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Success and Limitations of Using Fungicides to Control Cercospora Leaf Spot on Sugar Beet

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Abstract

Sugar beet (*Beta vulgaris L.*) provides about 25% of the world's sucrose requirement and are grown mainly in temperate climates. *Cercospora beticola*, the causal agent of Cercospora leaf spot (CLS), is one of the major limiting factor of sugar beet production especially in warm and humid growing regions. Fungicide applications are necessary for economic returns in areas such as North Dakota and Minnesota where the pathogen is endemic. Over time, the pathogen has developed resistance to many fungicides. This paper describes the success and issues of using fungicides as a major method for controlling CLS on sugar beet in Minnesota and North Dakota, USA.

Keywords: *Beta vulgaris*; Fungicide resistance; *Cercospora beticola*; Sucrose

Introduction

Cercospora leaf spot (CLS), caused by the fungus *Cercospora beticola* Sacc., is one of the most damaging foliar disease of sugar beet (*Beta vulgaris L.*) grown in warm and humid regions worldwide [1-3]. The disease destroys the leaves that are the photosynthetic factories of the plant resulting in reduced tonnage, and increased impurities leading to reduced recoverable sucrose Smith & Ruppel [4]; Khan & Smith [5] and higher processing costs. Roots of CLS infected plants do not store and process well, in areas such as North Dakota (ND) and Minnesota (MN), where beets are stored and processed over a six to eight month period [4]. Growers integrate tolerant varieties, crop rotation with non-hosts, planting away from the previous year's fields, tillage that incorporates infected leaf debris, and annual fungicide applications to manage CLS [5,6].

Change in ownership resulted in change in seed policy

Growers in MN and ND started to produce sugar beet for factories built in East Grand Forks in 1926. Processing companies made available seed varieties that were more tolerant to *C. beticola* but had lower yield potential. Starting from 1973, growers in MN and ND purchased and managed their processing facilities and implemented an integrated production system. Since 1973, growers changed their seed policy to allow the use of higher yielding varieties; however, these varieties were more susceptible to *C. beticola* and required fungicide applications to maximize recoverable sucrose [7]. Sugar beet growers typically applied fungicides annually for controlling CLS [8,9].

Use of fungicides for controlling CLS

In the late 1970s and early 1980s, growers used benzimidazole fungicides to which the pathogen quickly developed resistance [1]. Growers then used triphenyltin hydroxide (TPTH – Agri Tin®, NuFarm; Super Tin®, UPI), and to a lesser extent ethylene bis-dithiocarbamate (EBDCs) (Manzate® and Penncozeb®, UPI) fungicides for control of CLS. Widespread and frequent use of TPTH as the main fungicide for nearly two decades resulted in over 83 and 92% of the *C. beticola* population, in Minn-Dak and Southern Minnesota Beet Sugar Cooperative (SMBSC), respectively, developing tolerance to TPTH at 1.0ppm, and a CLS epidemic in 1998 [10,11]. Growers in ND and MN lost over $100 million in reduced revenue because of the epidemic.

The lack of registered fungicides that were effective at controlling CLS on sugar beet resulted in the United States Environmental Protection Agency granting an emergency exemption from 1999 to 2004 for the use of tetraconazole (Eminent®, Sipcam USA) for controlling CLS on sugar beet. Initially, TPTH was sandwiched between two applications of tetraconazole for controlling CLS. The registration of several quinone outside inhibitor (QoI) fungicides, namely trifloxystrobin (Gem®, Bayer Crop Sciences) and pyraclostrobin (Headline®, BASF) resulted in growers initially replacing one tetraconazole application with mainly pyraclostrobin, and over time, reduced the number of TPTH applications because of lower inoculum pressure and lower disease severity.

The average number of fungicide applications for CLS were reduced from 3.74 in 1998, the year of the epidemic, to 2.06 applications in 2004 and 2005 [12]. Tetraconazole was finally registered in 2005, followed by several other triazoles (difenoconazole and propiconazole (Inspire® XT, Syngenta), prothioconazole (Proline®, Bayer CropScience), fenbuconazole (Enable®, Dow), and flutriafol (Topguard®, FMC)). Growers used research based recommendations Khan [13] and applied fungicides with different modes of action in a rotation program, and used mixtures of fungicides, mainly TPTH and thiophanate methyl (Topsin®, UPI) once and early in the season, to help manage fungicide resistance and control CLS (Figure 1 – Field with effective control of CLS using fungicides, 2015) [9,12]. Timely application of fungicides in a rotation program reduced the inoculum pressure, and over time, the average number of fungicide applications for control of CLS was reduced to 1.79 per season in 2014 [9].

Figure 1: Field in Minn-Dak factory district with effective control of CLS using fungicides, 2015.

Field failure of fungicides and economic losses

Figure 2: Field in Minn-Dak factory district with severe CLS after six fungicides application in 2016.

In 2015, there were a few reports of field failures of QoI fungicides, the average number of fungicide applications increased from 1.79 the previous year to 2.96, and it was easy to observe CLS symptoms in fields [9]. In 2016, one field in Wilkin County, MN, where a QoI fungicide (pyraclostrobin) was used in the first application in early July had severe CLS symptoms later in the month, and *C. beticola* isolates collected from the field were confirmed as resistant to QoI fungicides. Most growers tend to apply a QoI fungicide in their 3rd application, typically in middle to late August. Many fields - over 80% - in the SMBSC (Figure 2 –Field with severe CLS after six fungicides application in 2016) and Minn-Dak Farmers' Cooperative (Figure 3 –Field with severe CLS after five fungicides applications in 2016) suddenly had severe disease severity soon after the 3rd fungicide application. Subsequent fungicide applications with different modes of action were not effective at reducing the disease severity.

Figure 3: Field in Southern Minnesota Beet Sugar Cooperative with severe CLS after six fungicides applications in 2016.

CLS is typically most severe at the SMBSC (southern, warmer and wetter) followed by the Minn-Dak factory district (central). The more northern areas where American Crystal Sugar Company (ACSC) is located usually have the least severe CLS of the three sugar cooperatives. In 2016, growers at ACSC averaged 3 fungicide applications, growers at Minn-Dak averaged 5 applications, and growers at SMBSC averaged 6 applications [9]. The warm and wet conditions that prevailed in 2016, especially in the SMBSC and Minn-Dak areas, were conducive for rapid development of CLS, but also favorable for plant growth. As such, although there was a CLS epidemic, there were no other major root diseases and average yields (tonnage) were still relatively high. However, CLS caused a 1 to 2% reduction in the sucrose concentration of the crop in the entire production area. SMBSC estimated that their growers lost over $30 million from the CLS epidemic [14]. Minn-Dak have reported economic losses of $375 per acre from fields where CLS is not effectively controlled Metzger [15] which will translate to a loss of about $43 million. ACSC, with the largest acreage (400,000 acres) but overall lower CLS severity compared to the other cooperatives, had a lower sugar crop that resulted in a significant reduction (24%) in the price per ton of sugar beet. It was estimated that the lower sugar crop at ACSC resulted in over $143 million in lost revenue; easily 50% of the losses ($71.5 million) could be attributed to CLS.

Resistance and management strategy

CLS samples collected over the entire sugar beet production area of eastern North Dakota and Minnesota indicated that 90% of the isolates were resistant to pyraclostrobin and had the G143A

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mutation [16]. Consequently, SMBSC and Minn-Dak management decided not to recommend the use of QoI fungicides for control of CLS in 2017 [15,17]. This means that growers have one less fungicide chemistry to manage *C. beticola*. Growers were advised to use mixtures of fungicides in a rotation program, shorten application intervals, use high water volumes to provide good fungicidal coverage on the leaves, and plant varieties with more tolerance to the pathogen so as to effectively to manage CLS in 2017 [18].

Conclusion

Since the 1970s, growers in Minnesota and North Dakota, in most years, have successfully used fungicides to control CLS. Disease control was compromised in a few years when the fungicides became ineffective because of pathogen resistance and the environmental conditions were favorable for rapid disease development. Current research indicate that mixtures of fungicides with different modes of action should be applied in a timely manner to control CLS and manage fungicide resistance. The continued use of an integrated program that combines genetic resistance, cultural practices, and protecting triazoles fungicides by mixing with effective broad spectrum fungicides to delay or prevent development of resistant *C. beticola* isolates should result in effective control of CLS.

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