INTEGRATED MANAGEMENT OF CERCOSPORA LEAF SPOT

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Management of Cercospora leaf spot (CLS) is critical to both growers and processors because this disease reduces harvestable tons, sugar content, storability of harvested roots and decreases sugar extraction/ton in the extraction process through increased losses to impurities and molasses. In Montana and western North Dakota losses over the past 6 years have ranged from 1-3 tons/A, 0.5-1.5% sugar and increased net income of $0-350/A. Storage and factory losses have been more difficult to measure. Economically sound management of Cercospora leaf spot requires an integrated approach that incorporates crop rotation, planting varieties with at least an intermediate level of resistance, use of environmental monitoring to predict infection conditions, scouting and timely application of effective fungicides.

Crop rotation, tillage and other practices which hasten decay of infected leaves will reduce initial inoculum and initial infection. Disease development each year is dependent on inoculum that survives the winter in infected leaves and petioles of the previous year sugarbeet crop or weeds such as winged pigweed, lambsquater, pigweed, mallow, wild buckwheat and common unicorn flower. The *Cercospora beticola* fungus dies out rapidly once the leaves begin to decay, therefore tillage or other practices that hasten decay will reduce potential for overwintering inoculum. In the spring and early summer when temperatures exceed 60-65^0 F and the overwintering leaves are wet for long periods of time (4-24 hours depending on temperature) spores (conidia) are produced from fungal stroma in overwintered leaves and petioles. These spores are spread by wind or splashing water generally less than 100-150 yards. Insects, animals and equipment maybe involved in longer distance spread. In the narrow river valleys of Montana it can be difficult to separate current year planting sufficiently from previous years crop residues, therefore destruction of beet foliage residues is very critical.

Historically, sugarbeets with high levels of resistance to CLS (low KWS scores) have produced lower economic return (reduced tons and sugar content) than susceptible varieties when produced under an appropriate fungicide spray program. However, the use of moderately resistant varieties (KWS 5.0-5.5) is now widely accepted in most production areas because varieties with this level of resistance are competitive with susceptible varieties when sprayed with fungicides. The full potential of these varieties to reduce fungicide use has not been fully exploited since almost all research has been done with fungicide programs starting at disease onset and being repeated at 14 day intervals till 30 days before harvest. For the past three years we have studied the integration of moderately resistant varieties with reduced fungicide application. In 1999 and 2000 studies under light disease pressure our data has shown that varieties with KWS scores of 4.3 and 5.3 achieved equal yield and disease control with 1-2 fewer sprays than a susceptible variety with a KWS score of 6.3. In these years the Minnesota prediction model would have indicated the need for 2-3 sprays. In 2001 we studied these same varieties and disease pressure was moderately severe with the Minnesota prediction model indicating the need for 4 applications. Data from this trial are presented in Table 1.

As in 1999 and 2000, three varieties Beta 2185, HH 111 and HM 7054 were selected based on differences in their KWS scores and were examined for their response to varying numbers of fungicide applications and application based on the Minnesota predictive model. Disease severity as measured by area under the disease progress curve was 15.9 in 1999, 13.0 in 2000 and 58.3 in 2001for the susceptible variety Beta 2185. When 2001 data was analyzed across varieties there were no differences in % sucrose or % sucrose by treatment. However there were significant differences in ton/A and sucrose yield. The area under the disease progress curve (AUDPC) was significantly different for the 3 varieties and with treatment (Table 1.). To achieve optimal disease control and yield on the susceptible variety Beta 2185 (KWS=6.3) required 4 sprays, on the moderately susceptible HH111 (KWS=5.3) AUDPC required 4 sprays but yield was maximized with 2-3 sprays and on the highly resistant HM 7054 only two sprays were required to achieve optimal disease control as measured by AUDPC and yield was statistically unchanged by all fungicide programs except the biological Bac J program.(Table 1.). With no fungicide application the moderately susceptible HH 111 and the resistant HM 7054 had significantly higher yield and lower AUDPC than the susceptible variety Beta 2185 but these differences equalized with optimal fungicide programs.

Infection conditions as indicated by the Minnesota predictive model indicated that 4 applications were needed. This proved true for the susceptible Beta 2185 but not for the more resistant HH 111 and HM 7024 where 1-2 sprays could be saved and still achieve acceptable disease control and economic yield. The biological control treatment BAC J was more effective on the more resistant varieties than on the susceptible Beta 2185. Thus, the choice of a moderately resistant or resistant variety with reduced fungicide application would be more profitable than the susceptible variety with more fungicide applications and the integration of the biological Bac J is more successful on varieties with some resistance.

Table 1. Integration of variety resistance to Cercospora leaf spot, fungicides, fungicide application number and the biological control Bac J for Management of Cercospora leaf spot of sugarbeet

Treatment	Beta 2185 KWS = 6.3		HH 111 KWS = 5.3		HM 7054 KWS =4.3	
	AUDPC (4)	Sugar lbs per A	AUDPC	Sugar lbs. per A	AUDPC	Sugar lbs. per A
unsprayed	58.3	7425	48.6	8022	35.6	8084
4 sprays (1)	29.1	8768	24.8	8719	17.7	8463
3 sprays (2)	31.9	8059	30.9	8845	16.6	8390
2 sprays (3)	30.8	7836	30.1	8711	16.2	8343
Bac J preventive + 14, 28 and 42 days	54.5	8699	36.5	8509	24.9	8717
Eminent + Bac J onset + Bac J 14, 28, and 42 days	27.7	9161	23.8	8776	18.9	8552
Flsd 0.05	4.36	849	4.36	849	4.36	849

FLSD 0.05 for AUDPC =4.4, for Sugar /A=584 lbs
(1) Mean of spray at disease onset plus 14. 28 and 42 days and Minnesota predictive model since they were the same. First spray at disease onset =Eminent @ 13 oz./A, second spray=Benlate @ 0.5lb/A, third and fourth spray =SuperTin @ 5.0 oz/A
(2) First spray at disease onset=Eminent @ 13 oz./A, second spray=Benlate @ 0.5lb/A, third spray =SuperTin @ 5.0 oz/A.
(3) First spray at disease onset=Eminent @ 13 oz./A, second spray=Benlate @ 0.5lb/A
(4) AUDPC = Area under the disease progress curve.

The effective use of fungicides for control of CLS depends on the proper timing, application and use of fungicides that are effective on the local population of *C. beticola*. Two of these principles are clearly shown in the data in Tables 2 and 3. In Table 2 all fungicide programs provided significant disease control as measured by AUDPC. It should be noted that a significant % of isolates from this plot were resistant to the benzimidazole fungicides Benlate and Topsin M. Our data from leaves saved from 2000 at this location showed that approximately 5-9% of the isolates were resistant to benzimidazole fungicides and data from 2001 leaves shows that the majority of isolates are resistant to this class of fungicides. The importance of the first spray can be seen where treatments 17 (Benlate first spray) and 18, 19 or 20 (Eminent first spray) are compared. By applying a fungicide to which the *C. beticola* population was resistant, the first application was ineffective. The importance of fungicide resistance management is critical in that over the past 4 years we have detected not only benzimidazole resistance but tolerance to TPTH at up to 5 ppm, resistance to the new strobilurin class of fungicides (Flint, Headline, Quadris) at up to 10 ppm and tolerance to sterol biosynthesis inhibitor class fungicides (Tilt, Eminent) at up to 10 ppm. For this reason our research has focused primarily on the rotation of fungicide classes, integration of the biological Bac J and the potential integration of variety resistance to decrease fungicide selection pressure.

Effective fungicide spray programs increased % sugar, tons/A, sucrose per acre and gross returns. Fungicide programs # 2, 3, 5, 11, 12 and 14 significantly increased gross economic returns. These programs involved the fungicides Eminent, AgriTin/Super Tin, or the strobilurin fungicides Headline or Flint (USF 2004). Because of fungicide resistance management concerns growers should never utilize at treatment such as #5 where headline was used season long!

Table 2. Results of 2001 Cercospora Leaf Spot Fungicide Efficacy Trial at Sidney, MT

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Treatment	AUDPC[2]	% sucrose	Ton/A	Sucrose per Acre	$ gross return @$23.00 nsp
1.Untreated	55.8 a[1]	16.4 bcd	27.9 de	9145 c	1091 cd
2. Eminent 13 oz 1,3 */ Headline 9.2 oz+Agridex 0.25%v/v 2,4*	13.5 ef	17.2 a	30.5 abcd	10456 a	1276 a
3. Eminent 13 oz-1,3* /AgriTin 5 oz-2,4*	12.2 f	17.2 a	30.3 abcde	10439 a	1268 ab
4. Eminent 13 oz-1*/Headline 9.2oz-2* /AgriTin 5 oz-3,4*	14.6 cdef	16.7 abcd	29.9 abcde	10003 ab	1200 abc
5. Headline 9.2 oz+Agridex 0.25%v/v 1,2,3,4*	13.6 def	16.7 abcd	31.3 abc	10475 a	1256 ab
6. Headline 9.2 oz-1*/Eminent 13 oz-2*/Benlate 8 oz-3*/SuperTin 5 oz-4*	19.9 bcedf	16.5 abcd	29.9 abcde	9882 abc	1179 abcd
7. Eminent 13 oz-1,3*/SuperTin 5 oz-2,4*	19.3 bcedf	16.6 abcd	28.5 cde	9492 abc	1134 abcd
8. Eminent 13 oz-1*/Quadris 9.2 oz-2*/SuperTin 5 oz-3,4*	13.9 def	16.7 abcd	28.5 cde	9503 abc	1144 abcd
9. Quadris 9.2 oz-1,3*/Eminent 13 oz-2,4*	20.6 bcdef	16.6 abcd	29.0 abcde	9672 abc	1154 abcd
10. Eminent 13 oz-1*/DG14161 6.7 ml/l-2*/SuperTin 5 oz-3,4*	16.7 cdef	16.7 abcd	29.7 abcde	9918 abc	1192 abcd
11. USF2004 2 oz-1,3* /SuperTin 5 oz-2,4*	19.3 bcdef	16.6 abcd	31.8 a	10566 a	1265 ab
12. USF 2004 2.49 oz-1,3*/SuperTin 5 oz-2,4*	21.7 bcdef	16.6 abcd	31.7 ab	10546 a	1261 ab
13. USF 2004 3.01 oz-1,3*/SuperTin 5 oz-2,4*	19.2 bcdef	17.0 ab	28.7 abcde	9808 abc	1181 abcd
14. USF 2004 3.01 oz-1,3*/Eminent 13 oz-2,4*	13.4 ef	17.2 a	29.9 abcde	10260 ab	1251 ab
15. Stratego 10.02 oz-1,3*/SuperTin 5 oz-2,4*	14.3 cdef	16.8 abcd	30.3 abcde	10172 ab	1226 abc
16. Quadris 9.2 oz-1,3*/SuperTin 5 oz-2,4*	23.8 bcd	16.1 d	29.5 abcde	9470 abc	1123 bcd
17. Benlate 8 oz-1*/Eminent 13 oz-2*/SuperTin 5 oz-3* Pencozeb 2 lb.-4*	24.4 bc	16.2 d	27.3 e	8819 c	1049 d
18. Eminent 13 oz+Bac J-1*/Benlate 8 oz-2*/Bac J 3,4*	28.1 b	16.3 cd	30.6 abcd	9964 abc	1186 abcd
19. Eminent 13 oz-1,3*/Topsin 8 oz-2*/Penncozeb 2 lb.-4*	14.9 cdef	16.9 abc	29.7 abcde	10028 ab	1212 abc
20. Eminent 13 oz-1*/Topsin 8 oz-2*/Headline 9.2 oz-3*/Penncozeb 2 lb.-4*	22.8 bcde	17.0 abc	28.6 bcde	9702 abc	1177 abcd
Flsd p=0.05	10.2	0.72	3.12	1172.8	152.7

- = spray #
- 1. values followed by the same letters do not differ @ P=0.05

  2. AUDPC = Area Under the Disease Progress Curve

Table 3 contains information on the use of the MSU biological Bac J. Previous research has shown that Bac J works primarily as signal for induced systemic resistance and that the inducer signal is strongest from vegetative cells and is present in the fermentation beer. All plants have the genes to protect themselves from infection but in the susceptible reaction these genes are "turned on " to slowly for the plant to resist infection. When a signal is received to "turn on the genes" that govern induced systemic resistance the plant is effectively "immunized". This study examined the use of Bac J vegetative cells with beer and vegetative cells alone compared to cell free beer, unfermented cell free media and fungicides. As in previous years Bac J washed cells provided control nearly equal to the best fungicide treatments**.** The poor performance of Benlate was due to the presence Cercospora isolates resistant to Benlate. We did not see the synergy between Eminent and Bac J seen in some previous years.

Table 3. Effect of Bac J with fermentation beer, fermentation beer and washed Bac J cells compared with Eminent and Benlate fungicide on Area Under the Disease Progress Curve (AUDPC), % sucrose, yield and net returns

Treatment 4 applications	**AUDPC**	**% sucrose**	**Ton/A**	**Sucrose/A**	**Gross $/A @$23 nsp**
1. Untreated	**72.92 a**	**16.77 ab**	**23.9 abcd**	**8043 abc**	**985**
2. Bac J with beer	**48.66 bcd**	**16.05 b**	**21.4 d**	**6892 d**	**811**
3. Bac J washed cells	**45.32 cd**	**16.73 ab**	**26.0 ab**	**8689 ab**	**1046**
4. Cell free BAC J beer	**58.13 abc**	**17.0 a**	**21.7 d**	**7401 cd**	**893**
5. Media control	**63.16 ab**	**16.83 a**	**23.5 bcd**	**7919 bcd**	**953**
6. Benlate +BacJ	**38.54 d**	**16.3 ab**	**22.5 cd**	**7329 cd**	**872**
7. Eminent+Bac J	**14.30 e**	**16.8 ab**	**25.7 ab**	**8645 ab**	**1040**
8. Benlate	**43.45 cd**	**16.7 ab**	**24.9 abc**	**8323 abc**	**999**
9. Eminent	**8.67 e**	**16.9 a**	**26.9 a**	**9099 a**	**1098**
Flsd. P=0.05	**15.3**	**0.74**	**3.05**	**1095**	

- 1. values followed by the same letters do not differ @ P=0.05

The use of Bac J in fungicide resistance management programs has been shown over that past 4 years where fungicide resistance management has been studied. In these studies CLS infected leaves have been collected from every fungicide plot and isolates from these leaves have been evaluated for resistance or tolerance to TPTH, Benlate, Tilt/Eminent, Quadris/Headline /Flint as measured by conidial germination and inhibition of mycelial growth. Three observations can be made from these studies. 1) Tolerance as exhibited in conidial germination does not always reflect in inhibition of mycelial growth. 2) The rotation of fungicide classes generally results in the identification of only very low levels of resistant/tolerant isolates. 3) Where Bac J is co-applied with an effective fungicide or used in the fungicide rotation program no resistant/tolerant isolates have been found. It appears that incorporation of induced systemic resistance activators such as Bac J is another tool in managing fungicide resistance along with rotation of fungicide classes.

This research was supported by the Sugarbeet Research and Education Board (SBAR funds), the Montana Agricultural Experiment Station, USDA (NRI and Western Region IPM grants), Syngenta, Bayer, BASF, Griffin, and Sipcam Agro-USA.