRRI, 1965). As in the present study, a negative correlation between silica content and larval weight and silica content and deadheart was reported by Subba Rao and Perraju (1976). The silica cells in rice stems occur in numerous shapes: dumbbell, oblong, round, cubical and oryza type which show variations in form, from a compressed dumbbed to nearly cubical, but the vertical axis is always longer than the horizontal axis. In the resistant variety Yabami Montakhab, silica cells were of oryza type and densely distributed.

In the susceptible variety Sapan Kwai, the silica cells were oblong and sparsely distributed. In *O. ridleyi* which has been recorded as highly resistant to borers, they were large, dumbbell-shaped and densely distributed (IRRI, 1965).

Studies on the morphological structures of resistant and susceptible accessions revealed that the lumen diameter and length of ligule do not have any significant role in resistance to yellow stem borer. However, the length of trichomes and their distribution was found to be correlated with level of resistance. Shorter, sparsely distributed trichomes were recorded in the susceptible IR 62 as against longer, densely distributed trichomes in the resistant accessions (Fig. 10). Chandramohan (1983) also observed that the length of hair and spicule were longer in W 1263, a resistant accession than other accessions and they were densely distributed.

The role of these trichomes on resistance may be by interfering with the initial larval establishment and subsequent entry into the lumen leading to low deadheart or whitehead production. Similar effect of denticles on imparting resistance in sugarcane to *Scirpophaga niveralla* (Wlk.) was reported by Verma and Mathur (1950) and Agarwal (1969).

Experiments showed that varieties with a narrow stem lumen were less susceptible to borers (Seko and Kato, 1950a; Van and Guan, 1959; Israel et al., 1961). Stems with large lumen may provide space for the feeding larvae to move more freely. In many varieties, the cavity was smaller than the body width of the larvae, particularly in the later instars. Under these circumstances, the larvae were forced to enlarge the cavity by feeding, and this restriction on their movements may have caused low survival. However, in the present study no significant correlation was obtained between the lumen diameter and level of infestation by the yellow stem borer.

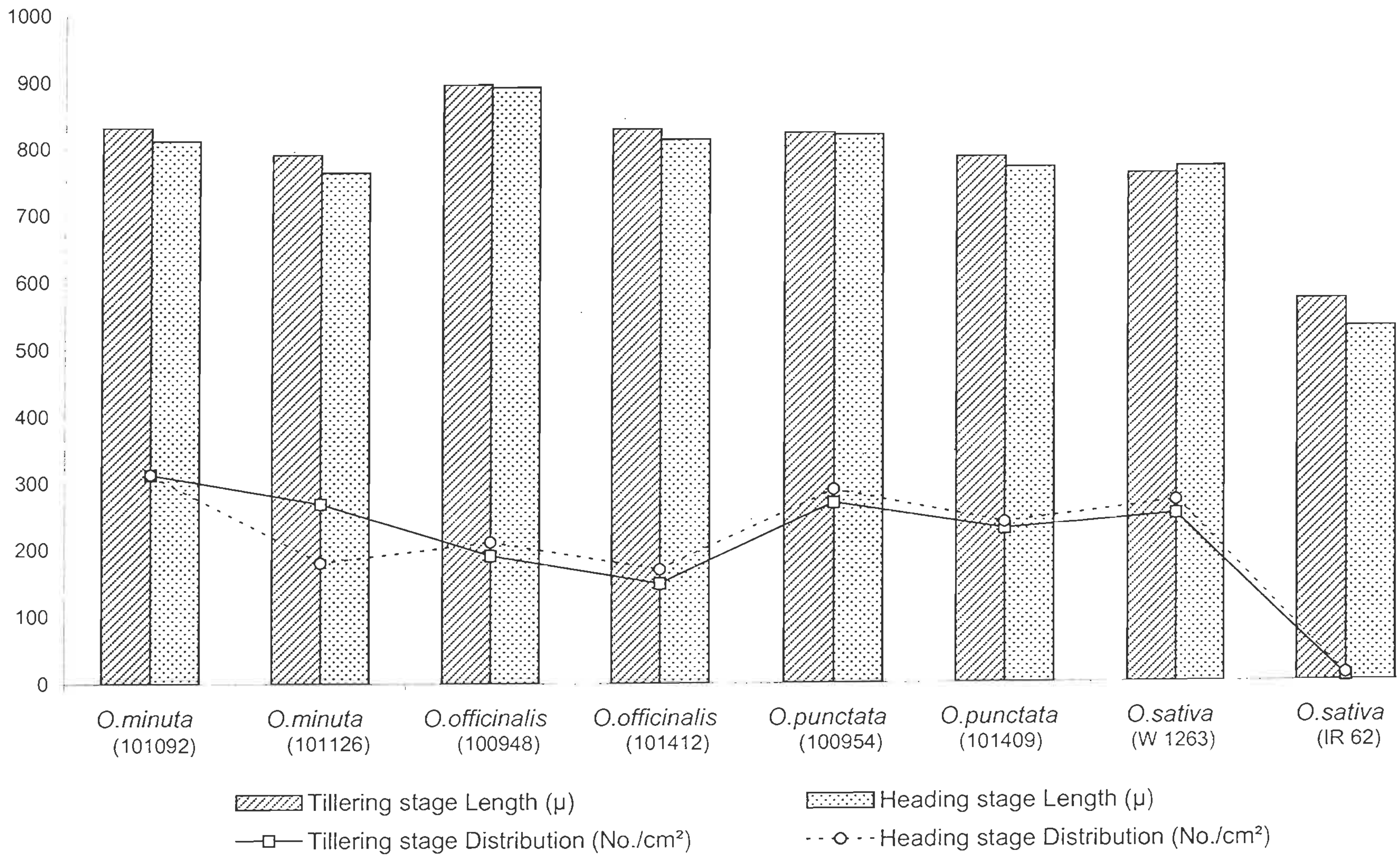


Fig. 10. Length and distribution of trichomes in different wild rice accessions

Phytochemicals produced by damaged plants may be detrimental to insects (Coleman and Jones, 1990). Green and Ryan (1972) first discovered that mechanically wounded tomato leaves stimulated the release of a proteinase inhibitor inducing factor into vascular transport system of damaged plants and the feeding of larvae of *Spodoptera littoralis* (Boisd) on damaged tomato leaves decreased by nine fold within eight hours after damage.

The variations in the increase in the total protein and free amino acid contents were not much pronounced among the accessions with different levels of resistance tested. The protein and amino acid content was high in the susceptible IR 62 at vegetative and heading stages indicating their nutritional superiority over the resistant accessions. However, the increase in the total phenol content was only 9.52 and 7.41 per cent in the susceptible IR 62 at tillering and heading stage as against 58.33 and 24.32 per cent respectively in the resistant *O. minuta* (101092) 48 h after infestation. In case of orthodihydroxy phenols there was 54.14 and 62.19 per cent increase 48 h after infestation in the resistant *O. minuta* as against 22.73 and 22.22 per cent only in the susceptible IR 62. Wounding induced the oxidation of plant phenols to produce tissue quiones and synthesis of mono and diphenols (Rhodes and Wooltorton, 1978).

A similar increase in the phenol content due to rice leaffolder *Cnaphalocrocis medinalis* (Guenee) infestation was reported by Ekambaram (1994) in the resistant accession of *O. brachyantha*. The rate of accumulation of total phenols in resistant accessions was more than in susceptible accessions (Sridhar, 1983; Muthuswami, 1988).

The use of wild rices in the development of high yielding rice cultivars has recently given increased attention. The result of the studies shows high levels of resistance in wild rices against yellow stem borer. Wild species have provided resistance sources where screening of the *O.sativa* germplasm collections has failed to identify adequate levels of resistance to certain rice insects. Although wild species are often incompatible with *O.sativa* in conventional breeding, they can be used as donor parents using wide hybridisation and embryo rescue techniques (Brar and khush, 1995). Rescue of hybrid embryos through tissue culture and backcrossing to *O. sativa* allows recovery of new lines which contain segments of wild genome introgressed into *O. sativa* background (Bennett *et al.*, 1997). In studies at International Rice Research Institute, genes from seven wild rice species have been transferred to *O. sativa* for resistance to brown planthopper and whitebacked planthopper and is in progress to yellow stem borer (Brar and khush, 1995). International Rice Research Institute breeding lines possessing a gene for brown planthopper resistance from *O. officinalis* were tested in the Mekong Delta, Viatnam, where they were more resistant than test cultivars with known resistant gene (Heinrichs and Quisenberry, 1999). Hence, the resistance in the wild rices to yellow stem borer can be successfully utilised by transferring to cultivated rices by wide hybridisation programmes.

SUMMARY

CHAPTER VI

SUMMARY

Investigations were carried out on the host plant resistance in wild rice accessions to the rice yellow stem borer, *Scirpophaga incertulas* (Walker) and the salient findings are summarised below:

1. Of the 24 wild rice accessions belonging to six wild rice species *viz*., *Oryza australiensis, O. latifolia, O. minuta, O. nivara, O. officinalis* and *O. punctata* screened, 14 were rated as resistant to yellow stem borer at tillering stage. The accessions, *O. minuta* (101092), *O. latifolia* (101443) and *O. officinalis* (100948) were found to be highly resistant with a mean damage score of one.

2. At booting stage, eight accessions were found resistant. Two accessions from *O. australiensis* (103318 and 101144), *O. latifolia* (101443, 102481) and *O. officinalis* (100948 and 100947) and one accession from *O. minuta* (101092) and *O. punctata* (100954) recorded a damage score of 3 or less.

3. The wild rice accessions differed in their susceptibility to yellow stem borer at tillering and booting stage. The wild rice accessions *O. latifolia* (100966), *O. minuta* (101079, 101086, 101096 and 101128) and *O. punctata* (101417) were resistant at tillering stage and susceptible at booting stage.

4. The weight gained by third instar larvae after 48 and 96 h of feeding in callus of resistant wild rices was significantly reduced. The weight gained in the susceptible IR 62 callus 48 and 96 h after feeding was 41.24 per cent and 82.42 per cent respectively where as it was only 14.72 and 30.34 per cent in the callus of the resistant *O. minuta* (101092) developed from leaves at tillering stage. The weight gained by larvae after 48 h of feeding in callus developed from leaves at booting stage ranged from 15.25 per cent in *O. minuta* (101092) to 40.21 per cent in IR 62.

5. The mean number of egg masses laid in free choice test on different accessions ranged from 11.00 to 17.25 at tillering stage and 11.50 to 17.50 at booting stage. There was no significant difference in the number of egg masses laid by yellow stem borer on the accessions with varying levels of resistance.

6. There was no marked difference in the number of larvae oriented towards different accessions even 12 h after release when more than 90 per cent of the released larvae, oriented and settled in different accessions in a free choice test.

7. The per cent larvae entering the lumen of different accessions at tillering stage ranged from 32.50 in the resistant accessions *O. minuta* (101092) and *O. officinalis* (100948) to 90.00 per cent in the susceptible check IR 62. Only 30.00 per cent of the larvae successfully entered the lumen of the resistant accessions *O. australiensis* (103318) and *O. officinalis* (100948) as against 87.50 per cent in IR 62 at the booting stage.

8. The place of larval entry into the lumen varied from 2.23 mm to 3.20 mm from node at tillering stage and 2.30 mm to 3.05 mm at booting stage among different accessions tested.

9. Five days after release, the larvae tunnelled to a distance of only 6.15 mm in the resistant wild rice accession *O. latifolia* (101443) at tillering stage and 6.13 mm in the resistant wild rice accession *O. australiensis* (103318) at booting stage, as against 20.38 and 17.55 mm in the susceptible check IR 62 at tillering and booting stage respectively.

10. The larval period was shortest when developed on the susceptible check IR 62 at tillering and booting stage (35.3 and 32.4 days respectively) and prolonged to 46.2 days in the resistant wild rice accession *O. australiensis* (103318) at tillering stage and 43.5 days in the resistant wild rice accessions *O. minuta* (101092) at booting stage.

11. At tillering stage, the pupal duration was minimum (8.5 days) in the susceptible check IR 62 which was on par with the resistant wild rice accessions *O. australiensis* (103318), *O. officinalis* (100948) and *O. latifolia* (101443). The pupal period varied from 8.5 to 10.6 days among different accessions tested at booting stage.

12. A maximum of only 10.00 per cent of the larvae released developed in to adult in the resistant wild rice accessions tested at the tillering stage. The percentage of adult emergence was only 5.00 per cent in the resistant wild rice accessions *O. australiensis* (103318), *O. latifolia* (101443) and *O. officinalis* (100948) at booting stage. In the susceptible check IR 62, 67.50 and 70.00 per cent of larvae developed in to adult at tillering and booting stage respectively.

13. The lowest adult female longevity of 2.4 days was recorded in the resistant wild rice accessions *O. latifolia* (101443) and *O. punctata* (100954) and lowest male longevity of 2.1 day was recorded in *O. punctata* (100954) when developed at tillering stage. Adult females and males lived longer when reared on the susceptible check IR 62 (5.1 and 4.9 days respectively). A similar trend in adult longevity was observed at booting stage also.

14. The number of egg masses laid by the female moths emerged from different accessions at tillering stage ranged from 1.6 egg masses/female in resistant wild rice accession *O. punctata* (100954) to 4.8 egg masses/female in the susceptible check IR 62. The females emerged from the susceptible check IR 62 at booting stage laid on an average of 4.4 egg masses which was 210 per cent more than the number of egg masses laid by the females developed from the resistant wild rice accessions *O. australiensis* (103318) and *O. officinalis* (100948).

15. The size of the egg masses was greatly influenced by host plants with varying levels of resistance. The length and width of egg masses laid by females emerged from resistant wild rice accession, *O. australiensis* (103318) at tillering stage was 5.80 mm and 3.13 mm respectively, with 110.75 eggs per egg mass, as against the egg masses laid by females emerged from IR 62 which was 11.95 mm in length and 5.45 mm in width with 270 eggs per egg mass. At booting stage, minimum length of egg mass was recorded in *O. minuta* (101092), a resistant accession.

16. The weight of the larvae reared on different accessions varied significantly. The larval weight was minimum (7.82 mg), 10 days after feeding on the resistant wild rice accession *O. australiensis*. The larval weight after 20 and 30 days of feeding was only 16.09 and 34.26 mg respectively in the resistant wild rice accession *O. punctata* (100954) as against 30.20 and 58.12 mg in the susceptible IR 62. At booting stage also, the larvae weighed significantly lower when reared on the resistant wild rice accessions.

17. The pupa developed from the resistant wild rice accessions ranged from 10.92 to 11.52 mg at tillering stage and 10.28 to 12.02 mg at booting stage which was less than 50 per cent of the weight of the pupa developed from susceptible check IR 62 (24.14 and 25.01 mg respectively at tillering and booting stage).

18. The weight of females emerged from different accessions at tillering stage ranged from 8.17 mg in the resistant *O. australiensis* (103318) to 21.18 mg in the susceptible check. In case of males, the weight ranged from 5.28 mg in *O. officinalis* (100948), a resistant accession to 15.33 mg in the susceptible check IR 62. The adults emerged from resistant accessions at booting stage weighed significantly lesser than the adults emerged from susceptible IR 62.

19. The length and width of the mandibles were significantly reduced when fed on the resistant wild rice accessions at both tillering and booting stage. There was marked wearing in the mandibles of the larvae fed on the resistant wild rice accessions which was well expressed in the larvae fed on *O. officinalis* (100948).

20. The steam distillate extract of resistant wild rice accessions did not influence the oviposition by adult females and the orientation response of the neonate larvae. However, more than 50 per cent of neonate larvae died when fed on the susceptible IR 62 plants sprayed with 2000 ppm extract from resistant wild rice accessions. The deadheart and whitehead damage was low in IR 62 when the plants were smeared with the steam distillate extract of resistant wild rice accessions, before infestation.

21. The cuticular wax extract of resistant wild rice accessions did not influence the oviposition of adult females and the orientation response of neonate larvae. After 5 days of feeding on the susceptible IR 62 plants smeared with 2000 ppm concentration of cuticular wax extract of resistant wild rice accessions, the survival of the larvae was significantly reduced.

22. The lumen diameter and the length of the ligule were not found to have any significant role in resistance to yellow stem borer.

23. The length of trichomes and their distribution had positive correlation with the resistance. Trichomes of more than 800 μ length were observed in the resistant wild rice accessions as against shorter trichomes (569.7 μ) in the susceptible IR 62. The number of trichomes present per square centimetre was more than 200 in the resistant accessions as against only 16.7 in the susceptible IR 62.

24. The total nitrogen content in the leaf sheath did not vary with level of resistance in the accessions tested. However, the resistant wild rice accessions recorded high content of crude silica, cellulose and lignin, at both tillering and booting stage.

25. The increase in the total protein and free amino acid content was not much pronounced in different accessions tested at tillering and booting stage.

26. The yellow stem borer infestation resulted in an increase in the phenol and OD phenol content, which was more pronounced in the resistant wild rice accessions. There was 24.32 and 54.14 per cent increase in total phenol and OD phenol content respectively two days after infestation in the resistant wild rice accessions *O. minuta* (101092).

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APPENDICES

Appendix I. Varieties/ breeding lines reported to be resistant to yellow stem borer

Accession	Origin	Reference(s)
5291-Ng-11-3-1	-	Soejitno (1977)
5291-Ng-11-3-2	-	Soejitno (1977)
AC 1368	India	Israel (1967)
AC 1977	India	Israel (1967), Prakasa Rao (1977), Chaudhary *et al.* (1984)
AC 2117	India	Israel (1967)
AC 2137	India	Israel (1967)
AC 2150	India	Israel (1967)
AC 250	India	Israel (1967)
AC 3998	India	Israel (1967)
AC 517	India	Khan *et al.* (1991)
AC536-313	India	Israel (1967)
AD9408	India	Subramanian and Jayaraman (1985), Saroja and Raju (1981)
ADT 1	India	Velusamy *et al.* (1975), Pawar *et al.* (1959), Israel (1967), Chaudhary *et al.* (1984)
ADT 2	India	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)
ADT 4	India	Israel (1967)
ADT 5	India	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)
ADT 6	India	Velusamy *et al.* (1975)
ADT 7	India	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)
ADT 8	India	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)
ADT 10	India	Velusamy *et al.* (1975)
ADT 11	India	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)
ADT 13	India	Velusamy *et al.* (1975)
ADT 14	India	Israel (1967), Prakasa Rao (1977), Chaudhary *et al.* (1984)
ADT 15	India	Khan *et al.* (1991)
ADT 17	India	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)
ADT 18	India	Khan *et al.* (1991)
ADT 21	India	Velusamy *et al.* (1975)
ADT 22	India	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)
ADT 24	India	Velusamy *et al.* (1975)
ADT 25	India	Velusamy *et al.* (1975)
Aen Okam	Indonesia	Khan *et al.* (1991)
Agali	Bangladesh	Khan *et al.* (1991)

Agniban	India	Khan *et al.* (1991)
AICRIP111-17 (HPU 2181)	India	Khan *et al.* (1991)
Ajab Beti	Bangladesh	Khan *et al.* (1991)
Ajan 246	India	Khan *et al.* (1991)
Ajiman	India	Khan *et al.* (1991)
Alad Kumar	Bangladesh	Khan *et al.* (1991)
Alas	Indonesia	Khan *et al.* (1991)
Alash	India	Khan *et al.* (1991)
Amla	India	Khan *et al.* (1991)
Ampek Tanjung	Indonesia	Khan *et al.* (1991)
Ang ay yuon	Cambodia	Khan *et al.* (1991)
Anga	Malaysia	Khan *et al.* (1991)
Angkei sang sao	Cambodia	Khan *et al.* (1991)
Angkok	Cambodia	Khan *et al.* (1991)
Angrocus	Cambodia	Khan *et al.* (1991)
Anlong Phnom	Cambodia	Khan *et al.* (1991)
Ansomg Deuth	Cambodia	Khan *et al.* (1991)
Arah	India	Khan *et al.* (1991)
ARC 5920	India	Shastry *et al.* (1971), Heinrichs *et al.* (1985a)
ARC 6033	India	Shastry *et al.* (1971), Heinrichs *et al.* (1985a)
ARC 6045	India	Shastry *et al.* (1971), Akinsola (1973), Heinrichs *et al.* (1985a)
ARC 6049	India	Shastry *et al.* (1971), Akinsola (1973), Heinrichs *et al.* (1985a)
ARC 6148	India	Shastry *et al.* (1971)
ARC 6184	India	Shastry *et al.* (1971), Heinrichs *et al.* (1985a)
ARC 6603	India	Shastry *et al.* (1971)
ARC 7037	India	Khan *et al.* (1991)
ARC 7052	India	Khan *et al.* (1991)
ARC 7054	India	Khan *et al.* (1991)
ARC 7072	India	Khan *et al.* (1991)
ARC 7080	India	Shastry *et al.* (1971), Akinsola (1973), Heinrichs *et al.* (1985a)
ARC 7090	India	Khan *et al.* (1991)
ARC 7098	India	Shastry *et al.* (1971), Heinrichs *et al.* (1985a)
ARC 7099	India	Khan *et al.* (1991)
ARC 7103	India	Khan *et al.* (1991)
ARC 7098	India	Shastry *et al.* (1971)
ARC 7104	India	Khan *et al.* (1991)
ARC 7108	India	Khan *et al.* (1991)

ARC 7119	India	Shastry *et al.* (1971), Heinrichs *et al.* (1985a)
ARC 7125	India	Khan *et al.* (1991)
ARC 7131	India	Khan *et al.* (1991)
ARC 7132	India	Shastry *et al.* (1971), Heinrichs *et al.* (1985a)
ARC 7137	India	Shastry *et al.* (1971), Heinrichs *et al.* (1985a)
ARC 7312	India	Shastry *et al.* (1971), Heinrichs *et al.* (1985a)
ARC 7316	India	Shastry *et al.* (1971), Heinrichs *et al.* (1985a)
ARC 10217	India	Shastry *et al.* (1971), Heinrichs *et al.* (1985a)
ARC 10257	India	Khush (1977), Heinrichs *et al.* (1985a)
ARC 10259	India	Khan *et al.* (1991)
ARC 10300	India	Khan *et al.* (1991)
ARC 10331	India	Khan *et al.* (1991)
ARC 10346	India	Shastry *et al.* (1971), Heinrichs *et al.* (1985a)
ARC 10379	India	Shastry *et al.* (1971), Heinrichs *et al.* (1985a)
ARC 10386	India	Shastry *et al.* (1971), Heinrichs *et al.* (1985a)
ARC 10443	India	Shastry *et al.* (1971), CRRI (1980), Heinrichs *et al.* (1985a)
ARC 10528	India	Shastry *et al.* (1971), Heinrichs *et al.* (1985a)
ARC 10539	India	Khan *et al.* (1991)
ARC 10598	India	Khush (1977), Heinrichs *et al.* (1985a)
ARC 10642	India	Khan *et al.* (1991)
ARC 10692	India	Khush (1977), Heinrichs *et al.* (1985a)
ARC 10784	India	Khan *et al.* (1991)
ARC 10788	India	Khan *et al.* (1991)
ARC 10958	India	Shastry *et al.* (1971), Heinrichs *et al.* (1985a)
ARC 10971	India	Khan *et al.* (1991)
ARC 11209	India	Khan *et al.* (1991)
ARC 11261	India	Shastry *et al.* (1971), Heinrichs *et al.* (1985a), Khan *et al.* (1991)
ARC 11296	India	Khan *et al.* (1991)
ARC 11310	India	Khan *et al.* (1991)
ARC 11311	India	Khan *et al.* (1991)
ARC 11313	India	Shastry *et al.* (1971), Heinrichs *et al.* (1985a)
ARC 11332	India	Shastry *et al.* (1971), Chaudhary *et al.* (1984)
ARC 11346	India	Khan *et al.* (1991)
ARC 11497	India	Khan *et al.* (1991)
ARC 11537	India	Shastry *et al.* (1971), Heinrichs *et al.* (1985a)
ARC 11591	India	Khan *et al.* (1991)
ARC 11637	India	Khan *et al.* (1991)
ARC 11685	India	Khan *et al.* (1991)
ARC 11693	India	Khan *et al.* (1991)

ARC 11703	India	Khan *et al.* (1991)
ARC 11713	India	Khan *et al.* (1991)
ARC 11716	India	Khan *et al.* (1991)
ARC 11726	India	Khan *et al.* (1991)
ARC 11744	India	Khan *et al.* (1991)
ARC 11799	India	Khan *et al.* (1991)
ARC 11966	India	Khan *et al.* (1991)
ARC 11979	India	Khan *et al.* (1991)
ARC 11983	India	Khan *et al.* (1991)
ARC 11991	India	Khan *et al.* (1991)
ARC 12008	India	Khan *et al.* (1991)
ARC 12012	India	Khan *et al.* (1991)
ARC 12015	India	Khan *et al.* (1991)
ARC 12024	India	Khan *et al.* (1991)
ARC 12026	India	Khan *et al.* (1991)
ARC 12029	India	Khan *et al.* (1991)
ARC 12039	India	Khan *et al.* (1991)
ARC 12047	India	Khan *et al.* (1991)
ARC 12089	India	Khan *et al.* (1991)
ARC 12092	India	Khan *et al.* (1991)
ARC 12094	India	Khan *et al.* (1991)
ARC 12097	India	Khan *et al.* (1991)
ARC 12109	India	Khan *et al.* (1991)
ARC 12120	India	Khan *et al.* (1991)
ARC 12162	India	Khan *et al.* (1991)
ARC 12163	India	Khan *et al.* (1991)
ARC 12164	India	Khan *et al.* (1991)
ARC 12168	India	Khan *et al.* (1991)
ARC 12171	India	Khan *et al.* (1991)
ARC 12173	India	Khan *et al.* (1991)
ARC 12177	India	Khan *et al.* (1991)
ARC 12180	India	Khan *et al.* (1991)
ARC 12319	India	Khan *et al.* (1991)
ARC 12387	India	Khan *et al.* (1991)
ARC 12501	India	Chaudhary *et al.* (1984), Khan *et al.* (1991)
ARC 12505	India	Khan *et al.* (1991)
ARC 12548	India	Khan *et al.* (1991)
ARC 12746	India	Khan *et al.* (1991)
ARC 12586	India	Khan *et al.* (1991)
ARC 12588	India	Khan *et al.* (1991)
ARC 12591	India	Khan *et al.* (1991)

ARC 12598	India	Khan *et al.* (1991)
ARC 12602	India	Khan *et al.* (1991)
ARC 12604	India	Khan *et al.* (1991)
ARC 12605	India	Khan *et al.* (1991)
ARC 12610	India	Khan *et al.* (1991)
ARC 12613	India	Khan *et al.* (1991)
ARC 12615	India	Khan *et al.* (1991)
ARC 12625	India	Khan *et al.* (1991)
ARC 12629	India	Khan *et al.* (1991)
ARC 12718	India	Khan *et al.* (1991)
ARC 12720	India	Khan *et al.* (1991)
ARC 12721	India	Khan *et al.* (1991)
ARC 12724	India	Khan *et al.* (1991)
ARC 12745	India	Khan *et al.* (1991)
ARC 12830	India	Khan *et al.* (1991)
ARC 12859	India	Khan *et al.* (1991)
ARC 12890	India	Khan *et al.* (1991)
ARC 13202	India	Khan *et al.* (1991)
ARC 13204	India	Khan *et al.* (1991)
ARC 13235	India	Khan *et al.* (1991)
ARC 13259	India	Khan *et al.* (1991)
ARC 13283	India	Khan *et al.* (1991)
ARC 13292	India	Khan *et al.* (1991)
ARC 13295	India	Khan *et al.* (1991)
ARC 13300	India	Khan *et al.* (1991)
ARC 13304	India	Khan *et al.* (1991)
ARC 13306	India	Khan *et al.* (1991)
ARC 13367	India	Khan *et al.* (1991)
ARC 13840	India	Khan *et al.* (1991)
ARC 14137	India	Khan *et al.* (1991)
ARC 14202	India	Khan *et al.* (1991)
ARC 14340	India	Khan *et al.* (1991)
ARC 14759	India	Khan *et al.* (1991)
ARC 14945	India	Khan *et al.* (1991)
ARC 14960	India	Khan *et al.* (1991)
ARC 15022	India	Khan *et al.* (1991)
ARC 15104	India	Khan *et al.* (1991)
ARC 15157	India	Khan *et al.* (1991)
ARC 15197	India	Khan *et al.* (1991)
ARC 15265	India	Khan *et al.* (1991)
ARC 15275	India	Khan *et al.* (1991)

ARC 15313	India	Khan *et al.* (1991)
ARC 15357	India	Khan *et al.* (1991)
ARC 15361	India	Khan *et al.* (1991)
ARC 15373	India	Khan *et al.* (1991)
ARC 15379	India	Khan *et al.* (1991)
ARC 15394	India	Khan *et al.* (1991)
ARC 15409	India	Khan *et al.* (1991)
ARC 15422	India	Khan *et al.* (1991)
ARC 15432	India	Khan *et al.* (1991)
ARC 15639	India	Khan *et al.* (1991)
ARC 15671	India	Khan *et al.* (1991)
ARC 15759	India	Khan *et al.* (1991)
ARC 15788	India	Khan *et al.* (1991)
ARC 15814	India	Khan *et al.* (1991)
ARC 15850	India	Khan *et al.* (1991)
ARC 15866	India	Khan *et al.* (1991)
ARC 15896	India	Khan *et al.* (1991)
ARC 15929	India	Khan *et al.* (1991)
ARC 15935	India	Khan *et al.* (1991)
ARC 15959	India	Khan *et al.* (1991)
ARC 18312	India	Khan *et al.* (1991)
ARC 18582	India	Khan *et al.* (1991)
ARC 18603	India	Khan *et al.* (1991)
ARC 18618	India	Khan *et al.* (1991)
Arjundhan	India	Khan *et al.* (1991)
Arjunsail	India	Khan *et al.* (1991)
AS 2	India	Israel (1967)
AS 3	India	Israel (1967)
ASD 2	India	Pawar *et al.* (1959), Israel (1967), Prakasa Rao (1977)
ASD 4	India	Velusamy *et al.* (1975)
ASD 5	India	Velusamy *et al.* (1975)
ASD 6	India	Velusamy *et al.* (1975)
ASD 7	India	Velusamy *et al.* (1975), Pongprasert *et al.* (1975), Heinrichs *et al.* (1985a)
ASD 8	India	Israel (1967)
ASD 9	India	Israel (1967)
ASD 10	India	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)
ASD 11	India	Velusamy *et al.* (1975)
ASD 12	India	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)

ASD 13	India	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)
Ashkata	India	Khan *et al.* (1991)
Ashni	Bangladesh	Khan *et al.* (1991)
Assam Aus	India	Khan *et al.* (1991)
Auda	India	Khan *et al.* (1991)
Aus Balam	Bangladesh	Chaudhary *et al.* (1984), Heinrichs *et al.* (1985a), Khan *et al.* (1991)
Aus Jhari	Bangladesh	Khan *et al.* (1991)
Ausdhan	India	Khan *et al.* (1991)
Auspapri	India	Khan *et al.* (1991)
B1047B-PN-18-1-4	Indonesia	Khan *et al.* (1991)
B1047d-Kn-51-3-2	Indonesia	Chaudhary *et al.* (1984)
B189b-52-8-3-1	Indonesia	Alam *et al.* (1979)
B1991b-Pn-43-4-1	Indonesia	Chaudhary *et al.* (1984)
B2358-4-1-2-7	Indonesia	Chaudhary *et al.* (1984)
B2360-11-3-4-6	Indonesia	Chaudhary *et al.* (1984)
B2360-6-5-1-10	Indonesia	Khan *et al.* (1991)
B2360-6-9-2-6-MR-2	Indonesia	Khan *et al.* (1991)
B2360-8-9-5	Indonesia	Khan *et al.* (1991)
B2378-4-5-IR-12	Indonesia	Chaudhary *et al.* (1984)
B404-43 (PM)	Brazil	Khan *et al.* (1991)
B459b-Pa-132-3-5	Indonesia	Alam *et al.* (1979)
B643b-Pa-11-4	Indonesia	Chaudhary *et al.* (1984)
B1087b-Pa-47-2-5	Indonesia	Soejitno (1977)
B173h-Pa-40-1	Indonesia	Soejitno (1977)
B189c-Ka-45-1-3	Indonesia	Soejitno (1977)
B1991b-Pn-43-4-1	Indonesia	Soejitno (1977)
B2149c(a)50546	Indonesia	Soejitno (1977)
B2149c(c) 50548	Indonesia	Soejitno (1977)
B217 Basumathi	India	Velusamy *et al.* (1975)
B452c-Kn-139-3-3	Indonesia	Soejitno (1977)
B453b-22-5-3-3	Indonesia	Soejitno (1977)
B539b-Kpj-1-2-4-2-4	Indonesia	Soejitno (1977)
B539b-Kpj-1-2-5-2-4	Indonesia	Soejitno (1977)
B539b-Kpj-1-3-5-3-2	Indonesia	Soejitno (1977)
B57d-Ng-14-2-3	Indonesia	Soejitno (1977)
B58(IR36/Co13)	-	Subramanian and Jayaraman (1985)
B58d-Tg-64-2-2-1-2	Indonesia	Soejitno (1977)
B629d-Pn-8-2-2	Indonesia	Soejitno (1977)
B643b-Pa-11-4	Indonesia	Soejitno (1977)
B643b-Pn-47	Indonesia	Soejitno (1977)

B9b.Tk-23-5-5-2-2	Indonesia	Soejitno (1977)
Babo	Cambodia	Khan *et al.* (1991)
Bachhaikalm	India	Khan *et al.* (1991)
Badshabhog	India	Banerjee (1951), Israel (1967), Alam *et al.* (1979)
Badursail	India	Khan *et al.* (1991)
Baiang	Indonesia	Viado and Matthysse (1955)
Bakcham Roeus	Cambodia	Khan *et al.* (1991)
Balalake	India	Khan *et al.* (1991)
Balam	Bangladesh	Chaudhary *et al.* (1984)
Balambachai	India	Khan *et al.* (1991)
Balammota	India	Khan *et al.* (1991)
Balasang	India	Khan *et al.* (1991)
Ballatinao (Diket)	India	Khan *et al.* (1991)
Banchur	India	Khan *et al.* (1991)
Banla Phdao	Cambodia	Khan *et al.* (1991)
Banteas Phlouk P 57	Cambodia	Khan *et al.* (1991)
Banya	India	Khan *et al.* (1991)
Basmati 370 with cry 2A gene	-	Magbool *et al.* (1998)
Basmati 385	India	Rianz *et al.* (1993)
BAU 157	Vietnam	Khan *et al.* (1991)
Bd 5	India	Chaudhary *et al.* (1984)
Bd 27	India	Chaudhary *et al.* (1984)
Bd 98	India	Chaudhary *et al.* (1984)
Bd 650	India	Chaudhary *et al.* (1984)
BE IT	India	Khan *et al.* (1991)
Bei Kuor	Cambodia	Khan *et al.* (1991)
Benaful	India	Khan *et al.* (1991)
Benama	India	Khan *et al.* (1991)
Beo Rayak	Indonesia	Khan *et al.* (1991)
Betalga	Philippines	Khan *et al.* (1991)
Beta repot	Bangladesh	Soechardjan and Leeuwangh (1972), Heinrichs *et al.* (1985a)
BG 367 -3	Sri Lanka	Saroja *et al.* (1987b)
BG 399-1	Sri Lanka	Khan *et al.* (1991)
BGDA7-3PE-1	India	Khan *et al.* (1991)
Bhadoia	India	Chaudhary *et al.* (1984)
Bhasmanik	India	Banerjee (1951), Israel (1967)
Bhatagurmatia	India	Khan *et al.* (1991)
BIET 820	India	Khan *et al.* (1991)

Binar	Malaysia	Khan *et al.* (1991)
Binato	India	Khan *et al.* (1991)
Binato (Diquit)	-	Khan *et al.* (1991)
Binumay	-	Khan *et al.* (1991)
Biplab	Bangladesh	Chaudhary *et al.* (1984), Heinrichs *et al.* (1985a)
BK 3	India	Israel *et al.* (1959), Israel (1967), Chaudhary *et al.* (1984)
BKN 6805-2-7	Thailand	Weerapat *et al.* (1975)
BKN 6806-18-1-3	Thailand	Chaudhary *et al.* (1984)
BKN 6806-18-13	Thailand	Weerapat *et al.* (1975)
BKN 6806-18-72	Thailand	Weerapat *et al.* (1975)
BKN 6806-46-54	Thailand	Weerapat *et al.* (1975)
BKN 6806-46-95	Thailand	Weerapat *et al.* (1975), Chaudhary *et al.* (1984)
BKN 6914-63	Thailand	Chaudhary *et al.* (1984)
BKNBR 76003-12-0-1-1	Thailand	Catling *et al.* (1984)
Blue bonnet 50	USA	CRRI (1969)
Bombilla	Brazil	Khan *et al.* (1991)
Bomitog	Philippines	Khan *et al.* (1991)
Boro II	Bangladesh	Israel (1967)
Boro IV	Bangladesh	Israel (1967)
Boro V	Bangladesh	Israel (1967)
Bow Pagal	Bangladesh	Khan *et al.* (1991)
BP 13-2	Philippines	Bueno (1983)
BP 176	Philippines	Bueno (1983)
BP 176*10/DAWN	India	Khan *et al.* (1991)
BPI RI-2	Philippines	Bueno (1983), Khan *et al.* (1991)
BPI RI-4	Philippines	Bueno (1983)
BPT 4229	India	Gubbiah and Revanna (1993)
BPT 4243	India	Gubbiah and Revanna (1993)
BPT 4245	India	Gubbiah and Revanna (1993)
BPT 4298	India	Gubbiah and Revanna (1993)
BPT 436	India	Edward *et al* .(1992a)
BPT 4365	India	Edward *et al* .(1992a)
BPT 6093	India	Singh *et al.* (1995)
BPT 7986	India	Singh *et al.* (1995)
BPT 8799	India	Singh *et al.* (1995)
BPT 11711	India	Gubbiah and Revanna (1993)

BR 17	Philippines	Israel *et al.* (1959), Israel (1967), Chaudhary *et al.* (1984)
BR 18350-93-2	Bangladesh	Edward *et al.* (1992b)
BR2-29-2-8-1	Bangladesh	Prakasa Rao (1977)
BR 224-2B-2-5	Bangladesh	Catling *et al.* (1984)
BR232-2B-3-4-HR19	Bangladesh	Catling *et al.* (1987)
BR232-2B-3-4-HR28	Bangladesh	Catling *et al.* (1987)
BR 3	Bangladesh	Israel (1967)
BR308-B-2-3-HR-8	Bangladesh	Catling *et al.* (1987)
BR 319-1	Bangladesh	Edward *et al.* (1992b)
BR51-19B-2	Bangladesh	Alam *et al.* (1979)
BR51-46-5	Bangladesh	Alam *et al.* (1979)
BR40-39-1-3	Bangladesh	Khan *et al.* (1991)
BR51-196-2	Bangladesh	Khan *et al.* (1991)
BR51-26-10	Bangladesh	Khan *et al.* (1991)
BRC 16-127-4-1	-	Edward *et al.* (1992b)
BRJ 1	Bangladesh	Alam *et al.* (1979)
BRJ1-19B-11	Bangladesh	Alam *et al.* (1979)
Brown Gora S.N.43	India	Khan *et al.* (1991)
Brown Gora S.N.84	India	Khan *et al.* (1991)
Buacao	Philippines	Khan *et al.* (1991)
Bucayab	Philippines	Khan *et al.* (1991)
Bugis Chelom	Malaysia	Khan *et al.* (1991)
Bukhaido	USSR	Khan *et al.* (1991)
Bullilising (Diket)	Philippines	Khan *et al.* (1991)
Buntut Semut Hitam	Indonesia	Khan *et al.* (1991)
C12	Brazil	Bueno (1983)
C168	Philippines	Bueno (1983)
C_4-63	Philippines	Soejitno (1977)
C_4-137	Philippines	Bueno (1983)
C20	Sudan	Alam *et al.* (1979)
Cabitena	Philippines	Khan *et al.* (1991)
Camuroi Na Puti	Philippines	Khan *et al.* (1991)
Candenavia	Philippines	Khan *et al.* (1991)
Carmeling	Philippines	Khan *et al.* (1991)
C31	India	Israel *et al.* (1959), Israel (1967), CRRI (1969); Prakasa Rao (1977), Chaudhary *et al.* (1984)
C32	India	CRRI (1969)
Campo Sprang	Indonesia	Khan *et al.* (1991)
Campo Unel	Indonesia	Khan *et al.* (1991)

Cere Air	Indonesia	Khan *et al.* (1991)
CH 47	India	Prakasa Rao (1977), Chaudhary *et al.* (1984)
CH 62	India	CRRI (1969)
Chaing Meanh	Cambodia	Khan *et al.* (1991)
Chakulia	Bangladesh	Khan *et al.* (1991)
Chambok Dan	Cambodia	Khan *et al.* (1991)
Chamlak Tonsay	Cambodia	Khan *et al.* (1991)
Champou Pean	Cambodia	Khan *et al.* (1991)
Chamroeum	Cambodia	Khan *et al.* (1991)
Chandane Boso	Bangladesh	Khan *et al.* (1991)
Chandina	Bangladesh	Rezaul Karim *et al.* (1978)
Chaplo	Bangladesh	Khan *et al.* (1991)
Chautukalu	India	Pawar *et al.* (1959), Israel (1967), Chaudhary *et al.* (1984)
Chianan 2	Taiwan-China	IRRI (1970), Chang *et al.* (1975), Chaudhary *et al.* (1984)
China 3	-	Israel (1967)
China 4	India	Israel (1967), Chaudhary *et al.* (1984)
China 22	China	Israel (1967)
China 25	China	Israel (1967)
China 29	China	Israel (1967)
China 42	China	Israel (1967)
China 47	-	Khush (1977)
China 51	China	Israel (1967)
Chinsurah Boro 1	India	Khan *et al.* (1991)
Chinagong I	-	Alam *et al.* (1979)
Chiu Shih Iri	Brazil	Khan *et al.* (1991)
Chosang Kogyando	Korea	Chaudhary *et al.* (1984)
Chukyo-asahi	Japan	Chaudhary *et al.* (1984)
Chungur Bali	Bangladesh	Khan *et al.* (1991)
CI 6002-1	Philippines	Pongprasert *et al.* (1975), Heinrichs *et al.* (1985a)
Cicih Beton	Indonesia	Khan *et al.* (1991)
Cicih Gundil	Indonesia	Khan *et al.* (1991)
CN 506-147-14-2	India	Catling *et al.* (1984)
CN 547-1-9	India	Catling *et al.* (1984)
CN 694-4-13	India	Catling *et al.* (1984)
CN 695-2-17	India	Catling *et al.* (1984)
CN704-7-3	India	Catling *et al.* (1984)
CNBP220-226	India	Khan *et al.* (1991)
CNBP 301-4	India	Khan *et al.* (1991)
CNM 539	India	Catling *et al.* (1984)
CO 1	India	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)

CO 3	India	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)
CO 4	India	Velusamy *et al.* (1975)
CO 5	India	Velusamy *et al.* (1975)
CO 7	India	Velusamy *et al.* (1975), Chaudhary *et al.* (1984)
C0 11	India	Velusamy *et al.* (1975)
CO 12	India	Velusamy *et al.* (1975)
CO 15	India	Velusamy *et al.* (1975), Chaudhary *et al.* (1984)
CO 18	India	Chaudhary *et al.* (1984), Chandramohan and Chelliah 1983, 1984), Heinrichs *et al.* (1985a), Khan *et al.* (1991)
CO 19	India	Velusamy *et al.* (1975), Heinrichs *et al.*, (1985a)
CO 21	India	Chang *et al.* (1981), Chaudhary *et al.* (1984), Heinrichs *et al.* (1985a), Khan *et al.* (1991)
CO 22	India	Soejitno (1974), Khush (1977), Heinrichs *et al.* (1985a)
CO 23	India	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)
CO 25	India	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)
CO 26	India	Velusamy *et al.* (1975)
CO 27	India	Velusamy *et al.* (1975)
CO 28	India	Velusamy *et al.* (1975)
CO 30	India	Velusamy *et al.* (1975)
CO 32	India	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)
CO 43	India	Subramanian and Jayaraman (1985)
CP 12	India	Israel (1967)
CR 10-4181-1	India	Velusamy *et al.* (1975)
CR34-73-200	India	Chaudhary *et al.* (1984)
CR 103	India	Prakasa Rao (1972b)
CR 139-1047	India	Prakasa Rao (1977), CRRI (1976)
CR157-392-4	India	Heinrichs *et al.* (1978)
CR157-41-112	India	Prakasa Rao (1977)
CR189-62-15	India	Mathur (1977, 1979)
CR190-1	India	Mathur (1977, 1979)
CR191-4	India	Mathur (1977, 1979)
CR200-1	India	Mathur (1977, 1979)
CR256-30-211-2-708	India	Prakasa Rao and Gangadharan (1986)
CR260-151-224	India	Prakasa Rao and Gangadharan (1986)
CR260-151-81-2-710	India	Prakasa Rao and Gangadharan (1986)
CR260-163-238	India	Prakasa Rao and Gangadharan (1986)
CR260-167-247-179	India	Prakasa Rao and Gangadharan (1986)
CR260-176-1-702	India	Prakasa Rao and Gangadharan (1986)
CR260-228	India	Prakasa Rao and Gangadharan (1986)
CR260-30	India	Prakasa Rao and Gangadharan (1986)

CR43-76	India	Khush (1977)
CR44-1	India	CRRI (1980)
CR44-140-2-1051	India	Khan *et al.* (1991)
CR94-13	India	Chaudhary *et al.* (1984)
CR57-MR 1526	India	CRRI (1980)
CR90-MR	India	Prakasa Rao (1977)
CR94-MR	India	CRRI (1976)
CR156-5021-207	India	Khan *et al.* (1991)
CR203-1-717	India	Khan *et al.* (1991)
CRM10-5747	-	Saroja and Raju (1981)
Cross 116	India	Israel *et al.* (1959), Israel (1967), Chaudhary *et al.* (1984)
Cul 147	India	Khan *et al.* (1991)
Dabiao Bloc	Vietnam	Khan *et al.* (1991)
Dambnocub Theang	Cambodia	Khan *et al.* (1991)
Damnocub Pras	Cambodia	Khan *et al.* (1991)
Damnocub Pratas	Cambodia	Khan *et al.* (1991)
Damnocub Roley	Cambodia	Khan *et al.* (1991)
Damnocub Rumduol	Cambodia	Khan *et al.* (1991)
Damnocub Sak	Cambodia	Khan *et al.* (1991)
Dang Ejah	Malaysia	Khan *et al.* (1991)
Daw Dawk Pow 48-3-123	Thailand	Khan *et al.* (1991)
Daw Leanuang 181	Thailand	Khan *et al.* (1991)
Daw Nam-Man Wua	Thailand	Khan *et al.* (1991)
Daw Pone	Thailand	Khan *et al.* (1991)
DCA 6	-	Israel (1967)
DCA 22	-	CRRI (1960)
Dee-geo-woo-gen	Taiwan-China	Khush (1977)
Dendekkolon	Indonesia	Khush (1977), Heinrichs *et al.* (1985a)
Dhaliboro 94	Bangladesh	Khan *et al.* (1991)
Dhola Digha	Bangladesh	Chaudhary *et al.* (1984)
DI 3	Japan	Israel (1967)
DI 4	Japan	Israel (1967)
Dik Wee	Sri Lanka	Khan *et al.* (1991)
Diket	Philippines	Khan *et al.* (1991)
Dikwee	Nigeria	Pongprasert *et al.* (1975), Heinrichs *et al.* (1985a)
Dingras	Philippines	Khan *et al.* (1991)
DM 27	Bangladesh	Chaudhary *et al.* (1984)
DNJ 97	Bangladesh	Pongprasert *et al.* (1975), Heinrichs *et al.* (1985a)
Doli Khama	Bangladesh	Khan *et al.* (1991)
Donangnovan	Laos	Chaudhary *et al.* (1984)

Dose	Philippines	Khan *et al.* (1991)
DPI 1091/1-3	-	Balasubramanian *et al.* (1986)
DR 82	-	Rustamani *et al.* (1995)
DV 139	Bangladesh	Chang *et al.* (1975)
E-lub	Thailand	Khan *et al.* (1991)
E-pua Khao	Thailand	Khan *et al.* (1991)
EK 1240	-	Weerapat *et al.* (1975)
EK 1252	-	Alam *et al.* (1979)
EK 1253	-	Alam *et al.* (1979)
EK 1257	-	Alam *et al.* (1979)
EK 1259	-	Alam *et al.* (1979)
EK 1262	-	Alam *et al.* (1979)
EK 1263	-	Khush and Beachell (1972), Alam *et al.* (1979)
Ekka Seeya Paha	Sri Lanka	Khan *et al.* (1991)
Elwee	Sri Lanka	Khan *et al.* (1991)
EPJ1-6B-9	-	Alam *et al.* (1979)
EPJ1-6B-16	-	Alam *et al.* (1979)
EPJ1-9B-8	-	Alam *et al.* (1979)
EPJ1-9B-21	-	Alam *et al.* (1979)
Eswarakora	-	Israel (1967), Weerapat *et al.* (1975), Chaudhary *et al.* (1984)
Eunicoo 6	Korea	Chaudhary *et al.* (1984)
FNAI-8-7-X-X	India	Khan *et al.* (1991)
Fortuna	-	Viado and Matthysse (1955)
Foych (AG 1-17)	Liberia	Khan *et al.* (1991)
Foych (AG 1-46)	Liberia	Khan *et al.* (1991)
Fusakushiraj-sai No.7	Japan	Chaudhary *et al.* (1984)
Gallano	Philippines	Khan *et al.* (1991)
Gampaha Samba	Sri Lanka	Khan *et al.* (1991)
Ganado	Philippines	Khan *et al.* (1991)
Gangala	India	Pongprasent *et al.* (1975), Heinrichs *et al.* (1985a)
Garia	Bangaldesh	Khan *et al.* (1991)
Garman	Liberia	Khan *et al.* (1991)
Gbaikpai (D 21)	Liberia	Khan *et al.* (1991)
GEB 24	India	Prakasa Rao (1972b), Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)
Gei Moi (Hoatong)	Vietnam	Khan *et al.* (1991)
Gerimas	Philippines	Khan *et al.* (1991)
Ghora	Bangladesh	Khan *et al.* (1991)
Gie Moi 1035	Vietnam	Khan *et al.* (1991)
Gin-Awa	Philippines	Khan *et al.* (1991)

Ginatuday	Philippines	Khan *et al.* (1991)
Ginbozu	Japan	Chaudhary *et al.* (1984)
Gobua	Bangladesh	Khan *et al.* (1991)
Gochi	Bangladesh	Khan *et al.* (1991)
Goia	Bangladesh	Khan *et al.* (1991)
Gori	Bangladesh	Khan *et al.* (1991)
Gouri Saita	Bangladesh	Khan *et al.* (1991)
Goyal	Bangladesh	Khan *et al.* (1991)
Grunangang	-	Viado and Matthysse (1955)
Gurjo Mukli	Bangladesh	Khan *et al.* (1991)
H4	Sri Lanka	Fernando (1967), Akinsola (1973), Velusamy *et al.* (1975), Chaudhary *et al.* (1984), Heinrichs *et al.* (1985a)
Habiganj 6	-	Shahjahan and Zakir Hussain (1975)
Habiganj Aman IV-HR 36	Bangladesh	Catling *et al.* (1987)
Habiganj Aman VIII	Bangladesh	Chaudhary *et al.* (1984)
Habiganj Boro VI	Bangladesh	Alam *et al.* (1979)
Hanpa (Black	Bangladesh	Khan *et al.* (1991)
Hanpa (Yellow)	Bangaldesh	Khan *et al.* (1991)
Hansh Badol	Bangladesh	Khan *et al.* (1991)
Hashikalmi	Bangladesh	Pongprasert *et al.* (1975), Heinrichs *et al.* (1985a)
Hashiribozu No.1	Japan	Chaudhary *et al.* (1984)
Hathiel	Sri Lanka	Pongprasert *et al.* (1975), Heinrichs *et al.* (1985a)
Hijal Digha	Bangladesh	Chaudhary *et al.* (1984)
Hikari	Japan	Chaudhary *et al.* (1984)
Hinon	Philippines	Khan *et al.* (1991)
HKR 243	-	Kushwaha *et al.* (1992)
HKR 90-143	-	Mann and Shukla (1999)
HR 19	India	Israel (1967)
HR 21	India	Israel (1967)
Hsunschu	-	Israel (1967)
Htsu Mishiki 120	Brazil	Khan *et al.* (1991)
Hung-Mei-Tsao	China	Khan *et al.* (1991)
Hurohondarawla	-	Alam *et al.* (1979)
IAC 68 P	Brazil	Khan *et al.* (1991)
IARI 5829	India	Chaudhary *et al.* (1984)
IARI 5981 A	India	Velusamy *et al.* (1975)
IARI 5993	India	Velusamy *et al.* (1975)
IARI 6579	India	Velusamy *et al.* (1975)
IARI 6600	India	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)
IARI 6638	India	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)

IB56-8	Myanmar	Chaudhary *et al.* (1984), Heinrichs *et al.* (1985a)
Idrasail	Bangladesh	Khan *et al.* (1991)
IET 1785	India	CRRI (1976)
IET 2812	India	Seshu (1976)
IET 2845	India	Heinrichs *et al.* (1978)
IET 3093	India	Seshu (1976)
IET 3127	India	Seshu (1976)
IET 5121	India	Chang *et al.* (1981)
IET 5540	India	Heinrichs *et al.* (1978)
IET 6262	India	Subramanian and Jayaraman (1985)
IET 9576	India	Muthuswami and Gunathilagaraj (1989)
Ihara No.5	Japan	Chaudhary *et al.* (1984)
Ilchin	Korea	Chaudhary *et al.* (1984)
Ilis Air	Indonesia	Khan *et al.* (1991)
Iniang	Philippines	Khan *et al.* (1991)
Iniaday	Philippines	Khan *et al.* (1991)
Inianod	Philippines	Khan *et al.* (1991)
Intip	Indonesia	Khan *et al.* (1991)
IR 5	Philippines	Khush (1977), Bueno (1983)
IR 20	Philippines	Akinsola (1973), Soejitno (1977), Rezaul Karim *et al.* (1978)
IR 22	Philippines	Alam *et al.* (1979)
IR 24	Philippines	Bueno (1983)
IR 26	Philippines	Soejitno (1977)
IR 28	Philippines	Alam *et al.* (1979), Bueno (1983)
IR 29	Philippines	Soejitno (1977)
IR 30	Philippines	Soejitno (1977)
IR 32	Philippines	Bueno (1983)
IR 34	Philippines	Chaudhary *et al.* (1984)
IR 36	Philippines	Heinrichs *et al.* (1978, 1982, 1985a,b), Chang *et al.* (1981), Chaudhary *et al.* (1984)
IR 37	Philippines	Bueno (1983)
IR 40	Philippines	Heinrichs *et al.* (1982, 1985a,b) Chaudhary *et al.* (1984)
IR 42	Philippines	Bueno (1983)
IR 44	Philippines	Bueno (1983)
IR 46	Philippines	Viajante and Heinrichs (1985)
IR 48	Philippines	Bueno (1983)
IR 50	Philippines	Heinrichs *et al.* (1982, 1985a,b), Yein and Das (1988)
IR 54	Philippines	Heinrichs *et al.* (1982, 1985a,b)

IR 56	Philippines	Bueno (1983)
IR 60	Philippines	Viajante and Heinrichs (1985)
IR 72	Philippines	Singh and Pandey (1997)
IR 11185-B-B-850-1	Philippines	Catling *et al.* (1984)
IR 11185-R-0-7	Philippines	Catling *et al.* (1984)
IR 13260-100-1E-P3	Philippines	Catling *et al.* (1984)
IR 1330-51-1	Philippines	Khush (1977)
IR 1330-90-2	Philippines	Khush (1977)
IR 13639-39	Philippines	Chandramohan and Chelliah (1983, 1984)
IR 13641-4	Philippines	Chandramohan and Chelliah (1983, 1984)
IR 13641-18	Philippines	Chaudhary *et al.* (1984)
IR 1514A-#597	Philippines	Khush (1977)
IR 1514A-E597-2	Philippines	Alam *et al.* (1979)
IR1514A-E666	Philippines	Heinrichs *et al.* (1978)
IR 15323-78-1-3-1	Philippines	Chang *et al.* (1981)
IR 1539-823-1-4	Philippines	Khush (1977)
IR 1544-340-6-1	Philippines	Alam *et al.* (1979)
IR 1561-228-3-3	Philippines	Chaudhary *et al.* (1984)
IR15723-45-3-2-2-2	Philippines	Chang *et al.* (1981)
IR 15795-151-2-3-2-2	Philippines	Chang *et al.* (1981)
IR 1721-11-6-8	Philippines	Khush (1977)
IR 18209-52-2	Philippines	Khush (1977), Pathak and Saxena (1980)
IR 1820-52-2-4-1	Philippines	Chaudhary (1984), Heinrichs *et al.* (1985a)
IR 18350-93-2	Philippines	Edward *et al.* (1992b)
IR 1917-3-19	Philippines	Khush (1977)
IR 19362-183	Philippines	Chang *et al.* (1981)
IR 19735-30-3-3-2-2	Philippines	Chang *et al.* (1981)
IR 19774-42-2-1-3-2	Philippines	Chang *et al.* (1981)
IR2024-102-2-1-3-2	Philippines	Alam *et al.* (1979)
IR2035-255-2-3-1	Philippines	Alam *et al.* (1979)
IR2035-290-2-3-1	Philippines	Alam *et al.* (1979)
IR2042-175-3-2-2	Philippines	Alam *et al.* (1979)
IR2061-213-2	Philippines	Manwan (1975)
IR2070-178-2-3	Philippines	Alam *et al.* (1979)
IR2070-24-1-5-1	Philippines	Soejitno (1977)
IR2070-820-2	Philippines	Manwan (1975), Manwan and Vega (1975)
IR2070-820-2-3	Philippines	Soejitno (1977)
IR2071-747-6-3-2	Philippines	Khan *et al.* (1991)
IR 21567-9-2-2-3-1-3	Philippines	Edward *et. al.* (1992b)
IR2157-7-Pn-4-1	Philippines	Soejitno (1977)
IR2160-10-Pn-7-3-2	Philippines	Soejitno (1977)

IR2172-15-1-1	Philippines	Alam *et al.* (1979)
IR2172-61	Philippines	Alam *et al.* (1979)
IR23097-62-1	Philippines	Alam *et al.* (1979)
IR2307-84-2-1-2	Philippines	Khan *et al.* (1991)
IR2328-27-3-6	Philippines	Alam *et al.* (1979)
IR2328-491-1-1-1	Philippines	Heinrichs *et al.* (1978)
IR 25588-7-3-1	Philippines	Edward *et al.* (1992b)
IR2588-132-1-2	Philippines	Alam *et al.* (1979)
IR2681-34-5-6	Philippines	Alam *et al.* (1979)
IR2706-3-3	Philippines	Alam *et al.* (1979)
IR272-4-1-2	Philippines	Alam *et al.* (1979)
IR2754-E1-5-6-3	Philippines	Alam *et al.* (1979)
IR2757-E2-1-2-1	Philippines	Alam *et al.* (1979)
IR2760-E1-33-1-2	Philippines	Alam *et al.* (1979)
IR2763-El-1-2-1	Philippines	Alam *et al.* (1979)
IR2793-15-2	Philippines	Alam *et al.* (1979)
IR2798-107-3	Philippines	Alam *et al.* (1979)
IR2798-143-3-2	Philippines	Heinrichs *et al.* (1978)
IR2798-86-6	Philippines	Alam *et al.* (1979)
IR2863-31-3	Philippines	Alam *et al.* (1979)
IR2863-38-1	Philippines	Alam *et al.* (1979)
IR2863-39-2	Philippines	Alam *et al.* (1979)
IR297-9-13-2-2-2	Philippines	Alam *et al.* (1979)
IR305-3-1	Philippines	Velusamy *et al.* (1975)
IR305-4-20-3-3	Philippines	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)
IR3255-19-215-2	Philippines	Soejitno (1977)
IR3265-P193-2-5	Philippines	Soejitno (1977)
IR3265-P193-6-3	Philippines	Soejitno (1977)
IR3265-P461-2-2	Philippines	Soejitno (1977)
IR3268-P742-4-4	Philippines	Soejitno (1977)
IR3275-A1732-7	Philippines	Soejitno (1977)
IR356	Philippines	Chaudhary *et al.* (1984)
IR3941-2-1-3	Philippines	Heinrichs *et al* (1985a)
IR3941-9-2	Philippines	Heinrichs *et al.* (1985a)
IR3941-97-1	Philippines	Heinrichs *et al.* (1978)
IR4691-89	Philippines	Heinrichs *et al.* (1978)
IR516-34-1	Philippines	Chaudhary *et al.* (1984)
IR532-14-6-1-2	Philippines	Alam *et al.* (1979)
IR532-E-239	Philippines	Chaudhary *et al.* (1984)
IR532-PK24-C2	Philippines	Shafi *et al.* (1972)
IR532-PK27-C2	Philippines	Shafi *et al.* (1972)

IR532-PK36-C2	Philippines	Shafi *et al.* (1972)
IR532-PK67-C2	Philippines	Shafi *et al.* (1972)
IR 54742-11-1-9-15-1	Philippines	Velusamy *et al.* (1993)
IR 54742-11-22-2-22-2	Philippines	Velusamy *et al.* (1993)
IR 54742-18-3-8-22-1	Philippines	Velusamy *et al.* (1993)
IR 54742-18-17-20-2-3	Philippines	Velusamy *et al.* (1993)
IR 54742-33-18-20-3-2	Philippines	Velusamy *et al.* (1993)
IR 54742-38-13-15-11-1	Philippines	Velusamy *et al.* (1993)
IR 54742-2-21-12-17-5	Philippines	Velusamy *et al.* (1993)
IR 54742-50-19-19-3	Philippines	Velusamy *et al.* (1993)
IR577-24-1-1-5	Philippines	Velusamy *et al.* (1975)
IR578-76-1-2-1	Philippines	Velusamy *et al.* (1975)
IR5853-196-1-81	Philippines	Catling *et al.* (1984)
IR589-87-2-3	Philippines	Velusamy *et al.* (1975)
IR6-156-2-2	Philippines	Alam *et al.* (1979)
IR6-67-1-3	Philippines	Alam *et al.* (1979)
IR747B2-12-1-1-2	Philippines	Chaudhary *et al.* (1984)
IR7691-07-4-2-1-1	Philippines	Catling *et al.* (1984)
IR8	Philippines	Chang *et al.* (1975)
IR8608-75-3-1-3	Philippines	Chang *et al.* (1981)
IR9129-169-3-2-3-3	Philippines	Chang *et al.* (1981)
IR9828-23-1	Philippines	Chang *et al.* (1981)
IR2344-PIPB-6-1-1B	Philippines	Khan *et al.* (1991)
IR2344-PIPB-9-1-1B	Philippines	Khan *et al.* (1991)
IR2344-PIPB-9-1-2B	Philippines	Khan *et al.* (1991)
IR2344-PIPB-9-2-3B	Philippines	Khan *et al.* (1991)
IR2403-PIPB-5-3-2B	Philippines	Khan *et al.* (1991)
IR3256-89-5	Philippines	Khan *et al.* (1991)
IR3261-97-9-2-2	Philippines	Khan *et al.* (1991)
IR3941-1	Philippines	Khan *et al.* (1991)
IR3941-2-1-3	Philippines	Khan *et al.* (1991)
IR3941-4-PIP-2B	Philippines	Khan *et al.* (1991)
IR3941-58-3	Philippines	Khan *et al.* (1991)
IR3941-6-1	Philippines	Khan *et al.* (1991)
IR3941-68-1-3-2	Philippines	Khan *et al.* (1991)
IR3941-9-2	Philippines	Khan *et al.* (1991)
IR4478-7-2-3	Philippines	Khan *et al.* (1991)
IR4482-3-3-3-3	Philippines	Khan *et al.* (1991)
IR4482-5-3-9-5	Philippines	Khan *et al.* (1991)
IR4500-19-2-1	Philippines	Khan *et al.* (1991)
IR4530-7-3-3	Philippines	Khan *et al.* (1991)

IR4531-10062-2-2	Philippines	Khan *et al.* (1991)
IR4531-5-3-2	Philippines	Khan *et al.* (1991)
IR4531-9-1-2	Philippines	Khan *et al.* (1991)
IR4532-8-2-2	Philippines	Khan *et al.* (1991)
IR4543-1-1-1	Philippines	Khan *et al.* (1991)
IR5-36-801	Philippines	Khan *et al.* (1991)
IR5-36-813	Philippines	Khan *et al.* (1991)
IR5-36-814	Philippines	Khan *et al.* (1991)
IR5098-B-JN-1B	Philippines	Heinrichs *et al.* (1985a), Khan *et al.* (1991)
IR5467-2-2-2	Philippines	Khan *et al.* (1991)
IR5495	Philippines	Khan *et al.* (1991)
IR5825-41-2-P1	Philippines	Khan *et al.* (1991)
IR5825-41-2-P4	Philippines	Khan *et al.* (1991)
IR5853-135-3-P3	Philippines	Khan *et al.* (1991)
IR5857-10-1E-1	Philippines	Khan *et al.* (1991)
IR5857-3-2E-2	Philippines	Khan *et al.* (1991)
IR5906-56-2	Philippines	Khan *et al.* (1991)
IR5908-15-1	Philippines	Khan *et al.* (1991)
IR5908-79-2	Philippines	Heinrichs *et al.* (1985a), Khan *et al.* (1991)
IR5908-84-3	Philippines	Khan *et al.* (1991)
IR5908-85-3	Philippines	Khan *et al.* (1991)
IR5908-96-2	Philippines	Khan *et al.* (1991)
IR8-202	Philippines	Rustamani *et al.* (1995)
IR8-5	Philippines	Rustamani *et al.* (1995)
IR8/3 x Zenith	India	Velusamy *et al.* (1975)
IR865-32-3	Philippines	Khan *et al.* (1991)
IR908-111-3	Philippines	Khan *et al.* (1991)
IR9673-9-6-5	Philippines	Khan *et al.* (1991)
IRAM1622	Madagascar	Soejitno (1977)
IRAM1642	Madagascar	Chaudhary *et al.* (1984)
IRATOM24	Pakistan	Shahjahan and Zakir Hussain (1975)
IRATOM38	Pakistan	Shahjahan and Zakir Hussain (1975)
IRGC Acc.12852	Sri Lanka	Velusamy *et al.* (1975)
IRGC Acc.45966	Myanmar	Alam *et al.* (1979)
IRGC Acc.6300	India	Alam *et al.* (1979)
ISLA	Philippines	Khan *et al.* (1991)
Jagal Shaita	Bangladesh	Khan *et al.* (1991)
Jalath	-	Chaudhary *et al.* (1984)
Jao Daeng	Thailand	Khan *et al.* (1991)
Jaya	India	Khush (1977)
Jeeragasamba	India	Velusamy *et al.* (1975)

Jelutuk Bulu Putih	Indonesia	Khan *et al.* (1991)
Jemadi	Indonesia	Khan *et al.* (1991)
Jepang	Indonesia	Khan *et al.* (1991)
Jhangi	India	Israel *et al.* (1959), Israel (1967), Chaudhary *et al.* (1984)
Jhingasail	Bangladesh	Khan *et al.* (1991)
Jongkong Pendek	Indonesia	Khan *et al.* (1991)
Jyothi	India	Khan *et al.* (1991)
K8(Mutant)Scl	Sri Lanka	Soejitno (1977)
K42-55-B	India	Khan *et al.* (1991)
K42-86-B-1	India	Khan *et al.* (1991)
K94	USSR	Khan *et al.* (1991)
Kacha Nuni	Bangladesh	Khan *et al.* (1991)
Kaciak M[illegible]manah	Indonesia	Khan *et al.* (1991)
Maciak Sum[illegible]i	Indonesia	Khan *et al.* (1991)
Kala Aman	Bangladesh	Chaudhary *et al.* (1984)
Kala Harsel	-	Chaudhary *et al.* (1984)
Kalijira	Bangladesh	Alam *et al.* (1979)
Kalihatti	Bangladesh	Khan *et al.* (1991)
Kalimot-tog	Philippines	Khan *et al.* (1991)
Kalinga 2	India	Chaudhary *et al.* (1984), Heinrichs *et al.* (1985a)
Kalu Heenati	Sri Lanka	Chaudhary *et al.* (1984), Heinrichs *et al.* (1985a)
Kalu Hewariderri	Sri Lanka	Khan *et al.* (1991)
Kartuni	Indonesia	Khan *et al.* (1991)
Kasih Baranak	Indonesia	Khan *et al.* (1991)
Katiak Pianggu	Indonesia	Khan *et al.* (1991)
Katigued	Philippines	Khan *et al.* (1991)
Keora	Bangladesh	Chaudhary *et al.* (1984)
Keriting Putih	Indonesia	Khan *et al.* (1991)
Ketan Jambe	Indonesia	Khan *et al.* (1991)
Ketan Kasumba	Indonesia	Khan *et al.* (1991)
Ketan Koneng	Indonesia	Khan *et al.* (1991)
Ketan Mayang	Indonesia	Khan *et al.* (1991)
Ketan Pb	Indonesia	Khan *et al.* (1991)
Ketan Untup Randa Kaya	Indonesia	Khan *et al.* (1991)
Keudah Grulumpang	Indonesia	Khan *et al.* (1991)
Khangkhouay	Laos	Khan *et al.* (1991)
Khao Luum Hawn	Thailand	Khan *et al.* (1991)
Khao Moon	Thailand	Khan *et al.* (1991)
Khao Phei Phalo	Laos	Khan *et al.* (1991)
Khao Phie DENG	Laos	Khan *et al.* (1991)

Khao Pongxeng	Laos	Khan *et al.* (1991)
Khao Ton Lek 339-6-20	Thailand	Khan *et al.* (1991)
Khewali	Bangladesh	Khan *et al.* (1991)
Khoiamotor	Bangladesh	Khan *et al.* (1991)
Khud Boilum	Bangladesh	Khan *et al.* (1991)
Khukni	Liberia	Khan *et al.* (1991)
Kidama	Japan	Chaudhary *et al.* (1984)
Kinai-wase No.70	Japan	Chaudhary *et al.* (1984)
Kinastila	Philippines	Khan *et al.* (1991)
Kinmaze	Japan	Chaudhary *et al.* (1984)
Kipusa	Urundi	Akinsola (1973), Khush (1977), Prakasa Rao (1977), Heinrichs *et al.* (1985a)
Kn-1b-361-1-8-6-6-1-10-2	Indonesia	Khan *et al.* (1991)
Kn-1b-361-8-6-9-2-7	Indonesia	Heinrichs *et al.* (1985a), Khan *et al.* (1991)
Kobumasari	Philippines	Manwan (1975)
Kong Kambot	Cambodia	Khan *et al.* (1991)
Kong Keo	Cambodia	Khan *et al.* (1991)
Kucir	Indonesia	Khan *et al.* (1991)
Kumar	India	Khan *et al.* (1991)
Kumargore	India	Khan *et al.* (1991)
Kuning Halus	Indonesia	Khan *et al.* (1991)
Kuntu Putih	Indonesia	Khan *et al.* (1991)
Kurohondarawala	Sri Lanka	Pongprasert *et al.* (1975), Heinrichs *et al.* (1985a)
Kwa-hwa-yuan	Philippines	Manwan (1975)
L41	India	Khan *et al.* (1991)
L45	India	Khan *et al.* (1991)
L79	India	Khan *et al.* (1991)
Lal Megi	Liberia	Khan *et al.* (1991)
Lal Taura	Liberia	Khan *et al.* (1991)
Lalboro	Bangladesh	Khan *et al.* (1991)
Lampung	Philippines	Khan *et al.* (1991)
Landis	Philippines	Khan *et al.* (1991)
Laskmitia	Bangladesh	Khan *et al.* (1991)
Lata Say	Liberia	Khan *et al.* (1991)
Latisail	Bangladesh	Banerjee (1951), Israel (1967)
Lepgu	Philippines	Chaudhary *et al.* (1984), Heinrichs *et al.* (1985a)
Leri	Indonesia	Khush (1977), Heinrichs *et al.* (1985a)
Liberian Coll.D 1-122	Liberia	Khan *et al.* (1991)
Liberian Coll. D 1-172	Liberia	Khan *et al.* (1991)
Liberian Coll.D 1-182	Liberia	Khan *et al.* (1991)
Liberian Coll.D. 1-183	Liberia	Khan *et al.* (1991)

Liberian Coll.D. 1-186	Liberia	Khan *et al.* (1991)
Liberian Coll.D 2-127	Liberia	Khan *et al.* (1991)
Liberian Coll. Y 35	Liberia	Khan *et al.* (1991)
Liberian Coll. Y-082	Liberia	Khan *et al.* (1991)
Linagawe	Philippines	Khan *et al.* (1991)
Lohargura	Bangladesh	Khan *et al.* (1991)
Lor Beol Medium	India	Khan *et al.* (1991)
Los Barios	Philippines	Khan *et al.* (1991)
Lunah	-	Soechardjan and Leeuwangh (1972), Heinrichs *et al.* (1985a)
M7 with cry 2A gene	-	Maqbool *et al.* (1998)
Madhu Malati	Liberia	Khan *et al.* (1991)
Magoti	East Africa	Heinrichs *et al.* (1985a)
Mahlenyaw	Thailand	Khan *et al.* (1991)
Mahsuri	Malaysia	Prakasa Rao (1977), Heinrichs *et al.* (1985a)
Mainagiri	India	Chaudhary *et al.* (1984), Heinrichs *et al.* (1985a)
Mak Hing	Laos	Khan *et al.* (1991)
Mak Nam	Laos	Khan *et al.* (1991)
Makham	Laos	Khan *et al.* (1991)
Malagkit	Philippines	Viado and Matthysee (1955)
Malinja	Malaysia	Chaudhary *et al.* (1984)
Malkhog Nuri	Liberia	Khan *et al.* (1991)
Mangasa	Philippines	Viado and Matthysse (1955)
Manglar	Indonesia	Soejitno (1974), Heinrichs *et al.* (1985a)
Manik Kalma	Liberia	Khan *et al.* (1991)
Manovari	Indonesia	Soejitno (1974), Heinrichs *et al.* (1985a)
Marech S.V.R.	Cambodia	Khan *et al.* (1991)
Mean down	Taiwan-China	Akinsola (1973)
Meghi	Liberia	Khan *et al.* (1991)
Mchren	-	Khush (1977)
Mena Muri	Liberia	Khan *et al.* (1991)
Mete Dhamri	Liberia	Khan *et al.* (1991)
Mete Jumri	Liberia	Khan *et al.* (1991)
Miho 111	Japan	Heinrichs *et al.* (1985a)
Mihonishiki	Japan	Chaudhary *et al.* (1984)
Milfor	Philippines	Viado and Matthysse (1955)
MNP119	-	Khush (1977)
Mohis Kani	Bangladesh	Khan *et al.* (1991)
Mohishdo	Bangladesh	Khan *et al.* (1991)
Molshira	Bangladesh	Khan *et al.* (1991)
Moni Mukul	Bangladesh	Khan *et al.* (1991)

Morseng	Philippines	Khan *et al.* (1991)
MR7	Malaysia	Chang *et al.* (1981)
MTU15	India	Prakasa Rao (1977), Chang *et al.* (1981), Chaudhary *et al.* (1984), Heinrichs *et al.* (1985a)
MTU18	India	Israel (1967)
MTU19	India	Chang *et al.* (1975)
MTU20	India	CRRI (1960), Israel (1967)
MTU3502	India	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)
MTU42476	India	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)
MTU8431	India	Khan *et al.* (1991)
Mudgo	India	Chang *et al.* (1975)
Mudo	Liberia	Khan *et al.* (1991)
Munda	Liberia	Khan *et al.* (1991)
Mundarp Lumuik	Indonesia	Khan *et al.* (1991)
N136	India	Israel (1967)
Nagra	Bangladesh	Banerjee (1951), Israel (1967)
Nah Khwan	Thailand	Khan *et al.* (1991)
Naka-Okayama-mochi	Japan	Chaudhary *et al.* (1984)
NAWN51-9-79	Thailand	Khan *et al.* (1991)
Nazerail	-	Alam *et al.* (1979)
NC493	India	Catling *et al.* (1984)
NC496	India	Catling *et al.* (1984)
NC55	Liberia	Khan *et al.* (1991)
NC73	Liberia	Khan *et al.* (1991)
NDR6017	India	Singh and Pandey (2000)
Nean Mao	Cambodia	Khan *et al.* (1991)
Neang Chen	Cambodia	Khan *et al.* (1991)
Neang Chhmar K.T.	Cambodia	Khan *et al.* (1991)
Neang Kang K.P.	Cambodia	Khan *et al.* (1991)
Neang Meas Angkor	Cambodia	Khan *et al.* (1991)
Neang Phtong	Cambodia	Khan *et al.* (1991)
Neang Phuong	Cambodia	Khan *et al.* (1991)
Neang Prom	Cambodia	Khan *et al.* (1991)
Neang Stong K 176	Cambodia	Khan *et al.* (1991)
Neang Tei	Cambodia	Khan *et al.* (1991)
Niaw Khiaw Ngro	Thailand	Khan *et al.* (1991)
Nortai	USA	Khan *et al.* (1991)
NR326	-	Yein and Das (1988)
OC52	Liberia	Khan *et al.* (1991)
OR101-1	India	Khan *et al.* (1991)
OR100-5	India	Khan *et al.* (1991)

OR100-7	India	Khan *et al.* (1991)
OR100-9	India	Khan *et al.* (1991)
OR100-16	India	Khan *et al.* (1991)
OR1302-15-1	India	Mann and Shukla (1999)
P33-C-19	India	Khan *et al.* (1991)
P33-C-30	India	Khan *et al.* (1991)
P4-1-11-21	India	Khan *et al.* (1991)
Pa Ang	Cambodia	Khan *et al.* (1991)
Pachhaiperumal 2462/11	Sri Lanka	Israel (1967)
Padi	Indonesia	Soechardjan and Leeuwangh (1972), Heinrichs *et al.* (1985a)
Padi Bayak	Indonesia	Khan *et al.* (1991)
Padi Ikue Kambiang	Indonesia	Khan *et al.* (1991)
Padi Kapuas	Malaysia	Khan *et al.* (1991)
Padi Payo Cino	Indonesia	Khan *et al.* (1991)
Pah Leuang 29-11-112	Thailand	Khan *et al.* (1991)
Pah Puang 73-4-19	Thailand	Khan *et al.* (1991)
Paiyur 1	India	Balasubramanian *et al.* (1986)
Pala Jore	Liberia	Khan *et al.* (1991)
Palaidang Mirah	Indonesia	Khan *et al.* (1991)
Palawan	Philippines	Viado and Matthysse (1955)
Palman 579	Philippines	Khush (1977)
Pathong	Taiwan-China	Soejitno (1974), Heinrichs *et al.* (1985a)
Patnai 6	India	Israel (1977)
Patnai 23	India	Banerjee (1951), Israel (1967)
PB5	-	Soejitno (1977)
Pelita I-1	Indonesia	Soejitno (1977)
Pelopor	Indonesia	Khush (1977), Heinrichs *et al.* (1985a)
Perubak Avang	Malaysia	Khan *et al.* (1991)
Peswari	Liberia	Khan *et al.* (1991)
Peta	Indonesia	Viado and Matthysse (1955), Khush and Beachell (1972)
Phanphei	Laos	Khan *et al.* (1991)
Phear Chambak P.P.	Cambodia	Khan *et al.* (1991)
Phear Chan	Cambodia	Khan *et al.* (1991)
Phear Poul K 15	Cambodia	Khan *et al.* (1991)
Phdao Pen DK 81	Cambodia	Khan *et al.* (1991)
Phdao Pen T2	Cambodia	Khan *et al.* (1991)
Phdauk P 38	Cambodia	Khan *et al.* (1991)
Phei Do	Laos	Khan *et al.* (1991)
Phulkari	-	Chaudhary *et al.* (1984)

Pinidwa Qan Qipugo Binaquk	Philippines	Khan *et al.* (1991)
PJRC81030	Thailand	Catling *et al.* (1984)
PLR1	India	Velusamy *et al.* (1975)
Pong-kaat Gi	Cambodia	Khan *et al.* (1991)
PR107	Puerto Rico	Dhaliwal and Singh (1982)
PTB10	India	Israel (1967), CRRI (1969), Nadarajan and Rajappan Nair (1983)
PTB15	India	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)
PTB18	India	Khush (1977), Pongprasert *et al.* (1975), CRRI (1980), Heinrichs *et al.* (1985a)
PTB21	India	Pongprasert *et al.* (1975), Heinrichs *et al.* (1985a)
Pukhi	Bangladesh	Khan *et al.* (1991)
Pulut Bara	Indonesia	Khan *et al.* (1991)
Pulut Kelapa	Indonesia	Khan *et al.* (1991)
Pulut Kemenyan	Indonesia	Khan *et al.* (1991)
Purple Puttu	-	Velusamy *et al.* (1975)
Pusa 169	India	Subramanian and Jayaraman (1985)
PVR1	India	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)
R2384	India	Shrivastava (1979)
R35-2750	India	Shrivastava (1979)
R35-2751	India	Shrivastava (1979)
R35-2752	India	Shrivastava (1979)
R650-1817	India	Singh *et al.* (1995)
R.Kumis	Indonesia	Khan *et al.* (1991)
Raden Mas	Indonesia	Khan *et al.* (1991)
Raghusail	India	Banerjee (1951), Israel (1967)
Ranadja	-	Israel (1967)
Rangpura Jali	Bangladesh	Khan *et al.* (1991)
Rascadam	-	Velusamy *et al.* (1975)
Rataun	-	Israel (1967)
Ratna	India	Prakasa Rao (1972b), CRRI (1980), Chaudhary *et al.* (1984)
Ratna (CR44-11)	India	Heinrichs *et al.* (1985a)
Ratusen	Indonesia	Khan *et al.* (1991)
RAU 83-83-4	-	Edward *et al.* (1992a)
Raya Tembahau	Indonesia	Khan *et al.* (1991)
Rindu	Indonesia	Soejitno (1974), Heinrichs *et al.* (1985a)
RNR56103-1	India	Khan *et al.* (1991)
Ro Hen Do	Vietnam	Khan *et al.* (1991)
Roal	Liberia	Khan *et al.* (1991)

Ronda Kuning	Indonesia	Khan *et al.* (1991)
Roya	Liberia	Khan *et al.* (1991)
Royna	Bangladesh	Khan *et al.* (1991)
RP 1746-12360-340	India	Edward *et al.* (1992a)
RP260-533-4	India	Velusamy *et al.* (1975)
RP260-675-5	India	Velusamy *et al.* (1975)
RP291-20	India	Velusamy *et al.* (1975)
RP319-34-8-1-3	India	Khan *et al.* (1991)
RP4-10	India	Velusamy *et al.* (1975)
RP4-12	India	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)
RP4-13	India	Velusamy *et al.* (1975)
RP423-2-4-2-3	India	Khan *et al.* (1991)
RP6-156-3-6	India	Khan *et al.* (1991)
RP6-590-22-6	India	Seshu (1976)
RP6-590-22-6-4-3	India	Khan *et al.* (1991)
RP611-106-1-10	India	Mathur and Chaturvedi (1978), Chaudhary *et al.* (1984)
RP633-519-1	India	Mathur and Chaturvedi (1978), Chaudhary *et al.* (1984)
RP79-116892	India	Velusamy *et al.* (1975)
RP887-46-1	India	Chaudhary *et al.* (1984)
RP9-4	India	Shrivastava (1979)
RP9-6	India	Alam *et al.* (1979)
RPCBIB7078	India	Khan *et al.* (1991)
RPW6-13	-	CRRI (1980)
RPW6-17	India	Shrivastava (1979)
RPW6-1899-14-1-2	-	Velusamy *et al.* (1975)
RPW6-508-2-3	-	Velusamy *et al.* (1975)
Rungan	Malaysia	Khan *et al.* (1991)
S317	India	Israel (1967)
Sada	Liberia	Khan *et al.* (1991)
Sada Katari	Liberia	Khan *et al.* (1991)
Sadajira 19-241	Bangladesh	Khan *et al.* (1991)
Sajira	Nepal	Israel (1967)
Samba	Sri Lanka	Israel (1967)
Samba Kongo	Liberia	Khan *et al.* (1991)
Sani 6	Liberia	Khan *et al.* (1991)
Sanna Swarnavari	India	Akinsola (1973)
Sanpatong	Laos	Khan *et al.* (1991)
Saripul	Indonesia	Khan *et al.* (1991)
Saru Bhadoi	Liberia	Khan *et al.* (1991)
SB13	-	Balasubramanian *et al.* (1986)
SB19	-	Balasubramanian *et al.* (1986)

Senbon-asahi	Japan	Chaudhari *et al.* (1984)
Seri Jedah	Malaysia	Soechardjan and Leeuwangh (1972), Heinrichs *et al.* (1985a)
Sete Sail	Liberia	Khan *et al.* (1991)
Shada Goira	Bangladesh	Khan *et al.* (1991)
Shete	Liberia	Khan *et al.* (1991)
Shiga-shira-mochi	Japan	Chaudhary *et al.* (1984)
Shinishijiro	Japan	Chaudhary *et al.* (1984)
Shitabhog	Bangladesh	Khan *et al.* (1991)
Shoni	Bangladesh	Khan *et al.* (1991)
Shulpan	Bangladesh	Catling *et al.* (1983)
Shyamala Meghi	Liberia	Khan *et al.* (1991)
Siansimun	Indonesia	Khan *et al.* (1991)
Siantar-situar	Indonesia	Khan *et al.* (1991)
Sidek	Indonesia	Khan *et al.* (1991)
Sigabe	Indonesia	Khan *et al.* (1991)
Sigabe Taon	Indonesia	Khan *et al.* (1991)
Sigugguk	Indonesia	Khan *et al.* (1991)
Sihalus	Indonesia	Khan *et al.* (1991)
Si Jambe	Indonesia	Soejitno (1974), Heinrichs *et al.* (1985a)
Sijan	Indonesia	Khan *et al.* (1991)
Sijeer	Indonesia	Khan *et al.* (1991)
Siketumbar	Indonesia	Khan *et al.* (1991)
Silum	Indonesia	Khan *et al.* (1991)
Simet 2	Indonesia	Khan *et al.* (1991)
Sinantonio	-	Viado and Matthysse (1955)
Sipasso	Vietnam	Khan *et al.* (1991)
Sipeget	Indonesia	Khan *et al.* (1991)
Sipegdek-sumbul	Indonesia	Khan *et al.* (1991)
Sipilian	Indonesia	Khan *et al.* (1991)
Siraga	Indonesia	Khan *et al.* (1991)
Sirandah Bulu	Indonesia	Khan *et al.* (1991)
Siribu	Indonesia	Khan *et al.* (1991)
Sisior	Indonesia	Khan *et al.* (1991)
Siyam Salaka-siam	-	Khan *et al.* (1991)
SLO 6	India	Israel (1967)
SLO 12	India	Israel *et al.* (1959), Israel (1967), Prakasa Rao (1977), Chaudhary *et al.* (1984)
SLO 17	India	Prakasa Rao (1977), Heinrichs *et al.* (1985a)
SLO 19	Liberia	Khan *et al.* (1991)
Sona Meta Jumri	Liberia	Khan *et al.* (1991)

Soni	Liberia	Khan *et al.* (1991)
Sornavazhai	India	Chandramohan and Chelliah (1983, 1984), Balasubramanian *et al.* (1986)
Sossoupa	Vietnam	Khan *et al.* (1991)
SPR7233-32-1-5-2	Thailand	Catling *et al.* (1984)
SPR 7284-14	Thailand	Chaudhary *et al.* (1984)
SR26B	India, Japan	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a), Edward *et al.* (1992b)
SR3(G12A)	Liberia	Khan *et al.* (1991)
Sri Kutu	Indonesia	Khan *et al.* (1991)
STB Res. 12708	Bangladesh	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)
Su-yai 20	China	IRRI (1970), Pathak *et al.* (1971), Chang *et al.* (1975), Chaudhary *et al.* (1984)
Sudwai 306	Sri Lanka	Israel (1967)
Sukwang	Korea	Chaudhary *et al.* (1984)
Sulpan	Bangladesh	Chaudhary *et al.* (1984)
Suna Digha	Bangladesh	Khan *et al.* (1991)
Surja Mani	Liberia	Khan *et al.* (1991)
SXC199	Liberia	Khan *et al.* (1991)
SXC223	Liberia	Khan *et al.* (1991)
SXC238	Liberia	Khan *et al.* (1991)
SXC244	Liberia	Khan *et al.* (1991)
SXC286	Liberia	Khan *et al.* (1991)
SXC323	Liberia	Khan *et al.* (1991)
T1559	India	Israel (1967)
T2018	India	Israel *et al.* (1959), Israel (1967), Chaudhary *et al.* (1984)
T2048	India	Israel *et al.* (1959), Israel (1967), Chaudhary *et al.* (1984)
T380	India	Israel (1967)
T657	India	Israel (1967)
T980	India	Israel (1967)
Ta-poo-cho-z	China	Pongprasert *et al.* (1975), Heinrichs *et al.* (1985a)
Tadukan	Philippines	Alam *et al.* (1979)
Tahun Bato	Indonesia	Khan *et al.* (1991)
Tahun Buluh	Indonesia	Khan *et al.* (1991)
Taisho-akaho No.66	Japan	Chaudhary *et al.* (1984)
Taisho-mochi	Japan	Chaudhary *et al. (1984)*
Taitung 16	India	Chaudhary *et al.* (1984)
Takeda-wase	Japan	Chaudhary *et al.* (1984)
Talai Sunga	Malaysia	Khan *et al.* (1991)

Tamaguem	Korea	Chaudhary *et al.* (1984)
Tango-chuto	Japan	Chaudhary *et al.* (1984)
Tapa-1	-	Prakasa Rao (1977), Chaudhary *et al.* (1984)
Taring Pelanduk	Bangladesh	Khan *et al.* (1991)
Tarom Molaii with cry IA(b) gene	-	Ghareyazie *et al.* (1997)
TC37	Indonesia	Prakasa Rao (1977), Heinrichs *et al.* (1985a)
TCA4	Thailand	Tiwary *et al.*(1988)
TCA12	Thailand	Tiwary *et al.* (1991)
TCA19	Thailand	Tiwary *et al.* (1991)
TCA24	Thailand	Tiwary *et al.* (1991)
TCA32	Thailand	Catling *et al.* (19843)
TCA 214	Thailand	Tiwary *et al.* (1988)
TCA 269	Thailand	Tiwary *et al.* (1988)
TCA180-4	Thailand	Catling *et al.* (19843)
TCA181-1	Thailand	Catling *et al.* (19843)
Tepa I	India	Israel (1967), CRRI (1969)
Tepa II	India	Israel (1967)
Terabali	Bangladesh	Khan *et al.* (1991)
Terung Daun	Indonesia	Khan *et al.* (1991)
Tetep	Vietnam	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)
Tewadah	Thailand	Khan *et al.* (1991)
TKM 1	India	Velusamy *et al.* (1975)
TKM 2	India	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)
TKM 3	India	Israel (1967), CRRI (1969)
TKM 6	India	Prakasa Rao (1972b), CRRI (1976), Khush (1977), CRRI (1980), Chang *et al.* (1981), Chaudhary *et al.* (1984), Riaz *et al.* (1993), Edward *et al.* (1992a)
TKM 9	India	Balasubramanian *et al.* (1986)
TM8089	India	Saroja *et al.* (1987a)
TN1	Taiwan-China	Chang *et al.* (1981)
TNR 1	India	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)
TNR 2	India	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)
TR 1	India	Velusamy *et al.* (1975), Heinrichs *et al.* (1985a)
TR 3	India	Israel (1967)
Ubak Abun	Malaysia	Khan *et al.* (1991)
UPL Ri-4	Philippines	Bueno (1983)
UPRB17	India	Khan *et al.* (1991)
UPRB42	India	Khan *et al.* (1991)
UPRB54	India	Khan *et al.* (1991)

UPRB79	India	Khan *et al.* (1991)
UPRB83	India	Khan *et al.* (1991)
Vaigai	India	Saroja *et al.* (1987a)
V.C.Miracle Rice	Vietnam	Khan *et al.* (1991)
Vijaya	India	Prakasa Rao (1972b)
W361	India	CRRI (1960)
W488	India	Israel (1967)
W1236	India	Banerjee (1972)
W1251	India	Banerjee (1972), Akinsola (1973), Manwan and Vega (1975), Khush (1977), Heinrichs *et al.* (1985a)
W1253	India	Banerjee (1972), Akinsola (1973), Manwan (1975), Manwan and Vega (1975), Khush (1977), Chaudhary *et al.* (1984), Heinrichs *et al.* (1985a), Prakasa Rao and Padhi (1988)
W1257	India	Khush (1977), Heinrichs *et al.* (1985a)
W1263	India	Israel (1967), velusamy *et al.* (1975), Manwan (1975), Khush (1977), CRRI (1980), Chang *et al.* (1981), Chandramohan and Chelliah (1983, 1984), Chaudhary *et al.* (1984), Heinrichs *et al.* (1985a), Prakasa Rao and Padhi (1988), Edward *et al.* (1992a,b)
White Atte	Nepal	Khan *et al.* (1991)
White Gora S.N.40	India	Khan *et al.* (1991)
White Gora S.N.117	India	Khan *et al.* (1991)
White Puttu	India	Velusamy *et al.* (1975)
WIR3022	USSR	Khan *et al.* (1991)
WND-1	India	Israel (1967)
Yabami Montakhab	Egypt	Chaudhary *et al.* (1984)
Yamadanishiki	Japan	Chaudhary *et al.* (1984)
Yanghuke	Nepal	Khan *et al.* (1991)
Ytay	Laos	Khan *et al.* (1991)
YTENG	Laos	Khan *et al.* (1991)
Yungkwang	Korea	Chaudhary *et al.* (1984)
Yuubae	Japan	Chaudhary *et al.* (1984)