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SUMMARY OF POTATO RESEARCH ACCOMPLISHMENTS
For 2002 – 2007

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Project Title:
Potato Variety Improvement Through Gene Transfer and Virological Studies

2007

A rapid and precise PCR test for identification of Potato virus Y necrotic strain "N". *(Dr. James Crosslin, 509-786-9253, jcrosslin@pars.ars.usda.gov):* Various strains of Potato virus Y (PVY) exist in nature. Some of these strains are called necrotic or "N" strains and can cause symptoms in potato tubers. Traditional tests such as ELISA have difficulty identifying all of the "N" strains. A rapid molecular-based test (coupled, one-tube, extractionless RT-PCR) was developed for quick detection and identification of "N" strains. This new test makes possible rapid and reliable identification of these strains and should be useful for certification agencies, regulatory personnel, and researchers.

Identification of potato psyllid as the causal organism for "Zebra Chip" disorder in potatoes. *(Dr. James Crosslin, 509-786-9253, jcrosslin@pars.ars.usda.gov):* A disorder of processing potatoes called "zebra chip" has recently been identified in potatoes grown in Texas, Nebraska, Mexico, and several other areas. The exact cause of the disorder has not been positively identified. Significant progress has been made by identifying potato psyllid (a sucking insect) as the causal organism for this disorder. This finding has allowed growers to target this insect for control and thereby greatly reduce the economic losses they have been suffering due to "zebra chip".

Discovery of Russian thistle (a common weed) as an alternate host for BLTVA. ***(Dr. James Crosslin, 509-786-9253, jcrosslin@pars.ars.usda.gov)*** The potato purple top phytoplasma, also called BLTVA, affects all cultivars of potatoes grown in the Columbia Basin. The phytoplasma has a wide host range and infects many other crop plants and weeds. The phytoplasma is transmitted by the beet leafhopper from weed hosts to potatoes. Although it was known that many wild mustard-type plants carried the phytoplasma, recent studies have led to the discovery of "wild" Russian thistle plants, a common weed in the area. Since the Russian thistle is also a preferred host of the beet leafhopper, we feel that finding the phytoplasma in this plant has implications for the epidemiology of purple top disease in the Columbia Basin.

Developing root-knot nematode resistant potato germplasm. ***(Dr. Charles Brown, 509-786-9252, cbrown@pars.ars.usda.gov):*** Columbia root-knot nematode is widespread in the Columbia Basin causing damage that is preventable only by fumigation. We have developed a line of potato that is resistant to all root-knot nematodes in the Pacific Northwest. It has limited root resistance but a strong and broadly active tuber resistance. It is also resistant to corky ringspot disease transmitted by the stubby root nematode. A grower can save up to 350 dollars per acre by not fumigating for these two pests, or 15 % of the cost of production. Growers could reduce fumigation costs in Washington by 20 million dollars. In addition, this would protect ground water from contamination by the fumigants metam sodium and 1, 3 dichloropropene.

Metabolic profiling of potato phytonutrients. ***(Dr. Duroy Navarre, 509-786-9261, rnavarre@pars.ars.usda.gov):*** Negative media coverage over the last few years has created an unjustified perception amongst some consumers that potato is not a nutritious vegetable. In actuality, as the most eaten vegetable in the United States, potato has tremendous potential to be developed as an important contributor of vitamins and phytonutrients to the diet. Germplasm mining can take advantage of potato's genetic diversity to enhance its phytonutrient content. Folate deficiency is a leading cause of birth defects and has numerous other negative consequences. We measured folate concentrations in more than 80 potato genotypes and found an over 3-fold range between high and low. We found that folate is stable or increases during potato cold storage, unlike the case with Vitamin C. We found differences in expression of specific folate metabolic genes among high and low germplasm. Phenolic compounds can have multiple health promoting effects. We found over a 10-fold range in total phenolics among genotypes, and the highest total phenolic potatoes in particular have substantial amounts that compare very favorably to other vegetables. We found one potato variety that had 30-fold higher flavonols than the lowest flavonol variety. We found that “baby potatoes” from all 3 varieties examined so far have substantially higher folate and phenolic concentrations than mature tubers. This work is showing that potatoes can have high amounts of health-promoting compounds and has the potential to create new marketing opportunties.

Importance of controlling hairy nightshade weeds to minimize the impact of root-knot nematode damage on potatoes. ***(Dr. Rick Boydston, 509-786-9267, boydston@pars.ars.usda.gov):*** Columbia root-knot nematode is a major pest of potato in the Pacific Northwest and is controlled by costly soil fumigation. Potato breeding lines have been developed with resistance to the predominant race 1 (CRKN-1) of Columbia root-knot nematode, but some potato lines had nematode damaged tubers in field trials. Nematode resistant potato breeding lines segregated in response to nematode damage on tubers only when grown in the presence of hairy nightshade in field trials. Some lines possessing root resistance were found to lack tuber resistance, which was only evident when grown in the presence of hairy nightshade, a host of the nematode. These findings demonstrate how weed hosts of root-knot nematodes may negate the positive impact of growing resistant potatoes that lack tuber resistance and the importance of weed control on managing plant parasitic nematode populations. Potato breeders can use this information to select for both root and tuber resistance in breeding materials.

Trace Gas Fluxes from an Irrigated Sandy Soil under Vegetable Cropping Systems. ***(Dr. Harold Collins, 509-768-9250, hcollins@pars.ars.usda.gov):*** The effect of N-fertilization, fertilizer type and cropping systems on N_2O emissions from agricultural soils under rain-fed agriculture has been widely reviewed in recent years. However, there is little information concerning trace gas fluxes from irrigated soils. This research was undertaken to determine trace gas emissions from irrigated cropping systems. Objectives were to 1) describe cropping season patterns of N_2O emissions and periods of peak losses following fertigation practices in a high-value irrigated potato rotation; 2) estimate season losses of N_2O and amount of fertilizer losses as N_2O; and 3) contrast field measured N_2O losses against predicted losses using IPCC methodology. Dr. Collins conducted and supervised a Post-doctorate in independent research to determine the effects of tillage on SOM and trace gas fluxes in irrigated production systems. The IPCC methodology for estimating direct N_2O emissions from fertilized agricultural soils assumes a N_2O emission factor of 1.25% ±1 of the fertilizer N applied. However emission from potato and corn fields were lower, where emissions from the 24 h and 48 h field studies without crops were higher, indicating that there is significant variability due to timing of sampling and rates of N fertilization. These data will refine estimates of trace gas emissions from irrigated croplands. Growers can now account for 1 to 7% of the N-fertilizer applied as a gaseous N_2O loss depending on the form of fertilizer applied.

2006

Diverse strains of Potato virus Y are widespread in certified potato seed lots produced in the US and Canada (Crosslin): Potato virus Y (PVY) occurs worldwide and reduces the yield and quality of infected potato crops. PVY occurs as various strains that differ in their effect on the crop, biological properties, and methods used for their detection and identification. The primary source of inoculum is the “seed” tuber used for planting. For this reason, certification agencies in the US and other countries monitor the occurrence of the virus in fields producing seed tubers and may refuse certification of the crop for use as seed if the virus incidence is above threshold values. In conjunction with researchers in Oregon, Idaho, and USDA-APHIS, Dr. Crosslin has determined that PVY is relatively common in certified potato seed lots produced in a number of states and Canadian provinces. Using serological, biological, and molecular techniques, Dr. Crosslin identified the PVY-O, PVY-N, and PVY-N:O strains of the virus in seed lot trials conducted in Washington and Oregon over a three year period. The PVY-N and PVY-N:O strains are considered regulated pathogens and their presence can preclude shipment of infected crops to some destinations. These findings document the threat posed to potato production by PVY and show that current measures to reduce the incidence of this virus in seed lots are inadequate.

Incorporation of Resistance to Columbia Root Knot Nematode in Potatoes (Brown): Potato Germplasm with combined root and tuber resistance to Columbia root-knot nematode. Columbia root-knot nematode is a serious pest of potato in the Pacific Northwest causing the most problem in the Columbia Basin. . This is too costly to the grower and also provides a pesticide contaminant to ground water. There is no ressistance to this nematode in commercial varieties. Race variation and emergence of biovars of the nematode makes the resistance already undergoing incorporation unstable. At USDA/ARS Prosser, a second component of resistance was discovered amongst breeding materials with genes from Mexican wild species of potato. Tubers as well as roots prevent the normal lifecycle of the nematode. Even if a nematode biovar overcomes the root resistance or weed root systems provide abundant nematodes in the soil, the tuber resistance mechanism will prevent passage of the nematodes. Annually 20 million dollars is spent on soil fumigants to prevent 40 million dollars of damage from this nematode. The incorporation of resistance will greatly reduce the cost of production and subject the grower to a lessened risk of nematode damage. Potato production in the Pacific Northwest is competing against a global market and cost reduction through enhanced host resistance to pests is essential to keep the industry viable in the future.

Analysis of phytochemicals in potato tubers (Navarre): Problem: Negative media coverage over the last few years as created an unjustified perception amongst some consumers that potato is not a nutritious vegetable. This has negatively impacted sales. In actuality, as the most eaten vegetable in the United States, potato has tremendous potential to be developed as an important contributor of vitamins and phytonutrients to the diet. Dr. Navarre's lab has developed innovative, high-throughput HPLC-MS methods that can quantitate over 60 compounds in a single short analysis and developed a microbial assay to measure folic acid. This metabolomic method creates new possibilities for both molecular and traditional breeding approaches to variety development. Some uses for which this technology is being used include helping to develop an even more nutritious potato, determination of which compounds are important for superior taste, and development of potatoes with enhanced disease and pest resistance. Using germplasm mining, we have identified varieties with markedly higher amounts of desirable compounds. For example, we have observed ten-fold difference in flavonoid levels and a two-fold difference in folic acid amongst different varieties. This research can lead to increased profitability for the industry by creating nutritionally enhanced varieties that allow new marketing opportunities and by improving disease and pest resistance, thereby decreasing input costs and pesticide usage.

Prediction of Volunteer Potato Problems in Rotation Crops Based on Monitoring Winter Soil Temperatures (Boydston): Volunteer potato is a difficult weed to manage in potato production regions with mild winters and is a major source of late blight disease, leaf roll virus, and nematodes. No previous studies have reported the freezing behavior of potato tubers in soil. Potato tuber freezing behavior was determined in soil columns and in field trials. Potato tubers were killed or severely injured when soil temperatures surrounding the tuber reached -1.4 to -1.9 C in hydrated soil. Potato tubers in dry soil were able to supercool to -3 to -7 C without injury. In field trials, extensive tuber death occurred when soil temperatures reached -2.8 or lower at tuber depth. Knowledge of soil temperatures required to kill potato tubers allows the prediction of volunteer potato severity by monitoring winter soil temperatures at several depths. This allows growers to make earlier management decisions and provides greater flexibility and ability to manage volunteer potatoes and plan rotation crops accordingly.

Nitrogen Transformation from Mustard Cover Crop and Availability to Potatoes (Collins): Farmers in the Pacific Northwest are using cover crops such as white and brown mustards in rotation with potatoes because it reduces potential wind erosion and serves as a biocontrol method for a number of plant pathogens. In order to understand the efficiency of N availability to a subsequent potato crop it is important to quantify the fate of N contained in cover crop residues. Dr. Collins and team used a ^{15}N isotopic crop residue exchange technique to assess N cycling potential in the field. They showed that a mustard cover crop recovered 34 to 51% of the 50 lbs of ^{15}N fertilizer applied. Nearly, 30 % of the N in the cover crop was cycled and absorbed by the following potato crop. This research found that the mustard cover crop can contribute about 27 to 36 lbs N acre^{-1} towards the N requirement of a subsequent potato crop, saving farmers $14-18 acre^{-1} at current fertilizer prices.

2005

Management of pink rot of potatoes (Porter): Pink rot caused by *Phytophthora erythroseptica* has cost potato growers in southeastern Idaho millions of dollars due to yield lost and management practices, particularly since the pathogen has developed resistance to the fungicide metalaxyl which has been used to manage this pathogen since 1987. Dr. Porter identified fields where mefenoxam-resistant isolates have developed and identified that wheat and barley used in the crop rotation with potatoes are also hosts of the pink rot pathogen. Identifying fields with resistance isolates has changed the management practices of the potato growers on those fields to use an alternative fungicide that has resulted in increased efficacy in managing the pink rot pathogen. Identifying that wheat and barley were hosts of the pink rot organism has helped growers understand why pink rot has become such a devastating disease on potatoes due to the build up of inoculum in the soil. Growers are now trying to find alternative crops they can include in their crop rotation that is not a host of the pink rot organism in an attempt to reduce the severity of the disease on potatoes which is the number one cash crop they grow in the area.

Quantitative, real time PCR (qPCR) for detection of the potato purple top phytoplasma in plants and insects (Crosslin): The potato purple top disease is caused by an organism called the beet leafhopper transmitted virescence agent (BLTVA). This pathogen, a phytoplasma, has been responsible for recent outbreaks of purple top in the Columbia Basin of Washington and Oregon. Dr. Crosslin , in collaboration with Dr. Peter Thomas (retired), have recently shown that the beet leafhopper is the most important insect vector of the pathogen in this area. Reliable detection of the phytoplasma has traditionally relied upon nested polymerase chain reaction (PCR) assays. These tests are time-, labor-, and material-intensive. Dr. Crosslin, in cooperation with Dr. George Vandemark (alfalfa CRIS at this location) have developed a more rapid diagnostic procedure for detection of the phytoplasma in plants and insects. The method, called real time, quantitative PCR (qPCR) not only detects the pathogen, but can determine the actual quantity of the pathogens' DNA present in a test sample. The qPCR technique speeds up the diagnostic process and can be used to rapidly determine the percentage of infected insect vectors present in a potato growing region. This information will aid growers in making insect control decisions and thereby reduce the incidence of potato purple top disease and the associated losses in yield and quality of the potato crop.

Carotenoid pathway in potato - improving phytonutrient value (Brown): Improving the nutritional attributes of potato is an important breeding goal and understanding the genetics of increasing carotenoid content is necessary to achieve this. Dr. Brown's research showed a correlation between the presence of a particular allelic form of the gene encoding beta-carotene hydroxylase (Bch), an enzyme important in the plant carotenoid pathway, and higher concentration of total carotenoid in diploid potato mapping population. Using sequence data from Genbank for tomato Bch genes, a similar gene was cloned from a high carotenoid potato developed at USDA/ARS Prosser, by Dr. Walter De Jong of Cornell University. The allelic form associated with high carotenoid content was scored in a mapping population with highly variable carotenoid content at USDA/ARS, Prosser, WA. The carotenoids in potato are the same types that are found in the human retina and the development of high carotenoid potatoes may serve as a functional food method to partially treat macular degeneration and cataracts in the population susceptible to these age-related eye maladies in the U.S. population.

Analysis of phenolic compounds in potato tubers (Navarre): Plant phenolics are important for numerous reasons, including their role in plant disease resistance and because it is becoming increasingly clear that they are health promoting phytonutrients in the human diet. As a staple food, potatoes are a potentially rich source of dietary phenolics, however this trait has not really been fully exploited, nor has the potential of phenolics to improve potato disease resistance been well utilized. Dr. Navarre developed a phenolic profiling method that rapidly extracts and analyzes potatoes for numerous important compounds, and does in a single analysis what used to take 3 separate, laborious techniques to do, shortening analysis time by hours per sample. This rapid HPLC-MS method that simultaneously measures phenolic compounds, vitamin C, and glycoalkaloid content of potato tubers. Additionally, we used MS/MS analysis to identify the most abundant soluble and cell-bound phenolic compounds in potato tubers, providing substantial new information about the phenolic profile of potato flesh and skin. Development of this rapid analytical method removes a major limitation impeding potato phenolic research and enables new approaches to develop potatoes with enhanced nutritional properties and to identify compounds that contribute to pest or pathogen resistance. This knowledge can be used for "germplasm mining" thereby exploiting the tremendous genetic diversity of potato by identifying varieties with unusual compounds or markedly different quantities of key compounds. This research provides new opportunities to understand how environmental signals modulate phenolic biosynthesis.

Biological and chemical control of volunteer potatoes (Boydston): Volunteer potato is the most difficult to manage weed in potato production regions with mild winters and is a major source of late blight disease. No studies have examined the combined effect of herbicide-induced stress and arthropod herbivory to suppress this weed. Fluroxypyr dose response bioassays on volunteer potato were conducted in the presence and absence of Colorado potato beetle herbivory. Sixty-five to over 85% less herbicide was needed to reduce volunteer potato tuber production in the presence of beetle feeding compared to herbicide needed to reduce tuber production an equivalent amount in the absence of beetles. In field trials, a single application of mesotrione applied at the time of tuber initiation controlled potato top growth 96 to 98%. Herbivory of volunteer potato by Colorado potato beetle reduced tuber number 21% and tuber density 23% in the absence of herbicides, and further suppressed the weed in combination with herbicides. Growers using this technology could greatly increase volunteer potato control, reduce herbicide use, and indirectly decrease fungicide use for control of late blight disease in potato.

Reduced Tillage in a Three Year Potato Rotation (Collins): Tillage in most crop rotations is used to prepare seed-beds, control weeds and other pests, manage crop residues, reduce soil compaction, and incorporate fertilizer and pesticides. Adopting conservation tillage to reduce erosion, increase N use efficiency, and build organic matter would improve soil and environmental quality under irrigated farming systems. Dr. Collins developed efficient and sustainable management strategies utilizing cover crops, crop rotation and tillage to improve soil microbial populations and activities, carbon and nitrogen cycling, and control trace gas (CO_2, N_2O, CH_4) fluxes and erosion in irrigated cropping systems of the Pacific Northwest. A reduced tillage system for potato based rotations was developed using existing commercial field equipment with minor modifications. This strategy reduced the total number of passes in potato rotations from nine to six and soil disturbance operations from seven to four, including harvest, compared to those used in conventional tilled treatments. For sweet corn, field operations were reduced 50%. After two years of reduced tillage little change has been observed in microbial communities or activities. There were no significant differences found in potato, sweet corn or field corn yields between treatments receiving variable fertilizer rates or timing of fertilizer applications under center pivot irrigation. This indicates no yield loss for adopting reduced tillage practices in irrigated potato cropping systems. Populations of several plant pathogenic fungi trended to increase with higher fertilization rates under both tillage regimes. *Pythium* and *V. dahliae* populations within the conventional tilled potato treatment were greater than those in the reduced tillage treatment. Whereas, *Fusarium* populations were greater under reduced tillage for potato as well as the two corn treatments. Compared to conventional tilled systems that leave little crop residue on the soil surface, reduced tillage maximizes residue retention and requires fewer trips across the field thereby saving time, labor, capital, and energy.

Set Points for scheduling Potato irrigation using Capacitance probes (Alva): Potato production in the US Pacific Northwest (PNW) is mostly on low organic matter sandy soils. The annual rainfall in some parts of this production region is <150 mm, thus, effective irrigation management is the key for sustainable production and net returns of Potatoes which is grown in 3 to 4 years rotation. The cumulative irrigation through center pivot systems (during May through August) in the Columbia basin production region varies from 720 – 800 mm. Potential leaching of nitrate below the rootzone is a concern. Improved N management practices combined with careful irrigation scheduling are necessary to increase crop water and nutrient uptake efficiencies and minimize N losses to groundwater. The tuber yield of optimal marketable quality is highly dependent on the adequate available soil water content during the growing season. Real time, continuous monitoring of soil water content within and below the root zone is necessary to fine tune irrigation scheduling to minimize the leaching loses below the root zone, while supplying adequate water for the plants to minimize the effects of water stress, which can have significant negative effects on the tuber production and quality. Capacitance probes were used in Potato fields to monitor the soil water content at 15, 30, 60, 90, and 120 cm depth. Depth integrated soil water content (0-60 cm depth soil. i.e. predominant root zone) corresponding to field capacity soil water content (Full point), 30 percent depletion of the available soil water content (Refill point), and at wilting point (Driest point) provided the set points for basing the irrigation. Our studies using Ranger Russet cultivar grown in a Quincy fine sand the Full point and Refill point were calculated as 72 and 54 mm for the top 60 cm depth soil, which represents the rooting depth for potatoes. The aim of irrigation management during the potato growing season should be to maintain the soil water content in the 0-60 cm depth between the “Full point” and the “Refill point” to minimize excess soil water content, which could leach below the root zone, and avoid soil water stress effects on the crop.

2004

Systemic Acquired Resistance to Columbia Root-knot Nematode (Brown): The Columbia root-knot nematode (CRN) is an important pest in the Columbia Basin costing the industry 20 million dollars annually to control by application of soil fumigants. Resistance to race 1 has been incorporated into advanced materials, and a knowledge of the possibility that the mechanism of resistance to race 1 may function against race 2 is important to understand. Dr. Charles Brown's research found that the resistance factor RMC1(blb) acted against race 2 of CRN if the challenge from this race followed a strong challenge from race 1. This discovery of systemic acquired resistance across races reduced reproduction of the nematode on the root system and lowered the tuber damage from race 2. Documentation of systemic acquired resistance in the host-pest system involving a nematode is a rare phenomenon, hence this finding is a new discovery in this host-pest interaction. The proof that a generalized resistance is activated and is functional against a biovar of the pest that is able to escape detection when it is the sole challenge is a significant finding and will lead to further experiments to elucidate the genetic nature of the resistance response. The practical and economic consequences of this finding are outstanding. First although the RMC1(blb) gene does not protect plants against race 2 when it is the sole challenger, the resistance reaction initiated upon exposure to race 1 may be sufficiently strong to protect against race 2 in commercial production fields. This would permit the farmer to not use fumigant, depending on the composition of the races in his/her field. The option of not using fumigants will significantly decrease the non-point pollution of the water table by fumigants and will also save the grower about $200 per acre nearly 10% of the production cost.

Induced disease resistance in potatoes (Navarre): A better understanding of how potatoes resist disease will enable scientists to produce plants with natural disease resistance and reduce the reliance on exhaustive and costly pesticide control measures. One method to improve the disease resistance of existing cultivars is to use "Induced Resistance" (IR), a natural mechanism that gives disease resistance to many pathogens. It is becoming increasingly clear that potato differs from most other plants in key aspects of salicylic acid mediated defense signaling. Dr. Roy Navarre's research showed that unexpected expression of inducible potato defense genes in plants grown in field conditions. These plants had very low levels of defense gene expression in the first half of the growing season, but higher levels as the summer progressed. This was measured in uninduced healthy plants that had no obvious sign of disease.

Progress Towards Minimizing the Impact of Potato Yellows Disease in the Pacific Northwest (Thomas): A new yellows-type disease, previously identified as beet leafhopper-transmitted virescence agent (BLTVA) by P.E. Thomas, markedly decreased yields and quality of potatoes in the Columbia Basin in 2002. Growers were seeking advice during the subsequent winter and spring on potential methods to control the disease in the 2003 season. Dr. Peter Thomas described the major aspects of BLTVA epidemiology in the Columbia Basin, including the life cycles and overwintering sources of both the insect vector and pathogen, and he was able to pin-point timing of the insect migration flight that carries the pathogen from overwintering hosts to potato fields. Growers targeted insecticide applications to coincide with the spring beet leafhopper migration flight. This largely eliminated the disease in treated fields in 2004. Some fields we monitored that were produced to meet standards for an "Organic" label, were not treated, and these were again devastated by the disease.

Integrated Crop Simulation Model for Prediction of Plant Growth, Yield, and Fate and Transport of Nitrogen in Potato Rotation Cropping Systems (Alva): The potato crop simulation model Simpotato was integrated into the multi-year, multi-crop simulation model CropSystVB to improve overall model capabilities for the assessment of N dynamics in potato-based cropping systems. In the integrated model, CropSystVB simulates the soil-water-plant-atmosphere system for a crop rotation, as well as the water and nitrogen budgets. When the crop in the rotation is potato, Simpotato simulates potato growth and development and plant C an N balances. Model predictions showed that unaccounted N at the end of the crop growth varied from 102 to 170 kg/ha in the year 2001, and were much greater in the year 2002. Results demonstrated the use of model predictions to assess N transport and losses under different water and N management practices. This information is useful to optimize the rate and timing of N and water applications to support the maximum production, while minimizing the negative effects of N losses.

Integrated Control of Field Bindweed (Boydston): Field bindweed (*Convolvulus arvensis*) is an aggressive perennial weed that infests numerous annual and perennial crops throughout North America. Field bindweed infests approximately 10% of irrigated acres in the Columbia Basin. Control of field bindweed with herbicides is usually incomplete resulting in crop losses and perpetuating the problem in ensuing years. Dr. Rick Boydston conducted research by combining a bio-control agent, i.e. a population of gall forming mites, *Aceria malherbae* in Washington State that was originally native to the Mediterranean region, and chemical control. This research demonstrated that integrating mite feeding and herbicides reduced growth of field bindweed more than mites or herbicides alone with no apparent detrimental effect on mite populations. Combinations of the mite with sublethal herbicide doses suppressed field bindweed while reducing potential herbicide injury to crops and maintaining mite populations. Establishment of the mite and integrating mites with herbicides should allow growers to reduce herbicide rates while improving control of this troublesome weed.

Beneficial Effects of Brassica Cover Crops in a Potato Production System (Collins): Dr. Hal Collins determined the benefit of *Brassica* cover crops on soil microbial populations, their activities and N-cycling in potato production systems. Research showed that the recovery of fertilizer N applied to *Brassica* cover crops was 60%, with 25% available to the subsequent potato crop. The remaining N is incorporated into the soil organic matter. These studies showed that increased N-mineralization potentials resulting from the application of the cover crops results in ~ 10% of fertilizer N being sequestered into soil organic matter with a 15-20 kg N /ha annual taken up by the subsequent potato crop which would result in a $6-8/ha savings to growers at current fertilizer costs.

2003

Controlling Corky Ringspot Disease of Potato by Cultural Management (Boydston): Corky ringspot disease (CRS) of potato, caused by tobacco rattle virus (TRV) and vectored by stubby root nematode, causes brown necrotic tissue in potato tubers making tubers unmarketable. Soil fumigation, costing $200/acre, is currently the only method of control. We have demonstrated that growing rotation crops of weed-free alfalfa or Scotch spearmint, which are hosts of stubby root nematode, but not hosts of TRV, cleanses CRS from soil. Weed hosts of TRV and stubby root nematode were identified, that when present in the crop rotation, prevent the cleansing of TRV. Three common nightshade species were all excellent hosts of TRV and stubby root nematode and when present in alfalfa and Scotch spearmint, prevented the cleansing of CRS disease and nullified the positive effects of crop rotation. CRS is present in approximately 5% of the potato acreage of the Columbia Basin. Targeted control of known weed hosts of TRV in alfalfa or Scotch spearmint rotation crops will should allow growers to eliminate CRS from fields using crop rotation. Growers could utilize crop rotation to eliminate or lesson the need for costly soil fumigation, saving approximately $1.5 million dollars to the industry.

Preplant and In-season Nitrogen Management for Potatoes (Alva): Three years of field experiments were conducted using three potato cultivars in a Quincy fine sand (mixed, mesic Xeric Torripsamments) in the Columbia Basin region in the Pacific Northwest (PNW). The results have shown no significant difference in total tuber yield or tuber quality with application of either 336 or 448 kg/ha total N. In-season fertigations of N in 5 or 10 applications, three weeks after the seedling emergence did not have significant affects on the tuber yield or quality. Tuber specific gravity was also not significantly influenced by the different pre-plant N rates, total N rates, or frequencies of in-season fertigations in all three years. Since in-season N application through the irrigation system is a convenient method of fertilizer delivery without an added cost of application, this study supports application of most of the N by fertigation during in-season with only about 56 kg/ha N as pre-plant is optimal for maximum tuber yield.

BLTVA as the Cause of Potato Yellow Disease (Thomas): An unknown yellows disease devastated much of the 2002 potato crop in the Columbia Basin. Nearly all plants in some fields were infected while neighboring, comparable fields were relatively disease free. There was much confusion as to the cause of the disease, and several laboratories failed in attempts to diagnose it. We identified the cause of the disease. We showed that beet leafhopper-transmitted viresence agent (BLTVA) was consistently associated with symptomatic plants by using a more sensitive type of PCR (polymerase chain reaction) assay and by conducting the assay with plant tissue from greenhouse-produced cuttings of field-infected plants. We also transmitted the disease of potato to tomato where it produced the tomato big bud disease that is highly diagnostic for BLTVA infection of tomato. In addition, our investigation of diseased vs. relatively disease-free potato fields provided anecdotal evidence that certain pesticide treatments applied during early stages of the beet leafhopper flight provided excellent control of the disease. This information has provided focus for an extensive, industry-sponsored research effort to control the unknown yellows disease. It has also provided insight for pest management recommendations (given by Dr. Alan Schriber, Agriculture Development Group, Pasco, WA) for potato growers this season.

A New Technique of Measuring Antioxidant Capacity of Carotenoids in Potatoes (Brown): Potatoes contain carotenoids, but knowledge concerning concentrations, genetic variability of concentrations and antioxidant and the relevance to breeding new varieties is lacking. A new technique for measuring antioxidant capacity for extracts of carotenoids from potato was developed. Carotenoid content and antioxidants were measured in established potato varieties, newly developed high carotenoid potato lines, and native cultivars obtained through collaboration with the international Potato center. Potatoes that had a forty-fold higher carotenoid content were discovered and the higher antioxidant content documented. Carotenoids are implicated in the prevention of heart disease and certain cancers. Development of high carotenoid varieties will give potato a new role in the nutritional health of the American population. High carotenoid content potatoes may be used to develop new products for the processed potato industry, providing opportunities to increase potato consumption thereby resuscitating declining sales of processed potato products.

The data generated during the course of this study is new to science. Higher levels of carotenoids than previously know have been revealed. The first measurements of antioxidant levels of carotenoids derived from potato were determined during this study.

Induced Disease Resistance in Potatoes (Navarre): Potato is highly susceptible to disease, which necessitates an exhaustive and costly pesticide control regime. One method to improve the disease resistance of existing cultivars is to use "Induced Resistance" (IR), a natural mechanism that gives disease resistance to many pathogens. In lab research worldwide, IR has had good success against pathogens; however, widespread use of this technology in the field has lagged. Optimal use of IR will likely require customization for each crop, and we are trying to adapt and exploit IR for use in potato. We have found key differences in induced resistance in potato, relative to other crops. Unlike most plants, potato has constitutive expression of a set of defense proteins (PR proteins), normally not turned on until after pathogen attack. Plants make salicylic acid, which plays a critical role in regulating many types of plant disease resistance genes, including the PR proteins. Unlike almost all other crops, potato has very high constitutive levels of SA, and this is the likely reason for the constitutive PR expression. Tubers also have very high levels of salicylates and this could be a very desirable and distinguishing nutritional characteristic for potato because as several recent high profile studies have shown aspirin (a salicylate) has many health benefits. We've also found that potato has a dramatically different sensitivity from other plants to some of the compounds that activate IR and more readily activates programmed cell death. These findings will help determine whether IR can be a viable technology in potato, and also yield basic insights into potato resistance mechanisms, useful for the generation of new varieties with enhanced disease resistance.

Alternative Environmentally Friendly Techniques for Nematode Control in Potatoes (Collins): The use of commercial soil fumigants (Kpam/Vapam) represents a significant economic cost ($200-300/acre) to potato production in the PNW, as well as, other potato producing regions of the US. With continued use of these compounds the potential for bio-degradation and loss of efficacy in controlling plant-parasitic nematodes are of concern. Several soils in the Columbia Basin of Eastern Washington have been recently identified with lowered Kpam/Vapam efficacy. Enhanced bio-degradation of these compounds is suspected. Alternative chemistry's are needed to offset the loss in efficacy. New generations of bio-nematicides are being studied for the control of plant-parasitic nematodes. Several of these compounds show promise for controlling plant-parasitic nematodes and have been found to have minimal effects on non-target soil microbial populations or functions. The use of alternative nematode control measures in conjunction with conventional methods of control in potato production systems will preserve the efficacy of several important soil fumigants. The use of bio-nematicides should also decrease the selection for microbial populations suspected of enhanced bio-degradation.

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Durability of high levels of resistance against potato late blight and description of sources of resistance in Mexican cultivars (Niklaus Grunwald): The Mexican national potato program has produced several cultivars with high levels of field resistance. We evaluated durability of resistance to potato late blight of a selection of 12 such cultivars using data from 1960 to the present. Data were extracted from the field notebooks located in the archives of the Mexican National Potato Program in the John S. Niederhauser Library in Toluca, Mexico. There was a trend to indicate that field resistances to potato late blight of Mexican cultivars released between 1965-1999 were durable. At least two of the cultivars, namely Sangema and Tollocan, have been grown on at least 4-5% of the potato acreage and over long periods of time without decay in levels of field resistance. Pedigrees of the 12 cultivars indicate that most of the field resistance was introgressed from *Solanum demissum*. Field resistance might also be derived from commonly grown land-race cultivars such as “Amarilla de Puebla” and “Leona.” These have been grown in Mexico since about the 1780’s. They have the appearance of *S. andigena*-derived material but their genetic background is unknown. All cultivars currently grown in the US have no resistance to potato late blight. Our work shows that (1) sources of horizontal resistance against potato late blight are available in Mexican cultivars, and (2) that this resistance is durable over many years. Our research identified a source of durable and high field resistance that can be introgressed into US germplasm for managing potato late blight.

Potatoes high in phytonutrients with increased health benefits (Charles Brown): Potatoes are known to be a good source of vitamin C, fiber, high quality protein in small amounts, and complex carbohydrates. They also contain flavonoids and carotenoids that are usually present at low levels. It would be possible to develop new products and markets if these compounds, commonly regarded as phytonutrients, were increased and exploited. We developed potatoes that have higher levels of these compounds and also much higher antioxidant values. Potatoes with high levels of anthocyanins in the flesh contain from 6 to 34 mg per 100 grams fresh weight. The antioxidant values are two to three times higher than white flesh potato putting them in the category of Brussels sprouts. We have developed potatoes that combined carotenoids and anthocyanins, a new combination with great potential in the processed food market. In processing tests we have found potatoes that combine red and yellow colors in startling starbursts of color that are very bright and appealing. This has created a market niche for potatoes enriched in phytonutrients for the fresh market and processing industry. Kettle Foods, an Oregon potato chip producer has developed a new market line, Garden Chips® based on one of our red fleshed breeding products, PA97B35-1. This has been given the working trade name of "Mountain Ridge Red." These types of potatoes have generated a flurry of interest that continues unabated. Breeding clones have been sent upon request to several breeders, and two big processors (Lamb Weston, H. J. Heinz) are starting product development programs. Sets of six promising clones have been sent to seed growers in Idaho, Maine and Oregon.

Critical Aspects in The Epidemiology of Major Potato Virus (P.E. Thomas): New questions regarding the epidemiology of potato viruses have arisen based on the fact that new strains of potato virus Y (PVY) have arisen in Western United States that cause necrosis in tubers. These viruses not only eliminate affected tubers from local markets, but may exclude all fresh potatoes grown in the region from international markets. The approach toward controlling these and other potato viruses is heavily dependent on critical aspects of their epidemiologies. If these viruses find suitable alternate hosts in the environment, they will become endemic, and their elimination is virtually impossible. Control must be directed toward the prevention of dissemination in the environment. Alternatively, if they depend entirely vegetative propagation in potato, elimination of the viruses is theoretically possible by eliminating them in seed sources. Our work indicates that strains of PVY, potato virus A (PVA) potato virus S (PVS), potato latent virus (PLV) potato virus M (PVM), and potato leafroll virus (PLRV) do not survive winter in alternate hosts in the Columbia Basin. None of these viruses were found infecting overwintering weeds in the vicinities of 35 potato fields that had been identified with high incidence levels of PVY and PLRV in the previous season. Furthermore, PVA, PVY, PVM, PVS or PLV did not infect any potato plants grown in plots over a 3-year period in a region of the Yakima Valley that was once an important potato production area but is now well separated from existing potato fields. While, we could not identify an overwintering weed host for any of these viruses, all were found among three predominate summer annual potato weeds: Solanum sarachoides, Solanum trifolium, and Solanum niger. These weeds are all excellent hosts of the major insect vector of potato viruses, the green peach aphid, Myzus persicae. With the exception that S. niger was previously but incorrectly reported as a host of PLRV, none of these weeds were known to host any of the potato viruses studied here. This work represents the first identification of natural alternate hosts for PVM and PVS. The potential importance of these weeds is illustrated in our discovery that high levels of resistance to PLRV can overcome when S. sarrachoides is present in the field. We demonstrated, both in replicated field plots, and in commercial fields that populations of the green peach aphid decline precipitously when infected with the green peach aphid virus that we recently discovered.

Mechanism of salicylic acid (SA) induced regulation of resistance to plant diseases (Roy Navarre): Salicylic acid (SA) plays a critical role in plants in regulating disease resistance to many pathogens. Many different types of plants, including potato, become hypersusceptible to a range of pathogens in the absence of a functional salicylic acid signal transduction system. Despite its prominent role in defense, the mechanism of SA resistance is not understood. We identified several proteins in tobacco that specifically bind SA and purified one of these SA binding protein (SABP2) from chloroplasts. This protein was then identified as carbonic anhydrase (CA). Evidence strongly suggests this CA has an antioxidative role separate from its normal enzymatic function. Gene silencing experiments in which CA is silenced support a role for CA in R-gene mediated resistance. Thus, CA emerges as an SA effector protein and one possible mechanism by which SA regulates disease resistance in plants.

Crop Residue Decomposition and Nitrogen Mineralization in Sandy Soils under an Irrigated Potato Rotation (Ashok Alva): Transformation of organic nitrogen (N) from both soil organic matter and from crop residues into inorganic forms is an important process which determines the pool of available N for the subsequent crop. The decomposition of crop residue and the mineralization of nitrogen (n) provides a source of plant available N to the next crop. Using an in-situ column incubation technique, we determined the N mineralized during January through September 2000 from corn, wheat, and potato crop residues. The dry weight of the crop residue in January soil samples, taken at the top 30 cm depth, ranged from 8.4 for potato to 26.5 Mg ha^{-1} corn, but decreased to 4.6 for potato and 12.7 Mg ha^{-1} for corn in March. Total N content in the crop residue was used to estimate potentially mineralizable N (PMN) at the time of sampling. The PMN in the top 30 cm soil depth, on the basis of residues sampled in January, were 398, 378, and 121 kg ha^{-1} for the corn, wheat, and potato crop residues, respectively, but decreased to 189, 114, 68 kg ha^{-1}, respectively, in March samples. Cumulative N mineralized in the top 30 cm depth of soil during January through September was 172, 128, and 72 kg ha^{-1} for corn, wheat, and potato residues, respectively. Cumulative N mineralized during January through May accounted for 53 percent of the total N mineralized from January through September. The fate of the mineralized N early in the cropping season is uncertain, since this period represents minimal N uptake by crops.

Soil Microbial responses to soil fumigation and cover crops in potato production systems (Harold P. Collins): The Columbia Basin of Eastern Washington provides ideal conditions for high potato yields of up to 90 Mg ha^{-1}. In the Basin, commercial soil fumigants such as metam-sodium are very effective for the control of soil borne pathogens, weeds, and nematodes that reduce crop yield and quality. Soil fumigation can exceed $250/ acre. Soil fumigation has been assumed to have minor impacts on the general soil microbial community. However, few published data are available that adequately describe changes in microbial populations. The use of cover crops may serve as an alternative to fumigation as well as mitigating losses to soil and environmental quality. Benefits of cover crops in annual production systems include decreasing soil erosion, sequestering excess soil nitrogen, replenishing soil organic matter reserves, suppressing weeds and nematodes, increasing the size and activity of the soil micro-flora, as well as enhancing microbial populations antagonistic to pathogenic organisms. Various *Brassica spp.* and other cover crop systems have been evaluated in the PNW for their effects on individual crops, but research evaluating the impact of various cover crops and soil fumigation on microbial populations and carbon and nitrogen dynamics in a total cropping system have not been conducted. In the initial year of this project (CY 2000-2001) we established cover crop field trials at the USDA-ARS field site near Paterson, WA. In addition we sampled and analyzed microbial characteristics of a commercial potato production field incorporating fumigation or mustard cover crops in rotation. In early September, 2001 we also established a large scale ^{15}N field study to measure the dynamics of mustard residue N, partitioning of N among various soil pools and incorporation into the succeeding potato crop. Results from these field studies showed that fumigation significantly reduced fungal populations but had only minor effects on bacterial populations with no significant loss in microbial mediated processes.