TEMPORAL ANALYSIS OF SEPTORIA LEAF BLOTCH PROGRESS IN WHEAT

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Abstract

To evaluate appropriate models for prediction of temporal progress of wheat Septoriosis caused by Septoria tritici, epidemiological studies were conducted in greenhouse and field for two consecutive growing seasons in 2006–2007 and 2007–2008. Disease progress was determined on five wheat cvs. Tajan, Zagros, Koohdasht, Shanghai, Shirrodi and two lines (N-80-60 and N-80-19) using a complete randomized block design with four replicates. Field experiments were carried out at Araghi-mahale research station in Gorgan province. Inoculation was repeated three times, in 15 days intervals. After symptom appearance, disease index was recorded and continued until flag leaf infection, every other day. Disease progress was recorded by Saari-Prescott (Double digit) method. Various epidemiological models including Monomolecular, logistic, log-logistic, Gompertz and Weibull were used to evaluate disease progress. Fitness of different models was examined by Coefficient of Correlation, Maximum Error, Root Mean Square Error, Coefficient of Determination, Modeling Efficiency, Coefficient of Residual Mass Parameters. The results of field experiments showed that monomolecular model was not a suitable model for any cultivar or line due to high RMSE and CRM, low CD and EF. The greenhouse experiments confirmed these results as well. Logistic model had high efficiency in all cultivars and lines with the exception of N-80-19 in 2006-2007. In this line, log- logistic model was evaluated as the most suitable model. Based on field experiments in 2007-2008 logistic model in cvs. Shirrodi, Shanghai, and N-80-6 line and log- logistic model in cvs. Tajan, Zagros, Koohdasht, N-80-6 and N-80-19 lines were the most appropriate models. The results of greenhouse experiments revealed that logistic model was evaluated as the most suitable model excepting Shanghai and N-80-19. Log- logistic and Weibull (c = 2) models were considered as preferred models in Shanghai and N-80-19, respectively. Greenhouse experiments were repeated twice and both of them confirmed these results. Generally, based on the results of field and greenhouse studies, logistic and log- logistic were the most appropriate models. This study examined temporal progress of wheat Septoriosis on common cultivars in the north of Iran for the first time.

Key words: epidemiological models, temporal progress, wheat, *Septoria tritici*

INTRODUCTION

The Septoria blotch diseases of wheat are incited by *Septoria tritici* Roberg in Desmaz. (Telemorph: *Mycosphaerella graminicola* (Fuckel) J. Schrot in Cohn) and cause major foliar disease of wheat, inflicting considerable yield losses in many countries worldwide. Disease importance and crop loss were significant when Mexican cultivars with good farm characters like high yield, toleration to various environments and resistance to rust were used in many countries. It caused significant crop loss in many countries because of susceptibility of these varieties to Septoriosis (Eyal, 1999).

This disease is the second important disease (after yellow rust) in hot and moderate climate of Iran. The epidemics of this disease occurred in most parts of Iran at 1996 (Dadrezaie et al., 2003) and in Golestan province during 2002-2003 (Kia et al., 2006). Leaf and glum wheat Septoria blotch decreases yield by 31 to 51 percent yearly (Eyal et al., 1987). The sources of primary inoculum are rather variable: airborne ascospores, pycnidiospores from plant residues, wild grasses and possibly infested seeds. Ascospores of *Mycosphaerella graminicola* produced on wheat stubble are an important inoculum source worldwide and play a significant role in disease epidemiology (Cunfer and Ueng, 1999). Pycindiospores are most important as secondary inoculum and high rainfall increases spore splashing and infection in early-sown autumn wheat. Precipitation helps disease dispersion to upper leaves during stem extension (Shaw and Royle, 1989). Disease incidence depends on cultivar susceptibility, inoculum availability, crop management practices and favorable environmental conditions (cool temperature, high humidity and frequent rain). The greatest risk to a crop is related to the occurrence of conditions that favor spore dispersal during and shortly after flag leaf emergence. Spore dispersal and infection at this time favors a second generation of the pathogen (Cordo et al., 1999).

There is no research on temporal analysis of wheat septoriosis in Iran. Septoria leaf blotch of wheat is one of the most important diseases of wheat which reduce yield yearly and temporal analysis is the first step for disease forecasting system. In this study, various epidemiological models were used to evaluate wheat septoriosis progress in time in greenhouse and field conditions and the best suitable models were introduced.

MATERIALS AND METHODS

Greenhouse study. Experiments were carried out in complete randomized block design with four replicates. Five wheat cultivars including Tajan, Zagros, Koohdasht, Shirrodi, Shanghai and two lines named N-80-6 and N-80-19 were used in these experiments. Based on cutivar- isolates interaction results, cvs. Shanghai and Tajan were resistant and susceptibile to Septoria blotch, respectively. Other cultivars and lines were moderately susceptible (unpublished data). Four pots per variety and/or line and five plants per pot were used. Two single-spored isolates of *Septoria tritici* which were collected from Golestan province were mixed and used for inoculation. Virulence of isolates was tested on cv. Darab2. These two isolates were determined to have the highest virulence among tested isolates. Potato dextrose broth was inoculated with 5-mm plug of each fungal isolate and was shaken for 4-7 days at 25°C. Spore concentration was adjusted to 2×10^6 spores/ml. Seedlings were inoculated at the two-leaf stage using the quantitative techniques of Eyal et al. (1987). After inoculation pots were covered with transparent plastic for 72 hours to increase humidity and promote infection. Greenhouse temperature was controlled at 22.5 ± 2.5°C. Disease severity was assessed 15 days after inoculation on the first (coleoptilar) and second leaves, using the Saari- Prescott (1975) scale. Disease recordings were continued until flowering.

Field study. The field study was conducted during 2006–2007 and 2007–2008 in Gorgan (Araghi-mahale) research station. Cultivars and lines which were used in greenhouse experiments, were sown at early December in four rows plots, 5 m long with 1.2 m width. The space between rows was 30 cm and within rows was 5 cm. A complete randomized block design was used. Inoculum was prepared as above and applied in calm and rainy

Tab. 1: Epidemiological models which were used for temporal analyses of Septoria leaf blotch of wheat

Model	Linearized form
Monomolecular	$\mathrm{Ln}[1/(1-y)] = \mathrm{Ln}[1/(1-y_0)] + r_m t$
Logistic	$\mathrm{Ln}[1/(1-y)] = \mathrm{Ln}[y_0/(1-y_0)] + r_R t$
Gompertz	$-\mathrm{Ln}[-\mathrm{Ln}(y)] = -\mathrm{Ln}[-\mathrm{Ln}(y_0)] + r_G t$
Log-logistic	$\mathrm{Ln}[y/(1-y)] = \mathrm{Ln}[y_1/(1-y_1)] + r_{ll}\mathrm{Ln}(t)$
Weibull	$\mathrm{Ln}[1/(1-y)]^{1/c} = -a/b + t/b$ or $\mathrm{Ln}[1/(1-y)]^{1/c} = -c\mathrm{Ln}(b) + c\mathrm{Ln}(t-a)$

weather during March at 2×10^7 spores/ml. Artificial inoculation was performed at three growth stages including tillering (GSZ, 37), stem elongation (GSZ, 45) and flag leaf opening (GSZ, 53). Disease severity was assessed after symptom appearance. Disease recording was continued until flag leaf infection every other day, using Saari-Prescott (1975) method. Double digit index and disease severity were recorded in both experiments.

Data analysis. Disease index and disease severity were evaluated with various epidemiological models including Monomolecular, logistic, log-logistic, Gompertz and Weibull (Table 1). The regression analyses were done using Statgraphic 3.0 software. Disease progress rate (r) was used to calculate dy/dt. Finally predicted and observed curves were drawn.

Fitness of models. Fitness of different models was examined by coefficient of correlation (R^2) and Mean Square Error (MSE). Analysis of residual errors, differences between observed and predicted values were used to evaluate model performance as well. Complementary analyses using Maximum Error (ME), Root Mean Square Error (RMSE), Coefficient of Determination (CD), Modeling Efficiency (EF) and Coefficient of Residual Mass (CRM) were carried out. The mathematical expressions of these statistics are as follow (Homaee et al., 2002):

$$R^2 = \frac{\sum (y_p - \bar{y})^2}{\sum (y_i - \bar{y})^2}$$

$$ME = \max\left|y_p - y_i\right|$$

$$CRM = \frac{\sum_{i=0}^{n} y_i - \sum_{i=0}^{n} y_p}{\sum_{i=0}^{n} y_i}$$

$$EF = \frac{\sum_{i=0}^{n}(y_i - \bar{y})^2 - \sum_{i=0}^{n}(y_p - y_i)^2}{\sum_{i=0}^{n}(y_i - \bar{y})^2}$$

$$RMSE = \left[\frac{\sum_{i=0}^{n}\left(y_p - y_i\right)^2}{n}\right]^{1/2}$$

$$D = \frac{\sum_{i=0}^{n}\left(y_i - \bar{y}\right)^2}{\sum_{i=0}^{n}\left(y_p - \bar{y}\right)^2}$$

Where y_p is the predicted values, y_i the observed values, n is the number of samples and Ō is the means values. The low limit for ME, RMSE and CD is zero. The maximum value for EF is one. Both EF and CRM can be negative. The ME value represents the worst case performance of the model, while the RMSE value shows how much the prediction overestimate or underestimate the observations. The CD gives the ratio between the scatter of the predicted values and of the observations. The EF value compares the predicted values to the averaged observed values. A negative EF value indicates that the averaged observed values give a better estimate than the predicted values. The CRM is the measure of the tendency of the model to overestimate or underestimate the observations. A negative CRM shows a tendency to overestimate. If all predicted and observed data are the same, the statistics yield: ME = 0; RMSE = 0; CD = 1; EF = 0; CRM = 0. Finally, simplicity of the model is one of the most important factors for choosing it.

RESULTS

Greenhouse study. Disease severity was assessed 15 days after inoculation. The results showed that logistic, Gompertz and Weibull models gave equal results in cv. Tajan due to R^2, ME, MSE and RMSE. When CD, EF and CRM were compared, both Weibull (c = 3) and logistic models were more efficient than the others in this cultivar for describing disease progress curve (Table 2). Finally, logistic model considered as the best model for disease progress describing due to simplicity of model.

Comparing R^2 and ME of the models for cv. Zagros showed that logistic, Gompertz and Weibull models are the same (Table 2). Weibull was not appropriate model due to high RMSE, CRM and low EF (Table 2). Neither monomolecular model was appropriate because of high ME, CRM and low CD (Table 2). Considering EF, CRM, RMSE and model simplicity logistic model was more efficient one.

Comparing the parameters which were described above showed that (Table 2) logistic model was the most appropriate model in cvs. Shirrodi, Koohdasht and N-80-6 line, while log-logistic and Weibull (c = 2) were more efficient models in cv. Shanghai and N-80-19 line, respectively. Monomolecular model was not a suitable model in all cultivars and lines due to high RMSE, CRM and low CD, EF (Table 2).

As a result, logistic was appropriate model in all studied cultivars and lines except for Shanghai and N-80-19. P values were less than 0.01 in this model in all cultivars and lines. Also it had the best residual distribution (between –2 and +2) than other models.

Both disease index and disease severity were used in statistical analysis. Results showed that disease index was more suitable than disease severity in disease progress modeling. Greenhouse experiment was repeated twice. Disease progress curves of best model for each cultivar and line was shown in Figure 1.

Field study

First year (2006–2007). Disease severity was assessed 30 days after inoculation. Data were analyzed using Statgraphic 3.0 software. The results showed that logistic, Gompertz and Weibull (c = 2) were the same in cvs. Tajan, Zagros and Shirrodi due to R^2, ME and RMSE (Table 3). Logistic and Weibull models were most appropriate when CD, EF and CRM were compared (Table 3). Finally, logistic was known as the suitable model due to simplicity of model.

Based on parameters which were compared above (Table 3), logistic was the most suitable model in cvs. Koohdasht, Shanghai and N-80-6 line. Log-logistic was the most efficient model in N-80-19 line.

Monomolecular model with high R^2 and low ME was not suitable model in disease progress modeling due to high RMSE, CRM and low CD, EF (Table 3).

Based on results, logistic was the most suitable model in all cultivars and lines except N-80-19 line. P value was less than 0.01 and the residual distribution pattern was the best. Results showed that disease index was more suitable than disease severity in disease progress modeling. Observed and predicted disease progress curves and dy/dt curves were shown in Figure 2.

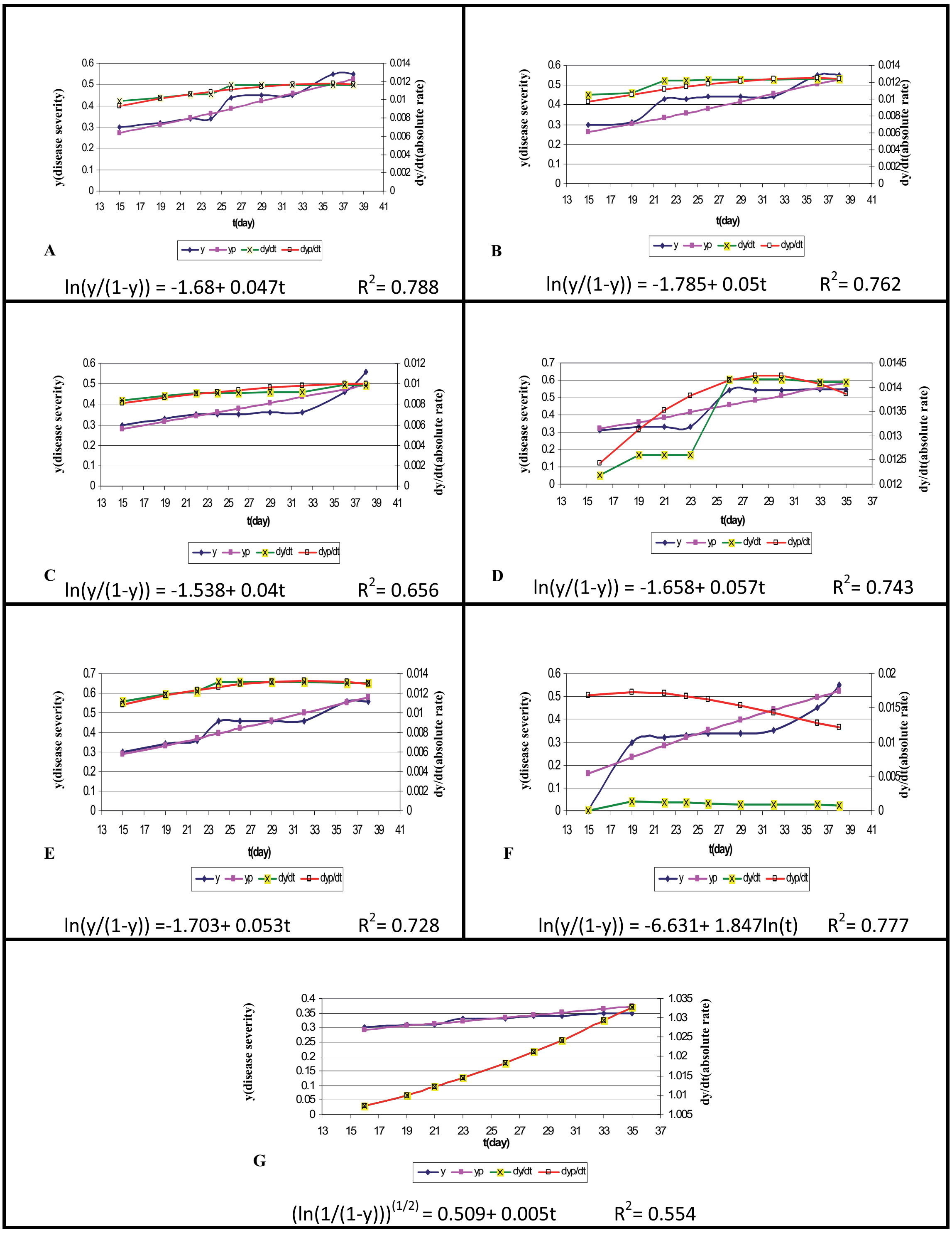
Second year (2007–2008). In this experiment, disease severity was assessed 30 days after inoculation as well

Tab. 2: Statistics values of disease progress evaluated models in cvs. Tajan, Zagros, Koohdasht, Shirrodi, Shanghai and N-80-6, N-80-19 lines at greenhouse condition

Cultivar/ Line	Model*	R^2	MSE	ME	RMSE	CD	EF	CRM
Tajan	M	0.762	0.007	0.03	0.03	0.116	–0.084	0.893
	L	0.788	0.033	0.02	0.03	1.200	0.891	0.042
	LL	0.712	0.045	0.04	0.04	1.360	0.843	0.044
	G	0.779	0.016	0.02	0.03	1.149	0.867	0.051
	W2	0.778	0.003	0.02	0.04	1.159	0.848	0.059
	W3	0.785	0.001	0.03	0.03	1.168	0.913	0.027
Zagros	M	0.757	0.008	0.03	0.05	0.083	–1.512	0.896
	L	0.762	0.043	0.01	0.05	0.769	0.627	0.089
	LL	0.713	0.053	0.02	0.05	0.835	0.651	0.088
	G	0.763	0.019	0.02	0.05	0.759	0.646	0.086
	W2	0.763	0.003	0.02	0.05	0.764	0.647	0.086
	W3	0.763	0.002	0.00	0.06	0.739	0.500	0.114
Shirrodi	M	0.616	0.01	0.09	0.05	0.110	–2.242	0.886
	L	0.656	0.047	0.08	0.04	1.213	0.729	0.020
	LL	0.583	0.057	0.07	0.05	1.406	0.647	0.018
	G	0.639	0.023	0.08	0.04	1.101	0.690	0.028
	W2	0.643	0.004	0.07	0.04	1.236	0.722	0.001
	W3	0.652	0.002	0.06	0.04	1.329	0.734	0.007
Koohdasht	M	0.751	0.008	0.10	0.05	0.192	–1.018	0.886
	L	0.743	0.043	0.08	0.05	1.665	0.782	0.014
	LL	0.758	0.041	0.09	0.05	1.676	0.793	0.010
	G	0.747	0.020	0.08	0.05	1.770	0.785	0.004
	W2	0.746	0.004	0.08	0.05	1.774	0.783	0.001
	W3	0.744	0.002	0.09	0.05	1.655	0.780	0.018
Shanghai	M	0.825	0.01	0.11	0.07	0.114	–1.196	0.883
	L	0.778	0.063	0.19	0.08	1.457	0.676	0.085
	LL	0.778	0.063	0.16	0.08	1.429	0.723	0.078
	G	0.794	0.023	0.18	0.08	1.493	0.707	0.071
	W2	0.713	0.016	0.10	0.09	0.771	0.639	0.018
	W3	0.593	0.024	0.11	0.11	0.584	0.458	0.031
N– 80– 6	M	0.689	0.014	0.05	0.03	0.086	–0.121	0.890
	L	0.728	0.057	0.04	0.03	0.859	0.877	0.018
	LL	0.680	0.068	0.04	0.03	0.953	0.890	0.025
	G	0.712	0.029	0.04	0.03	0.842	0.876	0.024
	W2	0.717	0.005	0.03	0.03	0.859	0.869	0.030
	W3	0.725	0.003	0.03	0.03	0.867	0.872	0.027
N– 80– 19	M	0.523	0.002	0.02	0.02	0.036	–7.129	0.885
	L	0.572	0.012	0.03	0.02	0.326	–0.012	–0.040
	LL	0.547	0.012	0.02	0.02	0.357	0.170	–0.037
	G	0.552	0.005	0.02	0.01	0.377	0.344	–0.027
	W2	0.554	0.001	0.02	0.01	0.434	0.584	–0.015
	W3	0.565	0.001	0.02	0.02	0.359	0.211	–0.033

*M = Monomolecular, L = Logistic, LL = Log-logistic, G = Gompertz, W2 = Weibull (c = 2), W3 = Weibull (c = 3)

Figure 1: Temporal progress of observed disease (y), predicted disease (yp), observed dy/dt (dy/dt), predicted dy/dt (dy p/dt) of wheat septoriosis using logistic model in cvs. Tajan (A), Zagros (B), Shirrodi (C), Koohdasht (D), N-80-6 (E) and Log- logistic model in cv. Shanghai (F) and Weibull (c = 2) in N-80-19 line (G) and compared them with actual data in greenhouse condition



Tab. 3: Statistics values of disease progress evaluated models in cvs. Tajan, Zagros, Koohdasht, Shirrodi, Shanghai and N-80-6, N-80-19 lines in 2006–2007

Cultivar/ Line	Model*	R^2	MSE	ME	RMSE	CD	EF	CRM
Tajan	M	0.955	0.14	0.00	0.12	0.06	–1.18	0.89
	L	0.959	0.18	0.00	0.07	0.74	0.92	0.05
	LL	0.950	0.22	0.00	0.07	0.68	0.91	0.05
	G	0.958	0.15	0.00	0.07	0.67	0.90	0.06
	W2	0.956	0.02	0.00	0.06	0.77	0.93	0.05
	W3	0.954	0.06	0.01	0.06	0.82	0.93	0.04
Zagros	M	0.957	0.09	0.01	0.08	0.61	0.89	0.06
	L	0.959	0.13	0.01	0.05	0.84	0.95	0.03
	LL	0.950	0.16	0.01	0.05	0.77	0.95	0.04
	G	0.960	0.11	0.01	0.06	0.75	0.94	0.04
	W2	0.958	0.01	0.03	0.04	0.90	0.96	0.02
	W3	0.953	0.005	0.04	0.05	0.91	0.95	0.03
Shirrodi	M	0.955	0.07	0.01	0.05	0.78	0.96	0.3
	L	0.957	0.11	0.01	0.02	0.99	0.99	0.01
	LL	0.957	0.11	0.01	0.02	0.91	0.99	0.02
	G	0.958	0.09	0.01	0.02	0.92	0.99	0.02
	W2	0.955	0.01	0.01	0.02	0.99	0.99	0.01
	W3	0.952	0.004	0.01	0.03	1.00	0.99	0.02
Koohdasht	M	0.946	0.11	0.00	0.08	0.67	0.90	0.06
	L	0.948	0.17	0.00	0.04	0.89	0.97	0.03
	LL	0.946	0.17	0.00	0.05	0.81	0.96	0.04
	G	0.948	0.14	0.00	0.05	0.81	0.95	0.04
	W2	0.946	0.02	0.00	0.04	0.63	0.97	0.03
	W3	0.944	0.006	0.01	0.05	0.91	0.96	0.04
Shanghai	M	0.897	0.13	0.15	0.09	0.65	0.84	0.42
	L	0.918	0.18	0.12	0.07	0.84	0.91	0.2
	LL	0.905	0.21	0.14	0.08	0.80	0.89	0.02
	G	0.909	0.15	0.14	0.08	0.79	0.90	0.02
	W2	0.918	0.02	0.12	0.07	0.84	0.91	0.02
	W3	0.923	0.006	0.12	0.07	0.90	0.92	0.01
N-80-6	M	0.934	0.11	0.00	0.07	0.68	0.91	0.06
	L	0.938	0.17	0.01	0.05	0.89	0.96	0.03
	LL	0.930	0.19	0.00	0.05	0.81	0.95	0.04
	G	0.937	0.13	0.00	0.06	0.79	0.95	0.05
	W2	0.937	0.02	0.01	0.04	0.90	0.97	0.03
	W3	0.935	0.006	0.01	0.05	0.90	0.95	0.04
N-80-19	M	0.956	0.07	0.01	0.06	0.72	0.93	0.04
	L	0.957	0.11	0.02	0.04	0.92	0.97	0.02
	LL	0.957	0.11	0.00	0.00	0.84	1.00	0.03
	G	0.958	0.09	0.01	0.05	0.83	0.96	0.03
	W2	0.955	0.01	0.02	0.04	0.92	0.97	0.02
	W3	0.926	0.02	0.02	0.23	0.32	0.08	0.20

*M = Monomolecular, L = Logistic, LL = Log-logistic, G = Gompertz, W2 = Weibull (c = 2), W3 = Weibull (c = 3)

and data were analyzed using Statgraphic 3.0 software. The results showed that in cv. Tajan logistic and log- logistic models were the same due to R^2 and ME (Table 4). Logistic was not efficient model due to high RMSE and positive CRM (Table 4). Log- logistic was the most suitable model in this cultivar and cvs. Zagros and Koohdasht (Table 4). Logistic was the appropriate model in cvs. Shirrodi and Shanghai. Both logistic and log-logistic models were the most suitable models in N-80-6 and N-80-19 lines. In N-80-19 line RMSE was zero and EF

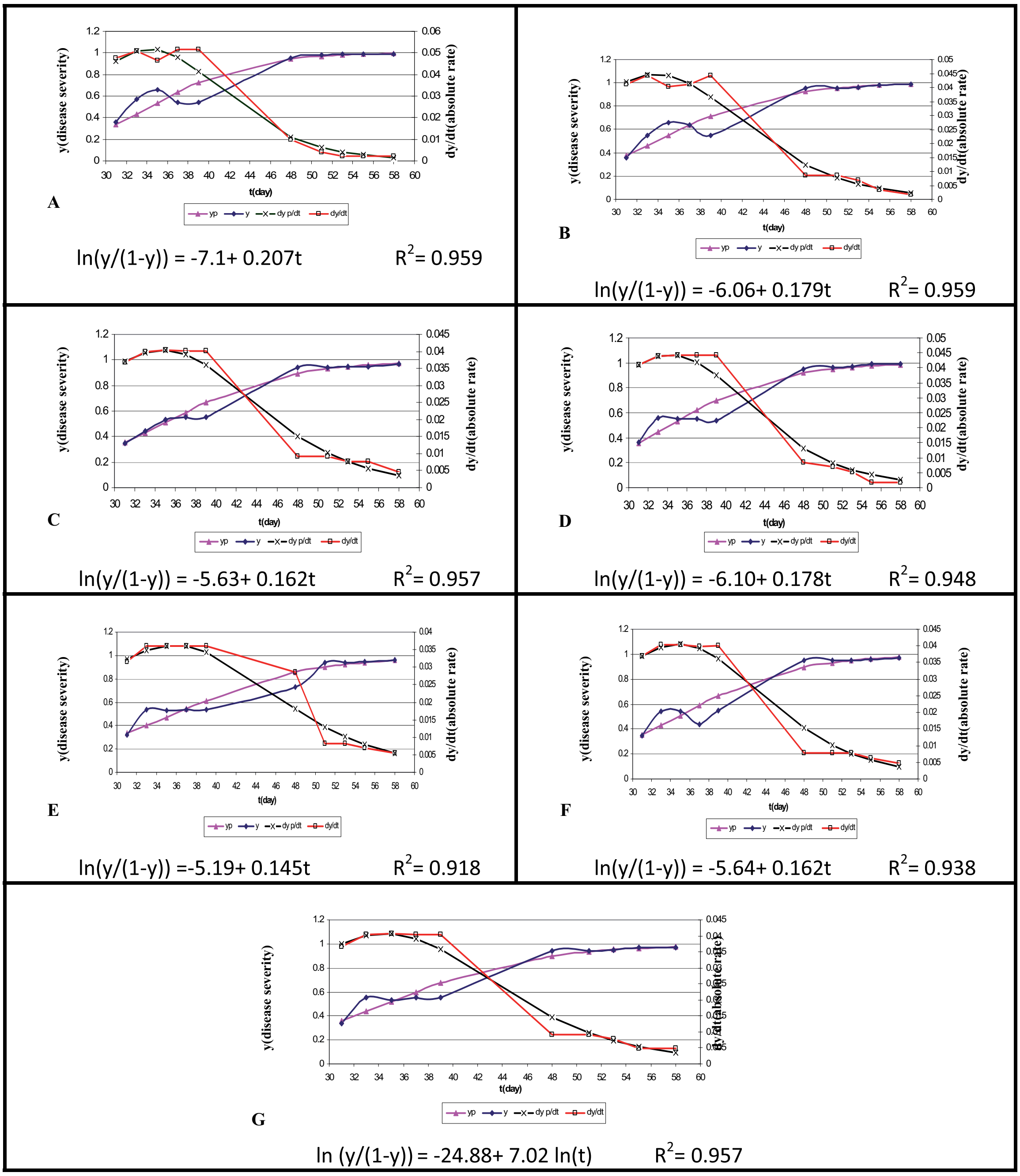


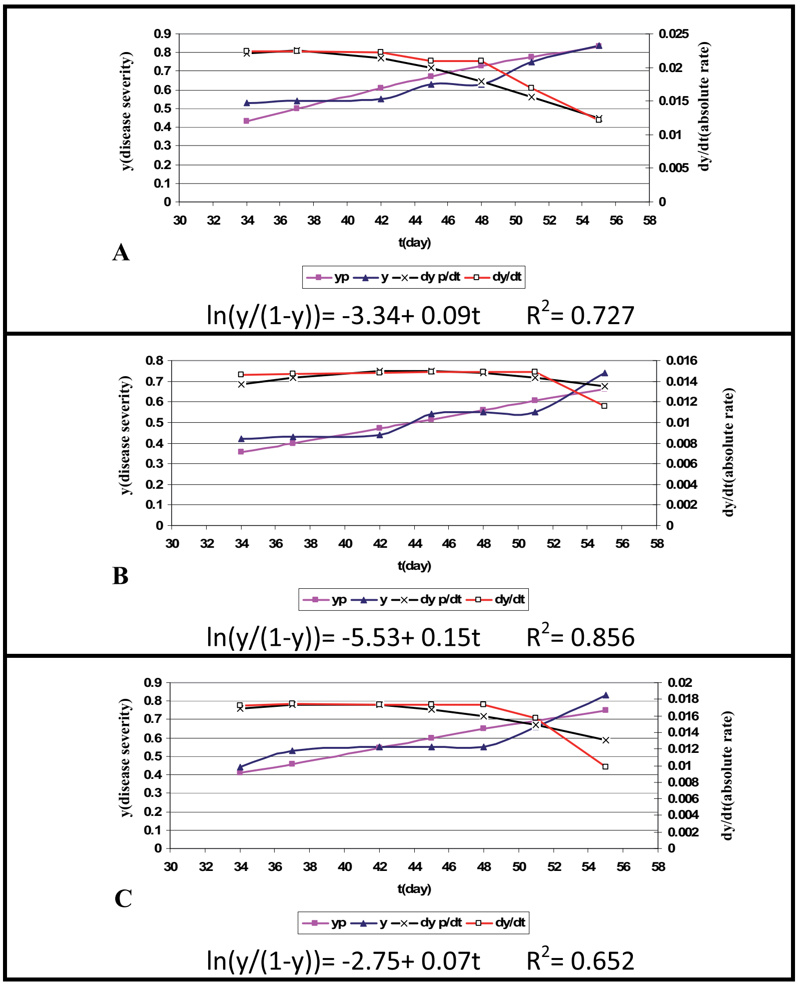
Figure 2: Temporal progress of observed disease (y), predicted disease (yp), observed dy/dt (dy/dt), predicted dy/dt (dy p/dt) of wheat septoriosis using logistic model in cvs. Tajan (A), Zagros (B), Shirrodi (C), Koohdasht (D), Shanghai (E) and N-80-6 (F) and Log-logistic in N-80-19 line (G) and compared them with actual data in field condition in 2006–2007

Tab. 4: Statistics values of disease progress evaluated models in cvs. Tajan, Zagros, Koohdasht, Shirrodi, Shanghai and N-80-6, N-80-19 lines in 2007–2008

Cultivar/ Line	*Model	R^2	MSE	ME	RMSE	CD	EF	CRM
Tajan	M	0.868	0.14	0.03	0.03	1.059	0.968	0.860
	L	0.863	0.22	0.04	0.03	1.331	0.965	0.002
	LL	0.883	0.19	0.05	0.02	1.210	0.977	–0.002
	G	0.866	0.18	0.09	0.04	1.573	0.920	–0.026
	W2	0.857	0.02	0.09	0.05	1.645	0.900	–0.031
	W3	0.0851	0.01	0.08	0.04	1.587	0.918	–0.024
Zagros	M	0.920	0.07	0.03	0.06	0.745	0.858	0.033
	L	0.932	0.09	0.02	0.04	0.923	0.931	0.035
	LL	0.926	0.10	0.05	0.04	0.948	0.935	0.010
	G	0. 927	0.08	0.09	0.04	1.090	0.929	–0.019
	W2	0.932	0.01	0.13	0.06	1.262	0.853	–0.059
	W3	0.933	0.003	0.08	0.04	1.164	0.946	–0.021
Shirrodi	M	0.654	0.11	0.09	0.09	0.465	0.345	0.029
	L	0.727	0.16	0.10	0.06	0.634	0.673	–0.017
	LL	0.691	0.18	0.10	0.07	0.647	0.623	–0.012
	G	0.694	0.13	0.05	0.08	0.501	0.407	0.073
	W2	0.732	0.02	0.15	0.09	0.547	0.331	–0.099
	W3	0.754	0.01	0.17	0.10	0.489	0.105	–0.130
Koohdasht	M	0.822	0.13	0.17	0.13	0.747	0.701	–0.802
	L	0.856	0.19	0.13	0.07	0.0875	0.835	–0.072
	LL	0.822	0.24	0.11	0.07	0.852	0.872	–0.026
	G	0.843	0.15	0.06	0.07	0.695	0.835	0.039
	W2	0.861	0.02	–0.06	0.13	0.383	0.513	0.173
	W3	0.868	0.01	0.15	0.08	0.887	0.793	–0.096
Shanghai	M	0.727	0.02	0.04	0.07	0.821	0.593	0.073
	L	0.750	0.06	0.05	0.05	1.013	0.781	0.030
	LL	0.716	0.07	0.04	0.05	1.057	0.721	0.042
	G	0.743	0.03	–0.01	0.09	0.708	0.285	0.141
	W2	0.749	0.01	0.13	0.08	0.726	0.452	–0.110
	W3	0.752	0.002	–0.10	0.16	0.379	–1.276	0.285
N–80–6	M	0.626	0.07	0.18	0.10	0.684	0.208	–0.130
	L	0.652	0.14	0.10	0.06	1.020	0.728	0.001
	LL	0.601	0.16	0.10	0.06	1.083	0.691	0.000
	G	0.641	0.10	0.15	0.08	0.836	0.541	–0.071
	W2	0.649	0.01	0.03	0.09	0.776	0.397	0.115
	W3	0.655	0.01	–0.15	0.23	0.239	–2.995	0.380
N–80–19	M	0.703	0.28	0.07	0.09	0.592	0.685	0.022
	L	0.731	0.42	0.10	0.06	0.870	0.846	–0.041
	LL	0.718	0.44	0.08	0.00	0.778	1.000	–0.006
	G	0.718	0.34	0.10	0.07	0.816	0.824	–0.031
	W2	0.733	0.04	–0.07	0.13	0.474	0.300	0.160
	W3	0.742	0.01	0.14	0.08	0.901	0.710	–0.091

*M = Monomolecular, L = Logistic, LL = Log-logistic, G = Gompertz, W2 = Weibull (c = 2), W3 = Weibull (c = 3)

Figure 3: Temporal progress of observed disease (y), predicted disease (yp), observed dy/dt (dy/dt), predicted dy/dt (dy p/dt) of wheat septoriosis using logistic model in cvs. Shirrodi (A), Shanghai (B) and N-80-6 (C), and compared them with actual data in field condition in 2007–2008



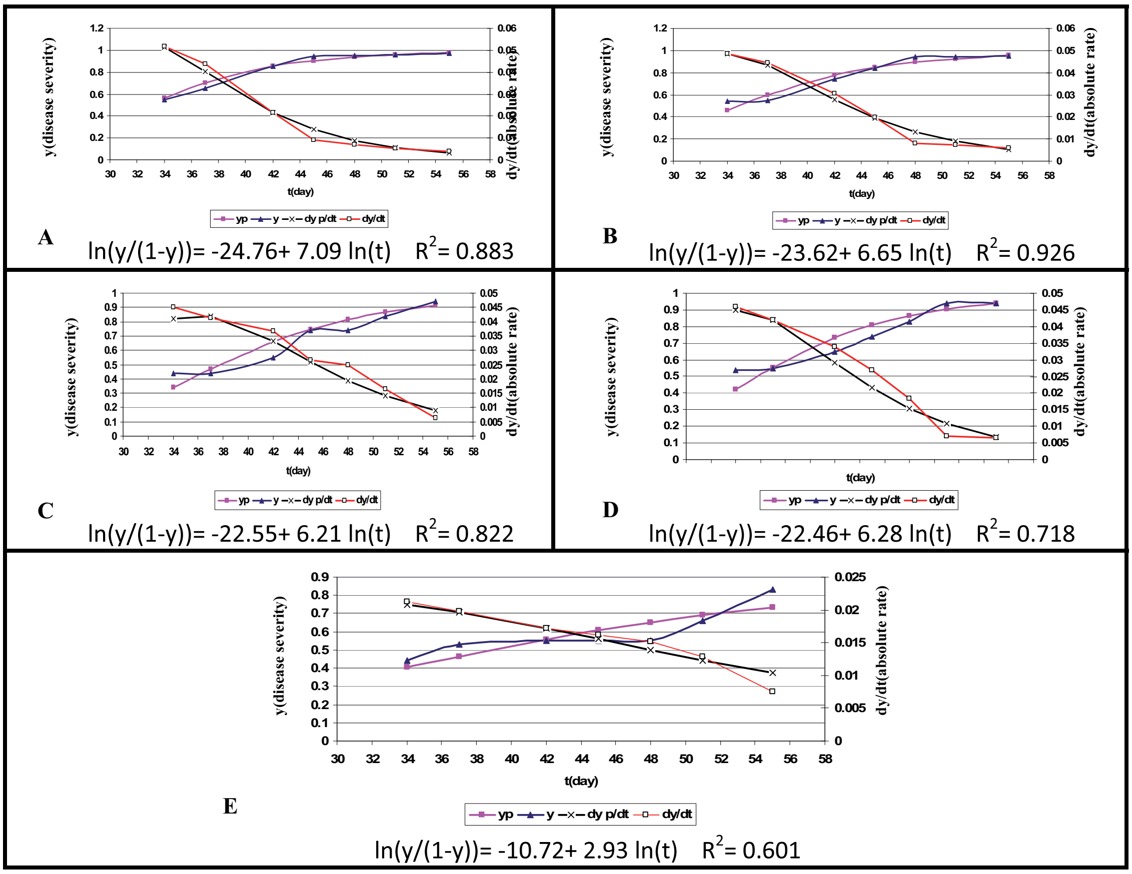
was one that showed better model's efficiency than other models (Table 4). Based on results, logistic and log- logistic were the most suitable models in all cultivars and lines. Observed and predicted curves were shown in Figures 3 and 4.

DISCUSSION

Weather data (Table 5) revealed that lower temperature, higher precipitation and relative humidity during March and April of 2006-7 provide favorable conditions for penetration, establishing of pathogen and disease progression leading to higher disease severity in this year.

Epidemiological models were used to evaluate temporal disease progress in greenhouse and field experiments. Fitness of each model were examined by R^2, ME, RMSE, CD, EF and CRM. Fitness of epidemiological models has been examined to choose the best model in different studies (Campbell, 1986; Campbell and Madden, 1990; Habili and Nutter, 1997; Parker et al., 1997; Ward et al., 1997). Greenhouse experiments showed that logistic was the most suitable model in all cultivars and lines except Shanghai and N-80-19. Log-logistic and Weibull (c = 2) were efficient model in cv. Shanghai and N-80-19 line, respectively. Zadoks (1961) introduced logistic model for yellow rust progress (Campbell and Madden, 1990) which is a polycyclic disease as Septoria leaf blotch. The results of field experiments in two consecutive growing seasons showed that monomolecular model was not a suitable model in any cultivar or line due to high RMSE and CRM, low CD and EF. The greenhouse experiments

Figure 4: Temporal progress of observed disease (y), predicted disease (yp), observed dy/dt (dy/dt), predicted dy/dt (dy p/dt) of wheat septoriosis using Log- logistic model in cvs. Tajan (A), Zagros (B), Koohdasht (C), N-80-19 (D) and N-80-6 (E) and compared them with actual data in field condition in 2007–2008



confirmed these results as well. Field experiment in 2006–2007 showed that logistic model was the most appropriate model in all cultivars and lines except N-80-19 line. Log-logistic model was efficient for N-80-19 line. Based on field experiment in 2007–2008, logistic was the most appropriate model in cvs. Shirrodi, Shanghai and N-80-6 line. Log-logistic was the most appropriate model in cvs. Tajan, Zagros, Kohdasht and N-80-6, N-80-19 lines. Generally, based on the greenhouse and field studies, logistic and log-logistic models were the most suitable models in disease progress describing. In grapevine leaf roll virus disease, Gompertz and logistic were the most efficient models and logistic model was chosen due to its simplicity (Habili and Nutter, 1997). Also, logistic model was used in pine white rust (Campbell, 1986), Septoria leaf blotch of tomato (Parker et al., 1997) and Cercospora leaf blotch of corn (Ward et al., 1997). The most appropriate model for sugarcane Cercospora leaf blotch was logistic (Madanian et al., 2004). Taliee et al. (2005) introduced logistic and log-logistic models as the best suitable for Fusarium blight of wheat. Based on the results, there was no significant relation be-

Tab. 5: Meteorological data collected from Hashem abad weather station

Parameters/period (monthly mean)	2006–2007			2007–2008		
	March	April	May	March	April	May
Temperature (∘C)	10.33	14.27	20.68	15.75	18.10	20.01
Relative humidity (%)	77.45	81.12	64.53	62.79	67.48	65.58
Precipitation (mm)	4.003	1.09	1.01	1.12	0.56	0.86

tween cultivars and lines susceptibility to Septoria blotch and the best suitable model. In this study, we introduce logistic and its derivative (log-logistic) as the most efficient models for wheat septoriosis in greenhouse and field conditions which are in concordance with the other studies that introduced logistic model as a suitable describer for disease progress in polycyclic diseases in different hosts. This study examined temporal progress of wheat Septoriosis on common cultivars in the north of Iran for the first time.

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