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Tar Spot of Corn in the U.S. and Canada

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SUMMARY

- Tar spot *(Phyllachora maydis)* is a relatively new disease of corn in the U.S., first appearing in Illinois and Indiana in 2015 and subsequently spreading to neighboring states.
- In 2018, tar spot established itself as an economic concern for corn production in the Midwest, with severe outbreaks affecting corn yield reported in several states.
- Tar spot gets its name from the fungal fruiting bodies it produces on corn leaves that look like spots of tar, developing black oval or circular lesions on the corn leaf.
- Tar spot is favored by cool temperatures (60-70 °F, 16-20 °C), high relative humidity (>75%), frequent cloudy days, and 7+ hours of dew at night.
- Tar spot can rapidly spread through the corn canopy under favorable conditions, causing premature leaf senescence.
- Commercial corn hybrids vary widely in their susceptibility to tar spot. Hybrid selection should be a primary consideration in managing for tar spot.
- Fungicide treatments have shown some effectiveness in reducing tar spot symptoms; however, application timing can be critical for achieving adequate control and two application may be needed in some cases.

TAR SPOT: AN EMERGING DISEASE OF CORN

Corn leaves infected with tar spot in a field in Illinois in 2018.

TAR SPOT ORIGINS

Tar spot in corn is caused by the fungus *Phyllachora maydis*, which was first observed over a century ago in high valleys in Mexico. *P. maydis* was subsequently detected in several countries in the Caribbean and Central and South America (Table 1). Despite its decades-long presence in many of these countries, it was not detected in the Continental U.S. until 2015.

Historically, *P. maydis* was not typically associated with yield loss unless a second pathogen, *Monographella maydis*, was also present, the combination of which is referred to as tar spot complex. In Mexico, the complex of *P. maydis* and *M. maydis* has been associated with yield losses of up to 30% (Hock et al., 1995). In some cases, a third pathogen, *Coniothyrium phyllachorae*, has been associated with the complex. Only *P. maydis* is known to be present in the United States but it has proven capable of causing significant yield losses, even without the presence of an additional pathogen.

Table 1. Country and year of first detection of *P. maydis* (Valle-Torres et al., 2020).

Region	Country	Year
Caribbean	Dominican Republic	1944
	U.S. Virgin Islands	1951
	Trinidad and Tobago	1951
	Cuba	1968
	Puerto Rico	1973
	Haiti	1994
Central America	Guatemala	1944
	Honduras	1967
	Nicaragua	1967
	Panama	1967
	El Salvador	1994
	Costa Rica	1994
North America	Mexico	1904
	United States	2015
	Canada	2020
South America	Peru	1931
	Bolivia	1949
	Colombia	1969
	Venezuela	1972
	Ecuador	1994

TAR SPOT SPREAD TO THE U.S. AND CANADA

The first confirmations of tar spot in North America outside of Mexico were in Illinois and Indiana in 2015 (Bissonnette, 2015; Ruhl et al., 2016). It has subsequently spread to Michigan (2016), Wisconsin (2016), Iowa (2016), Ohio (2018), Minnesota (2019), Missouri (2019), Pennsylvania (2020), Ontario (2020), Kentucky (2021), New York (2021), and Nebraska (2021). Its presence was also confirmed in Florida in 2016 (Miller, 2016) and in Georgia in 2021.

2018 Outbreak

During the first few years of its presence in the U.S., it appeared that tar spot might remain a relatively minor cosmetic disease of little economic impact. In 2018, however; tar spot established itself as an economic concern for corn production in the Midwest, with severe outbreaks reported in Illinois, Indiana, Wisconsin, Iowa, Ohio, and Michigan. Significant corn yield losses associated with tar spot were reported in some areas. University corn hybrid trials conducted in 2018 suggested potential yield losses of up to 39 bu/acre under the most severe infestations (Telenko et al., 2019). Growers in areas severely impacted by tar spot anecdotally reported yield reductions of 30-50% compared to 2016 and 2017 yield levels. Yield losses specifically attributable to tar spot were often difficult to determine however, because of the presence of other corn diseases due to conditions generally favorable for disease development. Instances of greatest tar spot severity in 2018 were largely concentrated in northern Illinois and southern Wisconsin, where other foliar diseases and stalk rots were also prevalent.

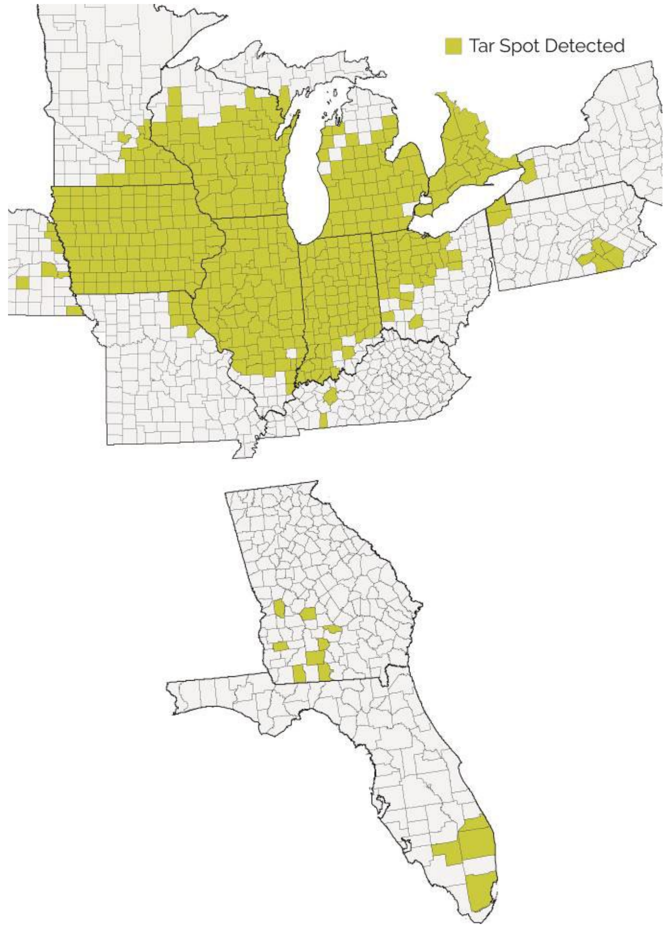

Figure 1. Counties with confirmed or suspected incidence of tar spot, as of October 2021. (Corn ipmPIPE, 2021).

2019 and 2020 Observations

In 2019, tar spot severity was generally lower across much of the Corn Belt and appeared later and more slowly compared to 2018, although severe infestations were still observed in some areas. There is no clear explanation for why tar spot severity was lower in 2019 in areas where it was severe 2018. Less favorable conditions for disease development during the latter part of the growing season in 2019 may have played a role. Reduced winter survival may have been a factor as well. Winter temperatures in some tar spot-affected areas oscillated between warm periods and extreme cold, which may have affected fungal dormancy and survival (Kleczewski, 2019).

Despite the generally lower disease severity, tar spot continued to expand its geographic range in 2019. In Iowa, tar spot presence was limited to around a dozen eastern counties in 2018 but expanded to cover most of the state in 2019 (Figure 1). Tar spot was confirmed in Minnesota for the first time in September of 2019 (Malvick, 2019). Tar spot spread to the south and east as well, with new confirmations in parts of Missouri, Indiana, Ohio, and Michigan.

2020 brought another year of generally lower tar spot severity in the Corn Belt, with severe infestations mostly limited to irrigated corn and areas that received greater than average rainfall or developing late enough in the season that they had minimal impact on yield. Tar spot continued to spread, however; with the first confirmation of tar spot in Pennsylvania. Tar spot was also confirmed to be present in corn in Ontario, marking the first time the disease had been detected in Canada.

2021 Outbreak

The 2021 growing season proved that the 2018 outbreak was not a fluke, with a severe outbreak of tar spot once again impacting corn over a large portion of the Corn Belt. Wet conditions early in the summer appeared to be a key factor in allowing tar spot to get a foothold in the crop. Whereas in 2018, when tar spot appeared to be mainly driven by wet conditions in August and September, in 2021 many impacted areas were relatively dry during the latter portion of the summer. Wet conditions early in the summer were apparently enough to allow the disease to get established in the crop and enabled it to take off quickly when a window of favorable conditions opened up later in the summer. The 2021 season also provided numerous demonstrations of the speed with which tar spot can proliferate, enabled by its rapid reinfection cycle (Figure 2).

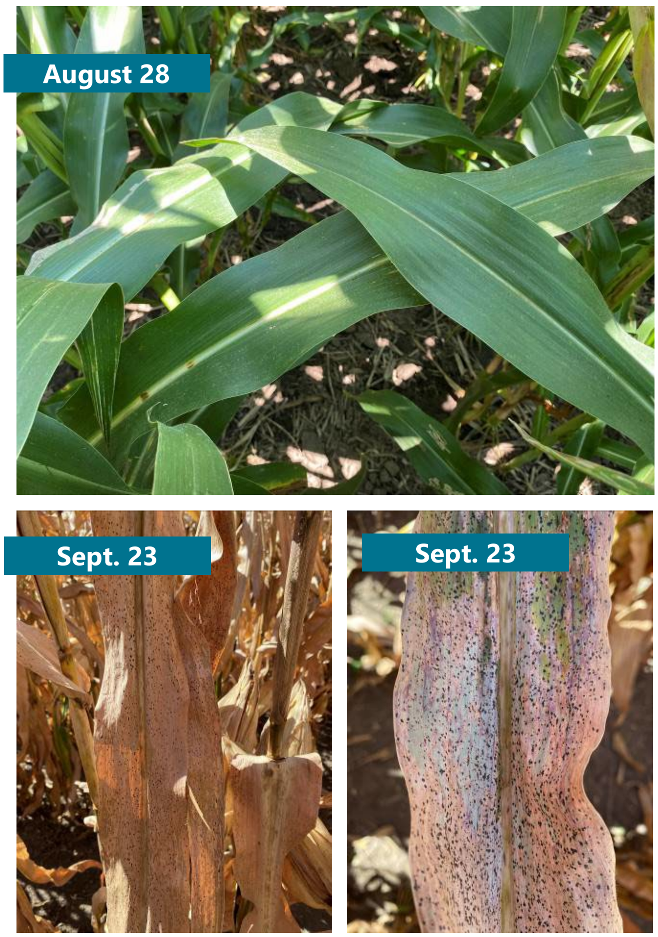

Figure 2. A corn field with almost no visible foliar disease on August 28, 2021 and the same field with extensive tar spot infection on September 23.

In the USA, the availability of several fungicides labeled for tar spot allowed growers to get a better look at fungicide efficacy. Fungicide application timing proved to be critical for controlling tar spot in 2021. In some cases, two applications were necessary to provide adequate control.

IDENTIFICATION AND SYMPTOMS

Tar spot is the physical manifestation of fungal fruiting bodies, the ascomata, developing on the leaf. The ascomata look like spots of tar, developing black oval or circular lesions on the corn leaf (Figure 3). The texture of the leaf becomes bumpy and uneven when the fruiting bodies are present. These black structures can densely cover the leaf and may resemble the pustules of rust fungi (Figure 3 and 4). Tar spot spreads from the lowest leaves to the upper leaves, leaf sheathes, and eventually the husks of the developing ears (Bajet et al., 1994).

Figure 3. A corn leaf with tar spot symptoms.

Figure 4. Corn leaf under magnification showing dense coverage with tar spot ascomata.

Figure 5. Microscopic view of fungal spores of *P. maydis.*

Under a microscope, *P. maydis* spores can be distinguished by the presence of eight ascospores inside an elongated ascus, resembling a pod containing eight seeds (Figure 5).

Tar Spot Look-Alikes

Common rust (*Puccinia sorghi*) and southern rust (*Puccinia polysora*) can both be mistaken for tar spot, particularly late in the growing season when pustules on the leaves produce black teliospores (Figure 6a). Rust pustules can be distinguished from tar spot ascomata by their jagged edges caused by the spores breaking through the epidermis of the leaf (Figure 6b). Rust spores can be scraped off the leaf surface with a fingernail, while tar spot cannot. Saprophytic fungi growing on senesced leaf tissue can also be mistaken for tar spot.

Figure 6a. Southern rust in the teliospore stage late in the season, which can resemble tar spot (left). **Figure 6b.** Corn leaf with common rust spores showing jagged edges around the pustules (right).

Figure 7. Corn leaf with tar spot symptoms.

TAR SPOT ARRIVAL IN THE U.S.

Numerous reports have speculated that *P. maydis* spores may have been carried to the U.S. via air currents associated with a hurricane in 2015, the same mechanism believed to have brought Asian soybean rust (*Phakopsora pachyrhizi*) to the U.S. several years earlier. However, Mottaleb et al. (2018) believe that this scenario is unlikely and that it is more plausible that spores were brought into the U.S. by movement of people and/or plant material. Ascospores of *P. maydis* are not especially aerodynamic and are not evolved to facilitate spread over extremely long distances by air.

Tar spot was observed in corn in Mexico for over a century prior to its arrival in the U.S., during which time numerous hurricanes occurred that could have carried spores into the U.S. Chalkley (2010) notes that *P. Maydis* occurs in cooler areas at higher elevations in Mexico, which coupled with its lack of alternate hosts would limit its ability to spread across climatic zones dissimilar to its native range. Chalkley also notes the possibility of transporting spores via fresh or dry plant material and that the disease is not known to be seedborne.

TAR SPOT EPIDEMIOLOGY

Much is still being learned about the epidemiology of tar spot, even in its native regions, and especially in the U.S. and Canada. *P. maydis* is part of a large genus of fungal species that cause disease in numerous other species; however, *P. maydis* is the only *Phyllachora* species known to infect corn, and it appears to only infect corn (Chalkley, 2010).

P. maydis is an obligate pathogen, which means it needs a living host to grow and reproduce. It is capable of overwintering in the Midwestern U.S. in infected crop residue on the soil surface. Tar spot is favored by cool temperatures (60-70 ºF, 16-20 ºC), high relative humidity (>75%), frequent cloudy days, and 7+ hours of dew at night. Tar spot is polycyclic and can continue to produce spores and spread to new plants as long as environmental conditions are favorable. *P. maydis* produces windborne spores that have been shown to disperse up to 800 ft. Spores are released during periods of high humidity.

MANAGEMENT CONSIDERATIONS

Yield Impact

2018 was the first time that corn yield reductions associated with tar spot were documented in the U.S. University corn hybrid trials conducted in 2018 suggested potential yield losses of up to 39 bu/acre under heavy infestations (Telenko et al., 2019). Pioneer on-farm research trials, along with grower reports, showed yield losses of up to 50% under the most extreme infestations during the 2018 season and again in the 2021 growing season.

Differences in Hybrid Response

Observations in hybrid trials have shown that hybrids differ in susceptibility to tar spot (Kleczewski and Smith, 2018). Tar spot affects yield by reducing the photosynthetic capacity of leaves and causing rapid premature leaf senescence. Longer maturity hybrids for a given location have been shown to have a greater risk of yield loss from tar spot than shorter maturity hybrids (Telenko et al., 2019). Pioneer agronomists and sales professionals continue to collect data on disease symptoms and hybrid performance in locations where tar spot is present to assist growers with hybrid management. Pioneer brand corn products in Eastern Canada have been scored for Tar Spot (Figure 8). Pioneer hybrid trials have shown differences in canopy staygreen among Pioneer® brand corn products* and competitor products under tar spot disease pressure (Figure 9). Genetic resistance to tar spot should be the number one consideration when seeking to manage this disease, as it appears to have a greater impact on symptoms and yield loss than either cultural or chemical management practices.

Product		Heat Units	Technology Segment	CRM	Tar Spot
P9301	New	2725		93	4
P9301AM		2750	AM,LL,RR2	93	4
P9301Q		2750	Q,LL,RR2	93	4
P9466AML	New	2800	AML,LL,RR2	94	5
P9492AM		2825	AM,LL,RR2	94	6**
P9492		2825		94	6**
P9535AM		2825	AM,LL,RR2	95	6**
P9608		2800		96	5
P9608AM		2850	AM,LL,RR2	96	5
P9608Q		2850	Q,LL,RR2	96	5
P9624Q	New	2850	Q,LL,RR2	96	6
P9815AM		2925	AM,LL,RR2	98	5**
P9823Q		2925	Q,LL,RR2	98	5**
P9845AM	New	2950	AM,LL,RR2	98	4
P9946		3000		99	5
P9946AML		2950	AML,LL,RR2	99	5
P9998		2900		99	5
P9998AM		2950	AM,LL,RR2	99	5
P9998Q		2950	Q,LL,RR2	99	5
P0035AM		3000	AM,LL,RR2	100	7
P0035Q		2975	Q,LL,RR2	100	7
P0075		3000		100	6**
P0075AM		3000	AM,LL,RR2	100	6**
P0075Q		3000	Q,LL,RR2	100	6**
P0157		3000		101	5
P0157AM		3000	AM,LL,RR2	101	5
P0157AMXT		3050	AMXT,LL,RR2	101	5
P0306AM		3100	AM,LL,RR2	103	5**
P0306Q		3100	Q,LL,RR2	103	5**
P0404AM		3125	AM,LL,RR2	104	4
P0404Q		3125	Q,LL,RR2	104	4
P0434AM		3125	AM,LL,RR2	104	5
P0434YHR		3125	YGCB,HX1,LL,RR2	104	5
P0487		3100		104	6
P0487Q		3125	Q,LL,RR2	104	6
P0506AM		3150	AM,LL,RR2	105	6
P0506		3100		105	6
P0529Q	New	3150	Q,LL,RR2	105	6**
P0720AM		3225	AM,LL,RR2	107	7
P0720Q		3250	Q,LL,RR2	107	7
P0806AM		3250	AM,LL,RR2	108	6
P0953AM		3300	AM,LL,RR2	109	5
P1197AM		3400	AM,LL,RR2	111	6**
P1197AMXT		3400	AMXT,LL,RR2	111	6**

Figure 8. Eastern Canada Pioneer hybrid rating for Tar Spot. Scores will be updated as more data becomes available. ** denotes ratings based on preliminary data.

Stalk Quality

Severe tar spot infestations have been associated with reduced stalk quality (Figure 10). Stress factors that reduce the amount of photosynthetically functioning leaf area during grain fill can increase the plant's reliance on resources remobilized from the stalk and roots to complete kernel fill. Remobilizing carbohydrates from the stalk reduces its ability to defend against soil-borne pathogens, which can lead to stalk rots and lodging.

Tar spot seems to be particularly adept at causing stalk quality issues due to the speed with which it can infest the corn canopy, causing the crop to senesce prematurely. If foliar symptoms are present, stalk quality should be monitored carefully to determine harvest timing.

1	P0688AM™ (AM,LL,RR2)	12	DKC 55-53 RIB
2	P0075AM™ (AM,LL,RR2)	13	P0720Q™(Q,LL,RR2)
3	DKC 51-40 RIB	14	DKC 55-85 RIB
4	DKC 52-35 RIB	15	P0825AM™ (AM,LL,RR2)
5	P0306Q™(Q,LL,RR2)	16	DKC 56-45 RIB
6	DKC 52-68 RIB	17	P0977AM™ (AM,LL,RR2)
7	P0506AM™ (AM,LL,RR2)	18	DKC 58-34 RIB
8	DKC 53-27 RIB	19	P0963AM™ (AM,LL,RR2)
9	P0574AM™ (AM,LL,RR2)	20	DKC 59-82 RIB
10	DKC 54-64 RIB	21	P1077AM™ (AM,LL,RR2)
11	P0688AM™ (AM,LL,RR2)		

Figure 9. Pioneer on-farm trial in Ottawa County, Michigan with high tar spot pressure showing differences in canopy staygreen among hybrids (September 27, 2019).

Figure 10. Field with severe tar spot infection and extensive stalk lodging in Wisconsin in 2018. Photo: Scott Rowntree, Pioneer Field Agronomist.

Fungicide Treatments

Research has shown that fungicide treatments can be effective against tar spot (Bajet et al., 1994). Specific management recommendations for the use of fungicides in managing tar spot in the Midwestern U.S. are still in development as more research is done. Currently there is research underway in Ontario as well, though no fungicides are currently labelled for tar spot.

U.S. University trials., conducted in 2018 in locations where tar spot was present provided evidence that fungicides can reduce tar spot symptoms and potentially help protect yield. However, initial work also suggested that tar spot may be challenging to control with a single fungicide application due to its rapid reinfection cycle, particularly in irrigated corn.

A 2019 Purdue University study compared single-pass and two-pass treatments for tar spot control using Aproach® (picoxystrobin) and Aproach® Prima (picoxystrobin + cyproconazole) fungicides under moderate to high tar spot severity (Da Silva et al., 2019). Fungicide treatments were applied at the VT (August 8) and R2 stage (August 22), and disease symptoms were assessed on September 30. Results showed that all treatments significantly reduced tar spot symptoms relative to the nontreated check, with Aproach Prima fungicide applied at VT and two-pass treatments at VT and R2 providing the greatest reduction in tar spot stroma and associated chlorosis and necrosis on the ear leaf (Figure 11).

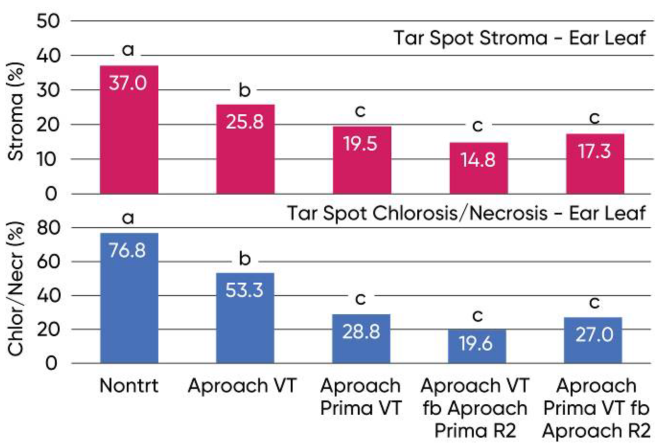

Figure 11. Fungicide treatment effects on tar spot symptoms in a 2019 Purdue University study. Visually assessed tar spot stroma and chlorosis/necrosis (0-100%) on the ear leaf.

Means followed by the same letter are not significantly different based on Fisher's Least Significant Difference test (LSD; α=0.05)

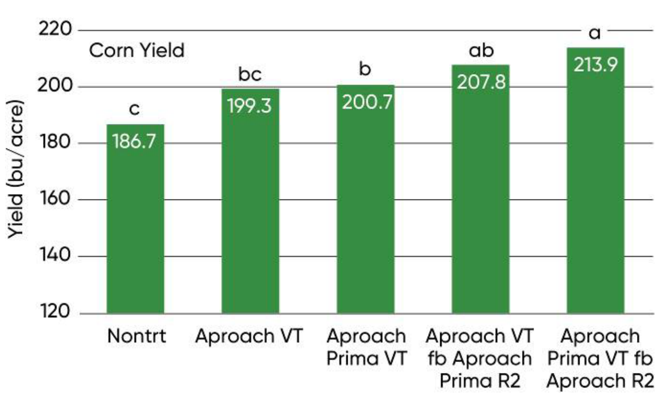

Figure 12. Fungicide treatment effects on corn yield in a 2019 Purdue University study.

Means followed by the same letter are not significantly different based on Fisher's Least Significant Difference test (LSD; α=0.05)

Aproach® Prima fungicide applied at VT and the two-pass treatments all significantly increased yield relative to the nontreated check. Aproach Prima fungicide applied at VT followed by Aproach® fungicide at R2 had the greatest yield, although it was not significantly greater than Aproach followed by Aproach Prima (Figure 12).

On-farm fungicide trials in the U.S. conducted in 2021 appeared to confirm concerns that the rapid reinfection rate of tar spot would make it difficult to control with a single pass fungicide treatment. Precise application timing was often critical, and two applications were necessary in some cases to provide adequate tar spot control. Disease forecasting models such as Tarspotter, developed at the University of Wisconsin, may be helpful in optimizing timing of fungicide applications. Tarspotter uses several variables including weather to forecast the risk of tar spot fungus being present in a corn field.

https://ipcm.wisc.edu/apps/tarspotter/

It is important to note, that there are no registered fungicides in Canada labelled for tar spot control. Always read and follow product label directions.

Agronomic Practices

The pathogen that causes tar spot overwinters in corn residue but to what extent the amount of residue on the soil surface in a field affects disease severity the following year is unknown. Spores are known to disperse up to 800 ft, so any benefit from rotation or tillage practices that reduce corn residue in a field may be negated by spores moving in from neighboring fields. Observations so far suggest that rotation and tillage probably have little effect on tar spot severity.

Duration of leaf surface wetness appears to be a key factor in the development and spread of tar spot. Farmers with irrigated corn in areas affected by tar spot have experimented with irrigating at night to reduce the duration of leaf wetness, although the potential effectiveness of this practice to reduce tar spot has not yet been determined.

Yield potential of a field appears to be positively correlated with tar spot risk, with high productivity, high nitrogen fertility fields seeming to experience the greatest disease severity in affected areas. Research on *P. maydis* in Latin America has also suggested a correlation between high nitrogen application rates and tar spot severity (Kleczewski et al., 2019).

Mycotoxins

There is no evidence at this point that tar spot causes ear rot or produces harmful mycotoxins (Kleczewski, 2018).

HOW FAR WILL TAR SPOT SPREAD?

Mottaleb et al. (2018) used climate modeling based on long-term temperature and rainfall data to predict areas at risk of tar spot infection based on the similarity of climate to the current area of infestation. Model forecasts indicated the areas beyond the then-current range of infestation at highest risk for spread of tar spot were central Iowa and northwest Ohio. Observations in recent growing seasons have been consistent with model predictions, with further spread of tar spot to the east in Ohio, Ontario, and Pennsylvania and a dramatic expansion of tar spot across Iowa and into parts of Minnesota and Missouri.

Results indicated the potential for further expansion to the north and south but primarily to the east and west, including corn production areas of New York, Pennsylvania, Ohio, Missouri, Nebraska, South Dakota, eastern Kansas, and southern Minnesota.

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