SUGAR BEET (*Beta vulgaris*)
Rhizomania; *Beet necrotic yellow vein virus*
Storage rot; *Athelia*-like sp., *Botrytis cinerea*, *Penicillium* sp., and *Phoma betae*

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**Ft. Collins sugar beet germplasm evaluated for rhizomania and storage rot resistance in Idaho, 2013.**

Fifty sugar beet (*Beta vulgaris* L.) lines from the USDA-ARS Ft. Collins sugar beet program and four check cultivars were screened for resistance to *Beet necrotic yellow vein virus* (BNYVV), the causal agent of rhizomania, and storage rot in 2013. The rhizomania evaluation was conducted at the USDA-ARS North Farm in Kimberly, ID which has Portneuf silt loam soil and had been in barley in 2012. The field was fall plowed and in the spring, fertilized (90 lb N and 110 lb $P_2O_5$/A) on 19 Apr 13, sprayed with the herbicide Ethotron (2 pt/A), and roller harrowed. The germplasm was planted (density of 142,560 seeds/A) on 23 Apr. The plots were one row 10 ft long with 22-in row spacing and arranged in a randomized complete block design with six replications. The crop was managed according to standard cultural practices. Plant populations were thinned to 47,500 plants/A on 15 May. The trial relied on natural infection for rhizomania and storage rot development. The plots were rated for rhizomania foliar symptom (percentage of plants with yellow, stunted, upright leaves) development on 22 Jul. The plants were mechanically topped and hand harvested with the aid of a single-row lifter on 7 Oct. At harvest, ten roots in the plots were rated for symptom development using a scale of 0 to 9 (0 = healthy and 9 = dead; Plant Dis. 93:632-638), with disease index (DI) treated as a continuous variable. At harvest, eight roots per plot were also placed in a mesh-onion bag and placed in an indoor commercial storage facility (temperature set point 34°F) in Paul, ID on 7 Oct. On 10 Feb14 after 127 days in storage, the roots were evaluated for the percentage of root surface area covered by fungal growth. Data were analyzed in SAS (Ver. 9.2) using the general linear models procedure (Proc GLM), and Fisher's protected least significant difference (LSD; $\alpha = 0.05$) was used for mean comparisons.

Rhizomania symptom development was uniform and other disease problems were not evident in the plot area. Three entries germinated poorly which resulted in very poor stand for entries 12, 16, and 19. Thus, these entries were not included in the analysis. The rhizomania susceptible check (entry 51) had 72% foliar symptoms and a high root disease severity rating. The three check entries (52, 53, and 54) with resistance to BNYVV, had a range of symptoms and root ratings depending on the resistance source. Entries 1, 2, and 7 had both high foliar and root ratings which were similar or worse than the susceptible check and the pedigrees of these lines do not include rhizomania resistant parents. Most other entries had fewer foliar symptoms and a better root rating than the susceptible check. Based on both BNYVV foliar and root ratings, entries 21, 28, 29, 30, 33, and 37 had resistance that was similar to the most resistant check. These are a series of lines and hybrids that have been genotyped using single nucleotide polymorphism (SNP) markers for rhizomania resistance and have both the *Rz1* and *Rz2* rhizomania resistance genes in their pedigree (see table below). If roots are compromised by BNYVV and other diseases, or lack storability, they will rot in storage as indicated by fungal growth on the root surface. The primary fungal growth was an *Athelia*-like Basidiomycete (Mycologia 104:70-78), but *Botrytis cinerea*, *Penicillium* sp., and *Phoma betae* were also frequently present. Based on all variables, entries 28, 30, and 33 were the most resistant entries. Some of the other top performing entries for resistance to fungal growth in storage had no resistance to rhizomania such as entry 5, and in previous studies have also shown resistance to root rot caused by *Fusarium oxysporum*. Entry 50 performed well for all three variables and in previous studies has exhibited resistance to *F. oxysporum* root rot and the sugar beet cyst nematode. All of the breeding lines developed at Fort Collins that are selected in the field, are then vernalized for 90 to 120 d in milk crates stored in a cold room at 5°C in 90 to 100% humidity. Although not selected intentionally for resistance to storage rot, every year rotted roots are discarded and not taken further in the breeding program. This unintentional selection most likely has resulted in an increased resistance to storage rots, especially in a line like entry 1, which was the most rhizomania susceptible germplasm and yet not significantly different from the entry most resistant to fungal growth in storage. Some of these entries may serve as a starting point for identifying novel sources of resistance to both BNYVV and storage rot fungi.

| | | | Rhizomania | | |
|---|---|---|---|---|---|
| Entry[z] | Source | Description | Fungal growth in storage (%)[y] | Foliar rating (% susceptible plants) on 13 Jul | Root rating[x] |
| 1 | 1997A050 | FC607, LSR/CTR, O-type, 2X, mm, self-sterile | 12 i-q | 90 ab | 33.15 a |
| 51 | | **Roberta (*rzrz*)** | 70 a | 72 b-d | 31.43 ab |
| 2 | 20101008 | (Best FC LSR X Best EL LSR) - mm seedballs | 24 d-j | 89 ab | 30.63 a-c |
| 7 | 20111030 | 20091030PF; Increase 5 highest CLR families | 27 c-g | 98 a | 28.62 b-d |
| 17 | 20121054 | Bulk LSR Sucrose$_{MM}$ x PI 535833 (Saturn) | 14 g-q | 55 d-h | 27.98 b-e |
| 40 | 20131003HO8 | X rest of FC708CMS | 7 l-q | 35 h-l | 27.44 c-f |
| 20 | 20121057 | LSR MM selected for RhzcR - ½sib 10A-1775 | 12 h-q | 10 n-p | 27.35 c-f |
| 4 | 20101012 | C790-15cms x RZM-CR-% (FC712 x 9931)F3 | 16 f-o | 62 c-g | 26.89 c-g |
| 32 | 20131002HO3 | X FC708CMS (*rz1rz1rz2rz2*) | 14 g-q | 58 d-g | 26.49 d-h |
| 6 | 20111029 | 20091029PF; Bulk BGRC 45511 (LSR) x Sucrose$_{MM}$ | 46 b | 62 c-g | 26.29 d-i |
| 38 | 20131003HO6 | X C869CMS (*rz1rz1rz2rz2*) | 16 f-p | 56 d-h | 26.14 d-i |
| 3 | 20101010 | C790-15cms x 05-FC1018 | 18 f-n | 56 d-h | 25.86 d-j |
| 31 | 20131002HO2 | X FC708CMS (*Rz1Rz1rz2rz2*) | 43 b | 82 a-c | 25.65 d-j |
| 9 | 20121012HO1 | C833-H5 CMS x 03-FC1014-22(A,aa) | 10 k-q | 69 b-e | 25.48 d-j |
| 18 | 20131001pfHO | LSR Bvm (PI540596 biennial - France) x S%$_{MM}$ pop | 9 k-q | 15 l-p | 25.18 d-j |
| 8 | 20121012HO | 03-FC1014-22 (½ selection within FC201) - sel in 6R | 19 e-m | 54 d-h | 25.02 d-k |
| 23 | 20131001HO4 | X FC708CMS (*Rz1_Rz2rz2*) | 18 f-n | 67 c-f | 25.01 d-k |
| 14 | 20121035PF | Bulk [(FC907 x FC709-2) and 9931 (Salinas)] | 14 g-q | 50 e-i | 24.83 d-k |
| 22 | 20131001HO3 | X FC708CMS (*Rz1Rz1rz2rz2*) | 6 m-q | 43 g-k | 24.56 e-l |
| 10 | 20121019HO | 03-FC1015 FC201 derivative - sel Rhizoc in 6R | 1 q | 10 n-p | 24.44 e-m |
| 5 | 20111028 | CLR family (BGRC 45511 X Sucrose$_{MM}$) | 5 n-q | 79 a-c | 24.40 e-m |
| 35 | 20131002pfHO | FC1741 (*rz1rz1Rz2Rz2*) | 18 f-n | 13 m-p | 24.33 e-m |
| 53 | | **Beta G017 (*Rz2Rz2*)** | 28 c-f | 32 i-m | 24.02 f-n |
| 24 | 20131001HO6 | X rest of FC708CMS | 16 f-o | 32 i-m | 23.99 f-n |
| 27 | 20131001HO9 | X C869CMS (*Rz1_Rz2rz2*) | 17 f-o | 14 l-p | 23.82 f-o |
| 11 | 20121019HO1 | CMS equivalent of 03-FC1015 - sel Rhizoc in 6R | 3 o-q | 13 m-p | 23.70 f-o |
| 13 | 20121035MS | Bulk increase [(FC907 x FC709-2) and 9931 | 18 f-n | 27 j-n | 23.51 g-p |
| 41 | 20131004HO | FC1743 (*Rz1Rz1 Rz2rz2 and rz2rz2*) | 10 j-q | 24 k-o | 22.79 h-q |
| 43 | 20131004HO4 | X C869CMS (*Rz1Rz1rz2rz2*) | 25 c-i | 8 n-p | 22.54 i-r |
| 36 | 20131003HO3 | X FC708CMS (*Rz1rz1rz2rz2*) | 44 b | 47 f-j | 22.31 j-r |
| 34 | 20131002HO8 | X rest of C869CMS | 21 e-k | 18 l-p | 22.23 j-r |
| 15 | 20121036 | Bulk [C790-15cms x FC1036]/[(FC907 x FC709-2)&9931] | 21 e-k | 21 l-p | 22.22 j-r |
| 44 | 20131004HO5 | X C869CMS (*Rz1rz1rz2rz2*) | 25 d-i | 6 n-p | 22.22 j-r |
| 49 | 2013A008 | 4933-14, CR933-14, PI 652892 | 15 f-p | 0 p | 22.22 j-r |
| 46 | 2013A005 | C869, PI 628754 | 33 b-e | 0 p | 22.20 j-s |
| 25 | 20131001HO7 | X C869CMS (*Rz1Rz1rz2rz2*) | 16 f-o | 11 m-p | 21.33 k-s |
| 42 | 20131004HO2 | X FC708CMS (*Rz1Rz1rz2rz2*) | 5 n-q | 20 l-p | 21.26 k-t |
| 45 | 20131004HO6 | X rest of C869CMS | 6 m-q | 0 p | 20.86 l-u |
| 52 | | **Beta 4430R (*Rz1Rz1*)** | 43 b | 2 p | 20.80 l-u |
| 39 | 20131003HO7 | X rest of FC708CMS | 9 k-q | 4 op | 20.67 m-u |
| 47 | 2013A006 | C931, 4931, PI 636340 | 20 e-l | 7 n-p | 20.20 n-u |
| 48 | 2013A007 | 5933, CR933, PI 652891 | 38 b-d | 7 n-p | 20.20 n-u |
| 26 | 20131001HO8 | X C869CMS (*Rz1rz1rz2rz2*) | 39 bc | 12 m-p | 20.15 o-u |
| 50 | 2013A009 | N412, CN12, PI 636338 | 2 pq | 6 n-p | 20.12 o-u |
| 33 | 20131002HO5 | X C869CMS (-- -- *rz2rz2*) | 8 k-q | 1 p | 19.78 p-v |
| 54 | | **Angelina (*Rz1Rz1Rz2Rz2*)** | 26 c-h | 0 p | 19.03 q-v |
| 28 | 20131001HO10 | X C869CMS (*Rz1_Rz2rz2*) | 14 g-q | 10 n-p | 18.77 r-v |
| 30 | 20131001pfHO | FC1740 (*Rz1Rz1Rz2Rz2*) | 5 n-q | 2 p | 18.37 s-v |

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|---|---|---|---|---|---|
| 29 | 20131001HO11 | X rest of C869CMS | 27 c-g | 2 p | 17.46 t-v |
| 21 | 2012A035 | R840 (Bulk of R740) | 18 f-n | 3 op | 17.36 uv |
| 37 | 20131003HO5 | X C869CMS (*Rz1Rz1rz2rz2*) | 25 d-i | 12 m-p | 16.28 v |
| Overall mean | | | 20 | 31 | 23.48 |
| *P* > *F*[w] | | | <0.0001 | <0.0001 | <0.0001 |
| LSD (α = 0.05) | | | 14 | 21 | 3.83 |

[z] All lines were *Beta vulgaris*. Four entries were check cultivars (bold): Roberta, Beta 4430R, Beta G017R, and Angelina.

[y] Fungal growth in storage = the percent of root surface area covered by fungal growth. Most of the fungal growth was by a recently described *Athelia*-like Basidiomycete (Mycologia 104:70-78).

[x] Ten roots per plot were evaluated using a scale of 0-9 (0 = healthy and 9 = dead; Plant Disease 93:632-638). Root rating = a disease severity index value for each plot established using the following formula: [((A)0+(B)1+(C)2+(D)3+(E)4+(F)5+(G)6+(H)7+(I)8+(J)9)/90]100, where A-J are the number of plants in categories 0-9, respectively.

[w] *P* > F was the probability associated with the F value. Within a column, means followed by the same letter did not differ significantly based on Fisher's protected least significant difference (LSD; α = 0.05).