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Chemical and Biochemical Responses of Rice Genotypes against Rice Leaf Folder, *Cnaphalocrocis medinalis* Guenee

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Abstract— *Investigations on impact of chemical constitution of leaves on per cent damaged leaves and number of larvae showed the highly significant positive correlation with nitrogen (r=0.8899 and 0.8768) and phosphorus (r=0.7623 and 0.7756, respectively) content. However, per cent damaged leaves and number of larvae showed non-significant positive correlation with magnesium (r=0.2699 and 0.1999), sulphur (r=0.1523 and 0.0310), iron (r=0.1322 and 0.0338,) and zinc (r=0.3023 and 0.3668, respectively) contents. Whereas, per cent damaged leaves and number of larvae showed the highly significant negative correlation with potassium content (r=-0.8240 and -0.7937), non-significant negative correlation with calcium (r=-0.3229 and -0.3243), manganese (r=-0.1946 and -0.2801) and copper (r=-0.1248 and -0.0751, respectively) contents. The results on biochemical constitution of leaves of test genotypes revealed that per cent damaged leaves and number of larvae showed the highly significant positive correlation with crude protein (r=0.9025 and 0.8838), total chlorophyll (r=0.8749 and 0.8234), total soluble sugar (r=0.8338 and 0.8163) and moisture (r=0.5263 and 0.5534, respectively) content*.

Keywords— Rice, Screening, Chemical, Biochemical, Resistance, Leaf folder, Cnaphalocrocis medinalis.

I. INTRODUCTION

Rice (*Oryza sativa* L.) belongs to the family Poaceae and is one of the most important cereal crops worldwide. It serves as a staple food for more than two billion people, particularly in developing countries, where it plays a vital role in food security, nutrition, employment and rural livelihoods (Appala et al., 2018). Rice 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). In India, farmers grow many kinds of cereals, among them rice is grown in 43.86 million hectares, the production level is 112 million tonnes and the average productivity is about 2600 kg/ha. Rice is grown in almost all the states in the country. The insect-pest incidence is one of the major constraints for crop failure due to outbreaks of insect-pests have been reported worldwide (Reddy, 2013). Among various pests of rice, rice leaf folder is one of the most serious and most important pest of rice crop in Indian subcontinent.

It was earlier considered a minor pest but now a days it assumed major pest status. The shift in pest status is mainly attributed to changes in crop management practices, increased insecticides applications and weather parameters (Chakraborty and Deb, 2011). According to Bhanu and Reddy (2008), in favorable conditions leaf folder affected crop adversely resulting in severe loss in India. The loss may extend up to 63 to 80 per cent depending on agro-ecological situations as reported by Rajendran et al. (1986). Host plant resistance is an important component of integrated pest management (IPM) for sustainable rice production. Understanding the chemical and biochemical basis of resistance can facilitate the development of resistant varieties, thereby reducing dependence on chemical insecticides. The present study was therefore undertaken to investigate the chemical and biochemical basis of resistance in rice genotypes against rice leaf folder.

II. MATERIALS AND METHODS

The field and laboratory investigations on screening of rice genotypes, chemical and biochemical basis of resistance against leaf folder was carried out at Main Rice Research Centre and PG Research Laboratory, Dept. of Agricultural Chemistry and Soil Science, Navsari Agricultural University, Navsari, Gujarat during *Kharif* 2020 and 2021. 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).

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

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.

2.2 Study of Chemical and Biochemical Basis of Resistance in Rice Genotypes against Rice Leaf Folder

In the present investigation, the third leaf from the apex was randomly collected from ten plants of each genotype in each replication at the peak incidence of rice leaf folder. The genotypes were evaluated for resistance or susceptibility based on the percentage of damaged leaves. The collected leaf samples were further analyzed for their chemical and biochemical constituents to determine their association with resistance to rice leaf folder. Plant samples were digested separately for the estimation of nitrogen and other nutrient elements following the method suggested by Bhargava and Raghupathi (1993).

2.2.1 Chemical Constituents of Resistance

Estimation of chemical constitutes of rice were determine as per method suggested by following authors.

Nutrient	Procedure	Author
Nitrogen	Micro-kjeldahl's method	Kjeldahl (1883)
Phosphorus	Vanadomolybdo phosphoric yellow colour	Jackson (1973)
Potassium	Flame photometric method	Jackson (1973)
Ca and Mg	E. D. T. A. method	Jackson (1973)
Sulphur	Turbidimetric method	Tabatabai and Bremner (1970)
Iron, Manganese, Zinc and Copper	Atomic absorption spectrophotometric method	Jackson (1973)

2.2.2 Biochemical Constituents of Resistance

- **Crude Protein (%)**: Crude Protein equation to work out per cent protein content separately: "% Protein = % N × 6.25."

- **Total Phenol (mg/g)**: Total phenol content in the leaf samples was estimated by the method described by Malik and Singh (1980).
- **Total Chlorophyll (mg/g)**: Total chlorophyll content in the leaves was estimated using the dimethyl sulphoxide (DMSO) method described by Hiscox and Israelstam (1979).
- **Total Soluble Sugar (mg/g)**: Total soluble sugar content was estimated using the phenol–sulphuric acid method as described by Bhatnagar et al. (2006).
- **Silica (%)**: Silica content in the leaves of each rice genotype was estimated following the procedure described by Jackson (1967).
- **Moisture Content (%)**: The moisture content of the leaf samples was determined by the method described by Bhargava and Raghupathi (1993).
- **Ash Content (%)**: Weight about 10 g of powder in to crucible. Heated it with burner, using a flame about 2 cm high and support a crucible. About 7 cm above the flame heated till vapor almost cease to be evolved, then lower the dish and heat more strongly until all the carbon is burnt off. Cool the ash and weight ash and calculate the per cent of total ash.
- **Calculation**: Weight of empty dish = X, Weight of sample taken = Y, Weight of dish + Ash = Z and Weight of ash = (Z-X) gm.

Plate 1: Flame photometer

Plate 2: Spectrophotometer

Plate 3: Atomic absorption spectrophotometer

Plate 4: Nitrogen digestion and distillation system

III. RESULTS AND DISCUSSION

3.1 Resistance Based on Chemical Content

3.1.1 Nitrogen content (%)

Nitrogen content among the rice genotypes ranged from 0.25 to 0.45%, with an average of 0.34%. TN-1 recorded the highest nitrogen content (0.45%) which was at par with GNR-4 and GR-11 (0.40%), while Kala Namak recorded the lowest (0.25%), at par with GRH-2 (0.29%). Moderately susceptible genotypes generally had higher nitrogen content (0.34–0.38%), whereas moderately resistant genotypes had lower levels (0.25–0.33%). Nitrogen content showed highly significant positive correlations with damaged leaves (r=0.8899) and larval population (r=0.8768). This suggests that higher nitrogen content in leaves may provide better nutrition for the larvae, leading to higher infestation. Nitrogen is a key nutrient for insect growth and development, and higher nitrogen content in plant tissues is often associated with increased herbivory.

3.1.2 Phosphorus content (%)

Phosphorus content showed limited variation in relation to leaf folder damage. The highest phosphorus content was recorded in TN-1 (0.21%) which was at par with GR-11 (0.19%) and NAUR-1 (0.18%), while the lowest was observed in GR-17 (0.06%) followed by GNR-5, GNR-7 and NVSR-396 (0.07–0.09%). Moderately resistant genotypes had lower phosphorus content (0.06–0.14%) than moderately susceptible genotypes (0.14–0.18%). Phosphorus content exhibited highly significant positive correlations with damaged leaves (r=0.7623) and larval population (r=0.7756), indicating that higher phosphorus content was associated with greater leaf folder infestation.

Overall, both nitrogen and phosphorus contents exhibited highly significant positive correlations with leaf folder infestation, indicating that genotypes with higher nitrogen and phosphorus contents generally tended to support greater leaf damage and larval population. In contrast, moderately resistant genotypes generally possessed comparatively lower nitrogen and phosphorus contents. This may be due to the role of nitrogen and phosphorus as essential nutrients for insect growth and development.

3.1.3 Potassium content (%)

Potassium content ranged from 1.05 to 2.40%, with an average of 1.84%. The highest potassium content was recorded in Kala Namak (2.40%), while the lowest was observed in TN-1 (1.05%). Susceptible, moderately susceptible and moderately resistant genotypes showed potassium contents of 1.15–1.22, 1.54–1.92 and 1.80–2.40%, respectively. Potassium content exhibited highly significant negative correlations with damaged leaves (r=-0.8240) and larval population (r=-0.7937). Higher potassium content may contribute to resistance by improving plant vigour and stress tolerance, or by affecting the nutritional quality of leaves for insect herbivores.

3.1.4 Calcium content (%)

Calcium content was highest in NAUR-1 (0.36%) and lowest in GRH-2 and GR-11 (0.10%). Calcium showed a non-significant negative correlation with damaged leaves (r=-0.3229) and larval population (r=-0.3243).

3.1.5 Magnesium content (%)

Magnesium content was highest in GNR-7 (0.68%) and lowest in Mahsuri (0.28%). It showed a non-significant positive correlation with damaged leaves (r=0.2699) and larval population (r=0.1999).

3.1.6 Sulphur content (%)

Sulphur content ranged from 0.02 to 0.19%, with the highest in GNR-4 (0.19%) and the lowest in several moderately resistant genotypes (0.02%). Sulphur showed a non-significant positive correlation with damaged leaves (r=0.1523) and larval population (r=0.0310).

3.1.7 Iron content (%)

Iron content was highest in GNR-4 (0.059%) and lowest in GNR-3 (0.018%). It showed a non-significant positive correlation with damaged leaves (r=0.1322) and larval population (r=0.0338).

3.1.8 Manganese content (%)

Manganese content was highest in GNR-2 (0.077%) and lowest in Chittimuthyalu (0.025%). It showed a non-significant negative correlation with damaged leaves (r=-0.1946) and larval population (r=-0.2801).

3.1.9 Zinc content (ppm)

Zinc content was highest in GR-11 (44.00 ppm) and lowest in GNR-2 (10.75 ppm). Zinc showed a non-significant positive correlation with damaged leaves (r=0.3023) and larval population (r=0.3668).

3.1.10 Copper content (ppm)

Copper content was highest in GR-101 (16.05 ppm) and lowest in NVSR-396 (6.80 ppm). Moderately resistant genotypes had 6.80–12.85 ppm, while moderately susceptible genotypes had 8.50–16.05 ppm. Copper showed a non-significant negative correlation with damaged leaves (r=-0.1248) and larval population (r=-0.0751).

Overall, calcium, manganese and copper showed negative, while magnesium, sulphur, iron and zinc showed positive associations with leaf folder infestation; however, all correlations were non-significant. The non-significant correlations for secondary nutrients and micronutrients suggest that these elements may have limited direct influence on leaf folder resistance under the present experimental conditions, or that their effects may be masked by interactions with other factors. According to Chavan (2013), white earheads showed significant positive correlation with plant nitrogen and significant negative correlation with potassium content. Gajjar (2017) reported that nitrogen and phosphorous content had significant positive correlation and calcium, magnesium, sulphur, ferrous, manganese & zinc content showed non-significant positive correlation, while copper content showed non-significant negative correlation with per cent damaged leaves and number of larvae. But in case of calcium and manganese, these findings are in controversy with present findings due to different type genotype and environmental conditions prevailing during the study period. According to Ashrith et al. (2020), potassium content was significantly more with the resistant check TKM 6 (17.902 mg/g). Kumar et al. (2021) reported that the amount of nitrogen & phosphorous was recorded higher in the susceptible genotype, while potassium was found significantly higher in resistant genotypes.

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

SN	Genotype	Damaged leaves (%)			Number of larvae			Based on % DL	
		Kharif-2020	Kharif-2021	Pooled	Kharif-2020	Kharif-2021	Pooled	Scale	Reaction
1	GNR-6	28.34 (22.60)*	29.38 (24.12)*	28.86 (23.36)*	1.94 (3.30)#	2.01 (3.56)#	1.98 (3.43)#	5	MS
2	IR-28	30.36 (25.58)	31.35 (27.08)	30.86 (26.33)	2.13 (4.05)	2.16 (4.15)	2.14 (4.10)	5	MS
3	NVSR-392	34.20 (31.61)	35.09 (33.06)	34.65 (32.34)	2.29 (4.75)	2.31 (4.85)	2.30 (4.80)	5	MS
4	NVSR-395	33.93 (31.18)	34.81 (32.60)	34.37 (31.89)	2.26 (4.60)	2.29 (4.75)	2.27 (4.68)	5	MS
5	NVSR-396	25.61 (18.73)	26.52 (19.96)	26.07 (19.34)	1.83 (2.85)	1.95 (3.30)	1.89 (3.08)	3	MR
6	GNRH-1	23.34 (15.76)	24.70 (17.49)	24.03 (16.62)	1.70 (2.40)	1.76 (2.60)	1.73 (2.50)	3	MR
7	NAUR-1	28.82 (23.31)	29.64 (24.51)	29.23 (23.91)	2.14 (4.10)	2.11 (3.95)	2.13 (4.03)	5	MS
8	GNR-2	25.31 (18.35)	26.26 (19.68)	25.79 (19.02)	1.81 (2.80)	1.86 (2.95)	1.83 (2.88)	3	MR
9	GNR-3	20.58 (12.41)	22.23 (14.41)	21.42 (13.41)	1.63 (2.15)	1.68 (2.35)	1.65 (2.25)	3	MR
10	GNR-5	20.96 (12.86)	21.97 (14.04)	21.47 (13.45)	1.64 (2.20)	1.71 (2.45)	1.68 (2.33)	3	MR
11	GNR-7	21.67 (13.65)	22.92 (15.22)	22.30 (14.43)	1.61 (2.10)	1.74 (2.55)	1.68 (2.33)	3	MR
12	GR-15	23.05 (15.36)	24.08 (16.69)	23.57 (16.02)	1.70 (2.40)	1.88 (3.05)	1.79 (2.73)	3	MR
13	GR-17	23.82 (16.35)	24.63 (17.43)	24.23 (16.89)	1.79 (2.70)	1.87 (3.00)	1.83 (2.85)	3	MR
14	Mahsuri	23.37 (15.84)	24.42 (17.21)	23.90 (16.52)	1.79 (2.70)	1.83 (2.85)	1.81 (2.78)	3	MR
15	GNR-4	37.16 (36.61)	38.02 (38.02)	37.59 (37.32)	2.28 (4.70)	2.21 (4.40)	2.25 (4.55)	7	S
16	GR-101	29.96 (24.95)	31.55 (27.39)	30.76 (26.17)	2.07 (3.85)	2.14 (4.10)	2.11 (3.98)	5	MS
17	Krishna Kamod	30.21 (25.47)	31.51 (27.46)	30.87 (26.47)	2.21 (4.40)	2.20 (4.35)	2.21 (4.38)	5	MS
18	GAR-13	28.41 (22.67)	29.50 (24.29)	28.96 (23.48)	2.10 (3.90)	2.12 (4.00)	2.11 (3.95)	5	MS
19	Kala Namak	19.77 (11.47)	21.23 (13.17)	20.51 (12.32)	1.61 (2.10)	1.67 (2.30)	1.64 (2.20)	3	MR
20	Chittimuthyalu	28.76 (23.20)	30.25 (25.42)	29.51 (24.31)	2.13 (4.05)	2.14 (4.10)	2.14 (4.08)	5	MS
21	GRH-2	21.34 (13.28)	22.40 (14.57)	21.87 (13.92)	1.63 (2.15)	1.76 (2.60)	1.69 (2.38)	3	MR
22	GR-11	38.03 (38.00)	39.36 (40.22)	38.70 (39.11)	2.57 (6.10)	2.75 (7.05)	2.66 (6.58)	7	S
23	TN-1	47.07 (53.59)	48.54 (56.13)	47.80 (54.86)	2.69 (6.75)	2.90 (7.90)	2.80 (7.33)	9	HS
S. Em. ±		1.86	1.9	1.87	0.09	0.1	0.09	-	-
C.D. at 5%		5.45	5.57	5.47	0.27	0.29	0.25	-	-
C.V. (%)		9.38	9.21	9.24	6.63	6.74	6.03	-	-

Figures in the parentheses are original values, while those outside are arcsine transformed values.
#Figures in the parentheses are original values, while those outside are square root (√(X+0.5)) transformed values.
% DL: % Damaged leaves, MR: Moderately Resistant, MS: Moderately Susceptible, S: Susceptible and HS: Highly Susceptible

3.2 Resistance Based on Biochemical Content

3.2.1 Crude protein (%)

Crude protein content ranged from 1.59 to 2.84%, with the highest in TN-1 (2.84%) and lowest in Kala Namak (1.59%). It showed highly significant positive correlations with damaged leaves (r=0.9025) and larval population (r=0.8838). Higher protein content in leaves may provide better nutrition for the larvae, supporting their growth and development, leading to higher infestation.

3.2.2 Total phenol (mg/g)

Phenol content was highest in Kala Namak (2.21 mg/g) and lowest in TN-1 (1.69 mg/g). It exhibited highly significant negative correlations with damaged leaves (r=-0.7706) and larval population (r=-0.7675), indicating higher phenol content was associated with lower infestation. Phenols are known to act as feeding deterrents and antimicrobial compounds, contributing to plant defense against herbivores.

3.2.3 Total chlorophyll (mg/g)

Chlorophyll content ranged from 2.56 to 5.33 mg/g, with the highest in GNR-4 (5.33 mg/g) and lowest in GNR-7 (2.56 mg/g). It showed highly significant positive correlations with damaged leaves (r=0.8749) and larval population (r=0.8234). Higher chlorophyll content may indicate better plant vigour and nutrition, which may attract more herbivores or support better larval development.

3.2.4 Total soluble sugar (mg/g)

Sugar content ranged from 0.70 to 2.12 mg/g, with the highest in TN-1 (2.12 mg/g) and lowest in Kala Namak (0.70 mg/g). It showed highly significant positive correlations with damaged leaves (r=0.8338) and larval population (r=0.8163). Higher sugar content may provide a readily available energy source for larvae, increasing their survival and development.

3.2.5 Silica (%)

Silica content ranged from 3.04 to 4.58%, with the highest in Kala Namak (4.58%) and lowest in TN-1 (3.04%). Silica exhibited highly significant negative correlations with damaged leaves (r=-0.8765) and larval population (r=-0.8547), indicating its possible role in resistance. Silica acts as a physical barrier, increasing leaf toughness and reducing digestibility for herbivores.

3.2.6 Moisture content (%)

Moisture content was highest in TN-1 (59.45%) and lowest in GNR-2 (45.73%). It showed highly significant positive correlations with damaged leaves (r=0.5263) and larval population (r=0.5534). Higher moisture content may indicate better plant vigour and succulence, which may be more attractive to herbivores.

3.2.7 Ash content (%)

Ash content ranged from 5.17 to 10.07%, with the highest in GR-17 (10.07%) and lowest in IR-28 (5.17%). It showed a significant negative correlation with damaged leaves (r=-0.4266) and a non-significant negative correlation with larval population (r=-0.3851).

Overall, higher protein, chlorophyll, sugar and moisture contents were associated with greater leaf folder infestation, whereas higher phenol and silica contents were associated with reduced infestation. These findings agree with earlier reports highlighting the role of phenols and silica in rice resistance to leaf folder. Chavan (2013) reported a significant positive correlation between protein content and white earheads, while total phenol showed a significant negative correlation. Padmavathi et al. (2013) observed that leaf folder injury reduced chlorophyll and photosynthate availability, affecting water relations and increasing yield loss. Han et al. (2015) reported higher silicon content in leaf folder resistant rice varieties. Gajjar (2017) found that protein, chlorophyll and sugar were positively correlated, whereas phenol and silica were negatively correlated with leaf damage and larval population. Patel et al. (2017) reported silica content in rice straw ranging from 3.52 to 9.80% in Middle Gujarat. Ashrith et al. (2020) observed higher silicon and phenol contents in resistant genotypes and higher total sugar in susceptible genotypes. Tang et al. (2020) reported that fresh rice straw may contain up to 65.45% moisture.

TABLE 2
EFFECT OF NITROGEN, PHOSPHORUS, POTASSIUM, CALCIUM AND MAGNESIUM CONTENT OF RICE GENOTYPES ON LEAF FOLDER INFESTATION

S. No.	Genotype	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Calcium (%)	Magnesium (%)	Damaged leaves (%)	Number of larvae	Reaction (% DL)
1	GNR-6	0.36	0.14	1.54	0.27	0.47	23.36	3.43	MS
2	IR-28	0.37	0.15	1.8	0.17	0.51	26.33	4.1	MS
3	NVSR-392	0.38	0.14	1.85	0.13	0.51	32.34	4.8	MS
4	NVSR-395	0.35	0.14	1.88	0.12	0.43	31.89	4.68	MS
5	NVSR-396	0.3	0.09	2.19	0.29	0.4	19.34	3.08	MR
6	GNRH-1	0.31	0.13	1.91	0.14	0.41	16.62	2.5	MR
7	NAUR-1	0.37	0.18	1.81	0.36	0.43	23.91	4.03	MS
8	GNR-2	0.31	0.12	2	0.17	0.37	19.02	2.88	MR
9	GNR-3	0.32	0.11	2.05	0.18	0.44	13.41	2.25	MR
10	GNR-5	0.33	0.07	1.94	0.13	0.4	13.45	2.33	MR
11	GNR-7	0.32	0.07	1.95	0.23	0.68	14.43	2.33	MR
12	GR-15	0.31	0.13	2.33	0.28	0.6	16.02	2.73	MR
13	GR-17	0.33	0.06	1.94	0.22	0.39	16.89	2.85	MR
14	Mahsuri	0.31	0.13	2.17	0.13	0.28	16.52	2.78	MR
15	GNR-4	0.4	0.17	1.22	0.18	0.55	37.32	4.55	S
16	GR-101	0.34	0.14	1.68	0.14	0.41	26.17	3.98	MS
17	Krishna Kamod	0.34	0.14	1.92	0.12	0.4	26.47	4.38	MS
18	GAR-13	0.35	0.15	1.83	0.15	0.3	23.48	3.95	MS
19	Kala Namak	0.25	0.11	2.4	0.21	0.49	12.32	2.2	MR
20	Chittimuthyalu	0.38	0.14	1.63	0.21	0.3	24.31	4.08	MS
21	GRH-2	0.29	0.14	1.8	0.1	0.45	13.92	2.38	MR
22	GR-11	0.4	0.19	1.15	0.1	0.53	39.11	6.58	S
23	TN-1	0.45	0.21	1.05	0.11	0.57	54.86	7.33	HS
GM		0.34	0.14	1.82	0.18	0.45	23.54	3.66	-
S. Em. ±		0.01	0.01	0.06	0.01	0.03	2.82	0.34	-
C.D. at 5%		0.04	0.03	0.16	0.03	0.08	8.28	0.98	-
C.V. (%)		6.11	9.57	4.3	9.13	8.74	16.95	12.97	-
Corr. coefficient (r) of Nitrogen (%)		-	-	-	-		0.8899**	0.8768**	-
Corr. coefficient (r) of Phosphorus (%)		-	-	-	-		0.7623**	0.7756**	-
Corr. coefficient (r) of Potassium (%)		-	-	-	-		-0.8240**	-0.7937**	-
Corr. coefficient (r) of Calcium (%)		-	-	-	-		-0.3229^{NS}	-0.3243^{NS}	-
Corr. coefficient (r) of Magnesium (%)		-	-	-	-		0.2699^{NS}	0.1999^{NS}	-

MR: Moderately Resistant, MS: Moderately Susceptible, S: Susceptible and HS: Highly Susceptible

TABLE 3
EFFECT OF SULPHUR, IRON, MANGANESE, ZINC AND COPPER CONTENT OF RICE GENOTYPES ON LEAF FOLDER INFESTATION

SN	Genotype	Sulphur (%)	Iron (%)	Manganese (%)	Zinc (ppm)	Copper (ppm)	Damaged leaves (%)	Number of larvae	Reaction (% DL)
1	GNR-6	0.36	0.052	0.048	34.25	8.7	23.36	3.43	MS
2	IR-28	0.06	0.049	0.054	33	11.3	26.33	4.1	MS
3	NVSR-392	0.04	0.051	0.05	22.95	8.5	32.34	4.8	MS
4	NVSR-395	0.03	0.035	0.065	30.05	8.65	31.89	4.68	MS
5	NVSR-396	0.03	0.051	0.063	18.4	6.8	19.34	3.08	MR
6	GNRH-1	0.08	0.051	0.071	19.5	10.6	16.62	2.5	MR
7	NAUR-1	0.09	0.031	0.07	11.45	10.35	23.91	4.03	MS
8	GNR-2	0.06	0.035	0.077	10.75	12.85	19.02	2.88	MR
9	GNR-3	0.03	0.018	0.075	11.8	7.7	13.41	2.25	MR
10	GNR-5	0.03	0.038	0.068	43.35	10.6	13.45	2.33	MR
11	GNR-7	0.08	0.021	0.064	27.2	8.8	14.43	2.33	MR
12	GR-15	0.08	0.023	0.053	20.95	9.45	16.02	2.73	MR
13	GR-17	0.04	0.034	0.07	24.95	11.5	16.89	2.85	MR
14	Mahsuri	0.03	0.03	0.059	25.8	8.7	16.52	2.78	MR
15	GNR-4	0.06	0.059	0.064	27.9	6.86	37.32	4.55	S
16	GR-101	0.19	0.045	0.044	27.05	16.05	26.17	3.98	MS
17	Krishna Kamod	0.02	0.042	0.051	36.15	8.75	26.47	4.38	MS
18	GAR-13	0.11	0.027	0.048	30.1	12	23.48	3.95	MS
19	Kala Namak	0.02	0.037	0.056	28.95	8.65	12.32	2.2	MR
20	Chittimuthyalu	0.02	0.025	0.025	35.85	10.6	24.31	4.08	MS
21	GRH-2	0.02	0.024	0.051	33.65	8.6	13.92	2.38	MR
22	GR-11	0.02	0.024	0.052	44	8.8	39.11	6.58	S
23	TN-1	0.04	0.022	0.06	32.85	8.55	54.86	7.33	HS
GM		0.05	0.04	0.06	27.43	0.45	9.71	3.66	-
S. Em. ±		0.01	0	0	1.41	0.03	0.39	0.34	-
C.D. at 5%		0.01	0.01	0.01	4.12	0.08	1.15	0.98	-
C.V. (%)		13.92	10.42	9.19	7.24	8.74	5.71	12.97	-
Corr. coefficient (r) of Sulphur (%)		-	-	-	-		0.1523^{NS}	0.0310^{NS}	-
Corr. coefficient (r) of Iron (%)		-	-	-	-		0.1322^{NS}	0.0338^{NS}	-
Corr. coefficient (r) of Manganese (%)		-	-	-	-		-0.1946^{NS}	-0.2801^{NS}	-
Corr. coefficient (r) of Zinc (%)		-	-	-	-		0.3023^{NS}	0.3668^{NS}	-
Corr. coefficient (r) of Copper (%)		-	-	-	-		-0.1248^{NS}	-0.0751^{NS}	-

MR: Moderately Resistant, MS: Moderately Susceptible, S: Susceptible and HS: Highly Susceptible

TABLE 4
EFFECT OF CRUDE PROTEIN, TOTAL PHENOL AND TOTAL CHLOROPHYLL CONTENT OF RICE GENOTYPES ON LEAF FOLDER INFESTATION

SN	Genotype	Crude protein (%)	Total phenol (mg/g)	Total chlorophyll (mg/g)	Damaged Leaves (%)	Number of larvae	Reaction (% DL)
1	GNR-6	2.22	1.97	3.74	23.36	3.43	MS
2	IR-28	2.3	1.91	4.28	26.33	4.1	MS
3	NVSR-392	2.37	1.7	4.74	32.34	4.8	MS
4	NVSR-395	2.21	1.86	4.62	31.89	4.68	MS
5	NVSR-396	1.86	1.86	3.39	19.34	3.08	MR
6	GNRH-1	1.95	1.95	3.95	16.62	2.5	MR
7	NAUR-1	2.34	1.94	3.85	23.91	4.03	MS
8	GNR-2	1.96	1.86	3.51	19.02	2.88	MR
9	GNR-3	2.01	2.14	2.67	13.41	2.25	MR
10	GNR-5	2.04	2.16	2.73	13.45	2.33	MR
11	GNR-7	1.98	2	2.56	14.43	2.33	MR
12	GR-15	1.94	1.87	2.95	16.02	2.73	MR
13	GR-17	2.07	1.96	3.06	16.89	2.85	MR
14	Mahsuri	1.92	1.93	2.91	16.52	2.78	MR
15	GNR-4	2.5	1.86	5.33	37.32	4.55	S
16	GR-101	2.12	1.91	4.22	26.17	3.98	MS
17	Krishna Kamod	2.11	1.91	4.11	26.47	4.38	MS
18	GAR-13	2.16	1.95	3.6	23.48	3.95	MS
19	Kala Namak	1.59	2.21	3.57	12.32	2.2	MR
20	Chittimuthyalu	2.35	1.94	3.92	24.31	4.08	MS
21	GRH-2	1.83	2	2.73	13.92	2.38	MR
22	GR-11	2.48	1.75	4.48	39.11	6.58	S
23	TN-1	2.84	1.69	5.17	54.86	7.33	HS
GM		2.14	1.92	3.74	23.54	3.66	-
S. Em. ±		0.09	0.07	0.18	2.82	0.34	-
C.D. at 5%		0.27	0.21	0.53	8.28	0.98	-
C.V. (%)		6.11	5.16	6.83	16.95	12.97	-
Correlation coefficient (r) of Crude protein (%)		-	-		0.9025**	0.8838**	-
Correlation coefficient (r) of Total Phenol (mg/g)		-	-		-0.7706**	-0.7675**	-
Correlation coefficient (r) of Total Chlorophyll (mg/g)		-	-		0.8749**	0.8234**	-

MR: Moderately Resistant, MS: Moderately Susceptible, S: Susceptible and HS: Highly Susceptible

TABLE 5
EFFECT OF TOTAL SOLUBLE SUGAR, SILICA, MOISTURE AND ASH CONTENT OF RICE GENOTYPES ON LEAF FOLDER INFESTATION

SN	Genotype	Total soluble sugar (mg/g)	Silica (%)	Moisture (%)	Ash (%)	Damaged Leaves (%)	Number of larvae	Reaction (% DL)
1	GNR-6	1.16	3.87	48.32	6.98	23.36	3.43	MS
2	IR-28	1.32	3.8	54.31	5.17	26.33	4.1	MS
3	NVSR-392	1.61	3.59	56.79	7.01	32.34	4.8	MS
4	NVSR-395	1.6	3.8	51.62	5.88	31.89	4.68	MS
5	NVSR-396	1.04	3.81	49.62	6.9	19.34	3.08	MR
6	GNRH-1	0.88	3.83	46.05	8.43	16.62	2.5	MR
7	NAUR-1	1.11	3.74	55.43	6.12	23.91	4.03	MS
8	GNR-2	1.07	3.76	45.73	6.16	19.02	2.88	MR
9	GNR-3	0.91	4.19	53.22	9.84	13.41	2.25	MR
10	GNR-5	0.83	4.11	54.64	8.52	13.45	2.33	MR
11	GNR-7	0.99	4.18	56.57	6.05	14.43	2.33	MR
12	GR-15	0.82	3.88	51.62	5.67	16.02	2.73	MR
13	GR-17	1.03	3.9	46.07	10.07	16.89	2.85	MR
14	Mahsuri	1.96	3.98	49.2	7.06	16.52	2.78	MR
15	GNR-4	1.86	3.57	56.71	6.44	37.32	4.55	S
16	GR-101	1.33	3.78	52.19	8.14	26.17	3.98	MS
17	Krishna Kamod	1.33	3.68	52.61	8.01	26.47	4.38	MS
18	GAR-13	1.18	3.98	54.89	6.12	23.48	3.95	MS
19	Kala Namak	0.7	4.58	55.2	9.2	12.32	2.2	MR
20	Chittimuthyalu	1.22	4.01	56.33	8.87	24.31	4.08	MS
21	GRH-2	0.75	4.06	51.8	8.92	13.92	2.38	MR
22	GR-11	1.96	3.39	57.64	7.62	39.11	6.58	S
23	TN-1	2.12	3.04	59.45	5.8	54.86	7.33	HS
GM		1.25	3.85	52.87	7.35	23.54	3.66	-
S. Em. ±		0.08	0.12	1.52	0.4	2.82	0.34	-
C.D. at 5%		0.25	0.34	4.47	1.17	8.28	0.98	-
C.V. (%)		9.46	4.28	4.07	7.68	16.95	12.97	-
Correlation coefficient (r) of TSS (mg/g)		-	-			0.8338**	0.8163**	-
Correlation coefficient (r) of Silica (%)		-	-			-0.8765**	-0.8547**	-
Correlation coefficient (r) of Total Moisture (%)		-	-			0.5263**	0.5534**	-
Correlation coefficient (r) of Ash (%)		-	-			-0.4266*	-0.3851NS	-

MR: Moderately Resistant, MS: Moderately Susceptible, S: Susceptible and HS: Highly Susceptible

IV. DISCUSSION

The results of the present investigation reveal that certain chemical and biochemical constituents of rice leaves are significantly associated with resistance or susceptibility to leaf folder infestation. The highly significant positive correlations of nitrogen and phosphorus with infestation parameters (r=0.8899 and 0.7623, respectively) indicate that genotypes with higher levels of these nutrients tend to support greater leaf damage and larval populations. This is consistent with the general understanding that nitrogen and phosphorus are essential nutrients for insect growth and development, and higher concentrations in plant tissues may enhance insect performance (Kumar et al., 2021). Conversely, the highly significant negative correlation of potassium with infestation (r=-0.8240) suggests that higher potassium content may contribute to resistance, possibly by improving plant vigour and stress tolerance or by affecting the nutritional quality of leaves (Ashrith et al., 2020).

Among biochemical parameters, the highly significant positive correlations of crude protein (r=0.9025), chlorophyll (r=0.8749), and total soluble sugar (r=0.8338) with infestation indicate that higher levels of these constituents are associated with increased susceptibility. This may be because these compounds provide essential nutrients and energy sources for the larvae, supporting their growth and development (Gajjar, 2017). In contrast, the highly significant negative correlations of total phenol (r=-0.7706) and silica (r=-0.8765) with infestation suggest that these compounds play a crucial role in resistance. Phenols are known to act as feeding deterrents and antimicrobial compounds, while silica acts as a physical barrier, increasing leaf toughness and reducing digestibility (Han et al., 2015; Ashrith et al., 2020).

The non-significant correlations observed for secondary nutrients (Ca, Mg, S) and micronutrients (Fe, Mn, Zn, Cu) suggest that these elements may have limited direct influence on leaf folder resistance under the present experimental conditions. This may be due to their relatively low concentrations in plant tissues or interactions with other factors that mask their effects. However, the role of these nutrients in plant defense cannot be completely ruled out, as they may contribute to resistance indirectly by influencing plant health and vigour.

The moderately resistant genotypes identified in the companion screening study (Kala Namak, GNR-5, GNR-3, GRH-2, etc.) generally exhibited lower nitrogen and phosphorus, higher potassium, higher phenol, and higher silica contents compared to susceptible genotypes. This suggests that these biochemical markers could be useful for screening and selecting rice genotypes with enhanced resistance to leaf folder. The consistent performance of these genotypes across two seasons indicates stable resistance, which is desirable for breeding purposes.

V. CONCLUSION

The rice genotypes Kala Namak, GNR-5, GNR-3, GRH-2, GNR-7, GR-15, GNRH-1, Mahsuri, GR-17, GNR-2 and NVSR-396 were identified as moderately resistant or least susceptible to rice leaf folder. These genotypes can serve as valuable resistance sources in breeding programmes for developing leaf folder-resistant varieties and strengthening integrated pest management (IPM). Biochemical and nutritional constituents were closely associated with rice leaf folder resistance. Higher nitrogen, phosphorus, crude protein, chlorophyll, soluble sugar and moisture contents were generally associated with greater leaf damage and larval population, whereas higher potassium, phenol and silica contents were associated with reduced infestation. Secondary nutrients and micronutrients showed mostly non-significant relationships with leaf folder infestation, indicating their comparatively limited contribution under the present conditions. Thus, lower N and P and higher K, phenol and silica contents may serve as useful biochemical indicators for identifying and screening leaf folder-resistant rice genotypes.

Limitations of the Study: The study was conducted at a single location (Navsari, Gujarat) over two seasons. The biochemical correlations are associative rather than causal, and the mechanisms underlying the observed associations were not investigated. Future research should include multi-location trials, mechanistic studies (e.g., antixenosis, antibiosis, tolerance), and investigation of the genetic basis of the biochemical traits associated with resistance.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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