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1. Site and Clone Effects on the Potato Root-Associated Core Microbiome and its Relationship to Tuber Yield and Nutrients

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Abstract
The aim of this study was to describe the variability in the root-associated bacterial community due to location and clone, and to determine whether an underlying core bacterial community exists that might benefit the quality of the potato crop. Root-associated bacterial communities from one growing season were examined with 454 sequencing. Variance analysis using perMANOVA attributed 45.4 % and 24.1 % of the community variability to site and clone effects, respectively. A total of 123 bacterial operational taxonomic units were correlated with tuber yield and/or tuber nutrient content, a majority belong to the order Rhizobiales. Rhizobiales bacteria are recognized contributors to crop nitrogen needs for many legumes; however, no known symbiotic relationship between potato roots and nitrogen fixing bacteria exists. Within the Rhizobiales order, the genus Devosia is a major contributor to both the presence/absence core "bacteriome" and the sparse partial least squares core "bacteriome," thus further exploration into this unknown relationship is warranted.

Keywords
Soil microbiome – Rhizosphere - Solanum tuberosum - 454 DNA pyrosequencing - Tuber nutrients - Bacteria

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2. Yield Response and Late Blight Reaction of Potato Genotypes in Rwanda

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Abstract
Potato (*Solanum tuberosum* L.) genotypes with relatively high yield level and resistance to the late blight disease are being developed by the International Potato Centre (CIP) and made available to developing countries. However, for effective breeding for high yield and late blight resistance, these CIP materials and locally adapted genotypes need to be evaluated and screened under target growing environmental conditions. The objectives of the study were to determine yield response and late blight resistance of potato genotypes grown in Rwanda and candidate clones obtained from CIP and to identify suitable parents for breeding. A total of 44 potato genotypes, 30 acquired from CIP and 14 local varieties were evaluated under three environments (Kinigi, Rwerere and Nyamagabe). Experiments were laid out in an 11 × 4 alpha lattice design with two replications. Data were collected on late blight severity (%) based on the relative area under the disease progress curve (RAUDPC: 100 % max), total tuber yield, marketable

tuber weight and dry matter content. Genotypes had significant differences on blight resistance and yield levels among test locations. Eight genotypes (391,047.34, 393,385.39, 393,280.82, 396,036.201, Gikungu, Ngunda, Kigega and Nderera) were identified as promising parents for subsequent crosses. The selected genotypes display farmers-preferred traits, productive flowers, high to medium late blight resistance and high yields.

Keywords:
Disease resistance – Genotypes - Late blight – Potato - Rwanda

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3. Studies on varietal response to different strains of Potato virus Y (PVY) reveal hypersensitive resistance in Exploits to PVY^{O} and extreme resistance in F87084 to all tested strains

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Abstract
Potato cultivar Exploits and breeding clone F87084 have been considered resistant to *Potato virus Y* (PVY). To further explore the degree of resistance and whether the resistance is strain specific, these materials, together with cultivar Rochdale Gold-Dorée and breeding line F02010, were investigated for their response to different PVY strains including PVY^{O}, PVY$^{N:O}$, PVY^{NTN} and PVY^{N}. Both F02010 and Rochdale Gold-Dorée were readily infected with all tested PVY strains after either mechanical or graft inoculation, indicating susceptibility of the materials to PVY. F87084 was unable to be infected by any of the tested PVY strains as no ELISA-detectable level of PVY were found in plants after either mechanical or graft inoculation, demonstrating extreme resistance in F87084 to all strains of PVY tested. Exploits was infected with PVY$^{N:O}$/PVY^{NTN}/PVY^{N} after either mechanical or graft inoculation, indicating susceptibility of the cultivar to these PVY strains. The cultivar was also infected readily with PVY^{O} after graft inoculation. However, despite induction of local lesions on the inoculated leaves, mechanical inoculation with PVY^{O} may or may not lead to systemic symptoms and ELISA-detectable level of PVY, depending on temperature. At low temperature (e.g., 22 °C), no visible systemic symptoms or ELISA-detectable level of PVY was found in the plants; whereas at high temperature (e.g., 30 °C), systemic symptoms and high level of PVY were detected in the plants. These results demonstrate that Exploits possesses temperature-dependent hypersensitive resistance to PVY^{O}. Analysis of a segregating population of F87084 × F02010 revealed that the ER in F87084 is controlled by a dominant resistance gene.

Keywords
Extreme resistance - Hypersensitive resistance – Inheritance - Potato - *Potato virus Y* (PVY)

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4. The Effects of Chlorpropham Exposure on Field-Grown Potatoes

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Abstract
Chlorpropham (CIPC) is a highly effective potato (*Solanum tuberosum* L.) sprout inhibitor. Some export regulations require CIPC or other sprout inhibitor to be applied to potatoes as a general phytosanitary measure. In addition, due to trucking and temporary storage issues, seed potatoes may be inadvertently exposed to CIPC. The objective of this 2-year study was to document the effects of several low rates of CIPC application or contamination on emergence, yield, and grade of the subsequent crop. CIPC was sprayed on whole 'Russet Burbank' seed tubers at rates of 0, 1.3, 2.5, 5.0, and 10.0 ppm CIPC. Seed tubers were cut, planted and grown under typical commercial practices for Idaho. Low rates of CIPC (1.3 and 2.5 ppm) applied to tubers resulted in significant delays in emergence compared to the untreated control. Some plants failed to emerge from seed treated with 5 or 10 ppm CIPC. CIPC treatment resulted in total yield decreases of 26 % (2.5 ppm CIPC) to 78 % (10 ppm CIPC) in 2009 and 36 % (1.3 ppm CIPC) to 94 % (10 ppm CIPC) in 2010 compared to the untreated controls in each respective year. Harvested tuber size profile was significantly altered by CIPC applications with higher rates producing smaller potatoes. These dramatic reductions in yield reinforce the importance of avoiding all potential for CIPC contamination of seed. The study also documents the severe consequences of planting commercial potatoes exported for consumption that have been treated with CIPC.

Keywords
Isopropyl N-(3-chlorophenyl carbamate) - Potato storage - Stem number - Tuber number - Marketable yield - Tuber size distribution

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5. Screening Potato Cultivars for new Sources of Resistance to *Potato virus Y*

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Abstract
Potato virus Y (PVY) strains have been defined based on genetic reactions in potato indicators expressing hypersensitive reaction (HR) response due to the presence of three different N genes, and also based on genomic information. Nine strains are known currently, with five PVY strains defined biologically, PVY^{O}, PVY^{C}, PVY^{Z}, PVY^{N}, and PVY^{E}. The genetic background of the majority of North American potato cultivars has so far been poorly characterized for the presence of N genes inducing HR towards different PVY strains. Here, the HR response was studied in eight potato cultivars, elicited by five strains of PVY circulating in North America. These PVY isolates included representative isolates of PVY^{N-Wi}, PVY^{NA-N}, PVY^{O}, PVY^{Z}, and PVY^{N} strains. Potato cultivars tested included Russet Burbank, Russet Norkotah, Shepody, Ranger Russet, Western Russet, Alturas, Rio Grande Russet, and Yukon Gem, grown in the U.S., and standard indicators Desiree and Maris Bard with the known genetic background. Three additional strains, $PVY^{N:O}$, PVY-NE11, and PVY^{E}, were tested on Yukon Gem. Virus-free potato plants were mechanically inoculated with PVY inoculum, and local and systemic foliar symptoms were observed for 8 weeks post-inoculation under different climate-controlled conditions. Virus status of the inoculated plants was tested starting at 3 weeks post-inoculation, by serotype-specific ELISA and RT-PCR, in order to monitor successful infections and confirm the identity of the inoculated PVY isolate. This systematic approach allowed us to identify Ny_{tbr} and Nz_{tbr} genes present in several North American cultivars. Two more new, putative N genes were postulated to be expressed in the cultivar Yukon Gem, and one additional putative N gene was postulated to be expressed in two cultivars, Yukon Gem and Rio Grande Russet. These N genes may represent valuable sources of resistance against multiple strains of PVY.

Keywords
Potato virus Y – Resistance - N genes

6. Characteristics of Polish Isolates of *Fusarium sambucinum*: Molecular Identification, Pathogenicity, Diversity and Reaction to Control Agents

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Abstract
Pathogenicity of 28 Polish isolates of *F. sambucinum* to potato tubers, their sensitivity to control agents, diversity among isolates and molecular methods of species identification were examined. All isolates were pathogenic to potato tubers and differences in pathogenicity were found. Isolates on the PDA were classified into three different color groups of mycelium (B - bright-beige, P - salmon pink, R - rose) that varied in pathogenicity and mycelium growth rate on PDA. P colonies showed the greatest tuber damage, but they grew the slowest on the PDA. Isolates showed varied reaction to different concentrations of 4 control agents (M - mancozeb, C- captan, CO - copper oxychloride and GE - grapefruit extract). The highest mycelium growth inhibition (MGI) was caused by M and the lowest by CO. Strong MGI by GE was observed especially for P isolates. Individual isolates showed different susceptibility to the control agents. Identification of isolates was determined in PCR assay with species specific FSF1/FSR1 primers, by sequencing of DNA fragments derived from ITS regions and the translation elongation factor-1 alpha gene (TEF). Sequence of the ITS regions were identical for all isolates. Analysis of the TEF DNA fragments showed one SNP (transition C↔T) in the sequences of isolates from the three different color groups.

Keywords
Fusarium sambucinum - Potato – Pathogenicity - Control - ITS - TEF

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7. Influence of Location, Year, Potato Rotation, and Chemical Seed Treatment on Incidence and Severity of Silver Scurf on Progeny Tubers

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Abstract
A three-year study was conducted in 1999, 2001, and 2002 to examine the influence of seed-borne inoculum and fludioxonil+mancozeb seed treatment on silver scurf (caused by *Helminthosporium solani*) development on progeny tubers at six locations under different potato rotations in the semi-arid U.S. Pacific Northwest. Disease-free pre-nuclear seed and diseased generation 3 seed was either treated or not treated with fludioxonil plus mancozeb, planted, and progeny tubers were harvested and then evaluated for silver scurf incidence and severity. Experiments were conducted in the southern Columbia Basin (Oregon), northern Columbia Basin (Washington), central Oregon, southern Oregon, western Idaho, and eastern Idaho under short (<3 years), normal (3–5 years), and long (>5 years) potato rotations over the three years for a total of 19 location-year-rotation combinations. Significant differences were observed among years and locations with disease incidence being highest in central Oregon. Progeny tubers from

untreated generation 3 seed had significantly higher silver scurf incidence (18.4 %) and severity (1.3) compared to untreated progeny tubers from pre-nuclear seed (1.2 % and 0.04 for incidence and severity, respectively). Seed treatment with fludioxonil+mancozeb reduced incidence (3.8 %) and severity (0.2) significantly compared to the untreated control (15.8 % and 1.1 for incidence and severity, respectively). Significant ($P < 0.0001$) interactions between treatments and location-year-rotation were observed and additive main effects multiplicative interaction analysis discriminated those with high incidence, severity, and variability. These data indicate that seed, not soil, is the primary source of progeny tuber infection in the field in the Pacific Northwest. For long term storage, purchase of clean seed is an essential component for managing silver scurf.

Keywords
Helminthosporium solani - Additive main effects multiplicative interaction (AMMI)

8. Use of Hill Shape with Various Nitrogen Timing Splits to Improve Fertilizer Use Efficiency

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Abstract
The efficient use of fertilizer nitrogen (N) is critical for potato production in regions with sandy soils as concerns for groundwater contamination have become more apparent. The interactive effects of different hill shapes and distribution of in-season N fertilizer applications at various timings were evaluated in a 3-year potato (*Solanum tuberosum* L. cv. Russet Burbank) field experiment on a sandy soil in central Wisconsin. A split-plot design was used with hill shape (standard, shaped-plateau, or pointed) as the main plots and 202 kg N ha^{-1} divided into two, three, or four applications as the split plots. Broader, flatter hills provided tuber yield increases of 7 to 10 %, tuber size and grade improvements of 8 to 25 %, and increased tuber N uptake an average of 22 % in some years; however, post-emergence hilling operations negatively affected yield and tuber size and grade out in 1 of 2 years. Splitting the N into three in-season applications (emergence, early tuberization, and tuberization + 20 days) increased tuber yield by about 4 % or tuber size by 19 % in years where rain increased leaching potential on this sandy soil, but further splitting increased the proportion of small tubers that passed a 5.1-cm screen. This study confirmed that more blocky-shaped hills with only one hilling operation at emergence can significantly benefit potato yield and quality, and fertilizer N use efficiency on these sandy soils.

Keywords
Nitrogen uptake - Tuber greening - Specific gravity - Petiole nitrate

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9. A Multi-Year Survey of Stem-End Chip Defect in Chipping Potatoes (*Solanum Tuberosum* L.)

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Abstract
One of the most serious tuber quality concerns of US chip potato growers is stem-end chip defect, which is defined as a localized post-fry discoloration in and adjacent to the vasculature on the stem end portion of

potato chips. The severity and incidence of stem-end chip defect vary with growing location and variety, but quantitative data describing this are not available. A multi-year and location study was conducted to evaluate chipping potato varieties for tolerance to stem-end chip defect formation and to quantify defect severity and incidence regionally and temporally. It was observed that higher night temperature in July and August compared to the regional 30-year history was consistently associated with higher SECD severity. Average SECD severity was linearly correlated with incidence of chips having severe SECD. Chip color and tuber stem-end glucose content were significantly correlated with average SECD score across all treatments. Multiple tuber samplings from early growing season to mid post-harvest storage demonstrated that some varieties, such as Nicolet and Pike, had fewer stem-end chip defects than other varieties across years and locations. Stem-end chip defect was rarely observed prior to harvest, but was apparent at the time of harvest on multiple varieties depending on the year and location. Tuber stem-end sucrose and glucose prior to harvest were not indicators of defect development at harvest and out of storage, but pre-harvest chip color was significantly correlated with defect severity 10 weeks after preconditioning was finished.

Keywords
White potato - Stem-end chip defect - Chipping potato varieties - Potato chip quality - Average chip defect score - Severe chip defect incidence - Tuber sucrose and glucose concentration

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10. Relationship Between Plant Vascular Architecture and Within-Plant Distribution of '*Candidatus* Liberibacter solanacearum' in Potato

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Abstract
'*Candidatus* Liberibacter solanacearum' is an important pathogen of *Solanaceous* crops that causes zebra chip disease of potato. This pathogen is transmitted among plants by the potato psyllid *Bactericera cockerelli*. Within-plant spatial variability in Liberibacter infection impedes the ability to detect the bacterium before the onset of visible symptoms. The goal of our study was to test whether vascular architecture of potato explains the uneven distribution of Liberibacter after inoculation of leaves. The movement of rhodamine B among leaves was used to identify vascular connectivity among leaves. Three weeks after inoculating a single leaf with Liberibacter, the pathogen infected significantly more leaflets that had direct vascular connectivity with the inoculated leaf than leaflets with minimal connectivity. In a separate study, significantly more psyllids confined to whole leaves with direct vascular connectivity to a Liberibacter-infected leaf acquired the pathogen than did psyllids confined to leaves with indirect or partial connectivity to the infected leaf. Using fluorescence in situ hybridization, the pathogen was observed in the inner and outer phloem above and below the export leaf, respectively, corresponding with passive movement of Liberibacter in the phloem. Results of this study indicate that the distribution of Liberibacter in potato is at least partly limited by vascular architecture. This knowledge should improve the design of sampling methods to detect Liberibacter in asymptomatic plants.

Keywords
Liberibacter psyllaurous - Orthostichous - *Bactericera cockerelli* - *Solanum*

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11. The Influence of Ethephon Application Timing and Rate on Plant Growth, Yield, Tuber Size Distribution and Skin Color of Red LaSoda Potatoes

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Abstract
Optimizing the response of growth regulators depends in part on finding the most appropriate application rate and timing. Preliminary trials indicate that ethephon (2-chloroethylphosphonic acid) may be useful for improving potato (*Solanum tuberosum* L.) tuber appearance and skin color of red-skinned cultivars, but relatively little is known about optimum application practices. Two separate trials were conducted at the University of Idaho Parma Research and Extension Center to evaluate the effect of ethephon foliar application timing and rate on plant growth, tuber yield, size distribution, and skin color of the cultivar Red LaSoda. Skin color was rated visually and by colorimeter at harvest and periodically throughout storage at 4 °C. In 2011, ethephon application timing did not influence plant height, total yield, tuber size or skin color but did affect some tuber size classes. In contrast, all of these parameters were significantly influenced by application timing in 2012. The optimum application timing to influence skin color was a relatively narrow window during initial flower development, to 10 days after initial flowering (coinciding with tuber initiation). Increasing rates of ethephon significantly reduced plant height, increased foliar injury symptoms, and reduced average tuber size, but did not influence total yield in Red LaSoda. Higher ethephon rates resulted in significantly darker tuber skin (lower L* values) and increased red color (increased chroma and reduce hue angle values) when compared to the non-treated control. Evaluation of samples held in storage showed that differences in skin color ratings at harvest were maintained throughout the storage period. It is concluded that two foliar applications of ethephon at a rate between 292 and 438 ml ha^{-1}applied ten days apart, initiated at pre-bloom, will provide the optimum change in skin color and reduce average tuber size without reducing total yield.

Keywords
Growth regulators - Appearance - Tuber size distribution - Ethylene

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12. Infection Risk Potential of South American *Spongospora subterranea* f.sp. *subterranea* Root Gall and Tuber Lesion Inoculum on Potato (*Solanum tuberosum* ssp. *tuberosum*)

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Abstract
Spongospora subterranea f. sp. *subterranea* causes the potato diseases powdery scab on tubers and galls on roots, and occurs in most potato production areas worldwide. The pathogen was probably introduced to Europe from South America in the 16th century. Three different genotype clusters have been found worldwide: the genetically variable groups from South America (native), and, in contrast, the nearly clonal group outside South America (invasive). An inoculation experiment was carried out with the long-day potato host 'Agria' comparing three different native *Spongospora* resting spore inocula with an invasive one, to determine the infection risk potential on a widely grown potato subspecies. All inocula led to root infection. Invasive tuber lesion sporosori from 'Agria' produced the greatest amount of infection, whereas the tuber lesion inoculum from the Venezuelan *S. tuberosum* ssp. *tuberosum* host and the root gall inoculum from the Colombian *S. phureja* host caused the least infections. The inoculum genotypes corresponded to all of the three previously described groups. Most root galls showed the invasive group type, independent of the inoculum. These results suggest that the most successful invasive genotype is

still present in native pathogen populations and emphasize the need for continued quarantine vigilance to prevent new virulent recombinants of the pathogen.

Keywords
Powdery scab - Invasive species - Genetic variability - Global seed trade - Quarantine measures

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13. Soil Phosphorus Increases Dry Matter and Nutrient Accumulation and Allocation in Potato Cultivars

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Abstract
Understanding the influence of P in the pattern of production and partitioning of dry matter (DM) and nutrients to the tubers of potato cultivars is critical for development of rational fertilization strategies to optimize tuber yield. The objective of this study was to evaluate the effect of soil P availability (Low P: 10 mg dm^{-3} and High P: 111 mg dm^{-3}) in the leaf nutrients concentration, nutrients and DM accumulation and allocation to tubers of five potato cultivars (Agata, Asterix, Atlantic, Markies, and Mondial). The experiment was conducted under greenhouse conditions in pots containing 35 L of a Typic Acrortox soil. High P availability in the soil increased P concentrations in all plant organs, uptake of P and Cu, and DM production of all potato cultivars. The cultivars showed differences in the harvest index (HI) and uptake and allocation of N, K, Ca, Mg, S, Fe, Mn, and Zn to the tubers in response to P supply. Even with higher whole plant DM production and HI under high P availability in the soil, some of the cultivars did not increase the uptake and proportion allocated to the tubers of some nutrients as a response to the high P supply. This highly controlled greenhouse experiment was able to reveal cultivar differences in DM, HI, and nutrient accumulation influenced by P, a first step toward future studies exploiting these differences in the field production environment.

Keywords
Solanum tuberosum - Macronutrients - Micronutrients - Biomass partitioning - Nutrient partitioning

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14. Low-Cost Potato Tissue Culture with Microwave and Bleach Media Preparation and Sterilization

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Abstract
Labor and equipment costs are the main expenses in potato micropropagation. To determine if we could reduce costs associated with media sterilization, a disinfectant, sodium hypochlorite (NaOCl), in combination with microwave heating, were assayed as media sterilants. Incorporating a common 5 % NaOCl household beach at a concentration of 9 ppm (active chlorine) in media sterilized with an autoclave or microwave oven controlled microorganism growth and maintained plantlet growth performance. Non-sterile 473 ml (16 oz.) clear deli containers were selected as an inexpensive replacement for traditional culture vessels and were effectively sterilized with a 50 ppm (active chlorine) NaOCl solution. Reuse of the non-sterile clear deli containers and alternate media water sources were also tested but this decreased plantlet growth performance. Comparison of a controlled growth chamber and ambient laboratory conditions was also investigated. Microorganism growth was significantly less in a controlled growth chamber (5 %) as compared to uncontrolled conditions (26–36 %).

Keywords
Sodium hypochlorite - Clear deli container - Contamination - Micropropagation - Plantlets

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15. Propensity for Flying and Walking by the Colorado Potato Beetles Treated with Imidacloprid

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Abstract
The Colorado potato beetle, *Leptinotarsa decemlineata* (Say) is a very serious pest of potatoes which is highly mobile and capable of rapid evolution of resistance to chemical control. Insect movement, resulting in gene flow between resistant and susceptible populations, is considered to be an important factor affecting the development and spread of insecticide resistance. We investigated the movement of adult Colorado potato beetles by flight and by walking following the treatment with a sublethal dose of imidacloprid in the laboratory. Imidacloprid had a pronounced negative effect on beetle mobility. The proportion of beetles flying and walking, as well as the number and duration of performed flights, were significantly decreased for the treated beetles. Since local selection followed by long-distance dispersal have been reported to lead to serious area-wide problems with the insecticide-resistant Colorado potato beetle, long-term suppression of flight activity recorded in our study suggests that imidacloprid applications may reduce outflow of resistant alleles.

Keywords
Leptinotarsa decemlineata - Movement - Insecticide resistance - Sublethal effect

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16. Mechanical Transmission of Potato Virus Y (PVY) Through Seed Cutting and Plant Wounding

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Abstract
The transmission of PVY strains, PVY^{O}, $PVY^{N:O}$, and PVY^{NTN} via tuber cutting and plant wounding was investigated in PVY susceptible cultivars Shepody and Russet Norkotah. For the tuber cutting experiment, after one infected tuber was cut with a knife, four uninfected tubers were cut sequentially with the same knife without disinfecting it between the cuts. In the plant wounding experiments, wounds were induced in

the healthy and infected plants of Shepody by bouncing, brushing, hammering, squeezing, and Carborundum rubbing treatments. These treatments allowed exchange of sap between the healthy and infected plants. Results demonstrated that seed cutting did not transmit PVY, whereas plant wounding treatments caused varying levels of PVY transmission, depending on the wounding treatment. Plant bouncing was the least effective whereas hammering was the most effective.

Keywords
Shepody - Russet Norkotah - Strains - PVY^{O} - $PVY^{N:O}$ - PVY^{NTN} - ELISA - RT-PCR

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17. Rapid Cycling of Potato Tuber Generations by Overcoming Dormancy

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Abstract
Dormancy hinders progress in attempts to fast track potato tuber generations. In this study, we evaluated the ability of gibberellic acid (GA) to overcome dormancy in freshly harvested tubers of 11 potato cultivars in 2 years of field trials. Tubers were wounded and dipped in 0, 10, 100, and 1,000 ppm GA. Then they were planted in the field 5 days later. Vine length and stem number were measured throughout the season. Tubers were also harvested and weighed. Cultivars varied in their response to GA treatment. However, for all cultivars, wounding followed by treatment with 10 or 100 ppm effectively overcame dormancy. The 1,000 ppm treatment produced excessive vine growth and lower yield compared to the lower concentrations. Consequently, wounding of freshly harvested tubers, followed by a dip in 10 or 100 ppm GA is recommended to overcome tuber dormancy in programs interested in rapid cycling.

Keywords
Gibberellic acid - Tuber dormancy