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VN Kitale
Plant Pathology and Agricultural Microbiology Section, College of Agriculture, Pune, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist.-Ahilyanagar, Maharashtra, India

VM Sali
Junior Plant Pathologist, Regional Wheat Rust Research Station, Mahabaleshwar-412 806, Dist. Satara, Maharashtra, India

MA Sushir
Junior Wheat Pathologist, Regional Wheat Rust Research Station, Mahabaleshwar-412 806, Dist. Satara, Maharashtra, India

AC Jadhav
Junior Mycologist, AICRP on Mushroom, College of Agriculture, Pune, Maharashtra, India

PR Lakde
Plant Pathology and Agricultural Microbiology Section, College of Agriculture, Pune, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist.-Ahilyanagar, Maharashtra, India

VM Karade
Associate Professor, Division of Plant pathology and Agricultural Microbiology, College of Agriculture, Pune, Maharashtra, India

DS Kadam
Wheat Rust Mycologist, Regional Wheat Rust Research Station, Mahabaleshwar, Dist. Satara, Maharashtra, India

RA Karande
Assistant Professor, RCSM, College of Agriculture, Kolhapur, Maharashtra, India

DP Deshmukh
Associate Professor, RCSM, College of Agriculture, Kolhapur, Maharashtra, India

Corresponding Author:
VN Kitale
Plant Pathology and Agricultural Microbiology Section, College of Agriculture, Pune, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist.-Ahilyanagar, Maharashtra, India

Investigations into leaf rust of wheat incited by *Puccinia triticina* Eriks

VN Kitale, VM Sali, MA Sushir, AC Jadhav, PR Lakde, VM Karade, DS Kadam, RA Karande and DP Deshmukh

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Abstract
The present study entitled "Investigations into leaf rust of wheat incited by *Puccinia triticina* Eriks" Based on the results in the seedling resistance test out of 23 wheat varieties 03 resistant varieties were found namely NIDW 1149, NIAW 3624 and NIAW 1415.
In the adult plant resistance test out of 23 wheat varieties 06 wheat varieties were found resistant to leaf rust whereas, 03 wheat varieties were found moderately resistant to leaf rust. While 05 wheat varieties had shown moderately susceptible reaction to leaf rust. Although 09 wheat varieties had shown susceptible reaction to leaf rust.
Studies on adult plant resistance by AUDPC, out of 23 wheat varieties none of the variety was found immune while, 13 wheat varieties expressed values of "AUDPC" less than 100 whereas, 05 wheat varieties expressed values of "AUDPC" between 101 to 200 against leaf rust. This indicates that considerable amount of resistance against leaf rust. 3 wheat varieties expressed value between 201 to 300 while 2 wheat varieties expressed "AUDPC" value above 500. These wheat varieties had shown susceptibility against leaf rust.
Epidemiological study showed that the first incidence of disease was noticed in 1st meteorological week (First week of January 2025). The maximum ACI was observed 80 in 6th Meteorological week (Second week of February 2025). Then it was declined. The data revealed that, the maximum temperature and morning humidity showed positive correlation. In case of minimum temperature and evening humidity showed negative correlation.

Keywords: *Puccinia triticina*, leaf rust, wheat resistance, AUDPC, epidemiology

Introduction
Wheat (*Triticum aestivum* L.) is a key staple crop that underpins global food and nutritional security. In India, it is second only to rice in area and production, supplying a major share of daily calories and protein. However, its productivity is constrained by several diseases, of which leaf rust (*Puccinia triticina*) is the most widespread and damaging. The disease develops rapidly under favorable climates, reducing grain weight and quality at both seedling and adult stages. Race-specific resistance is often short-lived, whereas adult plant resistance is more durable. Fungicides serve as supplementary measures where resistant varieties are long-lived.
Management of leaf rust primarily relies on host resistance and fungicides. Resistant varieties provide the most economical and environmentally safe solution, yet race-specific resistance governed by single genes is often overcome by new virulent races. By contrast, adult plant resistance (APR), generally controlled by multiple minor genes, is more durable, though not always sufficient during severe epidemics. Fungicides such as triazoles (Propiconazole, Tebuconazole) and strobilurins (Azoxystrobin, Trifloxystrobin) are widely used as supplementary measures. However, large-scale dependence on chemical control is not sustainable, emphasizing the need for integrated strategies. (Bhardwaj *et al.*, 2019) [2].
Epidemiological studies play a key role in understanding the relationship between disease progression and weather parameters such as temperature, humidity, and dew duration. Such insights help in forecasting epidemics and enabling timely interventions.
The cultivation of improved resistant cultivars has contributed significantly to increased wheat yields. However, continuous monocropping has occasionally resulted in leaf rust epidemics.

Continuous efforts are always made to reduce the yield losses in wheat caused by the rusts. Although chemical control of this disease is known but it is not practical, economically feasible and environmentally friendly to use on such a large scale. Therefore, resistance to rusts in wheat is of critical importance. The utilization of resistance genes in wheat is the most effective, economic and environmentally safe approach for controlling rusts (Joshi *et al.*, 1980) [4].

In this background, the present study was conducted with the objectives of evaluating fungicides against leaf rust, assessing seedling and adult plant resistance of released varieties, quantifying disease development using AUDPC, and studying epidemiological factors affecting disease progression.

Materials and methods

1. Seedling resistance of released wheat varieties against virulent races of leaf rust

In this trial released wheat varieties were evaluated under controlled conditions in glasshouse, for seedling resistance to virulent races of leaf rust pathogen.

Experimental details

Location: Regional Wheat Rust Research Station, Mahabaleshwar.

Varieties evaluated

1. NI 345
2. Kenphad 25
3. NI 747-19
4. NIAW 4028
5. NI 9947
6. N 5439
7. N 5749
8. NIAW 34
9. NI 5643
10. Niphad-4
11. NIAW 3170
12. Kenphad-39
13. Jay
14. NIDW 1149
15. N 146
16. NIDW 1149
17. NIDW 295
18. NIAW 1994
19. NIAW 301
20. NI 917
21. NIAW 917
22. NIAW 1415
23. NIDW 15

Methodology

The Seedling Resistance Test (SRT) was carried out with individual virulent pathotypes of leaf rust *viz*.,77-5, 104-2, 77-8, 77-2, 12-1, 77-9, 17, 104-1, 77-1, 77, 12-5, 162A and 77A1 under glasshouse condition. For growing seedlings, aluminium pans or trays admeasuring 35 cm x 25 cm x 9 cm were used. These trays were filled with soil and compost and marked in to 6 rows of 10 holes in a row with the help of iron marker for sowing of seeds. Every seventh hole in each row was sown with universal susceptible Agra Local variety. The wheat varieties were sown in sequence of serial numbers. These seedlings were grown in spore proof conditions in seedling room and watered regularly. Spore suspension of the individual pathotypes was inoculated at the stage of maximum expanded 1st leaf and non-emergence of second leaf. The inoculated trays were then incubated under moist humid chambers for 48 hrs and subsequently were transferred to glasshouse benches.

Observations recorded

Infection types were categorized into 11 groups as given below to record the host pathogen interaction (Nayer *et.al.*, 1997).

Table 1: Infection types classes for rust (seedling stage) Nayar *et al.*, 1997

Reaction type	Category	Symptoms
0; (Naught fleck)	Immune	No visible infection
; - (fleck minus)	Nearly Immune	Slight necrosis/micro flecking visible
; (fleck)	Very Resistant	No uredia but hypersensitive flecks present
1 (one)	Very Resistant	Uredia minute, surrounded by distinct necrotic areas
2 (two)	Moderately Resistant	Uredia small to medium, surrounded by chlorotic or necrotic border
3 (three)	Moderately Susceptible	Uredia small to medium size, chlorotic areas may be present
33^+ (three three plus)	Susceptible	In leaf rust no chlorosis or necrosis, uredia profusely sporulating. In stripe rust uredia profusely sporulating
3^+ /4 (three plus/four)	Highly Susceptible	In brown rust no chlorosis or necrosis, uredia profusely sporulating, rings may be formed. In yellow rust uredia profusely sporulating and form stripes in adult plants
X	Heterogeneous	Variable types of uredia
Y	Heterogeneous	Susceptible types of uredia at the tip and resistant towards the base of leaf
Z	Heterogeneous	Resistant types of uredia at the tip and susceptible types towards the leaf base

2. Adult plant resistance of released wheat varieties for leaf rust

In this experiment, released wheat varieties were screened against the mixture of leaf rust pathotypes *viz*., 12-5, 77-1, 77-5, 77-9, 104-2 at adult plant stage under artificial epiphytotic condition in field.

Experimental details

Location: Regional Wheat Rust Research Station, Mahabaleshwar.

Varieties evaluated

1. NI 345
2. Kenphad 25
3. NI 747-19
4. NIAW 4028
5. NI 9947
6. N 5439
7. N 5749
8. NIAW 34
9. NI 5643
10. Niphad-4
11. NIAW 3170
12. Kenphad-39
13. Jay
14. NIDW 1149
15. N 146
16. NIAW 3624
17. NIDW 295
18. NIAW 1994
19. NIAW 301
20. NI 917
21. NIAW 917
22. NIAW 1415
23. NIDW 15

Methodology

Released wheat varieties were sown on flat bed admeasuring 3.0 m x 1.3 m with a spacing of 22.5 cm between rows. Single row of 1.0 m length of each variety was sown. After every 20th entry, a line of resistant (Check 'a' NIDW 1149, NIAW 3624, NIDW 295, NIAW 301, NIAW 917 and NIAW 1415) and susceptible (check 'b' NIDW 1149,

NIAW 3624, NIDW 295, NIAW 301, NIAW 917 and NIAW 1415) were sown, in order to compare the rust development. Wheat varieties sown on each bed were surrounded by two rows of the varietal mixture consisting of Jay, N 146 and NI 917, NIDW 1149, NIAW 3624, NIDW 295, NIAW 301, NIAW 917 and NIAW 1415 Agra local, vijay, Pusa 4, A 206 having susceptibility to leaf rust. Inside lines were sown along with test varieties and outside lines were sown after one week, to provide continuous rust inoculum supply and built up of high inoculum density during the early stage of the test varieties. These infector/spreader rows were inoculated several times with mixture of leaf rust pathotypes. High humidity (more than 90%) was maintained by covering the beds with cages and gunny curtains overnight for rust development.

Observations recorded

Observations on intensity of leaf rust were noted as per the modified cobb's scale on the basis of per cent rust infection.

Table 2: Field response, symbol, and severity rating by modified cobb's scale. (Peterson *et al.*, 1948)

Symbol	Field Response	Symptoms	Constant Value
0	Immune	No visible infection.	
R	Resistant	Visible chlorosis or necrosis, no uredia are present	0.2
MR	Moderately Resistant	Small uredia are present and surrounded by chlorotic areas.	0.4
M	Intermediate (Mixed)	Variable sized uredia are present some with chlorosis, necrosis or both.	0.6
MS	Moderately Susceptible	Medium sized uredia are present and possibly surrounded by some chlorotic areas.	0.8
S	Susceptible	Large uredia are present, generally with little or no chlorosis or necrosis.	1.0

For observations of severity of wheat leaf rust, the modified cobb's scale (Peterson *et al.*, 1948) was used. The disease severity is recorded as a percentage according to this scale.

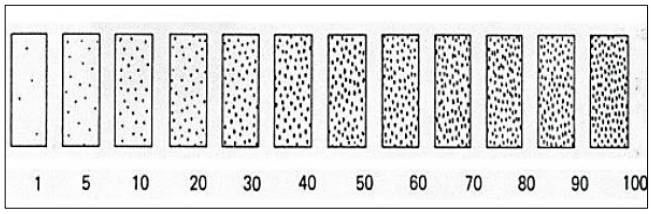

Fig 1: Modified cobb's scale

AUDPC: Observations were recorded weekly soon after the appearance of rust pustules of leaf rust on the stem. Observations on per cent disease severity and infection types were recorded. Average Coefficient of Infection (ACI) was calculated by multiplying per cent severity and response value of infection type. Area under Disease Progress Curve (AUDPC) was calculated by using mathematical tool AUDPC formula suggested by Wilcoxson *et al.*, (1975):

$$AUDPC = \frac{1}{2}\sum_{i=1}^{n}(S_i + S_{i-1})\,d$$

Where;

- i^{th} = Number of successive observations recorded from 1 to k
- k = Total number of observations recorded
- Si = ACI at i^{th} observation.
- d = Duration (in days) between two successive observations.

3. To study epidemiology of leaf rust disease of wheat

Availability of susceptible host and prevalence of favourable weather condition play important role in the process of disease development. Epidemiological study would be helpful to know the time of occurrence and intensity of particular disease on specific location based on various weather parameters which might help us to formulate the management strategy.

- **Objectives:** To study epidemiological parameters related to leaf rust disease of wheat.
- **Experimental details**
- **Location:** Regional Wheat Rust Research Station, Mahabaleshwar
- **Crop and variety:** Wheat (A 206)
- **Season:** Rabi 2024
- **Spacing:** Row to row 22.5 cm
- **Seed rate:** 100 kg/ha
- **Fertilizers:** 120:60:40 (N, P_2O_5, K_2O kg/ha)
- **Date of sowing:** November 15, 2024
- **Date of harvesting:** April 14, 2025

Methodology

A field trial on epidemiological studies was be conducted during *Rabi*-2024 at Regional Wheat Rust Research Station, Mahabaleshwar on A 206 variety. All the recommended agronomical package of practices were adopted for raising the crop. No plant protection measures were took in this plot. The meteorological data were recorded from meteorological observatory of Regional Wheat Rust Research Station, Mahabaleshwar.

Observations recorded

The weekly observations on weather parameters *viz.*, maximum temperature (°C), minimum temperature (°C), morning relative humidity (%) and evening relative humidity (%) were recorded. Intensity of disease was recorded from the first appearance of leaf rust disease. Correlation study was carried out between disease intensity and dependent weather parameter. In this study, the regression models were adjusted to include weather variables to forecast the rise in the per cent of leaf rust, as follows:

$Y = b + (-0.43)\,X_1 + (-1.42)\,X_2 + (0.44)\,X_3 + (-0.48)\,X_4 + (0.27)\,X_5$

Where;

- Y= Disease severity
- b = Constant (6.94)
- X_1 = Maximum temperature
- X_2= Minimum temperature
- X_3= Morning humidity
- X_4= Evening humidity
- X_5= Afternoon humidity

Results and discussion

1. To appraise seedling resistance of released wheat varieties against most virulent races of leaf rust

In this experiment 23 released wheat varieties were tested for their resistance to most virulent races of leaf rust, at seedling stage. The virulent pathotypes used in the study included 77-5, 104-2, 77-8, 77-2, 12-1, 77-9, 17, 104-1, 77-1, 77, 12-5, 162A and 77A1. The testing of the wheat varieties revealed that, out of 23wheat varieties(NI 345, Kenphad 25, NI 747-19, NIAW 4028, NI 9947, N 5439, N 5749, NIAW 34, NI 5643, Niphad-4, NIAW 3170, Kenphad-39, Jay, NIDW 1149, N 146, NIAW 3624, NIDW 295, NIAW 1994, NIAW 301, NI 917, NIAW 917, NIAW 1415, NIDW 15), 03 wheat varieties namely NIDW 1149,NIAW 3624 and NIAW 1415were found resistant to all the 13 leaf rust pathotypes under study (Table 3). Nagarajan *et al.* (1990) [6] evaluated ten Chinese wheat cultivars for resistance against 23 races of the leaf rust pathogen. Among them, Zheng-Zhou 741 and Zheng-Zhou 742 exhibited strong seedling resistance to group 77 races. Patil *et al.* (2001) [7] evaluated 95 wheat cultivars for resistance to stem rust (*Puccinia graminis* f. sp. *tritici*) and leaf rust (*Puccinia recondita f. sp. tritici*) under artificial epiphytotic conditions using three specific pathotypes: 40A, 12-5, and 77-5. Their results revealed that none of the cultivars exhibited complete resistance to all pathotypes. However, eight cultivars Karchiya Mutant, Bijaga Red, MACS 2846, PBW 34, NI 9947, RAJ 1515, WH 542, and Coorang showed relatively high levels of resistance, with less than 20% disease susceptibility to both rusts.

Table 3: Seedling Resistance Test of released wheat varieties against leaf rust.

Sr. No.	Wheat variety	Leaf Rust Pathotypes												
		77-5	104-2	77-8	77-2	12-1	77-9	17	104-1	77-1	77	12-5	162A	77A1
1	NI 345	S	S	MS	R	R	S	R	R	MS	R	R	R	R
2	Kenphad 25	S	S	MS	R	R	S	R	R	MR	R	R	R	MR
3	NI 747-19	S	S	MR	R	R	R	R	R	MR	R	R	R	R
4	NIAW 4028	MR	MR	R	R	R	R	R	R	R	R	R	R	R
5	NI 9947	S	S	R	MR	R	R	R	R	S	R	R	R	R
6	N 5439	MS	S	R	R	R	R	R	R	MS	R	R	R	R
7	N 5749	S	S	R	MR	R	MS	R	R	MR	R	R	R	R
8	NIAW 34	S	S	S	R	R	S	R	R	R	R	R	R	R
9	NI 5643	S	S	R	R	R	MS	R	R	MS	R	R	R	R
10	Niphad-4	S	S	S	R	R	MR	R	R	S	R	R	R	R
11	NIAW 3170	S	MR	R	MR	R	R	R	R	R	R	R	R	R
12	Kenphad-39	S	S	S	MR	R	S	R	R	MS	R	R	R	R
13	Jay	S	S	R	R	R	R	R	R	R	R	R	R	R
14	NIDW 1149	R	R	R	R	R	R	R	R	R	R	R	R	R
15	N 146	S	S	MS	R	R	R	R	R	MR	R	R	R	R
16	NIAW 3624	R	R	R	R	R	R	R	R	R	R	R	R	R
17	NIDW 295	MR	S	MS	R	R	R	R	R	R	R	R	R	R
18	NIAW 1994	MR	MR	R	MR	R	R	R	R	MR	R	R	R	R
19	NIAW 301	S	S	S	R	R	MS	R	R	R	R	R	R	R
20	NI 917	S	S	MS	R	R	R	R	R	R	R	R	R	R
21	NIAW 917	R	S	R	R	R	R	R	R	R	R	R	R	R
22	NIAW 1415	R	R	R	R	R	R	R	R	R	R	R	R	R
23	NIDW 15	R	MS	R	R	R	R	R	R	R	R	R	R	R

2. Adult plant resistance test of released wheat varieties against leaf rust under field conditions

In the present investigation, 23 released wheat varieties were screened against mixture of prevalent pathotypes of leaf rust. Results of the investigation revealed that 06 wheat varieties *viz.* NIDW 1149, NIAW 3624(Phule Anupam), NIDW 295(Godavari), NIAW 301 (Trimbak), NIAW 917 (Tapovan) and NIAW 1415(Netravati)were resistant to leaf rust whereas, 03 wheat varieties *viz.* NIAW 4028(Phule Anurag), NIAW 3170(Phule Satwik) and NIDW 15(Panchavati)were moderately resistant to leaf rust. While 05 wheat varieties namely NIAW 34, Jay, N 146, NIAW 1994 (Phule Samadhan) and NI 917wheat varieties had shown moderately susceptible reaction to leaf rust. Although 09 wheat varieties namely NI 345, Kenphad 25, NI 747-19, NI 9947 (Kadava), N 5439, N 5749, NI 5643, Niphad-4 and Kenphad-39 had shown susceptible reaction to leaf rust.

Saritha *et al.* (2006) [10] evaluated the seedling and adult plant responses of 13 wheat genotypes against leaf rust pathotype 77-5. They reported that genotypes Sel. T 3171, Sel. T 3114, and Sel. T 3170 exhibited resistance at both the seedling and adult plant stages, indicating stable resistance. In contrast, Sel. T 3168, Sel. 3073, WR 544, and Kundan were susceptible at the seedling stage but showed moderate to high resistance at the adult stage, suggesting the presence of adult plant resistance (APR). However, genotypes Agra Local, Sonalika, and WL 711 were susceptible at both stages, with disease severity reaching up to 60S, indicating a lack of effective resistance genes. Moreover Muhammad *et al.* (2015) [5] conducted a two-year field study to evaluate 325 bread wheat genotypes for resistance to leaf rust caused by *Puccinia triticina*. The trials were carried out under natural field conditions during the 2010-11 and 2011-12 cropping seasons using local pathotypes. In the 2010-11 season, 225 genotypes showed no reaction to leaf rust, while the remaining genotypes displayed varying degrees of resistance and susceptibility. Specifically, 12 genotypes were resistant, 20 moderately resistant, 40 moderately susceptible, 15 moderately resistant to moderately susceptible, and 13 susceptible. During 2011-12, 233 genotypes again showed no reaction, while others showed similar variable responses. Slow-rusting genotypes were associated with low AUDPC (Area under Disease Progress Curve) values, while high rusting genotypes had high

AUDPC values. This suggested that slow rusting played a role in disease management. The study also highlighted that leaf rust development was significantly influenced by environmental factors. There was a strong statistical correlation between rust severity and climatic variables such as average temperature, maximum and minimum temperature, rainfall, and relative humidity.

Table 4: Wheat varieties showing different reactions to leaf rusts at adult plant stage

Sr. No.	Wheat variety	Leaf rust reaction
1	NI 345	40S
2	Kenphad 25	60S
3	NI 747-19	20S
4	NIAW 4028 (Phule Anurag)	TMR
5	NI 9947 (Kadava)	20S
6	N 5439	40S
7	N 5749	10S
8	NIAW 34	10MS
9	NI 5643	20S
10	Niphad-4	40S
11	NIAW 3170 (Phule Satwik)	10MR
12	Kenphad-39	60S
13	Jay	20MS
14	NIDW 1149	R
15	N 146	10MS
16	NIAW 3624 (Phule Anupam)	R
17	NIDW 295 (Godavari)	R
18	NIAW 1994 (Phule Samadhan)	20MS
19	NIAW 301 (Trimbak)	R
20	NI 917	20MS
21	NIAW 917 (Tapovan)	R
22	NIAW 1415 (Netravati)	R
23	NIDW 15 (Panchavati)	TMR

NG: Not Germinated, 0: Immune, R: Resistant, MS: Moderately Susceptible, MR: Moderately Resistant, S: Susceptible, TMR: Trace Moderately Resistant

Studies on adult plant resistance in released wheat varieties against leaf rust by using a mathematical tool AUDPC (Area under Disease Progress Curve)

Results depicted in Table 5 revealed that, out of 23 wheat varieties none of the variety was found immune to leaf rust while, 13wheat varieties expressed values of AUDPC less than 100 against leaf rust whereas, 05wheat varieties expressed values of AUDPC between 101 to 200 against leaf rust. These wheat varieties had considerable amount of resistance against leaf rust. Three wheat varieties expressed value of AUDPC between 201 to 300 while two wheat varieties expressed AUDPC value above 500. These wheat varieties had shown susceptibility against leaf rust. Ahmed *et al.* (2010) screened 50 wheat varieties/lines for leaf rust resistance, of which 45 showed symptoms and 5 remained asymptomatic. Yield losses were assessed using the area under disease progress curve (AUDPC). As AUDPC values increased, yield losses also rose, ranging from 3.43% (1-50 AUDPC) to 38% (1500-2000 AUDPC). Varieties with 500-1000 AUDPC suffered significant yield loss of 21.50%, highlighting the strong correlation between disease severity and yield reduction. Similarly, Hasabnis *et al.* (2003) [3] evaluated the adult plant response of 55 wheat varieties to leaf rust under artificial epiphytotic conditions during the 1999-2000 season. Out of the tested varieties, 34 exhibited hypersensitive resistance, while 21 were categorized as susceptible to moderately susceptible. Notably, varieties HD 2285 and Sonalika showed high terminal Average Coefficient of Infection (ACI), with values of 80.00 and 70.71 respectively. Corresponding Area under Disease Progress Curve (AUDPC) values were highest for Sonalika (1186.20), followed by UP 2425 (821.00) and HD 2285 (712.60), indicating severe disease progression. HUW 234 and UP 2425 also exhibited the highest infection rates at 0.35 units per day. In contrast, ten varieties, including B. Yellow and HD 2189, showed low AUDPC values and slower disease development, suggesting that these lines possess slow-rusting traits and are promising candidates for developing leaf rust-resistant wheat varieties.

Table 5: Wheat varieties showing the AUDPC value

AUDPC value	Wheat varieties
Leaf Rust	
0	Nil
1-100	NIAW 4028 (Phule Anurag), N 5749, NIAW 34, NIAW 3170 (Phule Satwik), NIDW 1149, N 146, NIAW 3624 (Phule Anupam), NIDW 295 (Godavari), NIAW 1994 (Phule Samadhan), NIAW 301 (Trimbak), NIAW 917 (Tapovan), NIAW 1415 (Netravati), NIDW 15 (Panchavati) (13)
101-200	NI 747-19,NI 9947 (Kadava), NI 5643, Jay, NI 917 (05)
201-300	NI 345, N 5439, Niphad-4 (03)
301-400	Nil
401-500	Nil
Above 500	Kenphad 25, Kenphad-39 (02)

4. Epidemiology of leaf rust disease of wheat

During the period of observation, the first incidence of leaf rust disease was noticed in 1st meteorological week. The maximum ACI was observed 80 in 6th Meteorological week. Then it was declined.

Table 6: The weekly average weather data and per cent disease intensity of leaf rust of wheat during crop season of the year 2024-25

Standard Meteorological Week	ACI	Increase In ACI	Temp Max	Temp Min	Humidity	
					Morning	Evening
46	0	0	24.99	13.93	94.8	81.8
47	0	0	24.56	8.53	97.32	81.87
48	0	0	24.14	9.3	93.27	70.97
49	0	0	25.25	13.97	97.71	87.21
50	0	0	24.86	8.65	97.47	70.06
51	0	0	24.99	7.71	94.61	68.19
52	0	0	23.83	10.2	98.09	89.97
1	5	0	25.91	9.14	96.32	53.42
2	10	5	23.82	9.19	97.91	70.14
3	20	10	24.88	8.4	98.14	65.9
4	40	20	27.54	8.6	96.93	52.31
5	60	20	26.79	8.25	97.06	58.59
6	80	20	27.11	8.68	97.53	56.84
7	60	-20	28.56	8.34	90.7	35.96
8	40	-20	28.98	8.6	87.19	34.97
9	20	-20	29.00	9.78	86.06	43.33
10	10	-10	30.4	10.91	69.51	31.73
11	5	-5	30.58	12.98	74.64	43.15
12	0	0	29.88	11.48	64.17	44.24
13	0	0	30.43	13.94	68.85	57.82
14	0	0	29.79	13.34	86.04	60.54
15	0	0	33.27	15.75	73.04	61.65

ACI = Average coefficient of Infection

When the correlation was analyzed between four independent variables (averaged over the previous seven days) and the dependent variable (leaf rust severity), the maximum temperature and morning humidity (0.082505), (0.262162) showed a positive correlation with the severity of leaf rust of wheat. In case of minimum temperature and evening humidity (-0.48719) (-0.42249) showed negative correlation with the severity of leaf rust of wheat, respectively. This data is presented in Table 7

Table 7: Correlation Matrix

	Max. Temperature	Min. Temperature	Morning Humidity	Evening Humidity
ACI	0.082505	-0.48719	0.262162	-0.42249

Riaz *et al.* (2013) [8] studied the effect of weather conditions on wheat leaf rust development in three major wheat-growing regions of Pakistan Faisalabad, Bahawalpur, and Sakrand between 2003 and 2009. They evaluated six wheat cultivars and found that temperature and relative humidity had a significant positive correlation with leaf rust severity, while wind velocity showed a suppressive effect. Bahawalpur was identified as the most favourable site for leaf rust outbreaks due to its optimal temperature (16.85°C-20.44°C), high humidity (57.08%-76.95%), and low wind speed (1.98-4.07 km/hr). Furthermore, Mateen and Khan (2014) reported that environmental factors had great effect on the progress of stripe rust disease of wheat. A positive linear relationship between temperature (maximum and minimum) and disease severity showed that maximum stripe rust was highly noticed at 28-320C maximum temperatures and14-180C minimum temperatures. While, other environmental factors like relative humidity, rainfall and wind speed also showed positive correlation. Sandhu *et al.* (2017) [9] investigated the influence of weather parameters on stripe rust incidence and severity in wheat cultivar PBW 343 during the 2012-13 and 2013-14 cropping seasons under both natural and artificial conditions. Their findings showed that disease incidence was higher in 2012-13, which was attributed to increased rainfall that season. The study revealed a positive correlation between disease severity and temperature as well as sunshine hours, while relative humidity was negatively correlated. The researchers concluded that temperature and humidity were the most critical environmental factors driving stripe rust outbreaks in wheat. Results of the present are in general agreement with those of foregoing researchers.

Conclusion

The study revealed that among 23 wheat varieties, 3 showed resistance at the seedling stage, while 6 varieties were resistant and 3 moderately resistant at the adult plant stage. Based on AUDPC values, none were immune, but 13 varieties exhibited good resistance (<100 AUDPC). Disease first appeared in the 1st week of January 2025, peaked in mid-February (80 ACI), and then declined. Epidemiological analysis showed that maximum temperature and morning humidity favored disease development, while minimum temperature and evening humidity had a negative effect.

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