Varied response of *Beta vulgaris* L. Plant Introductions to *Cercospora beticola* in different environments.

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Introduction

Progress in increasing leaf spot resistance was made early through mass selection of open-pollinated sugar beet varieties. It quickly was realized that mass selection within open-pollinated varieties was not going to bring the quick results that had been seen in the development of resistance to curly top virus and, therefore, inbreeding programs were developed. Mass selection was continued within these inbred populations and lines. One of the major problems in sugar beet lines with resistance to Cercospora leaf spot has been the loss of vigor due to the continual inbreeding, which was noted early on (Coons, 1955) and has been a concern ever since (McFarlane, 1971). The development of hybrid varieties, and their heterotic response, has helped in solving this problem, but seed production on O-type males and CMS females still is poor. Because of the large environmental variation encountered in breeding for Cercospora resistance, it is difficult to make progress in developing resistance through mass selection. This large environmental variation also has made it difficult to incorporate high levels of leaf spot resistance into varieties that maintain superior agronomic performance (Smith and Campbell, 1996). In many areas, commercial resistant varieties require some fungicide application to provide adequate levels of protection against leaf spot (Miller et al., 1994).

Most of the USDA-ARS Cercospora-resistant germplasm from Fort Collins owes its origin to the material that came out of Munerati's program in Italy, in which *B. vulgaris* spp. *maritima* was the donor of the resistance genes (Lewellen, 1992; Panella, 1998). However, since that time, there has been very few efforts to locate and incorporate new sources of resistance to Cercospora into this narrow germplasm base. Thirty-five Plant Introductions (PIs) from the USDA-ARS National Plant Germplasm System's (NPGS) *Beta* collection were screened for resistance to *Cercospora beticola* Sacc. at three locations: 1) an artificially produced epiphytotic in Windsor, CO.; 2) an artificially produced epiphytotic in Osijek, Croatia; and 3) a naturally occurring epiphytotic in Osijek, Croatia. These accessions included sugar beet, leaf beet, garden beet, fodder beet accessions (*Beta vulgaris* subspecies *vulgaris*), as well as wild sea beet accessions (*Beta vulgaris* subspecies *maritima*). These PI accessions were grown in these different environments to monitor potential interactions among genotype, environment, and Cercospora isolates.

Materials & Methods

The nurseries to evaluate germplasm were planted in randomized complete-block designs, with two replications. Internal controls included a highly susceptible synthetic check and a resistant hybrid check, FC(504 X 502/2) X SP6322-0. Two-row plots were 12 ft. long, with 22 in. between rows. The nursery was planted on May 1st. Fertilization was 75% of the soil test recommendation to minimize leaf growth, which can interfere with visual evaluations. The field was sprayed 14 days after planting with Betamix Progress (1.25 pint/acre) and Upbeet (0.75 oz./acre) and again 26 dap with Betamix Progress (1.25 pint/acre), Upbeet (0.75 oz./acre), and Stinger (0.25 pint/acre). Any additional weed control was by hand hoeing, and the plots were thinned to 8 in. spacing between beets starting 5 wk after planting.

The growing season in Croatia begins about one month earlier than it does in Colorado. The climate is mild and winters not too severe. The artificially inoculated nurseries were inoculated twice (Ruppel & Gaskill, 1971; Panella, 1998), on June 13th and 23rd in Osijek, and on June 27th and July 8th in Windsor. Visual evaluations were used to determine a disease index rating of the PIs on a scale from 0 (no disease) to 10 (plant dead). Visual observations in the natural and artificial Cercospora epiphytotics were made in Croatia on August 8th, 18th, and 28th. Visual Observations in Windsor were made on September 2nd, 9th, and 16th, with the peak of the epiphytotic occurring on or about the last date.

Results

In Windsor, the 1997 leaf spot epidemic progressed rather slowly at first, but rapidly became quite severe by late August to early September due to high humidity and temperature. At our third evaluation, means of the resistant and susceptible internal controls were 3.7 and 7.3, respectively, across all trials in the nursery. An analysis of variance (PROC ANOVA - SAS) on the disease indices (visual evaluation scores) determined that there were significant differences among entries ($P=0.05$) on all three dates at all three locations (Table 1). An LSD was generated for mean separations. Only complete data sets were used to generate the LSD and CVs. Thirty-seven accessions were used from the Windsor trial and 22 accessions from each of the Croatian trials (not the same 22 accessions). The Artificially created epidemic in Croatia was more severe than the natural one, as was expected. Both were, however, quite severe on the most susceptible accessions. Although the variation was higher in Osijek, some entries performed very differently at the different locations (Table 1).

Screening of Plant Introduction (PI) Germplasm

The National Plant Germplasm System (NPGS) *Beta* collection has over 2,000 Plant Introduction (PI) accessions. The material that has been used most often in breeding comes from the taxa *Beta vulgaris* spp. *vulgaris*, which includes all of the biennial sugar beet types and *Beta vulgaris* spp. *maritima*, which contains the closely related wild sea beet and has both annual and biennial types. Germplasm with a biennial flowering habit is not only easier to introgress but also much easier to screen. At the latitude of Fort Collins (40E 35' N), annual beets flower early and begin to senescence. The small size of their leaves makes it very difficult to get a good estimation of the level of Cercospora infestation. However, just because a resistant accession is biennial does not necessarily mean that it will be easy to work with. A fodder beet root still has a long way to go before it reaches an acceptable agronomic form that can be used in a commercial breeding program

Discussion

The data in the top half of Table 2 are from those accessions that had full data sets in all of

Table 1. This tables lists the Plant Introduction (PI) accessions from the National Plant Germplasm System, their origin, and taxonomic classification, and the evaluation results from all three locations. The mean disease index value (0 = no disease to 10 = plant dead) for each visual observation is given. In Croatia, many of the annual PIs flowered and senesced before they could be evaluated. Missing data are marked with a dash

			Windsor - Artificial			Osijek - Artificial			Osijek - Natural		
			Evaluation Date[1]			Evaluation Date[1]			Evaluation Date[1]		
Identification	Origin	subspecies	1	2	3	1	2	3	1	2	3
		. $LSD_{(0.05)}$[2]	1.1	1.1	1.4	1.8	3.2	3.1	0.9	1.8	1.9
		CV[2]	10.7	9.2	9.7	28.5	32.9	26.4	36.9	25.5	20.2
Ames10837	China - Heilongjiang	*vulgaris*	3.5	4.5	6.3	1.0	1.1	2.0	0.0	1.0	2.0
Ames10838	China - Heilongjiang	*vulgaris*	2.5	3.8	5.0	1.5	2.5	3.5	0.0	2.5	3.0
Ames10839	China - Heilongjiang	*vulgaris*	3.8	5.0	7.0	1.0	2.5	3.0	0.0	1.0	2.0
Ames15637	United States - CA	*vulgaris*	5.5	7.3	8.5	1.0	6.0	8.0	1.5	3.0	4.5
PI109038	Turkey	*vulgaris*	5.3	6.5	7.0	-	-	-	1.0	3.0	4.0
PI120704	Turkey	*vulgaris*	7.0	8.3	8.8	7.5	9.5	9.5	4.5	7.0	8.5
PI120706	Turkey	*vulgaris*	6.8	8.3	8.8	5.5	6.0	7.0	1.5	4.5	5.5
PI140357	Iran	*vulgaris*	8.0	8.3	9.0	8.0	10.0	10.0	4.0	6.0	6.5
PI165037	Turkey	*vulgaris*	6.5	7.5	9.0	7.0	9.0	9.0	2.5	5.5	6.5
PI165062	Turkey	*vulgaris*	7.0	8.5	8.8	5.0	7.5	8.5	1.0	4.0	5.0
PI165485	India	*vulgaris*	4.8	6.5	6.8	3.0	6.5	7.0	2.0	4.5	5.5
PI169014	Turkey	*vulgaris*	5.3	6.5	7.8	2.5	5.5	7.0	0.0	3.5	4.5
PI169015	Turkey	*vulgaris*	6.3	7.0	7.5	4.0	4.5	5.5	1.0	3.0	4.5
PI169020	Turkey	*vulgaris*	5.8	6.8	7.5	2.0	4.0	5.0	1.0	2.5	3.5
PI169023	Turkey	*vulgaris*	5.0	6.5	7.0	3.5	3.5	4.0	1.5	5.0	6.0
PI169027	Turkey	*vulgaris*	5.3	7.0	8.0	2.5	3.5	4.5	0.5	2.0	3.5
PI169030	Turkey	*vulgaris*	4.8	6.5	8.0	3.0	3.0	3.5	1.0	3.5	4.5
PI171504	Turkey	*vulgaris*	6.5	7.8	7.8	5.0	7.5	8.5	1.5	5.5	6.5
PI179844	India	*vulgaris*	4.5	6.3	6.8	-	-	-	-	-	-
PI179845	India	*vulgaris*	4.5	5.3	7.0	-	-	-	-	-	-
PI180409	India	*vulgaris*	5.5	6.5	8.5	-	-	-	-	-	-
PI181011	India	*vulgaris*	5.0	6.3	7.5	-	-	-	-	-	-
PI504192	Italy	*vulgaris var. maritima*	4.8	5.8	7.0	-	-	-	-	-	-
PI504193	Italy	*vulgaris var. maritima*	5.3	6.5	7.5	-	-	-	-	-	-
PI504196	Italy	*vulgaris var. maritima*	3.8	5.8	6.8	-	-	-	-	-	-
PI504208	Italy	*vulgaris var. maritima*	2.8	4.0	4.8	-	-	-	-	-	-
PI504220	Italy	*vulgaris var. maritima*	4.3	5.5	6.3	-	-	-	-	-	-
PI535826	Poland	*vulgaris ssp. vulgaris*	3.0	4.8	5.8	0.5	1.0	2.0	-	-	-
PI535843	Poland	*vulgaris ssp. vulgaris*	3.8	4.3	6.0	-	-	-	-	-	-
PI540599	France	*vulgaris var. maritima*	3.5	4.0	5.3	-	-	-	-	-	-
PI540605	France	*vulgaris var. maritima*	2.8	4.0	5.5	-	-	-	0.0	2.0	3.0
PI546530	Italy - Sicily	*vulgaris var. maritima*	5.0	5.8	7.0	-	-	-	-	-	-
PI546533	Greece - Thessaly	*vulgaris var. maritima*	4.8	5.8	6.5	-	-	-	-	-	-
PI546536	Greece - Central Greece	*vulgaris*	5.5	6.5	7.8	0.5	1.0	2.5	0.5	0.5	1.5
PI546539	Greece - Peloponnese	*vulgaris*	3.5	5.0	6.3	0.0	0.5	2.0	-	-	-
931002	Susceptible Check	*vulgaris*	6.3	7.0	8.0	2.0	7.0	8.5	0.5	3.0	4.5
821051H2	Resistant Check	*vulgaris*	2.5	2.8	4.3	2.0	1.0	2.0	0.5	1.0	2.0

[1] Visual evaluations in the Cercospora epiphytotics were made in Croatia on August 8th, 18th, and 28th and in Windsor on September 2nd, 9th, and 16th.

[2] Least Significant Difference (0.05) and Coefficient of Variation were determined using the only the full data sets (37 Accessions for Windsor and 22 for each of the Croatian trials).

Table 2. In the table below are listed the final (most severe) disease index ratings (0 = no disease to 10 = plant death) of each of the accessions. To the right of the rating for each of the three trials is the ranking of that accession in that trial; when multiple accessions had the same score they were given the same rank (e.g., four accessions in the artificially created epidemic in Osijek had the lowest score and all were ranked 1 and the next lowest was ranked 5).

Identification	subspecies	Windsor Artificial		Osijek Artificial		Osijek Natural	
	$LSD_{(0.05)}$	1.4	Rank	3.1	Rank	1.9	Rank
821051H2	Resistant Check	4.3	1	2.0	1	2.0	2
Ames 10837	vulgaris	6.3	8	2.0	1	2.0	2
PI 546536	vulgaris	7.8	25	2.5	5	1.5	1
Ames 10839	vulgaris	7.0	15	3.0	6	2.0	2
PI 169030	vulgaris	8.0	28	3.5	7	4.5	10
Ames 10838	vulgaris	5.0	3	3.5	7	3.0	5
PI 169023	vulgaris	7.0	15	4.0	9	6.0	18
PI 169027	vulgaris	8.0	28	4.5	10	3.5	7
PI 169020	vulgaris	7.5	21	5.0	11	3.5	7
PI 169015	vulgaris	7.5	21	5.5	12	4.5	10
PI 165485	vulgaris	6.8	12	7.0	13	5.5	16
PI 120706	vulgaris	8.8	33	7.0	13	5.5	16
PI 169014	vulgaris	7.8	25	7.0	13	4.5	10
Ames 15637	vulgaris	8.5	31	8.0	16	4.5	10
PI 165062	vulgaris	8.8	33	8.5	17	5.0	15
931002	Susceptible Check	8.0	28	8.5	17	4.5	10
PI 171504	vulgaris	7.8	25	8.5	17	6.5	19
PI 165037	vulgaris	9.0	36	9.0	20	6.5	19
PI 120704	vulgaris	8.8	33	9.5	21	8.5	22
PI 140357	vulgaris	9.0	36	10.0	22	6.5	19
PI 504208	vulgaris var. maritima	4.8	2	-		-	
PI 540599	vulgaris var. maritima	5.3	4	-		-	
PI 540605	vulgaris var. maritima	5.5	5	-		3.0	5
PI 535826	vulgaris ssp. vulgaris	5.8	6	2.0	1	-	
PI 535843	vulgaris ssp. vulgaris	6.0	7	-		-	
PI 504220	vulgaris var. maritima	6.3	8	-		-	
PI 546539	vulgaris	6.3	8	2.0	1	-	
PI 546533	vulgaris var. maritima	6.5	11	-		-	
PI 504196	vulgaris var. maritima	6.8	12	-		-	
PI 179844	vulgaris	6.8	12	-		-	
PI 504192	vulgaris var. maritima	7.0	15	-		-	
PI 179845	vulgaris	7.0	15	-		-	
PI 109038	vulgaris	7.0	15	-		4.0	9
PI 546530	vulgaris var. maritima	7.0	15	-		-	
PI 504193	vulgaris var. maritima	7.5	21	-		-	
PI 181011	vulgaris	7.5	21	-		-	
PI 180409	vulgaris	8.5	31	-		-	

the trials. They are ranked according to their performance in the artificially inoculated trial in Osijek. There are very few differences between the trials in Croatia, which was expected. There are, however, some accessions that performed very well in Croatia, which were severely damaged in the artificial epiphytotic in Colorado. The converse is not true, i.e. none of those that performed well in Colorado were severely damaged in Croatia, and the USDA-ARS leaf spot resistant check, (FC504

X FC502/2) X SP6322-0, performed very well in all locations. This has also been seen with ARS germplasm lines and commercial material (data not shown), in which those that are highly resistant in Colorado remain so in Croatia, but moderately resistant ARS germplasm and resistant (in Osijek) Croatian germplasm may show different responses in the different environments. These results are preliminary and need to be repeated to understand the potential Cercospora isolate x sugar beet genotype x environment interactions that may be present.

I believe that there is a strong need to continue to evaluate PIs from the NPGS *Beta* collection for disease resistance in order to infuse our commercial disease-resistant germplasm with a broader genetic base than we have today. Commercial hybrid parents are becoming more inbred, and, therefore, it is important that their germplasm base has the diversity necessary to provide for maximum gain through heterosis. It is time to revisit the use of wild beet germplasm in developing new pools of disease resistant germplasm, perhaps, with techniques similar to the model presented by Bosemark (1989). We must, however, be aware of potential environment x genotype interactions and genotype x pathotype interactions.

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