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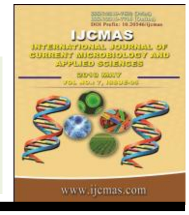

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Weather Based Forewarning Model for Yellow Rust of Wheat in Scarcity Zone of Jammu and Kashmir, India

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A B S T R A C T

A forewarning model of stripe rust of wheat for predicting the disease initiation in Jammu sub-tropics was developed by the analysis of disease severity data pertaining to the years from 2005-06 to 2012-13 obtained from AICRP research experiments available in the Division of Plant Pathology. The analyzed data was validated during *rabi* season 2014-16. Predicted severity by Gompertz model (1.93 to 55.93%) was very close to the observed values (1.14 to 57.66%) with a precision of 99.50 per cent from 1st to 14th SMW as compared to predicted estimate of 4.42 to 54.70 per cent by Logistic model having precision of 98.50 per cent in 2005-13. The prediction of disease severity through analyzed data of 2014-16 by using models (Logistic and Gompertz) revealed that Gompertz showed an accuracy of 99.60 per cent in which predicted severity was 2.47 to 57.60 per cent.

Introduction

Globally wheat is being cultivated in 220 million ha with production of 743 million tones, whereas it is cultivated over an area of 29.80 million ha with production of 90 million tonnes in India (Anonymous, 2016a). In Jammu and Kashmir, wheat was cultivated over an area of 2.91 lakh ha having production of 0.58 million tonnes during 2014-15 (Anonymous, 2016b). Stripe rust of wheat has been most widely distributed in cooler wheat growing regions comprising more than 60 countries in the world and has caused severe damage in central East and West Asia, Europe, Uganda, Ethopia, Kenya, Australia, New Zealand, North and South America, Mexico and Chile (Chen *et al.*, 2009; Wellings, 2011). Cultivation of susceptible cultivars coupled with very early infection of the disease causes 100 per cent yield losses (Afzal *et al.*, 2007). The annual losses due to stripe rust were estimated to be 0.8 to 1.5 million tonnes in India (Brennan and Murray, 1988; Wan *et al.*, 2004). Various management strategies employed against stripe rust included combination of cultural practices, host resistance along with fungicide applications (Roelfs *et al.,* 1992). Although chemical fungicides have been effective to manage the disease but are not considered eco-friendly and exert negative effects on the environment and human health (Jensen and Jorgensen, 1991), whereas growing of resistant cultivars is the most economical, effective and environmentally safe (Line, 2002). Severe stripe rust epidemics generally occur due to the occurrence of new pathotypes which overcome prevailing resistance genes (Chen, 2007). Forecasting of the disease is another alternative in devising the strategies to manage the disease and presently various models are available to predict the plant diseases (Maanen and Xu, 2003a; Foster *et al.*, 2011). Environmental conditions play a decisive role in driving the pathogen-host-rust epidemic system (Khan, 1997). Gompertz and Logistic regression approaches were employed widely between disease severity and epidemiological factors in forecasting plant diseases (Chen, 2009; Eddy, 2009). The prediction of disease epidemics or disease forecasting provides information regarding the timing of disease infection, infection cycle, severity of disease infection, crop loss and estimating the frequency or the probability of the disease (Maanen and Xu, 2003b). Keeping in view the importance of the disease in the region, the present studies were undertaken.

Materials and Methods

Epidemiological studies

To develop prediction model of stripe rust of wheat for Jammu sub-tropics, nine years (2005-13) data of disease severity of stripe rust of wheat (cv. PBW 343) from Division of Plant Pathology, Faculty of Agriculture, SKUAST-Jammu. In order to validate the developed model, the experiments were conducted at the University Research Farm, Chatha during *rabi* seasons of 2014-15 and 2015-16.

Layout of experiment

The seed of susceptible wheat variety PBW 343 was obtained from the Division of Plant Pathology and experimental plots were laid out with plot size of 2mx4m on 8th November, 2014 and 11th November, 2015, in randomize block design (RBD) with four replications having row to row distance of 22.5 cm.

Monitoring disease severity and data collection

Severity of stripe rust was observed on weekly intervals starting from the appearance of first disease symptoms till the end of the season (January to April, 2014-16). The infected plants were labelled randomly (5/plot) and the disease severity was recorded using modified Cobb's scale (Peterson *et al.,* 1948).

Data Analysis

The rate of disease increase with time was assessed using logistic model (Van der Plank, 1963) and Gompertz model (Berger, 1981). Analysis of variance (ANOVA) were also calculated for assessment of weather and disease severity which were computed by least significant difference test ($P<0.05$).

Results and Discussion

Non-linear regression of stripe rust severity of wheat

Logistic and Gompertz models were computed during 2005-13 and 2014-16 and the findings (Table 1) revealed that the apparent infection rate (a), rate of change in apparent infection with time (b) and maximum carrying capacity of disease (c) were 0.64, 21.69, 54.84 and 0.42, 5.15, 56.72 per cent having R^2 of 0.985 and 0.995, respectively during 2005-13. During 2014-16 the value of a, b, c was 0.65, 19.34, 56.54 and 0.43, 4.58, 58.27 per cent with R^2 of 0.987 and 0.996 for Logistic and Gompertz models, respectively. Predicted severity by Gompertz model (1.93 to 55.93%) was very close to the observed values (1.14 to 57.66%) with a precision of 99.50 per cent from 1st to 14th SMW as compared to predicted estimate of 4.42 to 54.70 per cent by Logistic model having precision of 98.50 per cent during 1st to 14th SMW in 2005-13 (Fig. 1). The prediction of disease severity through analyzed data of 2014-16 by using models (Logistic and Gompertz) revealed that Gompertz showed an accuracy of 99.60 per cent in which predicted severity was 2.47 to 57.60 per cent as compared to observed severity of 2.00 to 59.00 per cent from 1st to 14th SMW as comparable to predicted estimate (5.09 to 56.42%) by Logistic model (Fig. 1).

Gompertz model has been ascertained and more applicable for the study of development of the disease (Berger, 1981), which determines the initial disease appearance, estimation of epidemics rate and protection from spread of disease severity by adopting management practices.

Table.1 Non-linear regression of stripe rust severity of wheat

Parameter	2005-13		2014-16	
	Logistic	Gompertz	Logistic	Gompertz
a	0.64	0.42	0.65	0.43
b	21.69	5.15	19.34	4.58
c	54.84	56.72	56.54	58.27
R^2	0.985	0.995	0.987	0.996
MSE	7.01	2.412	6.24	1.925

a= Apparent infection rate, b= Rate of change in apparent infection with time, c=Maximum carrying capacity of disease

Table.2 Analysis of variance of severity of stripe rust of wheat during 2005-13

Source	SS	DF	MS	F-Value	*P*-value
Month	35501.60	3	11833.86	422.32	0.001*
Year	209.19	8	26.15	0.93	0.495
Replication	56.14	2	28.07	1.00	0.372
Year x Month	639.46	24	26.64	0.95	0.538
Error	1961.46	70	28.02		
Total	213034.48	108			

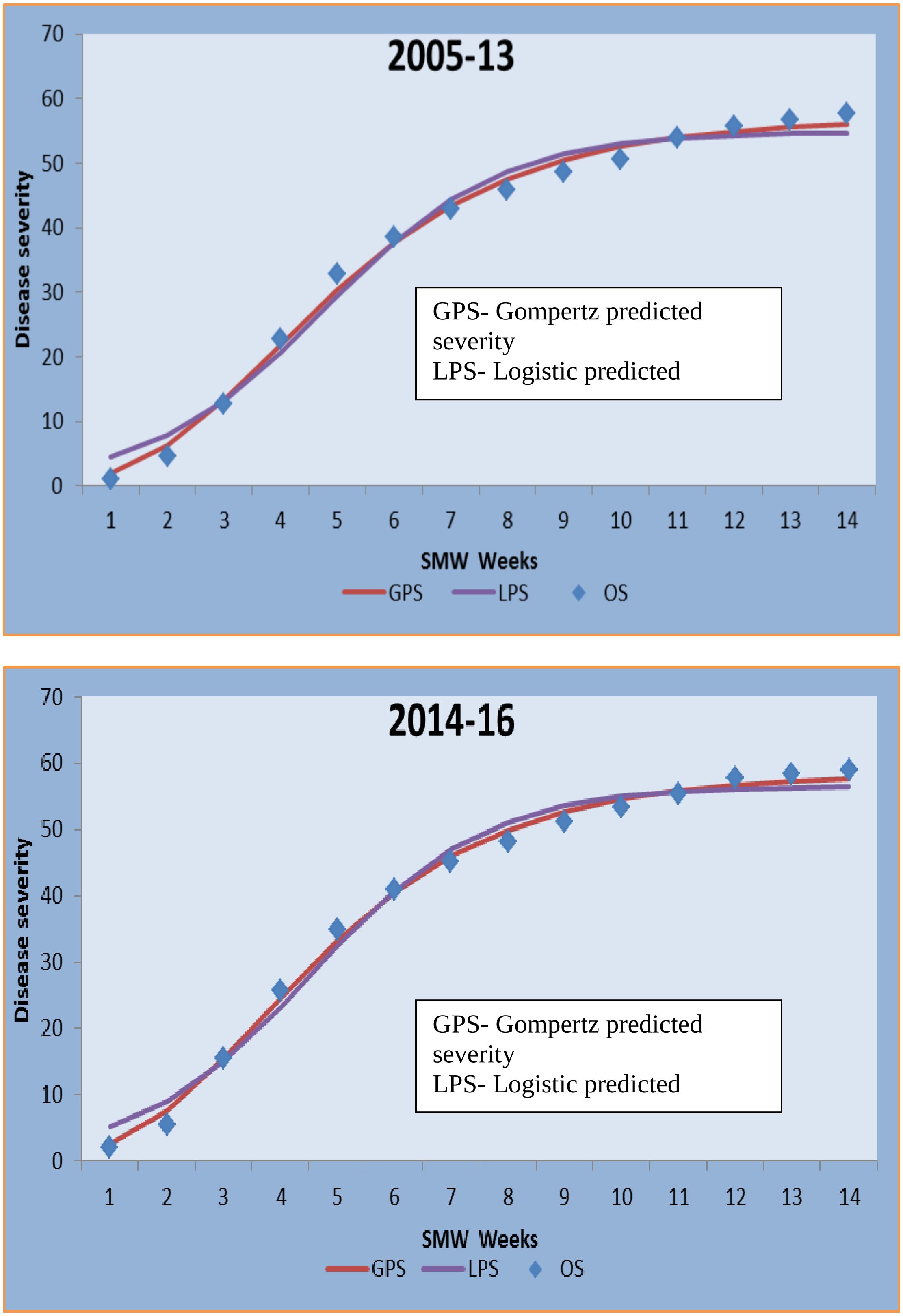
*Significant at $P<0.05$

Table.3 Analysis of variance of severity of stripe rust during 2014-16

Source	SS	DF	MS	F-Value	*P*-value
Year	2.891	1	2.891	11.141	**0.005***
Month	7815.006	3	2605.002	1004	**0.000***
Replication	0.059	2	0.029	0.113	0.894
Year x Month	0.046	3	0.015	0.059	0.980
Error	3.633	14	0.260		
Total	50225.703	24			

*Significant at $P<0.05$

Fig.1 Prediction of disease severity of stripe rust of wheat by Logistic and Gompertz models



Although the Logistic model (van der Plank, 1963) has been widely used for comparison of the rate of disease progress in several plant pathosystems, but Gompertz model has been proved more appropriate for analysis of the progress of epidemics. Similarly, Gompertz model was reported best fitted in various pathosystems especially in polycyclic diseases such as wheat leaf rust, apple scab and groundnut rust (Hau and Kranz, 1977; Analytis, 1979; Das and Raj, 2000).

Analysis of variance of severity of stripe rust of wheat

Data (Table 2) indicated that the effect of year and interaction of year and month was non-significant whereas individual effect of month was significant during 2005-13, which indicated that there were great variations of disease severity with respect to month. Further, data in the Table 3 revealed that the effect of year and month on the severity of stripe rust during 2014-16 was significant but the interaction of year and month was not significant which indicated that there was variation of disease severity with respect to month and year. Ahmad *et al.*, (2010) reported that stripe rust severity increased with increase of minimum temperature and relative humidity but severity decreased with the increase of maximum temperature.

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