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Prevalence and distribution in different agro-ecologies and identification of resistance source for wheat stripe rust

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To assess the prevalence and distribution of wheat stripe rust (*Puccinia striiformis*), a survey of the randomly selected wheat fields located in sub-tropical to temperate agro-ecologies of Jammu province of Jammu and Kashmir was conducted consecutively for three years during *rabi* seasons of 2009-2010, 2010-2011 and 2011-2012. The results revealed that, by and large, all the wheat growing areas under study were found infested by this disease with maximum and minimum Area Under Rust Progress Curve (AURPC) values of 2422.21 and 351.70 reported from Jammu sub-tropics and inter-mediate Doda districts, respectively. The cropping season of *rabi* 2010-2011 recorded highest disease prevalence, probably due to conducive environmental conditions coupled with virulent pathotypes out-break and monoculture of wheat varieties. Among twenty one germplasms of wheat screened for source of disease resistance against stripe rust under epiphytotic conditions, Agra local and PBW-343 were found susceptible, RSP-561 showed moderate resistance, whereas, all the other cultivars were moderately susceptible to *Puccinia striiformis*.

Key words:*Puccinia striiformis*, stripe rust, wheat, distribution, resistance.

INTRODUCTION

In India, wheat (*Triticum aestivum* L.) is the second most important cereal crop next to rice. It is cultivated over an area of 29.9 million hectare with present production of 93.90 million tones and projected demand of 100 millions tones by 2030 AD (Sharma, 2011). Out of various biotic factors, stripe rust (yellow rust) caused by *Puccinia striiformis* West. f. sp. *tritici* is one of the main constraints in realizing the genetic potential of most of the cultivated varieties both in respect of yield and grain quality. Monoculture of wheat cultivars coupled with broad adaptation of the pathogen to diverse climatic conditions and emergence of new pathotypes, make the disease a matter of great concern (Kolmer, 2005). In early 1970 and mid 1980's, the stripe rust epidemics occurred in North Africa, Indian subcontinent, Middle east, East Africa highland and China due to the breakdown of resistance

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genes (*Yr2* and *Yr9*) which were present in most of the cultivated varieties (Saari and Prescott, 1985; McIntosh, 2009; Chen et al., 2009). Presently, stripe rust is spreading rapidly in vast tracts stretching from Turkey, Syria and Northern Iraq to Southern Uzbekistan and the potential crop loss is in billions of dollars. In most wheat producing areas yield losses caused by stripe rust have ranged from 10 to 70 per cent, depending on the susceptibility of cultivar, earliness of the initial infection, rate of disease development and duration of disease (Chen, 2005). The distribution of the disease depends much upon climatic factors such as rainfall, humidity, temperature, etc. (Emge and Johnson, 1972). Lower temperature of 6 to 18°C, wet conditions along with intermittent rains favors stripe rust epidemics (Cortazar, 1985).

In India, yellow rust was observed in Punjab, Haryana, Western Uttar Pradesh and Jammu and Kashmir and was adjudged to be responsible for considerable yield losses (Nagarajan et al., 1984). During cropping season of 2010-11, the stripe rust appeared in severe form in almost all the wheat growing areas of Jammu region of Jammu and Kashmir state of India, wherein, wheat was grown over an area of 239 thousand hectares with a production and productivity of 465.33 thousand tones and 19.47q ha^{-1}, respectively (Anonymous, 2011). Further, variation in climatic conditions had led to a breakdown of disease resistance in mega wheat variety PBW-343 as well as out-breaks of new pathotypes, which caused a significant loss to the production of wheat. Timely application of newly identified fungicide molecules restricted the spread of stripe rust (Chen, 2005) but its use was found to be uneconomical and ecologically unsafe. Hence, growing of wheat cultivars having resistance genes against the *P. striiformis* remains the most inexpensive, efficient and sustainable method to manage the disease (Ittu, 2000). Generally, race-specific resistance genes and non-specific resistance genes have been detected and incorporated into commercial cultivars for providing effective protection against the disease. As the resistance is transitory because of outbreak of new virulent races (Stubbs, 1985), there is a need to investigate new source of resistance against the *P. striiformis*. Keeping in view, the role of this staple crop in food security and its economic value for the region, the present study was undertaken to know the distribution and prevalence of stripe rust of wheat and determination of its source of resistance.

MATERIALS AND METHODS

Occurrence of the stripe rust of wheat

The major wheat growing areas of Jammu province, that is, sub-tropical: Kathua, Samba, and Jammu districts with an altitude of 300 to 800 m above msl and rainfall of 1069 mm; intermediate: Rajouri, Udhampur and Doda districts having altitudinal range of 800 to 1500 m above msl and rainfall of 1478 mm; and temperate Kishtwar district with altitude of more than15000 m above msl and 1052 mm rainfall were surveyed to ascertain the distribution of stripe rust, during *rabi* seasons of 2009-2010, 2010-2011 and 2011-2012. Disease incidence and disease severity (percent plant part) infected were recorded at fifteen days interval from January onwards till harvesting of the crop by simple random sampling using Modified Cobb's Scale (Peterson et al., 1948), and the value for area under rust progress curve (AURPC) was calculated using the formula given by Pandey et al (1989). The infected leaves of different cultivars from different locations were collected, pressed and dried in the laboratory and were submitted to Directorate of Wheat Research (ICAR), Regional Station Flowewrdale, Shimla for the pathotype identification.

Screening of germplasm

Twenty one germplasms of wheat *viz.* PBW-343, PBW-550, Raj-3765, Raj-3077, PBW-502, PBW-373, PBW-396, VL-804, TL-2966, HPW-289, VL-916, HS-508, TL-2942, TL-2963, HS-240, VL-907, HS-507, Agra Local, TBW-17, V-21 and RSP-561 were screened under artificial epiphytotic conditions for stripe rust resistances at Research Farm, SKUAST-J, Chatha, of Jammu and Kashmir state (India) during cropping season of *rabi* 2009 to 2010. The varieties were grown in lines of 1.5 m length with a row to row spacing of 22.5 cm in last week of November. Whole of the experimental area was surrounded by two rows of susceptible cultivar (A 9-30-1). The spore dust (mixed inoculums of various pathotypes) of urediospores of stripe rust was obtained from Regional Rust Research Centre (ICAR), Flowerdale, Shimla. The suspension was prepared by suspending the inoculum in distilled sterile water (95 ml) with small amount of Tween-20 (5 ml). 10 to 12 seedlings were maintained in each of the earthen pots filled with sterilized soil. The spore suspension so prepared was sprayed on two weeks old seedlings of susceptible wheat variety (A 9-30-1) thoroughly using an atomizer. Some plants were also inoculated directly by using lancet needle. The inoculated plants were misted with the help of hand sprayer and the polythene bags containing plants were kept in glass house for 48 h. These inoculated plants were then transferred in green house and irrigated regularly to create humid conditions. Regular monitoring was done for symptom development. On the development of symptoms, the inoculated pots were immediately transferred to the field to carry out the screening studies. The data on disease severity and host reaction was recorded according to modified Cobb's Scale (Peterson et al.,1948) and was combined to calculate the coefficient of infection (CI) by multiplying the severity value by 0.10, 0.4, 0.8 or 1.00 for host response ratings of resistant (R), moderately resistant (MR), moderately susceptible (MS) or susceptible (S), respectively (Pathan and Park, 2006) to classify the wheat varieties into different groups. The relationships of final rust severity (FRS) and AURPC with coefficient of infection were determined by correlation.

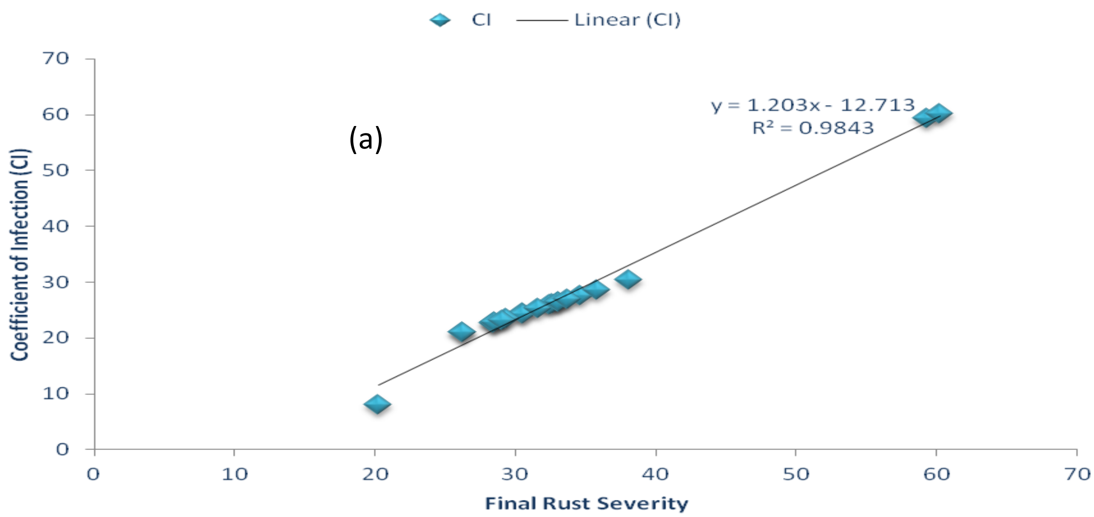
RESULTS AND DISCUSSION

The data presented in Table 1 revealed that the stripe rust of wheat was found- prevalent in all the major wheat growing areas of Jammu province in all the three cropping seasons of 2009-2010, 2010-2011 and 2011-2012. During 2009-2010, Jammu district recorded the maximum disease incidence, disease severity, final rust severity (FRS) and area under rust progressive curve (AURPC) with their corresponding values of 23.35, 22.42, 42.83 and 1312.55%, respectively, whereas, minimum disease incidence, disease severity, final rust severity

Table 1. Prevalence of stripe rust of wheat in Jammu province during 2009 to 2011.

District	Disease severity (%)			Disease severity (%)			Final rust severity (%)			AURPC Value		
	2009-2010	2010-2011	2011-2012	2009-2010	2010-2011	2011-2012	2009-2010	2010-2011	2011-2012	2009-2010	2010-2011	2011-2012
Kathua	15.07	21.88	21.77	14.37	39.43	37.43	34.67	80.33	75.33	817.4	1733.62	1333.12
Samba	21.3	25.97	21.97	17.15	44.5	41.11	33.92	82.95	80.95	987.25	1788.37	1754.17
Jammu	23.35	41.57	39.57	22.52	59.9	56.78	42.83	88.83	85.83	1312.55	2998.05	2956.05
Rajouri	11.72	13.72	12.92	11.05	17.55	16.05	36.75	40.75	38.57	397.43	477.32	462.22
Udhampur	10.91	12.91	12.67	9.57	12.97	12.57	35.33	48.77	45.77	405.72	428.32	418.32
Doda	10.8	12.8	11.66	7.14	11.84	11.09	28.57	38.67	35.67	321.28	378.12	355.72
Kishtwar	13.39	16.39	15.67	12.87	22.24	21.74	38.75	41.75	40.75	781.37	853.22	837.37
Mean± S.E	15.22± 1.67	20.75± 3.94	19.46± 3.71	13.52± 1.93	29.77± 6.94	28.11± 6.53	35.83± 1.66	60.29± 8.52	57.55± 8.34	717.57±119.33	1236.72±370.58	1159.56±358.46
Range	10.8-23.35	12.80-41.57	11.66-39.57	7.14-22.52	11.84-59.90	11.14-59.78	28.57- 42.83	38.67-88.83	35.67-85.83	321.28-1312.55	378.12-2998.05	355.72-2956.05

(FRS) and area under rust progressive curve (AURPC) values of 10.80, 7.14, 28.57 and 321.28%, respectively were recorded in district Doda. In the next cropping season of 2010 to 2011, the stripe rust showed increased incidence and severity in all the areas as compared to the preceding year of 2009 to 2010 with maximum incidence and severity of 41.57 and 59.90%, respectively, in Jammu district and minimum incidence and severity of 12.80 and 11.84%, respectively, in Doda. However, the disease incidence and severity showed decreasing trend in 2011 to 2012 but it was found to be higher than first year (2009-10) and the values for disease incidence and disease severity were 39.57 and 56.78% in Jammu district and 11.66 and 11.09%, respectively, in Doda district. It was found that all the major cultivars succumbed to the disease, which may be due to the advent of new race(s) or changes in genetic makeup of the existing races as the rust pathogen itself is highly mutable and equipped with means to recombine this variability into a new lineage group. The capacity to develop durable and efficient control methods is largely based on the knowledge of the pathogen population structure and its potential for adaptation to new cultivars (Brown, 1996). Out of different pathotypes, two races of the stripe rust, 78S84 and 46S119, were observed to be prevalent in the area, however, 78S84(*Yr27*) was predominant and more aggressive in the Jammu province due to the widespread cultivation of susceptible wheat variety (PBW-343). New pathotypes with specific adaptation facilitated by acquisition of specific single gene virulence, and virulence combinations, were major factors underlying regional epidemics. The acquisition of virulence for *Yr2* in the 1970s, *Yr9* in 1990s, and *Yr27* in recent years contributed significantly to regional and continental epidemics, resulting in heavy yield losses (Wellings et al., 2009). The information regarding the surveys of pathogen populations and the genetic characterization of virulence genes provide valuable information to design breeding strategies and prioritize which physiological races are to be targeted for durable resistance in wheat. Hailuar and Fininsab (2006) have also reported that stripe rust epidemics vary significantly between locations, seasons and also among cultivars. The weather data of Jammu sub-tropics observed during the three cropping season and given in Figures 1 to 4 revealed that the average maximum and minimum temperatures of 23.1 and 10.1°C; maximum and minimum relative humidity of 86.5 and 52.00%, respectively and rainfall of 32.8 mm recorded during 2010 to 2011 were found to be quite favorable for the development of stripe rust epidemics as compared to the years 2009-2010 and 2011-2012. Further, the cultivation of susceptible varieties on large scale in the irrigated areas of sub-tropics along with intermittent rains during February, and March played a major role in the build-up of inoculums for development of the stripe rust. Although the replacement of susceptible varieties was through on mass scale but the presence of inoculum increased the disease severity and incidence in the successive year, whereas in the intermediate region, the maximum area under cultivation of wheat was rainfed and the average rainfall (84.30 mm) was also high and was in consonance with the critical water requirement stages of the crop , but due to low relative humidity, the rate of disease development was slow and the hosts showed tolerance response against the disease. In temperate zone, all the abiotic factors remained favorable for the development of the disease and the favorable



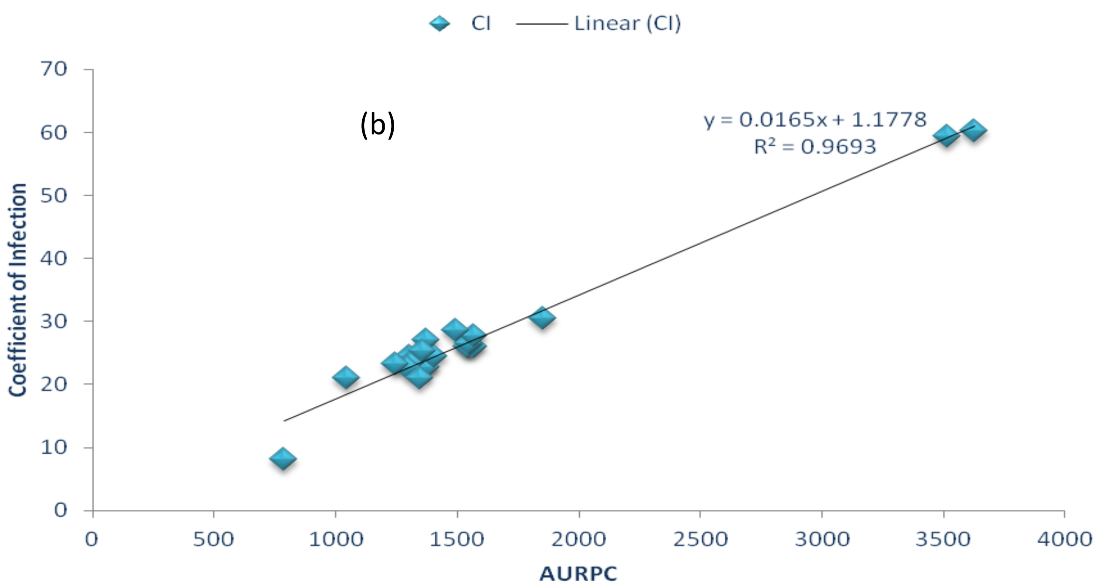


Figure 1. (a) Association between final rust severity (FRS) and coefficient of infection (CI). (b) Association between area under rust progress curve (AURPC) and coefficient of infection (CI).

weather conditions along with cultivation of susceptible and primitive varieties, usual delayed sowing, and presence of green bridges all might have contributed to the development of disease in all the three cropping seasons. Ali et al. (2009) recorded considerable variation in the expression of partial resistance to stripe rust across the locations having varied climatic conditions. Qamar et al. (2012) found that the temperature in January and February is positively correlated with yellow rust severity.

Among the twenty one germplasms of wheat screened against stripe rust (Table 2), the disease severity ranged from 0.57 to 19.26% in 1st week of February but by the end of crop season the disease severity on different cultivars varied from 20.21 to 60.23% with highest in Agra local (60.23%) followed by PBW-343 (59.32%) and lowest on RSP-561 (20.61%). From these results, it is apparent that stripe rust infection was well established in all the wheat germplasms screened for the disease. The germplasm *viz*., RSP-561 was ranked as moderately resistant with Area Under Rust Progress Curve (AURPC) of 787.13, whereas, PBW-550, PBW-373, HS-508, VL-804 TL-2963, HS-240, VL-907, Raj-3765, Raj-3077, PBW-502, PBW-396, TL-2966, HPW-289, VL-916, HS-508, TL-507, VL-21 and TBW-17 were ranked as moderately susceptible to yellow rust with AURPC ranging between 1043.93 and 1850.78, while Agra local

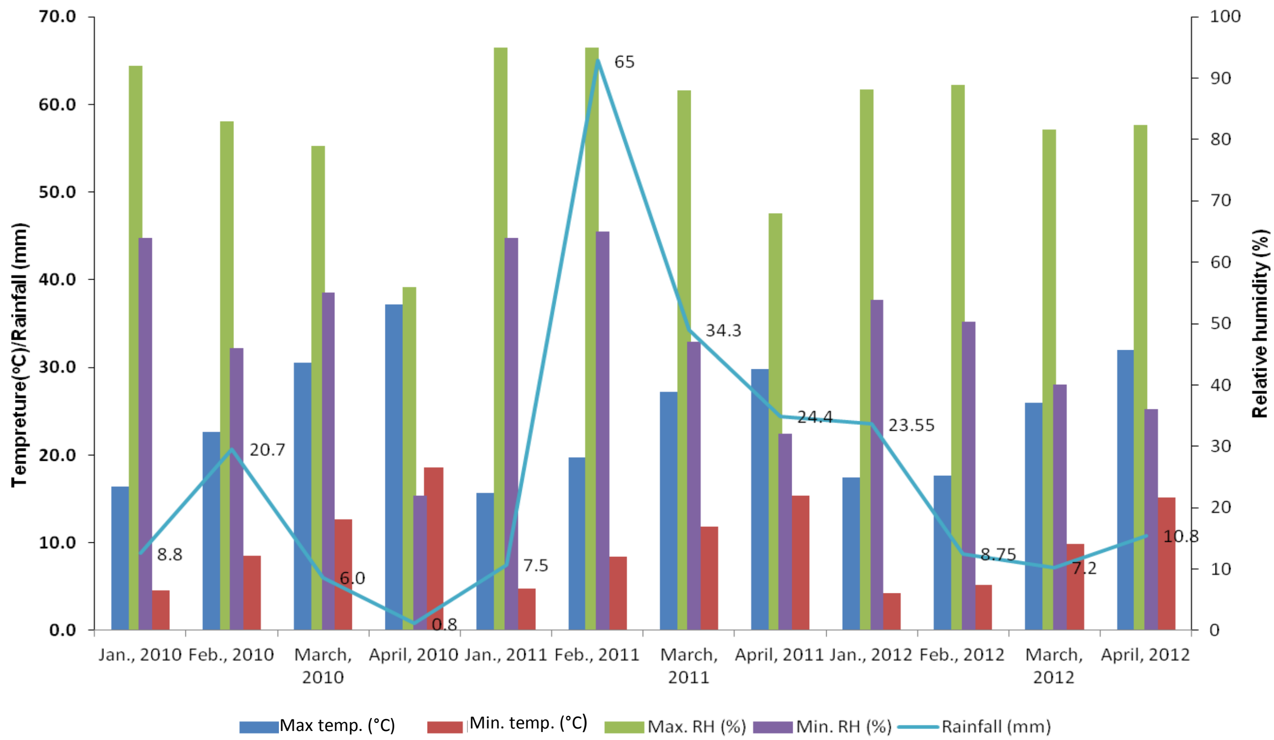


Figure 2. Meteorological data of Sub-tropics region during 2010-2011 and 2012.

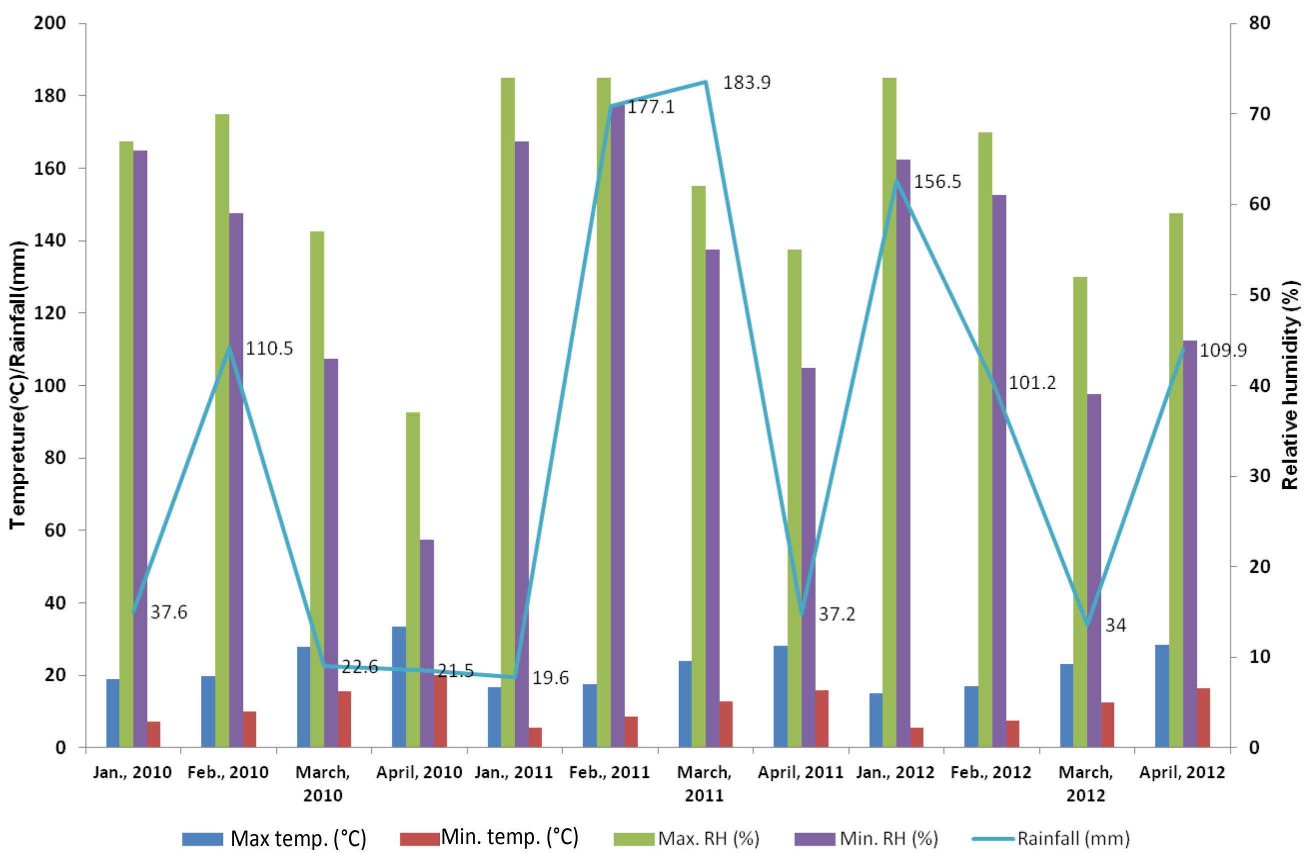


Figure 3. Meteorological data of Intermediate region during 2010-2011 and 2012.

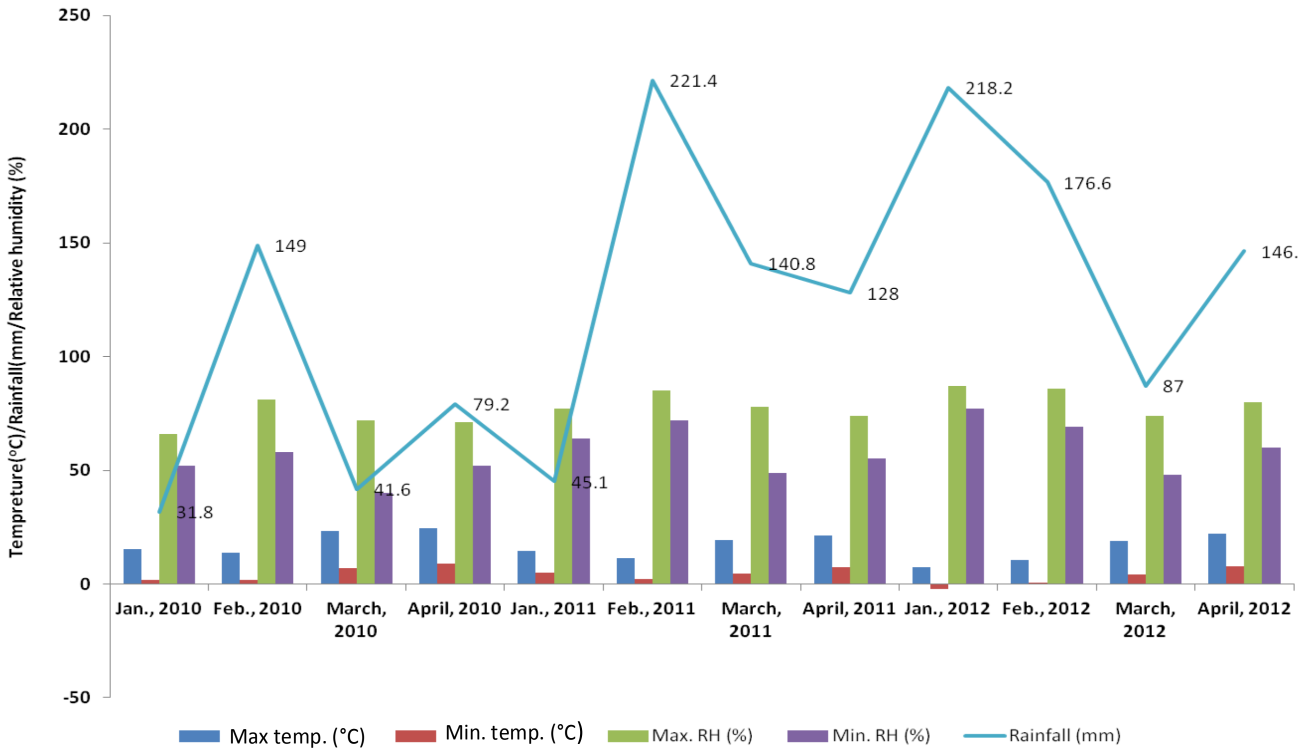


Figure 4. Meteorological data of temperate region during 2010-2011 and 2012.

Table 2. Screening of wheat germplasm against stripe rust under epiphytotic conditions, during 2009-10.

Germplasm	Percent disease severity at different intervals						AURPC	C.I.
	1st Feb	15th Feb	2nd March	17th March	1st April	16th April		
PBW-343	18.39	36.69	45.62	54.97	58.32	59.32	3516.83	59.32
PBW-550	5.03	15.83	17.83	21.65	23.54	26.21	1043.93	20.97
Raj-3765	3.13	10.17	12.33	25.33	27.31	28.46	1364.03	22.77
Raj-3077	3.03	9.17	15.67	28.67	31.22	32.58	1538.03	26.06
PBW-502	2.34	10.17	15.33	30.00	31.65	32.41	1567.88	25.93
PBW-373	3.87	10.83	12.67	30.00	31.56	33.01	1552.50	26.41
PBW-396	3.24	10.50	12.33	25.33	27.37	28.41	1370.33	22.73
VL-804	2.15	8.50	12.00	27.33	29.45	30.52	1404.23	24.42
TL-2966	2.43	7.89	14.33	30.33	32.66	33.06	1544.33	26.45
HPW-289	3.46	10.30	20.33	35.33	36.67	38.05	1850.78	30.44
VL-916	3.98	11.33	12.00	30.00	31.78	34.59	1565.93	27.67
HS-508	0.57	5.89	12.33	25.33	27.64	30.49	1300.80	24.39
TL-2942	0.99	6.33	14.67	28.67	31.45	35.78	1492.58	28.62
TL-2963	1.76	8.36	12.00	25.00	26.34	29.29	1308.38	23.43
HS-240	1.21	6.67	12.33	26.33	28.65	33.72	1371.68	26.98
VL-907	2.85	9.36	12.00	23.33	25.67	28.47	1290.30	22.78
HS-507	2.65	8.54	12.00	22.00	24.72	29.04	1246.58	23.23
Agra local	19.26	38.60	47.43	56.74	59.21	60.23	3625.88	60.23
TBW-17	1.43	6.33	12.67	25.33	29.46	31.62	1354.73	25.30
V-21	5.26	8.60	17.43	22.74	25.21	26.23	1345.88	20.98
RSP-561	3.43	9.83	12.33	18.83	19.54	20.21	787.13	8.08

AURPC: Area under rust progress curve; C.I: Coefficient of infection.

Table 3. Response of different wheat germplasm against stripe rust, during 2009-2010.

Disease score	Disease reaction	Germplasm
1	Immune (0)	Nil
2	Nearly immune (1 to 5%)	Nil
3	Resistant (6-10%)	Nil
4	Moderately resistant (11-25%)	RSP-561
5	Moderately susceptible (26-40%)	TL-2963, HS 240, VL-907, Raj-3765, Raj-3077, PBW-502, PBW-396,VL-804, TL-2966, HPW-289, VL-916, HS-508, HS 507, TL-507, TBW-17, PBW-373, PBW-550, V-21.
6	Susceptible (41-65%)	Agra local, PBW-343
7	Highly susceptible (>65%)	Nil

and PBW-343 having AURPC of 3625.88 and 3516.83, respectively, were ranked as susceptible to yellow rust. None of the germplasm showed resistant reaction against the disease (Table 3). The positive correlation coefficient of infection (Figure 1a and b) was found with FRS and AURPC with R^2 value of 0.984 and 0.969, respectively, which was found to be in conformity with findings of Ali et al. (2008) who had also found strong association between coefficient of infection (CI), with FRS and AURPC. Sinha et al. (2006) have found that the popular variety PBW 343 grown in the state of Punjab had fallen susceptible to the newly identified race 78S84 of yellow rust. Dadrezaei and Torabi (2001) on the other hand reported that the disease appeared late on the resistant cultivars as compared to the susceptible cultivars. The delay in the appearance of yellow rust and its slow development on resistant cultivars resulted in late secondary infections until unfavorable climatic conditions occurred. Ahmad et al. *(*2006) reported that there was a considerable amount of genetic variation among various entries ranging from immune to susceptible response. They observed that among the entries screened, 19 entries (17.60%) were found to be totally immune (average coefficient of infection value = 0.00), 13 entries (12.03%) as resistant (C.I ≤ 3), 29 entries (26.85%) susceptibility (CI < 10), and the rest were rated as highly susceptible (CI > 10).

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