Use of Climatic Parameters to Predict the Global Distribution of Ascochyta Blight on Chickpea

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ABSTRACT

Diekmann, M. 1992. Use of climatic parameters to predict the global distribution of Ascochyta blight on chickpea. Plant Dis. 76:409-412.

Climatic data of areas where chickpea (*Cicer arietinum*) is grown were analyzed by stepwise discriminant analysis to identify parameters that allow a discrimination of locations with and without occurrence of Ascochyta blight (caused by *Ascochyta rabiei*). A discriminant function was computed, based on mean daily temperature in month 1 of the vegetation, mean precipitation in month 2, average precipitation per rainy day in months 1 and 2, and mean number of rainy days in months 1 and 2. This linear function can be used to predict the disease risk for various agrogeographical zones and growth seasons. The model can help to concentrate disease control measures, such as quarantine, on high-risk areas or identify low-risk areas or seasons for the production of healthy seed.

Chickpea (*Cicer arietinum* L.) is a major source of protein in many parts of the world, particularly in India and Pakistan. Other important producers include Burma, Ethiopia, Mexico, and Turkey. The crop also plays a significant role in providing high-quality crop residues for animal feed and maintaining soil fertility through biological nitrogen fixation. In 1988, the world chickpea-producing area was 10 million hectares, with a yield of about 7 million metric tons. The average yield varied from around 300 kg/ha in Algeria and Tanzania to more than 1,700 kg/ha in Egypt (11). Pests and diseases rank high among the constraints to production, and particularly Ascochyta blight, caused by *Ascochyta rabiei* (Pass.) Labrousse, may cause large crop losses if epidemics develop. In Spain, for example, Ascochyta blight caused a total yield loss in the 1930s (8).

The disease has been reported from Algeria, Australia, Bulgaria, Canada, Cyprus, Ethiopia, France, Greece, India, Iran, Iraq, Israel, Italy, Lebanon, Morocco, Pakistan, Portugal, Romania, Spain, Syria, Tanzania, Turkey, United States, and USSR (5), as well as Bangladesh, Jordan, and Tunisia (22), Egypt (1), Hungary (18), and Mexico (23). Ascochyta blight is extremely important in areas between 31° and 45° north latitude and occasionally important between 26° and 30° (26). In India, the disease occurs in the states of Punjab, Bihar, Haryana, Uttar Pradesh, and Himachal Pradesh (9,16,25,27,28), but not in Andhra Pradesh (25), and only occasionally in Madhya Pradesh (17,24). In the United States, the pathogen was first recorded in the early 1980s in Washington and Idaho and caused severe epi-

Accepted for publication 6 September 1991 (submitted for electronic processing).

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Table 1. Reports of Ascochyta blight on chickpea by meteorological stations

Station locations	Growing season	Ascochyta blight[a]
Algeria		
Algiers	January–May	+
Oran	January–May	+
Argentina		
Cordoba	June–October	−
Australia		
Melbourne	May–September	+
Bangladesh		
Narayanganj	November–March	−
Canada		
Saskatoon, Saskatchewan	May–September	+
Chile		
Valparaiso	September–January	−
Egypt		
Alexandria	November–March	+
Ethiopia		
Addis Ababa	July–November	+
	September–January	−
India		
Hyderabad	November–March	−
New Delhi	November–March	+
Raipur	November–March	−
Iran		
Teheran	March–July	+
Italy		
Palermo	January–May	+
Rome	February–June	+
Jordan		
Amman	December–April	+
Malawi		
Blantyre	February–June	−
Mexico		
Guaymas	December–April	+
Morocco		
Casablanca	December–April	+
Rabat	December–April	+
Nepal		
Katmandu	November–March	−
Pakistan		
Peshawar	November–March	+
Spain		
Granada	March–July	+
Seville	March–July	+
Syria		
Aleppo	December–April	+
Tunisia		
Tunis	March–July	+
Turkey		
Ankara	March–July	+
Bursa	April–August	+
Erzurum	April–August	+
Izmir	January–May	+
United States		
Fresno, California	February–June	−
San Francisco, California	April–August	−
Spokane, Washington	April–August	+
Walla Walla, Washington	April–August	+
Zambia		
Lusaka	February–June	−

[a] + = Reported, − = not reported.

demics (14,15). It was not, however, mentioned in an extensive survey of chickpea diseases in California (4). In Ethiopia, Ascochyta blight has only been observed when chickpeas are planted in July instead of September (3). There are no reports of the disease from Burma, Nepal, Argentina, Bolivia, Chile, Colombia, Peru, Libya, Malawi, Zambia, Sudan, Uganda, and Yugoslavia, which all grow considerable areas of chickpea (11).

The pathogen survives from season to season in plant debris and seed. Infected seed also serves as a vehicle for transfer of the pathogen from one area to another (6,7,13,14,20). Climatic factors play a major role in disease development. By analyzing climatic data from locations where the disease is reported to occur, as well as from those where it does not occur, important climatic factors can be determined and used in a risk analysis for locations where the crop is newly introduced. This paper reports the development of a model to predict the disease risk of Ascochyta blight.

MATERIALS AND METHODS

Chickpea growing areas and seasons. From the literature, conventional planting and harvesting times in locations growing chickpea were identified (Table 1). There may be inaccuracies with these, because cultivar differences and other factors could not be taken into account. Also, planting may extend over more than 1 mo.

Climatological data. Monthly data for mean daily maximum and minimum temperature, precipitation and number of days with precipitation, and wind speed were selected from a total of 36 standard stations in the chickpea-growing areas (21).

Development of the model. Stepwise discriminant analysis (2,12) was applied to the data set. This technique can be used to classify an individual location into one of two alternative groups (climatic conditions favorable or unfavorable for disease development) based on a set of measurements (climatic parameters). At each step the variable that adds most to the discrimination between the groups is entered into the discriminant function. The resulting linear function can be used to classify data sets not used

Table 2. Risk of Ascochyta blight on chickpea at various locations during various growing seasons

Location	Month of planting	Climatic parameters[a]						Score	Disease
		x_1	x_2	x_3	x_4	x_5	x_6	(y)[b]	risk
Plovdiv, Bulgaria	April	12.2	55	6.1	6.1	7	9	−3.84	+
Bogotá, Colombia	April	13.7	105	5.3	5.0	19	21	−7.94	+
Neustadt, Germany	April	10.0	50	3.4	3.8	14	13	−4.37	+
Kenyan highlands	June	15.7	17	5.8	3.4	5	5	0.98	−
Aleppo, Syria	March	10.9	28	5.4	7.0	7	4	−0.76	+
Aleppo, Syria	April	16.4	8	7.0	4.0	4	2	3.46	−

[a] x_1 = Mean daily temperature in month 1 of the vegetation, x_2 = mean precipitation in month 2, x_3 = average precipitation per rainy day in month 1, x_4 = average precipitation per rainy day in month 2, x_5 = mean number of days with precipitation in month 1, x_6 = mean number of days with precipitation in month 2.

[b] $y = 1.11 + 0.22\,x_1 + 0.05\,x_2 + 0.32\,x_3 - 0.91\,x_4 + 0.51\,x_5 - 1.15\,x_6$

in the development of the function. This method has been widely used in plant taxonomy (e.g., by Fisher to separate *Iris* species [12]), or in plant genetics (10). The technique has also been used in the development of plant disease prediction models (19).

Initially, the data for the month of planting and the four subsequent months were analyzed. Almost 100 equations were tested for fit, and those variables that did not contribute significantly to the discrimination (e.g., the fourth and fifth month of vegetation), were successively dropped. In addition to the original data, simple transformations, such as the product of rain and wind, the difference between maximum and minimum temperature, the quotient of rain and number of rainy days, or the quotient of rain and minimum temperature, were included. Such transformed data may be more meaningful for the epidemiology of the disease than the original data. Spore dispersal and, thus, disease spread, for example, are promoted by a combination of wet and windy conditions, but not by either high rainfall nor high wind speed alone (22).

RESULTS AND DISCUSSION

From the classification functions, the discriminant function was computed as $y = 1.11 + 0.22\ x_1 + 0.05\ x_2 + 0.32\ x_3 - 0.91\ x_4 + 0.51\ x_5 - 1.15\ x_6$, where x_1 = mean daily temperature in month 1 of the vegetation, x_2 = mean precipitation in month 2, x_3 = average precipitation per rainy day in month 1, x_4 = average precipitation per rainy day in month 2, x_5 = mean number of rainy days in month 1, and x_6 = mean number of rainy days in month 2. The canonical correlation was 0.7556.

The disease risk can be estimated for any location if the above parameters are known. If the computed score (y) is greater than 0, the location is classified as "no disease risk"; if it is less than 0, it is "disease risk." A "no disease risk" result, however, does not mean that the disease will not occur in the area; outbreaks may result from favorable weather in a particular year or from planting of new susceptible cultivars. However, the risk of Ascochyta blight developing to epidemic proportions is low in these areas. Those locations that receive a score close to 0 should be considered "areas of sporadic attack" sensu Weltzien (29).

Of the six parameters contributing to the discrimination, five are related to rainfall in the first 2 mo of vegetation, and the sixth is the mean daily temperature in the first month after planting. Particularly important are the precipitation parameters in the second month of vegetation (i.e., rainfall, number of days with rainfall, and the average rainfall per rainy day). The last is obtained by a division of the former two and may be more important for the development of the disease. Two coefficients are negative, namely, the average precipitation per rainy day and the number of rainy days in month 2 of the vegetation. This indicates that locations with larger values of these variables may more likely be classified as "disease risk." Both parameters result in prolonged periods of leaf wetness, which is favorable for an epidemic of fungi requiring leaf wetness for infection, such as Ascochyta blight. Rainfall in the second month of vegetation (x_2) has a positive coefficient, which seems to counteract the effect of the previous two parameters. A comparison of the standardized coefficients ($x_2 = 0.09$, $x_4 = -1.70$, $x_6 = -2.14$) indicates that this is the case only to a relatively small extent. The average precipitation per rainy day and the number of rainy days in month 1 of the vegetation, as well as the mean temperature in the same period, also neutralize the effect of x_4 and x_6: if they are high, the computed score is more likely to be positive, and thus the disease risk tends to be lower. The reason for this could be that high temperature and rainfall parameters boost plant growth shortly after planting, and that their effect on disease development is relatively low during the period of germination and seedling growth.

In Table 2, some examples for the application of this method are given. For the areas of Plovdiv, Bulgaria; Bogotá, Colombia; and Neustadt, Germany, the computed score indicates a disease risk, whereas for the Kenyan highlands, no serious outbreaks of Ascochyta blight are expected. Although in Bulgaria a high incidence of Ascochyta blight is reported (22), the disease has not been reported from Colombia or Germany. For the area of Bogotá, a disease risk is predicted for chickpea planted in April, and care should be taken not to introduce the pathogen. No chickpea is grown in Germany, and a reflection on a disease risk in absence of the crop seems very theoretical. However, farmers could decide that chickpea is a potentially valuable crop, and in such a case it would be advisable to be prepared for potential disease risks.

When this data set was classified in a new analysis, using the function derived from the original data set, the probabilities of belonging to the disease risk group were 100% for Bogotá, 98.9% for Neustadt, and 98.1% for Plovdiv. The probability of belonging to the non-disease group was 71.2% for the Kenyan highlands. The canonical correlation for the combined data sets was 0.7633.

Disease risk that is dependent upon planting time in a location can also be assessed. In the area of Aleppo in northern Syria, the disease occurs if chickpeas are planted in December (Table 1). If planting is delayed until March, the prediction is still "disease risk," but the probability drops from 99.4% to 70.0%. A further delay to April would result in the prediction "no disease risk," with a 3.3% probability of belonging to the risk group. Spring planting, although it considerably reduces crop yields, is in fact a common practice of farmers in this area in order to avoid outbreaks of Ascochyta blight. In extraordinarily wet years, March plantings are affected by Ascochyta blight (K. B. Singh, *personal communication*).

It is recognized that besides unfavorable climatic conditions, there possibly are other reasons for the absence of reports on the disease in areas where chickpea is grown, such as those locations marked in Table 1. There is a chance that the disease occurs but was never described in the internationally accessible literature. In this case, it can be assumed that the incidence is low, or that the disease does not occur regularly. Another reason for the absence of the disease could be the lack of inoculum. However, since international exchange of seeds entails the risk of infected seeds being planted in these areas, an outbreak of a seedborne disease such as Ascochyta blight can be expected under favorable conditions.

Because climate data (i.e., long-term averages), and not weather data, are used for the analysis, this approach is not suitable for a disease forecast, in the sense that disease development in a particular year is predicted. It is to be seen in the concept of geophytopathology (29). This technique, which can also be applied to other hosts, pathogens, or pests, could be valuable in focusing quarantine efforts on pathogens that pose a high risk of epidemic development to an area if introduced, such as in the above-mentioned example of Colombia. An estimation of the potential disease risk may also be useful when new crops are introduced into a region, as was the case with chickpea in eastern Washington and northern Idaho in the 1970s (14).

ACKNOWLEDGMENTS

I thank Joop van Leur, K. B. Singh, and Surendra Varma for helpful suggestions on the manuscript.

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