

**EVALUATION AND ASSESSMENT OF YIELD LOSSES BY STRIPE  
RUST (*Puccinia striiformis* f.sp. *tritici*) IN WHEAT**

by

**Girja Devi**

**(J-22-M-909)**

**Thesis submitted to  
Faculty of Agriculture  
in partial fulfilment of the requirements  
for the degree of**

**MASTER OF SCIENCE IN AGRICULTURE  
PLANT PATHOLOGY**



**Division of Plant Pathology**

Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu  
Main Campus, Chatha, Jammu 180009

**2024**

## CERTIFICATE – I

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This is to certify that the thesis entitled “**Evaluation and assessment of yield losses by stripe rust (*Puccinia striiformis* f.sp. *tritici*) in wheat**” submitted in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture (Plant Pathology)** to the Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, is original work and has similarities with published work not more than minor similarities as per UGC norms of 2018 adopted by the University. Further the level of minor similarities has been declared after checking the manuscript with “**DRILLBIT**” software provided by the University.

The work has been carried out by, **Ms. Girja Devi**, under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma. It is further certified that help and assistance received during the course of thesis investigation have been duly acknowledged.



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**(Major Advisor)**

**Place: Chatha, Jammu**

**Date: 20-08-2024**



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### CERTIFICATE-III

This is to certify that the thesis entitled "**Evaluation and assessment of yield losses by stripe rust (*Puccinia striiformis* f. sp. tritici) in wheat**", submitted by **Ms. Girja Devi**, Registration No. **J-22-M-909**, to the Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu, in partial fulfilment of the requirements for the degree of **Master of Science in Agriculture (Plant Pathology)**, was examined and approved by the advisory committee and external examiner(s) on **24.10.2024**.

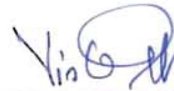


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*Girja Devi*  
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## ABSTRACT

**Title of Thesis** : Evaluation and assessment of yield losses by stripe rust (*Puccinia striiformis* f.sp. *tritici*) in wheat  
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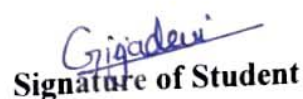
Stripe rust (*Puccinia striiformis* f. sp. *tritici*) is the most damaging disease of wheat crop under cold weather conditions in Hill Zone and North Western Plain Zone of India. Stripe rust cause 40 to 100 per cent yield losses in wheat crop depending upon the level of resistance in a variety the objective of present study was to evaluate the wheat germplasm and assess the yield associated with different levels of stripe rust resistance in commercial wheat cultivars experimentation was carried out in the field of AICRP Wheat and Barley, Division of Plant Breeding and Genetics, SKUAST-J.

The current study comprised of 195 wheat germplasm were evaluated in order to find out potentially novel source of resistance against stripe rust. Out of 195 lines, forty-seven lines showed immune (0) response, three were resistance (R), thirty-five showed moderately resistance (MR), fifty-seven showed moderately susceptible (MS) and fifty showed susceptible (S) infection type. Highest disease severity was recorded in two susceptible wheat lines varieties PBW 343 and HD 3086. AUDPC values with 0 were recorded in fifty-two germplasm, 1-10 in one germplasm, 11-100 in twenty-eight germplasm and 101-200 in forty germplasm, AUDPC values from 201 to 500 in twenty-eight germplasm, 501 to 800 in twenty germplasm and AUDPC values greater than 800 was observed in twenty-six germplasm. Average CDL value was observed between 0.000 to 0.810 among the tested germplasms. Highest CDL values observed in PBW343 (0.810) followed by HD-3086 (0.640) and Agra local (0.360). Zero CDL values observed in (50) germplasm. "r" value with 0.000 was observed in seventy-seven germplasm and 0.001- 0.015 r value was observed in sixty- two germplasm. From 0.016 to 0.030 r value was recorded in fifty-two germplasm while >0.300 r value was recorded in Agra local, HD3086, PBW343. New released variety PBW725 showed only 3.3 rust score reaction of stripe rust indicating its resistance nature to pathotypes. It also indicated that there was different level of resistance in different varieties to stripe rust pathogen. The spray of propiconazole @ 0.1 per cent drastically reduced the rust incidence in all the varieties evaluated.

**Keywords:** Strip rust, Resistance, Pathotype, Germplasms



Signature of Advisor



Signature of Student

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## LIST OF ABBREVIATIONS

%	Per cent
/	per
$\geq$	Greater than or equals to
$\leq$	Lesser than or equals to
$\times$	Multiply
$^{\circ}\text{C}$	Degree Celsius
@	At the rate of
ACI	Average Coefficient of Infection
BCR	Benefit Cost Ratio
CM	Centimetre
CD	Critical difference
Doesn't	Does not
EC	Emulsifiable concentrate
et al.,	et alia(co-workers)
etc.	etcetera
Fig.	Figure
g/l	Gram per litre
HP	Himachal Pradesh
i.e.,	id. est. (that is)
J&K	Jammu and Kashmir
Kg/ha	Kilogram per hectare
L	litre
M	Meter
Mha	Million hectares
MT	Million tons

No.	Number
q/ha	Quintals per hectare
SC	Suspension concentrate
SE	Suspo-emulsion
S. No.	Series Number
WG	Water-dispersible Granule
Viz.,	Videlicet (namely)

### INTRODUCTION

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Wheat (*Triticum aestivum* L.) is the most widely crop with a serious role in food security with different biotic and abiotic stresses limit its production (Kushnirenko *et al.*, 2021). This crop was originated in the Central Asian region, which covers 225 million hectares and contributes to a global production of 750 million tons (Singh *et al.*, 2023). Asia is the leading contributor to global wheat production, accounting for 44% of the total. Europe follows with 34%, while the Americas contribute 15%. Oceania and Africa each have modest shares of around 3.4% to 3.5% (Erienstein *et al.*, 2022). According to an estimate, the world population will touch nearly nine billion from existing 7 billion in 2-3 decades, for which an annual increase of 2% in wheat production is, must in order to ensure food security. To meet the food requirements of ever-increasing population, 60% increase in wheat production is projected by 2050. India is one of the leading producers of wheat in the world. India ranks second in wheat production, with 109.52 million tons, accounting for 13% of the global wheat supply (Singh *et al.*, 2023). Wheat is synonym to the economic well-being of India. In the Jammu region of the Union Territory of Jammu and Kashmir, wheat is cultivated across 290 thousand hectares, yielding 488.3 million tons in 2023.

As forecasted by climatologists, with the existing cultivars and practices, 30 % reduction in South Asia's wheat yield is expected. To increase and sustain wheat yield, the crop must be kept free from diseases (Bhardwaj *et al.*, 2009). There are many abiotic and biotic factors affect the growth and yield of wheat crop (Hafez *et al.*, 2020; Alnusairi *et al.*, 2021; Abdelaal *et al.*, 2021). One of the most serious biotic stresses is stripe rust, stripe rust (also known as yellow rust) is an old disease that has emerged as a problem in some areas and develops new races that overcome resistance to wheat cultivars and/or new strains that adapt to new conditions (Omara *et al.*, 2021). Rusts caused by three different species of fungus *Puccinia* are the main biotic impediments in our efforts to sustain and boost production of wheat. Their ability to spread aerielly over the continents, production of infectious propagules geometrically and evolving new physiologic forms (pathotypes), make the management of wheat rusts a very challenging task. To counter the ever-emerging threat of wheat rusts, efforts are going on worldwide. Identification of pathotypes, anticipatory breeding, evaluation for rust resistance and deployment of rust resistant cultivars are the important constituents of rust management. More than 210 rust resistance genes and associated markers

for many are available for the use of breeders. However, the rust pathogens have always outdone the efforts of the breeders and new virulent pathotypes have emerged which could overcome the immune and novel rust resistance genes. Thus, screening and use of resistance germplasm is a prime objective of breeding programme.

Stripe rust of wheat caused by *Puccinia striiformis* f. sp. *tritici* reduces the yield and quality of the grain and forage. Seed produced from crop damaged by stripe rust have low vigor and thus express poor emergence after germination. Stripe rust can cause 100% yield loss if infection occurs very early and the disease continues to develop during the growing season provided the cultivars are susceptible. In most wheat producing areas, yield losses caused by stripe rust have ranged from 10-70% depending upon the susceptibility of cultivar, earliness of the initial infection, rate of disease development and duration of the disease (Chen, 2005). Grant and John (2005) reported from Australia that stripe rust attacks all the above-ground parts of the wheat plant and is characterized by powdery masses (pustules) of yellow spores, which form stripes on the leaf surface. The pustules occur in blotches covering large areas of affected leaves on young plants while pustules are arranged in parallel lines, giving affected leaves a characteristic striped appearance on older plants.

In India the work on losses was done in earlier 70's and losses up to 70 per cent were reported (Nagarajan and Joshi, 1975; Aujla *et al.*, 1975). But with the development of resistant varieties in breeding program and change of varieties after 1980 especially after introduction of PBW 343, we forgot stripe rust in India. As we know that breakdown of resistance to stripe rust occurs at regular intervals therefore, management strategies critical for minimizing losses in these intervals when effective resistance is not deployed or till its deployment, is our main objective. So, with reappearance of new pathotypes in North West Plain zone of India, it became urgent need to assess losses and to make strategy for the efficient management of this disease until and unless new resistant material of wheat having some different gene pool is developed. Keeping all this in view, an experiment shall be conducting to find out exact losses due to stripe rust in cultivars of wheat having different level of resistance.

Infection of leaf sheaths and stems can also occur, but spore production on these parts is less than on leaves. Stripe rust can also attack the heads. The rust fungus infects the glumes and awns at flowering. This results in an accumulation of spores in the florets and on the surface of the developing grain. In Victoria, stripe rust can reduce yield by up to 50% and leaf rust by greater than 20% in susceptible varieties. Colson and Wilkinson (2006) also witnessed this disease throughout the wheat growing regions of Queensland in 2005. In Ethiopia,

yellow rust epiphytotics were recorded in 1977, 1980-1983, 1986, 1988 and 1990 with severe losses during 1988 in bread wheat (Badebo and Bayu, 1992). Major epiphytotics were recorded in Egypt once in each decade since 1960s with the most recently reported in the Delta region during 1995. The average grain yield loss ranged from 14% to 26% in this region, while the national loss was about 10% (El-Daoudi *et al.*, 1996).

The global spread of yellow rust epidemics in recent years (Hovmøller *et al.*, 2010) as well as the spread of epidemics to new locations where the illness was previously absent or unnoticed, has reinforced the need to understand the dissemination, establishment, and evolution of yellow rust races on a global scale (Hovmøller *et al.*, 2011; Walter *et al.*, 2016). In 2011, two new races, known as the Warrior and Kranich races, were discovered on wheat and triticale in a number of European countries. Furthermore, Singh *et al.*, (2004) found that rust infections reduced grain production by more than 50% in sensitive wheat varieties. The loss inflicted by wheat disease such as rusts that could be controlled by the joint efforts of scientists involved in diverse agricultural disciplines and plant breeding programs (Braun *et al.*, 1998). Rust is a unanimous name for a group of disease, caused by Puccinia species (fungal pathogens) infecting cereal crops (wheat, rye, barley, and triticale) and grasses (Brown and Hovmoller, 2002).

**Objectives:**

1. To evaluate wheat germplasm against stripe rust at different crop growth stage.
2. To assess the yield losses associated with different levels of stripe rust resistance of commercial wheat cultivars.

### REVIEW OF LITERATURE

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Wheat rusts have been coevolving and coexisting during domestication of wheat as a major staple food crop. Kislev (1982) documented archaeological evidence of *Puccinia graminis*. Rusts of wheat have proven most destructive as compared to the other crop diseases. Since it is a compound interest disease, under congenial conditions as it can spread very fast in monoculture over a large area, results in epidemics and havoc to wheat. In wheat, stripe rust incited by *Puccinia striiformis* West. (Pst) appears in temperate or cold temperature with increase in temperature lead to brown rust caused by *Puccinia triticina* Eriks. (Pt) and stem rust incited by *Puccinia graminis* Pers. f.sp. *tritici* Eriks. and Henn. (Pgt) predominates at higher temperature. In India, *Puccinia striiformis* West. (Pst) is restricted to cooler regions of North Western Plains Zone (NWPZ) and Northern Hills Zone (NHZ) comprising states of Punjab, Haryana, Foot Hills Zone of Himachal Pradesh and Jammu & Kashmir, Tarai areas of Uttarakhand, western Uttar Pradesh and Rajasthan and in South India, Nilgiri and Pulni hills (Joshi *et al.*, 1974). High temperature inhibits the growth of the disease development or induces the pathogen to enter dormancy.

#### History

The stripe (or yellow) rust disease was first described in 1777 in Europe by Gadd and Bjerkander but taxonomically under the name of *Uredo glumarum* infecting barley glumes first described by Schmidt in 1827 (Humphrey *et al.*, 1924). Westendorp in 1854 used *Puccinia striiformis* collected from rye stripe rust (Stubbs, 1985). Eriksson and Henning (1986), stripe rust resulted from a separate pathogen given the name as *Puccinia glumarum*. Later on, in the early 1890s, Jacob Eriksson in Sweden made first scientific study on stripe rust. This name of stripe rust pathogen was in the trend until Hylander *et al.* (1953) revive the name as *Puccinia striiformis* Westend. Since, Eriksson, subdivided the *Puccinia striiformis* Westend into five *formae speciales* (Chen, 2005). After many changes and modification made by many scientists, stripe rust of wheat pathogen is added scientific name as, *Puccinia striiformis* Westend f. sp. *tritici* Erikss & Henn is being used in present day literature (Chen and Kang, 2017a). Humphrey *et al.*, (1924) were proposed common name of disease as 'stripe rust'.

## Symptomatology

Symptoms of the disease start appearing about one week after inoculation and sporulation starts about two weeks after infection under optimum temperature conditions. This disease is basically distinguished from other rusts by yellowish pustules resulting from uredia, arranged in the form of yellow, narrow linear streaks primarily on leaf blade. The obligate fungus forms tiny, yellow to orange-coloured rust pustules, called uredia. Pustules can occur on leaf sheath, stalk, glumes, awns and ear heads which rarely infest the developing grains in case of extreme infection. Yellowish pustules lined with the veins Streak contains amount of elliptical, lemon shaped, while under severe infection, and streak patterns become undistinguishable and arranged into clusters. Pathogen on infecting leaf lamina remains partially systemic and the stripes keep on enlarging. Uredospores never break in susceptible host. But eventually to act like, exposing a yellow spore mass to wind dispersion. Each uredium contains thousands of uredinospores. When temperature was increased, then these stripes turn black resulting in urediospore changed in teliosori. Telia are dull black in colour, besides on other portions of the plant and appear mostly beneath the leaf exterior. As like uredia, telia are also organized in the long stripes and wrapped by the host epidermis as a smooth blackish incrustation (Chen *et al.*, 2014).

## Pathogen

Stripe rust is caused by a heteroecious fungus, *Puccinia striiformis* West. f.sp. *tritici* Erik. Uredospores are basically small, binucleate, unicellular and spherical to oval, yellow to orange in colour, echinulate and some angular walls with 6-18 scattered germ pores (Chen *et al.*, 2014). Uredospore size is variable being  $23-35 \times 20-25 \mu\text{m}$ . After the spores germinate, germ tube creates a minute delicate appressorium near a stomatal opening (Stubbs *et al.*, 1985). Urediospores can germinate rapidly when free moisture (rain or dewdrops) occurs on the leaf surfaces and when the temperatures range is between 7 and 12°C. A penetration peg originating from appressoria get entry into the stomatal opening and produces an extensive, compact substomatal tube inside the stomatal space. Below host epidermis, hyphae gather to build teliospores that are two celled, chestnut brown to black in colour, thick walled and  $35-63 \times 12-30 \mu\text{m}$  in size, and are interspersed with brown unicellular paraphyses (Singh, *et al.*, 1990). Pycnial and aecial stages occur on berberis plants (Jin *et al.*, 2010). Since, Berberis have no role reported in India, uredospores may survive on collateral hosts such as *Bromus japonicus* (Joshi and Manchanda *et al.*, 1963).

## **Geographical distribution**

Stripe rust epidemics have occurred in so many countries throughout the world (Stubbs, 1985; Li and Zeng, 2002; Kang *et al.*, 2017). Chen (2005) reported that stripe rust has been observed in more than 60 countries in every continent, except Antarctica. Wellings (2011) conducted an international survey on the severity and frequencies of stripe rust and reported that stripe rust occurred on more than 60 countries in year 2000 to 2009. Stripe rust was found more frequently in the South America, East African highlands, Middle East, Western United States, Northern Europe, Australia, Indian subcontinent, New Zealand, China, Pacific coast, inter-mountain areas of North America, Rocky Mountains in the North and Canada in cool and moist environment conditions (Boshoff *et al.*, 2002; Dickson, 1947). Stripe rust is found along with British and northwest Europe, the northwest Pacific coastal area and intermountain regions of North America, Rocky Mountain range in the north, cooler areas of Canada and cooler plain area southern regions of Argentina (Dickson, 1947). Also, it is rampant in South America's temperate zone, central and north-western China, east Africa, Mediterranean regions and north-western India (Hassebrauk, 1965). Stripe rust is mostly considered to be a low-temperature loving disease and restricted in the areas with temperate and cooler environmental conditions. But, the recent devastating epidemics in warmer areas where stripe rust was earlier uncommon or absent (Hovmøller *et al.*, 2010; Mboup *et al.*, 2009), which indicated that Pst populations had adapted to higher temperature, and supporting evidence have been published by Milus *et al.*, (2009).

## **Economics importance**

Stripe rust is the important disease of wheat and most damaging to obstructing higher wheat production worldwide (McIntosh *et al.*, 1995) including India. Worldwide, 43 million ha (46%) and in India about 9.4 million ha (>35 per cent) area under wheat cultivation is prone to stripe rust (Singh *et al.*, 2004b). Stripe rust has a powerful impact on the economy as a result of yield losses and costs of chemicals used to manage the disease. Seed produced has low vigour and low germination and poor emergence after germination. Stripe rust can cause heavy yield losses if infection occurs very early and disease developing during the long growing season. Yellow rust is continuing to be a serious threat and dominant factor limiting yield potential in wheat worldwide (Wellings 2011; Chen *et al.*, 2014). In an infected field, the yield reduction can reach up to 50 per cent due to shrivelled grains and reduced spike size caused by this disease (Ash and Brown 1990). Stripe on leaves, causes substantial losses in

yield through damaging its photosynthetic system, kills foliar parts, makes growth of plant stunted, most importantly reduced grain weight and affecting its quality (Line, 2002; Chen, 2005). Grain losses caused by this devastating pathogen have been reported from 10-70%. In severe stripe rust epidemics, the grain damage scales up to 100% (Chen, 2005). A global grain yield loss of about 5.5 mt per year have been estimated as result of stripe rust infection in wheat crop (Beddow *et al.*, 2015).

In Asia, stripe rust remains a major constraint for wheat production, threatening 43 million ha of wheat area (Singh *et al.*, 2004a). In China, crop damage due to stripe rust have been reported from different wheat growing regions of northwest, southwest China in the year 1950, 1964, 1990, and 2002 (Wan *et al.*, 2004). During 2002, a Chinese Pst pathotype CYR32 has triggered the most recent widespread outbreak, which has virulence to nearly all Chinese wheat varieties and avirulence on gene *Yr5*, *Yr10*, *Yr15*, *Yr24*, and *Yr26* (Li *et al.*, 2006).

### **Present status of stripe rust in India**

Wheat rust epidemics in India have been documented by Nagarajan and Joshi (1975) and Joshi *et al.* (1975). In 2001, breakdown of *Yr27* gene with appearance of new variant of Pst race 78S84 created a distress of stripe rust epidemic due to wide cultivation of wheat cv. PBW 343 (Prashar *et al.*, 2007). Stripe rust appeared in severe form in foot hills of Punjab, Jammu & Kashmir, parts of Haryana, Himachal Pradesh and Tarai regions of Uttarakhand hills during 2008-09, 2009 10 and 2010–11. (Sharma and Saharan, 2011). Stripe rust again appeared on some popular wheat cultivars planted in plains of Jammu & Kashmir, foot hills of HP, Haryana, Punjab, tarai of UK and western UP during 2014-15 (Saharan *et al.*, 2010). According to their virulence analysis of isolates collected from the various places, two pathotypes namely 78S84 and 46S119 were most prevalent pathotypes in NWPZ and NHZ (Pannu *et al.*, 2010).

In India, Nagarajan *et al.* (1975) were carried out an extensive research on the stripe rust pathotypes in India. Susceptibility of predominant cultivars Sonalika, Sonara 64 and Kalayansonadu to virulence of *Yr2* against stripe rust races 66S64, 66S64-1 and 70S64 had been noticed, stripe rust race 110S119 was the more aggressive one with the highest ability to produce the decedent population (Bhardwaj *et al.*, 2019). Stripe rust race 38S102 reported from the southern hill zone area but it is still not reported from the other places in India. The susceptibility of Sonalika with three different stripe rust pathotypes viz., 70S69, 46S103,

47S103, emphasized the breeding programmes in India (Prashar *et al.*, 2007) Stripe rust race 47S102 became virulent on HD2329 and replaced by the named 46S119 migrated from Africa knock down the resistance for the gene *Yr9* gene, but PBW 343 remains resistant due to presence of the other resistance gene *Yr27* from (Selkirk) existing with *Yr9* (McDonald *et al.*, 2004). The wide cultivation of Kalayansona variety leads emergence of a new pathotype race “78S84” which brought drastic losses of up to 70% during 2007-2008 and even up to 80% estimated losses during 2008-2009 (Prashar *et al.*, 2007). Bhardwaj *et al.* (2011) stated that up to 2011, in India 32 pathotypes were identified. Besides these, five new pathotypes of stripe rust had been identified and conformed in 2021.

### **Disease resistance in host plant**

In India the work on losses was done in earlier 70's and losses up to 70 per cent were reported (Nagarajan and Joshi, 1975). Variety PBW 343 having resistance to 46S119 race of stripe rust released during 1995 covers maximum areas of wheat growing due to its high yield. Due mono culture of PBW343 in North Hill Zone and North Western Plain Zone of India, resulting in new race 78S84 appearance. During 2008-09, wide spread occurrence stripe rust was observed in foot hills, sub-mountainous areas North Hill Zone and Plane Zone of Haryana, Jammu and Kashmir and Punjab, and the disease severity was very high as 60S-80S which resulted in heavy yield losses.

Khanna *et al.* (2005) revealed that the presence of a new stripe rust resistance gene in CSP44 in addition to *Yr18*, which may also confer long lasting resistance and thus increase diversity for genes conferring durable resistance. Khanna *et al.*, (2005) reported that one of the stripe rust resistance genes in line CSP44 is allelic to the gene *Yr78* in RL6058. The linked non-hypersensitive adult plant resistance genes *Lr34* and *Yr18* are also linked with a gene for morphological marker, leaf tip necrosis (*Lm*) (Singh 1992a; b). The non-hypersensitive adult plant resistance conferred by the gene *Yr18* is believed to be durable (Mcintosh, 1992), but the level of resistance conferred by *Yr18* alone is not adequate for commercial exploitation (Singh *et al.*, 2001). Bariana and McIntosh (1995) suggested that a genotype with acceptable levels of adult plant resistance frequently carries at least two or more genes that often act additively.

Buxet *et al.*, (2011) observed that stripe rust resistance genes *Yr3*, *Yr5*, *Yr10*, *Yr15*, *Yr26*, *YrSp* and *YrCv* were resistant, while *Yr8* showed moderate susceptibility. Genes *YrA*, *Yr2*, *Yr6*, *Yr7*, *Yr8*, *Yr9*, *Yr17*, *Yr27* and gene combinations Opata (*Yr27+Yr18*) and Super Kauz

(*Yr9*, *Yr27*, *Yr18*) were found susceptible. Linked rust resistance genes are *Lr26/Sr31/Yr9/Pm8* (Most used gene in the world), *Lr24/Sr24*, *Lr19/Sr25*, *Lr37/Sr38/Yr17* (Very good adult plant resistance gene), *Lr52/Yr47* (Bansal *et al.*, 2011). Pleiotropic or tightly linked, slow rust, durable rust resistance genes are *Lr67/Yr46/Sr55*, *Lr34/Yr18/Sr57/Pm38* and *Lr46/Yr29/Pm39* (Sybil *et al.*, 2011).

### Screening of stripe rust resistance

Ahamad (2021) evaluated 20 varieties of wheat and reported that varieties WII 1105, WH 1121, WH 1124, WH 1142, VL 804, VL 907 and HS 240 were found to be resistant. The varieties of wheat, RSP 561, Raj 3765, PBW 664 and PBW 590 were moderately resistant. Other varieties Raj 3077, PBW 373, PBW 621, PBW 175, PBW 527 and HS 490 were moderately susceptible and PBW 343, PBW 550, HD 2967 were susceptible.

Ayeleet *al.* (2021) observed the response of 436 wheat genotypes against stripe rust. High adult plant resistance recorded in 114 lines, intermediate adult plant resistance observed in 233 lines and 281 lines were low adult plant resistance. rAUDPC range 1-10 showed in 27 lines, range 11-30 observed in 87 lines and range 31-100 showed in 322 lines with resistant, moderately resistant and susceptible response against stripe rust.

Sandhu *et al.* (2021) identified 41 wheat genotypes for resistance against stripe rust. Highest resistance wheat genotypes having ACI value ranging from 0.45-2 was observed in 15 wheat genotypes viz, 32nd SAWSN 3011, 22nd SAWYT 316, WH 1184, PBW 763, JAUW 672, HD 3086, PBW 750, PBW 752, HI 1619, 25th HRWSN 2105, 13th HTWYT 719, PBW 779, PBW 780, 47th IBWSN 1185 and PBW 801.

Shewaye and Mohammed (2021) conducted field experiment to identified the response of 192 elite wheat germplasm and eight checks against dominant races of yellow rust at seedling stage and adult plant stage. About 72.5 per cent (Meraro) and 42.5 per cent (Kulumsa) of the lines showed resistance to stripe rust during the field inspections. 16 genotypes at Meraro and 18 genotypes at Kulumsa showed zero severity and AUDPC. 72 genotypes showed resistant response (36%) at both sites in field condition for adult plant stage (CI <20).

Yaminet *al.* (2021) tested 30 wheat germplasms for resistance against yellow rust under artificial inoculated conditions and 16 germplasms were tested under natural

conditions. Out of 30 germplasms, 4 germplasm showed resistance response and rest of the germplasms were immune. All germplasm showed immune response under natural conditions.

Abebele *et al.* (2020) assessed durable resistance in 28 genotypes against stripe rust through the determination of FRS, AUDPC and ACI. Results revealed that twenty-four lines viz., ETBW 9486, ETBW 9556, ETBW 8858, ETBW 8583, ETBW 8668, ETBW 8896, ETBW 8595, ETBW 8684, ETBW 9561, ETBW 9560, ETBW 9552, ETBW 9554, ETBW 8870, ETBW 9558, ETBW 875, ETBW 9548, ETBW 9549, ETBW 8802, ETBW 8862, ETBW 8804, ETBW 9556, ETBW 9557, ETBW 8991, and ETBW 9559 had low level of FRS, AUDPC and ACI. These lines with slow rusting resistance are expected to have both major and minor resistance genes.

El-Orabey *et al.* (2020) evaluated 53 wheat genotypes at adult plant stage. Results showed that 34 wheat genotypes were resistant and had lowest FRS, AUDPC and ACI value. Out of them 10 wheat genotypes showed resistance response with highest 1000 kernel weight. Kim *et al.* (2020) studied six (*Yr5*, *Yr15*, *Yr18*, *Yr36*, *Yr7*, *Yr46*) stripe rust resistance genes out of 80 reported genes for stripe rust resistance. *Yr18*, *Yr46* and 136 showed durable resistance and are stable for several decades.

Elbasyoniet *et al.* (2019) evaluated 882 landraces and 912 improved accessions of wheat. Results shows that 140 improved accessions and 42 land races were resistant to yellow rust. Omara *et al.* (2018) observed partial resistance in 13 wheat cultivars using FRS, AUDPC and 'r' value parameter and revealed that all the parameter showed lower partial resistance in Sakha-94, Sakha-95, Misr-1 and Misr-2 rather than highly susceptible varieties viz., Sids-12 and Gemmeiza-11 and Morocco.

Khiaviet *et al.* (2017) evaluated one-hundred wheat genotypes against stripe rust under field and moist irrigated conditions. Results indicated that 1 per cent genotypes were immune, 29 per cent genotypes showed resistance, 52 per cent were moderately resistant and 18 per cent genotypes showed susceptible response at Ardabil area. 25 per cent of genotypes were immune, 59 per cent were moderately resistant and 16 per cent genotypes showed susceptible response to stripe rust at Moghan area.

Singh *et al.* (2017) assessed slow rust resistance in 62 germplasm against stripe rust through FRS, CI, rAUDPC and 'r' value. Slow rusting resistance was observed in 34 germplasm and all these germplasms showed susceptible response at seedling stage but resistant response at adult plant stage.

Buxet *et al.* (2012b) identified 200 wheat germplasm (20 Chinese cultivars, 95 synthetic hexaploids and 85 advanced breeding lines) for stripe rust resistance a seedling stage under controlled greenhouse conditions and at adult plant stage under field conditions. Seedling resistance was observed in synthetic hexaploids with the presence of yellow rust resistance genes (*Yr3*, *YrCV*, *PSP*, *Yr10*, *Yr15* and *Yr5*). Adult plant testing revealed that advanced lines and Chinese cultivars have adult plant resistance under field conditions.

Safavi and Afshari (2012) evaluated 26 germplasm for seedling resistance, slow and partial resistance under controlled greenhouse and field conditions. The highest values of CI, FRS, *r*, and rAUDPC were found in lines C-89-4, C-89-17, and C-89-16, as well as susceptible, indicating that they were moderately susceptible or susceptible lines, C-89-20, C-89-10, C-89-13, C-89-14, C89-8, C-89-9, and C-89-7 are susceptible in the seedling stage and cause less infection at the adult plant stage. Except for C-89-2, the remaining lines were immune, and they were chosen as resistant lines.

Kurt (2002) observed reactions of 12 wheat varieties against stripe rust and revealed that two varieties viz, Seri 82 and Kaklic showed susceptible response and four varieties viz., Orso, Pandas, Ege 88 and Diyarbakir 81 showed resistant response to stripe rust disease. Lowest infection rate was observed in Gemini and Kaklic and highest in Gonen, Diyarbakir 81 and Dicle 74.

Prabhu *et al.* (1993) evaluated slow rusting resistance to rust and expressed stable slow rusting resistance as measured by AUDPC. Slow rise in the infection rate and low infection frequency is important components of slow-rusting resistance in wheat cultivars (Luo and Zeng, 1988; Yang *et al.*, 1987). Saleem *et al.* (2015) evaluated 57 wheat lines for adult plant resistance-based CL FRS, AURPC and rAURPC and observed that 51 lines showed high level of resistance and three lines showed moderately partial resistance based on first rust severity, 54 lines based on AURPC and rAURPC showed high level of partial resistance. 47 lines showed adult plant resistance on the basis of CI value.

### **Statistic Analysis**

Johnson and Wilcoxson (1981) reported that "Area Under Disease Progress Curve" (AUDPC) as a important factor for the identification of slow rusting cultivars. Yang *et al.*, (1987) compared AUDPC with the "*r*" value from a logistic equation and "" from a Gompertz equation, the AUDPC provided the best description of slow rusting resistance. Singh and Rao (1989) also suggested that A-value and *r* value, used for slow rusting resistance. A study of

development of leaf rust on two sets of bread wheat breeding lines showed that the A-value and r-value (calculated as the slope of the regression line of disease progress data) are not necessarily correlated and that the initial inoculum level can have a marked effect on the A-value.

### **Yield loss assessment**

Stripe rust can cause significant effect on wheat quantity and grain quality. The most appropriate stripe rust management strategy varies from farm to farm, from one area to another area, and from year to year. There have been various approaches to stripe rust management strategy, such as variety seed selection or chemical application. It is imperative to note that growers chalk a strategy that is appropriate for their situation to resolve, and adopt it for best yield.

Nadeem *et al.* (2007) reported that Inquilab-91 was most resistant with minimum yield loss of 5.77% followed by Wafaq-2001 (6.63%) and Bakhtawar (14.90%) respectively. Sowing of Inquilab-91 and Bakhtawar is recommended to escape heavy yield losses wreaked by the stripe rust. Whereas Morocco, proved to be the most susceptible wheat variety with maximum yield deficit to Wafaq-2001 exhibited 2.24, 1.57 and 1.36 fold resistance in respect of wheat yield as compared to the most susceptible variety Morocco.

The susceptible wheat cultivars showed highest AUDPC values, i.e. Gemmeiza 11, Misr 1, Misr 2, and Sids 12 had the highest yield loss; ranged between 51.66% and 69.33% . . Partially resistant genotypes (Misr3 and Giza 171) showed lower AUDPC values, and also showed less than 12.46% yield loss. Wheat cvs.; Misr 3 and Giza 171 showed lower values of FRS(%), AUDPC and yield loss (%) in the same time they showed the lowest yield loss(%) in two yield components of the study at the four sites (Hussain *et al.*, 1999; Rhizwan *et al.*, 2007). Increased AUDPC and Final Rust Severity cause higher yield loss (Afzal *et al.*, 2007; Ashmawy *et al.*, 2013; Taye *et al.*, 2015). Yield loss is strongly correlated with Area Under Disease Progress Curve, which means that partial resistance prevents significant yield loss (Afzal *et al.*, 2007; Ahmad *et al.*, 2010).

**MATERIAL AND METHODS**

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The present research study entitled as “EVALUATION AND ASSESSMENT OF YIELD LOSSES BY STRIPE RUST (*Puccinia striiformis*) IN WHEAT” was conducted in the field of AICRP-Wheat and Barley, Division of Plant Breeding and Genetics at Research Farm Chatha, SKUAST-J during the Rabi season of 2023-24. The experimental material and the methods which were adopted to accomplish these experiments are described below:

**3.1 Planting material**

The experimental planting material consisted of CIMMYT genotypes, elite genotypes, IBWSN genotypes and resistant (PBW 725), moderately resistant (Unnat PBW343), and susceptible cultivar's (PBW 343, Agra Local, HD2967, HD3086 and) of wheat obtained from the Division of Plant Breeding & Genetics (AICRP-wheat), SKUAST-Jammu.

**3.2 Pathogen**

Inoculum of mixed pathotypes of stripe rust utilized for screening of wheat germplasm of stripe rust had been obtained from the Regional Station, Indian Institute of Wheat and Barley Research (ICAR), Flowerdale, Shimla (HP), IIWBR, Karnal. The mixed pathotypes were multiplied on highly susceptible mixture of germplasm viz., PBW 343, Agra local, HD2967 and HD3086 for evaluation of wheat germplasm and assessment of yield losses by stripe rust.

**3.3 Screening of Wheat Germplasm****3.3.1 Layout and sowing in field**

“To evaluate wheat germplasm against stripe rust at different crop growth stage” against stripe rust were sown in the experimental field of AICRP-Wheat and Barley, Division of Plant Breeding and Genetics at Research Farm Chatha, SKUAST-J, 08<sup>th</sup> November, 2023. In the experimental field all cultural practices viz, field preparation, fertilizer dose, weedicide applications, irrigation practices were done according to package and practices of SKUAST-Jammu. Seeds were sown by dibbling method with row-to-row spacing was 23 cm with 1.5 m long. After every 20 rows of tested germplasm, the mixture of highly susceptible wheat germplasm (HD 2967, HD 3086, PBW 343 and Agra Local) were also sown and experimental field were surrounded by mixture of highly susceptible wheat germplasm

against virulent pathotypes of stripe rust as border to ensure uniform spread of stripe rust inoculum.

### **3.3.2 Inoculation methods**

The rust inoculum obtained from the Regional Station, IIWBR (ICAR), Flowerdale, Shimla (HP) were mixed thoroughly in talcum powder with the help of painting brush. The seedlings of susceptible wheat cultivars were moistened with the help of hand sprayer and then mixed inoculum with talcum powder spread on the leaves with the help of painting brush during the evening time. After development of urediospores on leaf, spores were collected and stored in deep freezer.

For artificial inoculation of rust spore suspension was prepared by mixing the collected stripe rust urediospores with distilled water and few drops of Tween 20 were added and thoroughly mixed it. Tween 20 helps in adhering inoculum to the surface of leaves then spores suspension were sprayed with the help of small hand sprayer evenly on the wheat germplasm as border lines to create natural epiphytotic.

### **3.3.3 Combining severity and response reading**

Disease severity was recorded at different growth stage of wheat crop at 15 days intervals starting from first appearance of the symptom of the disease in the experiment plots. Per cent disease severity and their infection response recorded from individual lines as per modified Cobb's scale (Table 3.1) given by Peterson *et al.*, (1948). The severity of the disease was determined by visual observations, reading cannot be absolutely accurate. Therefore, below 5 per cent severity the intervals used were trace to 2. Usually, 5 per cent intervals were used between 5 to 20 per cent severity and 10 per cent intervals between 20 to 100 per cent. Reading for severity and response were recorded together with severity first (Table 3.2).

**Table 3.1: Modified Cobb's scale** (Peterson *et al.*, 1948)

Reaction types	Category Visible	Symptoms
O	Immune	No visible infection on plants
R	Resistant	Necrotic areas with or without minute uredia present
MR	Moderately resistant	Small uredia present surrounded by necrotic areas
MS	Moderately susceptible	Medium uredia with no necrosis but possibly some distinct chlorosis
S	Susceptible	Large uredia with no necrosis and little of no chlorosis present
X	Intermediate	Variable sized uredia, some with necrosis or chlorosis

**Table 3.2: Combined severity and response were recorded at the same time.**

Scale	Description
TR	Trace severity of a resistant type of infection.
5MS	5per cent severity of a moderately susceptible type of infection.
10MR	10 per cent severity of a moderately resistant type of infection.
30S or 100S	30 per cent or 100 per cent severity of a susceptible type of infection.

### Statistical analysis

The analysis of variance was carried out to find out the statistical differences among the screened germplasm of stripe rust for Average Coefficient of Infection, coefficient of disease level (CDL), Infection Rate per day ('r' values), Area Under Disease Progress Curve (A- values) and yield losses. ACI, CDL, r- value and AUDPC calculated on the basis of 5 observations at 15 days interval for stripe rust.

### Coefficient of infection

Coefficient of Infection (CI) value was calculated by combining the disease severity and the response value according to Ahmad *et al.*, (2010)

**CI= Disease severity x Response value**

**Table 3.3: The reaction type and their response value**

S. No.	Reaction type	Type of infection	Response value
1.	O	No Disease	0
2.	R	Resistant	0.2
3.	RMR	Resistant to Moderately Resistant	0.3
4.	MR	Moderately Resistant	0.4
5.	MRMS	Moderately Resistant to Moderately susceptible	0.6
6.	MS	Moderately susceptible	0.8
7.	MSS	Moderately susceptible to susceptible	0.9
8.	S	Susceptible	1

### 3.5 Evaluation of Treatments

The experiment was conducted at Research Farm, Chatha, SKUAST- Jammu during the cropping season of 2023-24. Stripe rust susceptible wheat germplasm, PBW343, Agra Local, PBW725, HD2967, HD3086 and Unnat, PBW343 were sown in plots (plots size is 1.5x 3.0 m) with row-to-row spacing 23 cm under irrigated conditions with recommended package and practices of SKUAST-J. The experiment was laid out in a Randomized Block Design (RBD) with three replications. Total six treatments viz., PBW 343, Agra Local, PBW 725, HD 2967, HD 3086 and Unnat PBW 343 were used during study programme. Artificial inoculation was done by spraying the stripe rust uredospores suspension with the help of hand sprayer. Two foliar sprays of fungicides were sprayed at their recommended dosage rates (Table 3.4). The first foliar spray of different fungicides was applied at 5 per cent leaves showed initial signs of infection, the second spray of same treatment was applied at 15 days interval. Disease severity were recorded as per cent of infection randomly from individual line using modified Cobb's scale given by Peterson *et al.*, (1948). At maturity plots were harvested individually then threshed, 1000 grain weight were assessed and yield of grains were recorded.

### 3.6.2 Determination of coefficient of disease level (CDL)

Coefficient of disease level (CDL) for every germplasm was calculated as per formula given by Gupta (1979):

$$\text{CDL} = \frac{\text{Percentage Incidence}}{100} \times \frac{\text{Loeering's Coefficient of Infection}}{100}$$

**Loeering's Coefficient of Infection = S x R**

Where, S= disease severity, R= response value

The response value for different infection types is assigned from 0-1 (Loeering, 1959). The maximum Coefficient of Disease level should be 1.0.

### 3.6.3 Determination of rate of infection ('r') of disease

The rate of infection of disease was calculated by using formula given by Vander Plank (1963).

$$r = \frac{2.3}{D} \left( \log_{10} \frac{y_2}{1-y_2} - \log_{10} \frac{y_1}{1-y_1} \right)$$

Where, D = total days between first and last disease observation, r = Average rate of infection of disease per unit(t), y<sub>1</sub> = CDI at the first date y<sub>2</sub> = CDI value of last date of disease observation, 1-y<sub>1</sub> and 1-y<sub>2</sub> are the correction factors in which one is considered as the maximum disease.

### 3.6.4 Area under disease progress curve (AUDPC)

The AUDPC were intended to estimate effect of disease on different germplasm given by Wilcoxson *et al.*, (1975). AUDPC is useful in quantitative study of disease over the time.

$$\text{A-values} = \sum_{i=1}^k 0.5 \times (X_i + X_{i-1}) D$$

Where, X<sub>i</sub> = Severity of rust at the end of time i, X<sub>i-1</sub> = the severity of rust time i-1, k = Number of rust evaluations, D = days intervals between two observations. Five observations were taken for Stripe Rust.

## RESULTS

To evaluate the wheat germplasms and assess the yield losses associated with different levels of stripe rust resistance of commercial wheat cultivars experimentation was carried out in the field of Division of Plant Breeding and Genetics, SKUAST-J. The wheat material under this study is consisted of CIMMYT, IBWSN germplasm, cultivars of NWPZ and susceptible varieties PBW 343, Agra Local, HD 2967 and HD3086 were obtained from the Division of Plant Breeding and Genetics (AICRP-wheat and Barley), SKUAST-Jammu. The detailed results based on Master's research study are presented here under the following heads.

#### 4.1 Evaluate Elite Wheat Germplasm against the Stripe Rust

##### 4.1.1 Disease severity and infection type

During crop season 2023-24, 195 wheat germplasm along with susceptible germplasm were evaluated. One month old seedlings of wheat germplasm were inoculated 2 times at 7 days interval with mixed pathotypes of stripe rust in the month of December and January for creating the epiphytotic conditions. First time disease severity was recorded on 09<sup>th</sup> January 2024 in the experiment field. The observations on stripe rust severity were recorded five times from 09-01-2024 to 09-03-2024 at 15 days intervals as per modified Cobb's scale (Table 4.1)

**Table 4.1: Disease severity of stripe rust on different wheat germplasm under epiphytotic conditions at different growth stage.**

S.No.	Germplasm	09-01-2024 (Tillering)	24-01-2024 (Jointing)	08-02-2024 (Booting)	23-02-2024 (Heating)	09-03-2024 (Ripening)
1.	GWJ 96	0 (0.0)	5MS (4.0)	10MS (8.0)	15MS (12.0)	20MS (16.0)
2.	GWJ97	5MS (4.0)	5MS (4.0)	10MS (8.0)	15MS (12.0)	20MS (16.0)
3.	GWJ 98	0 (0.0)	0 (0.0)	TR (0.0)	TR (0.0)	TR (0.0)
4.	GWJ 99	5S (5.0)	15S (15.0)	20S (20.0)	30S (30.0)	40S (40.0)
5.	GWJ 100	10S (10.0)	15S (15.0)	20S (20.0)	30S (30.0)	40S (40.0)

6.	GWJ 101	TR (0.0)	TMR (0.0)	TMR (0.0)	5MR (2.0)	5MR (2.0)
7.	GWJ 102	TR (0.0)	5R (1.0)	10R (2.0)	10MR (4.0)	10MR (4.0)
8.	GWJ 103	TR (0.0)	5R (1.0)	10R (2.0)	10MR (4.0)	10MR (4.0)
9.	GWJ 104	TR (0.0)	5R (1.1)	10R (2.0)	10MR (4.0)	10MR (4.0)
10.	GWJ 105	0 (0.0)	TR (0.0)	TR (0.0)	5R (1.0)	5R (1.0)
11.	GWJ 106	TR (0.0)	5R (1.0)	10MR (4.0)	10MR, MS (6.0)	10MS (8.0)
12.	GWJ 107	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0/PM (0.0)
13.	GWJ 108	TR (0.0)	5MR (2.0)	10MR (4.0)	10MS (8.0)	20MS (16.0)
14.	GWJ 109	TMS (0.0)	5MS (4.0)	10MS (8.0)	20S (20.0)	20S (20.0)
15.	GWJ 110	0 (0.0)	TR (0.0)	TR (0.0)	5MS (4.0)	10MS (8.0)
16.	GWJ 111	TR (0.0)	5MS (4.0)	10MS (8.0)	20MS (16.0)	20MS (16.0)
17.	GWJ 112	TR (0.0)	5MR (2.0)	5MR (2.0)	10MR (4.0)	10MR (4.0)
18.	GWJ 113	TMR (0.0)	5MR (2.0)	5MR (2.0)	5MS (4.0)	5MS (4.0)
19.	GWJ 114	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
20.	GWJ 115	TR (0.0)	5R (1.0)	10R (2.0)	10MR (4.0)	10MR (4.0)
21.	GWJ 116	TR (0.0)	5MR (2.0)	10MR, MS (6.0)	10MS (8.0)	10MS (8.0)
22.	GWJ 117	TR (0.0)	TMR (0.0)	TMR (0.0)	5MR (2.0)	5MR (2.0)
23.	GWJ 118	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
24.	GWJ 119	5MR, MS (3.0)	10MR, MS (6.0)	20MS (16.0)	20S (20.0)	40S (40.0)
25.	GWJ 120	TR (0.0)	5R (1.0)	5R, MS (0.0)	10MR (4.0)	10MR (4.0)

26.	GWJ 121	5MR, MS (3.0)	10MR, MS (6.0)	30MS (24.0)	40S (40.0)	60S (60.0)
27.	GWJ 122	5MR, MS (3.0)	10MR, MS (6.0)	20MS (16.0)	20S (20.0)	40S (40.0)
28.	GWJ 123	TR (0.0)	5MR (2.0)	5MS (4.0)	10MS (8.0)	10MS (8.0)
29.	GWJ 124	0 (0.0)	TR (0.0)	TR (0.0)	TR (0.0)	TR (0.0)
30.	GWJ 125	TR (0.0)	10MR (4.0)	20MS (16.0)	40S (40.0)	40S (40.0)
31.	GWJ 126	5MR (2.0)	10MR (4.0)	10MS (8.0)	20S (20.0)	20S (20.0)
32.	GWJ 127	10MR (4.0)	10MS (8.0)	20MS (16.0)	20S (20.0)	20S (20.0)
33.	GWJ 128	5MR (2.0)	5MS (4.0)	10MS (8.0)	20MS (16.0)	20MS (16.0)
34.	GWJ 129	10MS (8.0)	20MS (16.0)	20S (20.0)	30S (30.0)	40S (40.0)
35.	GWJ 130	10MS (8.0)	20MS (16.0)	20S (20.0)	30S (30.0)	40S (40.0)
36.	GWJ 131	5MR (2.0)	5MS (4.0)	10MS (8.0)	20MS (16.0)	20MS (16.0)
37.	GWJ 132	5MR (2.0)	5MS (4.0)	10MS (8.0)	20MS (16.0)	20MS (16.0)
38.	GWJ 133	5MR (2.0)	5MS (4.0)	10S (10.0)	20S (20.0)	20S (20.0)
39.	GWJ 134	0 (0.0)	0 (0.0)	5MR (2.0)	10MR (4.0)	10MR (4.0)
40.	GWJ 135	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
41.	GWJ 136	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
42.	GWJ 137	0 (0.0)	TR (0.0)	TR (0.0)	5MS (4.0)	10MS (8.0)
43.	GWJ 138	0 (0.0)	TR (0.0)	TR (0.0)	5MS (4.0)	10MS (8.0)
44.	GWJ 139	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
45.	GWJ 140	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

46.	GWJ 141	TR (0.0)	5R (1.0)	10MR (4.0)	10MR, MS (6.0)	10MS (8.0)
47.	GWJ 142	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
48.	GWJ 143	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
49.	GWJ 144	TR (0.0)	5R (1.0)	5MR (2.0)	10MR (4.0)	10MS (8.0)
50.	GWJ 145	5MR (2.0)	10MR (4.0)	10MS (8.0)	20S (20.0)	20S (20.0)
51.	GWJ 146	5S (5.0)	10S (10.0)	20S (20.0)	30S (30.0)	40S (40.0)
52.	GWJ 147	TR (0.0)	TMR (0.0)	TMR (0.0)	5MR (2.0)	5MR (2.0)
53.	GWJ 148	5MR (2.0)	10MR (4.0)	10MS (8.0)	20S (20.0)	20S (20.0)
54.	GWJ 149	5MR (2.0)	10MR (4.0)	10MS (8.0)	10S (10.0)	10S (10.0)
55.	GWJ 150	TR (0.0)	TR (0.0)	5MR (2.0)	10MR (4.0)	10MR (4.0)
56.	GWJ 151	5MR (2.0)	10MR (4.0)	10S (10.0)	20S (20.0)	20S (20.0)
57.	GWJ 152	TR (0.0)	TR (0.0)	5MR (2.0)	10MR (4.0)	10MS (8.0)
58.	GWJ 153	TR (0.0)	TR (0.0)	TMR (0.0)	5MR (2.0)	5MR (2.0)
59.	GWJ 154	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
60.	GWJ 155	TR (0.0)	5MR (2.0)	10MR (4.0)	20MS (16.0)	20MS (16.0)
61.	GWJ 156	0 (0.0)	0 (0.0)	TR (0.0)	TR (0.0)	TR (0.0)
62.	GWJ 157	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
63.	GWJ 158	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
64.	GWJ 159	0 (0.0)	TR (0.0)	TR (0.0)	5MS (4.0)	10MS (8.0)
65.	GWJ 160	TR (0.0)	5R (1.0)	5MR (2.0)	5MS (4.0)	5MS (4.0)

66.	GWJ 161	0 (0.0)	TR (0.0)	TR (0.0)	5MS (4.0)	10MS (8.0)
67.	GWJ 162	0 (0.0)	0 (0.0)	TR (0.0)	TR (0.0)	TR (0.0)
68.	GWJ 163	TR (0.0)	TR (0.0)	2MR (0.8)	5MR (2.0)	5MR (2.0)
69.	GWJ 164	0 (0.0)	TR (0.0)	2MR (0.8)	5MR (2.0)	5MR (2.0)
70.	GWJ 165	0 (0.0)	TR (0.0)	TR (0.0)	5MS (4.0)	10MS (8.0)
71.	GWJ 166	0 (0.0)	TR (0.0)	TR (0.0)	5MS (4.0)	10MS (8.0)
72.	GWJ 167	0 (0.0)	0 (0.0)	TR (0.0)	TR (0.0)	TR (0.0)
73.	GWJ 168	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
74.	GWJ 169	5MS (4.0)	10MS (8.0)	20S (20.0)	40S (40.0)	60S (60.0)
75.	GWJ 170	TMR (0.0)	5MR (2.0)	10MR (4.0)	10MS (8.0)	10S (10.0)
76.	GWJ 171	5MR (2.0)	10MR (4.0)	20MS (16.0)	30S (30.0)	40S (40.0)
77.	GWJ 172	10MR (4.0)	20MR (8.0)	30MR (12.0)	40S (40.0)	60S (60.0)
78.	GWJ 173	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	TMS (0.0)
79.	GWJ 174	10MR (4.0)	10MS (8.0)	20MS (16.0)	40S (40.0)	40S (40.0)
80.	GWJ 175	TMR (0.0)	5MR (2.0)	10MR (4.0)	10MS (8.0)	20MS (16.0)
81.	GWJ 176	0 (0.0)	TR (0.0)	2MR (0.8)	5MR (2.0)	5MR (2.0)
82.	GWJ 177	TMR (0.0)	5MR (2.0)	5MS (4.0)	10S (10.0)	10S (10.0)
83.	GWJ 178	5MR (2.0)	5MS (4.0)	10S (10.0)	20S (20.0)	20S (20.0)
84.	GWJ 179	5MR (2.0)	5MS (4.0)	10MS (8.0)	20S (20.0)	20S (20.0)

85.	GWJ 180	TR (0.0)	TR (0.0)	2MR (0.8)	5MR (2.0)	5MR (2.0)
86.	GWJ 181	TMR (0.0)	5MR (2.0)	5MS (4.0)	10MS (8.0)	10MS (8.0)
87.	GWJ 182	0 (0.0)	TR (0.0)	5MR (2.0)	10MR (4.0)	10MR (4.0)
88.	GWJ 183	0 (0.0)	TR (0.0)	5MR (2.0)	10MS (8.0)	10MS (8.0)
89.	GWJ 184	0 (0.0)	TR (0.0)	5MR (2.0)	5MS (4.0)	5MS (4.0)
90.	GWJ 185	0 (0.0)	TR (0.0)	TR (0.0)	5MR (2.0)	5MR (2.0)
91.	GWJ 186	TR (0.0)	5MR (2.0)	5MR (2.0)	5MS (4.0)	10MS (8.0)
92.	GWJ 187	5MR (2.0)	5MS (4.0)	10S (10.0)	20S (20.0)	20S (20.0)
93.	GWJ 188	TR (0.0)	TMR (0.0)	5MR (2.0)	10MR (4.0)	10MS (8.0)
94.	GWJ 189	TR (0.0)	2MR (0.8)	5MR,MS (3.0)	5MS (4.0)	5MS (4.0)
95.	GWJ 190	0 (0.0)	TR (0.0)	2MR (0.8)	5MR (2.0)	5MR (2.0)
96.	GWJ 191	0 (0.0)	TR (0.0)	2MR (0.8)	5MR (2.0)	5MR (2.0)
97.	GWJ 192	0 (0.0)	0 (0.0)	TR (0.0)	TR (0.0)	TR (0.0)
98.	GWJ 193	0 (0.0)	TR (0.0)	5MS (4.0)	10MS (8.0)	10MS (8.0)
99.	GWJ 194	TR (0.0)	TR (0.0)	5R, MR (1.5)	5MS (4.0)	5MS (4.0)
100.	GWJ 195	TR (0.0)	TR (0.0)	5R, MR (1.5)	5MS (4.0)	5MS (4.0)
101.	GWJ 196	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
102.	GWJ 197	TR (0.0)	TMR (0.0)	5MR (2.0)	10MR (4.0)	10MS (8.0)
103.	GWJ 198	10MR (4.0)	10S (10.0)	20S (20.0)	30S (30.0)	40S (40.0)
104.	GWJ 199	10MR (4.0)	10S (10.0)	20S (20.0)	30S (30.0)	40S (40.0)

105.	GWJ 200	5MR (2.0)	5MS (4.0)	10MS (8.0)	20MS (16.0)	20MS (16.0)
106.	GWJ 201	5MR (2.0)	5MR (2.0)	10MR (4.0)	10MS (8.0)	20MS (16.0)
107.	GWJ 202	10MR (4.0)	10MS (8.0)	10S (10.0)	20S (20.0)	40S (40.0)
108.	GWJ 203	TR (0.0)	TMR (0.0)	5MR (2.0)	5MS (4.0)	10MS (8.0)
109.	GWJ 204	TR (0.0)	TMR (0.0)	5MR (2.0)	10MS (8.0)	10MS (8.0)
110.	GWJ 205	TR (0.0)	TR (0.0)	5MR (2.0)	5MS (4.0)	5MS (4.0)
111.	GWJ 206	TR (0.0)	TMR (0.0)	5MR (2.0)	10MR (4.0)	10MS (8.0)
112.	GWJ 207	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
113.	GWJ 208	5MR (2.0)	10MR (4.0)	10MS (8.0)	10S (10.0)	20S (20.0)
114.	GWJ 209	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
115.	GWJ 210	5MR (2.0)	5MS (4.0)	5S (5.0)	10S (10.0)	10S (10.0)
116.	GWJ 211	0 (0.0)	TR (0.0)	2MR (0.8)	5MR (2.0)	5MR (2.0)
117.	GWJ 212	0 (0.0)	TR (0.0)	2MR (0.8)	5MR (2.0)	5MR (2.0)
118.	GWJ 213	0 (0.0)	TR (0.0)	2MR (0.8)	5MR (2.0)	5MR (2.0)
119.	GWJ 214	0 (0.0)	TR (0.0)	2MR (0.8)	5MR (2.0)	5MR (2.0)
120.	GWJ 215	0 (0.0)	0 (0.0)	TR (0.0)	TR (0.0)	TR (0.0)
121.	GWJ 216	5MR (2.0)	5MS (4.0)	5S (5.0)	10S (10.0)	20S (20.0)
122.	GWJ 217	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
123.	GWJ 218	0 (0.0)	TR (0.0)	TR (0.0)	5MS (4.0)	10MS (8.0)
124.	GWJ 219	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

125.	GWJ 220	0 (0.0)	TR (0.0)	TMR (0.0)	5MR (2.0)	10MR (4.0)
126.	GWJ 221	5MR (2.0)	5MS (4.0)	10MS (8.0)	10S (10.0)	20S (20.0)
127.	GWJ 222	5MR (2.0)	5MS (4.0)	10MS (8.0)	10S (10.0)	20S (20.0)
128.	GWJ 223	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
129.	GWJ 224	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
130.	GWJ 225	5MR (2.0)	5MS (4.0)	10MS (8.0)	10S (10.0)	10S (10.0)
131.	GWJ 226	5MR (2.0)	5MS (4.0)	10MS (8.0)	10S (10.0)	10S (10.0)
132.	GWJ 227	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
133.	GWJ 228	0 (0.0)	TR (0.0)	5MS (4.0)	10MS (8.0)	10MS (8.0)
134.	GWJ 229	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
135.	GWJ 230	TR (0.0)	TR (0.0)	2MR (0.8)	5MR (2.0)	5MR (2.0)
136.	GWJ 231	0 (0.0)	0 (0.0)	TR (0.0)	TR (0.0)	TR (0.0)
137.	GWJ 232	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
138.	GWJ 233	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
139.	GWJ 234	5MR, MS (3.0)	10MR, MS (6.0)	20MS (16.0)	20S (20.0)	40S (40.0)
140.	GWJ 235	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
141.	GWJ 236	0 (0.0)	TR (0.0)	TR (0.0)	5R (1.0)	5R (1.0)
142.	GWJ 237	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
143.	GWJ 238	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
144.	GWJ 239	0 (0.0)	0 (0.0)	TR (0.0)	TR (0.0)	TR (0.0)

145.	GWJ 240	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
146.	GWJ 241	0 (0.0)	0 (0.0)	5MR (2.0)	10MR (4.0)	10MR (4.0)
147.	GWJ 242	0 (0.0)	0 (0.0)	TR (0.0)	TR (0.0)	TR (0.0)
148.	GWJ 243	10S (10.0)	20S (20.0)	30S (30.0)	40S (40.0)	40S (40.0)
149.	GWJ 244	TR (0.0)	TR (0.0)	5R, MR (0.0)	5MS (4.0)	5MS (4.0)
150.	GWJ 245	0 (0.0)	0 (0.0)	TR (0.0)	TR (0.0)	TR (0.0)
151.	GWJ 246	TR (0.0)	2MR (0.8)	2MR (0.8)	5MR (2.0)	5MR (2.0)
152.	GWJ 247	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
153.	GWJ 248	0 (0.0)	2MR (0.0)	2MR (0.8)	5MR (0.8)	5MR (2.0)
154.	GWJ 249	TR (0.0)	TMS (0.0)	2MS (1.6)	5MS (4.0)	5MS (4.0)
155.	GWJ 250	TR (0.0)	TMS (0.0)	5MS (4.0)	10MS (8.0)	10MS (8.0)
156.	GWJ 251	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
157.	GWJ 252	5MR (2.0)	5MR (2.0)	10MR (4.0)	10MS (8.0)	10MS (8.0)
158.	GWJ 253	5MR (2.0)	5MS (4.0)	10MS (8.0)	10S (10.0)	10S (10.0)
159.	GWJ 254	5MR (2.0)	5MS (4.0)	10MS (8.0)	20S (20.0)	20S (20.0)
160.	GWJ 255	TR (0.0)	TR (0.0)	5MR (2.0)	10MS (8.0)	10MS (8.0)
161.	GWJ 256	TR (0.0)	TR (0.0)	5MR (2.0)	10MS (8.0)	10MS (8.0)
162.	GWJ 257	TR (0.0)	TR (0.0)	TMR (0.0)	5MR (2.0)	5MR (2.0)
163.	GWJ 258	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
164.	GWJ 259	TR (0.0)	TR (0.0)	5MR (2.0)	10MR (4.0)	10MS (8.0)

165.	GWJ 260	TR (0.0)	10MR (4.0)	20MS (16.0)	30MS (24.0)	40S (40.0)
166.	GWJ 261	0 (0.0)	0R (0.0)	TMS (0.0)	10MS (0.0)	10MS (0.0)
167.	GWJ 262	5MR (2.0)	10MR (4.0)	20MR (8.0)	20S (20.0)	20S (20.0)
168.	GWJ 263	TR (0.0)	TR (0.0)	TMR (0.0)	5MR (2.0)	5MR (2.0)
169.	GWJ 264	TR (0.0)	TMR (0.0)	5MR (2.0)	10MR (4.0)	10MR (4.0)
170.	GWJ 265	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
171.	GWJ 266	0 (0.0)	0 (0.0)	TR (0.0)	TR (0.0)	TR (0.0)
172.	GWJ 267	TR (0.0)	TR (0.0)	5R,MR (0.0)	5MS (4.0)	5MS (4.0)
173.	GWJ 268	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
174.	GWJ 269	TR (0.0)	10MR (4.0)	20MS (16.0)	30MS (24.0)	40S (40.0)
175.	GWJ 270	TR (0.0)	TR (0.0)	2MR (0.8)	5MR (2.0)	5MR (2.0)
176.	GWJ 271	0 (0.0)	TR (0.0)	TR (0.0)	5MS (4.0)	10MS (8.0)
177.	GWJ 272	0 (0.0)	TR (0.0)	TR (0.0)	5MS (4.0)	10MS (8.0)
178.	GWJ 273	0 (0.0)	0 (0.0)	5MR (2.0)	10MR (4.0)	10MR (4.0)
179.	GWJ 274	TR (0.0)	TR (0.0)	5R,MR (0.0)	5MS (4.0)	5MS (4.0)
180.	GWJ 275	0 (0.0)	0 (0.0)	5MR (2.0)	10MR (4.0)	10MR (4.0)
181.	GWJ 276	TR (0.0)	TR (0.0)	5MR (2.0)	5MS (4.0)	5MS (4.0)
182.	GWJ 277	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
183.	GWJ 278	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
184.	GWJ 279	TMS (0.0)	5MS (4.0)	10MS (8.0)	30S (30.0)	40S (40.0)

185.	GWJ 280	TR (0.0)	TR (0.0)	5MR (2.0)	5MS (4.0)	5MS (4.0)
186.	GWJ 281	TMS (0.0)	5MS (4.0)	10MS (8.0)	20MS (16.0)	20MS (16.0)
187.	GWJ 282	TMS (0.0)	5MS (4.0)	10MS (8.0)	20S (20.0)	40S (40.0)
188.	GWJ 283	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
189.	GWJ 284	TMS (0.0)	5MS (4.0)	10MS (8.0)	20S (20.0)	40S (40.0)
190.	PBW725	0 (0.0)	0 (0.0)	0 (0.0)	TR (0.0)	TR (0.0)
191.	Unnat 343	0 (0.0)	0 (0.0)	0 (0.0)	TR (0.0)	5R (0.0)
192.	Agra local	5S (5.0)	10S (10.0)	20S (20.0)	40S (40.0)	60S (60.0)
193.	HD2967	5MS (4.0)	10MS (8.0)	30MS (24.0)	20S (20.0)	40S (40.0)
194.	HD 3086	10S (10.0)	20S (20.0)	40S (40.0)	60S (60.0)	80S (80.0)
195.	PBW343	20S (20.0)	40S (40.0)	60S (60.0)	80S (80.0)	90S (90.0)

Figure in parentheses are Loegering's coefficient of infection, Rust disease severity in trace i.e., TS, TMS, TMR and TR evaluated as zero.

On the first disease observation on 9th January 2024, stripe rust severity varied from 0.0 to 20 per cent. Out of 195 germplasm lines, 147 germplasm lines showed zero to trace response. Maximum stripe rust severity 20 per cent was observed on line PBW 343 (20S) with susceptible reaction type. Second observation was taken on 24<sup>th</sup> January 2024, stripe rust severity ranged from trace to 40 per cent. Third observation on 8<sup>th</sup> February 2024, highest disease severity was recorded in PBW343(60) with susceptible response.

In fourth observation on 23<sup>rd</sup> February 2024, stripe rust severity ranged from 0 to 80 per cent. Final rust severity was recorded on 9th March 2024. Out of 195 lines, forty-seven lines showed immune (0) response, three were resistance (R), thirty-five showed moderately resistance (MR), Fifty- seven showed moderately susceptible (MS), 50 fifty showed susceptible(S) infection type. Highest disease severity was recorded on two wheat lines i.e., PBW 343, HD3086.

**Table4.2: Average Coefficient of Infection, AUDPC, “r” apparent rate of infection, CDL value, Yield Losses of wheat germplasm against stripe rust.**

S. No.	Germplasm	FRS	AUDPC	ACI	“r”	CDL
1.	GWJ 96	20MS	480	16	0.013	0.032
2.	GWJ97	20MS	510	16	0.013	0.032
3.	GWJ 98	TR	0	0	0.000	0
4.	GWJ 99	40S	1312.5	40	0.016	0.16
5.	GWJ 100	40S	1350	40	0.016	0.16
6.	GWJ 101	5MR	45	2	0.000	0.001
7.	GWJ 102	10MR	135	4	0.012	0.004
8.	GWJ 103	10MR	135	4	0.012	0.004
9.	GWJ 104	10MR	135	4	0.012	0.004
10.	GWJ 105	5R	22.5	1	0.000	0.0005
11.	GWJ 106	10MS	225	8	0.012	0.008
12.	GWJ 107	0/PM	0	0	0.000	0
13.	GWJ 108	20MS	330	16	0.025	0.032
14.	GWJ 109	20S	630	20	0.018	0.04
15.	GWJ 110	10MS	120	8	0.000	0.008
16.	GWJ 111	20MS	540	16	0.013	0.032
17.	GWJ 112	10MR	150	4	0.012	0.004
18.	GWJ 113	5MS	150	4	0.012	0.002
19.	GWJ 114	0	0	0	0.000	0
20.	GWJ 115	10MR	135	4	0.012	0.004
21.	GWJ 116	10MS	300	8	0.005	0.008
22.	GWJ 117	5MR	45	2	0.000	0.001
23.	GWJ 118	0	0	0	0.000	0

24.	GWJ 119	40S	952.5	40	0.021	0.16
25.	GWJ 120	10MR	105	4	0.000	0.004
26.	GWJ 121	60S	1522.5	60	0.026	0.36
27.	GWJ 122	40S	952.5	40	0.021	0.16
28.	GWJ 123	10MS	270	8	0.012	0.008
29.	GWJ 124	TR	0	0	0.000	0
30.	GWJ 125	40S	1200	40	0.021	0.16
31.	GWJ 126	20S	645	20	0.018	0.04
32.	GWJ 127	20S	840	20	0.005	0.04
33.	GWJ 128	20MS	555	16	0.013	0.032
34.	GWJ 129	40S	1350	40	0.016	0.16
35.	GWJ 130	40S	1350	40	0.016	0.16
36.	GWJ 131	20MS	555	16	0.013	0.032
37.	GWJ 132	20MS	555	16	0.013	0.032
38.	GWJ 133	20S	675	20	0.013	0.04
39.	GWJ 134	10MR	120	4	0.012	0.004
40.	GWJ 135	0	0	0	0.000	0
41.	GWJ 136	0	0	0	0.000	0
42.	GWJ 137	10MS	120	8	0.000	0.008
43.	GWJ 138	10MS	120	8	0.000	0.008
44.	GWJ 139	0	0	0	0.000	0
45.	GWJ 140	0	0	0	0.000	0
46.	GWJ 141	10MS	225	8	0.012	0.008
47.	GWJ 142	0	0	0	0.000	0
48.	GWJ 143	0	0	0	0.000	0
49.	GWJ 144	10MS	165	8	0.024	0.008

50.	GWJ 145	20S	645	20	0.018	0.04
51.	GWJ 146	40S	1237.5	40	0.016	0.16
52.	GWJ 147	5MR	45	2	0.000	0.001
53.	GWJ 148	20S	645	20	0.018	0.04
54.	GWJ 149	10S	420	10	0.004	0.01
55.	GWJ 150	10MR	120	4	0.012	0.004
56.	GWJ 151	20S	675	20	0.013	0.04
57.	GWJ 152	10MS	150	8	0.024	0.008
58.	GWJ 153	5MR	45	2	0.000	0.001
59.	GWJ 154	0	0	0	0.000	0
60.	GWJ 155	20MS	450	16	0.025	0.032
61.	GWJ 156	TR	0	0	0.000	0
62.	GWJ 157	0	0	0	0.000	0
63.	GWJ 158	0	0	0	0.000	0
64.	GWJ 159	10MNS	0	0	0.000	0
65.	GWJ 160	5MS	135	4	0.012	0.002
66.	GWJ 161	10MS	120	8	0.000	0.008
67.	GWJ 162	TR	0	0	0.000	0
68.	GWJ 163	5MR	57	2	0.015	0.001
69.	GWJ 164	5MR	57	2	0.015	0.001
70.	GWJ 165	10MS	120	8	0.000	0.008
71.	GWJ 166	10MS	120	8	0.000	0.008
72.	GWJ 167	TR	0	0	0.000	0
73.	GWJ 168	0	0	0	0.000	0
74.	GWJ 169	60S	1500	60	0.030	0.36
75.	GWJ 170	10S	285	10	0.016	0.01

76.	GWJ 171	40S	1065	40	0.021	0.16
77.	GWJ 172	60S	1380	60	0.040	0.36
78.	GWJ 173	TMS	0	0	0.000	0
79.	GWJ 174	40S	1290	40	0.021	0.16
80.	GWJ 175	20MS	330	16	0.025	0.032
81.	GWJ 176	5MR	57	2	0.015	0.001
82.	GWJ 177	10S	315	10	0.016	0.01
83.	GWJ 178	20S	675	20	0.013	0.04
84.	GWJ 179	20S	645	20	0.018	0.04
85.	GWJ 180	5MR	57	2	0.015	0.001
86.	GWJ 181	10MS	270	8	0.012	0.008
87.	GWJ 182	10MR	120	4	0.012	0.004
88.	GWJ 183	10MS	210	8	0.024	0.008
89.	GWJ 184	5MS	120	4	0.012	0.002
90.	GWJ 185	5MR	45	2	0.000	0.001
91.	GWJ 186	10MS	180	8	0.024	0.008
92.	GWJ 187	20S	675	20	0.013	0.04
93.	GWJ 188	10MS	150	8	0.024	0.008
94.	GWJ 189	5MS	147	4	0.005	0.002
95.	GWJ 190	5MR	57	2	0.015	0.001
96.	GWJ 191	5MR	57	2	0.015	0.001
97.	GWJ 192	TR	0	0	0.000	0
98.	GWJ 193	10MS	240	8	0.012	0.008
99.	GWJ 194	5MS	112.5	4	0.017	0.002
100.	GWJ 195	5MS	112.5	4	0.017	0.002
101.	GWJ 196	0	0	0	0.000	0

102.	GWJ 197	10MS	150	8	0.024	0.008
103.	GWJ 198	40S	1230	40	0.016	0.16
104.	GWJ 199	40S	1230	40	0.016	0.16
105.	GWJ 200	20MS	555	16	0.013	0.032
106.	GWJ 201	20MS	345	16	0.025	0.032
107.	GWJ 202	40S	900	40	0.030	0.16
108.	GWJ 203	10MS	150	8	0.024	0.008
109.	GWJ 204	10MS	210	8	0.024	0.008
110.	GWJ 205	5MS	120	4	0.012	0.002
111.	GWJ 206	10MS	150	8	0.024	0.008
112.	GWJ 207	0	0	0	0.000	0
113.	GWJ 208	20S	495	20	0.018	0.04
114.	GWJ 209	0	0	0	0.000	0
115.	GWJ 210	10S	375	10	0.012	0.01
116.	GWJ 211	5MR	57	2	0.015	0.001
117.	GWJ 212	5MR	57	2	0.015	0.001
118.	GWJ 213	5MR	57	2	0.015	0.001
119.	GWJ 214	5MR	57	2	0.015	0.001
120.	GWJ 215	TR	0	0	0.000	0
121.	GWJ 216	20S	450	20	0.026	0.04
122.	GWJ 217	0	0	0	0.000	0
123.	GWJ 218	10MS	120	8	0.000	0.008
124.	GWJ 219	0	0	0	0.000	0
125.	GWJ 220	10MR	60	4	0.000	0.004
126.	GWJ 221	20S	495	20	0.018	0.04
127.	GWJ 222	20S	495	20	0.018	0.04

128.	GWJ 223	0	0	0	0.000	0
129.	GWJ 224	0	0	0	0.000	0
130.	GWJ 225	10S	420	10	0.004	0.01
131.	GWJ 226	10S	420	10	0.004	0.01
132.	GWJ 227	0	0	0	0.000	0
133.	GWJ 228	10MS	240	8	0.012	0.008
134.	GWJ 229	0	0	0	0.000	0
135.	GWJ 230	5MR	57	2	0.015	0.001
136.	GWJ 231	TR	0	0	0.000	0
137.	GWJ 232	0	0	0	0.000	0
138.	GWJ 233	0	0	0	0.000	0
139.	GWJ 234	40S	952.5	40	0.021	0.16
140.	GWJ 235	0	0	0	0.000	0
141.	GWJ 236	5R	22.5	1	0.000	0.0005
142.	GWJ 237	0	0	0	0.000	0
143.	GWJ 238	0	0	0	0.000	0
144.	GWJ 239	TR	0	0	0.000	0
145.	GWJ 240	0	0	0	0.000	0
146.	GWJ 241	10MR	120	4	0.012	0.004
147.	GWJ 242	TR	0	0	0.000	0
148.	GWJ 243	40S	1725	40	0.007	0.16
149.	GWJ 244	5MS	90	4	0.000	0.002
150.	GWJ 245	TR	0	0	0.000	0
151.	GWJ 246	5MR	69	2	0.015	0.001
152.	GWJ 247	0	0	0	0.000	0
153.	GWJ 248	5MR	69	2	0.015	0.001

154.	GWJ 249	5MS	114	4	0.016	0.002
155.	GWJ 250	10MS	240	8	0.012	0.008
156.	GWJ 251	0	0	0	0.000	0
157.	GWJ 252	10MS	285	8	0.012	0.008
158.	GWJ 253	10S	420	10	0.004	0.01
159.	GWJ 254	20S	645	20	0.018	0.04
160.	GWJ 255	10MS	210	8	0.024	0.008
161.	GWJ 256	10MS	210	8	0.024	0.008
162.	GWJ 257	5MR	45	2	0.000	0.001
163.	GWJ 258	0	0	0	0.000	0
164.	GWJ 259	10MS	150	8	0.024	0.008
165.	GWJ 260	40S	960	40	0.021	0.16
166.	GWJ 261	10MS	0	0	0.000	0
167.	GWJ 262	20S	645	20	0.018	0.04
168.	GWJ 263	5MR	45	2	0.000	0.001
169.	GWJ 264	10MR	120	4	0.012	0.004
170.	GWJ 265	0	0	0	0.000	0
171.	GWJ 266	TR	0	0	0.000	0
172.	GWJ 267	5MS	90	4	0.000	0.002
173.	GWJ 268	0	0	0	0.000	0
174.	GWJ 269	40S	960	40	0.021	0.16
175.	GWJ 270	5MR	57	2	0.015	0.001
176.	GWJ 271	10MS	120	8	0.000	0.008
177.	GWJ 272	10MS	120	8	0.000	0.008
178.	GWJ 273	10MR	120	4	0.012	0.004
179.	GWJ 274	5MS	90	4	0.000	0.002

180.	GWJ 275	10MR	120	4	0.012	0.004
181.	GWJ 276	5MS	120	4	0.012	0.002
182.	GWJ 277	0	0	0	0.000	0
183.	GWJ 278	0	0	0	0.000	0
184.	GWJ 279	40S	930	40	0.034	0.16
185.	GWJ 280	5MS	120	4	0.012	0.002
186.	GWJ 281	20MS	540	16	0.000	0.032
187.	GWJ 282	40S	780	40	0.013	0.16
188.	GWJ 283	0	0	0	0.034	0
189.	GWJ 284	40S	780	40	0.000	0.16
190.	PBW725	TR	0	0	0.034	0
191.	Unnat343	5R	7.5	1	0.000	0.0005
192.	Agra Local	60S	1537.5	60	0.000	0.36
193.	HD2967	40S	1110	40	0.030	0.16
194.	HD3086	80S	2475	80	0.012	0.64
195.	PBW343	90S	3525	90	0.030	0.81

FRS= Final Rust Severity, CI=Coefficient of Infection, ACI= Average Coefficient of Infection, CDL= Coefficient of Disease Level, “r” = Apparent Rate of Infection, YL= Yield Losses

#### 4.1.2: Average Coefficient of Infection (ACI)

The average coefficient of infection values of wheat germplasm for cropping season during 2023-24 were summarised in the Table 4.3. ACI values with 0 recorded as immune in 52 germplasm, ACI values with 1-10 recorded in 87 germplasm, ACI values with 10-20 recorded in 28 germplasm, 20-40 in 22 germplasm, ACI values 40-60 recorded in 4 germplasm and ACI value more than 60 in 2 germplasm susceptible checks, PBW343 and HD3086.

**Table4.3: Average Coefficient of Infection of stripe rust of selected wheat germplasm (2023-24).**

S.No.	ACI
<b>0(immune)</b>	GWJ3, GWJ12, GWJ 19, GWJ23, GWJ29, GWJ40, GWJ41, GWJ44, GWJ45, GWJ47, GWJ48, GWJ59, GWJ61, GWJ62, GWJ63, GWJ64, GWJ67, GWJ72, GWJ73, GWJ78, GWJ97, GWJ101, GWJ112, GWJ114, GWJ120, GWJ122, GWJ124, GWJ128, GWJ129, GWJ132, GWJ134, GWJ136, GWJ137, GWJ138, GWJ140, GWJ142, GWJ143, GWJ144, GWJ145, GWJ147, GWJ150, GWJ152, GWJ156, GWJ163, GWJ166, GWJ170, GWJ171, GWJ173, GWJ182, GWJ183, GWJ188, PBW 725
<b>1-10</b>	GWJ6, GWJ7, GWJ8, GWJ9, GWJ10, GWJ11, GWJ15, GWJ17, GWJ18, GWJ20, GWJ21, GWJ22, GWJ25, GWJ28, GWJ39, GWJ42, GWJ43, GWJ46, GWJ49, GWJ52, GWJ55, GWJ57, GWJ58, GWJ65, GWJ66, GWJ68, GWJ69, GWJ70, GWJ71, GWJ75, GWJ78, GWJ81, GWJ82, GWJ85, GWJ86, GWJ87, GWJ88, GJW89, GWJ90, GWJ91, GWJ93, GWJ94, GWJ95, GWJ96, GWJ98, GWJ99, GWJ100, GWJ102, GWJ108, GWJ109, GWJ110, GWJ111, GWJ115, GWJ116, GWJ117, GWJ118, GWJ119, GWJ123, GWJ125, GWJ130, GWJ131, GWJ133, GWJ135, GWJ141, GWJ146, GWJ149, GWJ151, GWJ153, GWJ154, GWJ155, GWJ157, GWJ160, GWJ161, GWJ162, GWJ164, GWJ168, GWJ169, GWJ172, GWJ175, GWJ176, GWJ177, GWJ178, GWJ179, GWJ180, GWJ181, GWJ185, Unnat 343
<b>10-20</b>	GWJ1, GWJ2, GWJ13, GWJ14, GWJ16, GWJ31, GWJ32, GWJ33, GWJ36, GWJ37, GWJ38, GWJ50, GWJ53, GWJ56, GWJ60, GWJ80, GWJ83, GWJ84, GWJ92, GWJ105, GWJ106, GWJ113, GWJ121, GWJ126, GWJ127, GWJ159, GWJ167, GWJ186
<b>20-40</b>	GWJ4, GWJ5, GWJ24, GWJ27, GWJ30, GWJ34, GWJ35, GWJ51, GWJ76, GWJ79, GWJ103, GWJ104, GWJ107, GWJ139, GWJ148, GWJ165, GWJ174, GWJ184, GWJ186, GWJ187, GWJ189, HD 2967
<b>40-60</b>	GWJ26, GWJ74, GWJ77, Agra Local
<b>&gt;60</b>	HD3086, PBW 343

#### 4.1.3: Area Under Disease Progress Curve (AUDPC)

Area Under Disease Progress Curve of stripe rust of wheat germplasm for cropping season during 2023-24 represented in Table 4.4. AUDPC values with 0 recorded in fifty-two germplasm, 1-10 in one germplasm, 11-100 in twenty-eight germplasm and 101-200 in forty germplasm, AUDPC values from 201 to 500 in twenty-eight germplasm, AUDPC values from 501 to 800 in twenty germplasm and AUDPC values greater than 800 was observed in twenty-six germplasm.

**Table 4.4: Average Area under disease progress curve of selected wheat germplasm against stripe rust pathogen during 2023-24.**

<b>AUDPC Value</b>	<b>Germplasm</b>
<b>0</b>	GWJ3, GWJ12, GWJ19, GWJ23, GWJ29, GWJ40, GWJ41, GWJ44, GWJ45, GWJ47, GWJ48, GWJ59, GWJ61, GWJ62, GWJ63, GWJ64, GWJ67, GWJ72, GWJ73, GWJ78, GWJ97, GWJ101, GWJ112, GWJ114, GWJ120, GWJ122, GWJ124, GWJ128, GWJ129, GWJ132, GWJ134, GWJ136, GWJ137, GWJ138, GWJ140, GWJ142, GWJ143, GWJ144, GWJ145, GWJ147, GWJ150, GWJ152, GWJ156, GWJ163, GWJ166, GWJ170, GWJ171, GWJ173, GWJ182, GWJ183, GWJ188, PBW 725
<b>1-10</b>	Unnat 343
<b>11-100</b>	GWJ6, GWJ10, GWJ11, GWJ22, GWJ52, GWJ58, GWJ68, GWJ69, GWJ81, GWJ85, GWJ90, GWJ95, GWJ96, GWJ116, GWJ117, GWJ118, GWJ119, GWJ125, GWJ135, GWJ141, GWJ149, GWJ151, GWJ153, GWJ162, GWJ168, GWJ172, GWJ175, GWJ179
<b>101-200</b>	GWJ7, GWJ8, GWJ9, GWJ15, GWJ17, GWJ18, GWJ20, GWJ25, GWJ39, GWJ42, GWJ43, GWJ49, GWJ55, GWJ57, GWJ65, GWJ66, GWJ70, GWJ71, GWJ87, GWJ89, GWJ91, GWJ93, GWJ94, GWJ99, GWJ100, GWJ102, GWJ108, GWJ110, GWJ111, GWJ123, GWJ146, GWJ154, GWJ164, GWJ169, GWJ176, GWJ177, GWJ178, GWJ180, GWJ181, GWJ185
<b>201-500</b>	GWJ1, GWJ13, GWJ21, GWJ28, GWJ46, GWJ54, GWJ60, GWJ75, GWJ80, GWJ82, GWJ86, GWJ88, GWJ98, GWJ106, GWJ109, GWJ113, GWJ115, GWJ121, GWJ126, GWJ127, GWJ130, GWJ131, GWJ133, GWJ155, GWJ157, GWJ158, GWJ160, GWJ161
<b>501-800</b>	GWJ2, GWJ14, GWJ16, GWJ31, GWJ33, GWJ36, GWJ37, GWJ38, GWJ50, GWJ53, GWJ56, GWJ83, GWJ84, GWJ92, GWJ105, GWJ159, GWJ167, GWJ186, GWJ187, GWJ189
<b>&gt;800</b>	GWJ4, GWJ5, GWJ24, GWJ26, GWJ27, GWJ30, GWJ32, GWJ34, GWJ35, GWJ51, GWJ74, GWJ76, GWJ77, GWJ79, GWJ103, GWJ104, GWJ107, GWJ139, GWJ148, GWJ165, GWJ174, GWJ184, Agra Local, HD 2967, HD 3086, PBW 343

#### **4.1.4: Average Coefficient of Disease Level (CDL)**

The average CDL of stripe rust was calculated as for the formula given by Gupta (1979) during cropping season 2023-24 presented in the Table 4.5. Average CDL value was observed between 0.000 to 0.810 among the tested germplasm. Highest CDL values observed in PBW343 (0.810) followed by HD-3086 (0.640) and Agra local (0.360). Zero CDL values

observed in (50) germplasm GWJ3, GWJ12, GWJ19, GWJ23, GWJ29, GWJ40, GWJ41, GWJ44, GWJ45, GWJ47, GWJ48, GWJ59, GWJ61, GWJ62, GWJ63, GWJ64, GWJ67, GWJ72, GWJ73, GWJ78, GWJ97, GWJ101, GWJ112, GWJ120, GWJ124, GWJ128, GWJ129, GWJ132, GWJ134, GWJ136, GWJ137, GWJ138, GWJ140, GWJ142, GWJ143, GWJ144, GWJ145, GWJ147, GWJ150, GWJ152, GWJ156, GWJ163, GWJ166, GWJ170, GWJ171, GWJ173, GWJ182, GWJ183, GWJ188, GWJ190.

**Table 4.5: Average Coefficient of Disease Level (CDL)**

CDL	Germplasm
0	GWJ3, GWJ12, GWJ19, GWJ23, GWJ29, GWJ40, GWJ41, GWJ44, GWJ45, GWJ47, GWJ48, GWJ59, GWJ61, GWJ62, GWJ63, GWJ64, GWJ67, GWJ72, GWJ73, GWJ78, GWJ97, GWJ101, GWJ112, GWJ114, GWJ120, GWJ122, GWJ124, GWJ128, GWJ129, GWJ132, GWJ134, GWJ136, GWJ137, GWJ138, GWJ140, GWJ142, GWJ143, GWJ144, GWJ145, GWJ147, GWJ150, GWJ152, GWJ156, GWJ163, GWJ166, GWJ170, GWJ171, GWJ173, GWJ182, GWJ183, GWJ188, PBW 725
0.001- 0.015	GWJ6, GWJ7, GWJ8, GWJ9, GWJ10, GWJ11, GWJ15, GWJ17, GWJ18, GWJ20, GWJ21, GWJ22, GWJ25, GWJ28, GWJ39, GWJ42, GWJ43, GWJ46, GWJ49, GWJ52, GWJ55, GWJ57, GWJ58, GWJ65, GWJ66, GWJ68, GWJ69, GWJ70, GWJ71, GWJ81, GWJ85, GWJ86, GWJ87, GWJ88, GWJ89, GWJ90, GWJ91, GWJ93, GWJ94, GWJ95, GWJ96, GWJ98, GWJ99, GWJ100, GWJ102, GWJ108, GWJ109, GWJ110, GWJ111, GWJ116, GWJ117, GWJ118, GWJ119, GWJ123, GWJ125, GWJ133, GWJ135, GWJ141, GWJ146, GWJ149, GWJ151, GWJ153, GWJ154, GWJ155, GWJ157, GWJ160, GWJ161, GWJ162, GWJ164, GWJ168, GWJ169, GWJ172, GWJ175, GWJ176, GWJ177, GWJ178, GWJ179, GWJ180, GWJ181, GWJ185, Unnat 343
0.016 - 0.032	GWJ1, GWJ2, GWJ13, GWJ16, GWJ33, GWJ36, GWJ37, GWJ60, GWJ80, GWJ105, GWJ106, GWJ186
0.01-0.15	GWJ14, GWJ31, GWJ32, GWJ38, GWJ50, GWJ53, GWJ54, GWJ56, GWJ75, GWJ82, GWJ83, GWJ84, GWJ92, GWJ113, GWJ115, GWJ121, GWJ126, GWJ127, GWJ130, GWJ131, GWJ158, GWJ159, GWJ167
0.16- 0.30	GWJ4, GWJ5, GWJ24, GWJ27, GWJ30, GWJ34, GWJ35, GWJ51, GWJ76, GWJ79, GWJ103, GWJ104, GWJ107, GWJ139, GWJ148, GWJ165, GWJ174, GWJ184, GWJ187, GWJ189, HD 2967
>0.30	GWJ26, GWJ74, GWJ77, Agra local, HD3086, PBW 343

#### 4.1.5: Average Apparent Rate of Infection ("r")

The average Apparent Rate of Infection ("r") for stripe rust calculated and categorized for the cropping season during 2023-24 represented in the Table 4.6. "r" value with 0.000 observed in seventy-seven germplasm and 0.001- 0.015 r value was observed in sixty- two germplasm. From 0.016 to 0.030 r value recorded in fifty-two germplasm while >0.300 r value was recorded in Agra local, HD3086, PBW343.

**Table4.6: Average Apparent rate of infection 'r' of stripe rust on different germplasm of wheat.**

"r"	Germplasm
0.000	GWJ3, GWJ6, GWJ10, GWJ12, GWJ15, GWJ19, GWJ22, GWJ23, GWJ25, GWJ29, GWJ40, GWJ41, GWJ42, GWJ43, GWJ44, GWJ45, GWJ47, GWJ48, GWJ52, GWJ58, GWJ59, GWJ61, GWJ62, GWJ63, GWJ64, GWJ66, GWJ67, GWJ70, GWJ71, GWJ72, GWJ73, GWJ78, GWJ90, GWJ97, GWJ101, GWJ112, GWJ114, GWJ120, GWJ122, GWJ123, GWJ124, GWJ125, GWJ128, GWJ129, GWJ132, GWJ134, GWJ136, GWJ137, GWJ138, GWJ140, GWJ141, GWJ142, GWJ143, GWJ144, GWJ145, GWJ147, GWJ149, GWJ150, GWJ152, GWJ156, GWJ162, GWJ163, GWJ166, GWJ168, GWJ170, GWJ171, GWJ172, GWJ173, GWJ176, GWJ177, GWJ179, GWJ182, GWJ183, GWJ186, GWJ189, Unnat 343, Agra Local
0.001-0.015	GWJ1, GWJ2, GWJ7, GWJ8, GWJ9, GWJ11, GWJ16, GWJ17, GWJ18, GWJ20, GWJ21, GWJ28, GWJ32, GWJ33, GWJ36, GWJ37, GWJ38, GWJ39, GWJ46, GWJ54, GWJ55, GWJ56, GWJ65, GWJ68, GWJ69, GWJ81, GWJ83, GWJ85, GWJ86, GWJ87, GWJ89, GWJ92, GWJ94, GWJ95, GWJ96, GWJ98, GWJ105, GWJ110, GWJ115, GWJ116, GWJ117, GWJ118, GWJ119, GWJ130, GWJ131, GWJ133, GWJ135, GWJ146, GWJ148, GWJ151, GWJ153, GWJ155, GWJ157, GWJ158, GWJ169, GWJ175, GWJ178, GWJ180, GWJ181, GWJ185, GWJ187, HD 3086
0.016- 0.030	GWJ4, GWJ5, GWJ13, GWJ14, GWJ24, GWJ26, GWJ27, GWJ30, GWJ31, GWJ34, GWJ35, GWJ49, GWJ50, GWJ51, GWJ53, GWJ57, GWJ60, GWJ74, GWJ75, GWJ76, GWJ79, GWJ80, GWJ82, GWJ84, GWJ88, GWJ91, GWJ93, GWJ99, GWJ100, GWJ102, GWJ103, GWJ104, GWJ106, GWJ107, GWJ108, GWJ109, GWJ111, GWJ113, GWJ121, GWJ126, GWJ127, GWJ139, GWJ154, GWJ159, GWJ160, GWJ161, GWJ164, GWJ165, GWJ167, GWJ174, HD 2967, PBW 343
0.031- 0.045	GJW77, GWJ184, GWJ188, PBW 725

#### **4.2 Assessment of yield losses associated with different level of stripe rust resistant of commercial wheat cultivars**

Analysis of data presented in Table 4.7 indicated that in unprotected plots, cultivars were having more stripe rust as compared to ones where Propiconazole (Tilt) @0.1 per cent was sprayed and there is negative correlation between disease level and wheat yield. Rust development was higher on unsprayed plots Agra Local, PBW725, Unnat343, HD2967, HD3086 and PBW 343. In some plots its scored up to 80S. Comparison of mean values revealed that PBW343 was susceptible having mean infection level of 86.0 followed by Agra Local, HD2967 and HD3086 which were having more than 60S reaction. However, the new released variety PBW725 showed only 3.3 rust score reaction of stripe rust indicating its resistance to pathotypes. It also indicated that there is different level of resistance in different varieties to stripe rust pathogen. The spray of Tilt @ 0.1 Per cent drastically reduced the rust in all the varieties evaluated. Data pertaining to yield was subjected statistical analysis. Analysis of variance pertaining to wheat yield in diseased and disease free plots indicated highly significant difference among different varieties.

The yield losses due to stripe rust were calculated by comparing yield of protected and unprotected plots. The losses in yield due to stripe rust varied depending upon the resistance of variety. Maximum yield reduction of 12.09 q/ha in protected with spray and 19.71 q/ha in unprotected was observed in cultivar, PBW343, which is highly susceptible to stripe rust followed by Agra Local, HD3086 HD2967 and Unnat343.

**Table 4.7 Assessment of yield losses associated with different level of stripe rust resistant of commercial wheat cultivars**

Variety	Rust score		Yield (q/ha)		Increase in yield over protected (q/ha)	Yield loss (q/ha)	
	Protected with Spray	Un- protected	Protected with spray (q/ha)	Un- protected (q/ha)		Protected	Un protected
PBW 725	1.3	3.3	47.23	46.67	0.56	0	0
Unnat343	6.6	46.7	46.58	45.39	1.19	0.65	1.28
HD2967	13.3	46.6	44.56	41.25	3.31	2.67	5.42
HD3086	16.7	66.6	41.80	35.54	6.26	5.43	11.13
PBW 343	20.0	86.0	35.14	26.96	8.18	12.09	19.71
Agra Local	23.3	73.3	36.62	28.25	8.37	10.61	18.42
CD at 5% level			0.86	2.3			

### DISCUSSION

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Stripe rust of wheat (*Puccinia striiformis* f. sp. *tritici*) is a serious disease of wheat in North India and cooler region of all over the world. Rao *et al.*, (1981) revealed that in India, commercially cultivated wheat stripe rust resistance varieties have a life span of only 3 to 5 years only. Vertical stripe rust resistance gene varieties typically effective for a few years because of high selection pressure on pathogen population with mutations, such narrow spectrum genes are often broken by the development of new virulent races (Saleem *et al.*, 2015). In 1996, the major stripe rust seedling resistance gene *Yr9* was frequently broken, which is virulent on the Kalyan-sona variety of wheat and make it susceptible (Nayar *et al.*, 1997). Another stripe rust pathotype, 78584, was first observed in 2001, it is virulent on mega wheat cultivar PBW 343 which contain *Yr9* and *Yr27* genes. 78884 pathotype also vanquished another major cultivar like as PBW 502, PBW 550 and WL 711. Prashar *et al.* (2007) stated that the strain of pathotype 468119 have been evolved from pre-existing pathotype 468103. The evaluation of this strain from the pre-existing strain is due to the forward mutation for a single factor of virulence. The same pathotype repeatedly obtained additional virulence for Suwon93×Omar and it has lost the virulence nature for Henies VII which resulted in the evaluation of two new pathotypes named as 1108119 and 465117 respectively. During the crop year 2023-24, stripe rust pathotypes 2388119, 1108119, 46S119, 6S0, T, 110S84 were identified in six Indian states and in Nepal. These pathotypes were virulent to *Yr2*, *Yr9*, *Yr17*, *Yr18*, *Yr19*, *Fr-21*, *122*, *Yr23*, *Yr3*, *Yr4*, *Yr6*, *Yr7*, *Yr8*, *Yr25*, *YrA* and avirulent to *Yr10*, *Yr15*, *Yr5*, *YrSp*. The frequency of pathotype 2388119 was most (49.57%) followed by 1108119 (29.42 %), 468119 (15.12%), 47S103, 110S84, 6S0 (Anonymous, 2021b).

Development of resistant wheat varieties are most preferable approach for stripe rust management due to its cost-effective and environment friendly in nature (Lin and Chen, 2007). Multiple point mutations are very rare in nature therefore, germplasm with appropriate levels of slow rusting inhibit the emergence of novel virulent races of the fungus. Various factors, such as the dormant period, the numbers of uredosori (per unit area), the size of uredosori and the rate of sporulation, all contribute to the delay in epiphytotic development. Due to the lower selection pressure, the chances of novel variations or pathotypes are reduced. Identification of resistant genetic resources knowledge of the host-pathogen interaction and appropriate methods to mobilise and use the necessary genes in the main breeding programme are all

required for this. Therefore, the research study, entitled "Evaluation and assessment of yield losses by stripe rust (*Puccinia striiformis*) in wheat" was undertaken.

### **5.1 Evaluation of wheat germplasm against the stripe rust at different crop growth stages.**

First time disease severity was recorded on 09<sup>th</sup> January 2024 in the experiment field. The observations on stripe rust severity were recorded five times from 09-01-2024 to 09-03-2024 at 15 days intervals as per modified Cobb's scale. On the first disease observation on 9<sup>th</sup> January 2024, stripe rust severity varied from 0.0 to 20 per cent. Out of 195 germplasm lines, 147 germplasm lines showed zero to trace response. Maximum stripe rust severity 20 per cent was observed on line PBW 343 (20S) with susceptible reaction type. Second observation was taken on 24<sup>th</sup> January 2024, stripe rust severity ranged from trace to 40 per cent. Third observation on 8<sup>th</sup> February 2024, highest disease severity was recorded in PBW343(60) with susceptible response.

On fourth observation on 23<sup>rd</sup> February 2024, stripe rust severity ranged from 0 to 80 per cent. Final rust severity was recorded on 9<sup>th</sup> March 2024. Out of 195 lines, forty-seven lines showed immune (0) response, three were resistance (R), thirty-five showed moderately resistance (MR), Fifty- seven showed moderately susceptible (MS), 50 fifty showed susceptible (S) infection type. Highest disease severity was recorded on two wheat lines i.e., PBW 343, HD3086. Adult plant resistant gene effective only at adult plant stage, this type of resistance is important for durable rust resistance (Kumar, 2013). Similar results were reported by Sadotra (2020); Kumar (2013) and Rani (2022).

#### **5.1.2: Average Coefficient of Infection (ACI)**

The average coefficient of infection values of wheat germplasm for cropping season during 2023-24 were summarised. ACI values with 0 recorded as immune in 52 germplasm, ACI values with 1-10 recorded in 87 germplasm, ACI values with 10-20 recorded in 28 germplasm, 20-40 in 22 germplasm, ACI values 40-60 recorded in 4 germplasm and ACI value more than 60 in 2 germplasm susceptible checks, PBW343 and HD3086. Similar results and categorization of low-level slow rusting/ APR were reported by Singh *et al.*, (2005); Shain *et al.*, (2021); Singh *et al.*, (2022); Singh *et al.*, (2017); Singh *et al.*, (2015)

#### **5.1.3: Area Under Disease Progress Curve (AUDPC)**

Area Under Disease Progress Curve of stripe rust of wheat germplasm for cropping season during 2023-24 represented. AUDPC values with 0 recorded in fifty-two germplasm,

1-10 in one germplasm, 11-100 in twenty-eight germplasm and 101-200 in forty germplasm, AUDPC values from 201 to 500 in twenty-eight germplasm, AUDPC values from 501 to 800 in twenty germplasm and AUDPC values greater than 800 was observed in twenty-six germplasm. Similar results and categorization of AUDPC values were reported by Singh *et al.*, (2017); Menkonnen *et al.*, (2019); Shain *et al.*, (2021); Singh *et al.*, (2022).

#### **5.1.4: Average Coefficient of Disease Level (CDL)**

The average CDL of stripe rust was calculated as for the formula given by Gupta (1979) during cropping season 2023-24 presented. Average CDL value was observed between 0.000 to 0.810 among the tested germplasm. Highest CDL values observed in PBW343 (0.810) followed by HD-3086 (0.640) and Agra local (0.360). Zero CDL values observed in (50) germplasm 3, 12, 19, 23, 29, 40, 41, 44, 45, 47, 48, 59, 61, 62, 63, 64, 67, 72, 73, 78, 97, 101, 112, 120, 124, 128, 129, 132, 134, 136, 137, 138, 140, 142, 143, 144, 145, 147, 150, 152, 156, 163, 166, 170, 171, 173, 182, 183, 188, 190. Similar result way of CDL value calculated by Promila (2022), Sadotra (2020), and Kumar (2013).

#### **5.1.5: Average Apparent Rate of Infection ("r")**

The average Apparent Rate of Infection ("r") for stripe rust calculated and categorized for the cropping season during 2023-24 represented. "r" value with 0.000 observed in seventy-seven germplasm and 0.001- 0.015 r value was observed in sixty- two germplasm. From 0.016 to 0.030 r value recorded in fifty-two germplasm while >0.300 r value was recorded in Agra local, HD3086, PBW343. Similar results and categorization were done by Attri and Dey (2021) and Singh *et al.*, (2022).

### **5.2: Assessment of yield losses associated with different level of stripe rust resistant of commercial wheat cultivars**

In unprotected plots, cultivars were having more stripe rust as compared to ones where Propiconazole (Tilt) @0.1 per cent was sprayed and there is negative correlation between disease level and wheat yield. Rust development was higher on unsprayed plots Agra Local, PBW725, Unnat343, HD2967, HD3086 and PBW 343. In some plots its scored up to 80S. Comparison of mean values revealed that PBW343 was susceptible having mean infection level of 86.0 followed by Agra Local, HD2967 and HD3086 which were having more than 60S reaction. However, the new released variety PBW725 showed only 3.3 rust score reaction of stripe rust indicating its resistance to pathotypes. It also indicated that there is different level of resistance in different varieties to stripe rust pathogen. The spray of Tilt @ 0.1 Per cent

drastically reduced the rust in all the varieties evaluated. Data pertaining to yield was subjected statistical analysis. Analysis of variance pertaining to wheat yield in diseased and disease free plots indicated highly significant difference among different varieties.

The yield losses due to stripe rust were calculated by comparing yield of protected and unprotected plots. The losses in yield due to stripe rust varied depending upon the resistance of (Jindal *et al.*, 2014) variety. Maximum yield reduction of 12.09 q/ha in protected with spray and 19.71 q/ha in unprotected was observed in cultivar, PBW343, which is highly susceptible to stripe rust followed by Agra Local, HD3086 HD2967 and Unnat343. outbreak of stripe rust resulted in losses of 50-60 per cent in susceptible varieties (Sache and de Vallavieille- Pope, 1993; Saari and Prescott, 1985). Experiment trial were conduct by many researchers in world and it has been established that there is an association between epidemic and yield losses in wheat (Syeed *et al.*, 2007). It has been reported by Salman et al., (2006) that yield loss increases proportionately with increase in disease severity.

### SUMMARY AND CONCLUSIONS

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Stripe rust (*Puccinia striiformis* f. sp. *tritici*) is the most damaging disease of wheat crop under cold weather conditions in North Western Plain Zone of India. Stripe rust cause yield losses in wheat crop about 40 per cent to 100 per cent depending upon the level of resistance in a variety. Till now, the disease has been managed by using a combination of host resistance and chemical fungicides. Due to frequent breakdown of major seedling resistance genes, there was a difficulty in quick replacement of susceptible wheat varieties. Therefore, it is necessary to develop the other type of resistant wheat varieties like, adult plant resistant, durable resistant, partial resistant and slow rusting resistant in breeding programme and test the efficacy of new fungicides for manage the stripe rust.

- Therefore, the current study made use of 195 wheat germplasm along with susceptible germplasm were evaluated at Research Farm, SKUAST-J in order to find out potentially novel source of resistance.
- Out of 195 lines, forty-seven lines showed immune (0) response, three were resistance (R), thirty-five showed moderately resistance (MR), Fifty-seven showed moderately susceptible (MS), fifty showed susceptible (S) infection type. Highest disease severity was recorded on two wheat lines i.e., PBW 343, HD3086.
- ACI values with 0 recorded as immune in 52 germplasm, ACI values with 1-10 recorded in 87 germplasm, ACI values with 10-20 recorded in 28 germplasm, 20-40 in 22 germplasm, ACI values 40-60 recorded in 4 germplasm and ACI value more than 60 in 2 germplasm susceptible checks, PBW343 and HD3086.
- AUDPC values with 0 recorded in fifty-two germplasm, 1-10 in one germplasm, 11-100 in twenty-eight germplasm and 101-200 in forty germplasm, AUDPC values from 201 to 500 in twenty-eight germplasm, AUDPC values from 501 to 800 in twenty germplasm and AUDPC values greater than 800 was observed in twenty-six germplasm. Similar results and categorization of AUDPC values were reported by Singh *et al.*, (2017); Menkonnet *et al.*, (2019); Shain *et al.*, (2021); Singh *et al.*, (2022).
- Average CDL value was observed between 0.000 to 0.810 among the tested germplasm. Highest CDL values observed in PBW343 (0.810) followed by HD-3086 (0.640) and Agra local (0.360). Zero CDL values observed in (50) germplasm GWJ3,

GWJ12, GWJ19, GWJ23, GWJ29, GWJ40, GWJ41, GWJ44, GWJ45, GWJ47, GWJ48, GWJ59, GWJ61, GWJ62, GWJ63, GWJ64, GWJ67, GWJ72, GWJ73, GWJ78, GWJ97, GWJ101, GWJ112, GWJ120, GWJ124, GWJ128, GWJ129, GWJ132, GWJ134, GWJ136, GWJ137, GWJ138, GWJ140, GWJ142, GWJ143, GWJ144, GWJ145, GWJ147, GWJ150, GWJ152, GWJ156, GWJ163, GWJ166, GWJ170, GWJ171, GWJ173, GWJ182, GWJ183, GWJ188, GWJ190.

- "r" value with 0.000 observed in seventy-seven germplasm and 0.001- 0.015 r value was observed in sixty- two germplasm. From 0.016 to 0.030 r value recorded in fifty- two germplasm while >0.300 r value was recorded in Agra local, HD3086, PBW343.
- In unprotected plots, cultivars were having more stripe rust as compared to ones where Propiconazole (Tilt) @0.1 percent was sprayed and there is negative correlation between disease level and wheat yield. Rust development was higher on unsprayed plots Agra Local, PBW725, Unnat343, HD2967, HD3086 and PBW 343. New released variety PBW725 showed only 3.3 rust score reaction of stripe rust indicating its resistance to pathotypes. It also indicated that there is different level of resistance in different varieties to stripe rust pathogen. The spray of Tilt @ 0.1 Per cent drastically reduced the rust in all the varieties evaluated. The losses in yield due to stripe rust varied depending upon the resistance of. Maximum yield reduction of 12.09 q/ha in protected with spray and 19.71 q/ha in unprotected was observed in cultivar, PBW343, which is highly susceptible to stripe rust followed by Agra Local, HD3086 HD2967 and Unnat343.

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## CERTIFICATE-IV

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Certified that all necessary corrections as suggested by the external examiner and advisory committee have been duly incorporated in the thesis entitled "**Evaluation and assessment of yield losses by stripe rust (*Puccinia striiformis* f. sp. *tritici*) in wheat**", submitted by **Ms. Girja devi**, Registration No. **J-22-M-909**.



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