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Development of prediction equations for early blight leaf spot on tomato under different fungicides treatments

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ABSTRACT

Field experiment was conducted during 2008-09 and 2009-10 to study the influence of different weather factors on the development of early blight on tomato caused by *Alternaria solani* (Ell. and Mart.) under six different fungicidal treatments and also to compare the two transformation models viz. Logit and Gompertz through which the disease progress curve move over time. Here, different prediction equationswere developed for each fungicide treatment separately through step down multiple regression analysis which showed that different meteorological factors having different influence on disease severity and these were done after Logistic and Gompertz transformation of the realized observed value of the disease severity (expressed as AUDPC).Results revealed that among the six fungicides tested Mancozeb was superior in controlling the disease severity with the lowest (AUDPC: 97.34 and 95.74) for the two experimental years respectively. Linearization of area under disease progress curve (AUDPC) following the two models (Logit and Gompit) showed that Gompit fit better than Logit for the prediction of early blight disease severity and this was confirmed by the low standard error estimate value of Gompertz. The co-efficient of determination value (R^2) showed thatvariation in disease severity can be explained up to 77 percent (with an exception 85percent in case of Mancozeb application in 2009-10) in Logistic as well as 88 percent in Gompertz with combined effect of the weather variables included in the present study. Among the seven meteorological factors considered only average temperature,RH and total rainfall were found to act positively and significantly,whereas, bright sunshine hours were found to have negative significant effect on early blight disease severity on tomato. These situations were observed in both the transformation models but vary with in the treatments and with in the years.

Keywords : Area under disease progress curve, early blight, Logistic andGompertz model, prediction equation, weather parameters

Tomato (*Lycopersicon esculentum* Mill) is one of the most popular vegetable grown all over the world. In India tomato has wider coverage in comparison to other vegetables. The leading tomato growing states are Uttar Pradesh, Karnataka, Maharashtra, Haryana, Punjab, West Bengal, Assam and Bihar. West Bengal is the leading producer of tomato accounting 1063.7 ('000 ton)in 2010-11 (Anonymous, 2012)and share 6.43percent of the total production. Tomato universally treated as "Protective Food" is being extensively grown as annual plant all over the world. It is a very good source of income to small and marginal farmers and contributes to the nutrition of the consumers. Tomato is a rich source of minerals, vitamins and organic acids. There are various types of flavouring compounds found in the fruits, which enrich the taste.

Every year cultivation of tomato cause is declining due to different biotic and abiotic stresses. Among the biotic stresses, diseases play pivotal role and among the fungal diseases, early blight caused by (*Alternaria solani*) is the most destructive one (Doolittle, 1948). Tomescu and Negru (2003) also reported that the main fungi causing the economical losses in all region is *Alternaria solani*. The infection occurs on all the plant parts, leaves, stem, petiole, calyx and fruits. It is prevalent throughout the tomato growing areas in the world (Calvo *et al.*, 1990) and also causes major yield loss (Waals *et al.,* 2001). Yield losses ranges between 50-86 percent (Mathur and Shekhawat, 1986). Yield losses upto 79 percent from early blight damage have been reported from India, Canada, United States and Nigeria. Saha and Das (2012) reported that losses in yield was 0.76 t ha^{-1} for every 1 percent increase in disease severity.

Environmental factors play an important role on the development of disease as they help the pathogen for growth, dissemination and infection (Walker, 1965). The occurrence and development of infection by *Alternaria* *solani* are favoured by the availability of primary infection source, temperature, RH and the presence of water drops (from rainfall, dew or sprinkler irrigation) on plants for >2 hr/day Dragomir (1995). Disease progress most rapidly when alternating period of dry and wet weather occur (Singh *et al.*, 2001).

Tomato can be grown throughout the year but the severity of the disease varies during different years possibly as a result of changing environmental parameter in the field.

It is well known facts that study on the factors affecting epidemic development of the disease are important for successful and economic management of disease. Applications of different fungicides are known to reduce the early blight disease severity but its efficacy variesin different years due to the prevalence of different meteorological parameters.

So, before drawing any conclusion regarding the nature of relationship between the disease severity in different chemicals applied plots and the weather parameters it is essential to verify the linearity of disease progress in simulation studies. Linearization of disease progress curve was essential to determine the rate of epidemic, project future disease development and estimated initial disease severity. Normally the disease progress of early blight of tomato is sigmoidal. It is in consonance with the polycyclic nature of the pathogen and is amenable to linearization through suitable transformation (Mayee and Datar,1986). Here, two transformation equations were used for devising linearized mathematical models, viz., logistic (Van der Plank,1963) and Gompertz (Berger,1981) .

The current status of work was undertaken to study the influence of different weather factors that act as a predisposing factor for the development of early blight leaf spot on tomato and to formulate suitable prediction equations through step down multiple regression analysis of disease severity data from different chemicals applied plots in two different transformation models which ultimately aim to develop suitable economic management techniques through the use of right fungicide at right time on the basis of predicted disease severity involving the prevailing weather parameters.

MATERIALS AND METHODS

The field experiment was conducted on tomato taking the variety "Patharkuchi" (indeterminate type and susceptible to *Alternaria* blight) during the year 2008-09 and 2009-10 at the University In-check Farm Kalyani, under Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal. The soil of the farm was sandy loam in texture and belongs to the hyperthermic family with the pH 7.2.The experiment was laid out as randomized block design with three replicationsand the plot size was 5m×5m. All the other recommended cultural practices were followed.

Treatments details

The following chemical fungicides were sprayed Mancozeb (Indofil M 45 75% WP), Carbendazim (Bavistin 50% WP), Propiconazole (Tilt 25% EC), Chlorothalonil (Isshan 75% WP), Hexaconazole (Mass Plus 5% EC) and Difenaconazole (Score 25% EC) three times where first spray was given at the initiation of disease and then twice at 15 days interval after first spray.

Disease scoring

The onset time was monitored as the appearance of first symptoms and disease severity were recorded every 10 days subsequently 0-9 scale (Mayee and Datar, 1986). Ten plants per plot were selected for recording the disease severity under natural epiphytotic condition at random and whole plant were assessed upto the 15 days before harvest. Borders rows were discarded for assessment. The disease severity was calculated by using the following formula given by Mckinney (1923)

$$\text{Percent disease index (PDI)} = \frac{\text{Sum of all numerical ratings} \times 100}{\text{Total number of leaf observed} \times \text{maximum rating}}$$

The disease severity was averaged over the three replications and disease progress curves were plotted. For each replication the area under disease progress curve was calculated as per (Wilcoxon *et al.* 1975). The formula used as follows:

AUDPC = Ni=1" $[(Y_{i+1} + Y_i)/ 2 (X_{i+1} - X_i)]$

Here, AUDPC = area under disease progress curve, Y_i = severity at 1st observation, X_i = time (days) at first observation, N = total number of observation.

Transformation models used under study

The data obtained were subjected to both Gompertz (Kranz,1974; Berger, 1981) and Logistic transformation (Van der Plank,1963) using the following equation:

Logistic = Logit (x) = ln [x/1-x)]

Gompertz = Gompit (x) = - ln [-ln(x)]

Where x = Proportion of disease tissue.

Apparent infection rate calculated either as logistic infection rate (r) or Gompertz infection rate (k), for each increment of time determined using the respective formulae:

dx/dt = xr(1-x) in case of polycyclic pathogen, Vander Plank (1963)

x= the proportion of tissue diseased.

r= apparent infection rate.

(1-x)= the proportion of tissue available for infection.

exp.In = Logarithms (to the base e)

a,k,c,b and 0.05 = constant

The best fit of a specific model to the data was determined by comparison of the rate parameters (*'r'* for logistic and *'k'* for Gompertz), which is nothing but the regression coefficient *'b'*, *y*-intercept (*a*).

Weather parameters and statistical analysis

Data on weather variables viz. average temperature (T_{mean}), average relative humidity (RH), vapour pressure (VP), cloudiness (C), total rainfall (Rain), wind velocity (WV) and bright sunshine hour (BSH) The meteorological data was collected from AICRP on Agro-Meteorology, Kalyani. Ten days mean of weather parameters (variables) were calculated except rainfall where ten days cumulative rainfall and total number of rainy days were worked out. To predict the disease development, multiple regression equations were computed for the cultivar by using SPSS computer software. Coefficient of determination (R^2) was also calculated and tested for significance at 1percent level of probability. Disease prediction models were developed by the following equation:

$$Y\ (PDI) = a + b_iX_i + e$$

Where, Y= predicted disease index, a= intercept, b_i = regression coefficient for X_i (i=1……n) and X_i = independent variable (i=1……n i.e weather parameters),e= random error.

Step down multiple regression analysis was applied to disease severity data. The goodness of fit to the model so obtained was evaluated by co-efficient determination (R^2); adjusted determination of co-efficient (R^2 adj) and error means square (MSE). So, a final evaluation of the model was determined based on the above three criteria (Berenson *et al.* 1983, Coakley *et al.*1988).

RESULTS AND DISCUSSION

The results indicated that among the six fungicides tested, Mancozeb was found significantly superior in controlling early blight disease severity with the AUDPC value 97.34 and 95.74 respectively for the year 2008-09 and 2009-10 (Table 1 and 2). It was followed by Hexaconazole(AUDPC: 97.53) in the year 2008-09. Other fungicides like Carbendazim (AUDPC: 97.85), Chlorothalonil (AUDPC: 99.30), Difenconazole (AUDPC: 99.80) and Propiconazole (AUDPC: 100.77) were next effective in reducing early blight of tomato in the year 2008-09. Whereas Carbendazim (AUDPC: 96.20) was found next to Mancozeb in reducing the early blight disease in the year 2009-10. It was followed by Hexaconazole (AUDPC: 97.01), Difenconazole (AUDPC: 98.57), Chlorothalonil (AUDPC: 98.84), and Propiconazole (AUDPC: 99.81). In both the two experimental years control plot showed maximum disease severity with the AUDPC of 102.59 and 101.80 respectively.

Mohammad (1988) and Choulwar and Datar (1988) reported that preventive spray of Mancozeb (0.25percent) gave effective control in early blight of tomato. This result also in accordance with the result of Chaulwar and Datar(1992), Follas *et al.*(1992), Devanthan and Ramanujam (1995) and Mate *et al.*(2005).

The results showed in the Tables 1 and 2 concluded that both the model can be equally fit to depict the disease progression over time but lower standard errors ofGompertz model suggested that Gompit fit better thanLogitin case of early blight in tomato. Among the Logit transformation, it was best fit in chlorothalonil and propiconazole applied plot with (k=0.124 and 0.052 a=3.861 and 4.341 b=(-) 0.698 and (-)1.098 with MSE value=0.092 and 0.008) in the year 2008-09 and 2009-10 respectively. In case of gompertz transformation a,b value is always lower than the logit and also showed low MSE value.

The dynamic process of plant disease depends upon the interactions among the host, pathogen and the environment. The variation in any one of the factor influence the disease development. Here, environmental

Table 1: Characteristics of early blight disease severity on tomato subjecting to Logit and Gompit transformation under different chemicals treatment during the years 2008-09

Treatments	AUDPC	Logit transformation value				Gompit transformation value			
	2008-09	k	a	b	MSE	a	b	c	MSE
Mancozeb	97.34	0.593	4.702	(-)0.959	1.143	0.183	0.008	0.785	0.002
Propiconazole	100.77	0.050	4.457	(-)1.166	1.543	0.061	0.019	0.596	0.536
Hexaconazole	97.53	0.077	4.674	(-)1.002	1.388	0.108	0.014	0.681	0.007
Carbendazim	97.85	0.204	3.954	(-)0.539	1.025	0.002	0.001	1.022	0.147
Chlorothalonil	99.30	0.124	3.861	(-)0.698	0.092	0.520	0.008	0.835	0.005
Difenconazole	99.80	0.090	4.168	(-)0.916	1.121	0.050	0.001	0.896	0.004
Control	102.59	0.181	3.882	(-)0.551	0.987	0.178	0.024	0.769	0.147

AUDPC = Area under disease progress curve, MSE= Error mean square

Table 2: Characteristics of early blight disease severity on tomato subjecting to Logit and Gompit transformation under different chemicals treatment during the years 2009-10

Treatments	AUDPC	Logit transformation value				Gompit transformation value			
	2009-10	k	a	b	MSE	a	B	c	MSE
Mancozeb	95.74	0.062	4.533	(-)0.920	1.023	0.196	0.008	0.790	0.006
Propiconazole	99.81	0.052	4.341	(-)1.098	0.008	0.061	0.020	0.599	0.007
Hexaconazole	97.01	0.069	4.913	(-)1.134	1.001	0.079	0.013	0.611	0.002
Carbendazim	96.20	0.207	3.790	(-)0.500	1.015	0.003	0.002	1.012	0.009
Chlorothalonil	98.84	0.098	3.977	(-)0.891	0.875	0.466	0.010	0.827	0.003
Difenconazole	98.27	0.091	4.124	(-)0.921	0.179	0.226	0.001	0.898	0.006
Control	101.80	0.132	3.557	(-)0.596	0.489	0.105	0.029	0.681	0.006

AUDPC = Area under disease progress curve, MSE= Error mean square

variation was considered over the two experimental periods and took it as an independent variable in the regression equation to develop prediction equationsconsidering both the model Logit and Gompit to linearise the disease progress curves. Depending upon the nature of the disease progress curves, one model may fit better than the other into a specific plant pathosystem.

Prediction equations

The average temperature (T_{mean}), relative humidity (RH), rainfall (Rain) were positively andsignificantly correlated and bright sunshine hours (BSH) were negativelyand significantly correlated with the progression of the disease through AUDPC following the two different models tested. In the year 2008-09 predicted disease severity portrayed from the Logit model was found to be correlated positively significantly with the relative humidity (RH) and the mean temperature (T_{mean}) for all the chemical treatments.In the year 2009-10 only temperature mean was found to be significantly and positively relatedwith all the treatments except Chlorothalonil where temperature average was found to have no effect in the prediction of disease severity.

Unlike Logit, under Gompertz prediction equation it was observed that the disease severity in all the chemical treatments depend upon both relative humidity and rainfall positively and significantly except Hexaconazole and Carbendazim where average temperature was related positively and significantly along with relative humidity

Table 3: Multiple regression equation for early blight disease severity on tomato under different chemical treatments during 2008-09.

Treatments	Regression equation	Coefficient of determination (R^2)	Adjusted (R^2)	Std. Error of the estimate
Mancozeb	(L)Y= -0.154+ 0.124 T_{mean}+ 0.233 RH	0.770**	0.740	0.514
	(G)Y= - 0.146 + 0.103 RH+ 0.004 Rain	0.856**	0.832	0.213
Propiconazole	(L)Y= -0.151+ 0.004 T_{mean}+ 0.783RH	0.395*	0.324	0.416
	(G)Y= - 0.146 + 0.139 Rain + 05673RH	0.700**	0.725	0.215
Hexaconazole	(L)Y= -0.213+ 0.340 T_{mean} + 0.475 RH	0.445*	0.431	0.397
	(G)Y= - 0.193 +0.234 T_{mean}+ 0.504 RH	0.743**	0.729	0.118
Carbendazim	(L)Y= -0.205+ 0.158 T_{mean}+ 0.855 RH	0.458*	0.432	0.619
	(G)Y= - 0.223 + 0.605 RH	0.862**	0.833	0.302
Chlorothalonil	(L)Y= -0.234+ 0.467 T_{mean}+ 0.355 RH	0.545*	0.531	0.521
	(G)Y= - 0.243 + 0.578 RH + 0.159 Rain	0.845**	0.831	0.322
Difenconazole	(L)Y= -0.237+ 0.583 T_{mean}+ 0.367 RH	0.444*	0.429	0.623
	(G)Y= - 0.260 + 0.236 RH + 0.479 Rain	0.876**	0.832	0.523
Control	(L)Y= -0.208+ 0.345T_{mean}+ 0.675 RH	0.345*	0.332	0.619
	(G)Y= - 0.201 + 0.465 RH + 0.579 Rain	0.643**	0.629	0.419

L= Prediction equation depicted from logistic transformation, G= Prediction equation depicted from Gompertz transformation, **= Singnificant at 1percent level of probability,*= Singnificant at 5percent level of probability

Table 4: Multiple regression equation for early blight disease severity on tomato under different chemical treatments during 2009-10.

Treatments	Regression equation	Coefficient of determination (R^2)	Adjusted (R^2)	Std. Error of the estimate
Mancozeb	(L)Y= 0.161+ 0.578 T_{mean}- 0.018 BSH	0.854**	0.542	0.313
	(G)Y= 0.154 + 0.324 T_{mean}- 0.018 BSH	0.553*	0.542	0.113
Propiconazole	(L)Y= 0.188 + 0.458 T_{mean}- 0.022 BSH	0.365*	0.356	0.612
	(G)Y= 0.182+ 0.675 Rain - 0.021 BSH	0.667**	0.659	0.211
Hexaconazole	(L)Y= 0.230 + 0.356 T_{mean}- 0.026 BSH	0.659**	0.648	0.517
	(G)Y= 0.215 + 0.564 RH - 0.025 BSH	0.864**	0.855	0.714
Carbendazim	(L)Y= 0.207+ 0.543 T_{mean}- 0.023 BSH	0.753**	0.741	0.618
	(G)Y= 0.212 + 0.134 Rain - 0.024 BSH	0.848**	0.835	0.719
Chlorothalonil	(L)Y= 0.267- 0.030 BSH	0.558*	0.549	0.519
	(G)Y= 0.267+ 0.576Rain - 0.003 BSH	0.889**	0.837	0.423
Difenconazole	(L)Y= 0.271+ 0.532 T_{mean}-0.031 BSH	0.759**	0.649	0.419
	(G)Y= 0.262 - 0.030 BSH	0.749**	0.737	0.523
Control	(L)Y= 0.223 + 0.533 T_{mean} 0.025 BSH	0.355*	0.324	0.417
	(G)Y= 0.236 + 0.327 T_{mean}- 0.027 BSH	0.764**	0.735	0.315

L= Prediction equation depicted from logistic transformation, G= Prediction equation depicted from Gompertz transformation, **= Singnificant at 1percent level of probability,*= Singnificant at 5percent level of probability instead of rainfall and in case of Carbendazim only relative humidity affects positively and significantly discarding the effect of the other two parameters in the year 2008-09 (Table 3).

During 2009-10, predicted disease index following Gompertz model showing variation due to the prevalence of different weather factors. In case of Mancozeb, Difenconazole applied plot along with the control plot it was observed that disease severity depended upon BSH negatively and significantly and related with the T_{mean} positively and significantly. Total rainfall was significantly and positively correlated with disease severity in case of Propiconazole, Carbendazim and Chlorothalonil applied plot whereas bright sunshine hours was negatively significantly related with the predicted disease index in those treatments. Only bright sunshine hours was found negatively and significantly related with the disease severity in Chlorothalonil and Difenconazole application.

From the above equations it is observed that, T_{mean} plays the major role for initiation and spread of the early blight disease. In both the year T_{mean} relates positively and significantly with the disease severity and RH and Rainfall (thin film of water adherence after rain) help in spore germination it is also related positively and significantly. Unlike RH, BSH make the leaves dry which is having adverse effect in spore germination so, it is negatively significantly related with disease severity. In the year 2009-10, may be due to the effect of BSH overall progression of disease is comparatively lower than 2008-09 as indicated in table 1 and 2.

Coefficient of determination (R^2) value indicated that the predicted value of PDI can be explained 34.5 percent to 77.0 percent of the total variation in the PDI in case Logit transformation scale and Gompit exhibit 64.3 percent to 87.6 percent variation in the prediction of disease severity in the year 2008-09. In 2009-10, this variation was from 35.5 percent to 85.4 percent under Logit and 55.3 percent to 88.9 percent under Gompit respectively.

The best fit of one model over the other has been attained by comparison of the regression parameter *Y*-intercept (Fried *et al.* 1979); R^2(Berger, 1981 and Waggoner, 1986) Among the two transformation model, high co-efficient of determination value (R^2) of Gompit and low standard error estimate of Gompit in both the year prove that Gompit fit better than Logit in case of early blight of tomato when treated with different fungicides. In the year, 2009-10, high co-efficient of determination value (R^2) of Logit in case of Mancozeb applied plot may fit better than Gompit but low standard error estimate of Gompit again prove that Gompit fit better in this situation also (Table 4). The estimation and comparison of all the parameters in the present investigation resulted in fitting of 85.42 percent and 88.9 percent of the disease progress curves into the logistic and Gempertz models, respectively.

CONCLUSION

These general observations on different disease progress curves of six chemicals tested over the period of two seasons have been well defined in the regression equation developed taking environmental parameter into account which showed that independent parameters are more closely associated with the development of early blight. The regression line in Gompertz model was more fit compared with those in Logit model. Our findings have shown a good correlation between the two models (coefficient of determination value 0.77 and 0.85 in logistic as well as 0.88 in Gompertz model). Where gompertz value showed 0.88, it means in case of chlorothalonil applied plot there is a change of 88 percent disease severity with the positive significant effect of rainfall and negative significant effect of bright sunshine hours in combination. It is also applicable under different situations, since the present disease progress curves encompass a wide spectrum of disease severities ranging from 0.09 to 0.59 logistic and 0 to 0.52 Gompertz apparent infection rates, which are generally encountered under different environmental conditions. These curves will have wider practical applicability in an integrated disease management program, while taking a decision as to whether to take profilactive measures or not.

REFERENCES

Anonymous, 2012 (Source, http://data.gov.in/dataset/all-india-and-state-wise-area-and-production-vegetables)

Berger,R.D. (1981). Comparison of Gompertz and Logistic equations to describe disease progress. *Phytopatholgy,* **71**: 716-719.

Berenson,M., Sevine, D. and Goldstein, M. (1983). Intermediate Statistical Methods and application. Prentice Hall.XVII 579 pp

Calvo, D.G., French, J.B., Siman, J. and Kooper,T. (1990).

Agroeconomic characterization of phytoprotection in tomato crop in the central valley of Costa Rica. *Manego Integrado do Plagas.,* 15: 67-82.

Chaulwar, A.B. and Datar, V.V. (1988). Cross linked spray scheduling for the management of tomato early blight. *Ind. Phytopathol.,* 41 (4): 603-606.

Chaulwar, A.B. and Datar, V.V. (1992). Management of tomato early blight with chemicals. *J. Maharashtra Agri. Uni.,* 17 (2): 214-216.

Coakley, S.M., Mc. Daniel, L.R. and Shaner, G. (1988). Predicting stripe rust severity on winter wheat using an improved method for analyzing meteorological and rust data. *Phytopathol.,* 78: 543-550.

Devanathan, M. and Ramanujam, K. (1995). Evaluation of fungicides for the management of early blight of tomato caused by *Alternaria Solani.Madras. Agric. J.*, 82: 228-229.

Doolittle, S.P. (1948). *Vegetable crops*.486pp.

Dragomir,N. (1995). Contribution to the study of the epidemiology and control of the fungi *Alternaria porri sp solani* (Ell.andMart.)Neerg. and *Cladosporium fulvum* Cooke attacking the outdoor early tomato crop. *Anale Institutul de Cercetari Pentru Legumicultura Si Vidra.,* 13: 235-242.

Follas, G.B., Beetz, H.M. and Popay, A.J. (1992). Control of leaf spots in carrots and early blight of potatoes and tomatoes with difenconazole. *Proceedings New Zealand Plant Protection Conference.,* 2: 46-49.

Fried, P.M., Mackenzie, D.R. and Nelson, R.R. (1979). Disease progress curves of *Erysiphe graminis f.sp.tritici* on chancellor wheat and four multilines. *Phytopathol*., 95: 151-166.

Kranz, J. (1974). The role and scope of mathematical analyse and modeling in epidemiology. In Epidemics and Plant Diseases, Mathematical Analysis and Modeling (Ed. J. Kranz), pp. 7-54 Sringer, New York, 170 pp.

Mate, G.d., Deshmukh,V.V., Jiotode,D.J., Chore,N.S. and Mayur,D. (2005). Efficacy of plant products and fungicides on tomato early blight caused by *Alternaria solani*. *Res Crops,*6 (2): 349-351.

Mathur,K. and Sekhawat, K.S. (1986). Chemical control of early blight in kharif sown tomato. *Indian J. Mycol. Pl. Pathol*., 16: 235-238.

Mayee, C.D. (1986). Epidemiology and management of groundnut rust in: Vistas in Plant Pathology (eds Verma, A and Verma, J.P.) New Delhi, Malhotra Publishing House, 307-309pp.

Mayee, C.D. and Datar,V.V. (1986). Phytopathometry, Technical Buletien-1 (Special Buletein -3), Marathwada Agric. Univ. Parbhani, India, 218pp.

Mc.Kinney,H.H. (1923).Influence of soil temperature and moisture on infection of wheat seedling by *Helminthosporium sativum*. *J.Agric.Res.,*26: 195-217.

Mohammad, S.E. (1988). Control of tomato early blight under plastihouse condition in Ninevah Province Iraq.*Mesopotami J Agric.,*20(2): 359-366.

Saha, P. and Das, S. (2012). Assessment of Yield Loss Due to Early Blight (*Alternaria solani)* in Tomato. *Ind. J. Pl. Protec.*, 40 (3): 195-198

Singh, R.P., Sher, S., Rana, M.K. and Singh, S. (2001). Effect of host nutrition on early blight of tomato. *J. Mycol. Pl. Pathol.,* 31 (2): 248-250.

Tomescu, A. and Negru, G. (2003). An overview on fungal diseases and pests on the field tomato crops in Romania. *Acta Horticulturae.*, 613: 259-266.

Vander Plank, J.E.(1963). Plant Disease Epidemics and control. Academic Press. NewYork. 349 pp.

Waals, J.E., Korsten, L. and Aveling, T.A.S. (2001). A review of early blight of potato. *African Plant Protection.,* 7 (2): 91-102.

Waggoner, P.E. (1986). Progress curves of foliar diseases: Their interpretation and use. Pages 3-37, In: Plant Disease Epidemiology: Population Dynamics and Management Vol.I. Leonard, K.J. and Fry, E.W. ed., MacMillan publishing Co., New York.372pp.

Walker, J. C. (1965). Use of environmental factors inscreening for disease resistance. *Ann. Rev. Phytopathol.,* 3:197-208.

Wilcoxcon, R.D., Shovm, B. and Asit, A.A.(1975). Evaluation of wheat cultivar for the ability to retard development of stem rust. *Ann.App.Biol.,*86(2): 275-287.

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