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RUST DEVELOPMENT IN PEARL MILLET CAUSED BY *PUCCINIA SUBSTRIATA* VAR. *PENICILLARIAE* IN RELATION TO DATE OF SOWING AND WEATHER PARAMETERS

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SUMMARY

Rust caused by *Puccinia substriata* var. *penicillariae* is one of the major diseases affecting both forage and grain production in pearl millet, particularly in the post-rainy cool season (**rabi**) crop. Attempt was made to find out the effect of rust of pearl millet on HHB 197, HHB 223 and HHB 197 at three different dates of sowing. Rust appearance in HHB 223 was more in comparison to HHB 197 and HHB 67 Imp. The per cent rust severity was more at recommended date of sowing in comparison to early sown and late sown crop. AUDPC was more in HHB 223 corroborating with HHB 197 but less in HHB 67 Imp. There was drastic change in apparent infection rate with adjustment in date of sowing and apparent infection rate was variable at different stages. Rust development was in progression phase when mean temperature ranged between 21°C to 28°C.

Key words : Pearl millet, rust severity, development, weather parameters

Pearl millet [*Pennisetum glaucum* (L.) R. Br. Syn. *Pennisetum americanum* (L.) Leeke] is an important staple cereal in the arid and semi-arid region of the world, particularly in Asia and Africa. India is considered to be the secondary centre of pearl millet diversity. Being most tolerant to drought and salinity, the crop is by and large grown in different countries of the world. Due to its adaptability under very wide range of agro-climatic conditions, this crop is mostly grown in the states of Andhra Pradesh, Gujarat, Haryana, Karnataka, Madhya Pradesh, Rajasthan, Tamil Nadu, parts of Delhi, Punjab and Uttar Pradesh (Annu *et al.*, 2016). In India, the total production of crop was 9.25 m tonne with area of 7.89 m ha during 2013-14 (Anonymous, 2013-14). Pearl millet is also one of major **kharif** crops of Haryana with area of 4.04 lakh ha and total grain production of 8.31 lakh tonne during 2013-14. The yield of pearl millet has increased considerably with the introduction of hybrids, but these have become susceptible to fungal diseases. Among various diseases, rust, downy mildew, ergot and smut are of economic importance in major pearl millet growing areas of the world (Raj *et al.*, 2014). *Puccinia substriata* var. *indica* Ramchar and Cumm (syn: *Puccinia substriata* Ell. and Barth. var. *penicillariae* (Carvalho *et al.*, (2006); *Puccinia penniseti Zimm*) cause rust disease in pearl millet. Identification of resistance sources is supportive step in management of diseases. In this experiment, rust development was observed in relation to date of sowing under natural conditions.

MATERIALS AND METHODS

Three genotypes viz., HHB 197, HHB 223 and HHB 67 Imp. were sown in a randomized block design with three replications on three different dates : 19th June (Early), 14th July (Recommended) and 31st July (Late) during **kharif** 2015 at the experimental area of Plant Pathology, College of Agriculture, CCSHAU, Hisar (Haryana) in 5 m row length by maintaining 50 cm between row to row and 10 cm distance between plant to plant.

Thirty plants in 5 m row were selected and tagged. First appearance of disease was observed and after first appearance rust severity was recorded at four days intervals. Area under disease progress curve (AUDPC) was calculated using the formula given by Wilcoxon *et al.* (1975).

$$[A] = \sum_{i=1}^{k=1} \frac{1}{2}(Y_i + Y_{i-1}) \times (d)$$

Where,

A=AUDPC values
Yi=Disease severity at ith day or evaluation
K=No. of successive intervals
d=Interval between ith and i- 1th evaluation

The apparent infection rate (r) was calculated by the using formula of Vanderplank (1963).

$$\mathbf{r= \frac{1}{t_2 - t_1}\left(log \frac{X_2}{1 - X_2} - log \frac{X_1}{1 - X_1}\right)}$$

Where,

r=Apparent infection rate
t_1=First date of recording disease severity
t_2=Second date of recording disease severity
X_1=Disease index at time t_1
X_2=Disease index at time t_2

Disease progress was measured at four days interval after the first appearance of the disease by using rust severity rating scale (Singh *et al.*, 1997). Weather data were collected from Department of Meteorology, CCS Haryana Agricultural University, Hisar. The data were also analyzed for regression coefficients of determinant.

RESULTS AND DISCUSSION

In this experiment, rust development in relation to date of sowing under natural conditions was observed on three hybrids viz., HHB 197, HHB 223 and HHB 67 Imp. at three different dates of sowing. It was observed that rust severity reduced with the adjustment in date of sowing of pearl millet. Rust was first observed on 10th October on hybrids HHB 197, HHB 223, whereas on hybrid HHB 67 Imp. on 15th October. The per cent rust severity in HHB 197 was 52.78 per cent in early sown and 64.60 per cent in late sown and it was comparatively lesser than the recommended sown i. e. 82.73 per cent (Table 1). Similar trend was also observed in HHB 223 and HHB 67 Imp. (Tables 2 and 3). Data presented in Tabled 1 and 2 depict that on HHB 197 and HHB 223 the rust severity was maximum during 2nd date of sowing (recommended sown) followed by 3rd date of sowing (late sown) and then on 1st date of sowing (early sown) but on HHB 67 Imp rust severity was maximum during 3rd date of sowing followed by 2nd date of sowing and then on 1st date of sowing (Table 3). Among three genotypes (hybrids), rust severity was minimum on HHB 67 Imp., whereas on HHB 223 and HHB 197 rust severity was

TABLE 1
Effect of sowing date on rust severity in pearl millet hybrid HHB 197

Observations	First date of sowing (19-06-2015)				
	Date of observation				
	10 Oct.	14 Oct.	18 Oct.	22 Oct.	26 Oct.
Rust Severity (%)	1.17	7.67	21.72	34.39	52.78
AUDPC		17.67	58.77	112.22	174.33
Apparent infection rate (r)		0.212	0.131	0.069	0.082
Second date of sowing (14-07-2015)					
	14 Oct	18 Oct	22 Oct	26 Oct	30 Oct
Rust Severity (%)	4.53	22.0	46.50	69.87	82.73
AUDPC		53.07	137.00	232.73	305.20
Apparent infection rate (r)		0.193	0.122	0.107	0.169
Third date of sowing (31-07-2015)					
	18 Oct	22 Oct	26 Oct	30 Oct	3 Nov
Rust Severity (%)	3.63	17.57	34.63	51.73	64.60
AUDPC		42.40	104.40	172.73	232.67
Apparent infection rate (r)		0.188	0.099	0.076	0.058

TABLE 2
Effect of sowing date on rust severity in pearl millet hybrid HHB 223

Observations	First date of sowing (19-06-2015)				
	Date of observation				
	10 Oct.	14 Oct.	18 Oct.	22 Oct.	26 Oct.
Rust Severity (%)	2.94	8.89	25.50	43.17	58.50
AUDPC		23.67	68.78	137.33	203.33
Apparent infection rate (r)		0.127	0.136	0.087	0.067
Second date of sowing (14-07-2015)					
	14 Oct	18 Oct	22 Oct	26 Oct	30 Oct
Rust Severity (%)	5.67	24.33	50.17	71.89	85.17
AUDPC		60.00	149.00	244.00	314.11
Apparent infection rate (r)		0.182	0.124	0.101	0.088
Third date of sowing (31-07-2015)					
	18 Oct	22 Oct	26 Oct	30 Oct	3 Nov
Rust Severity (%)	5.11	18.17	36.33	53.44	60.33
AUDPC		46.55	109.00	179.55	227.55
Apparent infection rate (r)		0.154	0.103	0.076	0.031

TABLE 3
Effect of sowing date on rust severity in pearl millet hybrid HHB 67 Imp.

Observations	First date of sowing (19-06-2015)				
	Date of observation				
	10 Oct.	14 Oct.	18 Oct.	22 Oct.	26 Oct.
Rust Severity (%)	1.00	5.94	19.11	21.50	26.28
AUDPC		13.89	50.11	81.22	95.55
Apparent infection rate (r)		0.199	0.143	0.016	0.029
	Second date of sowing (14-07-2015)				
	19 Oct	23 Oct	27 Oct	31 Oct	4 Nov
Rust Severity (%)	3.50	14.67	21.33	24.17	28.00
AUDPC		36.33	72.00	91.00	104.33
Apparent infection rate (r)		0.169	0.050	0.018	0.022
	Third date of sowing (31-07-2015)				
	20 Oct	24 Oct	28 Oct	1 Nov	5 Nov
Rust Severity (%)	3.33	11.23	16.17	24.50	28.17
AUDPC		29.13	54.80	81.33	105.33
Apparent infection rate (r)		0.141	0.046	0.057	0.021

higher. These results are in corroboration with the observations of Pathak and Choudhary (1991) who reported that rust incidence was influenced by the date of sowing. Kumar (1999) studied rust severity after 15 days of inoculation in susceptible genotype of pearl millet HHB-67 at three different ages of plants and found that disease severity was more on upper side of lower, middle and upper leaves in older plants as compared to the upper side of lower, middle and upper leaves of younger plants, where disease intensity was less. Similar trend was observed on lower side of lower, middle and upper leaves. Singh *et al.* (2012) studied the effect of different dates of sowing (sowing dates October 15 to December 13) on rust of field pea in relation to weather parameters during three crop seasons. The crop showed least rust severity when pea was planted on October 15 during all the three crop seasons. The crop when sowing lately i.e. sown on November 14, November 29 and December 13 recorded highest severity of rust. Highest grain yield was recorded from November 14 (mid) sown crop as against least, while lowest grain yield was recorded in December 13 (late) sown crop. Subasinghe *et al.* (2009) conducted field experiments to determine the influence of sowing dates and weather parameters on development of white rust disease of raya and revealed that the crop sown on 15th October recorded significantly less disease severity as compared to the crop sown on 30th November and the disease index increased with delay in sowing date during both the cropping seasons on both the cultivars of raya.

Among three hybrids evaluated, AUDPC was more in HHB 223 corroborating with HHB 197 but less in HHB 67 Imp. There was drastic change in apparent infection rate with adjustment in date of sowing and

TABLE 4
Regression equation for the progression of rust severity of pearl millet on HHB 197 in relation to weather parameters

Date of observation	Regression equation			
	X_1=TEMP (MAX.) X_2=TEMP(MIN.)	R_2 Values	X_1=RH (M) X_2=RH (E)	R_2 values
1$_{st}$ DOS** (19-06-2015)	Y=599.722-18.627X1 + 4.693X2	0.9633	Y= 62.877+1.546 X1-5.218X2	0.5103
2nd DOS (14-07-2015)	Y=569.776-21.673X1+12.05011X2	0.9310	Y= -80.667+1.696X1--0.225X2	0.3425
3rd DOS (31-07-2015)	Y=284.704-7.375X1-0.333X2	0.9517	Y= -51.704+0.614X1--0.970X2	0.2046

TABLE 5
Regression equation for the progression of rust severity of pearl millet on HHB 223 in relation to weather parameters

Date of observation	Regression equation			
	X_1=TEMP (MAX.) X_2=TEMP(MIN.)	R_2 Values	X_1=RH (M) X_2=RH (E)	R_2 values
1st DOS (19-06-2015)	Y=639.986-21.245X1+7.641X2	0.9780	Y= 64.863+1.840X1--5.888X2	0.5328
2nd DOS (14-07-2015)	Y=581.901-22.563X1+13.163X2	0.9366	Y= -82.928+1.790X1-0.310X2	0.3588
3rd DOS (31-07-2015)	Y=218.480-3.709X1-3.657X2	0.9718	Y=-14.865-0.007X1-1.431X2	0.2047

apparent infection rate was variable at different stages depending upon weather factors. Kalappanavar and Rajaram (2012) studied that loss estimation due to rust incidence on grain yield and 1000-grain weight differed with respect to the values of "Area under Disease Progress Curve" (AUDPC) of leaf and stem rusts of wheat. Higher values of AUDPC of leaf rust and stem rust in the highly susceptible variety N 59 resulted in 60 per cent reduction in the yield and 53 per cent in 1000-grain weight. Lower values of AUDPC of leaf and stem rust were noticed in HD 2189, NIAW 34 and MACS 2846 with a lower loss in yield ranging from 9-13 per cent and loss in 1000-grain weight from 7-18 per cent (Hasabnis, 1998). In general, severe infection with both the rusts resulted in maximum reduction in seed germination and seedling vigour (Kalappanavar and Patil., 2000).

Rust development was in progression phase when mean temperature ranged between 21?C to 28?C indicating the average minimum temperature range of 14.9?C to 20.6?C, whereas the average maximum temperature range was 28.7?C to 36.9?C.

Rust progression was more on hybrid HHB 223 starting from 4.53 per cent of rust severity to the 82.73 per cent within 20 days after first appearance of the disease. During this period, morning relative humidity (mRH) remained more than 70 per cent reaching to the hike of 84.5 per cent and evening relative humidity (eRH) remained around 30 per cent. Rust progression on hybrid HHB 67 Imp was in corroboration with that of HHB 223. Panwar and Wilson (2001) reported that rust was not observed in the experimental plots until the average weekly temperatures fell below 27?C during 1997 and 1998. An increase in rust infection was associated with a decrease in maximum and minimum temperature. Average weekly minimum temperature at the termination of epidemics (death of susceptible varieties) was 19.2?C in 1997 and 16.7?C in 1998. These were within the optimum temperature range for urediniospore germination of *Puccinia substriata* var. *indica* (Tapsoba

TABLE 6

Regression equation for the progression of rust severity of pearl millet on HHB 67 Imp in relation to weather parameters

Date of observation	Regression equation			
	X_1=TEMP (MAX.) X_2=TEMP(MIN.)	R_2 Values	X_1=RH (M) X_2=RH (E)	R_2 values
1st DOS (19-06-2015)	Y=181.281-7.838X1+5.473X2	0.8222	Y=-30.289+0.585X1-0.051X2	0.2367
2nd DOS (14-07-2015)	Y=60.615-2.274X1-6.565X2	0.8198	Y=-2.068-0.147X1+0.826X2	0.1888
3rd DOS (31-07-2015)	Y=85.528-0.239X1-4.205X2	0.9935	Y=-84.029+0.889X1+0.675X2	0.6886

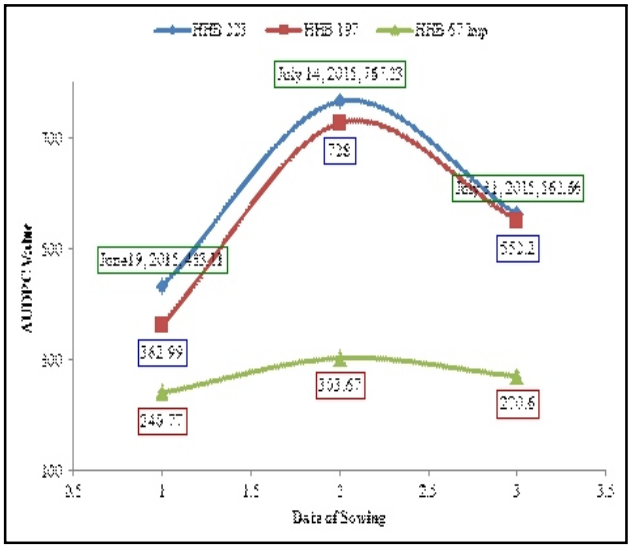

Fig. 1. Total AUDPC value in hybrid HHB 223, HHB 197 and HHB 67 Imp when sown on different dates of sowing.

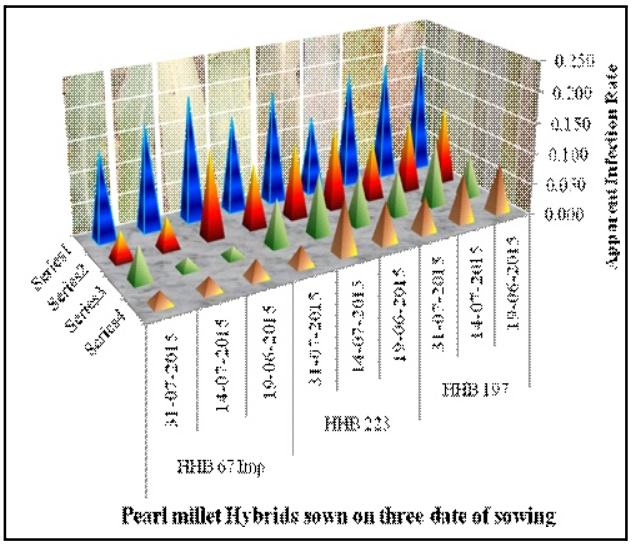

Fig. 2. Apparent rust infection rate of hybrids HHB 67 Imp., HHP 197 and HHB 223 sown on different dates of sowing.

and Wilson, 1997). Mean relative humidity (RH) reached a low of 62.5 per cent at the termination of the epidemics in 1998; lower than the RH recorded on several dates when no rust infection was observed by Muthusamy *et al*. (1981).

Periodical progression was more during last week of October when the average maximum temperature was 34.1?C and average minimum temperature 18.6?C and the relative humidity morning was 79 per cent and evening was 28 per cent. No direct effect of rainfall was observed for progression of rust on HHB 197. Cumulative progression was more in recommended date sown crop on hybrids HHB 197 and HHB 223, whereas on HHB 67 Imp cumulative progression was more in late sown crop corroborating with recommended date sown and minimum on early sown crop.

Regression coefficient of determinant (R^2) indicated in Table 4 that 96, 93 and 95% of the variation in rust severity was due to temperature factors included multiple regression equation in three dates of sowing on HHB 197. Regression coffiecient of determinant (R^2) of HHB 223 and HHB 67 Imp also indicated in Tables 5 and 6 that 97%, 93%, 97% and 82%, 81%, 91% respectively of the variation in rust severity was indicated due to weather parameter i.e. temperature factor even sown at three different date.

Rust appearance in HHB 223 was more in comparison to HHB 197 and HHB 67 Imp due to its physiological appearance in addition to the congenial environmental conditions. The rust progression was lesser in HHB 67 Imp. because leaf size was smaller in comparison to HHB 197 and HHB 223. Lesser rust severity in HHB 67 Imp may be attributed to other factors also.

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