Pakistan J. Zool., pp 1-6, 2023. DOI: https://dx.doi.org/10.17582/journal.pjz/20220920060917

Compatible and Non-Compatible Interaction of Rice Germplasms against Rice Leaf Folder *Cnaphalocrocis medinalis* (Guenee) (Lepidoptera: Pyralidae)

Khwaja Junaid* and Shah Alam Khan

Department of Plant Protection, Faculty of Crop Protection Sciences, The University of Agriculture, Peshawar

Article Information
Received 20 September 2022
Revised 11 December 2022
Accepted 22 January 2023
Available online 08 May 2023
(early access)

Authors' Contribution
KJ conducted the experiment and wrote the manuscript. SAK designed and supervised the experiment.

Key words
Rice leaf folder, Resistance,IPM, Economic threshold level

ABSTRACT

The rice leaf folder, *Cnaphalocrocis medinalis* Gueee (Lepidoptera: Pyralidae), is major leaf feeding pest of rice, *Oryza sativa* L. (Poaceae), and is widely distributed throughout the rice producing countries in Asian, causing considerable yield losses. Cultivation of susceptible rice varieties is among the major reasons of insect pest outbreak. Contrary, growing resistant rice varieties plays a key role in keeping the insect pest population below economic threshold level. Growing resistant varieties is considered as safe and cost-effective method for the control of (RLF). Keeping in view the importance of the pest and economic value of the crop this experiment is designed to screen thirty five genotypes for resistance against rice leaf folder. These genotypes were evaluated for resistance against RLF in green house in the Department of Plant Breeding and Genetics, Agriculture University Peshawar, by following the method of Heinrichs *et al.* (1985). In our findings the screened genotypes falls in to different categories as 16 genotypes are highly susceptible, 6 are susceptible, 5 are moderately susceptible, 5 are moderately resistant, and only 3 tested genotypes proved resistance against the *Cnaphalocrocis medinalis* while none of the screened genotype falls in the category of highly resistance against RLF. These resistant genotypes can be used in future IPM program for the management of RLF. Furthermore, these resistant germplasms can be used in breeding programs for the development of high yielding resistant varieties against RLF.

INTRODUCTION

Rice leaf folder (RLF) *Cnaphalocrocis medinalis* (Guenee) (Lepidoptera: Pyralidae) is one of the major insect pest of rice *Oryza sativa* L. (Poaceae) (Ezuka and Kaku, 2000; Rani *et al.*, 2007). The infestation of RLF causes substantial yield loss every year (Rehman, 2003; Salim *et al.*, 2003). RLF feeding on flag leaf at tillering stage causes maximum yield loss (Padmavathi *et al.*, 2013). Depending on the crop stage at time of pest infestation, it can cause damages from 18% to 58% in the rice crop (Ramasamy and Jatileksono, 1996). Even with the advancement in rice production techniques, the yield of rice production in Pakistan is still comparatively low from other rice producing countries of the world. Among the biotic and abiotic stresses and others yield limiting factors, the attack of insect pests is one of the major hurdle (Behura *et al.*, 2011).

Cultivation of susceptible rice cultivars is one of the major reasons of insect pest outbreak. Contrary, growing pest resistant rice cultivars play a key role in keeping the insect pest population below economic threshold level. Keeping in view the importance of pest resistant varieties, it is important to evaluate the varieties for resistance and integrate it with other methods for high yield with minimum investment. Breeding for resistant against rice pests is considered as cost-effective and safe method for the management of RLF (Song *et al.*, 2002; Li *et al.*, 2004). Heavy infestation of RLF can be seen on the leaves of infested plants as long transparent streaks and can dry up the rice plants (Murthy *et al.*, 2015). Unluckily, Nitrogen based fertilizers, which is required for obtaining high yield in modern varieties also boost the RLF infestation (Javvaji *et al.*, 2021; Chantaraprapha *et al.*, 1980; Upadhyay *et al.*, 1981; Rueda and Khan, 1988).

Different foliar insecticides have been found effective against RLF (Soomro *et al.*, 2020). However, insecticides are normally applied when the pest population reaches the

* Corresponding author: kjppr@aup.edu.pk
0030-9923/2022/0001-0001 $ 9.00/0

economic threshold level and it also causes resurgence of other insect pests (Ehi-Eromosele *et al*., 2013).

The method for screening of *C. medinalis* in a greenhouse was established in 1981, at International Rice Research Institute (Chang, 1983). Waldbauer and Marciano (1979) establish a method for mass rearing of *C. medinalis*, which makes it possible to screen large number rice germplasm in screen house. The method of mass rearing of *C. medinalis* was modified later by Heinrichs *et al*. (1985a). Screening of rice germplasms for resistance against RLF in field/green house is major part of resistant programme in modern agriculture (Bentur *et al*., 2021; Rekha *et al*., 2001).

Breeding of resistant varieties is thought to be one of the practical method against RLF infestation in tropical regions where most of the rice is cultivated (Dash *et al*., 2020). So far very little work has been done on screening of rice germplasm against *C. medinalis,* in Pakistan this may be because the expression of resistance is not clearly identified so far in any variety and it is highly variable. Thus, the resistance of rice germplasm to RLF is comparative/relative quality. Unluckily, all newly introduced high-yielding IR rice varieties (IR 5 to IR 74) are susceptible against *C. medinalis*. Even those varieties which are categorized as resistant against *C. medinalis* also get some damage under high pest population. Another limiting factor in the development of resistant varieties against *C. medinalis* is that this insect has comparatively very recently attained the status of major pest in a complex discovery with several other leaf folder species. Moreover, there is very limited information about the inheritance of resistance to this insect pest. Although, IRRI has started upgrading the level of resistance of rice plants against RLF by using the conventional pedigree method (Khan and Joshi, 1990; Ahmad *et al*., 2016). Screening and developing resistant varieties are therefore needed because cultivating resistant varieties are one of most effective tactic and integral part of Integrated Pest Management programme against the RLF.

MATERIALS AND METHODS

The experiment was conducted on 35 rice genotypes, M-Sub (202), Rachna, Shaheen Basmati, Kashmir Basmati, Kashmir Basmati-100, Basmati-198, Basmati-385, Basmati-612, Basmati-2008, Basmati-370, Basmati-2000, IR-6, IR-9, DR-92, DR-82, DR-83, Sathra, Shadab, Swat-1, KSK, KS-282, Dilrosh-97, Mathra, Kangni-27, Sadahayat, Khushbo, PK-386, Shua-92, Niphanbhare, IR-8, Swati-2014, Fakhr E Malakand, JP-5, PK-1121 and known susceptible TN-1. These genotypes were evaluated for resistance against RLF in green house in the Department of Plant Breeding and Genetics, Agriculture University Peshawar, during growing season (2019). Different genotypes were screened according to the method of Henrichs *et al*. (1985). The genotypes were exposed against the larvae of RLF under Screen house conditions. The susceptible cultivars were challenged against the insect either the tested plants may die/cause at least leaf damage up to 60%. After the 21 days of insect infestation, data on the extent of damage on each genotype were recorded. For each entry, all the leaves were examined and each leaf was rated (0-3) based on the extent of damage in which grade 0= No damage, 1= Up to 1/3 leaf area scraped, 2= More than 1/3 to ½ of leaf area scraped and 3= More than ½ of leaf area scraped.

Based on the number of leaves with each damage grade, damage rating Scale (R) was computed as follows:

$$A = \frac{(\text{No.leaves with damage grade } 1\times 100)}{\text{Total no.of leaves observed}} \quad \dots (1)$$

$$B = \frac{(\text{No. leaves with damage grade } 2\times 100)}{\text{Total no. of leaves observed}} \dots (2)$$

$$C = \frac{(\text{No. leaves with damage grade } 3\times 100)}{\text{Total no. of leaves observed}} \dots (3)$$

$$\text{Damage rating (R)} = \frac{A+B+C}{6}$$

The damage rating (R) was calculated for each genotype including TN-1 (susceptible check). Adjusting damage rating (D) was also determined for each entry as given below:

$$D = \frac{\text{R of test entry}}{\text{R of susceptible check}} \times 100$$

Adjusted damage rating (D) was converted into following 0 - 9 scale (Standard Evaluation System for Rice, 1996).

Damage rating %	Scale	Status
0	0	Highly resistant (HR)
1-10	1	Resistant (R)
11-30	3	Moderately resistant (MR)
31-50	5	Moderately susceptible (MS)
51-75	7	Susceptible (S)
More than 75	9	Highly susceptible (HS)

RESULTS

Resistant varieties plays a key role in keeping the pest population below the economic injury level, thus avoiding the use of insecticides and increasing the cost benefit ratio of the crop. In this experiment the method of Henrichs *et al*. (1985) was used for screening thirty-five rice varieties against RLF in this experiment in green house in the Department of Plant Breeding and Genetics, The University of Agriculture Peshawar, during 2019.

A lot of work has been done on host plant resistance in the era of modern agriculture specially in case of wheat and barley genotypes with no adverse effects like synthetic pesticides. The herbivores can break the resistance of the host plant, therefore, it is the need of the time to regularly monitor/screen the available crop sources against the major pests. Keeping in view the economic importance of the crop and pest, this experiment, was designed to determine the resistance of the selected rice genotypes to RLF.

Table I. Compatible and non-compatible interaction of rice germplasms against RLF (*Cnaphalocrocis medinalis* G.).

S. No	Varieties	Grade 0	Grade 1	Grade 2	Grade 3	Total	A (1%)	B (2%)	C (3%)	Damage rating (R)	Adjusted damage rating (D)	Damage rating scale	Re-sponses
1	M-SUB (202)	5	2	4	6	17	11.76	47.06	105.88	27.45	77.51	9	HS
2	RACHNA	6	2	5	7	20	10.00	50.00	105.00	27.50	77.65	9	HS
3	SHAHEEN BASMATI	7	5	2	1	15	33.33	26.67	20.00	13.33	37.65	5	MS
4	KASHMIR BASMATI	4	4	3	2	13	30.77	46.15	46.15	20.51	57.92	7	S
5	KASHMIR BASMATI-100	6	2	6	7	21	9.52	57.14	100.00	27.78	78.43	9	HS
6	BASMATI-198	7	8	1	2	18	44.44	11.11	33.33	14.81	41.83	5	MS
7	BASMATI-385	12	5	2	1	20	25.00	20.00	15.00	10.00	28.24	3	MR
8	BASMATI-612	8	2	4	7	21	9.52	38.10	100.00	24.60	69.47	7	S
9	BASMATI-2008	7	7	2	2	18	38.89	22.22	33.33	15.74	44.44	5	MS
10	BASMATI-370	10	5	1	1	17	29.41	11.76	17.65	9.80	27.68	3	MR
11	BASMATI-2000	14	3	0	0	17	17.65	0.00	0.00	2.94	8.30	1	R
12	IR-6	5	2	5	6	18	11.11	55.56	100.00	27.78	78.43	9	HS
13	IR-9	4	3	7	2	16	18.75	87.50	37.50	23.96	67.65	7	S
14	DR-92	11	5	1	1	18	27.78	11.11	16.67	9.26	26.14	3	MR
15	DR-82	17	2	1	0	20	10.00	10.00	0.00	3.33	9.41	1	R
16	DR-83	4	3	6	5	18	16.67	66.67	83.33	27.78	78.43	9	HS
17	SATHRA	3	8	5	2	18	44.44	55.56	33.33	22.22	62.75	7	S
18	SHADAB	7	7	2	2	18	38.89	22.22	33.33	15.74	44.44	5	MS
19	SWAT-1	8	6	3	1	18	33.33	33.33	16.67	13.89	39.22	5	MS
20	KSK	4	3	7	5	19	15.79	73.68	78.95	28.07	79.26	9	HS
21	KS-282	13	6	2	1	22	27.27	18.18	13.64	9.85	27.81	3	MR
22	DILROSH-97	4	3	3	5	15	20.00	40.00	100.00	26.67	75.29	9	HS
23	MATHRA	5	5	5	2	17	29.41	58.82	35.29	20.59	58.13	7	S
24	KANGNI-27	4	2	5	5	16	12.50	62.50	93.75	28.13	79.41	9	HS
25	SADAHAYAT	4	3	4	5	16	18.75	50.00	93.75	27.08	76.47	9	HS
26	KHUSHBO	4	2	3	5	14	14.29	42.86	107.14	27.38	77.31	9	HS
27	PK-386	4	3	2	5	14	21.43	28.57	107.14	26.19	73.95	7	S
28	SHUA-92	3	4	4	5	16	25.00	50.00	93.75	28.13	79.41	9	HS
29	TN-1	4	2	6	4	16	12.50	75.00	75.00	27.08	76.47	9	HS
30	NIPHANBHARE	3	3	5	4	15	20.00	66.67	80.00	27.78	78.43	9	HS
31	IR-8	13	3	0	0	16	18.75	0.00	0.00	3.13	8.82	1	R
32	SWATI-2014	3	1	6	3	13	7.69	92.31	69.23	28.21	79.64	9	HS
33	FAKHR E MALAKAND	9	4	3	0	16	25.00	37.50	0.00	10.42	29.41	3	MR
34	JP-5	3	3	4	4	14	21.43	57.14	85.71	27.38	77.31	9	HS
35	PK-1121	3	4	3	5	15	26.67	40.00	100.00	27.78	78.43	9	HS

The results in Table I showed resistant response (R) among the tested genotypes Basmati-2000, DR-82 and IR-8 on the basis of the damage rating scale having RLF infestation from 8.30% to 9.41%, Five genotypes Basmati-385, Basmati-370, DR-92, KS-282 and Fakhr e Malakand falls in the moderately resistant (MR) category with RLF infestation from 26.14% to 29.41%, five genotypes Shaheen Basmati, Basmati-198, Basmati-2008, Shadab and Swat-1 falls in moderately Susceptable (MS) category having RLF infestation from 37.65% to 44.44%, six varieties Kashmir Basmati, Basmati-612, IR-9, Sathra, Mathra and PK-386 falls in susceptible (S) category having RLF infestation from 57.92% to 73.95%, while sixteen varieties M-SUB (202), Rachna, Kashmir Basmati-100, IR-6, DR-83, KSK, Dilrosh-97, Kangni-27, Sadahayat, Khushbo, Shua-92, TN-1, Niphanbhare, Swati-2014, JP-5 and PK-1121 falls in highly susceptible (HS) category having RLF infestation from 75.29% to 79.64%.

Among all the tested varieties, Swati-2014 shows maximum leaf infestation with adjusted damage rating (D) of 79.64% against the RLF. While minimum leaf infestation with adjusted damage rating (D) of 8.30% was recorded on Basmati-2000 followed by IR-8 having 8.82% and DR-82 having 9.41% adjusted damage rating, these are the only three varieties gets position in the resistant categories among all the tested varieties.

DISCUSSION

The larval stage of the RLF, *Cnaphalocrocis medinalis* (Guenee) (Lepidoptera: Pyralidae) is the only destructive stage (Gangwar, 2015), and it can cause 30% to 80% yield losses in the rice crop (Shah *et al*., 2008). Host Plant resistance can play a key role in its management. Thus, keeping in mind the importance of the crop and pest this study was conducted to screen the selected varieties against RLF.

In this study we follow the method of Henrichs *et al*. (1985) for determining the level of resistance in the tested varieties, total thirty-five genotypes were tested for resistance to RLF under greenhouse conditions where only three selected genotypes display resistance against the tested insect i.e., Basmati-2000, DR-82 and IR-8 on the basis of the DRS damage rating scale having RLF infestation from 8.30% to 9.41%. In addition to these resistant genotypes five genotypes further showed moderately resistance against the RLF i.e., Basmati-385, Basmati-370, DR-92, KS-282 and Fakhr-e-Malakand with RLF infestation range from 26.14% to 29.41%. Similar results were also recorded by previous authors where rice cultivars, Basmati 515, IR-6, GEB-1, Super Basmati and KSK-133 had shown resistant response against the RLF, (Ahmad and Rehman, 2014; Shah *et al*., 2008). While some resistant cultivars also shows resistance against other insect pests along with RLF, like GEB24 shows resistance against, *Scirpophaga incertulas* (yellow stem borer), TKM6 shows resistance against *Chilo suppressalis* (striped stem borer) and *Nilaparvata lugens* (brown planthopper). Among the moderately resistant accessions against RLF, ASD7 (Acc. 6303) shows resistance against *Nilaparvata lugens* (brown planthopper) and *Nephotettix virescens* (green leafhopper) while, W1263 (Ace. 11057) shows resistance against *Orseolia oryzae* (gall midge) and *Scirpophaga incertulas* (yellow stem borer) and Ptb33 among the few rice varieties which shows high resistant against *Nilaparvata lugens* (brown planthopper) (Heinrichs *et al*., 1985; Vijay and Roy, 2013).

The resistance mechanism of the host plant against RLF may be because of morphological factors or biochemical factors or combination of both (Mithofer and Boland, 2012). Morphological factors are physical characteristics of the host plant which has negative effect on the pest development and biology (Fraenkel *et al*., 1981; Punithavalli *et al*., 2011, 2013). While biochemical factors are plant secondary metabolites which can affect the pest fecundity, fertility, oviposition, development, growth, feeding and food searching capabilities (Baldwin, 1999; Smith, 2005).

Host plant resistance is an integral part of any IPM package and is highly compatible with other control tactics. Rice varieties Basmati-2000, DR-82 and IR-8 can be cultivated in areas where the RLF infestation is high and can be used in combination with other control tactics to get maximum profit. Furthermore, these varieties can be used in breeding programs for developing new varieties having resistance against RLF. Thus, it is concluded that screening the available rice germplasm and determining the resistance against pests has its unique importance in efficient utilization of the existing Host Plant Resistance sources for the development and breeding of resistance varieties.

ACKNOWLEDGEMENT

Authors are grateful to Dr. Syed Mehar Ali Shah and Dr Sultan Akbar Jadoon, Department of Plant Breeding and Genetics, The University of Agriculture, Peshawar, for providing space and seeds to conduct this experiment.

Funding

The study was funded by Higher Education Commission under “Indigenous 5000 PhD Fellowship Program” for PhD Scholars.

IRB approval

Institutional Review Board of The University of Agriculture, Peshawar approved the study, vide letter no. 24/ORIC/UAP.

Ethical statement

The study does not deal with aminal or human trails.

Statement of conflict of interest

The authors have declared no conflict of interest.

REFERENCES

Ahmad, I. and Rehman, A., 2014. Green house screening of rice (*Oryza sativa* L.) germplasm against rice leaf folder (*Cnaphalocrocis medinalis* G.). *Eur. Acad. Res*., **2**: 11419-11431.

Ahmad, I., Rehman, A., Haq, E.U. and Mahmood, A., 2016. Resistance response of rice (*Oryza sativa* L.) germplasm against rice leaf folder *Cnaphalocrocis medinalis* (G.) under greenhouse condition in Pakistan. *Pak. J. agric. Res*., **29**: 268-272.

Baldwin, I.T., 1999. The eco-physiological complexity of plant responses to insect herbivores. *Planta*, **208**: 137–145. https://doi.org/10.1007/s004250050543

Behura, N., Sen, P. and Kar, M.K., 2011. Introgression of yellow stem borer (*Scirphopha incertulas*) resistance gene, into cultivated rice (*Oryza* sp.) from wild spp. *Indian J. agric. Sci*., **81**: 359-362.

Bentur, J.S., Sundaram, R.M., Mangrauthia, S.K. and Nair, S., 2021. Molecular approaches for insect pest management in rice. *Rice Improv*., pp. 379–342. https://doi.org/10.1007/978-3-030-66530-2_11

Chang, T.T., 1983. *Global role of the International Rice Germplasm Centre at the International Rice Research Institute*. In: "1983 Rice Germplasm Conservation Workshop." International Rice Research Institute, Los Banos, Philippines, pp. 57-65.

Chantaraprapha, N., Katanyukul, W., Semapetch, U. and Seetanun, W., 1980. Influence of ammonium phosphate levels on rice leaf roller incidence. *Int. Rice Res. Newsl*., **5**: 21.

Dash, L., Ramalakshmi, V., Padhy, D. and Tripathy, B., 2020. Breeding for resistance against leaf folder in rice. *Ind. J. Pure appl. Biosci*., **8**: 248-253. https://doi.org/10.18782/2582-2845.8456

Ehi-Eromosele, C.O., Nwinyi, O.C. and Ajani, O.O., 2013. *Weed and pest control*. *Conventional and new challengs* (Book). (**Please check this reference**).

Ezuka, A. and Kaku, H., 2000. A historical review of bacterial leaf blight of rice. *Bull. natl. Inst. Agrobiol. Resour*., **15**: 1-207.

Fraenkel, G., Fallil, F. and Kumarasingh, K.S., 1981. The feeding behaviour of the rice leaf folder, *Cnaphalocrocis medinalis*. *Ent. Exp. Appl.,* **29**: 147–161. https://doi.org/10.1111/j.1570-7458.1981.tb03054.x

Gangwar, R.K., 2015. Life cycle and abundance of rice leaf folder, *Cnaphalocrocis medinalis* (Guenee). A review. *J. Nat. Sci. Res*., **5**: 103-105.

Heinrichs, E.A., Camafiag, E., and Romena, A., 1985. Evaluation of rice cultivar for resistance to *Cnaphalocrocis medinalis* Guenée (Lepidoptera: Pyralidae). *J. econ. Ent*., **78**: 274-278. https://doi.org/10.1093/jee/78.1.274

Javvaji, S., Telugu, U.M., Venkata, R.D.B., Madhav, M.S., Rathod, S., and Chintalapati, P., 2021. Characterization of resistance to rice leaf folder, *Cnaphalocrocis medinalis,* in mutant Samba Mahsuri rice lines. *Ent. exp. Appl.,* **169**: 859-875. https://doi.org/10.1111/eea.13082

Khan, Z.R., and Joshi, R.C., 1990. Varietal resistance to *Cnaphalocrocis medinalis* (Guenée) in rice. *Crop Prot*., **9**: 243-251. https://doi.org/10.1016/0261-2194(90)90099-S

Li, D.H., Fu, Q., Wang, F., Yao, Q., Lai, F.X., Wu, J.C. and Zhang, Z.T., 2004. Resistance of transgenic rice containing both sck and crylac genes against *Chilo suppressalis* and *Cnaphalocrocis medinalis*. *Chin. J. Rice Sci*., **18**: 43–47.

Mithofer, A., and Boland, W., 2012. Plant defense against herbivores: Chemical aspects. *Annu. Rev. Pl. Biol. appl. natl. Sci. Found*., **63**: 431–450. https://doi.org/10.1146/annurev-arplant-042110-103854

Murthy, S.M., Nagaraj, S.K., Prabhuraj, A., Kalleswaraswamy, C.M., 2015. Rice leaf folder*Cnaphalocrocis medinalis* (Lepidoptera: Crambidae) on wheat (*Triticum aestivum*; Poales: Poaceae) in India. *Fla. Entomol*., **98**: 1269-1270. https://doi.org/10.1653/024.098.0446

Padmavathi, C., Katti, G., Padmakumari, A.P., Voleti, S.R., and SubbaRao, L.V., 2013. The effect of leaffolder *Cnaphalocrocis medinalis* (Guenee) [Lepidoptera: Pyralidae] injury on the plant physiology and yield loss in rice. *J. appl. Ent*., **137**: 249-256. https://doi.org/10.1111/j.1439-0418.2012.01741.x

Punithavalli, M., Muthukrishnan, N.M. and Rajkumar, M.B., 2011. Influence of rice leaf morphology on the folding characteristics of rice leaf folder, *Cnaphalocrocis medinalis*. *Indian J. Pl. Prot*., **39**: 93-99.

Ramasamy, C., and Jatileksono, T., 1996. Intercountry comparison of insect and disease losses, In: *Rice research in Asia: Progress and priorities* (eds. R.E. Evenson, R.W. Herdt and M. Hossain). CAB International and IRRI, Los Banos. pp. 305–316.

Rani, W.B., Amutha, R., Muthulakshmi, S., Indra, K. and Mareeswari, P., 2007. Diversity of rice leaf folder and their natural enemies. *Res. J. Agric. biol. Sci*., **3**: 394-397.

Rehman, A., 2003. *Screening and evaluation of rice germplasm for leaf folder (LF) resistance*. Final technical report. Rice program, NARC, Islamabad.

Rekha, L., Ram, Singh, R. and Singh, R., 2001. Sources and mechanisms of resistance in rice against rice leaf folder*Cnaphalocrocis medinaus* (Guenee). A review. *Agric. Rev*., **22**: 1 -12.

Rueda, B.P. and Khan, Z.R., 1988. *Effect of nitrogen levels on the incidence of rice leaf folder and stemborers on selected susceptible, moderately resistant and resistant rice varieties*. Poster presented at the 19th Anniversary and Annual Convention of the Pest Control Council of the Philippines, 3, 7 May 1988, Cebu City, Philippines

Salim, M., Akram, M., Ehsan, M. and Ashraf, M., 2003. *Rice a production handbook,* PARC, Pakistan.

Shah, S., Ali, M., Rehman, U.H., Rehman, A., Abbasi, F.M., Khalil, I.H., and Ali, A., 2008. Characterization of wild rice species in response to leaf folder (*C. madenalis*). *Sarhad J. Agric*., **24**: 69-74.

Smith, C.M., 2005. *Plant resistance to arthropods.* https://doi.org/10.1007/1-4020-3702-3

Song, X.L., Qiang, S., Liu, L.L., Xu, Y.H. and Liu, Y.L., 2002. Gene flow of pollen cross between *Oryza officinalis* wall and transgenic rice with bar gene. *J. Nanjing Agric. Univ*., **25**: 5–8. (in Chinese with an English abstract).

Soomro, A.S., Mazari, S.N., Hulio, M.H., Soomro, J.A., and Junejo, G.Q., 2020. Efficacy of different insecticides against rice leaf folder (*Cnaphalorosis medinalis*) under field conditions. *Int. J. appl. Sci. Biotechnol*., **8**: 211-215. https://doi.org/10.3126/ijasbt.v8i2.29582

Standard Evaluation System of Rice, 1996. *INGER Genetic Resources Center,* IRRI, Manila, Philippines. 4th ed. pp. 20-21.

Upadhyay, V.R., Shah, A.H. and Desai, N.D., 1981. Influence of levels of nitrogen and rice varieties on the incidence of rice leaf folder, *Cnaphalocrocis medinalis* Guen. *Gujarat Agric. Univ. Res. J*., **6**: 111-I 14.

Vijay, D. and Roy, B., 2013. *Chapter 4: Rice (*Oryza sativa *L.). Breeding, biotechnology and seed production of field crops.* pp. 71-122.

Waldbauer, G.P. and Marciano, A.P., 1979. Mass rearing of the rice leaffolder, *Cnaphalocrocis medinalis* Guenee (Lepidoptera: Pyralidae) under greenhouse conditions. *J. Entomol. Res.,* **3**: 1–8.