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Screening of Rice Genotypes for Resistant to Rice Leaf Folder, *Cnaphalocrocis medinalis* Guenee and Identification of Associated Morphological Traits

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Abstract— *Screening of 23 rice promising genotypes based on per cent damaged leaves revealed that eleven genotypes were found moderately resistant viz., Kala Namak (12.32%), GNR-3 (13.41%), GNR-5 (13.45%), GRH-2 (13.92%), GNR-7 (14.43%), GR-15 (16.02%), Mahsuri (16.52%), GNRH-1 (16.62%), GR-17 (16.89%), GNR-2 (19.02%) and NVSR-396 (19.34%) (Scale-3). Whereas, two genotypes were found susceptible i.e. GNR-4 (37.32%) and GR-11 (39.11%) (Scale-7) and one genotype TN-1 (54.86%) was found the highly susceptible (Scale-9). The plant height exhibited the highly significant negative correlation with per cent damaged leaves (r = -0.6157) and number of larvae (r = -0.5621), while others parameters were found non-significant positive and negative correlation. The highest grain and straw yield were recorded in GRH-2 (5946 & 6667 kg/ha) and lowest were recorded in TN-1 (3874 and 4559 kg/ha), respectively. Grain and straw yield exhibited the highly significant negative correlation with per cent damaged leaves (r = -0.5882 and r = -0.5828, respectively) and number of larvae (r = -0.5776 and r = -0.5711, respectively) indicated that there was decrease in yield with increase in infestation and vice-versa.*

Keywords— Rice, Screening, Morphological traits, Leaf folder, Cnaphalocrocis medinalis.

I. INTRODUCTION

Rice (*Oryza sativa* Linnaeus) belongs to the family of grasses (Poaceae) with most important cereal crops worldwide. It is grown over 120 million hectares to produce 600 million tonnes of grain with an average productivity of 5000 kg/ha (Jakarpong and Wiboon, 2017). India ranks first by covering the largest area (45 per cent) under rice and ranks second by contributing total food grain production of the world. In India rice is grown in 43.86 million hectares with 112 million tonnes production and the average productivity is about 2600 kg/ha (Anon., 2020). Rice production is confined to South and Middle Gujarat with wide range of agro-climatic variation within and between individual zones. Rice production is limited by both biotic and abiotic stresses of which insect pests alone caused about 25 per cent losses (Dhaliwal et al., 2007), hence there is need to reduce the yield losses due to major pests and diseases. Rice crop is attacked by more than 100 species of insects, out of them 20 species can cause economic damage during different stages of the crop (Jakarpong and Wiboon, 2017). Rice leaf folder is one of the most serious and most important pest of rice crop in Indian subcontinent (Shanmungam et al., 2006). Out of eight species of leaf folders, the widest spread and important one is *Cnaphalocrocis medinalis* (Guenee) (Pyralidae: Lepidoptera) (Bhatti, 1995). It was earlier considered a minor pest but now a days it assumed major pest status. Due to rice leaf folder, the loss may reach up to 63 to 80 per cent as reported by Rajendran et al. (1986). Host plant resistance is an important component of integrated pest management (IPM) for sustainable rice production. Screening of rice genotypes for resistance to leaf folder and identification of associated morphological traits can facilitate the development of resistant varieties, thereby reducing dependence on chemical insecticides. The present study was therefore undertaken to screen promising rice genotypes for resistance to rice leaf folder and to identify morphological traits associated with resistance.

II. MATERIALS AND METHODS

The field investigation on screening and morphological basis of resistance of rice genotypes against leaf folder was carried out at Main Rice Research Centre, Navsari Agricultural University, Navsari, Gujarat during *Kharif*-2020 and 2021 (Plate 1). Following twenty three rice genotypes viz., NAUR-1, GNR-2, GNR-3, GNR-4, GNR-5, GNR-6, GNR-7, IR-28, NVSR-392, NVSR-395, NVSR-396, GNRH-1, GR-15, GR-17, Mahsuri, GR-101, Krishna Kamod, GAR-13, Kala Namak, Chittimuthyalu and GRH-2. Along with state susceptible GR-11 and national susceptible check TN-1 were transplanted for screening against leaf folder. The experiment was laid out in a randomized completely block design with twenty three treatments and two replications. Each entry was planted in five rows of 1.95 meter length with a spacing 20 × 15 cm. Recommended agronomical practices of manure and fertilizer dose @ FYM: 10 tonnes/ha and N-P-K: 100-30-00 kg/ha was applied. No plant protection measures were provided to create optimum conditions for pest multiplication.

The observations of per cent leaf damage and numbers of larvae were recorded at 7th days after the commencement of pest appearance. From each genotype, 10 hills were selected randomly from each replication. Observations were recorded by counting the total number of larvae, leaves per 10 hills and total number of damaged leaves (Only if one-third of leaf area is damaged) per 10 hills. Thereafter, all the observations were recorded regularly at an interval of 15 days up to the harvest of crop. The highest per cent damaged leaves were taken for final interpretation. Per cent leaf damage was calculated by following formula given by Netam and Gupta (2015).

$$\text{Leaf damage (\%)} = \frac{\text{Total number of damaged leaves}}{\text{Total number of leaves (Healthy + Damaged)}} \times 100 \tag{1}$$

Morphological parameters were recorded from each genotype at the time of the highest per cent damaged leaves, morphological parameters for the same was considered for final interpretation from randomly selected five plants of each genotype from each replication. The rice genotypes were evaluated for various morphological traits, viz., plant height (cm), total number of tillers per hill, leaf length (cm), leaf thickness (mm), leaf width (cm), leaf colour, days to 50 per cent flowering and phyllotaxy.

2.1 Categorization of Rice Genotypes on the Basis of Damaged Leaves

Categorization of rice genotypes on the basis of damaged leaves was done by using Standard Evaluation System (SES, 2013) developed by IIRR for estimating relative resistance/susceptibility. The rice genotypes were categorized based on the percentage of damaged leaves using a 0-9 scale. A scale of 0 (no damage) was classified as highly resistant/immune, while 1 (1-10% damaged leaves) was categorized as resistant. A scale of 3 (11-20%) was considered moderately resistant, whereas 5 (21-35%) was classified as moderately susceptible. A scale of 7 (36-50%) was categorized as susceptible and a scale of 9 (51-100%) was considered highly susceptible.

PLATE 1: Screening of rice genotypes against rice leaf folder, *C. medinalis* during Kharif-2020 & 2021]

III. RESULTS AND DISCUSSION

3.1 Screening Based on Per Cent Damaged Leaves and Number of Larvae

The results revealed that all rice genotypes and checks showed varying levels of rice leaf folder infestation during *Kharif* 2020 and 2021. Based on pooled data, the percentage of damaged leaves ranged from 12.32% in Kala Namak to 54.86% in TN-1. Eleven genotypes viz., Kala Namak, GNR-3, GNR-5, GRH-2, GNR-7, GR-15, Mahsuri, GNRH-1, GR-17, GNR-2 and NVSR-396 showed a moderately resistant reaction (SES-3). Nine genotypes showed moderately susceptible, two susceptible and TN-1 highly susceptible reactions. The lowest larval population was recorded in Kala Namak (2.20 larvae), while the highest was observed in TN-1 (7.33 larvae). Lower larval population was generally associated with lower leaf damage. These findings are in agreement with Punithavalli et al. (2013) and Ashrith et al. (2020), who reported differential resistance among rice genotypes to leaf folder infestation. The identification of moderately resistant genotypes is particularly important as they can serve as donors in breeding programmes for developing leaf-folder-resistant rice varieties.

TABLE 1
SCREENING OF RICE GENOTYPES ON THE BASIS OF PER CENT DAMAGED LEAVES (KHARIF-2020, 2021 & POOLED)

Sr. No.	Genotype	Damaged leaves (%)			Scale	Reaction
		Kharif-2020	Kharif-2021	Pooled		
1	GNR-6	28.34 (22.60)*	29.38 (24.12)*	28.86 (23.36)*	5	MS
2	IR-28	30.36 (25.58)	31.35 (27.08)	30.86 (26.33)	5	MS
3	NVSR-392	34.20 (31.61)	35.09 (33.06)	34.65 (32.34)	5	MS
4	NVSR-395	33.93 (31.18)	34.81 (32.60)	34.37 (31.89)	5	MS
5	NVSR-396	25.61 (18.73)	26.52 (19.96)	26.07 (19.34)	3	MR
6	GNRH-1	23.34 (15.76)	24.70 (17.49)	24.03 (16.62)	3	MR
7	NAUR-1	28.82 (23.31)	29.64 (24.51)	29.23 (23.91)	5	MS
8	GNR-2	25.31 (18.35)	26.26 (19.68)	25.79 (19.02)	3	MR
9	GNR-3	20.58 (12.41)	22.23 (14.41)	21.42 (13.41)	3	MR
10	GNR-5	20.96 (12.86)	21.97 (14.04)	21.47 (13.45)	3	MR
11	GNR-7	21.67 (13.65)	22.92 (15.22)	22.30 (14.43)	3	MR
12	GR-15	23.05 (15.36)	24.08 (16.69)	23.57 (16.02)	3	MR
13	GR-17	23.82 (16.35)	24.63 (17.43)	24.23 (16.89)	3	MR
14	Mahsuri	23.37 (15.84)	24.42 (17.21)	23.90 (16.52)	3	MR
15	GNR-4	37.16 (36.61)	38.02 (38.02)	37.59 (37.32)	7	S
16	GR-101	29.96 (24.95)	31.55 (27.39)	30.76 (26.17)	5	MS
17	Krishna Kamod	30.21 (25.47)	31.51 (27.46)	30.87 (26.47)	5	MS
18	GAR-13	28.41 (22.67)	29.50 (24.29)	28.96 (23.48)	5	MS
19	Kala Namak	19.77 (11.47)	21.23 (13.17)	20.51 (12.32)	3	MR
20	Chittimuthyalu	28.76 (23.20)	30.25 (25.42)	29.51 (24.31)	5	MS
21	GRH-2	21.34 (13.28)	22.40 (14.57)	21.87 (13.92)	3	MR
22	GR-11	38.03 (38.00)	39.36 (40.22)	38.70 (39.11)	7	S
23	TN-1	47.07 (53.59)	48.54 (56.13)	47.80 (54.86)	9	HS
S. Em. ±		1.86	1.9	1.87	-	-
C.D. at 5%		5.45	5.57	5.47	-	-
C.V. (%)		9.38	9.21	9.24	-	-

Figures in the parentheses are original values, while those outside are arcsine transformed values.
MR: Moderately Resistant, MS: Moderately Susceptible, S: Susceptible and HS: Highly Susceptible

TABLE 2
SCREENING OF RICE GENOTYPES ON THE BASIS OF NUMBER OF LARVAE (KHARIF-2020, 2021 & POOLED)

Sr. No.	Genotype	Number of larvae			Av. % DL	Scale	Reaction
		Kharif-2020	Kharif-2021	Pooled			
1	GNR-6	1.94 (3.30)*	2.01 (3.56)*	1.98 (3.43)*	28.86 (23.36)	5	MS
2	IR-28	2.13 (4.05)	2.16 (4.15)	2.14 (4.10)	30.86 (26.33)	5	MS
3	NVSR-392	2.29 (4.75)	2.31 (4.85)	2.30 (4.80)	34.65 (32.34)	5	MS
4	NVSR-395	2.26 (4.60)	2.29 (4.75)	2.27 (4.68)	34.37 (31.89)	5	MS
5	NVSR-396	1.83 (2.85)	1.95 (3.30)	1.89 (3.08)	26.07 (19.34)	3	MR
6	GNRH-1	1.70 (2.40)	1.76 (2.60)	1.73 (2.50)	24.03 (16.62)	3	MR
7	NAUR-1	2.14 (4.10)	2.11 (3.95)	2.13 (4.03)	29.23 (23.91)	5	MS
8	GNR-2	1.81 (2.80)	1.86 (2.95)	1.83 (2.88)	25.79 (19.02)	3	MR
9	GNR-3	1.63 (2.15)	1.68 (2.35)	1.65 (2.25)	21.42 (13.41)	3	MR
10	GNR-5	1.64 (2.20)	1.71 (2.45)	1.68 (2.33)	21.47 (13.45)	3	MR
11	GNR-7	1.61 (2.10)	1.74 (2.55)	1.68 (2.33)	22.30 (14.43)	3	MR
12	GR-15	1.70 (2.40)	1.88 (3.05)	1.79 (2.73)	23.57 (16.02)	3	MR
13	GR-17	1.79 (2.70)	1.87 (3.00)	1.83 (2.85)	24.23 (16.89)	3	MR
14	Mahsuri	1.79 (2.70)	1.83 (2.85)	1.81 (2.78)	23.90 (16.52)	3	MR
15	GNR-4	2.28 (4.70)	2.21 (4.40)	2.25 (4.55)	37.59 (37.32)	7	S
16	GR-101	2.07 (3.85)	2.14 (4.10)	2.11 (3.98)	30.76 (26.17)	5	MS
17	Krishna Kamod	2.21 (4.40)	2.20 (4.35)	2.21 (4.38)	30.87 (26.47)	5	MS
18	GAR-13	2.10 (3.90)	2.12 (4.00)	2.11 (3.95)	28.96 (23.48)	5	MS
19	Kala Namak	1.61 (2.10)	1.67 (2.30)	1.64 (2.20)	20.51 (12.32)	3	MR
20	Chittimuthyalu	2.13 (4.05)	2.14 (4.10)	2.14 (4.08)	29.51 (24.31)	5	MS
21	GRH-2	1.63 (2.15)	1.76 (2.60)	1.69 (2.38)	21.87 (13.92)	3	MR
22	GR-11	2.57 (6.10)	2.75 (7.05)	2.66 (6.58)	38.70 (39.11)	7	S
23	TN-1	2.69 (6.75)	2.90 (7.90)	2.80 (7.33)	47.80 (54.86)	9	HS
S. Em. ±		0.09	0.1	0.09	1.87	-	-
C.D. at 5%		0.27	0.29	0.25	5.47	-	-
C.V. (%)		6.63	6.74	6.03	9.24	-	-

Figures in the parentheses are original values, while those outside are square root ($\sqrt{(X+0.5)}$) transformed values.
% DL: Per cent damaged leaves, MR: Moderately Resistant, MS: Moderately Susceptible, S: Susceptible and HS: Highly Susceptible

3.2 Resistance Based on Morphological Characters

Pooled data revealed that longer plant height, more tillers, thicker and broader leaves, green leaf colour and late flowering were generally associated with lower rice leaf folder infestation. Genotypes with long plant height recorded the lowest damaged leaves (17.51 ± 4.45%) and larval population (2.91 ± 0.73), whereas short plants showed the highest infestation (31.39 ± 9.90%). More tillers, thicker and broader leaves also showed comparatively lower leaf damage and larval population. Green-coloured leaves recorded the lowest damage (18.34 ± 5.11%) and larval population (3.00 ± 0.80), while light and dark green leaves showed higher infestation. Late-flowering genotypes exhibited lower damage (21.28 ± 6.47%) than early-flowering genotypes (25.62 ± 12.10%). All 23 genotypes possessed spiral phyllotaxy and therefore no variation in this trait could be associated with resistance.

The association between morphological traits and resistance can be explained through several mechanisms. Longer plant height may reduce oviposition preference by making plants less accessible to adult moths or may create a microclimate less favourable for larval development. Thicker and broader leaves may provide physical barriers to larval feeding and folding, while green leaf colour may be associated with lower sugar content or higher silica deposition, making leaves less palatable. Late flowering may result in asynchrony between susceptible crop stages and peak pest populations. These findings are in agreement with Punithavalli et al. (2013), who reported a positive association of leaf width and total productive tillers with rice leaf folder infestation, and Ashrith et al. (2020), who found significant positive association of leaf width with leaf folder infestation.

TABLE 3
INFLUENCE OF DIFFERENT MORPHOLOGICAL CHARACTERS OF GENOTYPE ON PER CENT DAMAGED LEAVES AND NUMBER OF LARVAE (KHARIF-2020, 2021 & POOLED)

Plant character	Category	Range	Damaged leaves (%)	Number of larvae	Range	Damaged leaves (%)	Number of larvae	Range	Damaged leaves (%)	Number of larvae
		Kharif-2020			Kharif-2021			Pooled		
Plant height (cm)	Long	≥ 114 (13)	16.75 ± 4.40	2.79 ± 0.80	≥ 112 (13)	18.17 ± 4.51	3.63 ± 1.64	≥ 113 (13)	17.51 ± 4.45	2.91 ± 0.73
	Short	< 114 (10)	30.51 ± 9.77	4.48 ± 1.14	< 112 (10)	32.26 ± 10.03	4.09 ± 0.58	< 113 (10)	31.39 ± 9.90	4.63 ± 1.30
Total tiller	More	≥ 14 (15)	20.24 ± 6.96	3.16 ± 0.96	≥ 14 (15)	21.77 ± 6.99	3.41 ± 0.79	≥ 14 (14)	21.00 ± 6.98	3.32 ± 0.87
	Less	< 14 (8)	26.60 ± 12.37	4.21 ± 1.49	< 14 (8)	28.38 ± 12.70	4.38 ± 1.83	< 14 (9)	27.49 ± 12.53	4.18 ± 1.68
Leaf length (cm)	Long	≥ 58 (10)	22.34 ± 8.29	3.59 ± 1.26	≥ 57 (10)	23.83 ± 8.52	4.26 ± 1.71	≥ 57 (10)	21.07 ± 6.52	3.92 ± 1.60
	Short	< 58 (13)	25.11 ± 11.09	3.48 ± 1.29	< 57 (13)	24.76 ± 11.25	3.71 ± 1.42	< 57 (13)	25.44 ± 11.74	3.59 ± 1.35
Leaf thickness (mm)	Thick	> 0.267 (10)	20.39 ± 7.11	3.26 ± 0.94	> 0.266 (10)	21.94 ± 7.17	3.36 ± 0.76	> 0.266 (10)	20.82 ± 7.74	3.31 ± 0.85
	Thin	< 0.267 (13)	24.53 ± 11.35	3.73 ± 1.45	< 0.266 (13)	26.21 ± 11.63	4.12 ± 1.64	< 0.266 (13)	25.29 ± 11.08	3.93 ± 1.54
Leaf width (cm)	Broad	> 1.268 (12)	21.18 ± 8.17	3.38 ± 1.21	> 1.275 (12)	22.23 ± 8.68	3.54 ± 1.20	> 1.272 (12)	21.92 ± 8.29	3.42 ± 1.15
	Narrow	< 1.268 (11)	24.43 ± 11.35	3.71 ± 1.34	< 1.275 (11)	26.67 ± 11.11	4.12 ± 1.54	< 1.272 (11)	25.31 ± 11.43	3.97 ± 1.46
Leaf colour	Light green	(7)	27.01 ± 12.99	3.99 ± 1.61	(7)	28.82 ± 13.42	4.54 ± 1.90	(7)	27.91 ± 13.20	4.27 ± 1.75
	Green	(10)	17.61 ± 5.08	2.90 ± 0.87	(10)	19.07 ± 5.15	3.09 ± 0.73	(10)	18.34 ± 5.11	3.00 ± 0.80
	Dark green	(6)	26.68 ± 7.89	4.03 ± 0.90	(6)	27.97 ± 7.66	4.42 ± 0.34	(6)	27.12 ± 7.78	4.05 ± 0.86
DFF	Early	> 93 (12)	24.72 ± 11.96	3.80 ± 1.47	> 95 (12)	26.52 ± 12.25	4.08 ± 1.70	> 94 (12)	25.62 ± 12.10	3.94 ± 1.57
	Late	< 93 (11)	20.56 ± 6.48	3.18 ± 0.91	< 95 (11)	21.99 ± 6.45	3.47 ± 0.82	< 94 (11)	21.28 ± 6.47	3.35 ± 0.88
Phyllotaxy	Spiral	(23)	22.73 ± 9.95	3.53 ± 1.28	(23)	24.35 ± 10.16	3.79 ± 1.39	(23)	23.54 ± 10.06	3.66 ± 1.32

3.3 Correlation Coefficient (r) of Different Morphological Characters

Result on pooled revealed that the plant height exhibited highly significant negative correlation with per cent damaged leaves (r = -0.6157) and number of larvae (r = -0.5621) implying increase in the plant height corresponds with decrease of the infestation and vice-versa. Per cent damaged leaves exhibited non-significant negative correlation with total numbers of tiller (r = -0.3223), leaf length (r = -0.2064) and leaf thickness (r = -0.1481). It exhibited non-significant positive correlation with leaf width (r = 0.0101) and days to 50% flowering (r = 0.0578). While in case of number of larvae, it exhibited non-significant negative correlation with total numbers of tiller (r = -0.2981), leaf length (r = -0.1732), leaf thickness (r = -0.0991) and leaf width (r = -0.0686). It exhibited non-significant positive correlation with days to 50% flowering (r = 0.0746) (Table 6). Ashrith et al. (2020) found that significant positive association (0.932) found with leaf width at midpoint. Among the morphological characters studied, only the number of trichomes and leaf width (cm) showed significant correlation with rice leaf folder infestation.

TABLE 4
CORRELATION COEFFICIENT (r) OF DIFFERENT MORPHOLOGICAL CHARACTERS OF GENOTYPES WITH PERCENT DAMAGED LEAVES AND NUMBER OF LARVAE DURING KHARIF-2020

SN	Genotype	Plant height (cm)	Total tiller/ hill	Leaf			DFF	Reaction (% DL)
				Length (cm)	Thickness (mm)	Width (cm)		
1	GNR-6	100	13	56	0.275	0.650	75	MS
2	IR-28	92	13	37	0.255	0.725	75	MS
3	NVSR-392	108	13	64	0.245	1.110	74	MS
4	NVSR-395	105	14	61	0.260	1.125	72	MS
5	NVSR-396	120	14	64	0.260	1.275	71	MR
6	GNRH-1	119	15	50	0.245	1.225	81	MR
7	NAUR-1	122	15	64	0.280	1.350	91	MS
8	GNR-2	101	12	57	0.270	1.500	95	MR
9	GNR-3	123	14	56	0.270	1.150	85	MR
10	GNR-5	121	15	58	0.270	1.350	105	MR
11	GNR-7	116	14	57	0.255	1.475	100	MR
12	GR-15	126	15	67	0.215	1.675	91	MR
13	GR-17	115	15	54	0.240	1.500	84	MR
14	Mahsuri	118	19	89	0.360	1.175	111	MR
15	GNR-4	97	15	50	0.275	2.000	106	S
16	GR-101	106	12	55	0.245	1.375	108	MS
17	Krishna Kamod	134	17	56	0.305	0.975	101	MS
18	GAR-13	106	15	51	0.260	1.475	100	MS
19	Kala Namak	136	13	55	0.255	1.050	113	MR
20	Chittimuthyalu	114	15	58	0.335	1.235	106	MS
21	GRH-2	130	12	58	0.275	1.270	89	MR
22	GR-11	102	13	58	0.260	1.275	103	S
23	TN-1	102	12	55	0.225	1.225	103	HS
S. Em. ±		**4.02**	**0.95**	**1.70**	**0.01**	**0.04**	**1.86**	-
C.D. at 5%		**11.78**	**2.77**	**4.99**	**0.02**	**0.13**	**5.47**	-
C.V. (%)		**5.00**	**9.46**	**4.16**	**4.13**	**4.81**	**2.83**	-
(r) value for % DL		**-0.6050****	**-0.2544^{NS}**	**-0.1701^{NS}**	**-0.1815^{NS}**	**0.0109^{NS}**	**0.0431^{NS}**	-
(r) value for NL		**-0.5584****	**-0.1822^{NS}**	**-0.1497^{NS}**	**-0.0803^{NS}**	**-0.0607^{NS}**	**0.0669^{NS}**	-

DFF: Days to 50% flowering, % DL: Per cent damaged leaves, NL: Number of larvae, R: Resistant, MR: Moderately Resistant, MS: Moderately Susceptible, S: Susceptible and HS: Highly Susceptible

TABLE 5
CORRELATION COEFFICIENT (r) OF DIFFERENT MORPHOLOGICAL CHARACTERS OF GENOTYPES WITH PER CENT DAMAGED LEAVES AND NUMBER OF LARVAE DURING KHARIF-2021

Sr. No.	Genotype	Plant height (cm)	Total tiller/ hill	Leaf			DFF	Reaction (% DL)
				Length (cm)	Thickness (mm)	Width (cm)		
1	GNR-6	98	13	54	0.275	0.675	77	MS
2	IR-28	90	13	39	0.260	0.800	77	MS
3	NVSR-392	106	11	60	0.255	1.075	76	MS
4	NVSR-395	103	15	61	0.265	1.100	74	MS
5	NVSR-396	118	14	66	0.255	1.300	73	MR
6	GNRH-1	117	15	52	0.260	1.225	83	MR
7	NAUR-1	122	15	62	0.270	1.300	93	MS
8	GNR-2	101	12	56	0.270	1.475	97	MR
9	GNR-3	123	14	56	0.270	1.255	87	MR
10	GNR-5	121	15	58	0.275	1.475	105	MR
11	GNR-7	114	15	55	0.245	1.525	102	MR
12	GR-15	124	14	67	0.200	1.600	93	MR
13	GR-17	112	15	54	0.250	1.375	86	MR
14	Mahsuri	114	19	85	0.345	1.200	113	MR
15	GNR-4	99	15	50	0.270	2.100	110	S
16	GR-101	104	12	55	0.250	1.350	108	MS
17	Krishna Kamod	130	15	56	0.300	1.000	103	MS
18	GAR-13	104	14	53	0.265	1.400	102	MS
19	Kala Namak	134	13	56	0.250	1.050	115	MR
20	Chittimuthyalu	112	15	57	0.330	1.200	108	MS
21	GRH-2	126	12	58	0.275	1.300	91	MR
22	GR-11	100	13	57	0.255	1.300	105	S
23	TN-1	98	12	55	0.235	1.250	105	HS
S. Em. ±		**3.65**	**0.73**	**1.49**	**0.01**	**0.04**	**1.48**	-
C.D. at 5%		**10.72**	**2.15**	**4.36**	**0.02**	**0.11**	**4.35**	-
C.V. (%)		**4.63**	**7.43**	**3.66**	**4.20**	**4.00**	**2.21**	-
(r) value for % DL		**-0.6225****	**-0.3019^{NS}**	**-0.2200^{NS}**	**-0.1241^{NS}**	**0.0094^{NS}**	**0.0720^{NS}**	-
(r) value for NL		**-0.5618****	**-0.3132^{NS}**	**-0.1646^{NS}**	**-0.1380^{NS}**	**-0.0755^{NS}**	**0.0795^{NS}**	-

DFF: Days to 50% flowering, % DL: Per cent damaged leaves, NL: Number of larvae, R: Resistant, MR: Moderately Resistant, MS: Moderately Susceptible, S: Susceptible and HS: Highly Susceptible

TABLE 6
CORRELATION COEFFICIENT (r) OF DIFFERENT MORPHOLOGICAL CHARACTERS OF GENOTYPES WITH PER CENT DAMAGED LEAVES AND NUMBER OF LARVAE (POOLED OF 2020 & 2021)

Sr. No.	Genotype	Plant height (cm)	Total tiller/ hill	Leaf			DFF	Reaction (% DL)
				Length (cm)	Thickness (mm)	Width (cm)		
1	GNR-6	99	13	55	0.275	0.663	76	MS
2	IR-28	91	13	38	0.260	0.763	76	MS
3	NVSR-392	107	12	62	0.250	1.093	75	MS
4	NVSR-395	104	15	61	0.263	1.113	73	MS
5	NVSR-396	119	14	65	0.260	1.288	72	MR
6	GNRH-1	118	15	51	0.253	1.225	82	MR
7	NAUR-1	122	15	63	0.265	1.325	92	MS
8	GNR-2	101	12	57	0.270	1.488	96	MR
9	GNR-3	123	14	56	0.268	1.203	86	MR
10	GNR-5	121	15	58	0.273	1.413	105	MR
11	GNR-7	115	15	56	0.250	1.500	101	MR
12	GR-15	125	15	67	0.208	1.638	92	MR
13	GR-17	114	15	54	0.245	1.438	85	MR
14	Mahsuri	116	19	87	0.353	1.188	112	MR
15	GNR-4	98	15	50	0.270	2.050	108	S
16	GR-101	105	12	55	0.250	1.363	108	MS
17	Krishna Kamod	132	16	56	0.303	0.988	102	MS
18	GAR-13	105	15	52	0.263	1.438	101	MS
19	Kala Namak	135	14	56	0.253	1.050	114	MR
20	Chittimuthyalu	113	15	58	0.333	1.218	107	MS
21	GRH-2	128	12	58	0.275	1.285	90	MR
22	GR-11	101	13	56	0.263	1.288	104	S
23	TN-1	100	12	55	0.230	1.238	104	HS
S. Em. ±		**2.59**	**0.68**	**0.98**	**0.01**	**0.03**	**1.49**	**-**
C.D. at 5%		**7.60**	**2.01**	**2.89**	**0.02**	**0.08**	**4.37**	**-**
C.V. (%)		**3.25**	**6.89**	**2.41**	**3.30**	**3.02**	**2.24**	**-**
(r) value for % DL		**-0.6157****	**-0.3223^{NS}**	**-0.2064^{NS}**	**-0.1481^{NS}**	**0.0101^{NS}**	**0.0578^{NS}**	**-**
(r) value for NL		**-0.5621****	**-0.2981^{NS}**	**-0.1732^{NS}**	**-0.0991^{NS}**	**-0.0686^{NS}**	**0.0746^{NS}**	**-**

DFF: Days to 50% flowering, % DL: Per cent damaged leaves, NL: Number of larvae, MR: Moderately Resistant, MS: Moderately Susceptible, S: Susceptible and HS: Highly Susceptible

3.4 Grain and Straw Yield of Different Rice Genotypes

Pooled data (Table 7) revealed that GRH-2 recorded the highest grain yield (5946 kg/ha) and was at par with GNR-3 (5738 kg/ha), GNR-5 (5723 kg/ha), GR-15 (5679 kg/ha), GAR-13 (5546 kg/ha), NAUR-1 (5436 kg/ha), GR-17 (5423 kg/ha) and GNR-7 (5362 kg/ha). Grain yield among the remaining genotypes ranged from 3431 kg/ha in Krishna Kamod to 4941 kg/ha in GNRH-1.

Similarly, GRH-2 recorded the highest straw yield (6667 kg/ha), which was at par with GNR-3 (6487 kg/ha), GNR-5 (6472 kg/ha), GR-15 (6436 kg/ha), GAR-13 (6282 kg/ha), NAUR-1 (6169 kg/ha), GR-17 (6159 kg/ha) and GNR-7 (6097 kg/ha). Among the remaining genotypes, straw yield ranged from 4026 kg/ha in Chittimuthyalu to 5651 kg/ha in GNRH-1. Overall, the genotypes showing better performance and lower leaf folder infestation also exhibited comparatively higher grain and straw yields.

TABLE 7
GRAIN AND STRAW YIELD OF DIFFERENT RICE GENOTYPES AND ITS CORRELATION (r) WITH PERCENT DAMAGED LEAVES AND NUMBER OF LARVAE (KHARIF-2020, 2021 & POOLED)

Sr. No.	Genotype	Grain Yield (Kg/ha)			Straw Yield (Kg/ha)			Reaction (% DL)
		2020	2021	Pooled	2020	2021	Pooled	
1	GNR-6	3933	3923	3928	4559	4523	4538	MS
2	IR-28	3662	3636	3649	4246	4241	4241	MS
3	NVSR-392	3579	3554	3567	4118	4149	4133	MS
4	NVSR-395	3579	3641	3610	4179	4246	4215	MS
5	NVSR-396	4226	4200	4213	4913	4795	4851	MR
6	GNRH-1	4979	4903	4941	5810	5497	5651	MR
7	NAUR-1	5446	5426	5436	6323	6021	6169	MS
8	GNR-2	4697	4621	4659	5451	5226	5338	MR
9	GNR-3	5759	5718	5738	6682	6297	6487	MR
10	GNR-5	5749	5697	5723	6656	6292	6472	MR
11	GNR-7	5400	5323	5362	6272	5928	6097	MR
12	GR-15	5697	5662	5679	6621	6256	6436	MR
13	GR-17	5441	5405	5423	6308	6010	6159	MR
14	Mahsuri	4503	4477	4490	5231	5062	5144	MR
15	GNR-4	3954	3954	3954	4590	4549	4569	S
16	GR-101	4133	4097	4115	5092	4692	4892	MS
17	Krishna Kamod	3436	3426	3431	4246	4056	4149	MS
18	GAR-13	5554	5538	5546	6426	6138	6282	MS
19	Kala Namak	4092	4054	4073	4759	4656	4708	MR
20	Chittimuthyalu	3467	3410	3438	4026	4021	4026	MS
21	GRH-2	5985	5908	5946	6836	6503	6667	MR
22	GR-11	4154	4077	4115	4821	4708	4764	S
23	TN-1	3913	3836	3874	4615	4497	4559	HS
S. Em. ±		209	228	217	248	227	233	-
C.D. at 5%		613	668	637	727	665	682	-
C.V. (%)		6.45	7.09	6.74	6.56	6.23	6.28	-
Correlation coefficient (r) % DL		-0.5844**	-0.5919**	-0.5882**	-0.5827**	-0.5824**	-0.5828**	
Correlation coefficient (r) NL		-0.6107**	-0.5422**	-0.5776**	-0.6066**	-0.5310**	-0.5711**	

% DL: Per cent damaged leaves, NL: Number of larvae, MR: Moderately Resistant, MS: Moderately Susceptible, S: Susceptible and HS: Highly Susceptible

3.5 Correlation Coefficient (r) of Grain and Straw Yield

Result on pooled revealed that the grain yield exhibited highly significant negative correlation with per cent damaged leaves (r = -0.5882) and number of larvae (r = -0.5776) implying increase in the infestation corresponds with decrease of the grain yield and vice-versa. Straw yield exhibited highly significant negative correlation with per cent damaged leaves (r = -0.5828) and number of larvae (r = -0.5711) implying increase in the infestation corresponds with decrease of the straw yield and vice-versa. Bautista et al. (1984) have clearly shown that loss in yield was positively related. In their studies, 17.5 per cent infested leaves, resulted in 16.5 per cent yield loss and a loss of 21.3 per cent yield occurred with 26.6% DL. Thus, past reports support the present findings. Cumulative effect of loss in chlorophyll reduced photosynthate availability and altered water relations caused by the leaf folder injury to flag leaf led to greater yield loss in rice (Padmavathi et al., 2013).

IV. DISCUSSION

The screening of 23 rice genotypes against leaf folder revealed significant variation in resistance levels, with eleven genotypes exhibiting moderately resistant reactions. The identification of these genotypes is particularly valuable as they can serve as donors in breeding programmes for developing leaf-folder-resistant rice varieties. The consistent performance of genotypes like Kala Namak, GNR-3, GNR-5, and GRH-2 across both seasons indicates stable resistance, which is desirable for breeding purposes.

The association between morphological traits and resistance observed in this study provides insights into the mechanisms underlying resistance. The highly significant negative correlation between plant height and infestation parameters (r = -0.6157 for % DL and r = -0.5621 for larval population) suggests that taller genotypes may be less preferred by adult moths for oviposition or may provide a less favourable microclimate for larval development. This finding is consistent with previous reports by Punithavalli et al. (2013) and Ashrith et al. (2020). The non-significant correlations of other morphological traits with infestation indicate that these traits may have weaker or inconsistent effects on resistance, possibly due to the complex nature of plant-insect interactions.

The significant negative correlation between grain yield and infestation parameters (r = -0.5882 for % DL and r = -0.5776 for larval population) clearly demonstrates the impact of leaf folder infestation on yield. Genotypes with lower infestation levels, such as GRH-2 (13.92% DL), GNR-3 (13.41% DL), and GNR-5 (13.45% DL), recorded higher grain yields (5946, 5738, and 5723 kg/ha, respectively). Conversely, susceptible genotypes like TN-1 (54.86% DL) recorded the lowest grain yield (3874 kg/ha). The yield loss is likely due to the reduction in photosynthetic area caused by leaf folder damage, which affects photosynthate availability and grain filling (Padmavathi et al., 2013).

The moderately resistant genotypes identified in this study, particularly those with high yield potential such as GRH-2, GNR-3, and GNR-5, are promising candidates for use in breeding programmes. Their utilization could contribute to the development of leaf-folder-resistant rice varieties and support integrated pest management (IPM) strategies. However, the mechanisms underlying the observed resistance need further investigation, including biochemical factors such as silica content, total phenols, and other secondary metabolites that may contribute to resistance.

V. CONCLUSION

The rice genotypes viz., Kala Namak, GNR-5, GNR-3, GRH-2, GNR-7, GR-15, GNRH-1, Mahsuri, GR-17, GNR-2 and NVSR-396 have been proved moderately resistant or least susceptible. Therefore, these genotypes could be utilized in further breeding programme. Their utilization could contribute to the development of leaf-folder-resistant rice varieties and support integrated pest management (IPM). Morphological traits associated with lower leaf folder infestation included longer plant height, more tillers, longer and thicker leaves, broader leaves, green leaf colour and late flowering. The highly significant negative correlation between plant height and infestation parameters suggests that plant height is an important morphological trait for resistance. Phyllotaxy showed no apparent effect on leaf folder infestation. Grain and straw yield exhibited highly significant negative correlations with per cent damaged leaves and larval population, confirming the impact of leaf folder infestation on yield. Thus, these resistant genotypes and associated morphological traits can be effectively utilized in breeding programmes for developing rice varieties with enhanced resistance to leaf folder.

Limitations of the Study: The study was conducted at a single location (Navsari, Gujarat) over two seasons. The genotype × environment interaction was not examined, and the mechanisms underlying the observed resistance were not investigated. Biochemical analysis (silica content, total phenols, etc.) was not performed. Future research should include multi-location trials, biochemical analysis, and investigation of the mechanisms of resistance (antixenosis, antibiosis, tolerance) in the identified moderately resistant genotypes.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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