The Pharma Innovation Journal 2022; SP-11(7): 436-442

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(7): 436-442

www.thepharmajournal.com
Received: 15-06-2022
Accepted: 19-07-2022

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To study the effect of different environment factor on disease development and progression of wheat stripe rust under field condition

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Abstract
Stripe rust of wheat caused by *Puccinia striiformis* f. sp. *tritici* is a major constraint for wheat production worldwide. The present investigations were carried out to study the relationship between development and progress of stripe rust (*Puccinia striiformis* f. sp. *tritici*) with different weather parameters during crop seasons 2020-21 and 2021-22. The first appearance of disease was noticed at the end of 1st standard week of January during the year 2020-2021 with Disease Index of 0.15 Percent in contrast with the year 2021-2022, where first appearance of disease was noticed at second standard week of January with Disease Index 0.10 Percent. Disease progression varied significantly between these two cropping years where highest disease progression was noticed during 2020-2021 with maximum Disease Index of 42.5 percent and AUDPC (Area under disease progress curve) of 1263.25. On the other hand, a maximum Disease Index 37.5 percent was noticed during the year 2021-2022 with AUDPC 1154.3 (Fig 1, 2; Table-1). Correlation coefficients indicated that maximum and minimum temperature, morning and evening relative humidity, rainfall and sunshine hours influence the disease development and progress.

Keywords: Wheat, stripe rust, weather parameters, temperature, diseases severity, relative humidity, rainfall and sunshine hours

Introduction
Stripe or yellow rust of wheat, caused by Puccinia striiformis Westend. f. sp. *tritici* Ericks., is one of the most important disease inflecting high economic yield losses in most of the wheat growing areas of the world (Chen *et al*., 2014) [3]. This disease appears in the form of yellow stripes on leaves, causes substantial losses in yield through damaging its photosynthetic system, most importantly reducing grain weight and affecting its quality (Line, 2002; Chen, 2005) [9, 4]. Stripe rust can cause 100 per cent yield losses in case of susceptible cultivars if infection occurs very early and the disease continues to develop during the growing season (Afzal *et al*., 2007) [1]. Chen (2005) [4] has reported that depending upon the susceptibility of cultivar, earliness of initial infection, rate of disease development and duration of disease, the yield losses ranges between 10-70 per cent due to stripe rust. Hence, the disease control practices are mostly required in order to prevent yield losses.

Wheat is the staple food of more than 40 per cent of the human population. In India, it is second most important food crop, cultivated extensively in North Western and Central zones. Wheat is the most important cereal crop of the Uttar Pradesh. Wheat crop is attacked by a large number of diseases which appear in epidemic proportions causing yield losses and deterioration in quality. Plant diseases affect 55 per cent of the global wheat growing area, causing an estimated loss of 20 million tonnes of wheat per annum (Kosina *et al*., 2007) [8]. Under the North-western plain zone of India, wheat rusts, viz., stripe or yellow rust (*Puccinia striformis* west end. f. sp. *tritici*) are of worldwide concern. Yellow rust appeared in severe form in plain areas of Jammu and Kashmir, foot hills of Punjab and Himachal Pradesh, parts of Haryana, tarai region of Uttarakhand hills during 2008-09, 2009-10 and 2010-11 (Pannu *et al*., 2010) [11]. High severity of stripe rust during the last decade (1994-2004) have resulted due to occurrence of new physiological races that were able to overcome widely used sources of resistance in wheat (Prasher *et al*., 2007) [12]. It occurred in the severe form in certain areas in North India including Jammu and Kashmir, Himachal Pradesh, Uttar Pradesh and in the sub-mountainous area of the Punjab and caused enormous yield losses during recent years. The disease is occurring in moderate to severe form since 2008 and responsible for losses about Rs

236 crores in Punjab (Jindal *et al*., 2012) [6]. The weather factors like temperature, relative humidity, rainfall and sun shine play a significant role in the occurrence, development, spread and progress of stripe rust. The present study was carried out to investigate the relationship of weather parameters with different components of disease under artificially inoculated conditions and disease development under natural conditions.

Materials and Methods

Wheat (*Triticum aestivum* L.) variety PBW 343, a variety with a crop duration of 130-135 days, which is susceptible to, yellow rust of wheat was selected for this study. In this experiment, seed were sown in 4×3m^2 size plots in three replication in field by maintaining the plant to plant/row to row spacing of 15 × 25 cm^2 at agricultural farm, chirodi, SVPUA&T on same dates during two cropping seasons *viz*. rabi 2020-21 and 2021-22 by following standard agronomical practices. For this study, no chemicals or botanicals of any kind were used so as to facilitate uninterrupted occurrence of yellow rust of wheat under natural conditions in relation to weather factors. The severity of yellow rust of wheat was recorded at different crop growth stage starting from jointing stage to maturity at weekly intervals by randomly selecting 20 plants from each plot replicate. Weekly meteorological data was collected throughout the crop season from meteorological observatory, Department of Soil Science and Agricultural chemistry, SVPUAT, Meerut. Severity of the disease was recorded according to Modified Cobb or Peterson scales at 5-day interval starting from the initial infection of the disease until terminal disease severity. After scoring the percent severity of yellow rust of wheat, the per cent disease index (PDI) was calculated using the following formula: Percent disease index (PDI) = (Total grade points/Number of leaves observed) × (100/Maximum grade observed). The weekly percent disease index (PDI) was recorded and correlated with mean weekly meteorological parameters like maximum and minimum temperatures (°C) (T-max; T-min), morning and evening relative humidity (percentage) (m-RH; a-RH), Bright sunshine hours (BSS) and total rainfall (RF) (mm) which were collected from the Agro-meteorological observatory, SVPUAT for the entire period of experimentation. Area under disease progress curve (AUDPC) which gives a quantitative measure of disease development and disease intensity was estimated using the following formula

$$\text{AUDPC} = \frac{N_1(X_1+X_2)}{2} + \frac{N_2(X_2+X_3)}{2}$$

This formula was given by (Milus and Line, 1986) Where, here X1, X2 and X3 = disease severity recorded on the first, second and third scoring dates, respectively. N1 = the interval day between X1, X2 and N2 = the interval day between X2, X3. Effect of crop growth stages and different meteorological parameters on disease severity was determined by correlation analysis.

Statistical analysis

The recorded data were subjected to statistical analysis using analysis of variance (ANOVA) for randomized block design. Standard error of mean in each case and the critical difference only for significant cases was computed at 5% level of probability as under.

Results and Discussion

Crop growth stages and disease progression

From the findings obtained in the present investigation, it was found that initiation of disease was first noticed at vegetative stage of growth and culminated in peak levels at maturity stage with sharp increase from reproductive phase to ripening phase. The first appearance of disease occurred at the end of 1st standard week of January during the year 2020-2021 (Table 1) with Disease Index of 0.15 Percent in contrast with the year 2021-2022, where first appearance of disease was noticed at second standard week of January with Disease Index 0.10 Percent. Disease progression varied significantly between these two cropping years where highest disease progression was noticed during 2020-2021 with maximum Disease Index of 42.5 percent and AUDPC (Area under disease progress curve) of 1263.25. On the other hand, a maximum Disease Index 37.5 percent was noticed during the year 2021-2022 with AUDPC 1154.3. These result were in agreement with the findings of Gupta *et al*. (2017) [5] who reported the initial severity (1%) of yellow rust disease of wheat during crop jointing growth stage (73 days after sowing) and increased disease progression thereafter towards maturity showing maximum disease severity. Development of yellow rust disease of wheat gets increased as crop progressed from vegetative phase to ripening phase especially during the period of January to march at normal prevailing weather conditions of relative humidity where the crop is tend to become more susceptible to the disease at that stage (Sandhu *et al*., 2017 and KaShya *et al*., 2018) [15, 7].

The reason behind heavy yellow rust disease of wheat when crop progress towards maturity is that with the maturity, crop become exhausted due to its major energy goes to reproduction and possibly less energy remain to be utilized for defense against disease and this may be a prominent reason why there is heavy disease when plants approach maturity.

Correlation of disease progress with temperature and relative humidity

From the findings obtained in the present investigation, it was found that Increase in PDI (Percent disease index) was observed at the mid and end of cropping season with corresponding decrease in weekly maximum temperature (T-max) during two consecutive years registering significant positive correlation (SPC) coefficients (r) of 0.915** and 0.950** during 2020-2021 and 2021-2022 respectively. Similarly, highly SPC was found between weekly PDI and weekly minimum temperature (T-min) coefficients (r) viz.- 0.978** and 0.905** during 2020-2021 and 2021-2022 respectively (Table; 2). From the above findings, it was clear that increase in both T-max and T-min at the end of cropping seasons may be unfavorable for progression of yellow rust disease in wheat during both consecutive years. Mateen and Khan (2014) [10] also reported positive linear relationship between temperature and disease severity. From the experimental findings, it was found that high weekly m-RH,s throughout the cropping period were noticed during the years 2020-2021 (>94.86 percent) in contrast with low Weekly m-RHs observed during the years 2021-2022 (<28.4 percent). On the other hand, afternoon relative humidity's (a-RH,s) exhibited negatively significant correlation (NSC) with weekly PDI to the end of the cropping season during in the year 2020-2021 (r=-0.830**). Whereas, highly SNC (R= -0.629**) a-RH and weekly PDI was noticed to the end of season during the years 2021-2022 indicating greater decline in a-RH to end of crop season.

From these results, it was evident that prolonged high weekly m-RH,s and a-RH,s accompanied by increased weekly T-max and T-min to the end of crop season in 2020-2021 were responsible for greater disease progression and maximum PDI in that year compared to that of 2021-2022 recording less weekly m-RH and a-RH,s. Gupta *et el*. (2017) [5] and Mateen and Khan (2014) [10] reported PBW 343 having severity of 1.0 per cent when the crop was at jointing stage (73 days after sowing) and the corresponding weather parameters (before one-week) having maximum temperature of 17.5 ºC, minimum temperature of 5 ºC, maximum relative humidity (RH) of 92.50 and minimum of 59 per cent.

Correlation of disease progress with rainfall and bright sunshine hours

From the experimental data it was reported that possivetily significant correlation found between rainfall and Percent disease index of stripe rust during both years 2020-2021 and 2021-2022. However, continual intermittent drizzles especially from vegetative stage to early reproductive stage during 2020-2021 might have been responsible for greater spore dispersal (high inoculum pressure) leading to higher PDI in those years in contrast with the year 2021-2022 as there was no precipitation at those stages in this year. Mateen and khan (2014) [10] reported similar findings that environmental factors had great effect on the progress of stripe rust disease of wheat. A positive linear relationship between temperature (maximum and minimum) and disease severity showed that maximum stripe rust was highly noticed at 28-32 ºC maximum temperatures and 14-18 ºC minimum temperatures. While, other environmental factors like relative humidity, rainfall and wind speed also showed positive correlation. From the present findings, non-significant negative correlation was noticed between Percent disease index (PDI) and Bright sunshine hours (BSS) to the both of cropping season during 2020-2021 and 2021-2022. KaShya *et al.* (2018) [7] and Sandhu *et al.* (2017) [15] also reported similar type findings.

Table 1: Weekly PDI in relation with different crop stages of wheat and total AUDPC (area under disease progress curve) during the year 2020-2021 and 2021-2022

2020-2021			2021-2022		
Crop stage	**Standard week**	**PDI**	**Crop stage**	**Standard week**	**PDI**
Vegetative stage	49	0	Vegetative stage	49	0
	50	0		50	0
	51	0		51	0
	52	0		52	0
	1	0.15		1	0
Late Vegetative stage	2	0.28	Late Vegetative stage	2	0.10
	3	0.80		3	0.70
	4	2.15		4	1.9
Reproductive stage	5	4.10	Reproductive stage	5	3.7
	6	6.45		6	5.2
	7	11.73		7	9.8
	8	16.45		8	15.4
	9	21.63		9	20.3
Ripening stage	10	26.96	Ripening stage	10	25.7
	11	31.37		11	29.3
	12	37.15		12	34.1
	13	42.5		13	37.4
	Total AUDPC	1263.25		Total AUDPC	1154.3

Table 2: Weekly meteorological parameters correlated with weekly PDI during the cropping season 2020-2021

Standard week	PDI	T max	T min	m-RH	a-RH	BSS	Rainfall
49	0	26.3	7.9	85	45	6.1	0
50	0	22.9	6.4	85.6	49.9	4.8	5.9
51	0	20.3	6	87.4	51.3	5.8	0
52	0	18.7	4.9	92.1	54.4	5.2	0.2
1	0.15	19.01	6.17	94.14	66.14	2.79	24
2	0.28	18.84	5.7	94.86	63.57	3.86	0
3	0.80	18.13	7.2	93.29	62.29	3.23	0
4	2.15	18.8	6.46	90	57.29	4.76	0
5	4.10	21.61	7.13	85.71	56	6.21	1.1
6	6.45	23.94	7.73	86	55.29	7.43	5.6
7	11.73	26.56	9.8	84.29	43	5.91	0
8	16.45	29.44	12.04	83.29	40.43	7.77	0
9	21.63	30.47	14.11	76.57	41.29	9.23	0.1
10	26.96	32.26	14.54	72.57	35.43	8.74	0
11	31.37	34.01	15.74	71	32.86	6.6	0
12	37.15	35.09	16.63	75.57	38	6.57	0
13	42.5	38.26	16.86	71.86	35.14	8.83	0

PDI-Percent disease index; Tmax-Maximium temperature; Tmin-Minimum temoerature; m-RH-morning relative humidity; a-RH-Afternoon relative humidity; BSS-Bright sunshine hours; RF-Rainfall.

	Correlation coefficient (r)
Max temp	0.915**
Min temp	0.978**
m-RH	-0.906**
a-RH	-0.830**
BSS	0.704**
Rainfall	-0.279^{NS}

Table 3: Weekly meteorological parameters correlated with weekly PDI during the cropping season 2021-2022

Standard week	PDI	T max	T min	m-RH	a-RH	BSS	Rainfall
49	0	23.07	11.64	84.29	48.14	4.21	0.9
50	0	22.4	9.36	83.43	39.43	5.8	0
51	0	20.74	7.17	82.43	38.43	6.2	0
52	0	20	6.49	88.63	49.5	4.69	2.5
1	0	20.6	7.5	84.6	61.1	4.1	9.9
2	0.10	17.7	5.3	91.9	80.6	1.2	67.5
3	0.70	16.2	4.7	92.6	71.1	1.6	3.7
4	1.9	16.6	5.3	91.6	67.9	3.2	33.9
5	3.7	20.1	6	88.6	67	2.6	18.4
6	5.2	20.5	7.3	85.9	64.1	5.3	4.5
7	9.8	24.3	8.3	82.6	57.4	6.9	0
8	15.4	25.9	9.9	82.7	50.3	7.4	0.7
9	20.3	26	10.5	88.6	53.1	8.3	31.5
10	25.7	30.3	13.4	76	43	8.8	0
11	29.3	34.2	17.1	71.1	39.6	8.5	0
12	34.1	37.5	20.1	67.4	34.3	8.9	0
13	37.4	38.7	20.3	58.9	28.4	9.3	0

PDI-Percent disease index; Tmax-Maximum temperature; Tmin-Minimum temoerature; m-RH-morning relative humidity; a-RH-Afternoon relative humidity; BSS-Bright sunshine hours; RF-Rainfall.

	Correlation coefficient (r)
Max temp	0.950**
Min temp	0.905**
m-RH	-0.853**
a-RH	-0.629**
BSS	0.837**
Rainfall	-0.268 ^{NS}

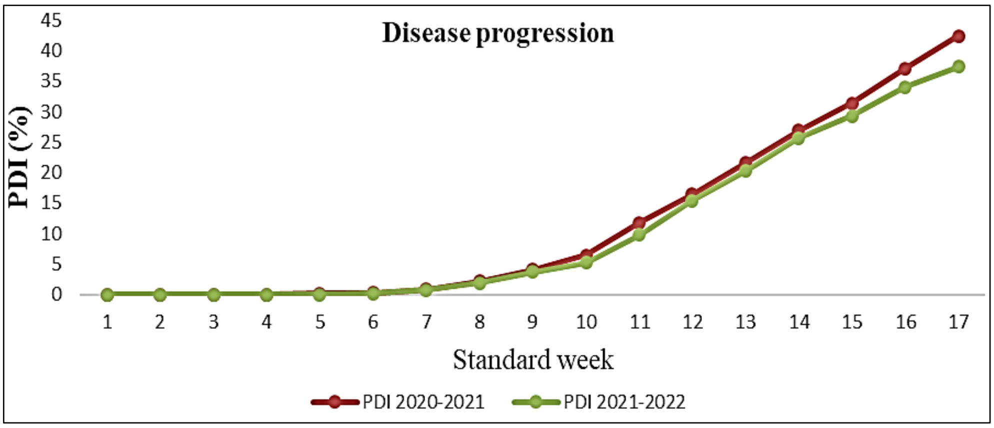


Fig 1: Percent disease index (PDI) at different standard week during the years 2020-21 and 2021-22.

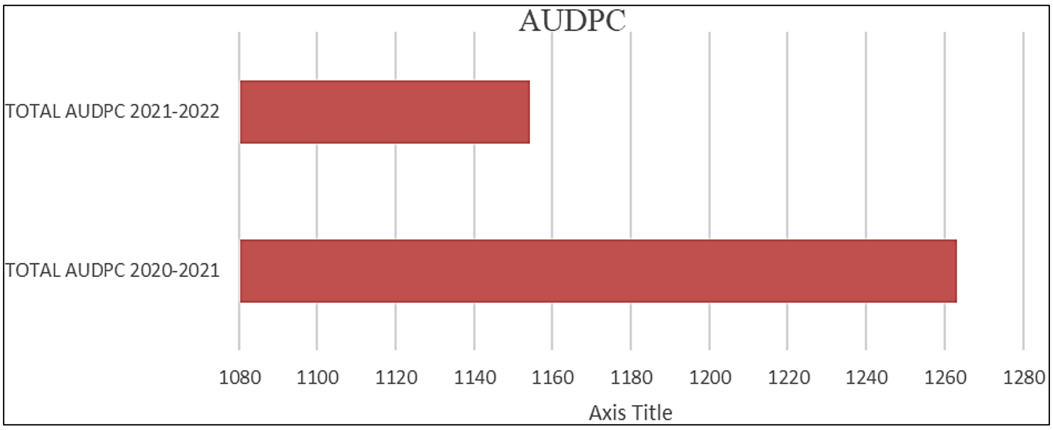
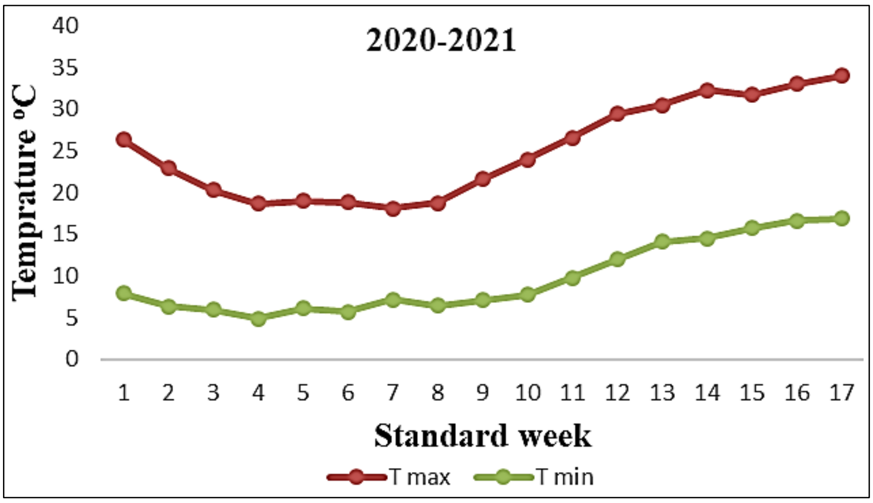


Fig 2: Area under disease progress curve (AUDPC) values during the years 2020-21 and 2021-22



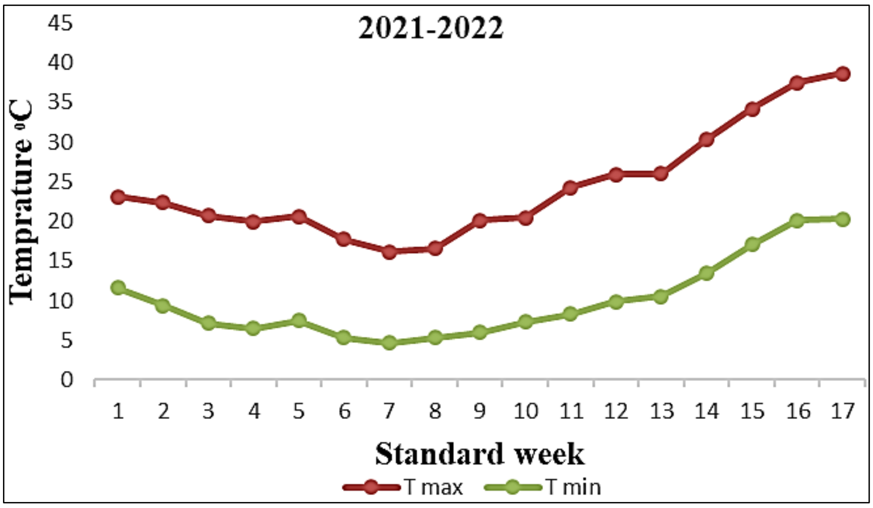


Fig 3: Trend of maximum (Tmax) and minimum (Tmin) temperature of cropping season 2020-20 and 2021-22.

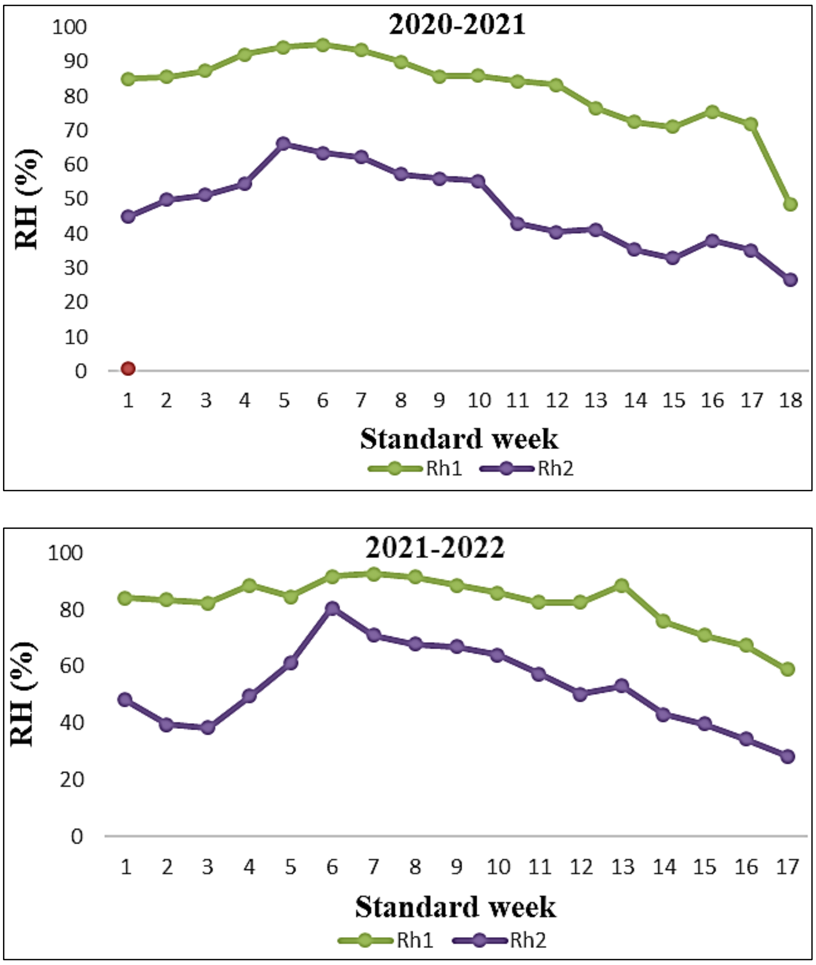


Fig 4: Trend of morning (RH1) and afternoon (RH2) temperature of cropping season 2020-20 and 2021-22

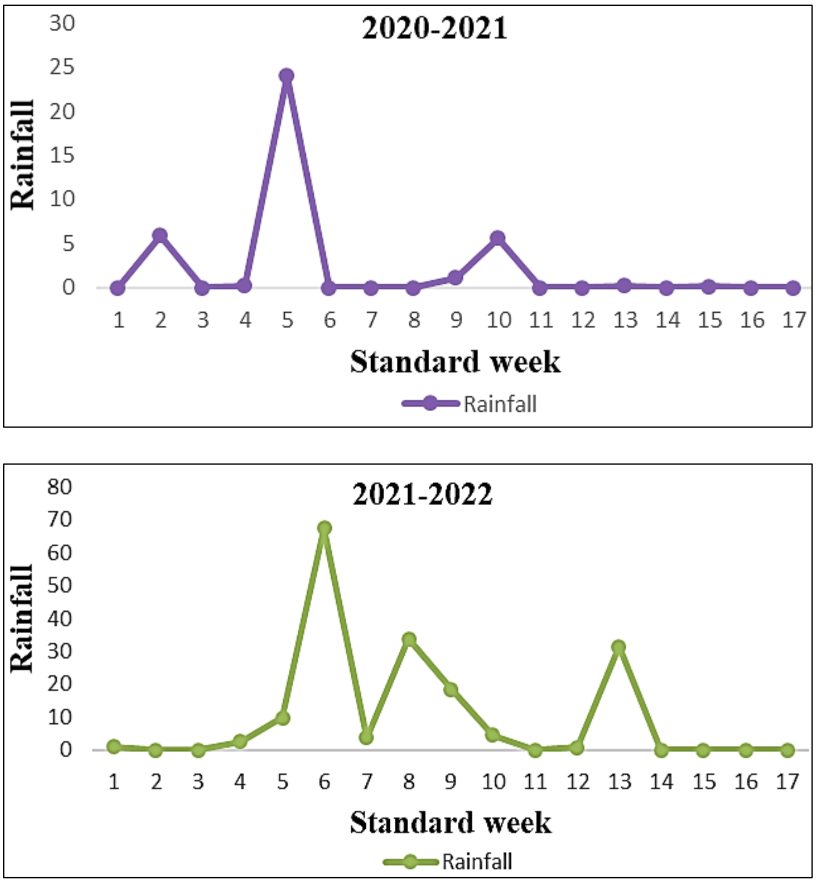
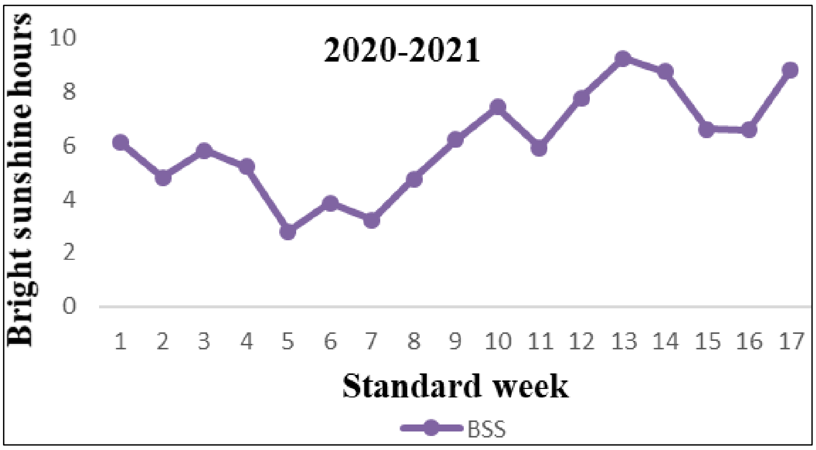


Fig 5: Trend of rainfall of cropping season during rabi season 2020-20 and 2021-22



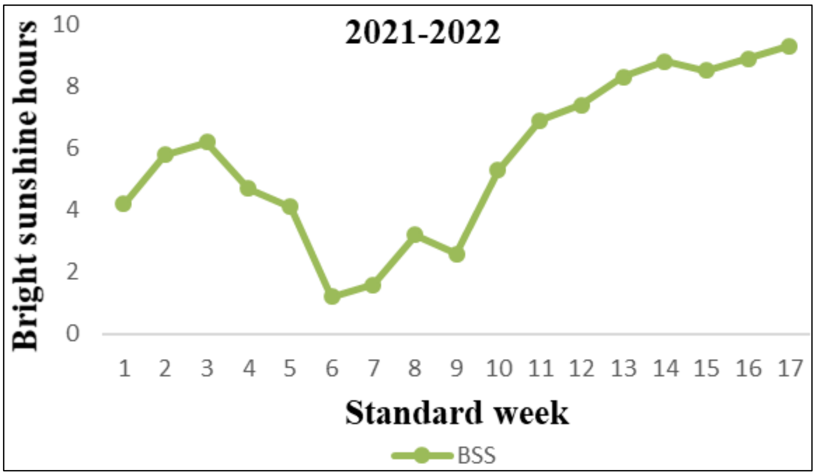


Fig 6: Trend of bright sunshine hours of cropping season during season 2020-20 and 2021-22

Acknowledgement

Authors are thankful to the Department of Plant Pathology, SVPUAT, Meerut for providing facilities to conduct the experiment. Sources of literatures are also dully acknowledged.

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