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A simple weather based forewarning model for white rust in *Brassica*

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ABSTRACT

Field experiments were carried out with two *Brassica* varieties Pusa Jaikisan and Bio-169-96 (a genotype at the final stages of release) at the Indian Agricultural Research Institute farm during two *rabi* seasons of 2004-05 and 2005-06. The two varieties were sown on 15th and 30th October. Observations on incidence and spread of white rust were recorded to develop a suitable forewarning model. Incidentally, the 30th October sown plants were found to be infested more by white rust to the tune of 30 and 35 per cent in Bio-169-96 and Pusa Jaikisan respectively, as compared to about 16 and 17 per cent in the 15th October sown plants. A thumb rule was developed to forewarn the incidence of white rust and model equations were developed using hourly weather data of the past to assess the disease severity quantitatively.

Keywords: *Brassica*, forewarning model, weather and white rust

In India, rapeseed and mustard are among those few crops which are closely associated with farming community probably because of their multiple uses like, seed for edible oil, cake for fodder, green leaves/ branches as vegetable or fodder and straw as good quality fuel in rural areas. In spite of its utility, the fact remains that area and production of rapeseed and mustard are not increasing at a required pace. Low productivity of mustard in India may be attributed to several biotic and abiotic stresses.

Among the biotic stresses, white rust caused by *Albugo candida,* plays a major role in reducing the seed yields particularly in Northwest part of the country. Saharan *et al., (*1984) reported yield losses to the tune of 36.8% due to floral infection in late sown mustard. It seems that when infection is restricted to leaves, the yield loss is less, but when it infects inflorescence, there is enormous reduction in the yield. Malik (1989) found 61.5 per cent loss in oil yield of *B. juncea* due to white rust infestation and indicated that all Indian cultivated species of *Brassica*, particularly, *B. juncea* were highly susceptible to this disease. Kumar *et al.,* (1995) studied role of various factors in development of white rust of rapeseed mustard and found that late sown crop of Indian mustard suffered maximum due to white rust as compared to early and normal sown crop. The white rust, which belongs to lower fungi Oomycetes overwinters as resting spores in decaying infected plant tissues (mainly stagheads) or, as a seed contaminant or, in soil. In all the cases the microenvironment particularly moisture and temperature play key role in germination of spore, incidence and spread of disease.

Khunti *et al*., (2004) found that maximum (between 22 and 27 ^oC) and minimum (between 8 and 11 ^oC) temperatures and the maximum relative humidity (>70%) favoured disease development. Low sunshine for 24-72 hrs during the flowering time coupled with low temperature and high relative humidity favoured staghead development. Rain played an important role in the development of the disease. Thus, though there were many attempts relating the white rust with various weather parameters, no attempt has been made to quantify the effect or to develop a weather based forewarning model and hence an attempt was made towards achieving this goal which as far as the authors know, is the first of its kind being reported among the mustard growing countries.

MATERIAL AND METHODS

Field experiments were conducted on the research farm of the Indian Agricultural Research Institute (IARI) New Delhi (longitude of 77^{o}0' E, latitude of 28^{o}10' N and at an altitude of 228.7 m above sea level) during two *rabi* seasons of 2004-05 and 2005-06. Two cultivars of *Brassica juncea* viz., Pusa Jaikisan and BIO-169-96 were sown on 15th and 30th October with a

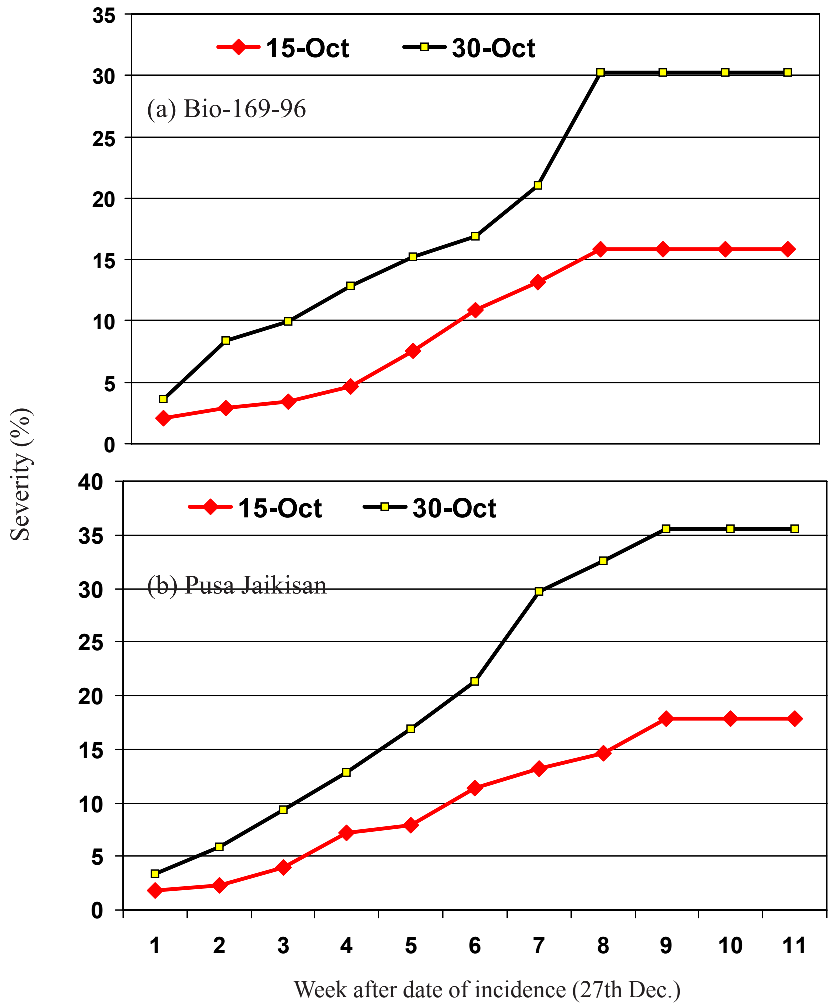

Fig. 1: Weekly proress of white rust severity during 2004-05 season

row-to-row spacing of 45-cm. and seed rate of 6 kg ha^{-1} in a randomized block design with three replicates. The crop was grown following the standard agronomic practices recommended for this area under "not-short of water" conditions. These two cultivars differ in their maturity and growth habits. The soils of the experimental site are sandy-clay-loam in texture and structure is weak to medium angular blocky. Pusa Jaikisan is a high yielding mustard variety with a plant type of semi - compact and medium plant height (approximately 185 cm). It is a medium duration (125-135 days), bold seeded and lodging resistance variety. Oil content of this variety is nearly 40 per cent. This cultivar is popular in the states of Rajasthan, Gujarat and parts of Maharashtra.

BIO-169-96 is a pipeline variety under multi-locational trial with encouraging results. It is a highly proliferating variety in terms of leaf area and biomass. It is a late maturing cultivar, which takes 140-150 days to complete its life cycle.

Ammonium sulphate @ 40 kg N ha^{-1} was applied as basal dose and Urea @ 40 kg N ha^{-1} was applied as top dressing after first irrigation. Single Super Phosphate @ 40 kg P_2O_5 ha^{-1} and Murate of Potash @ 40 kg K_2O ha^{-1} were also applied as basal dose as per recommendation during discing at the time of seedbed preparation. *Metasystox* was applied @ 2ml L^{-1} at required interval to control aphids and other insect damage in order to see the impact of weather on the white rust disease only.

Ten plants in each treatment combinations were selected and tagged to monitor white rust disease incidence and progress. Each leaf of all selected plants was visually observed and percentage area affected by white rust was noted down. The observations included total number of leaves in selected plants, number of infected leaves and percentage area affected in infected leaves. These observations were taken at weekly intervals and data obtained were used to calculate disease severity at different intervals. The percent disease intersity was converted into 0-5 grades (G).

$$\text{Severity (\%)} = \frac{(\Sigma\, N{*}G)}{\Sigma\, N5} \text{ x } 100$$

N = Number of leaves in each grade (G)

G= disease grade

Data on white rust disease during 2002-03 and 2003-04 *rabi* seasons (unpublished data generated from the same field) were used to develop relationship between disease and weather. Various relationships between different weather elements and white rust severity at different time were explored to assess the future disease conditions. Linear, second order, exponential were tried to quantify the relationship. Finally Multilinear regressions were developed using backward step technique starting with eight independent variables viz., maximum minimum temperatures, morning and evening relative humidity, sunshine hours, rainfall, wind speed and disease severity of previous week. Finally the number of variables was brought down to four significantly affecting variables.

Different combinations of temperature range and relative humidity were tried. Using hourly data, the number of hours of temperature between 10-15, 10-20 and 12-18^{o}C was counted. Similarly hours with relative humidity greater than 70 per cent and greater than 80 per cent were also counted separately. In addition, sunshine hours and rainfall were also analyzed. Using the data of 2002-03, 2003-04 and 2004-05 a thumb rule was made which was validated during 2005-06 (disease free year).

RESULTS AND DISCUSSION

In Pusa Jaikisan, during 2004-05 crop season, white rust was observed on 27th December in both the sowings and in both the varieties though the severity differed marginally in the initial stages (Fig.1). The disease severity was maximum in case of late sown crop throughout the season, touching a maximum of 35 per cent as compared to 17.8 per cent in the early sown crop.

In case of Bio-169-96 also, the disease incidence was noticed on 27th December and starting from this date, week numbers are represented in the diagram. The initial severity of 2.1 and 3.6 per cent was noticed in early and late sown crops, respectively. Disease severity increased with time and maximum severity was observed to be 15.8 in 8th week after incidence (5th Feb.2005) in the early sown crop while in the late sown crop, the severity was much more (30 per cent).

In both the cultivars the disease was observed to be maximum in the late sown plots. Quite interestingly, the disease was confined to leaves only, in all the plots. Higher severity in late sown crop was probably due to more susceptible foliage available for longer time as well as more favorable microenvironment after disease incidence. It also indicates the importance of plant factors in disease incidence and severity. A point to be borne in mind from this study is that though October 30th is within the sowing window recommended for Delhi region, there is every possibility that the crop sown on 30th October would have fair chances of getting infested with the white rust. Hence it is advisable to have the sowings at the earliest date to avoid the yield losses due to white rust disease.

During 2005-06 *rabi* season, the weather conditions were found to be in favor of the farmer in the sense that the long sunshine hours coupled with prolonged high humidity hours and absence of winter rain with foggy days during December/January inhibited the white rust appearance.

Seed yields

During *rabi* 2004-05, the seed yield of Pusa Jaikisan was 32.6 q ha^{-1} in the first sown crop while in the late sown crop, it was about 7 q ha^{-1} lower (Table

Table 1: Seed yield (q ha^{-1}) in Pusa Jaikisan and Bio-169-96 during 2004-05 (I) and 2005-06 (II) crop seasons sown on 15th and 30th October.

Date of sowing	Pusa Jaikisan (I)	Pusa Jaikisan (II)	BIO 169-96 (I)	BIO 169-96 (II)
15th October	32.6	21.4	34.6	24.7
30th October	25.7	23.9	25.0	23.0

1). Similarly, in the Bio 169-96 too, the seed yields were lower in the late sown crop by about 9.6q ha^{-1} as compared to the first sown crop which yielded 34.6 q ha^{-1}. Between the 15th and 30th October sowings, the reduction in seed yield was about 21 per cent in the Pusa Jaikisan and 28 per cent in the Bio-169-96. It is interesting to see that in the second season (2005-06), there was a marginal difference in the seed yields between the early and late sown crops in both the varieties.

Thus, in the absence of any major differences in weather or soil moisture conditions in both the seasons, the yield reduction of 21 and 28 per cent could probably be attributed to the white rust to a great extent. Saharan and Lakra (1988) also reported 23 to 54.5 per cent yield loss due to floral infection by white rust in late sown mustard in Haryana.

Forewarning model for white rust

After incidence, the disease progresses through secondary infection while its spread is primarily governed by plant and the weather conditions. In both the dates of sowing and cultivars, the rate of spread depended on weather/microenvironment conditions. The earlier reports by Kolte *et al.,* (1986) who found a positive correlation of rain with the development of stag heads and Lakra and Saharan (1990) who observed that relative humidity (RH) more than 65% and average temperature less than 15^{0}C favored the rapid progress of white rust gave a clue about factors responsible for the disease development.

For incidence forecasting, daily as well as hourly temperature and relative humidity values were analyzed for the common condition of "disease incidence" and "no incidence". For this purpose, disease and weather data of 2003-2004, 2004-2005 and 2005-2006 were used. After having surveyed the available literature it was decided to consider a temperature range of 10-15, 15-20, 12-18 and 10-20 ^{0}C, while relative humidity greater than 70 and 80 per cent as favorable to disease incidence. In all possible combinations for the above range, progressive sum (moving totals) of number of hours of past days was tried. Further, it was reported (Kumar *et al.,* 1995) that under control conditions disease symptoms appear after 6 to 8 days hence sum of past 6, 8, 10 and 12 days was tried for all possible combinations under above mentioned range to see the favorable conditions for disease incidence.

In the combination of temperature between 10-20°C and relative humidity greater than 80%, as well as sunshine hours, progressive sum of the number of hours for past 10 days for 2003-2004, 2004-2005 and 2005-06 were plotted. The disease data used were for crop sown between 15th and 30 October.

During 2003-04, disease incidence noticed on 24th December and the sum of past 10 days of temperatures between 10-20°C, RH>80% and sunshine hours for the same day were 189, 233 and 5.0 hours respectively. In the subsequent season (2004-05) sum of past 10 days of temperature between 10-20°C, RH>80% and sunshine hours for the same day were 175, 193 and 9.0 hours respectively.

Hourly weather data of 2002-03 was not available but sunshine hours and rainfall was analyzed. In this case rainy days modified the conditions and disease incidence was observed within 10 days of two rainy days with 14.2 and 14 mm rainfall. It indicates a bigger role of rainfall in deciding incidence of disease and hence if there are rainy days during December-January, disease is likely to occur.

A new thumb rule has emerged from this study as enumerated below:

If sum of hours in consecutive ten days with

a) Temperature ranging from 10 to 20 ^{o}C is more than 150;
b) Relative humidity more than 80 per cent is more then 180 and
c) Actual bright sunshine hours is less than 10

then, it is quite likely that the white rust disease would appear in the mustard crop.

OR

If there are rainy days during December and January along with the total sunshine hours of past ten day less than 40, then the white rust would appear.

Validation of the proposed thumb rule

For year 2005-06, sum of past 10 days of temperature between 10-20°C, RH>80% maximum were 111 and 222 hours while sun shine hours was not less than 32.3 hours. Here a condition for temperature and sunshine hours was not fulfilled and hence no disease was expected. In confirmation of this rule there was no incidence of disease during 2005-06.

Thus, among three parameters used, sunshine hours seem to be more sensitive parameter for incidence forewarning and hence in absence of hourly weather data, sunshine hours taken from nearby meteorological station can be incorporated for disease forewarning.

Though the proposed thumb rule was developed based on three years' data much needs to be done to make it more general which would be of immense use and would go a long way in disease forecast. This proposed thumb rule needs to be validated in different seasons and probably the limits may be modified according to the agro-ecological zones.

Forecasting the disease severity

Once disease has occurred it is important to observe and forecast disease severity. Various combinations of weather parameters were worked out to relate with progress of disease. Pair-wise linear, second order, third order, logarithmic and exponential relations were attempted taking weather parameter as independent variable and increase in disease severity in the current week as dependent variable. Finally it

Table 2: Multiple regression equation for disease severity forcasting

No.	Equation	R^2
	For 15 Oct. sown crop with past 3 day weather data	
1	$Y = 3.455 + 0.819Y_{(-1)}{}^{*} - 0.517Tmax + 0.628\ Tmin - 0.005\ RHm + 0.05\ RHe - 0.276Rain + 1.248\ SShr^{*}$ (0.102) (0.274) 0.354) (0.151) (0 .95) (0.325) (0.376) -1.048 wind speed* (0.402)	0.81
2	$Y = 6.406 + 0.821\ Y_{(-1)}{}^{*} - 0.538\ Tmax^{*} + 0.641\ Tmin^{*} - 1.105\ SShr^{*}. - 1.048\ Wind^{*}$ (1.026) (0.092) (0.114) (0.264) (0.105) (0.170)	0.80
	For 15 Oct. sown crop with past 6 day weather data	
3	$Y = 6.796 + 0.910\ Y_{(-1)}{}^{*} - 0.368\ Tmax^{*} - 1.277\ SShr^{*}. + 0.99$ Wind speed* (1.402) (0.092) (0.083) (0.274 (0.47)	0.79
	For 30 October swon crop with past 3 day weather data	
4	$Y = 4.013 + 1.092\ Y\ (-1)\ ^{*} -0.285\ Tmax + 0.426\ Tmin^{*} + 0.675\ Rain$ (1.113) (0.043) (.0143) (0.107) (0.157)	0.91
	For 30 October swon crop with past 6 day weather data	
5	$Y = 3.862 + 1.123\ Y_{(-1)}{}^{*} - 0.265\ Tmax + 0.393\ Tmin - 0.975\ rain^{*}$ (2.098) (0.043) (0.145) (0.112) (0.373)	0.90
6	$Y = 6.796 + 0.910\ Y_{(-1)*} - 0.368\ Tmax^{*} + 0.81\ Tmin^{*}. - 0.32\ SShrs^{*} + 0.47$ RH hrs*. (1.50) (0.072) (0.10) (0.21) (0.15) (0.17)	0.88

(Value in parenthesis is standard error of corresponding coefficients in equation,
*: Significant at 1 per cent).

was decided to go for backward stepwise multi-linear regression taking average of past three and six days of all above mentioned weather parameters as well as disease severity of last observation (a week ahead) as independent variable and disease severity as dependent variable.

$Y_{(-1)}$: Disease severity of previous week, Tmax: Maximum temperature, Tmin: Minimum temperature, SShrs : Sunshine hours and RH hrs: Hours of relative humidity >80per cent.

Thus, this weather-based forewarning model developed is considered to be highly useful in forewarning about the possible incidence of this disease at an early stage for taking preventive steps. However, this model thumb rule needs further fine-tuning and test at other locations. Moreover, it is recommended that the sowings be done on or about 15th October in the North West India to avoid the white rust infestation for the farmers to realize improved seed yields.

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