University of Minnesota
Department of Plant Pathology

2005
Potato Disease Report

Potato Pathology and Genomics

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Section I. Evaluating Potato Germplasm for Disease Resistance

SUMMARY: Disease screening plots were established at two locations (Rosemount and Becker, MN) in 2005. Entries were screened for resistance to late blight (caused by the Oomycete *Phytophthora infestans*; UMore Park, Rosemount, MN) and common scab (caused by the Actinomycete *Streptomyces scabies;* Sand Plain Research Farm, Becker, MN). Wild potatoes, *Solanum bulbocastanum* and *S. pinnatisectum* were screened for *Verticillium* resistance at Becker, MN. Germplasm was produced by the University of Minnesota Potato Breeding Program (126 entries tested for late blight, 127 entries tested for common scab), the University of Minnesota Potato Pathology and Genomics Program (109 entries tested for late blight, 10 entries tested for common scab, 12 entries tested for *Verticillium* at Hanckock WI and greenhouse St. Paul, and more than 500 genotypes of *S. bulbocastanum* and *S. pinnatisectum* tested for *Verticillium* at Becker MN), or was contributed by researchers throughout the Quad-State Region (17 entries tested for late blight and 19 for common scab) and North Central Region (18 entries tested for late blight and common scab). Seventeen entries were tested as part of the National Late Blight Trial (Rosemount) and 20 entries were tested as part of the National Scab Trial (Becker). Strengthening our commitment to conduct collaborative research with potato breeders and scientists throughout the Quad-state region, 52 clones submitted by the University of Wisconsin Potato Breeding Program were evaluated for late blight resistance.

Table 1. Source and number of entries screened at the late blight, common scab, early dying, and *Verticillium* nurseries.

Source	**Late Blight** (UMore Park, Rosemount, MN)	**Common Scab** (Sand Plain Research Farm, Becker, MN)	***Verticillium*** (Sand Plain Research Farm, Becker, MN)[a]
UM Potato Breeding	126	127	
UM Potato Pathology & Genomics	109	10	576
North Central Trial	18	18	
Quad-State Trial	17	19	
National Late Blight and Scab Trial	17	20	
University of Wisconsin	52		

[a]*Verticillium* liquid inoculation was applied on seedlings at the Sand Plain Research Farm (Becker, MN).

(A) Late Blight – Rosemount, MN

Late blight, caused by the oomycete *Phytophthorq infestans*, was responsible for the Irish Potato Famine of the mid-1800's. The disease is characterized by brown to black water-soaked lesions on potato leaves and stems. Under cool, humid conditions, late blight can destroy an entire field within 10-14 days. When sporangia or zoospores are washed into the soil, they can infect potato tubers. Tuber infection is characterized by a dry, brown, granular rot. Secondary pathogens, such as *Erwinia carotovora* (soft rot), *Phytophthora erythroseptica* (pink rot), and *Pythium* spp. (leak) frequently follow. Late blight is currently managed by intensive fungicide applications. This approach is expensive and not environmentally sustainable. Genetic resistance derived from cultivated or wild potato is a promising means to reduce pesticide dependency, risk to the environment, and costs to potato growers.

Resistance to late blight is evaluated at UMore Park (Rosemount, MN) in cooperation with Sr. Associate Dean Phil Larsen (Director), James Rowe (Administrative Professional), Jim Karelis (Sr. Research Plot Technician) and Kimon Karelis (Research Plot Coordinator). The UMore Park is geographically isolated from commercial potato farms allowing intentional inoculation with the late blight pathogen. Because the spores of the pathogen are air-borne, inoculations and late blight screening is restricted to non-production areas. To further protect regional growers, the Late Blight Nursery is planted 4 to 8 weeks later than commercial production fields in Minnesota and Wisconsin. Two different ways of disease inoculation were tested in 2005. Comparison of using spreader border row of susceptible variety vs. direct inoculation without border rows had effect only on the timing of disease progression, not on final outcome of resistance or susceptibility.

Disease screening methods are detailed in Appendix A. Complete results for individual entries from the University of Minnesota Potato Breeding Program, University of Minnesota Potato Pathology and Genomics Program, National Late Blight, North Central Region, and Quad State Region for 2005 are listed in Appendix B. Table 2 summarizes our findings.

Table 2. Number of entries in each late blight resistance class based on infection 25 days after inoculation with the potato late blight pathogen at Rosemount, MN 2004

Sources of entries	No. (percent) of entries 28 DAI
UM Potato Pathology & Genomics	
Resistant	27 (22.9%)
Moderately Resistant	28 (23.7%)
Moderately Susceptible	10 (8.5%)
Susceptible	53 (44.9%)
UM Potato Breeding	
Resistant	0 (0%)
Moderately Resistant	2 (1.6%)
Moderately Susceptible	3 (2.4%)
Susceptible	121 (96%)
National Late Blight Trial	
Resistant	5 (29.4%)
Moderately Resistant	7 (41.2%)
Moderately Susceptible	0 (0%)
Susceptible	5 (29.4%)
North Central Trial	
Resistant	0 (0%)
Moderately Resistant	2 (11.1%)
Moderately Susceptible	0 (0%)
Susceptible	16 (88.9%)
Quad-State Trial	
Resistant	0 (0%)
Moderately Resistant	0 (0%)
Moderately Susceptible	2 (11.8%)
Susceptible	15 (88.2%)
University of Wisconsin Potato Breeding	
Resistant	1 (1.9%)
Moderately Resistant	2 (3.8%)
Moderately Susceptible	17 (32.7%)
Susceptible	32 (61.6%)
All Entries	
Resistant	33 (9.5%)
Moderately Resistant	41 (11.8%)
Moderately Susceptible	32 (9.2%)
Susceptible	242 (69.5%)

(B) Wild Potato Germplasm Screening for Tolerance to *Verticillium* wilt

Verticillium wilt is caused by the soil borne pathogen *Verticillium dahliae.* The disease is a widespread problem in potato production areas in many parts of the world and severe infestations can result in significant yield reduction. Soil fumigation is somewhat effective at controlling this disease, but the cost can be prohibitive. Additionally, many of the compounds used for soil fumigation are dangerous and are likely to be banned in the future. Wild potato species are rich sources of genetic resistance to *Verticillium* wilt and resistance genes from wild potato species could be used for improvement of potato cultivars. As part of a multi-year study, our program is systematically characterizing wild potato species for resistance to *Verticillium* wilt. In 2005, we screened 57 accessions of the Mexican wild potatoes, *Solanum bulbocastanum* and *S. pinnatisectum* in seedling tests at the Sand Plain Research Farm. For each accession, 8 seedlings were inoculated with a known concentration of *V. dahliae,* planted, and visually surveyed at regular intervals throughout the growing season. Uninoculated controls were also included. We identified both resistant and susceptible accessions. Many of the species with which we work are not robust. However, the combination of ideal soil, available irrigation, and attentive husbandry at the Sand Plain Research Farm makes it an ideal location for our *Verticillium* seedling assays.

(C) Common Scab

Common scab, caused predominantly by the ubiquitous soil-borne bacterium *Streptomyces scabies*, is a disease of several root crops. In potato, symptoms include the development of corky lesions on the tuber that significantly reduce tuber quality and marketability, particularly for table stock varieties. In severe cases, common scab appears as deep sunken lesions ("pit scab") that invite secondary infection. Alkaline and dry soils exacerbate disease development. Genetic tolerance is sought after by potato breeders in Minnesota and throughout the US. Resistance to common scab is evaluated at the Sand Plain Research Farm located in Becker, MN in cooperation with Glenn Titrud (Administrative Director) and Ronald Faber (Sr. Research Plot Technician). The Sand Plain Research Farm is an ideal location for germplasm screening for resistance to common scab. In 2005, two field plots were established for common scab resistance screening:

(a) As in previous years, the Potato Pathology and Genomics program cooperated with the UM Potato Breeding Program and potato breeding programs at Michigan State University, University of Wisconsin, and North Dakota State University to screen breeding materials for tolerance to common scab. We also served as a test site for the replicated National Scab Trial. In 2005 we continued efforts to characterize heirloom potato cultivars as sources of resistance to common scab.

(b) Our existing common scab testing site was established approximately 30 years ago and has been continuously cropped with potatoes since then. As the plot has aged, the microbial communities in the soil have changed and the plot is becoming "suppressive", a natural phenomenon by which disease-causing microbes are replaced by non-pathogenic strains. As a result, disease severity has decreased. Eventually, the plot will not be useful for germplasm testing. With this in mind, in 2005, we initiated efforts to establish a new plot for common scab testing. The new plot is physically isolated from the existing test site. Lime was applied to the soil to raise soil pH and the plot was planted with the common scab susceptible potato cultivar 'Red Pontiac'. We anticipate the new plot will be fully functional for germplasm testing by 2008.

Detailed disease screening methods are listed in Appendix A. Severity and coverage ratings for all entries are listed in Appendix B. Table 3 summarizes our findings.

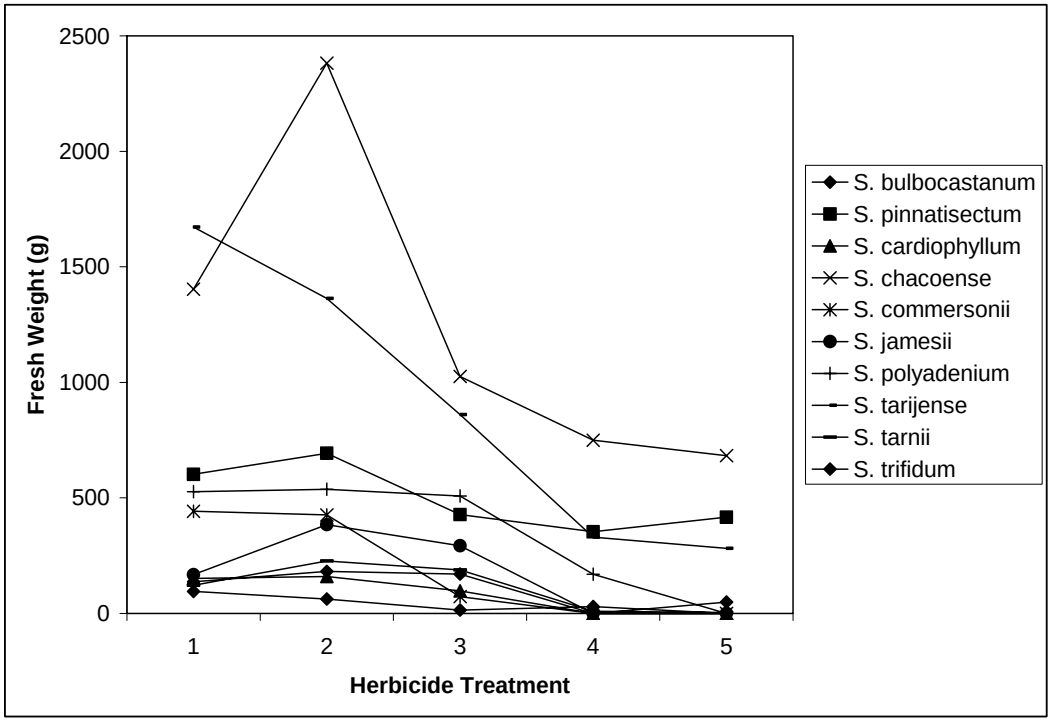
All 'Red Pontiac' plots that were planted next to test plots developed high levels of common scab, indicating disease pressure was fairly uniform throughout the plot. Coverage evaluations did not always correlate well with severity evaluations. Any tuber that received a 0 for severity also was scored with a 0 for coverage. However, scab lesions could range from superficial (severity = 1) to very deep (e.g. severity = 5) and only have 5% or less of the tuber surface covered (coverage = 2). Therefore, several entries that received a severity rating of 3 or 4 had coverage ratings of only 1 or 2. Since tubers can be rejected for sale when common scab lesions are severe, regardless of the degree of coverage, severity is a better measure of resistance in processing-type potatoes. Coverage may be the better assessment for fresh market reds.

Table 3. Number of entries in each common scab resistance class based on Severity and Coverage Ratings at Becker, MN 2004

Sources of entries	Severity Rating (%)	Coverage Rating (%)
UM Potato Pathology & Genomics		
Resistant	2 (20%)	3 (30%)
Moderately Resistant	0 (0%)	3 (30%)
Moderately Susceptible	3 (30%)	3 (30%)
Susceptible	5 (50%)	1 (10%)
UM Potato Breeding		
Resistant	2 (1.6%)	10 (7.9%)
Moderately Resistant	7 (5.5%)	49 (38.6%)
Moderately Susceptible	24 (18.9%)	49 (38.6%)
Susceptible	94 (74%)	19 (14.9%)
National Scab Trial		
Resistant	3 (15%)	5 (25%)
Moderately Resistant	3 (15%)	7 (35%)
Moderately Susceptible	6 (30%)	7 (35%)
Susceptible	8 (40%)	1 (5%)
North Central Trial		
Resistant	2 (11.1%)	4 (22.2%)
Moderately Resistant	0 (0%)	6 (33.3%)
Moderately Susceptible	6 (33.3%)	6 (33.3%)
Susceptible	10 (55.6%)	2 (11.1%)
Quad-State Trial		
Resistant	2(10.5%)	4 (21.1%)
Moderately Resistant	3 (15.8%)	10 (52.6%)
Moderately Susceptible	3 (15.8%)	2 (10.5%)
Susceptible	11 (57.9%)	3 (15.8%)
All Entries		
Resistant	11 (5.7%)	25 (13.4 %)
Moderately Resistant	13 (6.7%)	75 (38.7%)
Moderately Susceptible	42 (21.6%)	67 (34.5%)
Susceptible	128 (66%)	25 (13.4%)

Wild Potato Germplasm Screening for Tolerance to Common Herbicides

Wild *Solanum* species are rich sources of disease resistance genes. Our program works to identify, characterize, and utilize for potato improvement, disease resistance genes from diploid wild potatoes. Our efforts necessitate field screening of wild species, but the cultural conditions of wild germplasm can be very different from those of cultivated potato. In the past, fearing that wild potato might be susceptible to broad-leaf herbicides commonly used for potato production, we have hand weeded wild potato plots—a time consuming and costly endeavor. In 2005, we initiated a two year study looking at herbicide tolerance in wild potato. In total, 10 wild potato species were tested. Four seedlings of each of four different populations for each species were planted at the Sand Plain Research Farm under five different herbicide treatments: no broad-leaf herbicide, half strength Linuron, full strength Linuron, half strength Sencor, and full strength Sencor. Each plot received herbicide for grass control. Other cultural practices were identical. Plots were visually assessed on a biweekly basis. After six weeks, the above ground biomass for each experimental unit was measured and recorded. Our research points to differential susceptibility to herbicides. Some species were killed by Linuron and Sencor at all concentrations. Others were susceptible to one but not to both herbicides. For some species, certain genotypes are susceptible while others are resistant.



Total fresh weight (in grams) for each of 10 wild potato species (average of 4 different populations per species) 48 days after planting in plots treated with no broadleaf herbicide (treatment 1), half strength Linuron (treatment 2), full strength Linuron (treatment 3), half strength Sencor (treatment 4), or full strength Sencor (treatment 5).

References

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Henfling, J. W. 1987 Late blight of potato: *Phytophthora infestans*. Technical Information Bulletin 4. International Potato Center, Lima, Peru.

Hoyos, G. O., Zambino, P. J., and Anderson, N. A. 1991. An assay to quantify vascular colonization of potato by *Verticillium dahliae*. Am. Potato J. 68:727-742.

King, R. R., and Lawrence, C. H., and Clark, M. C. 1991. Correlation of phytotoxin production with pathogenicity of *Streptomyces scabies* isolates from scab infected potato tubers. Am. Potato J. 68:675-680.

Appendix A: Disease Screening Methods

(A) Late Blight

Tubers were planted on June 15. Entries were submitted by the University of Minnesota Potato Pathology and Genomics Program, the University of Minnesota Potato Breeding Program, the University of Wisconsin Potato Breeding Program, the National Late Blight Trial (conducted by Dr. Kathleen Haynes, USDA/ARS, Beltsville, MD), the North Central Region trials, and the Quad State Trials. Admire 2F insecticide was applied in furrow at a rate of 16 fl. oz./acre to all planted potatoes. No fungicides were applied to the field at any time during the season.

Two different ways of inoculation and evaluation were compared during the 2005 season. Two blocks were planted with same material from the Potato Pathology and Genomics Program, The University of Minnesota Potato Breeding Program, and the University of Wisconsin Potato Breeding Program. The first block was planted with single row experimental lines surrounded from each side with susceptible border cultivar "Norchip". The second block had no border rows.

All border rows in block one and all experimental lines in block two were inoculated with a suspension of *P. infestans* (US-8 strain) zoospores and sporangia at a concentration of 1000 sporangia /ml in the late evening of August 15. Inoculum was applied with a CO_2 sprayer at 20 psi using a single nozzle (6502 tip) wand. Plots were irrigated for 1 hour prior to inoculation. Sprinkler irrigation was applied the next morning and thereafter, 4 to 6 times per week depending upon weather conditions for 1 hour to prolong natural dew periods. All irrigation was accomplished using a low-volume, overhead mist-type sprinkler system.

Evaluations were initiated 14 days after inoculation and were made every 3 to 5 days until 28 days after inoculation (6 readings total). Each entry was visually scored for disease severity using the CIP scale (Henfling, 1987). The CIP rating system is as follows:

CIP	% Late Blight	
Rating	Mean	Limits
1	0	0
2	2.5	Trace to 5
3	10	5 to <15
4	25	15 to <35
5	50	35 to <65
6	75	65 to <85
7	90	85 to <95
8	97.5	95 to <100
9	100	100

After all disease ratings were made, the CIP ratings were categorized based on readings taken 25 DAI as follows:

Resistance Class	Score
Resistant	<2.5
Moderately Resistant	2.5-4.99
Moderately Susceptible	5-7.49
Susceptible	>7.5

(B) *Verticillium* Wilt

Potato seed pieces and wild potato species seedlings were planted by hand on May 26 at the Sand Plain Research Farm, Becker, MN. Entries were inoculated using ½ cup of grain inoculum (cultivated potato), 20ml of liquid inoculum (cultivated potato and wild potato seedlings), or no inoculum (wild potato seedling observation rows) as described above. Admire 2F insecticide was applied in furrow at a rate of 16 fl. oz./acre. Each entry consisted of four seed pieces (cultivated potato) or 10 seedlings (wild potato species) spaced 12 inches apart. The plot received weekly applications of Quadris (6.2 fl. oz./acre), rotated with Bravo WS (1.5 pt./acre) to control early and late blight. The plot was irrigated (1"/week) during dry periods. All experimental entries were rated for the percentage of foliage exhibiting senescence using the following scale (Hoyos et al., 1991).

1 = 1-12% wilt
2 = 13-25% wilt
3 = 26-50% wilt
4 = 51-75% wilt
5 = 76-90% wilt
6 = 91-100% wilt

Ratings were made on July 21, August 6, and August 17. Observation rows (uninoculated wild potato entries) remained healthy throughout the experiment.

(C) Common Scab

Potato seed pieces were planted on April 29 by hand and Admire 2F insecticide was applied in furrow at a rate of 16 fl. oz./acre. Each entry consisted of 4 seed pieces spaced 12 inches apart, followed by a four-foot space, then two seed pieces of 'Red Pontiac' 12 inches apart, followed by another four-foot space. The 'Red Pontiac' was used as a susceptible check, to measure disease pressure throughout the plot.

For evaluation, all potato hills were lifted from the ground and dropped back on the ground using a one-row potato harvester. Harvest was done on September 14 and evaluations were made on September 17, after a natural rainfall had washed much of the dirt from the tubers. All tubers from the four hills were rated as a group using the following scale:

Rating	Severity	Coverage
0	No scab visible	No scab visible
1	Scab <= 1 mm deep	Trace or 1-2 lesions less than 1 cm^2
2	Scab 2-3 mm deep	1 to 5 % tuber surface covered
3	Scab 3-4 mm deep	>5 to 50% tuber surface covered
4	Scab 4-5 mm deep	Over 50% tuber surface covered
5	Scab over 5 mm deep	---

Entries were considered resistant if the severity and coverage ratings were 0, moderately resistant for severity and coverage ratings of 1-2, moderately susceptible for severity and coverage ratings of 3, and susceptible for severity ratings of 4-5 or a coverage rating of 4.

Appendix B. Field Plot Data

(A) Late Blight: Disease resistance scores for entries in the (1) National Late Blight Trial, (2) North Central Trial, (3) Quad-State Trial, (4) University of Minnesota Potato Breeding Program, and (5) University of Minnesota Potato Pathology and Genomics Program.

1. National Late Blight Trial

Indirect / Border inoculation

Trial	Clone	Resistant Score
NLB	A97084-44	1.5
NLB	A9520-45	2
NLB	AWN86514-2	2
NLB	EGA970614	2
NLB	LBR8	2
NLB	B0692-4	2.5
NLB	A96517-2	3
NLB	AND 9552-7	3
NLB	B0718-3	3
NLB	AND 9552-10	3.5
NLB	B0767-2	3.5
NLB	MSI152-A	3.5
NLB	LBR5	7.5
NLB	LBR1R2R3R4	8.5
NLB	LBR2	9
NLB	LBR3 tbr	9
NLB	LBR4	9

Direct inoculation / no borders

Trial	Clone	Resistant Score
NLB	A97084-44	1.5
NLB	A9520-45	2
NLB	AWN86514-2	2
NLB	EGA970614	2
NLB	LBR8	2.5
NLB	A96517-2	3.5
NLB	B0718-3	3.5
NLB	AND 9552-7	4
NLB	B0692-4	4
NLB	B0767-2	4
NLB	MSI152-A	4.5
NLB	AND 9552-10	5
NLB	LBR5	8
NLB	LBR1R2R3R4	9
NLB	LBR2	9

NLB	LBR3 tbr	9
NLB	LBR4	9

2. North Central Trial

Indirect / Border inoculation

Trial	Clone	Resistant Score
NCR	MSJ461-1	3
NCR	MSI152-A	3.5
NCR	FV12246-6	8
NCR	W 2133-1	8
NCR	A9304-3	8.5
NCR	A9305-10	8.5
NCR	B0766-3	8.5
NCR	FV12486-2	9
NCR	Gemstar Russet	9
NCR	MSH095-4	9
NCR	MSI005-20Y	9
NCR	NY 126	9
NCR	Stampede Russet	9
NCR	V0319-1	9
NCR	V1102-1	9
NCR	Villetta Rose	9
NCR	W 1879-1Rus	9
NCR	W 2128-8	9

Direct inoculation / no borders

Trial	Clone	Resistant Score
NCR	MSJ461-1	2
NCR	MSI152-A	4.5
NCR	FV12246-6	8.5
NCR	A9304-3	9
NCR	A9305-10	9
NCR	B0766-3	9
NCR	FV12486-2	9
NCR	Gemstar Russet	9
NCR	MSH095-4	9
NCR	MSI005-20Y	9
NCR	NY 126	9
NCR	Stampede Russet	9
NCR	V0319-1	9
NCR	V1102-1	9
NCR	Villetta Rose	9
NCR	W 1879-1Rus	9
NCR	W 2128-8	9
NCR	W 2133-1	9

3. Quad-State Trial

Indirect / Border inoculation

Trial	Clone	Resistant score
QS	ND 7377Cb-1	6
QS	ND 7252-1Y	8
QS	W 2466-5Rus	8
QS	W 3140-3Rus	8.5
QS	(RB FILLER)	9
QS	(RB FILLER)	9
QS	AND 92475-2Russ	9
QS	AND 98324-1Russ	9
QS	ND 4756-1R	9
QS	ND 5490-6Rus	9
QS	ND 7196c-18	9
QS	ND 8304-2	9
QS	ND 8305-1	9
QS	W 2438-3Y	9
QS	W 2717-5	9
QS	W 2978-3	9
QS	W 3059-1YRus	9
QS	W 3328-1Rus	9
QS	W 3784-1	9

Direct inoculation / no borders

Trial	Clone	Resistant score
QS	ND 7377Cb-1	5
QS	ND 7252-1Y	7
QS	W 2466-5Rus	8.5
QS	W 3140-3Rus	8.5
QS	AND 92475-2Russ	9
QS	AND 98324-1Russ	9
QS	ND 4756-1R	9
QS	ND 5490-6Rus	9
QS	ND 7196c-18	9
QS	ND 8304-2	9
QS	ND 8305-1	9
QS	W 2438-3Y	9
QS	W 2717-5	9
QS	W 2978-3	9
QS	W 3059-1YRus	9
QS	W 3328-1Rus	9
QS	W 3784-1	9

4. University of Minnesota Potato Breeding Program

Indirect / Border inoculation

Trial	Clone	Resistant Score
E2	NDMN 03399-3	3.5
E2	ATMN 03527-1	4
E2	NDMN 03379-1	6.5
Int	MN 02 419	7
Int	MN 02 582	7
E2	AOMN 03211-1	7.5
E2	MN(DM) 03 5-1	7.5
E2	NDMN 03376-1	7.5
E2	NDMN 03382-2	7.5
Int	MN 02 536	7.5
Chk	**R. Pontiac**	8
Chk	**Snowden**	8
E2	AOMN 03188-2	8
E2	AOMN 03196-1	8
E2	AOMN 03246-3	8
E2	COMN 03020-5	8
E2	COMN 03049-5	8
E2	NDMN 03339-4	8
Int	MN 02 467	8
Chk	**Atlantic**	8.5
Chk	**NorValley**	8.5
E2	AOMN 03163-1	8.5
E2	AOMN 03178-2	8.5
E2	AOMN 03179-1	8.5
E2	AOMN 03193-1	8.5
E2	AOMN 03240-3	8.5
E2	AOMN 03247-1	8.5
E2	COMN 03016-4	8.5
E2	MN(DE) 03 14-4	8.5
E2	MN(DE) 03 4-3	8.5
E2	MN(DE) 03 4-4	8.5
E2	MN(DE) 03 8-2	8.5
E2	MN(DM) 03 1-2	8.5
E2	NDMN 03324-4	8.5
E2	NDMN 03334-1	8.5
Int	MN 02 422	8.5
Int	MN 02 452	8.5
Int	MN 02 574	8.5
Int	MN 02 588	8.5
Int	MN 02 589	8.5
Int	MN 02 598	8.5
Int	MN 02 633	8.5
Int	MN 02 645	8.5
Chk	**R. Burbank**	9
Chk	**R. Norkotah**	9
Chk	**R. Norland**	9

Chk	**Shepody**	9
Chk	**Y. Gold**	9
E2	AOMN 03102-1	9
E2	AOMN 03102-2	9
E2	AOMN 03102-5	9
E2	AOMN 03187-5	9
E2	AOMN 03218-4	9
E2	AOMN 03219-11	9
E2	AOMN 03230-1	9
E2	ATMN 03505-3	9
E2	COMN 03008-3	9
E2	COMN 03019-3	9
E2	COMN 03019-4	9
E2	COMN 03020-2	9
E2	COMN 03020-3	9
E2	COMN 03021-1	9
E2	COMN 03021-2	9
E2	COMN 03024-6	9
E2	COMN 03027-1	9
E2	COMN 03030-1	9
E2	COMN 03031-2	9
E2	COMN 03032-3	9
E2	COMN 03032-4	9
E2	COMN 03035-5	9
E2	COMN 03039-1	9
E2	COMN 03051-1	9
E2	COMN 03083-4	9
E2	MN(DE) 03 14-2	9
E2	MN(DM) 03 1-4	9
E2	MN(DM) 03 1-5	9
E2	MN(DM) 03 36-1	9
E2	MN(DM) 03 42-1	9
E2	MN(DM) 03 8-2	9
E2	NDMN 03308-1	9
E2	NDMN 03314-1	9
E2	NDMN 03316-1	9
E2	NDMN 03316-2	9
E2	NDMN 03316-3	9
E2	NDMN 03333-1	9
E2	NDMN 03333-2	9
E2	NDMN 03334-2	9
E2	NDMN 03337-1	9
E2	NDMN 03359-1	9
E2	NDMN 03374-1	9
E2	NDMN 03378-12	9
E2	NDMN 03378-9	9
E2	NDMN 03406-1	9
E2	NDMN 03407-2	9
E2	NDMN 03407-4	9
E2	NDMN 03407-7	9

E2	NDMN 03410-2	9
E2	NDMN 03412-3	9
Elite	MN 15620	9
Elite	MN 18153	9
Elite	MN 18710	9
Elite	MN 19298	9
Elite	MN 19350	9
Elite	MN 19470	9
Elite	MN 96013-1	9
Elite	MN 96072-4	9
Elite	MN 99460-14	9
Elite	MN 99460-21	9
Int	MN 02 417	9
Int	MN 02 458	9
Int	MN 02 480	9
Int	MN 02 510	9
Int	MN 02 515	9
Int	MN 02 524	9
Int	MN 02 529	9
Int	MN 02 537	9
Int	MN 02 586	9
Int	MN 02 587	9
Int	MN 02 616	9
Int	MN 02 618	9
Int	MN 02 644	9
Int	MN 02 678	9
Int	MN 02 689	9
Int	MN 02 696	9
Int	MN 02 703	9
Int	MN 02 709	9

Direct inoculation / no borders

Trial	Clone	Resistant score
E2	NDMN 03399-3	4.5
E2	ATMN 03527-1	5
Int	MN 02 419	7
E2	NDMN 03339-4	7.5
E2	MN(DE) 03 14-4	8
Int	MN 02 536	8
E2	AOMN 03179-1	8.5
E2	AOMN 03211-1	8.5
E2	AOMN 03246-3	8.5
E2	COMN 03049-5	8.5
E2	MN(DM) 03 5-1	8.5
E2	NDMN 03376-1	8.5
E2	NDMN 03379-1	8.5
Int	MN 02 452	8.5
Int	MN 02 467	8.5
Int	MN 02 510	8.5

Chk	**Atlantic**	9
Chk	**NorValley**	9
Chk	**R. Burbank**	9
Chk	**R. Norkotah**	9
Chk	**R. Norland**	9
Chk	**R. Pontiac**	9
Chk	**Shepody**	9
Chk	**Snowden**	9
Chk	**Y. Gold**	9
E2	AOMN 03102-1	9
E2	AOMN 03102-2	9
E2	AOMN 03102-5	9
E2	AOMN 03163-1	9
E2	AOMN 03178-2	9
E2	AOMN 03187-5	9
E2	AOMN 03188-2	9
E2	AOMN 03193-1	9
E2	AOMN 03196-1	9
E2	AOMN 03218-4	9
E2	AOMN 03219-11	9
E2	AOMN 03230-1	9
E2	AOMN 03240-3	9
E2	AOMN 03247-1	9
E2	ATMN 03505-3	9
E2	COMN 03008-3	9
E2	COMN 03016-4	9
E2	COMN 03019-3	9
E2	COMN 03019-4	9
E2	COMN 03020-2	9
E2	COMN 03020-3	9
E2	COMN 03020-5	9
E2	COMN 03021-1	9
E2	COMN 03021-2	9
E2	COMN 03024-6	9
E2	COMN 03027-1	9
E2	COMN 03030-1	9
E2	COMN 03031-2	9
E2	COMN 03032-3	9
E2	COMN 03032-4	9
E2	COMN 03035-5	9
E2	COMN 03039-1	9
E2	COMN 03051-1	9
E2	COMN 03083-4	9
E2	MN(DE) 03 14-2	9
E2	MN(DE) 03 4-3	9
E2	MN(DE) 03 4-4	9
E2	MN(DE) 03 8-2	9
E2	MN(DM) 03 1-2	9
E2	MN(DM) 03 1-4	9
E2	MN(DM) 03 1-5	9

E2	MN(DM) 03 36-1	9
E2	MN(DM) 03 42-1	9
E2	MN(DM) 03 8-2	9
E2	NDMN 03308-1	9
E2	NDMN 03314-1	9
E2	NDMN 03316-1	9
E2	NDMN 03316-2	9
E2	NDMN 03316-3	9
E2	NDMN 03324-4	9
E2	NDMN 03333-1	9
E2	NDMN 03333-2	9
E2	NDMN 03334-1	9
E2	NDMN 03334-2	9
E2	NDMN 03337-1	9
E2	NDMN 03359-1	9
E2	NDMN 03374-1	9
E2	NDMN 03378-12	9
E2	NDMN 03378-9	9
E2	NDMN 03382-2	9
E2	NDMN 03406-1	9
E2	NDMN 03407-2	9
E2	NDMN 03407-4	9
E2	NDMN 03407-7	9
E2	NDMN 03410-2	9
E2	NDMN 03412-3	9
Elite	MN 15620	9
Elite	MN 18153	9
Elite	MN 18710	9
Elite	MN 19298	9
Elite	MN 19350	9
Elite	MN 19470	9
Elite	MN 96013-1	9
Elite	MN 96072-4	9
Elite	MN 99460-14	9
Elite	MN 99460-21	9
Int	MN 02 417	9
Int	MN 02 422	9
Int	MN 02 458	9
Int	MN 02 480	9
Int	MN 02 515	9
Int	MN 02 524	9
Int	MN 02 529	9
Int	MN 02 537	9
Int	MN 02 574	9
Int	MN 02 582	9
Int	MN 02 586	9
Int	MN 02 587	9
Int	MN 02 588	9
Int	MN 02 589	9
Int	MN 02 598	9

Int	MN 02 616	9
Int	MN 02 618	9
Int	MN 02 633	9
Int	MN 02 644	9
Int	MN 02 645	9
Int	MN 02 678	9
Int	MN 02 689	9
Int	MN 02 696	9
Int	MN 02 703	9
Int	MN 02 709	9

5. University of Minnesota Potato Pathology and Genomics Program

Line	Resistant Score	Class
SP2105	1.67	R
SP2654	1.67	R
SP1464	1.67	R
SP1464	1.67	R
SP2113	2	R
SP2182	2	R
SP2184	2	R
SP2210	2	R
SP2211	2	R
SP2215	2	R
SP2564	2	R
SP2576	2	R
SP2577	2	R
SP2587	2	R
SP2665	2	R
SP2671	2	R
SP2511	2.33	R
SP2575	2.33	R
SP2662	2.33	R
SP918	2.33	R
SP922	2.33	R
SP1453	2.33	R
SP2174	2.67	MR
SP2366	2.67	MR
SP2466	2.67	MR
SP2658	2.67	MR
SP2193	3	MR
SP2193	3	MR
SP2466	3	MR
SP2565	3	MR
SP2572	3	MR
SP2588	3	MR

SP2619	3	MR
SP905	3	MR
SP951	3	MR
SP2423	3.33	MR
SP2424	3.33	MR
SP2466	3.33	MR
SP2564	3.33	MR
SP2574	3.33	MR
SP2585	3.33	MR
SP2663	3.67	MR
SP2573	4	MR
SP966	4	MR
SP2178	4.33	MR
SP2212	4.67	MR
SP2514	4.67	MR
SP2520	4.67	MR
SP2561	4.67	MR
SP2586	4.67	MR
SP2515	5	MS
SP2534	5	MS
SP2582	5	MS
SP2633	5	MS
SP2664	5.33	MS
SP2531	6	MS
Kathadin	8	S
Superior	8.33	S
R. Burbank	9	S
SP2354	9	S
SP2361	9	S
DRN	9	S

Indirect / Border inoculation

Cultivar	14 DAI	17 DAI	21 DAI	24 DAI	28 DAI	31 DAI
AC Blue Pride	2	2	4	5.5	6.5	8
AC Domino	2	2	4	6	7	8
ARRAN CONSUL	2	2	5	6.5	7.5	8.5
ARRAN VICTORY	2	2	5	6	8	8.5
Mrs. Moehlers	2	2	5.5	7	8	9
AC Red Island	2	3.5	7.5	8	8.5	9
LUMPERS	2	2.5	5.5	7	8.5	9
AK FROSTLESS	2	4	8.5	9	9	9
ARRAN PILOT	2	2.5	7	8	9	9
BEAUTY HEBRON	2	2.5	7	8	9	9
BINTJE	2	4	8	8.5	9	9
FORTYFOLD	2	3	6	8	9	9
French Fingerling	2	2	5	7	9	9
GREEN MOUNTAIN (COR)	2	3	6	8	9	9
Corne de Moutan	2	3.5	7	8	9	9

PURPLE VIKING	2	3.5	7	8	9	9
La RATTE	2	2.5	7	8	9	9
RED BEAUTY	2	2	7.5	9	9	9

Direct inoculation / no borders

Cultivar	14 DAI	17 DAI	21 DAI	24 DAI	28 DAI	31 DAI
Inca Gold	1.5	2	4	5.5	7	8
Reda	1	1.5	2.5	4.5	7	8
Hooksack	1.5	1.5	3	4.5	7.5	9
Albys Gold	1.5	2	4	6	8	9
Augsburg Gold	1.5	2	3.5	6.5	8	9
German Butterball-Hancock	2	2	4	6.5	8	9
German Butterball-Ronnigers	1.5	1	3.5	5.5	8	8.5
Ruby Crescent-Ronnigers	1	1.5	2.5	4.5	8	9
Butte	2	2.5	5	8	8.5	9
Pimpernel	2	2	3.5	6	8.5	8.5
Ruby Crescent-Hancock	1	1.5	4	6.5	8.5	9
Sieglinde	2	2	4.5	6.5	8.5	8.5
All Blue	2	1.5	5.5	7	9	9
All Red	1.5	2	7	8.5	9	9
Bake King	2	3	6.5	8	9	9
Candy Cane	2	3	7	8.5	9	9
Caribe	2	2.5	5.5	9	9	9
Carola-Hancock	2	2.5	6	8	9	9
Carola-Ronnigers	2	2.5	5	7.5	9	9
Denali	2	2.5	5.5	8	9	9
Gold Nugget	2	2	4.5	7.5	9	9
Huckleberry	1.5	1.5	6	8.5	9	9
King Edward	2	2	5.5	7.5	9	9
Pink Pearl	1.5	2	4.5	6.5	9	9
Princess Laratte	2	2	4.5	8	9	9
Red Thumb	1.5	2	5	8.5	9	9
Rose Gold	2	3.5	6.5	9	9	9
Russian Banana	2	2	4.5	8	9	9
Yellow Finn	2	2	4.5	8	9	9
Yukon Gold	2	3	6	8.5	9	9
Epicure	2	2	5	7.5	9	9
Red Warba	1.5	2.5	6	8.5	9	9
Saginaw Gold	2	2	5.5	7.5	9	9

Pimpernel	1.5	2	4.5	6	7.5	8
Sieglinde	1.5	2.5	4.5	6.5	7.5	8
Albys Gold	1.5	2	4	6.5	8	8
Augsburg Gold	1.5	3	6	7	8	9
German Butterball-Ronnigers	2	2	5.5	7	8	9
Hooksack	1.5	2	5	6.5	8	9

Reda	2	3	5	6.5	8	8.5
Ruby Crescent-Ronnigers	2	3	5	7	8	9
Bake King	3	5	8	9	8.5	9
German Butterball-Hancock	1.5	2	5.5	6.5	8.5	9
Inca Gold	1.5	2	5.5	7	8.5	9
Pink Pearl	1.5	2.5	5.5	7.5	8.5	9
Ruby Crescent-Hancock	1.5	2.5	5	6.5	8.5	9
Red Warba	1.5	3.5	8.5	8	8.5	9
All Blue	2	2	5.5	7.5	9	9
All Red	2.5	5.5	8	9	9	9
Butte	2	3.5	7.5	8.5	9	9
Candy Cane	2.5	4	8	9	9	9
Caribe	3	4.5	9	9	9	9
Carola-Hancock	2	4.5	7.5	8.5	9	9
Carola-Ronnigers	2	4	7	8.5	9	9
Denali	2	3	7.5	9	9	9
Gold Nugget	3	4	7.5	8.5	9	9
Huckleberry	1.5	2.5	8	9	9	9
King Edward	2	3	6.5	8.5	9	9
Princess Laratte	2	4	7	8	9	9
Red Thumb	2.5	4	8	9	9	9
Rose Gold	3.5	5.5	8.25	9	9	9
Russian Banana	2.5	4	7.5	8.5	9	9
Yellow Finn	2	2.5	6.5	8	9	9
Yukon Gold	2	3.5	8	9	9	9
Epicure	2.5	4	8	9	9	9
Saginaw Gold	2	2.5	7	8.5	9	9

Common Scab: Disease severity and coverage scores for entries in the (1) National Late Blight Trial, (2) North Central Trial, (3) Quad-State Trial, (4) University of Minnesota Potato Breeding Program, and (5) University of Minnesota Potato Pathology and Genomics Program.

1. National Scab Trial

Trial	Cultivar	Severity	Coverage
Natl Scab	Freedom Russet (W1836-3rus)	0	0
Natl Scab	A8893-1---NOVY	1.67	0.33
Natl Scab	GemStar Russet---NOVY	1	0.67
Natl Scab	Superior	1	0.67
Natl Scab	A93157-6LS ---NOVY	2.33	1.33
Natl Scab	Russet Burbank---NOVY	2.33	1.67
Natl Scab	B1992-166	3	1.67
Natl Scab	CO94183-1R/R	3	1.67
Natl Scab	Megachip	2.67	2
Natl Scab	VC0967-2R/Y	3.67	2.33
Natl Scab	AF2291-10	4	2.33
Natl Scab	CO94165-3P/P	4.67	2.33
Natl Scab	CO94035-15Ru	2.67	2.67
Natl Scab	Ranger Russet ---NOVY	3.33	2.67
Natl Scab	W 2128-8	3.67	2.67
Natl Scab	Atlantic	4	2.67
Natl Scab	AF2211-9	5	2.67
Natl Scab	B1816-5	4.67	3.33
Natl Scab	B1952-2	5	3.33
Natl Scab	A9045-7 --- NOVY	3.33	3.67

2. North Central Trial

Trial	Clone	Severity	Coverage
NCR	A9304-3	0	0
NCR	W 1879-1Rus	0.5	0.5
NCR	Gemstar Russet	2.5	1
NCR	MSH095-4	2.5	1
NCR	A9305-10	2.5	1.5
NCR	V0319-1	3	1.5
NCR	V1102-1	3.5	1.5
NCR	W 2133-1	3	2
NCR	MSI005-20Y	3.5	2
NCR	NY 126	3.5	2
NCR	FV12246-6	3.5	2.5
NCR	MSJ461-1	3.5	2.5
NCR	MSI152-A	4.5	2.5
NCR	Stampede Russet	3	3

NCR	W 2128-8	3.5	3
NCR	B0766-3	4	3
NCR	Villetta Rose	4.5	3.5
NCR	FV12486-2	5	4

3. Quad-State Trial

Trial	Clone	Severity	Coverage
QS	ND 5490-6Rus	0.5	0.5
QS	W 4132-1	1	1
QS	ND 7377Cb-1	2	1
QS	W 2717-5	2.5	1
QS	ND 4756-1R	2	1.5
QS	W 2438-3Y	2.5	1.5
QS	ND 8304-2	3.5	1.5
QS	W 2466-5Rus	3.5	1.5
QS	W 2978-3	3.5	1.5
QS	W 3328-1Rus	2	2
QS	W 3059-1YRus	2.5	2
QS	W 3140-3Rus	3.5	2
QS	W 3784-1	4	2
QS	ND 7252-1Y	4.5	2
QS	AND 92475-2Russ	4.5	3
QS	AND 98324-1Russ	4.5	3
QS	ND 7196c-18	4	3.5
QS	ND 8305-1	5	3.5
QS	W 4016-4	5	3.5

4. University of Minnesota Potato Breeding Program

Trial	Clone	severity	coverage
Elite	MN 18710	0.5	0.5
Int	MN 02 422	1	0.5
Int	MN 02 467	1.5	1
Int	MN 02 480	1.5	1
E2	MN(DM) 03 1-2	1.5	1
E2	AOMN 03247-1	2	1
Elite	MN 18153	2.5	1
Elite	MN 19470	2.5	1
Chk	**R. Burbank**	2.5	1
E2	AOMN 03196-1	3	1
Int	MN 02 616	1.5	1.5
E2	NDMN 03378-12	1.5	1.5
E2	AOMN 03187-5	2	1.5
E2	AOMN 03246-3	2.5	1.5
E2	MN(DM) 03 36-1	2.5	1.5
E2	NDMN 03324-4	2.5	1.5

E2	NDMN 03316-3	3	1.5
E2	NDMN 03399-3	3	1.5
Int	MN 02 574	3.5	1.5
Elite	MN 96072-4	3.5	1.5
E2	NDMN 03378-9	3.5	1.5
E2	COMN 03030-1	4.5	1.5
Int	MN 02 536	4.5	1.5
E2	NDMN 03407-4	4.5	1.5
E2	ATMN 03505-3	2.5	2
E2	MN(DE) 03 14-2	2.5	2
E2	NDMN 03308-1	2.5	2
E2	NDMN 03314-1	2.5	2
E2	NDMN 03412-3	2.5	2
E2	AOMN 03179-1	3	2
E2	AOMN 03240-3	3	2
E2	MN(DM) 03 1-4	3	2
E2	NDMN 03379-1	3	2
Chk	**R. Norkotah**	3	2
E2	AOMN 03102-5	3.5	2
E2	COMN 03032-3	3.5	2
Elite	MN 15620	3.5	2
E2	MN(DE) 03 14-4	3.5	2
E2	NDMN 03334-2	3.5	2
E2	NDMN 03406-1	3.5	2
Chk	**Shepody**	3.5	2
E2	AOMN 03102-1	4	2
E2	COMN 03021-1	4	2
E2	COMN 03051-1	4	2
Int	MN 02 703	4	2
Elite	MN 19298	4	2
E2	MN(DE) 03 4-3	4	2
E2	MN(DE) 03 8-2	4	2
E2	MN(DM) 03 1-5	4	2
E2	NDMN 03316-2	4	2
E2	NDMN 03374-1	4	2
Chk	**Snowden**	4	2
Chk	**Atlantic**	4.5	2
E2	COMN 03008-3	4.5	2
E2	COMN 03020-3	4.5	2
Int	MN 02 678	4.5	2
Elite	MN 19350	4.5	2
E2	NDMN 03410-2	4.5	2
E2	AOMN 03178-2	5	2
E2	ATMN 03527-1	2.5	2.5
E2	NDMN 03382-2	3	2.5
Chk	**R. Norland**	3	2.5
E2	AOMN 03218-4	3.5	2.5
E2	MN(DM) 03 42-1	3.5	2.5
E2	COMN 03019-3	4	2.5
E2	COMN 03039-1	4	2.5

Int	MN 02 458	4	2.5
E2	NDMN 03337-1	4	2.5
E2	NDMN 03376-1	4	2.5
E2	NDMN 03407-2	4	2.5
Chk	NorValley	4	2.5
E2	COMN 03021-2	4.5	2.5
E2	COMN 03031-2	4.5	2.5
E2	COMN 03032-4	4.5	2.5
E2	COMN 03083-4	4.5	2.5
Int	MN 02 598	4.5	2.5
Int	MN 02 618	4.5	2.5
Int	MN 02 644	4.5	2.5
E2	NDMN 03316-1	4.5	2.5
E2	NDMN 03334-1	4.5	2.5
E2	NDMN 03407-7	4.5	2.5
Chk	**Y. Gold**	4.5	2.5
E2	COMN 03027-1	5	2.5
Int	MN 02 589	5	2.5
Elite	MN 99460-14	5	2.5
E2	NDMN 03339-4	2.5	3
E2	COMN 03016-4	3	3
E2	AOMN 03188-2	3.5	3
Int	MN 02 633	3.5	3
Int	MN 02 645	4	3
E2	NDMN 03333-1	4	3
E2	NDMN 03333-2	4	3
E2	AOMN 03211-1	4.5	3
E2	AOMN 03230-1	4.5	3
E2	COMN 03024-6	4.5	3
Int	MN 02 452	4.5	3
Int	MN 02 587	4.5	3
Int	MN 02 689	4.5	3
Elite	MN 99380-1	4.5	3
E2	MN(DM) 03 5-1	4.5	3
E2	NDMN 03359-1	4.5	3
E2	COMN 03019-4	5	3
E2	COMN 03035-5	5	3
Int	MN 02 510	5	3
Int	MN 02 537	5	3
Int	MN 02 696	5	3
Elite	MN 96013-1	5	3
Chk	**R. Pontiac**	5	3
E2	COMN 03049-5	3.5	3.5
Int	MN 02 588	4	3.5
E2	AOMN 03163-1	4.5	3.5
E2	AOMN 03219-11	4.5	3.5
Int	MN 02 419	4.5	3.5
Int	MN 02 515	4.5	3.5
Int	MN 02 529	4.5	3.5
Int	MN 02 582	4.5	3.5

Int	MN 02 709	4.5	3.5
E2	MN(DE) 03 4-4	4.5	3.5
E2	AOMN 03102-2	5	3.5
E2	AOMN 03193-1	5	3.5
E2	COMN 03020-2	5	3.5
Int	MN 02 417	5	3.5
E2	MN(DM) 03 8-2	5	3.5
E2	COMN 03020-5	4.5	4
Int	MN 02 524	5	4
Int	MN 02 586	5	4
Elite	MN 99460-21	5	4

5. University of Minnesota Potato Pathology and Genomics Program

Cultivar	Severity	Coverage
Nooksack	0.33	0.33
Sieglinde	1.33	0.67
Russian Banana	3.33	1.33
Candy Cane	4	2
Ruby Crescent-Ronnigers	3	2.33
Ruby Crescent-Hancock	3.33	2.33
Carola-Hancock	4.67	2.67
Red Warba	5	3.33
Rose Gold	5	3.33
All Blue	5	3.67