WEATHER BASED PEST RISK MAPPING PROJECT

RISK ASSESSMENT:

Is *Harpophora maydis* (causal agent of late wilt) a threat to US corn production?

Cooperative agreement between NCSU and

USDA-APHIS-PPQ-CPHST-PERAL/ NCSU

Species Information:

The correct name for the causal agent is *Harpophora maydis* (Samra, Sabet and Hingorani) Gams as a replacement for *Cephalosporium maydis* Saleh and Leslie, 2004. Another synonym is *Acremonium maydis.*

Source CIMMYT, 2004.

Rationale:

H. maydis is included in the Cooperative Agriculture Pest Survery (CAPS) Program pest universe, and the American Phytopathology Society (APS) list. It also poses a serious potential threat to US Corn Production (USDA's Maize Crop Germplasm Committee, W. Dolezal, pers. comm.). In addition, the pathogen was included in a 1983 APS symposium on serious exotic pests (Warren, 1983). A National Plant Pest Recovery Plan on Late Wilt is also in preparation by the United States Department of Agriculture-Office of Pest Management.

The pathogen has a potential pathway into the United States, either in shipments containing infested soil or in illegal seed shipments. *H. maydis* could also potentially disrupt off-season US seed production in Chile and Argentina. Another reason for conducting a climatological risk assessment is that the fungus has a high temperature threshold making it likely to have widespread distribution in the southern United States.

Life History:

H. maydis is a serious pest of corn, while cotton and lupins may be secondary hosts (CABI, 2006). *H. maydis* is soilborne and infests corn seedlings through the roots or mesocotyl. The fungus is most common in hot, humid and heavy soils (CIMMYT, 2004). As plants mature, fewer are infected and they become immune about 50 days after planting (Sabet *et al.*, 1970)**.** Another report indicates plants are still susceptible to artificial inoculation 60 days after planting (Singh and Siradhana, 1987). After infection, the fungus rapidly colonizes the xylem tissue and is translocated to upper parts of the plant. When infections are severe the fungus colonizes the kernels, which may result in seedborne dissemination, seed rot and damping-off. The fungus can survive in the soil for several years and is weakly saprophytic.

There is substantial information about the growth of the fungus in culture. The minimum temperature for growth has been reported as 6^oC (Pecsi and Nemeth, 1998), between 10 and 15^oC (Singh and Siradhana, 1985), 12^oC (Samra *et al.*, 1963) and 10 to 13^oC (Sabet *et al.*, 1966b). The optimum for growth has been reported as 30^oC (Samra *et al.*, 1963), 25^oC (Singh and Siradhana, 1985) and between 27-30^oC (Sabet *et al.*, 1966b). The maximum temperature for growth has been reported as 38^oC (Pecsi and Nemeth, 1998), above 34^oC (Samra *et al.*, 1963), between 35 and 40^oC (Singh and Siradhana, 1985) and between 33 and 35^oC (Sabet *et al.*, 1966b). A field study using controlled heated enclosures suggests that wilt infection occurred between 20 and 32^oC with an optimum at 24^oC (Singh and Siradhana, 1987).

It is generally thought that the pathogen has no specific moisture requirements (El-Shafey and Clafin, 1999). Experiments with variable irrigations and field observations suggest that the disease was more severe with increased rain or irrigations (Singh and Siradhana, 1987).

Distribution:

The fungus has been reported in India, Egypt and in Hungary (Table 1, Fig. 1). Locations reported in were geocoded using an online tool (http://worldkit.org/geocoder/). Although it has not formally been identified in other countries, symptoms like those of late wilt were reported as having been seen on maize in Kenya (Ward and Bateman, 1999). Renfro and Ullstrup (1976) reported that late wilt disease is abundant and of major importance in tropical and subtropical regions (i.e., within latitude 34^o). Other workers have been unable to confirm this report during field visits in Africa (Leslie, pers. comm., 2007). The disease is absent or rarely found in highland tropical or temperature regions Renfro and Ullstrup, 1976. There has been a report from Hungary (Pecsi and Nemeth, 1998) but there are few details about its prevalence or severity in Hungary.

Table 1. Locations where *H. maydis* is known to occur.

Country	**Location**	**Reference**
India	Udaipur	Singh and Siradhana, 1987
India	Jaipur	Centraalbureau voor Schimmelcultures (CBS) Global Biodiversity Information Facility (http://data.gbif.org/occurrences/5339948)
India	Hyderabad	Payak *et al.*, 1970
Egypt	Sohag	Saleh *et al.*, 2003; Zeller *et al.*, 2002
Egypt	Fahoum	Saleh *et al.*, 2003
Egypt	Kafr El-Sheikh	Saleh *et al.*, 2003; Zeller *et al.*, 2002
Egypt	Gaza	Zeller *et al.*, 2002
Hungary	Unknown	Pecsi and Nemeth, 1998

Methods:

Risk maps were created with the NCSU APHIS Pest Forecasting System (NAPPFAST) system (Magarey *et al.*, 2007). The NAPPFAST system uses a web-based graphical user interface to link climatic and geographic databases with templates for biological modeling. The NAPPFAST system includes two daily weather databases with over 30-years of records. The global database is based upon the National Centers for Environmental Prediction (NOAA/NCEP) Global Reanalysis II data set (Kalnay *et al.*, 1996). This is a numerical grid created for use as input data for meteorological models. The spatial resolution of the grid is 28 km which has been resampled from a 1.875 degree (210 km) resolution. Station data from the International Station Hourly (ISH) data (Lott *et al.*, 2001) were used to supplement the NCEP backbone. The North American databases includes over 2000 stations for North America (Magarey *et al.*, 2007). The input weather data was interpolated to a 10 km^2 resolution using a 3-D multivariate interpolation (Splitt and Horrel, 1998). Daily soil temperature (5 cm) was derived from air temperature using a simple proprietary algorithm.

A simple infection model based on a temperature response function was used to model *H. maydis* (Magarey *et al.*, 2005). The input to the model was average daily soil temperature at 5 cm depth. The infection model had the following parameters: T_{min} = 12, T_{opt} = 30 and T_{max} = 38°C based on various literature reports (Pecsi and Nemeth, 1998; Sabet *et al.*, 1966a; Samra *et al.*, 1963; Singh and Siradhana, 1985). There was no moisture requirement. The infection model scores a value each day between 0 and 1, and these values are accumulated. Two periods of susceptibility were identified based upon a 50 day susceptibility period after planting (Sabet *et al.*, 1970). For simplicity, the primary susceptible period was defined as May-June (61 days) (NASS, 2002) for the northern hemisphere and November-December for the southern hemisphere.

A final risk map was created for the United States by combining relative climate and host risk maps, both on a scale of 1-10. (The relative climate risk map was converted to a 1-10 scale created by dividing the number of accumulated infection days by 61 and multiplying by 10.) The host risk map was generated for the United States using National Agricultural Statistics Service (NASS) commodity (corn) data. The scale of 1 to

10 describes the proportion of total host acreage per county: for example a rank of 1 indicates that there is no host acreage, and a score of 10 indicates that 0.75-1.0 of the acres in the county contain suitable hosts for the pest. Potential minor hosts such as cotton and lupins (CABI, 2006) are not addressed in this host map. A final risk map was created by adding the relative climate and host risk maps together and dividing by two.

Results and Discussion:

Areas in Egypt and India, where the disease is known to be a serious problem, had 30 or more days suitable for infection out of a possible total of 61 days (Fig. 2). Hungary had less than 20 favorable days (Fig. 3). There is no additional data from Hungary to indicate the distribution, prevalence or severity of the disease. In Europe, the most favorable areas for the disease were on the Mediterranean coast. Southern Spain and Greece had more than 30 days but other parts of southern Europe have less.

There was a lack of maize wilt observations to properly calibrate the model. Assuming that the Hungarian reports (Pecsi and Nemeth, 1998) are correct, a threshold of 20 favorable days might be suggested. A threshold of 20 or more days would suggest that maize wilt could be a problem every year in southern Spain if it was present (Fig. 3). Likewise, it would only be an occasional problem in France with the exception of small area of Provence. Other areas of southern Europe including Italy and Greece could also be at risk in most years. The model predicts wilt to be an occasional problem in Hungary, occurring less than 4 years in 10.

If the threshold of 20 days is correct, then much of the midwestern United States could be at risk in most years (Fig. 3). Additional data on the prevalence of the disease in Hungary or other countries in Europe would be helpful for calibrating the model. The final risk map based on climate and host layers shows that risk is less than might be expected because the areas with highest climate risk do not match the areas with highest crop acreages. The map suggests that the southern tier of the United States are most at risk. Other states with small areas of high risk include California, Illinois and Iowa.

The global maps (Fig. 2) may also be useful for determining the best southern hemisphere locations for seed propagation for shipments from at risk countries. For example, Northern Australia, east Africa and Brazil would be high risk sites for off-season seed propagation, while Chile, southern Australia and southern South Africa would be relatively lower risk. This global comparison assumes November-December susceptibility.

Finally, our analysis assumed that model parameters were T_{min} = 12, T_{opt} = 30 and T_{max} = 38°C based on the most common values reported in the literature (Pecsi and Nemeth, 1998; Sabet *et al.*, 1966a; Samra *et al.*, 1963; Singh and Siradhana, 1985). If the optimum was actually 25°C as reported by workers in India (Singh and Siradhana, 1985), then the risk in the United States would extend further north. Should the pathogen be introduced into the United States, the risk maps should be revised based on the epidemiological characteristics of the introduced pathotype. This study confirms earlier work that suggests that *H. maydis* could potentially be a serious threat to US corn production (Warren, 1983).

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Authors:

Roger Magarey, Jessica Engle and Betsy Randall-Schadel (Reviewing author), APHIS-PPQ-CPHST-PERAL.

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Figure 1. Geographic distribution (green circles) of *Harpophora maydis* based on literature reports of known locations detailed in Table 1. The pathogen has also been reported in Hungary.

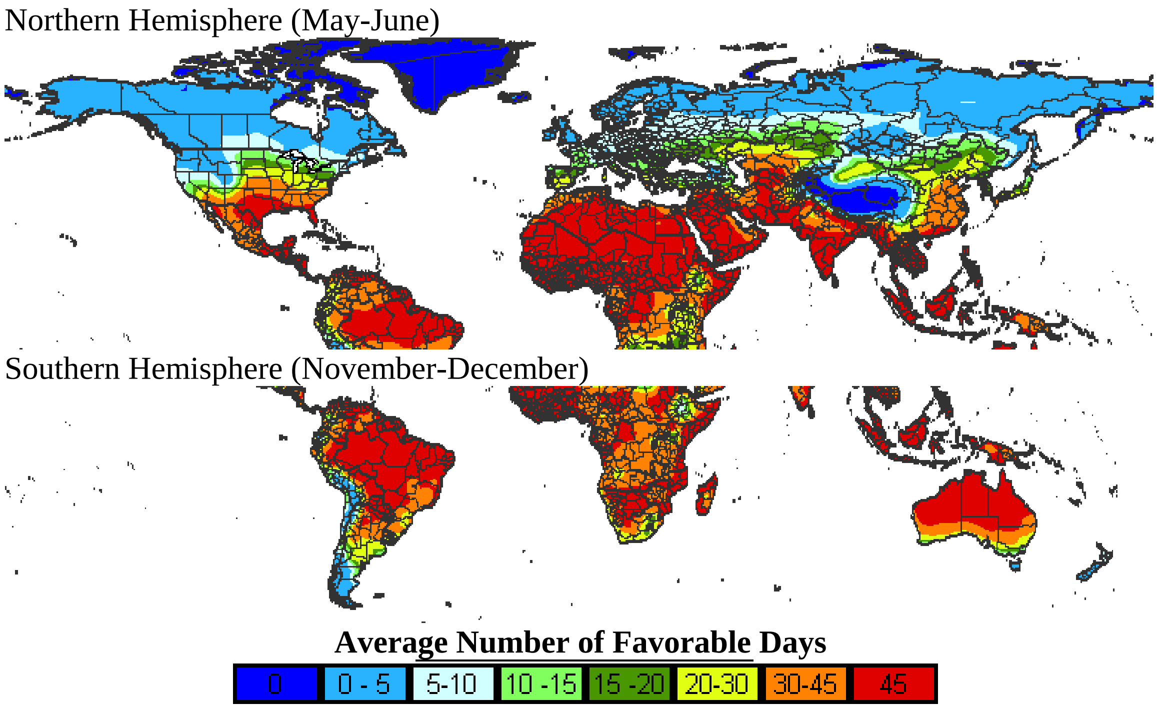

Figure 2. Average number of favorable days suitable for growth of *H. maydis* causal agent of maize wilt during May and June (Northern Hemisphere) and November/December (Southern Hemisphere) based on 10 years of climate data form the NAPPFAST global database.

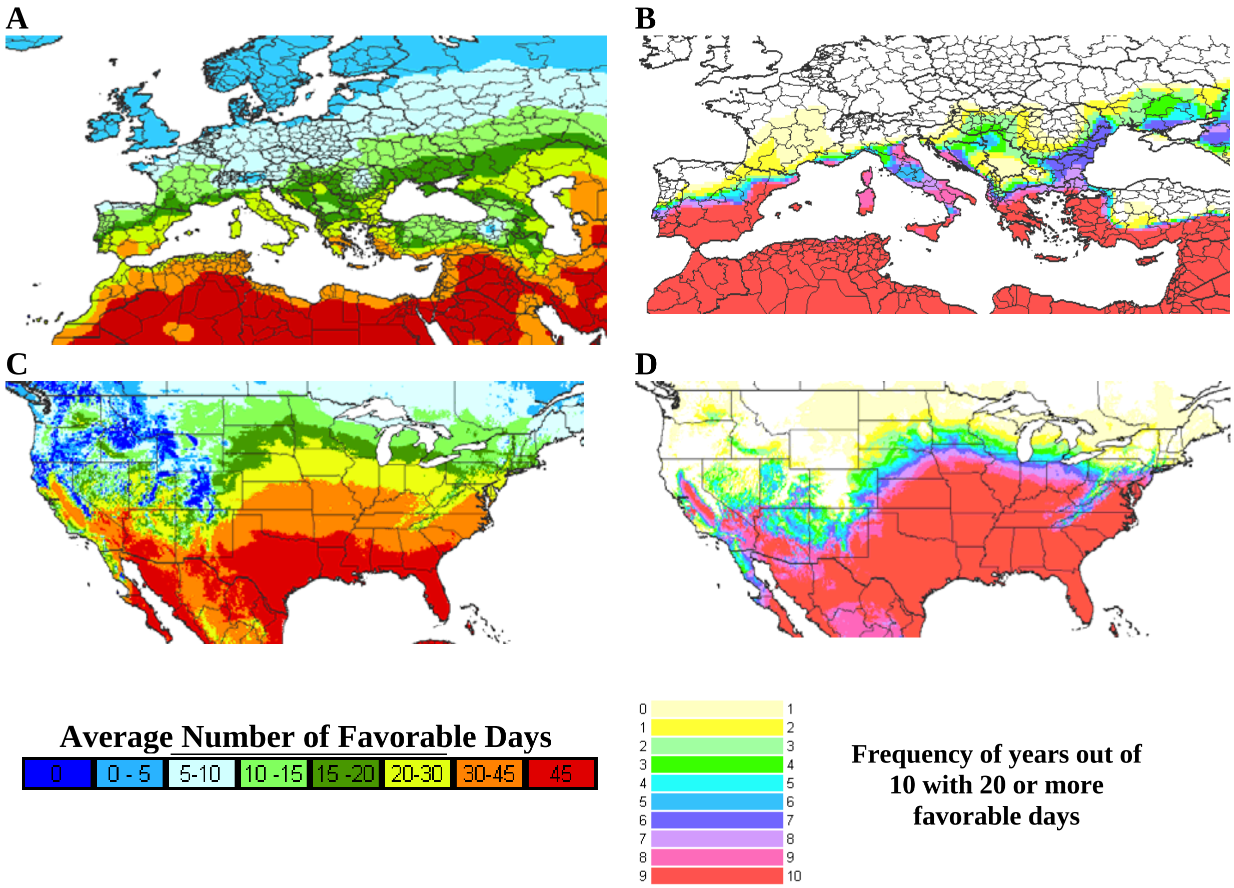

Figure 3. A comparison of the Europe (top) and the United States (bottom) for average number of favorable days (left) and frequency of years with 20 or more favorable days (right) for growth of *H. maydis* causal agent of maize wilt during May and June based on 10 years of climate data. Europe maps are based on NAPPFAST global data and US maps are base on NAPPFAST North American database.

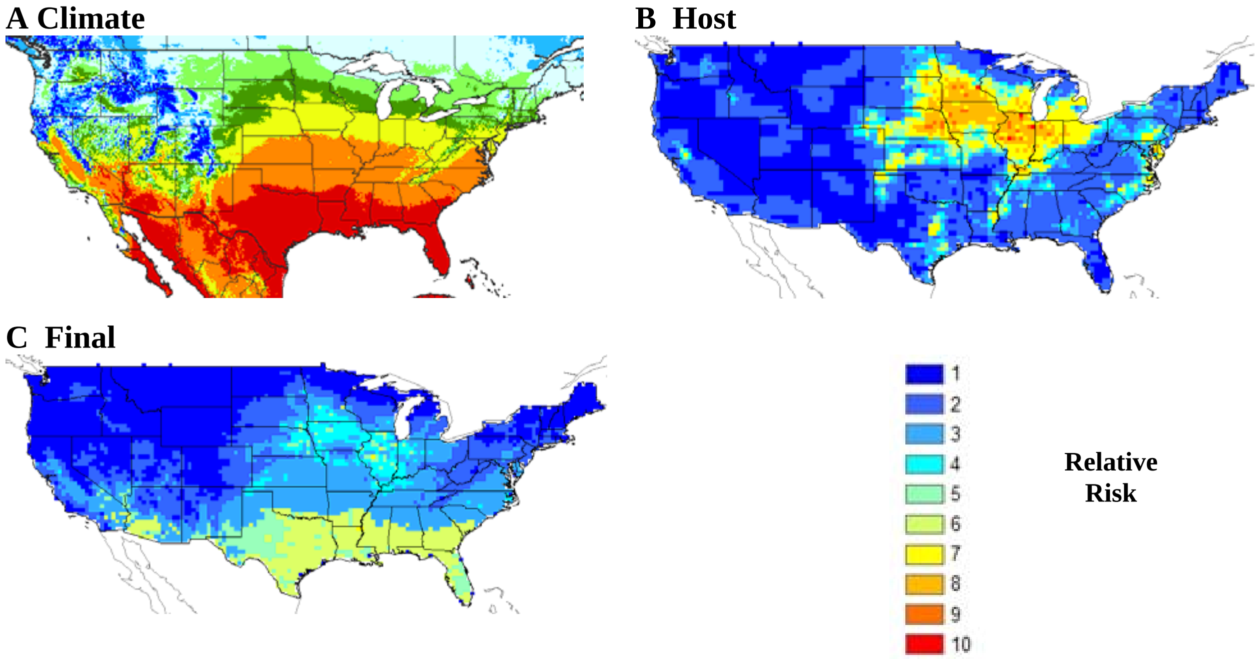

Figure 4. Risk maps for maize wilt based upon a) climate, b) host, and c) climate and host for growth of *H. maydis* causal agent of maize wilt during May and June based on 10 years of climate data.