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Research Article

EVALUATION OF *TRITICUM AESTIVUM* L. GERMPLASM AGAINST *PUCCINIA STRIIFORMIS* AND ITS MANAGEMENT THROUGH BOTANICALS

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Abstract

Wheat is the staple food of Pakistan and country facing wheat shortage during recent years leading to food security issue. Rust diseases of wheat are significantly important causing major dent in wheat production during last season's due to drastic climate change. Therefore, wheat germplasm was screened against wheat stripe rust during two consecutive years. Out of one hundred and five genotypes not even one showed immune response during 2018-19, 22 genotypes showed highly resistant response, 19 showed resistance response, 42 showed moderately resistance response and remaining genotypes showed susceptible response except five lines (CB-10, CB-65, CB-95, CB-84 and CB-31) that showed heterogeneous characters. Likewise, during 2019-20, 18 genotypes showed highly resistant response, 23 showed resistant response, 39 were moderately resistance and remaining genotypes showed susceptible response except four lines (CB-10, CB-65, CB-95 and CB-84) that showed heterogeneous response. For each year the value of area under disease progress curve (AUDPC) of all genotypes was also calculated which falls between 100-850. The efficacy of four plant extracts (neem, garlic, ginger and bell pepper) using seed soaking method in controlling the stripe rust disease of wheat was investigated in pots experiment. During both years, minimum disease was observed in case of garlic bulb extract followed by neem leaves extract. Ginger bulb and Bell pepper fruit extract also had significant effect against wheat stripe rust. From the current study it could be suggested that using highly resistant germplasm advance lines may be developed that exhibit the resistant genes against stripe rust pathogen and it is observed that instead if using fungicides, use of botanicals not only reduced the human health hazard but also control the disease effectively.

Keywords: Stripe Rust, Immune, Germplasm, Heterogeneous

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1. INTRODUCTION

Agriculture sector is a source of income to 42.3% total population of Pakistan, while it contributes 18.9% to the overall gross domestic product (GDP). In Pakistan, wheat is the staple food that provides essential calories in various form. As the main diet for the people of Pakistan, it accounts for the largest share of the total agricultural area in farming and farms production, accounting for1.8% of Pakistan's GDP and 9.2 % of the value added in agriculture (GOP, 2020-21). Wheat crop is susceptible to several diseases i.e. smut, powdery mildew and most importantly rust (Bockus *et al.*, 2010; Shafiq *et al.*, 2017;

Hakeem *et al.*, 2021). During early 1800 the prolong epidemics of the wheat rust was reported in Asia (Pakistan & India). It is believed that the cyclic evolution of rust is the main reason for the paucity of wheat grains around globe and the rust diseases are main cause of production losses (Ali *et al*., 2017). The wheat rusts have historically been key biotic constraints in Asia as well as other world. Out of 3000 rust species in the world, three are pathogenic on wheat (Safavi, 2015). Brown or leaf rust by *Puccinia recondita*, stem or black rust by *Puccinia graminis* and stripe or yellow rust by *Puccinia striiformis* are well known diseases of rust (Hussain *et al*., 2011).

Heavy production losses have been noted in case of stripe rust disease that appears periodically on wheat crop. In past, numerous wheat stripe rust epidemics have been reported and will prove to be hazardous for wheat production in the coming decades. More than 50% losses have been noted due to early infection development of stripe rust on susceptible wheat cultivars (Ahmad et al., 2010). The major reason of the rust epidemic are the favorable weather conditions as the chances of disease incidence under such favorable conditions are increased. (Singh and Tewari, 2001). In our region, stripe and leaf rust reduces the yield nearly 60 - 63% and 43 - 46% respectively, if vulnerable varieties are grownup. Wheat rust (*Puccinia spp.*) is a biotrophic parasite that survives on alternate host plants present in the field, roadside and highways due to the absence of wheat (Reis and Casa, 2007).

For the control of plant diseases excessive use of pesticides has negative impact on the health of humans, animals, and drastic effect on the agricultural environment. As an alternative to synthetic fungicides, botanicals like plant extracts, and other organic materials has gained the attention of researcher as these acts on plant pathogens directly or indirectly by inducing plant resistance (Shabana et al., 2017; Binyamin et al., 2019). To control plant diseases through the use of botanicals several studies have been done (Srivasata et al., 2011; Zeshan et al., 2020; Ahmed et al., 2021). Studies shows that plant extracts are active biological control agents against a variety of pathogens cause diseases in plants i.e. fungi, bacteria, and virus. According to the previous reports plant extracts of many higher plants such as neem (*Azadirachta indica*) showed antibacterial, antifungal, and insecticidal properties (Satish et al., 1999). Most frequently used plant extract for botanical purpose includes garlic (*Allium sativum*) and neem (*Azadirchta indica)* while indispensable oils i.e. tea tree (*Melaleuca alternifolia*), thyme (*Thymus vulgaris*, Linn), rue (*Ruta graveolens*, Linn) and nettle (*Urtica* spp.). The main purpose of the current research is to identify wheat germplasm resistant to stripe rust, and to evaluate indigenous plant extracts which will be safe substitute for disease control that leads to reduce use and dependence on synthetic fungicides.

2. MATERIALS AND METHODS

2.1. Establishment of stripe rust screening nursery

One hundred and five wheat genotypes used for screening against wheat stripe rust disease were obtained from Wheat Research Institute (AARI), Faisalabad. Wheat disease screening field was established during the year 2018-19 and 2019-20 at UAF, Sub-Campus Burewala-Vehari. In a row of 3 meters each sample entry was planted with a row to row distance of 30 cm. After five varieties, most susceptible variety (Morocco) was planted as check. The progress of the disease was calculated at weekly intervals for visual signs of stripe rust.

2.2. Data collection

Disease severity was recorded on the 0-6 disease rating scale and including X mesotheic factor adopted from modified Cobb's Scale described by (Johnston and Browder, 1966) after initiation of first symptoms in the field.

Table 1. Disease rating scale (0-6) for wheat rust disease.

Type of Infection	Rating	Disease Severity	Response	Symptoms
Resistant	0	0 %	No Disease	No urediospore or other visible sign of disease
	1	0-5 %	Highly Resistant	No urediospore, but locally produced necrotic or chlorotic spots present
	2	5-20 %	Resistant	Small urediospore bounds by necrosis
	3	20-30 %	Moderately resistant	Small to medium urediospore surrounded by chlorosis or necrosis
Susceptible	4	30-40 %	Susceptible	Medium size urediospore that may be associated with chlorosis
	5	40-60 %	Moderately Susceptible	Large urediospore no chlorosis or necrosis
	6	60-80 %	Highly Susceptible	Large urediospre with chlorosis and necrosis
Mesotheic	X		Heterogeneous	Distribution of spores of varying size randomly

2.3. Area under Disease Progress Curve (AUDPC)

AUDPC was calculated on the weekly base data by using $\text{AUDPC}=\sum_{i=1}^{n-1}[(x_i+x_{i+1})/2](t_{i+1}-t_i)$ formula developed by (Shaner and Finney, 1977).

- Xi = rust intensity on date i
- ti = time in days between i and date i + 1
- n = number of dates on which disease was recorded

2.4. In vitro assay

Preparation of plant extracts

Plant extracts were prepared in Plant Pathology laboratory at UAF Sub-Campus Burewala, in a blender using sterilized distilled water. Plant extracts that were used in current study along with extraction methods is given below.

Table 2. Plant extracts

Common Name	Scientific Name	Part Use
Neem	*Azadirachta indica*	Leaves
Garlic	*Allium sativum*	Bulb
Ginger	*Zingiber officinale*	Bulb
Bell Pepper	*Capsicum annum*	Fruit

2.5. Seed Priming

Plant extracts were evaluated as seed-soaking treatment to evaluate their response in reducing stripe rust disease by following the method described by (Shabana et al., 2017). Seeds of Morocco (highly susceptible) genotype were soaked for 24 h in each plant extract at conc. of 3% (v/v). Seeds of same genotype were soaked in sterilized distilled water as a control treatment. Seeds having all treatments were sown in pots with three replications.

2.6. Inoculation of P. striformis inoculum

The *P. striformis* spores were collected from infected wheat leaves at research area of UAF Sub-Campus, Burewala-Vehari. The inoculation of wheat plants in pots was done according to the method illustrated by (Stakman *et al*., 1962). Gently rubbed the leaves of seedling between fingers containing sand particle, then the collected uredospores suspension was prepared in sterilized distilled water and pots plants were inoculated by spraying the suspension. Inoculum was sprayed for three days, and inoculation was done twice a day, during early in the morning and evening time when temperature is low, and humidity is high to ensure the successful infection. After 15 days from inoculation, disease severity was recorded in terms of infection types and amount of pustules/leaf.

2.7. Statistical analysis

Statistics analysis were done by Statistics 8.1. The comparison of individual pot experiment means was achieved by the Least Significant Difference (LSD) at a probability / significance level of 0.05 percent according to (Steel *et al*., 1997).

3. RESULTS

3.1. Screening of wheat germplasm against stripe rust disease

During season 2018-19, out of 105 varieties/lines tested none of the variety showed immune response only 22 wheat genotypes included CB-66, CB-67, CB-100, CB-90, CB-86, CB-87, CB-3, CB-37, CB-39, CB-25, CB-11, CB-38, CB-78, CB-77, CB-76, CB-81, CB-36, CB-64, CB-72, CB-61, CB-40 and CB-30 were highly resistance to stripe rust disease. However, 19 lines showed resistant response to the stripe rust disease i.e., CB-92, CB-97, CB-13, CB-16, CB-52, CB-83, CB-58, CB-63, CB-62, CB-75, CB-69, CB-70, CB-54, CB-6, CB-44, CB-46, CB-42, CB-22, CB-41. While, 42 genotypes including CB-89, CB-80, CB-93, CB-14, CB-59, CB-56, CB-49, CB-5, CB-74, CB-4, CB-96, CB-89, CB-94, CB-88, CB-18, CB-19, CB-20, CB-50, CB-21, CB-17, CB-27, CB-26, CB-71, CB-82, CB-32, CB-60, CB-15, CB-57, CB-8, CB-47, FSD-08, JOHAR-16, CB-29, CB-2, CB-9, CB-7, CB-45, CB-24, CB-43, CB-55, CB-23, CB-63 were moderately resistant to the stripe rust disease. Only 12 varieties i.e. CB-12, CB-91, CB-28, CB-35, CB-73, CB-1, CB-53, Gandam-1, Galaxy-13, CB-33, CB-34, CB-58 were moderately susceptible. Three genotypes were susceptible to the stripe rust disease includes CB-99, CB-51, CB-68 while 2 genotypes were highly susceptible to the stripe rusts attack includes CB-48 and Morocco. Some genotypes also showed heterogenous response i.e. wilting, necrosis, chlorosis etc. symptoms other than disease included CB-10, CB-65, CB-95, CB-84, CB-31.

While during season 2019-20, out of 105 genotypes tested none of the genotype showed immune response only 18 wheat genotypes included CB-66, CB-67, CB-100, CB-90, CB-86, CB-87, CB-3, CB-37, CB-39, CB-25, CB-11, CB-38, CB-78, CB-77, CB-76, CB-81, CB-36, and CB-64 were highly resistance to stripe rust disease. However, 23 genotypes showed resistant response to the stripe rust disease and these lines include CB-92, CB-97, CB-13, CB-16, CB-52, CB-83, CB-58, CB-63, CB-62, CB-75, CB-69, CB-

70, CB-54, CB-6, CB-44, CB-46, CB-42, CB-22, CB-41, CB-72, CB-61, CB-40, and CB-30. While, 39 genotypes including CB-89, CB-80, CB-93, CB-14, CB-59, CB-56, CB-49, CB-5, CB-74, CB-4, CB-96, CB-89, CB-94, CB-88, CB-18, CB-19, CB-20, CB-50, CB-21, CB-17, CB-27, CB-26, CB-71, CB-82, CB-32, CB-60, CB-15, CB-57, CB-8, CB-47, FSD-08, CB-29, CB-2, CB-9, CB-7, CB-45, CB-24, CB-43 and CB-55 were moderately resistant. Only 13 varieties i.e. CB-12, CB-91, CB-28, CB-35, CB-73, CB-1, CB-53, Gandam-1, Galaxy-13, CB-33, CB-34, CB-58 and JOHAR-16 were moderately susceptible to attack of stripe rust. Moreover, 5 genotypes were susceptible to the stripe rust disease includes CB-99, CB-51, CB-68, CB-23 and CB-63 while 3 varieties were highly susceptible to the stripe rusts attack includes CB-31, CB-48 and Morocco. Some genotypes also showed heterogenous response i.e. wilting, necrosis, chlorosis etc. symptoms other than disease included CB-10, CB-65, CB-95 and CB-84.

Table 3. Response of wheat genotype against stripe rust of during 2018-19 and 2019-20

Response	**D. S**	**D. I range**	**No. of genotypes**	**Genotypes 2018-19**	**No. of genotypes**	**Genotypes 2019-20**
Immune	0 %	0	0	0	0	0
Resistant						
Highly Resistant	0-5 %	1	22	CB-66, CB-67, CB-100, CB-90, CB-86, CB-87, CB-3, CB-37, CB-39, CB-25, CB-11, CB-38, CB-78, CB-77, CB-76, CB-81, CB-36, CB-64, CB-72, CB-61, CB-40, CB-30	18	CB-66, CB-67, CB-100, CB-90, CB-86, CB-87, CB-3, CB-37, CB-39, CB-25, CB-11, CB-38, CB-78, CB-77, CB-76, CB-81, CB-36, CB-64,
Resistant	5-20 %	2	19	CB-92, CB-97, CB-13, CB-16, CB-52, CB-83, CB-58, CB-63, CB-62, CB-75, CB-69, CB-70, CB-54, CB-6, CB-44, CB-46, CB-42, CB-22, CB-41	23	CB-92, CB-97, CB-13, CB-16, CB-52, CB-83, CB-58, CB-63, CB-62, CB-75, CB-69, CB-70, CB-54, CB-6, CB-44, CB-46, CB-42, CB-22, CB-41, CB-72, CB-61, CB-40, CB-30
Moderately resistant	20-30 %	3	42	CB-89, CB-80, CB-93, CB-14, CB-59, CB-56, CB-49, CB-5, CB-74, CB-4, CB-96, CB-89, CB-94, CB-88, CB-18, CB-19, CB-20, CB-50, CB-21, CB-17, CB-27, CB-26, CB-71, CB-82, CB-32, CB-60, CB-15, CB-57, CB-8, CB-47, FSD-08, JOHAR-16, CB-29, CB-2, CB-9, CB-7, CB-45, CB-24, CB-	39	CB-89, CB-80, CB-93, CB-14, CB-59, CB-56, CB-49, CB-5, CB-74, CB-4, CB-96, CB-89, CB-94, CB-88, CB-18, CB-19, CB-20, CB-50, CB-21, CB-17, CB-27, CB-26, CB-71, CB-82, CB-32, CB-60, CB-15, CB-57, CB-8, CB-47, FSD-08, CB-29, CB-2, CB-9, CB-7, CB-45, CB-24, CB-43, CB-55,

				43, CB-55, CB-23, CB-63		
Susceptible						
Moderately Susceptible	30-40 %	4	12	CB-12, CB-91, CB-28, CB-35, CB-73, CB-1, CB-53, Gandam-1, Galaxy-13, CB-33, CB-34, CB-58	13	CB-12, CB-91, CB-28, CB-35, CB-73, CB-1, CB-53, Gandam-1, Galaxy-13, CB-33, CB-34, CB-58, JOHAR-16
Susceptible	40-60 %	5	3	CB-99, CB-51, CB-68	5	CB-99, CB-51, CB-68, CB-23, CB-63
Highly Susceptible	60-80 %	6	2	CB-48, Morocco	3	CB-31, CB-48, Morocco
Mesotheic	Heterogenous	X	5	CB-10, CB-65, CB-95, CB-84, CB-31	4	CB-10, CB-65, CB-95, CB-84,

3.2. Area under disease progression curve (AUDPC) during 2018-19 and 2019-20

For the year 2018-19 AUDPC was determined by trapezoidal assimilation of percent severity of disease over time for each genotype, taking into consideration the complete length of the plant assessed (Madden *et al.*, 2007).Wheat genotypes included CB-66, CB-67, CB-100, CB-90, CB-86, CB-3, CB-37, CB-87, CB-39, CB-25, CB-11, CB-38, CB-78, CB-77, CB-76, CB-81, CB-36, CB-64, CB-72, CB-61, CB-40, CB-30 showed highly resistant response to stripe rust disease and had minimum AUDPC range 100-200. However, 19 genotypes showed resistant response to the stripe rust disease, and these include CB-92, CB-97, CB-13, CB-16, CB-52, CB-83, CB-58, CB-63, CB-62, CB-75, CB-69, CB-70, CB-54, CB-6, CB-44, CB-46, CB-42, CB-22, CB-41 lies within value 201-300 of AUDPC range. 42 genotypes including CB-89, CB-80, CB-93, CB-14, CB-59, CB-56, CB-49, CB-5, CB-74, CB-4, CB-96, CB-89, CB-94, CB-88, CB-18, CB-19, CB-20, CB-50, CB-21, CB-17, CB-27, CB-26, CB-71, CB-82, CB-32, CB-60, CB-15, CB-57, CB-8, CB-47, FSD-08, Johar-16, CB-29, CB-2, CB-9, CB-7, CB-45, CB-24, CB-43, CB-55, CB-23, CB-63 were moderately resistant to the disease and had AUDPC value between 301-400. Only 12 genotypes i.e. CB-12, CB-91, CB-28, CB-35, CB-73, CB-1, CB-53, Gandam-1, Galaxy-13, CB-33, CB-34 and CB-58 fall between the range of 401-500 which were moderately susceptible to attack of stripe rust. Moreover, 3 genotypes were susceptible to the stripe rust disease includes CB-99, CB-51, CB-68 showed 501-600 AUDPC value while only 2 varieties were highly susceptible to the stripe rust attack includes CB-48 and Morocco those have 601-700 AUDPC value. 5 genotypes showed heterogenous response i.e. wilting, necrosis, chlorosis etc. symptoms other than disease had maximum value of AUDPC range 701-800 included CB-10, CB-65, CB-95, CB-84, CB-31.

Similarly, during 2019-20 AUDPC wheat genotypes included CB-66, CB-67, CB-100, CB-90, CB-86, CB-87, CB-3, CB-37, CB-39, CB-25, CB-11, CB-38, CB-78, CB-77, CB-76, CB-81, CB-36 and CB-64 showed highly resistant response to stripe rust disease and had minimum AUDPC range 100-200. However, 23 genotypes showed resistant response to the stripe rust disease and these lines include CB-92, CB-97, CB-13, CB-16, CB-52, CB-83, CB-58, CB-63, CB-62, CB-75, CB-69, CB-70, CB-54, CB-6, CB-44, CB-46, CB-42, CB-22, CB-41, CB-72, CB-61, CB-40, CB-30 and falls within value of 201-300 of AUDPC range. Thirty nine varieties including CB-89, CB-80, CB-93, CB-14, CB-59, CB-56, CB-49, CB-5, CB-74, CB-4, CB-96, CB-89, CB-94, CB-88, CB-18, CB-19, CB-20, CB-50, CB-21, CB-17, CB-27, CB-26, CB-71, CB-82, CB-32, CB-60, CB-15, CB-57, CB-8, CB-47, FSD-08, CB-29, CB-2, CB-9, CB-7, CB-45, CB-24, CB-43 and CB-55 were moderately resistant to the disease and had AUDPC value between 301-400. Only 13 varieties i.e. CB-12, CB-91, CB-28, CB-35, CB-73, CB-1, CB-53, Johar-16, Gandam-1, Galaxy-13, CB-33, CB-34 and CB-58 fall between the range of 401-500 which were moderately susceptible to attack of stripe rust. Moreover, 5 genotypes were susceptible to the stripe rust disease includes CB-99, CB-51, CB-68, CB-23, CB-63 showed 501-600 AUDPC value while only 3 genotypes were highly susceptible to the stripe rust attack includes CB-31, CB-48 and Morocco those have 601-700 AUDPC value. Four genotypes showed heterogenous response i.e. wilting, necrosis, chlorosis etc. symptoms other than disease had maximum value of AUDPC range 701-800 included CB-10, CB-65, CB-95 and CB-84.

Table 4. Area under disease progression curve (AUDPC) during 2018-19 and 2019-20

Sr. No.	**AUDPC Range**	**No. of genotypes 2018-19**	**Varieties/Lines**	**No. of genotypes 2019-20**	**Varieties/Lines**
1	100-200	22	CB-66, CB-67, CB-100, CB-90, CB-86, CB-87, CB-3, CB-37, CB-39, CB-25, CB-11, CB-38, CB-78, CB-77, CB-76, CB-81, CB-36, CB-64, CB-72, CB-61, CB-40, CB-30	18	CB-66, CB-67, CB-100, CB-90, CB-86, CB-87, CB-3, CB-37, CB-39, CB-25, CB-11, CB-38, CB-78, CB-77, CB-76, CB-81, CB-36, CB-64,
2	201-300	19	CB-92, CB-97, CB-13, CB-16, CB-52, CB-83, CB-58, CB-63, CB-62, CB-75, CB-69, CB-70, CB-54, CB-6, CB-44, CB-46, CB-42, CB-22, CB-41	23	CB-92, CB-97, CB-13, CB-16, CB-52, CB-83, CB-58, CB-63, CB-62, CB-75, CB-69, CB-70, CB-54, CB-6, CB-44, CB-46, CB-42, CB-22, CB-41, CB-72, CB-61, CB-40, CB-30
3	301-400	42	CB-89, CB-80, CB-93, CB-14, CB-59, CB-56, CB-49, CB-5, CB-74, CB-4, CB-96, CB-89, CB-94, CB-88, CB-18, CB-19, CB-20, CB-50, CB-21, CB-17, CB-27, CB-26, CB-71, CB-82, CB-32, CB-60, CB-15, CB-57, CB-	39	CB-89, CB-80, CB-93, CB-14, CB-59, CB-56, CB-49, CB-5, CB-74, CB-4, CB-96, CB-89, CB-94, CB-88, CB-18, CB-19, CB-20, CB-50, CB-21, CB-17, CB-27, CB-26, CB-71, CB-82, CB-32, CB-60, CB-15, CB-57, CB-8,

			8, CB-47, FSD-08, JOHAR-16, CB-29, CB-2, CB-9, CB-7, CB-45, CB-24, CB-43, CB-55, CB-23, CB-63		CB-47, FSD-08, CB-29, CB-2, CB-9, CB-7, CB-45, CB-24, CB-43, CB-55,
4	401-500	12	CB-12, CB-91, CB-28, CB-35, CB-73, CB-1, CB-53, Gandam-1, Galaxy-13, CB-33, CB-34, CB-58	13	CB-12, CB-91, CB-28, CB-35, CB-73, CB-1, CB-53, Johar-16, Gandam-1, Galaxy-13, CB-33, CB-34, CB-58,
5	501-600	3	CB-99, CB-51, CB-68,	5	CB-99, CB-51, CB-68, CB-23, CB-63
6	601-700	2	CB-48, Morocco	3	CB-31, CB-48, Morocco
7	701-850	5	CB-10, CB-65, CB-95, CB-84, CB-31	4	CB-10, CB-65, CB-95, CB-84,

3.3. Management of Stripe rust disease

Seed Priming Treatment

Wheat cultivar ‘‘Morocco” was used to evaluate plant extracts against stripe rust disease. All the plant extracts significantly decreased the disease severity of stripe rust. Priming with extracts of garlic and neem proven to be best treatment for the control of stripe rust disease. While ginger and pepper also showed significant results of disease control however, maximum disease severity was observed in case of negative control i.e. seeds treated with distilled water.

Table 5a. Effect of plant extracts on disease severity of Stripe rust during 2018-19.

Treatments	**Maximum Disease Severity %**			**Reaction Type**
	1st Week Disease Severity **%**	2nd Week Disease Severity **%**	3rd Week Disease Severity **%**	
Neem	0	5	20	R
Ginger	5	20	20	R
Garlic	0	0	5	HR
Bell Pepper	5	20	30	MR
Control	20	40	60	HS

Table 5b. Effect of plant extracts on disease severity of Stripe rust during 2018-19.

Treatments	**First Week Data**	**Second Week Data**	**Third Week Data**
Neem	0.0000 C	5.0000 C	18.667 B
Ginger	3.3333 B	9.3333 B	15.333 B
Garlic	0.0000 C	0.0000 D	5.0000 C
Pepper	4.1667 B	12.000 B	19.000 B
Control	20.000 A	40.000 A	60.000 A
LSD Value			

Values followed by the same letter are not significantly different according to LSD test at P = 5%.

Results showed that maximum stripe rust infection was observed in case of control. During the year 2018-19, among the tested plant extracts, Garlic extract was the most effective one, showed only 5% disease severity in third week of infection, followed by neem which showed (5%) disease severity during second week and (20%) in last week, Ginger bulb extract showed (5%) disease severity in first week and later disease progress was slow (20%) and Bell pepper fruit extract was least effective against stripe rust disease as disease progress gradually during each week and maximum 30% disease severity was noted in last week, (Table 5).

Table 6a. Effect of plant extracts on disease severity of Stripe rust during 2019-20.

Treatments	**Maximum Disease Severity %**			**Reaction Type**
	1st Week Disease Severity **%**	2nd Week Disease Severity **%**	3rd Week Disease Severity **%**	
Neem	>5	5-15	20	R
Ginger	5-10	15-20	30	MR
Garlic	>5	5-10	10-15	R
Bell Pepper	5	20	40	S
Control	20	40	60	HS

Table 6b. Effect of plant extracts on disease severity of Stripe rust during 2019-20.

Treatment	**First Week Data**	**Second Week Data**	**Third Week Data**
Neem	1.667 D	10.000 C	20.000 D
Ginger	6.667 B	16.667 B	30.000 C
Garlic	3.667 CD	6.667 C	16.667 E
Pepper	5.000 BC	20.000 B	40.000 B
Control	20.000 A	40.000 A	60.000 A
LSD Value			

Values followed by the same letter are not significantly different according to LSD test at P = 5%.

During the year 2019-20, a slight variation was observed among the results of used plant extracts. Garlic extract and neem leaves extract showed almost similar results and proven to be the most effective against stripe rust disease as only 20% disease severity was recorded in both extract during last observation, Ginger bulb extract showed (5-10%) disease severity in first week and later disease progression was slow and during third week of disease observation (30%) disease severity was recorded. Fruit extract of Bell pepper least effective against stripe rust disease as disease progress gradually during each week and maximum 40% disease severity was noted in last week (Table 6).

4. DISCUSSION

Under the current climate change scenario continuous screening and test of wheat germplasm is necessary in order to keep at toes against such vulnerable disease i.e., stripe rust of wheat. Results of current study were somewhat horrible because out of 105 genotypes none of the genotype showed immune response to disease. Our findings are somewhat in line with other researchers i.e., Afzal et al., (2009); Ahmad et al., (2010); Sobia et al., (2010), who screened genotypes against stripe rust and found almost similar level of response. Seedling level resistance and high temperature adult resistance results also showed similar results pattern against stripe rust disease (Bux et al., 2012).

These results indicate that such plant extracts induced resistance in wheat seedlings against stripe rust infection as seed soaking treatment. Biological means of controlling wheat rusts via plant extracts is a latest, new, advanced and environment friendly alternative method for rust management (Jarvis, 1988). Various plant extracts having their important role in the management of plant diseases is already reported (Joseph et al., 2008; Binyamin et al., 2011; Imran et al., 2012; Dey et al., 2014; Shabana et al., 2017). In this study, *in vitro*-tested plant extracts (neem, ginger, garlic, and bell pepper) inhibited spore germination and control the wheat rust severity by 70% or more. Garlic extract showed minimum disease severity percentage followed by neem. While ginger also showed significant on rust severity reduction. Bell pepper fruit extract proven to be less effective as maximum disease severity was recorded in this treatment i.e. 40%. Maximum disease was noted in case of control where only distilled water applied and kept as negative check. Plants have the ability to synthesize aromatic secondary metabo- lites, like phenols, phenolic acids, quinones, flavones, flavonoids, flavanols, tannins and coumarins (Cown, 1999). *In vitro* and *in vivo* efficacy of managing wheat leaf rust disease using eight plant extracts (clove, garlic, anthi mandhaari, Brazilian pepper, neem, black cumin, garden quinine, and white cedar) was investigated (Shabana et al., 2017). It was evident that spore germination was inhibited by more than 93% in all treatments under *in vitro* conditions. No significant difference was observed in Neem extract treatment where 98.99% spore germination inhibition was observed compared to the fungicide Sumi-8 (100%). Botanicals are environment friendly, and economical obtained from naturally available resources. Finally, it may be concluded that the use of plant extracts to control stripe rust disease of wheat is useful. The effective use of plant extracts in managing plant pathogenic fungi will lead towards promise for the organic and ecofriendly management of foliar diseases of wheat. The present findings may serve as the foundation for the use of plant extracts as an alternative, safe and cost-effective control method against rust diseases of wheat.

5. CONCLUSION

Screening of wheat germplasm should be carried out on a regular and regional basis under the current climate change scenario. Germplasm screened during the current study showed low resistance level against stripe rust. However, botanicals used as seed priming gave suitable results for disease management, and this approach could be further tested for field purpose.

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