Multistate Research Project Summary

Project Number:	W2008
Title:	Biology and Management of Iris yellow spot virus (IYSV), Other Diseases, and Thrips in Onions (from W1008)
Duration:	October 2012 to September 30, 2017
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Onion (Allium cepa) is an economically important crop in the U.S., generating over 900 million dollars annually in farm receipts from 2005 to 2010. U.S. onion production area ranges from 60,000 to 70,000 hectares annually, with over 80% of the summer production (50,000 hectares) in the western states (NASS, 2010). Worldwide, 53 million metric tons of onion bulbs are harvested annually from nearly 3 million hectares. A significant portion of the U.S. and world supply of onion seed is produced in the western U.S., primarily in the Pacific Northwest (PNW).

Onion thrips is the most serious pest of onion worldwide and it has become an even greater threat to onion as a vector of IYSV (Gent et al. 2004). Although onion thrips is the most common thrips pest of onion in the U.S., the western flower thrips (Frankliniella occidentalis) and the tobacco thrips (Frankliniella fusca) are also major pests of onion in parts of the western U.S. and southeastern U.S., respectively (Cranshaw, 2008). Infestations of thrips in onion fields are managed primarily with frequent insecticide applications (Schwartz and Bartolo, 1995; Mahaffey and Cranshaw, 2010; Nault and Shelton, 2010). In spite of chemical-intensive management, thrips continue to cause significant and increasing damage to onion because of widespread insecticide resistance to older insecticides that are still widely used by the industry (Al-dosari, 1995; Shelton et al., 2003 and 2006; MacIntyre-Allen et al., 2005). Therefore, thrips are a primary constraint to continued productive and sustainable onion production. Newer chemistries for thrips control continue to be released and incorporated into Integrated Pest Management (IPM) strategies.

In addition to feeding injury caused by thrips, Iris yellow spot virus (IYSV), which is vectored by onion thrips, has emerged as a devastating new disease of onion. It causes widespread disease of onion and other Allium species and has been observed throughout the U.S. in bulb onion, chive, leek and garlic crops in Arizona, California, Colorado, Georgia, Hawaii, Idaho, Michigan, Nevada, New Mexico, New York, Oregon, Pennsylvania, Texas, Utah and Washington (Bag et al., 2009c; Creamer et al., 2004; Crowe and Pappu, 2005; du Toit et al., 2004; Gent et al., 2007; Hausbeck, personal communication; Hoepting et al., 2007; Miller et al., 2006; Hoepting, personal communication; Moyer, personal communication; Pappu and Matheron, 2008; Poole et al., 2007; Schwartz et al., 2002 and 2007; Sether et al., 2010); as well as recently in neighboring onion-producing countries of Canada (Hoepting et al., 2008) and Mexico (Schwartz, personal communication).

Management of IYSV is challenging. Current management strategies include selection of cultivars less susceptible to the disease and/or the vector (du Toit and Pelter, 2005), increased and uniform plant population (Gent et al., 2004), selection of transplants free of IYSV and thrips (Gent et al., 2006), elimination of volunteer onions from previous crops and weeds during current cropping season (Gent et al., 2006; Schwartz et al., 2004), and separation of onion bulb and seed crops to break the green-bridge reservoirs of the thrips vector and the virus (Gent et al., 2006). Many growers also have implemented intensive thrips insecticide programs, which may provide some suppression of the disease (Schwartz et al., 2009).

Over the past decade, the U.S. onion industry has suffered millions of dollars in losses from IYSV. For example, the 2003 Colorado IYSV epidemic is estimated to have cost growers $2.5 to $5.0 million in farm receipts alone (Schwartz and Gent, unpublished). During 2004, outbreaks of IYSV seriously reduced yields of bulb onions as well as onion seed crops in Washington and Oregon. Some seed fields had 7 to 20% infected plants, in which the flower stalks (scapes) could not be harvested. One seed field in Washington was completely abandoned because the male parent was decimated by IYSV and thrips within two months of planting, at an estimated loss to the grower of $100,000 (du Toit, personal communication).

In spite of advances made in management of IYSV and thrips during the past 5 years the projected economic impacts of IYSV and thrips in the U.S. could reach 60 million dollars (10 percent loss) to 90 million dollars (15 percent loss). The use of 3 to 5 additional sprays for thrips control on 48,500 hectares of Allium crops per year adds 7.5 to 12.5 million dollars and uncalculatable environmental costs (Schwartz, unpublished). The rapid and international spread of this disease emphasizes the need to continue to develop economical and effective IPM strategies.

The initial version of this multi-state project (W1008) emphasized research on IYSV and onion thrips. At the time of the project initiation, IYSV was a newly recognized disease of onion, primarily in Western U.S. onion producing areas. Partly, as a result of the research supported by that project and the bringing together of scientists concerned with the horticultural, entomological and pathological aspects of onion production, our understanding of IYSV and its vectors has increased greatly. At the same time, these scientists have recognized that other disease problems, particularly those caused by several bacterial pathogens, are responsible for substantial losses in onions. Bacterial diseases of onion are recalcitrant. That is, materials and techniques for control or management of bacterial diseases are sorely lacking or are of questionable efficacy against bacterial pathogens. Thus, much greater understanding of the pathogens and the diseases they cause is needed in addition to effective means for reducing disease losses from them. The proposed W2008 project will continue to focus attention on IYSV and thrips. However, it also addresses the concerns expressed by the onion industry for the substantial losses to onions in the field and storage caused by bacterial and fungal pathogens.

More than 20 different bacterial and fungal pathogens cause onion losses under field and storage conditions. Each of these diseases can cause up to 50% crop loss, and stakeholders have requested IPM assistance from projects including the W1008. A total loss can be incurred if affected commercial onion loads are refused by buyers and have to be dumped (Schwartz and Mohan, 2008). The most important fungal diseases include purple blotch (Alternaria porri), downy mildew (Peronospora destructor), black mold (Aspergillis niger), Botrytis leaf blight/blast and neck rot (Botrytis species). The most common bacterial diseases are sour skin (Burkholderia cepacia), slippery skin (Burkholderia gladioli pv. alliicola), center rot (Pantoea ananatis and P. agglomerans), leaf streak (Pseudomonas viridiflava), soft rot (Pectobacterium carotovorum and Dickeya sp.) and Enterobacter bulb decay (Enterobacter cloacae). Many of these pathogens are important throughout the onion producing areas of the United States and the world. Other diseases, such as powdery mildew (Leveillula taurica) and white rot (Sclerotium cepivorum) are important in localized areas.

The exact extent of onion losses from bacterial and fungal pathogens in storage is unknown. However, Ceponis et al. (1986) summarized disorders found in onion shipments in the New York onion market from 1972-1984, and found disorders in >80% of the inspected shipments. Of 9,617 inspections of dry onion shipments, approximately 65% had >2% incidence of storage rot, which translates to a 100% loss as a result of non-compliance with the U.S. # 1 limit for rots for each infected lot. Empirical evidence and reports from onion stakeholders in the primary states of onion production indicate that growers and packers often suffer losses of 10% to 40% to storage rot pathogens. The losses from bacterial diseases appear to have increased over the past decade for reasons that are unclear. The onion industry clearly needs new management strategies to control these diseases.

The overall objectives of this project have been discussed in previous Allium, NARC and W1008 meetings by the participants in this regional project, and are strongly supported by the National Onion Association (NOA) (see attachment). The proposed collaboration, interaction and cooperation of the nations onion and other Allium researchers, extension educators and industry representatives will result in new management strategies that will reduce losses from diseases and thrips and sustain the nations onion industry.

Related, Current and Previous Work

A CRIS search was completed and although there are nine other multi-state projects that include onions as one of the crops being studied (see attachment), the proposed work relates to production and marketing perspectives rather than detailed breeding and pathology. Thus, there is no duplication of efforts.

Onion thrips and IYSV management resistant cultivars

The most promising and sustainable means for long-term thrips and IYSV management is cultivars with resistance or tolerance to thrips injury and IYSV. Entries have been evaluated in germplasm nurseries during 2007-2011 in Colorado, New Mexico, Oregon, New York, and Washington. Several promising entries have been identified (Boateng et al., 2010; Cramer, 2010a and 2010b). Recently, research has shown that cultivars that have yellow-green leaf color (correlated with low levels of cuticular wax on leaves) also had lower densities of thrips and less feeding damage compared with cultivars that had blue-green leaf color (higher levels of cuticular wax on leaves) (Shock et al., 2008; Diaz-Montano et al., 2010). Mechanisms of resistance in these cultivars to thrips appear to be a combination of antixenosis (non-preference) and antibiosis. Entries that may be genetic sources of thrips resistance have been identified, and breeding programs are currently attempting to incorporate these beneficial traits into commercial cultivars. Five plant introduction lines were selected as candidates for the translational genomics study (USDA-SCRI Project 2008-04804). Since the inception of W1008, growers have been encouraged by the progress in identifying onion varieties and breeding lines that are less preferred by thrips and affected by IYSV. Onion breeding efforts in the U.S. must continue to focus on developing IYSV and thrips-resistant cultivars. Until onion cultivars highly-resistant to thrips and IYSV become commercially available, more effort is needed to evaluate existing cultivars for tolerance to thrips and IYSV in conjunction with the use of selective insecticides and lower levels of nitrogen.

Onion thrips management - insecticides

Onion growers in the U.S. continue to rely almost exclusively on insecticides for thrips management. While insecticides are excellent management tools, frequent use of the same class of chemistry can select for resistance and cause control failures (Al-dosari, 1995; MacIntyre-Allen et al., 2005; Shelton et al., 2003 and 2006). Prior to 2005, very few insecticides provided high levels of thrips control reliably. Onion growers were in dire straits.

In 2005, Carzol was identified as providing excellent control of thrips and in 2006, the EPA granted multiple Section 18 Emergency Use exemptions for Carzol to control thrips on onions in most onion-growing states. Thrips control began to improve. Since then, other insecticides were identified as providing a high and consistent level of control including Agri-Mek, Spintor/Entrust, Radiant, Movento and the active ingredient, cyantraniliprole (Nault and Hessney, 2006, 2008a, 2008b, 2010, 2011a and 2011b). Currently, only

Agri-Mek, Movento and Entrust have federal labels for use on onion. Movento has received Section 18 Emergency Use exemptions in many states over the past 3 years. Preservation of these new insecticides for thrips control is extremely important for the U.S. onion industry. Therefore, insecticides should be used in accordance with IPM practices with an emphasis on insecticide resistance management principles. Minimizing the use of insecticides and improving their performance when applied are two of the most important insecticide resistance management principles.

Insecticide use can be minimized by timing sprays using action thresholds. Recently, Nault and Shelton (2010) found that action thresholds for thrips on onion should be adjusted according to the effectiveness of individual insecticides. Higher thresholds (e.g., 3 thrips larvae/leaf) can be used effectively for the best products (e.g., Radiant), while more conservative thresholds (e.g., 1 thrips larva/leaf) should be used for other products (e.g., Agri-Mek, Lannate and Movento) (Nault and Shelton, 2010; Nault, unpublished). Timing insecticide sprays for thrips control using action thresholds reduced the number of applications relative to a calendar-based spray program (Nault, unpublished). An additional benefit from reducing insecticide use and using newer, more selective insecticides is that natural predators may be more likely to help control thrips, at least at the beginning of the season (Cranshaw, 2006; Mahaffey and Cranshaw, 2010).

Individual insecticides should be used sparingly in each field each year. Ideally, no product would be used more than twice in a field and used consecutively (7 to 10 days apart) in a sequence to minimize the likelihood of exposing multiple generations of thrips. The risk of insecticide resistance development is likely to increase as successive insect generations are exposed to the same insecticide. An example of an insecticide sequence recommended for thrips control is to start with Movento and then follow with Agri-Mek, Lannate LV and finish with Radiant SC. The four products are not always needed. Research has shown that the sequence example above will provide season-long control of thrips (Nault, unpublished). In some cases, the order in which insecticides are placed in the sequence affected the level of season-long control with superior control achieved when the first product in the sequence was Movento (Nault, unpublished). To date, there is no evidence that insecticide sequences have mitigated resistance development in thrips populations. Yet, no control failures have been reported either.

Performance of new insecticides could be compromised when tank mixed with other pesticides. For example, Movento and Agri-Mek did not consistently work as well against thrips when tank mixed with a fungicide (Chloronil) that contained a spreader sticker (Nault et al., 2010). The concern is that the spreader sticker is interfering with the penetrant used to assist penetration of the insecticide into onion leaves. Recent research showed that tank mixing Movento and Agri-Mek with fungicides other than Chloronil did not reduce thrips control. Thus, either avoiding tank mixes with Chloronil or using a high rate of penetrating surfactant may overcome the problem (Nault et al., unpublished).

Onion thrips management cultural practices

Reliance on insecticides alone to control thrips in onions is not a sustainable long-term management strategy. Alternative thrips management strategies were examined, but do not seem to be effective and can be impractical and non-economical for typical large-scale commercial onion production. An example is applying straw mulch to the soil surface to delay the arrival of onion thrips and to provide some level of season-long suppression (Jensen et al., 2003; Larentzaki et al., 2008; Schwartz et al., 2010). Straw and labor to distribute the straw may be cost prohibitive. Other tactics are needed that are practical and economical.

Reducing the amount of nitrogen fertilization applied to the onion crop reduces thrips populations (Hsu et al., 2011). In New York, preliminary analyses of one field confirmed the results found in an earlier experiment; plots receiving lower amounts of N fertilizer had significantly fewer larval onion thrips compared with plots that received higher rates of N fertilizer. This may be due to possible negative effects that lower nitrogen levels in plant tissue could have on thrips colonization, reproduction, survival or emigration behaviors. Future analyses will estimate whether reductions in larval populations can reduce the number or timing of insecticide applications. Bulb weights did not differ significantly between plots receiving 74 or 125 lbs N/ac, but there was a higher number of bulbs > 2 inches in diameter in the highest N treatments (Hsu et al., 2010).

Kaolin can increase UV reflectance, which was shown to repel T. tabaci (Larentzaki et al., 2008) and Frankliniella thrips. Recently, field trials were conducted to determine if kaolin could reduce thrips damage in onion in the southeastern U.S., where tobacco thrips F. fusca and onion thrips are the most common species. Significantly more F. fusca, were found on untreated onions. Also, the end of season evaluation of feeding damage showed kaolin treated plants had significantly less damage than did untreated plants and had lower incidence of purple blotch. In the absence of rainfall, kaolin tended to persist on onion foliage, with no decrease in residue from 1 to 5 days after treatment.

Understanding Iris yellow spot virus (IYSV)

The rapid and international spread of IYSV emphasizes the need to continue to understand this disease and to develop effective IPM strategies. Seed transmission does not appear to be epidemiologically important in disease development (Mohan and Moyer, unpublished). Abad et al. (2003) reported that two genetically distinct populations of IYSV strains exist in onion in the western U.S. A third subgroup of strains infecting chive may constitute a new distinct tospovirus. A new strain of onion thrips that more efficiently acquires or transmits IYSV or a more virulent IYSV strain may have been introduced into the western U.S. In Georgia, Nischwitz et al. (2007a) demonstrated that another separate group of IYSV strains were introduced into Georgia from imported onion bulbs from Peru. These studies demonstrate that N gene diversity may reflect host or ecological niche specialization. Genetic diversity studies of IYSV isolates from different parts of the U.S. and the world are continuing. Results indicate that there is some influence of geographic delineation on the sequence diversity of these isolates (Bag et al., 2009a and 2009b). Genetic diversity studies would help us better understand the introductions, movement and evolution of the virus and virus populations.

Studies were conducted on the localization of IYSV in onion. Results showed a great degree of variability and unevenness in the distribution of IYSV throughout the onion plant (Pappu et al., 2008). The structure and organization of the complete genomic sequence of IYSV has been elucidated (Bag and Pappu, 2009; Bag et al., 2009a and 2009b; Nischwitz et al., 2006; Pappu et al., 2006a and 2009). Quantitative Real Time Reverse Transcriptase PCR (QRT-RT-PCR) can be used to quantify the amount of IYSV nucleoprotein genes at different points within the onion plant. Preliminary data shows that the amount of IYSV nucleoprotein gene present in 2 cm leaf samples taken from symptomatic onion leaves varies along the length of the leaf, with the highest concentration of IYSV at the lesion. When two populations of onion thrips infested with IYSV were reared on either radish or onion plants, the thrips reared on onion retained IYSV over subsequent generations, while thrips reared on radish lost the virus. This method of generating IYSV-free thrips may be useful in comparative studies between IYSV-infected and IYSV non-infected thrips (Szostek and Schwartz, 2011).

Effect of IYSV on yield

Controlled studies in the greenhouse compared onions exposed to thrips, IYSV, thrips+IYSV, and no pests for yield responses. In this study, there were no cultivar differences in onion bulb weight or size. Plants with no pests had the highest bulb weight (58 grams), followed by plants with only IYSV (36 g), plants damaged by thrips (20 g) and finally plants affected by thrips+IYSV (14 g) (Boateng and Schwartz, 2010). In 2 of 4 New

York fields surveyed, bulb weight from IYSV infected plants was lower than weight from non-infected ones (Hsu et al. 2010).

IYSV management spatial and temporal distribution considerations

The spatial distribution of IYSV-infected plants varies within and among onion fields depending on cultivar, plant population and location in the field. Infected plants most often are distributed randomly and secondary spread of IYSV within fields appears limited, although the highest IYSV incidence was often found on the borders of fields with the lowest incidence near the field centers in Colorado (Gent et al., 2004). Temporally, IYSV is most often detected in onion fields established from transplants before those established by direct seeding (Hsu et al., 2010). Despite detecting IYSV earlier in transplanted fields, the progression of IYSV incidence throughout most of the season is similar in transplanted and direct-seeded fields. However, final levels of IYSV at harvest tend to be greater in direct-seeded fields than transplanted ones, probably because most transplanted fields are harvested before direct-seeded fields; therefore, there is more time for IYSV to reach higher levels in direct-seeded fields (Hsu et al., 2010). These results and those from future efforts could help to improve the timing and efficiency of management strategies. In a spatial and temporal distribution of thrips and IYSV study, areas that had higher thrips also tended to have higher IYSV. The effect of thrips and IYSV on yield has been variable across production regions of the U.S. Relationships between thrips, IYSV and edaphic properties appear to be weak (Hsu et al., 2010; Schwartz et al., 2010). The NSs antibody is useful in quickly identifying IYSV transmitters among thrips, as not all thrips carrying the virus can transmit it. Then, it can be determined when most of the viruliferous thrips are entering or are present in the field.

IYSV management controlling its vector

The value of insecticides to control thrips in order to manage IYSV remains unresolved. Schwartz et al. (2009) found a linear relationship between thrips density in late June and the incidence of IYSV in early to mid-August. However, insecticide applications for thrips management often is regarded as ineffective for management of tospovirus diseases since viruliferous thrips originating from outside a field may be more important sources of inoculum compared to secondary spread from in-field thrips disperal (Gitaitis et al., 1998). Continued research is needed to investigate these dynamics, especially in relation to varying production systems, IPM components which reduce pest pressure, and selection of less susceptible cultivars.

IYSV management sources of inoculum

Several weed species have tested positive by DAS-ELISA in Colorado (Gent et al., 2006), Idaho (Sampangi et al., 2007), Georgia (Nischwitz et al., 2007), Utah (Evans et al., 2009a and 2009b) and New York (Hsu et al., 2011). Additionally, several weed species have been identified as reproductive hosts for onion thrips, suggesting that these particular weed species may be sources for IYSV in onion production systems (Smith et al., 2011). More research is needed to confirm whether onion thrips are capable of transferring IYSV from these weed species to onion and how frequently and when this occurs. Western blots have been investigated for improved accuracy of identifying IYSV in weeds, as there continues to be discrepancy between ELISA testing positive and PCR testing negative.

Other studies have found that IYSV may arrive on onion transplants imported into states such as Colorado and New York from areas where it is already known to occur (Hsu et al., 2011; Mahaffey and Cranshaw, 2010). T. tabaci often has been found on imported onion transplants (Mahaffey and Cranshaw, 2010; Schwartz et al., 1988; Schwartz et al., 2004). A study in New York monitored thrips populations and IYSV incidence in transplanted and direct-seeded fields, and concluded that concentrating the spatial arrangement of crops based on similar harvest dates could reduce spread of IYSV to later-maturing fields (Hsu et al., 2010). In addition, researchers concluded that imported bare root transplants, volunteer onions (when rogued out of onion fields in a timely manner) and bulbs from out of state are not major sources of IYSV in New York. Because IYSV has been shown to be endemic in these areas, effective control of onion thrips remains the first line of defense against IYSV. In Georgia it was proposed that a biotype of T. tabaci may have been imported from Peru in conjunction with the introduction of IYSV. It was feared that if the Peruvian biotype was more aggressive it had the potential to replace the endemic F. fusca species in the onion niche, but test results remain inconclusive (Srinivasan et al., 2011b).

IYSV management Actigard

In general, the induced resistance material, Actigard, applied before bulb initiation can reduce the incidence of IYSV. In a commercial field with moderate pressure, IYSV was reduced from 4 to 17%, and the yield of jumbos was increased 11 to 54% in most of the plots treated with Actigard (Schwartz et al., unpublished).

IYSV management cultural practices

Small increments of water stress on onion were found to be very detrimental to onion yield and grade in the presence of substantial IYSV incidence (Gent et. al. 2004; Shock et al., 2009, 2011). Reduction in thrips pressure as a result of using sprinkler irrigation has not been proven in trials in Oregon. Additional N fertilizer has not shown any consistent benefit to help onions continue growing in the presence of IYSV, and some studies suggest that this may favor thrips population buildup (Hsu et al., 2010).

Bacterial diseases of onion

During the past decade, bacterial diseases of onions have increased in economic importance nationwide. In New York, several newly recognized bacterial pathogens were identified and characterized in the field and following storage (Carr et al., 2010; Zaid et al., 2011; Beer et al., 2011). Further understanding of the biology and epidemiology of the causal pathogens will lead to the development of urgently needed effective management strategies. Realistically, management of bacterial diseases of onion will require an IPM approach that includes varietal selection, sanitation, chemical and biological control and several cultural techniques.

Bacterial disease management cultural practices

Onion genotypes with greater resistance to E. cloacae, B. cepacia and B. gladioli pv. alliicola have been identified (Schroeder et al., 2010a; Schroeder et al., 2010b). Investigations of various cultural practices for managing bacterial diseases are being emphasized currently as major foci in several research programs. In the Northeast, it was determined that reduced plant spacing and abandoning black plastic mulch significantly reduced bacterial bulb decay in small-scale intensive onion production (Hoepting et al., 2010). In Georgia, black plastic mulch increased the severity of center rot and advanced the onset of disease in contrast to bare ground or straw mulch (Gitaitis et al., 2004). In the same study, no reduction in center rot incidence was noted as a consequence of using drip irrigation compared to overhead sprinkler irrigation. Finally, double-cropping onions following pearl millet reduced levels of sour skin in 3 out of 5 years (Gitaitis et al., 2010). In the PNW, reducing curing temperature to < 35°C significantly reduced bacterial rots in storage caused by E. cloacae, B. cepacia and B. gladioli pv. alliicola (Schroeder and du Toit, 2010; Schroeder et al., unpublished). Much research is needed to evaluate cultural techniques on the different bacterial pathogens in the different onion growing regions nationwide.

Multidisciplinary approach

The W2008 project is designed to develop and improve IPM approaches to managing pests that threaten the sustainability of the U.S. onion industry. The multidisciplinary nature of W2008 will ensure that project personnel address potential interactions between strategies that are effective against one pathogen or pest that could negatively affect management of other pests of onions.

Objectives

1. Evaluate onion germplasm for greater levels of tolerance to IYSV, other pathogens and thrips.
2. Investigate thrips biology and IYSV epidemiology to improve management strategies.
3. Investigate the biology, ecology and epidemiology of other pathogens to improve management strategies.
4. Facilitate interaction and information transfer between W2008 participants, the onion industry and other stakeholders.

Methods

Objective 1: Evaluate onion germplasm for greater levels of tolerance to IYSV, other pathogens and thrips:

We will continue to uniformly evaluate and report the reactions of onion entries (advanced breeding lines, cultivars, germplasm accessions) when exposed to IYSV and thrips populations under field and controlled conditions at cooperating sites with varying environmental conditions that support short-day, intermediate-day, and long-day onion types. Advances have been made in the first five years of this project, and promising materials from initial screenings have been identified for use by the industry. This nursery format is available to all allium industry personnel including those involved with university, USDA and seed company projects. Additional screening and identification of promising materials will continue to be promoted for use in onion cultivar improvement efforts by public and private onion breeders at cooperating sites throughout the U.S. Participants will include scientists from Colorado, Idaho, New Mexico, New York, Oregon, Texas, Utah and Washington, as well as from the USDA-ARS.

Nursery Design: Participants are encouraged to adapt the following guidelines for nursery design, implementation and evaluation to promote uniform data acquisition across the United States. Trials should be randomized with a minimum of 3 replicates. Blocks should be planted on two beds with 1 or 2 lines per bed that are 3 m in length with a 1 m alleyway between blocks. Every third row should be planted with an IYSV/thrips susceptible border that is not treated with any insecticide to provide uniform pest pressure to the adjacent plots where the germplasm accessions are located. The nursery should be surrounded by a border 3 m wide of a local onion variety that receives all agronomic inputs except for insecticide treatments. Cooperators are encouraged to plant in an area with a history of IYSV and moderate to high thrips pressure. IYSV pressure may be increased by promoting development of IYSV infected volunteers and/or transplanting infected plants into and around the nursery.

Evaluation:To evaluate onion thrips, without removing plants, the number of adult and larval thrips per plant on 10 randomly selected plants per entry per replicate should be counted at 4 weeks pre-bulbing, 2 weeks pre-bulbing, bulbing, 2 weeks post-bulbing and 4 weeks post-bulbing. IYSVshould be rated at bulbing, 3 weeks post-bulbing, and 6 weeks post-bulbing. Without removing plants, determine the incidence of IYSV by the number of plants exhibiting symptoms out of 25 randomly selected plants per plot. IYSV severity should be rated on the plants that have visual symptoms using the following scale: 1 = 1-2 small lesions, 2 = 3-10 medium lesions, 3 = 11-25 medium to large lesions, and 4 = more than 25 medium to large lesions per infected leaf.

It is important that cultivars that are selected for tolerance to IYSV and/or onion thrips are not especially susceptible to other diseases of onions, which could limit their usefulness commercially. Although evaluation of other diseases is not the major focus of this project, attention will be paid to susceptibility to other diseases, especially bacterial diseases of all entries.

Disease screening information for plant introduction accessions will be reported to GRIN, if there is a descriptor available. Genetic material released from this breeding program will probably be released as a cultivar through an exclusive basis to one seed company.

Objective 2. Investigate thrips biology and IYSV epidemiology to improve management strategies.

Collaborators will conduct field, greenhouse and laboratory studies that will improve our understanding about thrips biology and IYSV epidemiology and lead to better management strategies for thrips and IYSV. These management strategies will be evaluated in trials at field stations and with cooperating growers. Experimental protocols will be based on methods that already have been used by project participants or will be developed through collaborative activities and meetings. Participants will include scientists and Extension personnel from Colorado, Florida, Georgia, Idaho, New York, Oregon, Utah and Washington.

Examine the biology of onion thrips: Dispersal of onion thrips in onion ecosystems is a key biological parameter that is not well known. Thrips dispersal will be examined through conventional sampling techniques such as visual counts of thrips in the surroundings of onion fields and on onion plants and numbers of adults captured on sticky cards as well as novel methods like using remote controlled airplanes to capture airborne thrips adults. Microsatellite DNA markers will be used to indirectly assess thrips movement within the landscape. Identifying alternative hosts for thrips that infest onions also will be a priority. Weeds and crops near onion fields will be sampled for thrips larvae and reared to adulthood in the laboratory to identify those that are suitable hosts. Similarly, thrips reproductive success on these alternative hosts as well as new onion cultivars shown to be less susceptible to thrips damage will be evaluated in the laboratory. Research also will focus on improving methods and techniques to sample thrips in onion fields.

Examine the epidemiology of IYSV: The epidemiology of IYSV will be examined at both the plant and field level. New methods for inoculating IYSV to onion are needed to determine how IYSV moves within and between onion plants. Research also will focus on describing the role that alternative hosts for IYSV have in the epidemiology of this virus in onion fields. Isolates of IYSV also will be identified from onion and non-onion hosts to assist in understanding epidemiology of IYSV, especially identifying sources of the virus. Molecular techniques such as reverse transcription-polymerase chain reaction (RT-PCR), immune capture reverse transcription-polymerase chain reaction (IC-RT-PCR) and IYSV-NSs antiserum based ACP ELISAs will be used to identify infected hosts. A non-molecular approach that may be used to detect IYSV in onion fields is the use of indicator hosts such as lisianthus. Additional research will concentrate on assessing the role that the environmental conditions and grower production practices have on the incidence and severity of IYSV (e.g., water, temperature, soil type, cultivar, planting/harvest dates, maturity, etc.).

Evaluate management strategies for thrips and IYSV: Advancements have been made in managing thrips, and to a lesser extent IYSV, over the past five years. Improvements in thrips management have relied almost solely on the use of new insecticides and new insecticide use patterns. Research will continue to evaluate new selective insecticides, insecticide use patterns or techniques, and strategies to monitor and reduce insecticide resistance. Complementary research will address the development of additional management strategies that are needed to prolong the longevity of new insecticides for onion growers. Cultural control tactics for thrips are needed and recent studies have identified reduced levels of nitrogen at planting as beneficial in reducing thrips populations without sacrificing yield. Research will continue to identify the overall role that nutrient management has on thrips populations. Use of live mulches, cover crops and foliar applications of kaolin are also among the cultural tactics that will be explored. As onion growers use more selective insecticides to manage thrips, natural thrips predators have become more common in onion fields. Research will identify natural enemy species that reduce thrips populations and strategies that will enhance natural predator populations and when these predators will have the greatest impact on suppressing thrips infestations. Progress in identifying host plant resistance to thrips and IYSV has been described in Objective 1, but additional work will identify onion characteristics that are less attractive to thrips. Research also will evaluate the possibility of induced and systemic acquired resistance for IYSV management.

Objective 3. Investigate the biology, ecology and epidemiology of other pathogens to improve management strategies.

Development and application of DNA macroarray: In the PNW, a DNA macroarray will be developed to detect the 26+ bacteria, fungi and a yeast that are known to cause onion bulb decay in storage, typically without obvious symptoms of infection at harvest. The overall goal is to develop a robust, sensitive, and rapid DNA macroarray to detect and differentiate bulb rot pathogens before bulbs are placed in storage. The specific objectives of the development of the DNA macroarray are: 1) develop a DNA macroarray for detecting and differentiating pathogens that can cause onion bulb rots in storage; and 2) evaluate and optimize the DNA macroarray for testing onion bulbs. The macroarray will be validated as a detection tool that: A) is specific for the target organisms (does not cross-react with non-target organisms); and B) can detect a range in inoculum of target pathogens in the presence of other organisms (pathogens and non-pathogens) using artificially inoculated onion bulbs. We will then establish that the macroarray can be used to detect bulb rot pathogens from latently-infected and symptomatic bulbs. Finally, bulbs will be inoculated with the pathogens individually and in combinations, and then assayed immediately after inoculation and after 3-4 months of storage to allow rots to develop. We will sample small plots and commercial crops, to correlate presence of the pathogens in the field prior to harvest and bulbs at harvest with environmental field and storage conditions, with incidence of rot(s) in storage.

This research is expected to provide stakeholders with access to a practical tool to assess which pathogens are present in individual bulb lots before storage. A macroarray that readily detects latent (symptomless) infections of bulb rot pathogens at harvest will allow growers and other stakeholders to make informed decisions about post harvest management, because this new technology will better predict the risk of storage rots. Information on cultural practices and curing techniques will be collected and related to the diseases identified by the DNA macroarray that become problematic during storage. Practices that decrease the risk of storage diseases will be identified and incorporated into an IPM program. Ultimately, losses due to onion bulb rots out of storage will be reduced and onion profitability increased. The DNA macroarray may be used in other onion producing areas, especially in the Northeast and Southeast for the same purpose. Participants will include scientists from Colorado, Georgia, New York, Pennsylvania and Washington.

Detect foodborne pathogens associated with harvested onions: The DNA macroarray mentioned above is slated to include the detection of Salmonella spp. and E. coli, certain strains of which are human pathogens and can pose food safety risks. If either of these genres of bacteria is detected using the DNA macroarray, further tests can be conducted to determine if the strains pathogenic to humans are present and if they pose a food safety risk. Bulb onions are generally perceived to pose a low risk for contamination with foodborne pathogens. The data collected from the DNA macroarray studies could be used to demonstrate and/or document this low risk. Also, if foodborne pathogens were identified, this technology might be used to elucidate where in the production chain (field, harvest, storage, packing, shipping, etc.) onions are at highest risk to become contaminated. This technology could be available to help to address other food safety issues as they arise in the onion industry.

Identification, biology, epidemiology and management of bacterial diseases: In NY, and the PNW, emphasis will be placed on studying the bacteria that have been found prominently associated with rotten bulbs following harvest and storage, which commonly account for 10% to 40% of losses to growers. These include B. cepacia, P. ananatis, P. agglomerans and E. cloacae. In addition, Rahnella species were isolated in NY from about 40% of the hundreds of cull onions assessed from representative growers in the state in 2011. Decay symptoms resulted when several pure cultures of Rahnella spp. were inoculated into putatively healthy onion bulbs. Rahnella species also have been putatively identified in the PNW, but Kochs postulates have not been completed. Thus, attention will be given to understanding the importance of this bacterium. In WA, known bacterial pathogens have been isolated and associated with bacterial bulb rot for only about 50% of the bulbs. There, a previously unidentified yeast was identified that was related to bulb rot following storage. During W2008, new microorganisms are likely to be identified that contribute to bacterial bulb rot of onion, and their importance to commercial onion production will be determined.

In PA, efforts are being directed towards identifying potential sources of inoculum (transplants, weeds, soil, etc.) for the bacterial species most commonly associated with yield losses of onion. Similar to NY, these include P. agglomerans, P. ananatis, as well as P.carotovorum, P. marginalis and to a lesser extent, E. cloacae. In 2011, increased losses due to B. cepacia and B. gladioli pv. allicola were observed as well as post-harvest losses due to Botrytis alli. The development of a multiplex PCR (Mansfield and Gugino, 2010) for detection of the eight most common bacterial species associated with onion in PA facilitated the efficient processing of numerous samples during the season.

Management of bacterial diseases will ultimately require an IPM approach. In NY and PA, extensive surveys of commercial onion fields are also being used to gain a better understanding of the environmental and production conditions (e.g. nitrogen fertility) that favor bacterial disease development, which will facilitate the implementation of a more targeted IPM program. Techniques will be developed to consistently initiate bacterial infection in the laboratory, controlled environment chambers and field to facilitate the evaluation of potential control materials and strategies. We envision that such studies also would increase our understanding of the epidemiology of bacterial pathogens of onion for which only scant information is available. Research on the use of cultural practices to manage bacterial diseases including narrow plant spacing, alternative mulch types and reduced nitrogen fertility will continue. Biological and chemical materials will be investigated that have potential to control bacterial decay through reducing populations of pathogens or enhancing the resistance of onions. Schedules for their application will be developed and their use incorporated into an IPM program.

In NY, inoculum of all pathogens found in cull onions following storage were found in a wide array of sampled muck soils collected at the time of onion planting in the spring (Beer et al., unpublished). In contrast, seed and transplants were free of the pathogens (with rare exceptions), thus indicating that effective control strategies might be directed towards soil-borne bacteria. Thus, the effect on bacterial diseases of reducing levels of inoculum in the soil using cultural techniques and soil amendments will be initiated through this project. There is a strong suspicion of an interaction between bacterial diseases of onion and onion thrips, and this relationship also will be investigated through this project. In addition, an investigation of the interaction between leaf injury caused by onion thrips, chemical or mechanical means and bacterial diseases will be conducted. Since the majority of bacterial problems on onion develop in storage, efforts in the PNW will focus on determining the impact of curing temperature and duration on disease progression.

Address diseases of new importance: The format of the W1008 multistate project proved to be a highly efficient and productive means for experts from multiple disciplines from across the country to network, share information, and collaboratively find solutions to problems facing the onion industry. Through W1008, tremendous progress was made towards understanding the biology and epidemiology of IYSV and onion thrips and developing management strategies for these serious pest threats to the onion industry. During the span of the W1008 project, bacterial diseases of onions increased in importance to sustainable onion production nationwide, and consequently have been added as an objective to the W2008 proposal with the intention that the multistate project approach will yield significant progress towards understanding and managing bacterial diseases. Fungal and bacterial diseases of new importance will be addressed by the W2008 as necessary.

Post-harvest management to improve quality following storage: As outlined in previous sections, investigation will take place to determine post-harvest management practices such as curing temperatures that reduce bacterial bulb decay or foodborne pathogens in storage. Also, some of the W2008 participants are project leaders of the SCRI multistate project led by Chanhying Li, University of Georgia, Advancing onion postharvest handling efficiency and sustainability by automated sorting, disease control, and waste stream management, for which two of the main objectives are to: i) identify internal defects (such as bacterial decay) by integrating x-ray hyperspectral imaging technologies, and; ii) reduce storage losses by developing gas sensing technologies and disease control strategies.

Objective 4: Facilitate interaction and information transfer between participants, the onion industry and other stakeholders.

The proceedings from the annual W2008 meetings will be documented and distributed to the entities mentioned but not limited to in the Outreach Plan mentioned below. We will expand and explore promotional efforts that will continue to promote the interaction of the W2008 participants and entities mentioned in the Outreach Plan. A concerted effort will be made to inform the onion community about www.alliumnet.com and upcoming W2008 meetings via trade magazines, email, internet promotions, etc.

A more integrated point of exchange between researchers, growers and other interested parties will be developed and expanded using the www.alliumnet.com web site while encouraging a more open dialogue of W2008 findings, concerns, questions and comments. The goal is to provide the most current research results and industry needs that can stand as a platform for further progress. We will support and initiate strategic plans that will identify priorities of the onion industry. Efforts are already underway to hold joint meetings of the W2008, National Allium Research Conference (NARC) and National Onion Association (NOA) to maximize interactions among the W2008 researchers and NARC groups, onion growers and allied industry representatives.

W2008 members will continue to share results from this project and learn from colleagues involved with various research and extension projects (e.g., translational genomics, ipmPIPE, pathogen diagnostics, and storage technology) funded in recent years by the Specialty Crop Research Initiative (SCRI) related to thrips, IYSV, other pathogens and onion production and storage issues of relevance to the national onion industry (Onion ipmPIPE Diagnostic Pocket Series, 2011; Szostek and Schwartz, 2010).

Measurement of Progress and Results

Outputs:

- Improved breeding lines and cultivars will possess increased levels of tolerance to IYSV, thrips and other pathogens. New tolerant cultivars will become available to onion growers in all growing regions in the U.S. Concurrently, molecular markers for new resistance or tolerance alleles and QTL for these pathogens and pests will be generated from this project.

- A detailed understanding of the extent and nature of the genetic diversity of IYSV in the U.S. will be obtained. New alternative methods of detection, inoculation, and/or screening environments for IYSV will be developed, which will serve as standardized protocols across the industry. Ultimately, the most appropriate inoculation method and the number and type of strains/isolates of IYSV and biotypes and species of thrips that need to be used for breeding and selection will be identified and standardized. Also, molecular diagnostic tools and genetic fingerprinting for detecting and monitoring pathogen and pest diversity in the U.S. will be utilized.
- A macroarray that readily detects latent infections by bulb rot and foodborne pathogens at harvest will be developed allowing onion growers and other stakeholders to make informed storage management decisions based on an improved ability to predict the risk of storage rots and comtamination of foodborne pathogens.
- New pathogens of onion will be identified, their importance determined and management strategies developed.
- Cultural control tactics with emphasis on reduced nitrogen fertility will be developed for managing thrips, IYSV and bacterial diseases of onions.
- Output 6: A comprehensive biologically based and sustainable IPM program will be developed for managing IYSV, onion thrips and bacterial diseases of onions. Output 7: A more integrated point of exchange between researchers, growers and other interested parties will be developed and expanded using the www.alliumnet.com web site. Output 8: Joint meetings among W2008, NARC and NOA will be held.

Outcomes or projected Impacts:

- Improved high yielding onion cultivars with increased tolerance to IYSV and/or thrips may dominate regional and national production. Area planted to new cultivars may increase by more than 10% leading to substantial yield increases in the participating states. Commercial value of new cultivars may exceed $100 million annually. Adoption of multiple-pest resistant cultivars may reduce pesticide use by 25% or more resulting in savings to the producers and impacting positively to healthier environments.
- New technology that allows for accurate prediction of potential storage losses will enable growers and other stakeholders to make informed marketing decisions regarding their crop. Sale of an onion crop immediately following harvest that would have otherwise resulted in unacceptable levels of bulb decay out of storage can potentially save producers hundreds of thousands of dollars and several million dollars nationwide.
- Availability of macroarray technology to identify Salmonella and E. coli on dry bulb onions may demonstrate the relative low risk of this crop for foodborne pathogens. Also, using this technology to test for foodborne pathogens prior to shipping could prevent detrimental outbreaks from occurring, proving the macroarray invaluable to preserving the reputation that the dry bulb onion industry has for producing a safe product.
- Adoption of reduced nitrogen fertility practices by onion producers to manage onion thrips, IYSV and bacterial pathogens of onions will increase the profitability and sustainability of the onion industry by millions of dollars in savings by reducing fertilizer and pesticide inputs, while realizing increased marketable yield and quality. Environmental contamination from heavy use of fertilizer and pesticides will also be reduced.
- Adoption of our research-based comprehensive IPM practices for managing IYSV, thrips and bacterial and fungal diseases of onions by onion producers will keep the U.S. onion industry profitable and

sustained.

- Outcome/Impact 6: Identification of new and emerging diseases and consequently determining best management practices for them in a timely manner will shave off years of unneccesary losses and save the U.S. onion industry million of dollars in preventable losses. Outcome/Impact 7: Joint W2008, NARC and NOA meetings and improved outreach techniques will result in increased onion grower participation at the W2008 and NARC meeting, and consequently increased sharing of information and collaboration among researchers, onion growers and the allied onion industry. Priority research issues and cooperative strategies to obtain funding, conduct research and information transfer will result.

Milestones:

(2012): Disseminate results and impacts from 5-year project W1008 on IYSV and thrips with the onion industry and other stakeholders. Submit a formal request to renew and expand the regional research committee (W2008), and invite participation by all interested agricultural experiment stations, USDA-ARS personnel, and onion commodity groups. Research to address the proposed objectives will be continued or initiated. The first W2008 meeting is planned to be held in conjunction with the NARC in New Mexico on December 12-14, 2012.

(2013): Research to address the proposed objectives will be continued or initiated. W2008 will meet in conjunction with NOA in December 2013.

(2014): DNA macroarray will be made available to national labs to utilize for testing onions for the presence of fungal, bacterial and yeast pathogens, as well as evaluating the efficacy of several control materials and strategies aimed at reducing bacterial decay of onions. Research to address the proposed objectives will be continued or initiated. W2008, NARC and NOA will have their first joint meeting.

(2015): The Onion ipmPIPE will have developed linked information platforms where onion stakeholders can check what pests were identified in their area, get assistance with pest diagnostics, link to pest images, and access information on the pest, life cycles, host range, and IPM tactics and validate a real-time risk management tool to be used by public stakeholders, extension, research and industry. Models for disease movement and development will also be available. Research to address the proposed objectives will be continued or initiated. W2008 will meet in conjunction with NOA.

(2017): Comprehensive IPM practices for managing thrips and bacterial diseases of onions will be readily adopted by producers nationwide. Disseminate results and impacts from 5-year project (W2008) on IYSV, other pathogens, thrips and interactions on storage health with the onion industry and other stakeholders. Discuss a proposal to renew or terminate the regional research committee (W2008) in 2018.

Projected Participation

Include a completed Appendix E

Outreach Plan

Annual meetings for the W2008 project will be held to share information, update participants on current research and extension, identify potential sources of support for research and extension needs, prioritize research and extension needs, establish cooperative approaches to research and extension needs, and assign committees to address specific IYSV, other disease and/or thrips related issues as needed. Every other year, e.g., 2012 (New Mexico), our committee will schedule its meeting in conjunction with the NARC. As often as feasible, these meetings will be scheduled in conjunction with NOA. Formal and informal participation at these meetings is encouraged from all participants from all organizations, regions and countries. Participants will include scientists and Extension professionals from Colorado, New Mexico, New York, Oregon, Texas, Utah, Washington, Wisconsin and USDA-ARS.

An annual report, including summaries and impact statements from each participant will be generated along with the minutes of the annual meeting and will be sent to committee members and archived on the www.alliumnet.com and NIMSS web sites. The annual report will also be sent to appropriate University Deans and Agricultural Experiment Station Directors, key legislators, and other identified stakeholders.

Research results from each sub-project will be published in refereed and non-refereed journals, extension bulletins, the trade magazine, Onion World, and posted on the web sites of individual institutions or programs, the W2008 website (www.alliumnet.com) and other media outlets. In-field research trials and demonstrations will be viewed by the onion industry where appropriate, such as at annual field and twilight meetings. Latest research results will be presented at grower educational meetings and workshops, professional society meetings and at NARC.

All of the major onion grower associations and committees, and seed and chemical companies will continue to be engaged by the W2008 (see attachment).

Organization / Governance

The directors of the various participating state institutions designate the W2008 participating researchers, who in-turn elect the officers of the Technical Committee. The project is considered a Western Regional Research Project, but has substantial participation by states in other onion producing regions of the U.S. and USDA-ARS researchers. The Technical Committee officers are a Chairperson, Vice-Chairperson, and Secretary. Unless he/she declines to serve, the Vice-Chairperson will succeed the Chairperson. The Secretary is elected annually and the previous Secretary will succeed the Vice-Chairperson, unless he/she declines to serve. An election will be held if any officer declines to serve in his/her office. The officers will be elected from the officially designated representatives, and may serve consecutive years if re-elected by the committee members. The Western Association of Agricultural Experiment Station Directors selects the Administrative Advisor who has no voting rights. For W1008 and W2008, this is Lee Sommers.

The responsibility of the Chair is to organize and chair the annual meeting. Organizing the meeting includes: making sure that the local arrangements are taken care of, which may be in conjunction with NOA and/or NARC planning committees; preparing the program agenda; and inviting the technical committee and other participants to attend the meeting, and advertising the annual meeting to the onion industry at large. The chair should maintain the most updated W2008 participant contact information.

Responsibilities of the Vice-Chair include coordinating the writing of the annual report and sending it to the Administrative Advisor for submission onto the NIMSS website, making sure that it does not exceed the deadline. The Vice-Chair should also distribute the annual report to the Technical Committee and other participants, for further distribution to other relevant stakeholders. Depending on the length, the annual report or a summary of it may be submitted to Onion World.

Responsibilities of the Secretary are to record the minutes from the annual meeting and submit them to the Administrative Advisor for submission onto the NIMSS website. Annual reports and minutes are also to be posted on the www.alliumnet.com website.

The Technical Committee will meet annually, unless otherwise planned, at a place, and on a date designated by a majority vote of the committee. Minutes will be recorded and an annual progress report will be prepared by the Technical Committee and both submitted through proper channels. At the annual meetings, participants are updated about current research and extension, information is shared on new outbreaks and ongoing concerns with IYSV, other pathogens and thrips problems, potential sources of support for research and extension needs are identified, research and extension needs are prioritized, cooperative approaches to research and extension needs are established, successful grant applications that involve stakeholders are pursued, and committees are assigned as needed to address specific issues as needed. New and upcoming publications and other educational and outreach resources are identified, as well as collaborations with other relevant multistate onion projects, such as SCRI projects. Formal and informal participation is encouraged from participants of all organizations from all regions and countries.

Present officers of the current W1008 Regional Project (2012): Chair: Shannon Pike, Onion Breeder, Enza Zaden USA - California Vice-Chair: Brian Nault, Entomologist, Cornell University New York Secretary: Joel Canestrino, Onion Breeder, Hazera Inc. New Mexico Past Chair: Hanu Pappu, Virologist, Washington State University W2008 proposal rewrite coordinator: Christy Hoepting, Vegetable Specialist, Cornell Cooperative Extension Vegetable Program.

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Attachments

[Current NIMSS Projects Involving Onions.pdf] [Organizations Engaged by W2008.pdf] [W 2008 Letter - NOA Dec '11.pdf]

Land Grant Participating States/Institutions

CO, Cornell Cooperative Extension, GA, NM, NYG, NYC, OR, Oregon Cooperative Extension, PA, WA, Washington Cooperative Extension

Non Land Grant Participating States/Institutions

Enza Zaden (Aust.) Pty Ltd Research Station, Sakata Farms

Signatures:

s:/Lee E. Sommers

Appendix E: Format for Reporting Projected Participation

Part 1: Participant List

Station / Institution and Department	Participant	Objective No.	Research						Extension	
			KA	SOI	FOS	SY	PY	TY	FTE	Program
Colorado - Colorado State University	Michael E Bartolo	1,4	102 111	110 210	1020 1020	0.00	0.00	0.00	0.00	• not specified
Colorado - Colorado State University	**Howard Schwartz**	1,2,3,4	216 212 211	1451 1451 1451	1170 1160 1160	0.25	0.25	0.25	0.25	
Cornell Cooperative Extension	Christine Hoepting	2,3,4	216 212 211 903	1451 1451 1451 1451	1160 1160 1130 1160	0.00	0.00	0.00	0.75	
Georgia - University of Georgia	**Ronald D Gitaitis**	2,3,4	212	1451	1101	0.10	0.00	0.10	0.10	
Georgia - University of Georgia	**Ronald D Gitaitis**	2,3	212	1451	1101	0.10	0.00	0.10	0.10	
New Mexico - New Mexico State University	Christopher Cramer	1	202	1451	1080	0.10	0.00	0.00	0.00	
New York -Geneva : Cornell University	Marc F Fuchs	2,4	212 212	1451 4030	1101 1101	0.05	0.00	0.00	0.00	
New York -Geneva : Cornell University	**Brian A. Nault**	1,2,4	211	1451	1130	0.20	0.00	0.00	0.10	• not specified
New York -Ithaca : Cornell University	**Steven V. Beer**	1,2,3,4	212	1451	1160	0.20	0.40	0.60	0.00	
New York -Ithaca : Cornell University	**Steven V. Beer**	2,3,4	212 212	1451 1451	1100 1160	0.20	0.20	1.50	0.50	
OTHER-Enza Zaden (Aust.) Pty Ltd Research Station	Juan C Brevis	1,4	212	1451	1060	0.10	0.00	0.00	0.00	
OTHER-Enza Zaden (Aust.) Pty Ltd Research Station	**Lewis R Lydon**	unknown	0	0	0	0.00	0.00	0.00	0.00	
OTHER-Enza Zaden (Aust.) Pty Ltd Research Station	Shannon Pike	1,4	212	1451	1060	0.10	0.00	0.00	0.00	
OTHER-Enza Zaden (Aust.) Pty Ltd Research Station	Paul R Purvis	unknown	0	0	0	0.00	0.00	0.00	0.00	
Oregon - Oregon State University	**Clinton C. Shock**	1,2,3,4	216 216 216	1451 1451 1451	1101 1130 1020	0.00	0.00	0.00	0.00	
Oregon Cooperative Extension	Stuart Reitz	3,4	211 212 216	1451 1451 1451	1130 1130 1130	0.10	0.00	0.00	0.00	• not specified
PRODUCER-Sakata Farms	**Robert T Sakata**	1,4	212	1451	1060	0.10	0.00	0.00	0.00	
Pennsylvania - Pennsylvania State	**Beth K Gugino**	3,4	212	1451	1160	0.25	0.00	0.00	0.00	
Washington - Washington State University	**Hanu Pappu**	1,2,4	212	1451	1101	0.10	0.00	0.00	0.00	

Washington - Washington State University	Brenda K Schroeder	4	212	1451	1101	0.10	0.00	0.00	0.00	
Washington - Washington State University	Lindsey J du Toit	1,2,3,4	212	1451	1160	0.10	0.00	0.00	0.40	
Washington Cooperative Extension	Timothy D Waters	2,4	211	1451	1130	0.10	0.00	0.00	1.00	

Part 2: Research Summary

Combination of KA, SOI, and FOS	Total SY	Total PY	Total TY
0-0-0	0.000	0.000	0.000
102-110-1020	0.000	0.000	0.000
111-210-1020	0.000	0.000	0.000
202-1451-1080	0.100	0.000	0.000
211-1451-1130	0.333	0.000	0.000
211-1451-1160	0.083	0.083	0.083
212-1451-1060	0.300	0.000	0.000
212-1451-1100	0.100	0.100	0.750
212-1451-1101	0.425	0.000	0.200
212-1451-1130	0.033	0.000	0.000
212-1451-1160	0.733	0.583	1.433
212-4030-1101	0.025	0.000	0.000
216-1451-1020	0.000	0.000	0.000
216-1451-1101	0.000	0.000	0.000
216-1451-1130	0.033	0.000	0.000
216-1451-1160	0.000	0.000	0.000
216-1451-1170	0.083	0.083	0.083
903-1451-1160	0.000	0.000	0.000
Grand Total:	2.250	0.850	2.550

Part 3: Extension Summary

Program	Total FTE
Grand FTE Total:	3.20