Project Description

(a) Problem, Background, and Justification

Potato leafhopper (PLH) [*Empoasca fabae* (Harris)] resistant alfalfa (*Medicago sativa* L.) cultivars were expected to eliminate PLH as the major pest of alfalfa in the USA. However to date, cultivars of alfalfa with high resistance to PLH still sustain economically significant damage when PLH populations are at very high numbers and/or the alfalfa plants are under other stresses, particularly in the establishment year. Alfalfa cultivars with resistance to PLH still support populations of PLH and thus some damage, although the number of PLH is half or less of a conventional alfalfa cultivar. Insecticide applications are effective, but the timing of applications requires regular monitoring of insect populations because PLH damage occurs before symptoms are highly visible, and insecticides are not labeled for use on alfalfa-grass mixtures.

Forage grasses do not support PLH populations, and when planted with alfalfa can cause PLH to emigrate to other host plants. We propose to test the potential for PLH-resistant alfalfa cultivars to be planted with forage grass as an IPM strategy to eliminate, not just reduce, PLH damage on alfalfa in the Northeast (NE) without the use of insecticides. Perennial forages are essential to the NE USA's cropping systems. Perennial forages provide high-quality feedstuffs to livestock, as well as providing environmental and agronomic benefits such as crop rotation, reduced soil erosion, and improved soil structure and fertility (Barnes et al., 1995). In addition to 1.15 million acres of alfalfa in New York and Pennsylvania; 2.35 million acres of "other hay" crops including alfalfa-grass mixtures, contribute to the region's agricultural economy (2003 NASS).

The proposed study addresses a number of NE Integrated Pest Management (IPM) identified priorities.

NE IPM Base Priority: Environmental stewardship and risk management
This proposal: Results will provide needed evaluation of a viable insect management option to minimize risk of PLH insect damage and a means to reduce or eliminate insecticide use to manage this pest on alfalfa in the NE. Planting alfalfa-grass mixtures provides other important environmental advantages over monoculture alfalfa including reduced herbicide application, soil erosion, nitrogen leaching, and harm to beneficial insects including pollinator insects.

NE IPM Base Priority: Importance and value of the crop or cropping system to the NE Region
This proposal: Results from this research would have direct application for NE region producers of alfalfa and alfalfa-grass mixed stands. Production of high quality home-grown forage is a critically important component for continued profitability of livestock operations in the NE. Rotations of corn and alfalfa or alfalfa-grass mixtures, both for production of stored feed in the form of silage, is the major cropping system used for dairies and other livestock production systems in the NE. This research would potentially

impact a large portion of the 1.27 million alfalfa and 3.09 million "other hay" acres reported by the National Agricultural Statistics Service for NY, PA, NJ, MD, WV.

NE IPM Base Priority: Importance of the pest or pest complex to the crop or cropping system.
This proposal: Potato leafhoppers are considered one of the most significant insect pests of alfalfa in the NE and the USA. Alfalfa and alfalfa-grass mixtures are widely grown and important feed crops supporting livestock production in the NE.

NE IPM Base Priority: Likelihood of implementation
This proposal: Results of this research have great potential for direct and immediate adoption by conventional and organic producers of alfalfa and alfalfa-grass mixtures in the NE and other regions. Alfalfa and forage grass variety attributes will likely have direct effect on the necessity for insecticide application for PLH control. Thus, variety selection for the benefit of pest management has a high likelihood of implementation.

In addition to a good fit with NE-IPM Base Priorities, the objectives of this proposal also fit with stakeholder-identified priorities by the NE IPM Center's Livestock and Field Crop Commodity Working Group (NEIPMC LFC CWG) report including those listed below. (See also: http://northeastipm.org/partners/priorities/LFC2003.htm).

NE IPM Commodity Working Group Priority:
Evaluate Cultural Control Practices and Develop Information Systems on Insect, Weed and Disease Management Especially Pertaining to Cover Crops, Tillage Systems, and Rotation.
This proposal: Results will evaluate the effect of integrating PLH-resistant alfalfa into alfalfa-grass mixtures or integrating grass into PLH-resistant alfalfa on PLH induced losses. Alfalfa-grass mixtures are already used by many producers as a means to reduce soil erosion, to minimize weed encroachment, and to help extend alfalfa production into soil situations less optimal for clear-seeded alfalfa. The newly available PLH-resistant alfalfa cultivars provide the additional benefit of a non-pesticide approach to reducing risk from a major insect pest. Results will provide needed information regarding this strategy as a viable management option, minimizing risk of insect damage, and reducing or eliminating need for insecticide use to manage PLH on alfalfa-grass mixed stands. Results could convince producers of monoculture alfalfa to grow alfalfa-grass mixtures for advantages in pest control.

Research and Development of Pest Management Strategies for Locally and Regionally Critical Pests of Field Crops in the Northeast, Including Efforts Centered on Pest Biology and Ecology.
This proposal: Results will develop research-based information to assess the potential impacts of PLH-resistant alfalfa combined with forage grass use to protect yield, forage quality, and reduce or eliminate insecticide use to manage PLH on alfalfa in the NE. Of critical importance to the success of this IPM strategy is to determine what characteristics of forage grass species cause PLH to emigrate. Forage grass species and varieties within species vary in maturity, height, biomass production, competitiveness, growth habit, and

leaf texture. This study will allow entomologists to begin to model the PLH/alfalfa/grass interactions under natural field conditions and PLH populations. These efforts may result in insights to PLH biology and ecology.

Organic Transition Methods.
This proposal: Results will develop research-based information necessary for organic cash crop and livestock producers, and those in transition to organic to better assess the utility of incorporating PLH-resistant alfalfa with or without forage grass as an insect management strategy in their crop rotations.

Keep Current on Key Pest Problems in the Field.
This proposal: The research project will field test impacts of a new technology and PLH management approach and build on new technologies available to reduce risk of PLH in alfalfa.

Use of Traditional Breeding for Resistance to Pests (insect, disease, weed) in Field Crops.
This proposal: Results will provide new information regarding variety specific attributes that have significant impact on crop pest control. Improvements in both alfalfa and forage grass varieties through traditional breeding for pest control attributes may eliminate PLH as an alfalfa insect pest when these specific variety types are planted. Improved variety development and marketing may be stimulated by this research project.

Alternative Pest Control on Grass and Legume Hay (includes insect, disease, weed, and vertebrate).
This proposal: The research will provide a direct test of the use of PLH-resistant alfalfa in alfalfa-grass mixtures to minimize impacts of one of the NE region's principal alfalfa insect pests.

Demonstration of New Technologies.
This proposal: While this proposal is a research proposal, results of the study will be shared with extension, producers, and other agricultural professionals. This information should encourage others to demonstrate the value of this approach to minimize PLH impacts on NE livestock and cropping operations.

Economic Evaluation of Pest Management Tactics.
This proposal: Partial budget analyses will provide results of costs (potential for reduced forage quality) and benefits (elimination of pesticide use) derived from using alternative pest management tactics and technologies.

Non-pesticide Alternatives in Field Crop Pest Management.
This proposal: Results will provide objective research-driven information regarding the integration of an insect pest resistant cultivar in alfalfa-grass mixtures and integration of forage grass in monoculture alfalfa to minimize or eliminate impacts of one of the NE regions principal alfalfa insect pests.

IPM Educational Programming and Resource Development.
This proposal: Results will provide insights to enhance extension outreach and foster development of outreach resources integrating new information on improved PLH management options.

This research project also directly addresses the NYSIPM 2006 Livestock/Fieldcrops IPM stakeholder-identified priorities of significant reductions in pesticide usage or potential reductions in pest related economic losses in 2-3 yr. if results are implemented, of integrated multi-authored proposals that will enhance understanding of the efficacy and economic impacts of cultural, biological, and/or least toxic approaches for management of target pests, and integrated management of significant pests affecting alfalfa (& grass mixtures) like potato leafhopper.

Northeast producers are faced with monitoring PLH populations on a weekly basis from June through August on all fields of alfalfa or alfalfa-grass mixtures, and harvesting prior to peak forage yield and quality or applying insecticides even to PLH-resistant alfalfa cultivars when insect levels go above economic thresholds. Because alfalfa is the highest yielding forage legume, alfalfa will continue to be grown for livestock feed. Protecting alfalfa from PLH through planting PLH-resistant alfalfa with forage grasses will benefit all of society through reduced use of pesticides that may pose negative environmental and health risks. Producers will likely benefit economically through reduced costs of pesticides associated with growing alfalfa, or through reduced risk to yield loss and lower plant vigor associated with harvesting alfalfa early to avoid PLH damage.

Even with PLH-resistant alfalfa cultivars, producers get the highest forage yield and quality from applying insecticides to alfalfa when PLH numbers are high. This is because PLH-resistant alfalfa still supports a population of PLH, and the PLH continue to feed and cause damage to the alfalfa. This research project aims to quantify the potential for further reduction in PLH damage to PLH-resistant alfalfa and to conventional alfalfa through incorporating forage grass as a non-host species in alfalfa-grass mixtures. Combining the two IPM strategies of PLH-resistant alfalfa with forage grass may eliminate the need for insecticide use as well as gaining other benefits associated with alfalfa-grass mixtures. Combining late-maturing forage grasses with alfalfa will limit the reduction in forage quality associated with adding forage grass to alfalfa cropping systems. These economically important aspects of alfalfa-grass mixtures will be quantified through this research project.

Intercropping alfalfa and grass is a well-established, regional agronomic practice in the NE due to the preponderance of variable soils. It is estimated that at least two-thirds of the alfalfa acreage in the NE includes a perennial forage grass. Mixed alfalfa-grass intercrops have many advantages to monoculture alfalfa. First, alfalfa will not persist on moderately to poorly drained soils and soils that have low pH that are common in New York and other areas of the NE. Many species of perennial forage grass are adapted to these types of soils. The grass in an alfalfa-grass mixture will usually grow and fill-in the areas of fields where the alfalfa is weak or dies out, thereby supplying more consistent forage yield over a range of environments. Intercropping alfalfa with grass will reduce

frost-heaving of the alfalfa, reduce soil erosion, and manage weed encroachment (Tesar and Marble, 1988). In addition, many producers include a grass in the mixture to reduce lodging of the hay crop and speed hay drying.

In northcentral USA, the acreage of alfalfa-grass mixtures has declined due to greater pesticide availability, greater difficulty in managing mixtures, and the potential for reduced forage quality (Spandl and Hesterman, 1997). Grasses mature at a faster rate than alfalfa. In mixtures of alfalfa with bromegrass (*Bromus inermis* L.) or timothy (*Phleum pretense* L.), forage quality of the mixtures was reduced at first harvest due to greater grass yield and maturity at this time compared to later harvests. Recently, seed companies have successfully introduced to the market place a number of late-maturing grass varieties that match better with alfalfa maturity in the spring than early-maturing smooth bromegrass or late-maturing timothy.

Potato leafhopper is the most damaging and widespread insect pest of alfalfa in the NE, causing risk to both new seeding establishment and survival, and to established stands during mid-to-late summer. When high populations of PLH are not controlled during the establishment year, large reductions in alfalfa yield and forage quality occur in the seeding year (Davis and Fick, 1995), and in the first harvest of the following year (Hansen et al., 2002). Potato leafhopper is a migratory insect, and source populations develop in the Gulf Coast and southeastern states (Taylor and Shields, 1995). Weekly monitoring of fields by producers or crop consultants is recommended from early June (after the first harvest) through late August because forage yield and quality losses from PLH damage occur before yellowing is visible on foliage (Undersander et al., 1991). Protecting alfalfa, both in monoculture and in grass mixtures, from yield and quality losses associated with PLH injury is a primary focus of NE alfalfa IPM efforts, and is a costly activity in both time associated with pest monitoring and increased chemical costs.

For alfalfa, several insecticides are registered to control PLH (Cornell Guide for Integrated Field Crop Management, 2006). These insecticides bear the restriction “Apply only to fields planted to pure stands of alfalfa” and as such are not appropriately labeled for alfalfa-grass mixtures. In New York, an estimated 460K acres of alfalfa-grass mixed stands are annually at potential risk from PLH and other insects, as in 2000 when producers in many areas of the NE lost whole fields due to an armyworm epidemic. To help producers minimize damage from insects in these crop mixtures, NYS Department of Environmental Conservation (DEC) and USEPA has issued a Crisis Exemption for the use of the insecticide Warrior in alfalfa-grass mixtures each year for the last four years. Without this exemption it is unlawful to spray Warrior or any other insecticide not specifically labeled for use on alfalfa-grass mixtures, and producers of alfalfa-grass mixtures would be left without any means of pest control other than harvesting early.

Non-pesticide management techniques to control PLH on alfalfa include harvesting forage early, planting PLH-resistant alfalfa cultivars, and planting perennial grass as a companion crop to the alfalfa. Early forage harvest can lower yields and potentially weaken the alfalfa stand making it susceptible to winter injury. Early forage harvest in the establishment year of spring seedings may be detrimental to seedling alfalfa survival. The

establishment year is when PLH populations cause the most damage (Flinn and Hower, 1984).

Potato leafhopper-resistant alfalfa cultivars have glandular-hairs from perennial wild-type tetraploid and diploid Medicago species with resistance to PLH (McCaslin, 1994). Hansen et al. (2002) have shown that recent PLH-resistant alfalfa cultivars, while not totally immune to PLH and damage from PLH, indeed have reduced PLH damage symptoms, were superior in feed quality than many of the conventional alfalfa cultivars tested, and were well adapted to New York growing conditions. However in the establishment year, the PLH-resistant alfalfa cultivars are still only moderately resistant to PLH damage. Similar results were found in caged alfalfa experiments in Iowa (Lefko et al, 2000) and in field trials conducted in Ohio, Indiana, Wisconsin, and Minnesota (Sulc, et al, 2001).

A limited number of new PLH-resistant cultivars are available to producers. The PLH-resistant cultivars have about 75% resistance to PLH insects (Peterson, 2003). Recent studies by Sulc et al. (2004) suggest an alfalfa cultivar with high resistance to PLH may have an economic threshold for damage by PLH that is three to four times higher than the threshold for a conventional, non-glandular haired cultivar. From PLH sweep data, Hansen, et al. (2002) found that planting a PLH-resistant alfalfa cultivar reduced PLH numbers by an average of 47% compared to planting a conventional alfalfa cultivar. This reduction was greater in the production years than in the establishment year. Thus, planting PLH-resistant alfalfa aids producers in managing PLH insect damage. However, producers need to continue to monitor PLH populations and occasionally spray or harvest early to avoid forage yield and quality reductions.

Entomologists have found that intercropping alfalfa with forage grasses can result in reduced PLH populations. Monocotyledonous plants such as grasses and sedges do not sustain the development of PLH nymphs (Lamp et al., 1994). In mixtures of conventional, nonglandular-haired alfalfa with smooth bromegrass or orchardgrass (*Dactylis glomerata* L.), PLH populations were reduced compared to alfalfa monocultures, but not below economic thresholds (DeGooyer et al., 1999). Research reported by Roda et al. (1997a), found that numbers of adult PLH were reduced by 22-48% in alfalfa-grass mixtures of either smooth bromegrass or orchardgrass. Also, as alfalfa biomass in the mixture increased, leafhopper emigration decreased. Further research showed that PLH emigration resulted from physical contact with grass rather than from grass volatiles (Roda et al., 1997b). Intercropping forage grass with alfalfa was shown to reduce PLH numbers at harvest by up to 48% (Roda, et al, 1997a).

Forage grass species and cultivars within species vary significantly in heading date, forage yield, and ability to produce forage in mid-summer. For optimum forage quality at first harvest, the forage grass component of the mixture should be in boot stage at the time when the alfalfa is at the bud stage. A system to evaluate forage quality of alfalfa-grass mixtures in spring growth was recently proposed (Parsons, 2005). Factors important in this system were Julian date, alfalfa height, and percent grass. Forage grass species like timothy have low yield in mid-summer when it is hotter and drier, whereas some species

like tall fescue (*Festuca arundinacea* S.) and orchardgrass continue to produce forage in mid-summer.

Potato leafhopper populations, PLH damage to the alfalfa, yield, and forage quality were measured on PLH-resistant alfalfa that was planted with and without timothy in 2003 in New York (Waldron et al., 2004). The alfalfa-grass mixture averaged 10% alfalfa, a significantly lower percentage of alfalfa than in studies by Davis and Fick (1995) and by Roda (1997a). The combination of the PLH- resistant cultivar and timothy resulted in significantly better PLH control than did the resistant cultivar alone. For the plots that were not sprayed with insecticide, the plot with the lowest PLH damage was the resistant alfalfa-grass mixture (score = 1.8; score 1=no damage to 5=severe damage), whereas the resistant cultivar alone scored 2.4 and the susceptible cultivar alone and with grass averaged 3.5. This study was not continued beyond the seeding year due to alfalfa stand decline from winter injury.

Producers may be able to effectively eliminate PLH damage to alfalfa by planting PLH-resistant alfalfa cultivars with a perennial forage grass species. Forage grass attributes that cause PLH to emigrate are not well understood. Factors that may contribute to PLH emigration are grass height, biomass, and growth habit. A complete agronomic and economic analysis of the IPM strategy of PLH-resistant alfalfa-grass mixtures compared to conventional alfalfa in monoculture and in mixtures is needed These research results would give producers the necessary information to make forage crop variety and mixture decisions that would minimize the risk from PLH. Data to document this forage management strategy would allow researchers to begin to model the complex alfalfa-grass-insect relationships. If the amount of grass needed in a mixture is small and grass species/variety choices are such that there is not a significant reduction in forage quality from growing alfalfa-grass mixtures, then the results of this research may convince producers of monoculture alfalfa in other areas of the USA to grow alfalfa-grass mixtures. Additionally, these results may convince producers that PLH-resistant alfalfa cultivars are sufficiently improved in agronomics to replace conventional alfalfa cultivars in their fields.

Forage producers, consultants, and extension agents would benefit from this research in gaining knowledge of forage production systems and improved economics through reduced use of pesticides. Seed company personnel would gain knowledge of factors important in developing seed mixes that have reduced risk of crop damage from pests for sale to producers. Society in general would benefits from reductions in use of pesticides and non-renewable resources to control pests of forage crops, and from benefits to the environment such as reduced erosion associated with alfalfa-grass mixtures.

We propose to plant trials to conduct detailed agronomic and economic analyses of the effects of PLH-resistant alfalfa intercropped with timothy, orchardgrass, and tall fescue on PLH populations and crop damage. Timothy will be used to model the forage grass species that have low mid-summer yields, and tall fescue and orchardgrass will be used to model the forage grass species that have higher mid-summer yields.

(b) Objectives and Anticipated Impacts

1. Compare PLH populations, and forage yield and quality in the establishment year and first production year of a conventional, PLH-susceptible alfalfa cultivar and a PLH-resistant alfalfa cultivar, each alone and intercropped with perennial forage grass species timothy, orchardgrass, and tall fescue.
2. Complete partial budget economic analysis of forage production using PLH-resistant alfalfa in alfalfa-grass mixtures.
3. Share results of this study in extension outreach opportunities throughout New York, Pennsylvania, and the NE region.

Type of Impact	**Potential impacts to be achieved through this research project**
Safeguarding human health and the environment	a. A new IPM practice of planting PLH-resistant alfalfa cultivars with perennial forage grasses could potentially be adopted on a majority of the alfalfa acres in the Northeast. b. Of the acres of monoculture alfalfa planted in NE, some percentage of these acres could be replanted to alfalfa-grass mixtures. This would benefit the environment by reducing soil erosion, and reduce use of herbicides that keep alfalfa stands weed free. c. Planting PLH-resistant alfalfa cultivars with perennial forage grasses would minimize and could potentially eliminate the use of insecticides to control PLH thereby protecting humans and beneficial insects including pollinator insects. d. The forage grass would utilize a portion of the nitrogen fixed by the alfalfa thereby reducing the amount of soil nitrogen available that could potentially leach into ground water.

Type of Impact	**Potential impacts to be achieved through this research project**
Economic benefits	a. Through strategic cultivar selection prior to planting, a producer could save money through reduced use of insecticides to control PLH and reduced use of herbicides. Grass cultivar selection would be critical to this IPM strategy success in selecting grass cultivars with appropriate maturity and biomass such that the pest control benefits would be gained without economically significant reductions in forage quality. b. In order to develop alfalfa-grass seed mixes, forage agronomists would be employed. Seedspeople and consultants would be able to communicate to producers the benefit of these seed mixes. Forage breeders would work to develop alfalfa with improved PLH resistance and forage grasses with desired characteristics that encourage PLH emigration. c. Assuming that PLH-resistant alfalfa cultivars and forage grasses act synergistically in PLH population reduction, then most producers that plant PLH-resistant alfalfa with forage grass will likely be satisfied with the reduction in PLH populations. In years where the alfalfa-grass mixtures are not harvested prior to a reduction in forage quality due to weather or equipment issues, it is important to quantify how much loss in forage quality can be offset by expenses associated with reduced pesticide use. All organic producers will likely be satisfied with the PLH-resistant alfalfa-grass mixtures because they do not have the choice of pesticide application for insects and weeds. d. Other potential financial benefits from PLH-resistant alfalfa-grass mixtures would be improved activities of beneficial insects, improved soil health due to reduced compaction from harvesting equipment, improved alfalfa health from reduced frost-heaving, winter injury and traffic injury.

Type of Impact	Potential impacts to be achieved through this research project
Implementation of IPM	a. This project will compare the agronomic and economic impacts of three IPM strategies on forage yield and quality, specifically: PLH-resistant alfalfa in monoculture, perennial forage grass planted with alfalfa, and the combination of PLH-resistant alfalfa with a perennial forage grass. These strategies will be compared to applying insecticides. b. Educational materials will be conveyed to stakeholders through six channels: extension agents and county newsletters, communications developed specifically for seed company personnel, field days for producers, extension agents, and seed company personnel, university press releases, certified crop adviser training and education, and IPM and forage related web sites. c. Over 500 people will be directly communicated with in NY and PA through field days and extension agent training sessions. d. Research impacts will be communicated through pages on currently existing websites. For New York, a web site that details results of forage variety testing would contain specific pages for selection of forage variety combinations for PLH control. Furthermore, research recommendations would be integrated into NE states forage crop management recommendation sites such as fieldcrops.org for NY. e. Through the sale and marketing of improved seed mixes, producers that are not currently using this IPM strategy would adopt this practice. Successful IPM strategies give producers confidence in proceeding with other types of IPM strategies in other areas of their business. f. Stakeholders are interested in reducing costs of doing business without sacrificing production capabilities. This research could result in reduced costs associated with producing high yield and quality of forage. Producers satisfied with improvements in one aspect of pest management could bring new ideas to the table and collaborate to achieve new production efficiencies.

(c) Approach and Procedures

This project is a multi-state collaboration between New York and Pennsylvania. New York and Pennsylvania together produce 86% of the NE Region's alfalfa and alfalfa-grass mixtures (NASS, 2003). Researchers with expertise in entomology, integrated pest management, agronomy, agricultural economics, and plant breeding at Cornell University and Pennsylvania State University will collaborate on the proposed project for two years. The three proposed locations for research plots are Landisville, Pennsylvania; Rock Springs, Pennsylvania; and Ithaca, New York. In the spring of 2006, a field plot trial will be planted at each of the three locations. These trials will be monitored for two years, since the PLH damage will likely be the highest at the seeding year (2006), and beyond the first production year (2007), uniform distribution of grass within the alfalfa plots may not be maintained. Funding for a second trial

location in New York will be applied for through the 2006 NYS IPM Agricultural Grants Program.

For each location, the trial design will be a split-plot with insecticide treatment as the main plot, and alfalfa and alfalfa-grass mixtures as the sub-plots. Five main plots will be planted. One-half of each main plot will be sprayed with insecticide to minimize damage from PLH and one-half will not be sprayed. The insecticide-treated plots will be sprayed with 'Warrior' insecticide every two to three weeks starting in mid-June. Alleyways between the main plots will be large enough to avoid drift of the pesticide when spraying.

Within the main plots, the sub-plots will be an alfalfa cultivar with high resistance to PLH and a conventional alfalfa cultivar each clear-seeded, and each seeded with a cultivar of timothy, a cultivar of tall fescue, and a cultivar of orchardgrass. Thus the total number of treatments per main plot will be eight.

Plot size will be 3 x 6 m and will be seeded with Carter seeders. Each plot will be seeded twice, first with alfalfa and then with either alfalfa or grass, for a within plot row spacing of 8 cm. Beginning in 2006 at the first harvest, and prior to forage harvests where there is moderate to severe PLH damage to the conventional alfalfa cultivar, the following data will be collected on each plot at each location: percent grass and alfalfa, height of grass, height of alfalfa, PLH damage score on the alfalfa, number of PLH nymphs per ten alfalfa stems per plot, PLH counts from sweep data, forage quality, and forage yield. If PLH damage is not present, as is expected at last harvest in 2006 and at first and last harvests in 2007, then the plots will be sampled for percent grass and alfalfa and forage quality, and harvested for yield.

For nymph counts, ten alfalfa stems will be cut from within each plot area, placed in a plastic bag (one bag per plot), and placed in a cooler for counting within two to three days after collection. Each plot will be swept with a sweep net, and the PLH adults and nymphs will be counted. Samples of the alfalfa and grass will be hand-harvested. The alfalfa and grass will be separated, and placed in separate paper bags for drying at 55 degrees C. The alfalfa and grass samples will each be measured for height. The alfalfa portion of the sample will be rated for PLH damage on a scale of one to five where one is a sample that has no apparent or minor PLH damage and a five is a sample with severe stunting and yellowing symptoms of PLH damage. Following hand harvest, the plots will be mechanically harvested for yield. Samples for dry matter correction will be taken from two plots of each treatment/spray combination (total of 40 dry matter samples). Plot dry matter will vary depending on the botanical composition of the plot and amount of PLH damage to the alfalfa.

Samples collected and dried for estimation of percent grass and alfalfa per plot will be recombined and used for forage quality analyses. The dried samples from all three trials will be sent to Cornell University Department of Plant Breeding and Genetics for grinding and collection of near infrared reflectance spectra (NIRS). All samples will be ground and analyzed with one set of grinding machines and one NIRS machine for maximum consistency of sample handling. Forage quality will be predicted by NIRS.

Approximately twenty percent of the samples collected will be analyzed in a wet-chemistry lab for concentrations of crude protein, and neutral detergent fiber. These data will be used to develop calibration equations that will be applied to the whole data set for prediction of forage quality components.

For the establishment of the plots, Pennsylvania State University will plant two trials and Cornell University will plant one trial. For harvesting and data collections, the trials in Pennsylvania will likely be sampled for PLH populations at two harvests in each of the two growing seasons. In New York state, the trials will likely be sampled at one harvest in each of the two years since PLH infestations usually are at damaging levels later in the growing season than they are in areas to the south. Forage quality samples from either all the plots in a trial or from a subset of samples, will be taken prior to each harvest time for use in the economic analysis. A subset of samples will be taken when PLH damage to the plots is not evident. Cornell University will take charge of processing the samples from all three trials for forage quality analyses.

All data will be sent to Cornell University for maintenance in a database. Data will be analyzed by the researcher in charge of the trial. The data will be analyzed as a split-plot by SAS Proc Mixed. Contrasts between PLH-resistant alfalfa and conventional alfalfa, between alfalfa-grass mixtures, and between alfalfa monoculture and alfalfa-grass mixtures will be estimated and tested for statistical significance. Furthermore, contrasts between insecticide-treated alfalfa-grass mixtures and no-insecticide alfalfa-grass mixtures will be tested for statistical significance.

A farm business manager's decision making efforts, regarding proposed changes in the farm business, benefit from information about the expected effects on financial performance. Partial budget analyses will be used to determine expected changes in profit, a measure of financial performance, associated with various changes in the farm business and changes in pest management practices. A partial budget analysis answers the following questions: What income and value of production will be added? What costs will be reduced? What income and value of production will be reduced? What costs will be added? Expected factors to be incorporated into the analyses include changes in: scouting costs and insecticide use; other costs of production; and value of forage produced due to changes in forage quantity and quality. Expected changes in profit associated with combinations of PLH resistant cultivars, grass mixes, and insecticide treatments will be used to identify an optimal pest management strategy(ies).

Conclusions and guidelines for producers to use in managing PLH damage to alfalfa and alfalfa-grass mixtures will be developed cooperatively by all principal investigators. Educational materials will be conveyed to stakeholders through six channels: extension agents and county newsletters, communications developed specifically for seed company personnel, field days for producers, extension agents, and seed company personnel, university press releases, certified crop adviser training and education, and IPM and forage related web sites. Also, peer-reviewed articles would be published in appropriate journal(s).

PROJECT TIME TABLE

Objective	Phase	Tasks	Compete by
Establish plots in PA and NY	1	Acquire donated seed	March 1, 2006
		Package seed	April 1, 2006
		Prepare field plots	April 15, 2006
		Plant trials	April 20-May 10, 2006
		Apply herbicides	Mid-late June, 2006
Apply treatments and sample at each harvest period –year 1	2	Apply insecticide	June-Sept., 2006
		Sample PLH populations	June-Sept. 2006
		Sample Forage Quality	June-Sept. 2006
		Harvest Plots	June-Sept. 2006
Analyze first year results	3	Process forage samples	Oct. 2006-Jan. 2007
		Analyze agronomic data	Oct. 2006-Jan. 2007
		Conduct economic analyses	Oct. 2006-Jan. 2007
		Develop, and present outreach materials for first year	Oct. 2006-July 2007
Apply treatments and sample at each harvest period – year 2	4	Apply insecticide	June-Sept., 2007
		Sample PLH populations	June-Sept. 2007
		Sample Forage Quality	June-Sept. 2007
		Harvest Plots	June-Sept. 2007
Analyze second year results	5	Process forage samples	Oct. 2007-Jan. 2008
		Analyze agronomic data	Oct. 2007-Jan. 2008
		Conduct economic analyses	Oct. 2007-Jan. 2008
		Develop, and present outreach materials –project conclusion	Oct. 2007-May 2008
Disseminate final project conclusions and outcomes	6	Write reports and articles, present results at meetings, develop web pages	Oct. 2007-

(d) Evaluation Plans

The project will be evaluated on the basis of successful research providing new information useful to forage producers, agronomists, and seedspeople in the NE. Information from this study is unlikely to result in one clear recommendation for all producers in the NE. Rather, success will be achieved through development of a set of guidelines for producers to use in predicting the potential for certain grass mixtures with PLH-resistant alfalfa to result in little or no forage yield and/or quality penalty for not applying insecticide.

Ultimately, the success of this study lies in grower adoption of project results, an increase in acreage of PLH-resistant alfalfa, and a decrease in insecticide use to manage PLH in alfalfa. Indications of success will be seen in seed catalogs where forage seed mixes have been developed specifically for reducing risk from PLH damage. These forage seed mixes, either premixed prior to sale or purchased separately by producers and mixed prior to planting, could be planted on most if not all of a producer's acres for forage production. No new technology would be needed for a producer to implement this IPM strategy. Rather strategic variety and cropping mix selections could potentially reduce management efforts required to control PLH.

It is estimated that at least two-thirds of the alfalfa acreage in the NE already include a perennial forage grass. Alfalfa-grass mixtures are grown to help improve stand persistence on moderate to poorly drained soils common to many areas of the NE, reduce soil erosion, manage weed encroachment, and aid speed of hay drying. Integrating PLH-resistant alfalfa cultivars into these mixtures should add an important pest management dimension by protecting forage yield and quality from impacts of this serious insect pest and enhancing net profitability through the virtual elimination of insecticide use in these settings. Furthermore, producers that currently do not intercrop alfalfa and grass, may choose to do so based on the project results. Perceived forage quality penalties from alfalfa-grass mixtures compared to alfalfa may not be significant with forage grass varieties whose maturity matches well with alfalfa maturity.

All forage grasses will likely not be equal in resulting in PLH emigration. One important research result will be to discover what factors in forage grass species are needed to encourage the PLH to move out of a particular field. It may be that the amount of grass biomass above the alfalfa canopy, or the amount of total grass biomass in a mixture is an important PLH deterrent. This research project will begin to gather information concerning the PLH-alfalfa-grass interactions and what factors determine crop suitability for the pest.

Results of this study will be effectively communicated to producers through extension meetings and presentations, field days, publications for farm magazines and newspapers, university press releases, CCA training and education, and IPM and forage related web sites. Similarly, seed companies and salespeople will be sent trial results and conclusions, such that seed mixtures could be developed for sale to producers that have the maximum likelihood of reducing yield and quality losses from PLH damage without insecticide applications.

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Key Personnel

Project Director:
Dr. Donald Viands, Professor of Plant Breeding and Genetics, Associate Dean and Director of Academic Programs, Cornell University

Dr. Viands will oversee progress of the research project, and will be available for advice and for design of all aspects of the project. He specifically will provide field space in Ithaca, planting and harvesting equipment, supplies, and computers that will be used by experienced personnel and seasonal employees to complete the work for the research project in Ithaca, New York. He will review the data summaries from each research plot, and be involved in drawing conclusions from these studies and in developing and reporting guidelines for producers. He will review all research publications that result from this project.

Project Co-Director:
J. Keith Waldron, Senior Extension Associate, IPM Coordinator, Cornell University

Keith will facilitate cooperative research between Cornell University and Pennsylvania. He will be involved in all aspects of research design, particularly in the collection of data relating to insect populations and economic analyses. Also, Keith will be involved in drawing conclusions from these studies and in developing guidelines for producers. He will use his expertise in determining the best avenues for dissemination of research results. Keith will travel to all trial locations to view the progress at each site, and to the scientific meetings to present results.

Project Co-Director:
Dr. Marvin Hall, Professor of Forage Management, Pennsylvania State University

Dr. Hall will direct all aspects of the research plots in Pennsylvania. He will specifically advise on the sampling for forage quality and on research related to alfalfa-grass mixtures. He will supervise personnel responsible for day-to-day activities for the research project at Rock Springs. He will review results of the research trials, and be involved in drawing conclusions from these studies and in developing guidelines for producers. As the Pennsylvania forage extension agronomist, he will provide new pest management information for extension personnel and producers.

Project Co-Director:
Dr. John Losey, Professor of Entomology, Cornell University

Dr. Losey will advise on all aspects of sampling for PLH in field trials and will supervise personnel responsible for assisting with plot research in New York. He will review results of the research trials and be involved in drawing conclusions from these studies. He will direct efforts to model alfalfa-grass intercrop interactions with PLH.

Project Co-Director:
Dr. David Johnson, Senior Project Director and Associate Professor

Dr. Johnson is manager of the Southeast Agricultural Research and Extension Center. He will provide field space and coordination of the research plot at Landisville, Pennsylvania. He will analyze and review results of the research trial at Landisville and be involved in drawing conclusions from these studies.

Project Co-Director:
John Hanchar, Extension Associate, Cornell University

John Hanchar will complete partial budget analyses for each trial location. He will be involved in drawing conclusions from these studies concerning the impact of this IPM strategy on producer crop profitability.

Project Co-Director:
Dr. Julie Hansen, Research Associate, Cornell University

Dr. Hansen will be responsible for all aspects of the trials in New York, as well as for the forage quality samples from the four trials. She will supervise and be involved in data collection on the trials, analyze the results from Ithaca, manage the database, review results from all trials, be involved in drawing conclusions from these studies and in writing research reports. As a Research Associate under the direction of Dr. Viands on the Cornell Forage Breeding Project, she would meet regularly with the Project Director concerning project progress.

Collaborator:
Dr. Jerry Cherney, Professor, Cornell University

Dr. Cherney will be available for advice on all aspects of the research project in New York and will be involved in reporting the research results to New York extension personnel and producers. He will use the data from these studies to validate his new alfalfa-grass mixtures forage quality prediction model.

Collaborator:
Dr. Dennis Calvin, Professor of Entomology, Pennsylvania State University

Dr. Calvin will advise on the sampling for insect populations and on research related to PLH. He will review results of the research trials, and be involved in drawing conclusions from these studies and in developing guidelines for producers.