

Beet curly top resistance in two USDA-ARS sugar beet germplasm panels, 2023.

Two germplasm panels consisting of thirty sugar beet (*Beta vulgaris* L.) lines each from USDA-ARS pre-breeding programs were screened for resistance to *Beet curly top virus* (BCTV) alongside three commercial check cultivars [Detroit Dark Red (susceptible), HM PM90 (resistant), and SV2012RR (susceptible)]. The curly top evaluation was conducted at the USDA-ARS North Farm in Kimberly, ID which has Portneuf silt loam soil and had been in barley in 2022. The field was fall plowed with a Terrano chisel plow. In the spring, the field was fertilized (115 lb N and 140 lb P₂O₅/A), disked, and roller harrowed on 10 Apr. The germplasm was planted (density of 114,048 seeds/A) on 2 May. The plots were two rows 10-ft long with 22-in. row spacing and treatments were arranged in a randomized complete block design with six replications. The field was sprinkler irrigated, cultivated, and hand weeded as necessary. Plants were inoculated at the four- to six-leaf growth stage on 12 Jun with approximately six viruliferous (containing the following BCTV strains: California/Logan and Severe) beet leafhoppers (*Circulifer tenellus* Baker) per plant. The beet leafhoppers were redistributed two times a day during the first seven days by dragging a tarp through the field. Plots were rated for foliar symptom development on 12 Jul using a scale of 0 to 9 (0 = healthy and 9 = dead; Plant Dis. 90:1539-1544). Data were rank transformed prior to nonparametric analysis in SAS (Ver. 9.4) using the PROC MIXED procedure as described by Shah and Madden (Phytopathology 94:33-43). Mean separation was based on a PDIFF comparison with a probability cutoff of 0.05.

Curly top symptom development was uniform and no other disease problems were evident in the plot area. The resistant and susceptible checks performed as expected for the visual ratings. The germplasm panels tested here represents a selection of both historical USDA-ARS germplasm releases, as well as unreleased material from the Fort Collins program. Germplasm in these panels were chosen with the aim of identifying 15 resistant/tolerant and 15 susceptible lines that represent a diversity of genetic backgrounds and captures the full phenotypic distribution curly top ratings for future genetic studies to map resistance traits. In Germplasm Panel 1 (Table 1), 19 of the entries contain at least some minor resistance as their visual ratings were significantly lower than those for both susceptible checks. However, only five entries (CP01, F1043, FC901, FC604, and C890) were not significantly different from the commercial resistant check. In Germplasm Panel 2 (Table 2), 19 of the entries contain at least some minor resistance since their visual ratings were significantly lower than those for both susceptible checks. However, only four entries (C869, CP01, SLC132, and 20161028pf) were not significantly different from the resistant check. The most resistant unreleased lines from each panel (20161028pf, 20151004HO1, 20171023HO1, 20141022pf, 20161017, 20151044PFHO, and 20171032HO/HO1) will be tested again to confirm resistance, and if confirmed, used for incorporation into USDA-ARS sugar beet breeding programs as a source of resistance to BCTV. These results will also be utilized for meta-analysis of genome sequencing data of germplasm in these panels to map candidate curly top resistance loci and to validate molecular markers. Phenotypic ratings for lines in each panel with assigned USDA-ARS NPGS PI numbers will be accessible to interested parties through the GRIN database www.ars-grin.gov. Raw per-plot phenotypic ratings will be made available through BeetBase, www.beetbase.scinet.usda.gov.

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Table 1: Germplasm Panel 1

Entry ^z	Source ^y	Description	Curly top rating ^x
CH6	HM PM90	Resistant check, sugar beet cultivar	3.6 j
3	20202517	CP01	4.0 j
9	20221002	F1043	4.6 ij
13	19931012	FC901	4.9 hij
1	19951041HO1	FC604	4.9 ghij
20	20141018	C890	5.0 ghij
14	20161028PF	20161028PF (B.I. of half-sib families of FC301 selected for CT/CLS/Rhzm resistance)	5.0 g-i
10	20141007	FC1740	5.0 g-i
4	20041022	C842	5.1 f-i
22	20141022PF	20141022PF (B.I. of 20111009, introgression of PI 142808 / IDBBNR 5215)	5.2 f-i
8	2009A004	EL54	5.3 f-h
2	2020A023	C869	5.4 f-h
5	1997A050	FC607	5.4 e-h
23	20161017	20161017 (Increase of F3 of CN12-446 x FC708)	5.4 e-h
6	20101011	FC1019	5.4 e-h
26	20151044PFHO	20151044PFHO (20131012MS x 20101015HO1 increase, selected for CLS resistance)	5.4 e-h
17	20221016	FC705/1 (new B.I seed lot)	5.5 e-h
16	20171023HO	20171023HO (B.I. of O-type/CMS pair – C812-41, FC1100)	5.6 e-g
15	20171023HO1	20171023HO1 (B.I. of O-type/CMS pair – C812-41, FC1100)	5.9 d-f
7	2013A031	CS42	6.2 de
19	20221010	F1002	6.3 cd
12	20141010	FC201	6.3 cd
21	20161016PF	20161016PF (B.I. of 20141035, introgression of PI 540596 for CLS resistance)	6.3 cd
11	19931005HO	FC721	6.3 cd
27	20151046PFHO	20151046PFHO (O-type/CMS pair of selfed families of 07-FC1015-420 x FC1015)	6.3 cd
28	20161004HO	20161004HO (increase of FC302 O-type/CMS pair selections for CLS & CT resistance)	6.4 cd
25	20181028	Rekord Poly	6.4 b-d
CH5	SV2012RR	Susceptible check, sugar beet cultivar	6.6 a-c
24	20141035	20141035 (B.I. of 20081012PF, introgression of PI 540596)	6.7 a-c
30	2013A037	PI169024	6.8 a-c
18	20231008	FC709-4	6.8 a-c
29	2001A021	Smooth Root from East Lansing (99J19-00mm; WC000254)	7.2 ab
RB	Detroit Dark Red	Susceptible check, red beet cultivar	7.3 a
$P > F^w$			<0.0001

^z Three entries were commercial check cultivars: CH5 (susceptible), CH6 (resistant), and RB (susceptible).

^y All lines were *Beta vulgaris* subspecies *vulgaris* (cultivated beet).

^x Curly top ratings = curly top was rated using a scale of 0 to 9 (0 = healthy and 9 = dead).

^w $P > F$ was the probability associated with the F value when using rank transformed data. Within a column, means followed by the same letter did not differ significantly based on PDIFF with a probability cutoff of 0.05. The non-transformed mean values are presented.

Table 2: Curly Top Rating Data for Germplasm Panel 2

Entry ^z	Source ^y	Description / PI number	Curly top rating ^x
CH6	HM PM90	Resistant check, sugar beet cultivar	3.8 n
2	2020A023	C869	4.2 n
13	20202517	CP01	4.4 mn
3	2013A017	SLC132	4.7 lmn
14	20161028pf	20161028pf (B.I. of half-sib families of FC301 selected for CT/CLS/Rhzm resistance)	4.8 klmn
5	1997A050	FC607	5.3 j-m
1	2015A021	CP09 CT	5.3 j-m
9	20221002	F1043	5.3 j-m
4	20041022	C842	5.3 j-m
27	20141018	C890	5.4 j-l
6	20101011	FC1019	5.4 i-k
7	2013A031	CS42	5.4 i-k
29	20161004HO1	20161004HO1 (increase of FC302 O-type/CMS pair selections for CLS & CT resistance)	5.6 h-j
28	20221009	F1024	5.6 h-j
11	2020A015	EL62	5.7 h-j
26	20091009	FC1022	5.9 g-i
8	2009A004	EL54	5.9 g-i
16	20181028	Rekord Poly	6.0 f-h
25	20161019PF	CR933	6.1 f-h
15	20171023HO1	20171023HO1 (B.I. of O-type/CMS pair – C812-41, FC1100)	6.1 f-h
12	19931005HO	FC721	6.3 e-g
10	20141007	FC1740	6.4 d-f
22	20101009	FC1018	6.4 c-f
CH5	SV2012RR	Susceptible check, sugar beet cultivar	6.5 b-e
30	2011A009	EL53	6.5 b-e
18	20231008	FC709-4	6.6 a-e
24	20071013	FC220	6.7 a-d
RB	Detroit Dark Red	Susceptible check, red beet cultivar	6.8 a-d
21	19921022	FC702/7	6.8 a-d
17	20221021	FC705/1	6.8 a-d
23	19951017	FC727	6.8 a-c
19	20221010	F1002	6.9 ab
20	19931018	FC701	7.0 a
$P > F^w$			<0.0001

^z Three entries were commercial check cultivars: CH5 (susceptible), CH6 (resistant), and RB (susceptible).

^y All lines were *Beta vulgaris* subspecies *vulgaris* (cultivated beet).

^x Curly top ratings = curly top was rated using a scale of 0 to 9 (0 = healthy and 9 = dead).

^w $P > F$ was the probability associated with the F value when using rank transformed data. Within a column, means followed by the same letter did not differ significantly based on PDIFF with a probability cutoff of 0.05. The non-transformed mean values are presented.