Lamb, R. J., P. A. MacKay, and A. Alyokhin. 2011. Population variability and persistence of three aphid pests of potatoes over 60 years. *Canadian Entomologist* 143: 91–101.
Abundance, persistence, and variability of populations of *Macrosiphum euphorbiae* (Thomas), *Myzus persicae* (Sulzer), and *Aphis nasturtii* Kaltenbach (Hemiptera: Aphididae) in potato plots for intervals of 58 years (n=1), 29 years (n=2), 19–20 years (n=3), and 9–10 years (n=6) were compared. The abundance of *M. euphorbiae* showed no trend among decades and varied 2.4-fold, whereas that of *M. persicae* and *A. nasturtii* declined and showed 54-fold and 3700-fold variation, respectively. All three aphid species persisted through the first five decades and *M. euphorbiae* also persisted through the sixth (last) decade, but *M. persicae* and *A. nasturti*i failed to persist for 1 and 3 years of the last decade, respectively. Population variability (a proportion between 0 and 1) measured over a 58-year interval was high: 0.585 for *M. euphorbiae*, 0.771 for *M. persicae*, and 0.830 for *A. nasturtii*. During the first three but not the last three decades, population variability increased with sampling interval, owing to dramatic declines in abundance for *M. persicae* and *A. nasturtii* and one stable decade for *M. euphorbiae*, but no evidence of a more-time 2 more-variation effect was detected. Persistence was not related to population variability, but declined with abundance. Populations did not reach equilibrium, because of declining abundance for *M. persica*e and *A. nasturtii* and changes in population variability from decade to decade for *M. euphorbia*e. Populations of *M. persicae* and *A. nasturtii* from this crop monoculture were less stable than previously studied natural populations of a native aphid species. In contrast, the population of M. euphorbiae, a native species, had variability in a potato crop similar to that of the previously studied native species. The high population variability of *M. persicae* and *A. nasturtii* may be associated with their status as introduced species. The dynamic and species-specific characteristics of population variability require that interspecific comparisons be considered cautiously.

Alyokhin, A. and R. Choban. 2010. Maturity-dependent mortality of Colorado potato beetle eggs treated with novaluron. *American Journal of Potato Research* 87: 557–560.
Novaluron is a chitin synthesis inhibitor (a benzoylphenyl urea) that kills larval stages and causes reversible cessation of laying viable eggs in adults of the Colorado potato beetle, *Leptinotarsa decemlineata* (Say). Previous studies also suggest that it has ovicidal properties, but not on all tested egg masses. We investigated if egg maturity at the time of exposure affects its susceptibility to novaluron. Novaluron application significantly reduced the hatch of eggs that were 0–24 h old at the moment of treatment, but had no effect on the eggs that were 96–120 h old. Novaluron also interfered with the development of the hatched larvae regardless of the egg age at the time of treatment, probably due to chorion feeding by neonates. Ovicidal properties of novaluron may contribute to Colorado potato beetle control, but their effect will be limited to newly laid eggs. If that window of susceptibility is missed, hatching larvae will be exposed to a fairly old novaluron residue that might be weathered down to sublethal levels. This supports the current recommendations to apply novaluron as a larvicide.

Finlayson, C., A. Alyokhin, S. Gross, and E. Porter. 2010. Differential consumption of four aphid species by four lady beetle species. 10pp. *Journal of Insect Science* 10:31, available online: insectscience.org/10.31.
The acceptability of four different aphid species, *Macrosiphum albifrons* (Essig), *Macrosiphum euphorbiae* (Thomas), *Macrosiphum pseudorosae* Patch, and *Myzus persica*e (Sulzer) (Hemiptera: Aphididae), as prey for four lady beetle species, one native species *Coccinella*

trifasciata L, and three non-native species, *Coccinella septempunctata* L, *Harmonia axyridis* Pallas, *Propylea quatuordecimpunctata* L (Coleoptera: Coccinellidae) were tested in the laboratory. The relative field abundance of adults of the same lady beetle species on host vegetation, *Lupinus polyphyllus* Lindl. (Fabales: Fabaceae), *Solanum tuberosum* L (Solanales: Solanaceae), and *Rosa multiflora* Thunberg(Rosales: Rosaceae), both with and without aphids present was also observed. In the laboratory, *H. axyridis* generally consumed the most aphids, while *P. quatuordecimpunctata* consumed the fewest. The exception was *P. quatuordecimpunctata*, which consumed a greater number of *M. albifrons* nymphs, and *C. trifasciata*, which consumed a greater number of *M. albifrons* nymphs and adults, compared with the other two beetle species. Lady beetles consumed fewer *M. albifrons* compared with the other three aphid species, likely because of deterrent compounds sequestered by this species from its host plant. In the field, *P. quatuordecimpunctata* was the most abundant species found on *L. polyphyllus* and *S. tuberosum*.

Alyokhin, A., J. Makatiani, and K. Takasu. 2010. Insecticide odour interference with food-searching behaviour of *Microplitis croceipes* (Hymenoptera: Braconidae) in a laboratory arena. *Biocontrol Science and Technology* 20: 317-329.

Response to odours plays an important role in resource location by natural enemies, particularly by parasitoid wasps. While a considerable research effort has been dedicated to studying the effects of insecticide intoxication on natural enemy search behaviour, it is yet unknown if the odours themselves interfere with distant chemoreception. We investigated this issue using the food-searching behaviour of *Microplitis croceipes* (Cresson)(Hymenoptera: Braconidae) in laboratory arenas as a model system. Odours of imidacloprid (Genesis®), spinosad (Entrust®), esfenvalerate (Asana®), methamidophos (Monitor®), and vanilla were tested for their ability to interfere with wasp response to the odour of honey. The wasps did not contact the chemicals. Honey odour was generally effective in triggering food-searching behaviour in both honey-fed (and thus conditioned to associate honey odour with food) and unfed, naïve wasps. Mixing honey with imidacloprid and spinosad did not affect wasp responses. The remaining compounds (esfenvalerate, methamidophos, and vanilla) significantly reduced the proportion of positively responding fed wasps, but only methamidophos had such an effect on the unfed wasps. Negative methamidophos effects became completely reversed when wasps were forced to feed on honey in the presence of methamidophos odour. Our results suggest that odours and provision of food may potentially be used to keep beneficial natural enemies away from insecticide-treated areas.

Alyokhin, A., R. Guillemette, and R. Choban. 2009. Stimulatory and suppressive effects of novaluron on the Colorado potato beetle reproduction. *Journal of Economic Entomology* 102: 2078-2083.

The Colorado potato beetle, *Leptinotarsa decemlineata* (Say), is one of the most damaging insect pests of potato. Novaluron is a relatively new benzoylphenyl urea insect growth regulator with good activity against this pest. Earlier studies revealed that feeding on potato foliage treated with novaluron induces reversible egg hatch inhibition in adult Colorado potato beetles. We investigated if novaluron effects depend on physiological state of the beetles at the time of exposure. The following four treatments were created: young beetles unmated at the beginning of the experiment and feeding on potato foliage treated with novaluron, young beetles unmated at the beginning of the experiment and feeding on untreated foliage, older beetles mated at the beginning of the experiment and feeding on foliage treated with novaluron, and older beetles

mated at the beginning of the experiment and feeding on untreated foliage. The beetles were exposed to the respective treatments for five days. After that, both young and older beetles feeding on novaluron-treated leaves were switched onto untreated leaves and monitored for another five days to test their ability to recover. Young beetles unmated at the beginning of the experiment produced more eggs after feeding on the treated foliage, possibly indicating the presence of a pesticide-induced homeostatic modulation. No such effect was observed in the older beetles. Regardless of beetle physiologigal state at the beginning of the experiment, eggs produced on treated foliage did not hatch. The beetles eventually resumed laying viable eggs after being switched onto untreated foliage, with the recovery being delayed by ca. 24 hours in young beetles compared to older beetles. Our results corroborate that novaluron reduces fertility of treated adults.

Finlayson, C. J., A. V. Alyokhin, and E. W. Porter. 2009. Interactions of native and non-native lady beetle species (Coleoptera: Coccinellidae) with aphid-tending ants in laboratory arenas. *Environmental Entomology* 38: 846-855.
Interactions between lady beetles and the European fire ant (*Myrmica rubra* L.) tending potato aphids [*Macrosiphum euphorbiae* (Thomas)] were compared in the laboratory. Lady beetle species native to North America (*Coccinella trifasciata perplexa* Mulsant, *Coleomegilla maculata lengi* Timberlake, *Hippodamia convergens* Guerin-Meneville) and non-native species of Palearctic origin [*Coccinella septempunctata* L., *Harmonia axyridis* (Pallas), *Hippodamia variegata* (Goeze), *Propylea quatuordecimpunctata* L.)] were evaluated. *Harmonia axyridis* consumed a significantly greater number of aphids compared with all other species but *C. septempunctata*. Ant stings affected *H. variegata* and *C. septempunctata* to a greater extent than other species. Ants showed a significantly greater amount of aggression toward *H. convergens* and *H. variegata* compared with *P. quatuordecimpunctata*. *P. quatuordecimpunctata*, *C. trifasciata*, and *H. axyridis* reacted significantly less to ants compared with *H. variegata*, *H. convergens*, *C. maculata*, and *C. septempunctata*. Differences in interactions with natural enemies may explain, in part, the successful establishment of some non-native coccinellids in new habitats.

Alyokhin, A. 2009. Colorado potato beetle management on potatoes: current challenges and future prospects. In: Tennant P, Benkeblia N (Eds) Potato II. *Fruit, Vegetable and Cereal Science and Biotechnology* 3 (Special Issue 1): 10-19. (Invited review article).
The Colorado potato beetle, *Leptinotarsa decemlineata* (Say) (Coleoptera: Chrysomelidae) is the most important insect defoliator of potatoes that can completely destroy potato crops. Its current range covers about 16 million km^2 in North America, Europe, and Asia and continues to expand. A complex and diverse life history, combined with an impressive ability to develop insecticide resistance, make the Colorado potato beetle a challenging pest to manage. Beetle populations on commercial farms are usually suppressed by insecticides, which are likely to remain the predominant approach for the foreseeable future. In addition, the beetles can be controlled through the use of relatively common cultural practices, with crop rotation being the most effective and easily implemented approach. In spite of a long history of breeding efforts, no commercial cultivars resistant to the Colorado potato beetles are currently available on the market. Natural enemies are usually incapable of reducing beetle densities below the economically damaging levels and have to be used in combination with other control techniques. Unfortunately, there will never be a “silver bullet” solution to preventing the damage caused by

this insect. The only sustainable way to protect potato crops is to integrate multiple control techniques into a scientifically sound management approach. This is not an easy task, but the only alternatives are recurrent crop losses in combination with environmental degradation.

Finlayson, C. J., K. M. Landry, and A. V. Alyokhin. 2008. Abundance of native and non-native lady beetles (Coleoptera: Coccinellidae) in different habitats in Maine. *Annals of the Entomological Society of America* 101: 1078-1087.

Several studies suggest the possibility that non-native lady beetles may have replaced native lady beetles in some agricultural habitats. There is relatively little information, however, about lady beetle species composition outside of agricultural habitats. Evans (2004) suggested that native species have retreated to nonagricultural habitats in response to the arrival of non-native lady beetles (habitat compression hypothesis). To test this hypothesis, a survey of lady beetles was conducted in 2004 and 2005 in different habitats in Maine. From May to October, lady beetles were sampled in a variety of agricultural and nonagricultural habitats. In total, 3,487 and 2,903 lady beetles were collected in 2004 and 2005, respectively. Non-native lady beetles were found in a variety of habitats, including the habitats that would have likely served as a refuge for native species if the habitat compression hypothesis applied to the surveyed areas. Native species were found in a higher proportion in agricultural habitats compared with nonagricultural habitats and in very low numbers in all of the habitats surveyed. *Hippodamia tredecimpunctata tibialis* (Say) and *Coccinella transversoguttata* Brown, the two native species that were once dominant here, made up only 1.09 and 0.07% of the total lady beetles collected, respectively. In this survey,we failed to detect evidence that native lady beetles have retreated to nonagricultural habitats in response to the arrival of non-native lady beetles.

Alyokhin, A., M. Baker, D. Mota-Sanchez, G. Dively, and E. Grafius. 2008. Colorado potato beetle resistance to insecticides. *American Journal of Potato Research* 85: 395–413. (Invited review article).

The Colorado potato beetle, *Leptinotarsa decemlineata* (Say), is widely regarded as the most important insect defoliator of potatoes. Its current range covers about 16 million km^2 in North America, Europe, and Asia and continues to expand. This insect has a complicated and diverse life history, which is well-suited to agricultural environments, and makes it a complex and challenging pest to control. Dispersal, closely connected with diapause, feeding, and reproduction, allow the Colorado potato beetle to employ "bet-hedging" reproductive strategies, distributing its offspring in both space (within and between fields) and time (within and between years).

The Colorado potato beetle played a large role in creating the modern pesticide industry, with hundreds of chemicals tested against it. High selection pressure, together with natural propensity to adapt to toxic substances, eventually resulted in a large number of insecticide-resistant Colorado potato beetle populations. Since the middle of the last century, the beetle has developed resistance to 52 different compounds belonging to all major insecticide classes. Resistance levels vary greatly among different populations and between beetle life stages, but in some cases can be very high (up to 2,000-fold).

Known mechanisms of Colorado potato beetle resistance to insecticides include enhanced metabolism involving esterases, carboxylesterases and monooxygenases, and target site insensitivity, as well as reduced insecticide penetration and increased excretion. There is also some evidence of behavioral resistance. Resistance mechanisms are sometimes highly diverse

even within a relatively narrow geographical area. Resistance is usually inherited as an incompletely dominant or incompletely recessive trait, with one or several genes involved in its determination. Because of pleiotropic effects of resistant alleles, insecticide-resistant beetles often have reduced relative fitness in the absence of insecticides.
Rotating different classes of insecticides and reducing insecticidal pressure on pest populations by provision of temporal and spatial refuges from exposure to toxins have been proposed to delay evolution of resistance. However, insecticide resistance in this insect will likely remain a major challenge to the pest control practitioners. Still limited understanding of beetle biology, its flexible life history, and grower reluctance to adopt some of the resistance management techniques create impediments to successful resistance management. Overcoming these obstacles is not an easy task, but it will be crucial for sustainable potato production.

Alyokhin, A., G. Sewell, and R. Choban. 2008. Reduced viability of Colorado potato beetle, *Leptinotarsa decemlineata*, eggs exposed to novaluron. *Pest Management Science* 64: 94-99.
BACKGROUND: Novaluron is a benzoylphenyl urea chitin synthesis inhibitor that combines good activity against larval stages of the Colorado potato beetle, *Leptinotarsa decemlineata* (Say) (Coleoptera: Chrysomelidae), with low mammalian toxicity. Previous studies suggest that it has deleterious sublethal effects on adults.
RESULTS: Continuous exposure ofadult Colorado potato beetles to novaluron-treated foliage as both ovipositional and feeding substrate did not affect their survivorship or the number ofeggs produced, but viable larvae hatched only from the eggs that were laid on the first day ofthe experiment. Viability was restored after adult beetles spent 48-96 hours on untreated leaves. In a separate experiment, direct exposure to novaluron ofeggs laid by unexposed beetles also reduced the number oflarvae hatching.
CONCLUSIONS: Results confirm a negative effect of novaluron on the number of progeny produced by the Colorado potato beetle. Direct toxicity did not explain all of the reduction in egg hatch observed, suggesting that novaluron probably acted on reproductive adults as well as on eggs after they were deposited.

Baker, M. B., A. Alyokhin, A. H. Porter, D. N. Ferro, S. R. Dastur , and N. Galal. 2007. Persistence and inheritance of costs of resistance to imidacloprid in Colorado potato beetle. *Journal of Economic Entomology* 100: 1871-1879.
Reduced fitness among resistant versus susceptible individuals slows resistance evolution and makes it easier to manage. A loss of resistance costs could indicate novel adaptations or mutations contributing to resistance. We measured costs of resistance to imidacloprid in a Massachusetts resistant population compared with a Massachusetts susceptible population in 1999 in terms of fecundity, hatching success, egg development time, and sprint speed. Resistance was additive and seemed to be polygenic with high heritability. The fecundity cost appeared overdominant in 1999, and the hatch rate cost was partly recessive in 1999, but neither was significantly different from dominant or recessive. In 2004, we repeated our measures of resistance costs in Massachusetts in terms of fecundity and hatching success, and we added a new resistant population from Maine. In 2005, we compared development time of Maine resistant and the laboratory susceptible colony eggs. Significant fecundity costs of resistance were found in both population in both 1999 and 2004, and significant egg developmental time costs were found in 1999 and 2005. However, the hatching success costs of resistance were

significant in 1999 and not apparent in 2004, suggesting some modification or replacement of the resistance genes in the intervening time.

Andreson, M.W., M. Teisl, G. Criner, S. Tisher, S. Smith, M. Hunter, S. Norton, J. Jellison, A. Alyokhin, E. Gallandt, S. Haggard, and E. Bicknell. 2007. Attitude changes of undergraduate university students in general education courses. *The Journal of General Education* 56: 149-168.
No abstract available.

Alyokhin, A., G. Dively, M. Patterson, C. Castaldo, D. Rogers, M. Mahoney, and J. Wollam. 2007. Resistance and cross-resistance to imidacloprid and thiamethoxam in the Colorado potato beetle. *Pest Management Science* 63: 32-41.
One of the major challenges in managing the Colorado potato beetle, *Leptinotarsa decemlineata* (Say) is its remarkable ability to develop insecticide resistance to virtually every chemical that has ever been used against it. Resistance is particularly common throughout northeastern U.S. as far north as Maine. The first instances of resistance to imidacloprid have been already reported from several locations in New York, Delaware, and southern Maine. Rotating insecticides with different modes of action may delay insecticide resistance, but successful implementation of this technique depends on a good understanding of resistance and cross-resistance patterns in populations of target pests. We measured LC50 values for imidacloprid and thiamethoxam in Colorado potato beetle populations from a variety of locations in the U.S. and Canada using diet incorporation bioassays. We also evaluated field performance of imidacloprid, thiamethoxam, and clothianidin against imidacloprid-resistant beetles on a commercial potato farm in southern Maine. Correlation between LC50 values for imidacloprid and thiamethoxam was highly significant, even when populations previously exposed to thiamethoxam were excluded from the analysis. There was no statistically detectable difference in the LC50 values between populations exposed to both chemicals and to imidacloprid alone. Applications of neonicotinoid insecticides at planting delayed build-up of imidacloprid-resistant beetle populations on field plots by 1-2 weeks, but failed to provide adequate crop protection. Consistently with bioassay results, there was also substantial cross-resistance among the three tested neonicotinoid insecticides. Results of the present study support the recommendation to avoid rotating imidacloprid with thiamethoxam as a part of resistance management plan.

Alyokhin, A., G. Dively, M. Patterson, D. Rogers, M. Mahoney, and J. Wollam. 2006. Susceptibility of imidacloprid-resistant Colorado potato beetles to non-neonicotinoid insecticides in the laboratory and field trials. *American Journal of Potato Research 83: 485-494.*
Repeated use of neonicotinoid insecticides has resulted in the first reported cases of Colorado potato beetle (*Leptinotarsa decemlineata* (Say)) resistance to imidacloprid. In the laboratory we determined susceptibility of the imidacloprid-resistant Colorado potato beetles from a population in Southern Maine to other insecticides currently registered for use on potato. This population was about 30-fold resistant to imidacloprid and could not be effectively controlled by its applications. Control mortality was significantly higher for the imidacloprid-resistant larvae than for the susceptible larvae, suggesting that fitness disadvantages may be associated with the resistance trait. Resistant larvae exhibited significantly less mortality than susceptible larvae

when exposed to cyfluthrin, carbaryl, azinphosmethyl, and methamidophos. Their susceptibility to oxamyl was also somewhat reduced, although it did provide nearly 100% mortality at the highest concentration tested. Disulfoton was highly toxic to the resistant larvae. Oxamyl killed about 40% of the adults in greenhouse assays with potted potato plants, altered their feeding behavior (fewer adults up on plants), and reduced defoliation by more than 90%. Disulfoton was not lethal to adults, but significantly suppressed their feeding. In field trials with the resistant population, oxamyl and imidacloprid + spinosad provided the best beetle control. Novaluron had no detectable effect on beetle densities. There was little difference between the plots treated with imidacloprid or thiamethoxam and the untreated control. Our results suggest that insecticide rotation may be a valuable option for managing imidacloprid-resistant Colorado potato beetle populations. We also had a good consistency between the results of the Petri dish, greenhouse, and field experiments, indicating that screening under laboratory confinement may be useful when developing initial recommendations to potato growers in areas affected by resistance to neonicotinoids.

Narayandas, G. and A. Alyokhin. 2006. Diurnal patterns in host finding by potato aphids, *Macrosiphum euphorbiae* (Homoptera: Aphididae). *Journal of Insect Behavior* 19: 347-356.
Potato aphid, *Macrosiphum euphorbiae* (Homoptera: Aphididae), is an abundant potato pest and vector of potato leaf-roll virus and potato virus Y in Maine and other potato growing areas. We investigated the circadian rhythmicity of its movement towards host plant odor. Effects of daily cycle (day or night) and illumination (light or dark) on the proportion of aphids colonizing potato leaflets were determined in a Petri plate arena and in a Y-tube olfactometer. In Petri dishes, both daily cycle and light had a highly signifi- cant effect on plant colonization. Increasing temperature reduced aphid colonization of the leaflets. In the olfactometer, light had a significant effect on the proportion of aphids walking towards the host plant. Interaction between time and light was also statistically significant, with the effect of illumination being smaller during the day than during the night. Our results suggest that circadian rhythm in host-finding behavior of the potato aphid is regulated by both exogenous and endogenous mechanisms.

Narayandas, G., A. Alyokhin, R. Alford, D. Weber, and J. C. Dickens. 2006. Response of potato aphid (Homoptera: Aphididae) to synthetic potato-derived Colorado potato beetle attractant and natural potato odor. *Journal of Economic Entomology* 99: 1203-1208.
A recently synthesized kairomone blend, based on the volatiles produced by potato plants, has been demonstrated to be attractive to both adult and larval stages of the Colorado potato beetle, *Leptinotarsa decemlineata* (Say). It was subsequently formulated in a viscous inert carrier for field applications and showed potential for aggregating beetles in treated areas of the field. We investigated effects of this kairomone formulation on the potato aphid, *Macrosiphum euphorbiae* (Thomas). The response of both winged and wingless adults to natural potato foliage and synthetic kairomone was tested in a Y-tube olfactometer. Aphid response to untreated potato foliage, foliage treated with the kairomone blend, and foliage treated with blank inert carrier was also tested in Petri dishes. In addition, aphid densities on field plots treated with kairomone and blank inert carrier were compared to the control plots. The untreated potato foliage was found to be attractive to wingless, but not winged, potato aphids. In the olfactometer, the foliage treated with synthetic Colorado potato beetle kairomone was not attractive to either winged or wingless aphids. In Petri dishes, aphids avoided leaflets treated with both kairomone formulation and its blank carrier. There was no statistical difference between any treatments compared in the field.

Narayandas, G. and A. Alyokhin. 2006. Interplant movement of potato aphid (Homoptera: Aphididae) in response to environmental stimuli. *Environmental Entomology* 35: 733-739.
Potato aphid, *Macrosiphum euphorbiae* (Thomas), is a highly mobile aphid species that dominates aphid communities in Maine potato fields and may contribute to virus transmission between potato plants. We studied effects of simulated rain, wind, mechanical raking, fungicide application, reflective mulch, and predator (lady beetle, *Harmonia axyridis* (Pallast) on the interplant movement of wingless adult potato aphids in greenhouse experimental arenas that imitated small segments of a potato field. The number of aphids dispersing from the central plant in the arena following tested perturbation was recorded. Experiments were repeated with 3-4 week old plants with non-overlapping canopies and with 4-5 week old plants with canopies overlapping within rows. Aphids moved between potato plants even when canopies did not overlap, and without any environmental perturbations. However, more aphids moved between larger plants with overlapping canopies. Rain significantly encouraged aphid movement between plants with non-overlapping canopies. Wind, rain, and mechanical raking significantly encouraged aphid movement between plants with overlapping canopies. Regardless of canopy overlap, most aphids moved within the rows of potato plants. However, there was also considerable movement between the rows, even though the aphids had to walk over bare soil.

Baker, M.B., Alyokhin, A., S. R. Dastur, A. H. Porter, and D. N. Ferro. 2005. Sperm precedence in the overwintered Colorado potato beetles (Coleoptera: Chrysomelidae) and its implications for insecticide resistance management. *Annals of the Entomological Society of America* 98: 989-995.
Colorado potato beetle, *Leptinotarsa decemlineata* (Say), is the most important insect defoliator of potatoes and is infamous for its ability to develop insecticide resistance. Sperm precedence is an important consideration in developing resistance management plans. We determined the precedence of sperm from a postdiapause spring mating by using irradiated sterile males. We also investigated whether spring mating (with or without fertilization) affects reproduction of overwintered females. Precedence of sperm from spring matings versus overwintered sperm from fall matings was almost complete. Some fertilization from fall matings did take place in this experiment, but it exceeded 10% in only one of the 22 pairings. Females mated only the previous fall laid fewer eggs than spring-mated females, but spring mating did not seem to improve the hatch rate of deposited eggs. On average, mated females started laying 1.6 d sooner than fall-mated females, but this difference was not significant. Hatch rate did not change with time. Precedence of spring matings over stored sperm can help compensate for assortative summer mating among resistant individuals due to differences in developmental time between refuges and treated areas.

Alyokhin, A., F. A. Drummond, and G. Sewell. 2005. Density-dependent regulation in populations of potato-colonizing aphids. *Population Ecology* 47: 257-266.
Scarcity of long-term (over 30 years) data series represents a major challenge for an accurate estimation of the role of density-dependent processes in population regulation. We analyzed population densities of the wingless parthenogenic morphs of buckthorn aphid (BA), *Aphis nasturtii* Kaltenbach, potato aphid (PA), *Macrosiphum euphorbiae* (Thomas), and green peach aphid (GPA), *Myzus persicae* (Sulzer) from 1949 to 2003 for signs of density dependent regulation. We found strong evidence of density-dependent regulation, with detection of density

dependence being fairly consistent among the different statistical techniques. Direct density-dependence was detected for the populations of all three species. There was also evidence of delayed density dependence for PA. The periodicity of population fluctuations for BA and GPA was 6.1 and 3.9 years, respectively. The periodicity for PA was not explicit, being highly variable throughout the time series. Effects of density-independent weather factors were relatively minor compared to density-dependent regulation. BA populations experienced a significant reduction in both density and annual oscillations starting in 1995, while GPA populations experienced a similar reduction in 1991. No such change was apparent for PA. The most likely explanation for the observed phenomenon is a change in the composition of the lady beetle community following the establishment of two alien coccinellid species, and/or changes in insecticide use by commercial growers in the area of the study.

Alyokhin, A. and R. Atlihan. 2005. Reduced fitness of the Colorado potato beetle (Coleoptera: Chrysomelidae) on potato plants grown in manure-amended soil. *Environmental Entomology* 34: 963-968.

Colorado potato beetle, *Leptinotarsa decemlineata* (Say), is the most important insect defoliator of potatoes worldwide. In this study, we conducted a series of no-choice assays comparing Colorado potato beetle reproduction and development on potato plants grown in manure-amended and synthetically fertilized soils. Manure-amended soil received annual applications of raw cow manure since 1991, and additional applications of cull potato compost and green manure between 1991-1998. Plants grown in manure-amended soil were inferior Colorado potato beetle hosts compared to plants grown in synthetically fertilized soil. The observed negative effects were broad in scope. Female fecundity was lower in field cages set up on manure-amended plots early in the season, although it later became comparable between the treatments. Fewer larvae survived past the first instar, and development of immature stages was slowed down on manure-amended plots. In the laboratory, first instars consumed less foliage from plants grown in manure-amended soils. These results demonstrate that organic soil management is associated with plant characteristics unfavorable for beetle reproduction and development, which should be taken into consideration when designing fully integrated crop management systems.

Alyokhin, A., G. Porter, E. Groden, and F. Drummond. 2005. Colorado potato beetle response to soil amendments: a case in support of the mineral balance hypothesis? *Agriculture, Ecosystems, and Environment* 109: 234-244.

The mineral balance hypothesis [Phelan, L.P., Norris, K.H., Mason, J.F., 1996. Soil management history and host preference by *Ostrinia nubilalis*: evidence for plant mineral balance mediating insect-plant interactions. Environ. Entomol. 25, 1329-1336] suggests that the organic matter and microbial activity associated with organically managed soils afford a buffering capability to maintain nutrient balance in plants. An optimal nutrient balance, in turn, results in both good plant growth and resistance to herbivory. Effects of soil amendment practices on Colorado potato beetle populations in potato fields and their interactions with crop rotation and two pest management approaches were investigated in the present study. Beetle densities were generally lower in plots receiving manure soil amendments in combination with reduced amounts of synthetic fertilizers compared to plots receiving full rates of synthetic fertilizers, but no manure. Crop rotation and pest management approaches had little or no effect. Unlike beetle abundance, plant height and canopy cover were comparable between plots receiving manure and synthetic fertilizer. Furthermore, tuber yields were higher in manure-amended plots. In direct accordance

with the mineral balance hypothesis, there was a dramatic dissimilarity in mineral composition of potato leaves collected from manure-amended and synthetic fertilizer-treated plots. Overall, there were differences in concentrations of nitrogen, calcium, magnesium, phosphorus, aluminum, boron, copper, iron, manganese, and zinc. Boron concentration was most dramatically affected by the soil amendment. Mineral content of potato leaves explained 40-57% of the variation in the Colorado potato beetle populations observed among the experimental plots.

Alyokhin, A. and G. Sewell. 2004. Changes in a lady beetle community following the establishment of three alien species. *Biological Invasions* 6: 463-471.

A number of recent studies indicated that establishment of exotic lady beetles (Coleoptera: Coccinellidae) may have adverse affects on native lady beetle species. In the present study, we analyzed changes in coccinellid community inhabiting potato crops in northern Maine over the past 31 years. Prior to 1980, lady beetle communities were comprised almost exclusively of the two native species, *Coccinella transversoguttata* Brown and *Hippodamia tredecimpunctata* (Say). Starting 1980, an exotic species *Coccinella septempunctata* L. became permanently established in potato crops and quickly started to dominate lady beetle community. Two other exotic species, *Harmonia axyridis* (Pallas), and *Propylea quatordecimpunctata* (L.) became prominent members of the lady beetle community in 1995 and 1996. Invasion by exotic species was followed by a significant decline in the abundance of *C. transversoguttata* and *H. tredecimpunctata*, and a significant increase in the overall diversity of lady beetle community. The abundance of aphid prey was substantially reduced after the establishment of *H. axyridis*. The observed trends demonstrate the profound effects that exotic natural enemies may have on target and non-target native species, and highlight the importance of their thorough evaluation before initiating biological control programs.

Alyokhin, A. V., P. Yang, and R. H. Messing. 2004. Oviposition of the invasive two-spotted leafhopper on an endemic tree: Effects of an alien weed, foliar pubescence, and habitat humidity. *7pp. Journal of Insect Science, 4:13, Available online: insectscience.org/4.13*.

The two-spotted leafhopper, *Sophonia rufofascia* (Kuoh and Kuoh), is an exotic pest from South-East Asia that attacks a wide variety of plant species in Hawaii. *Myrica faya* Aiton is an aggressive exotic weed that displaces and excludes native plants in Hawaiian forests. It has been argued that because of the high nutritional quality of its foliage, *M. faya* might facilitate leafhopper invasion of native Hawaiian ecosystems that were originally dominated by the endemic tree *Metrosideros polymorpha* (Gaudichaud). In the present study, we quantified suitability of *M. faya* and *M. polymorpha* as ovipositional hosts for *S. rufofascia*. Overall, leafhoppers preferred to deposit their eggs into the foliage of *M. faya*. *M. faya* presence in the area did not affect leafhopper oviposition on *M. polymorpha*. Foliar pubescence provided good protection of hirsute morphotypes of *M. polymorpha*. At the same time, glabrous *M. polymorpha* morphotypes were quite suitable for leafhopper oviposition. There was no difference in the abundance of leafhopper eggs along a precipitation gradient. Our results confirm that invasion of native Hawaiian forests by the weed *M. faya* will facilitate their invasion by *S. rufofascia*. Because of the broad host range characteristic of the two-spotted leafhopper, this build-up may adversely affect a number of endemic plant species growing in native forests.

Messing, R., A. Alyokhin, L. Quan, C. Yiqun, and F. Xiongxi. 2003. Parasitoids of *Sophonia* leafhoppers in Southern China. *Proceedings of the Hawaiian Entomological Society* 36: 111-114.

Leafhoppers and their parasitoids in Fuzhou, China, were sampled from 1998 to 2001 in order to find their natural enemies with potential for biological control of *Sophonia rufofascia* in Hawaii. Eleven parasitoid species were found, of which *Chaetomymar* sp. (Mymaridae) were the most abundant, accounting for 65.8% of total parasitism. Parasitism of leafhopper eggs in guava orchards averaged 61.9% from April to November, with peak parasitism in September of 91.4%.

Alyokhin, A. and G. Sewell. 2003. On-soil movement and plant colonization by walking wingless morphs of three aphid species (Homoptera: Aphididae) in greenhouse arenas. *Environmental Entomology*. 32: 1393-1398.

Potato aphid (*Macrosiphum euphorbiae* (Thomas)), green peach aphid (*Myzus persicae* (Sulzer)), and buckthorn aphid (*Aphis nasturtii* Kaltenbach) are polyphagous herbivores that commonly colonize potato plants (*Solanum tuberosum* L.) in Northeastern U.S. and Canada. Their movement influences spatial and temporal patterns of viral spread within potato fields. We investigated aphid movement between potato plants early in the season, with a particular focus on their ability to walk over bare soil. On average, aphids survived 1.16±0.04 days (mean±SE) on the surface of bare soil; all of them dying within three-days. Wingless aphids did not leave potato plants that were adequate as a food supply. When forcibly removed from the host plant and released on the soil surface, all three species colonized the nearest plant within one hour. However, when given no other choice, a significant proportion of aphids was fully capable of colonizing potato plants as far as 180 cm away from the point of release. Potato aphid, which is the largest in size, was the most mobile of the three species. The green peach aphid was intermediately mobile, and the buckthorn aphid was the least mobile species.

Kuhar, T., J. Speese III, J. Whalen, J. Alvarez, A. Alyokhin, G. Ghidiu, and M. Spellman. 2003. Current status of insecticidal control of wireworms in potatoes. *Pesticide Outlook*. 14: 265-267.

No abstract available.

Alyokhin, A. V. and R.H. Messing. 2003. Parasitism of Hawaiian non-frugivorous fruit flies (Diptera: Tephritidae) by an exotic parasitoid *Eurytoma tephritidis* Fullaway (Hymenoptera: Eurytomidae). *Proceedings of the Hawaiian Entomological Society*.36: 29-37.

Eurytoma tephritidis Fullaway (Hymenoptera: Eurytomidae) is an exotic solitary larval endoparasitoid that has been recorded to parasitize gall-forming tephritids in Hawaii. We surveyed *E. tephritidis* parasitism of *Tetreuaresta obscuriventris* (Loew.), *Ensina sonchi* (L.), *Acinia picturata* (Snow), *Procecidochares utilis* Stone, *P. alani* Steyskal, *Trupanea* sp. nr. *cratericola*, and *T. dubautiae* (Bryan) (Diptera: Tephritidae) on four major Hawaiian islands. No wasps emerged from *T. obscuriventris* and *E. sonchi*. Among other species, percent parasitism ranged from less than 1% to over 67%, depending on fly species and sampling location. Overall, *E. tephritidis* showed higher affinity for gall-forming tephritids than flowerhead-feeders, although it parasitized substantial numbers of the native flower-infesting *T.* sp. nr. *cratericola*. The implications of our findings for a more accurate estimation of the risks posed by biological control programs to non-target fruit flies in Hawaii are discussed.

Boiteau, G., A. Alyokhin, and D. N. Ferro. 2003. The Colorado potato beetle in movement. *Canadian Entomologist* 135: 1-22. *(Invited review article).*

The recent introduction of the concept of refuge areas for the management of the Colorado potato beetle, *Leptinotarsa decemlineata* (Say), on resistant potato highlighted the existence of

important gaps in our knowledge and understanding of this pest's dispersal. The objective of this review was to present a synthetic view of the information available for the benefit of crop managers and to identify subject areas in need of additional research. A traditional, somewhat encyclopedic, review of the old and recent literature on research methods, basics of flight and walking as well as abiotic and biotic conditions for dispersal revealed a considerable volume of information accumulated since the early 1900s. There is a consensus on the role of abiotic factors on flight and walking but a better understanding of the biotic factors will be required before the variability of the dispersal response can be fully explained or predicted. Cybernetic models of orientation proposed in the literature were pulled together into a schematic representation of the orientation process in walking *L. decmlineata*. The model begins the integration of the different conditions and underlying suggested mechanisms responsible for the orientation of the walking beetle. There is remarkably little information on the orientation of potato beetles during flight. Finally, the seasonality of walking and flight dispersal is reviewed in relation to the host habitat.

Alyokhin, A. V. , R.H. Messing, and and J. J. Duan. 2002. Infestation of *Elephantopus mollis* (Asteraceae) flowerheads by *Tetreuaresta obscuriventris* (Diptera: Tephritidae) on Kauai, Hawaiian Islands. *Entomological News* 113: 247-252.

Populations of successfully established exotic organisms rarely reach noticeable densities in their new environment, and little information is currently available on the population dynamics of the exotic insects released on the Hawaiian islands. In the present study, we surveyed present incidence of a tephritid fly of New World origin, *Tetreuaresta obscuriventris* (Loew.), on the island of Kauai. This fly was introduced to the island in 1961 for the biological control of an important weed species, *Elephantopus mollis* Kunth. Between 80 and 90% of flowerheads collected from *E. mollis* Kunth in our survey contained immature *T. obscuriventris*. An average infested flowerhead contained approximately 5.2 fly larvae. Fly populations in the surveyed areas followed aggregated distribution, and the mean number of flies per infested flowerhead was positively correlated with the percent of infested flowerheads.

Alyokhin, A., G. Sewell, and E. Groden. 2002. Aphid abundance and potato virus Y transmission in imidacloprid-treated potatoes. *American Journal of Potato Research* 79: 255-262.

Imidacloprid is a commonly used insecticide that is highly effective in controlling insect pests of potato. The relatively high cost of imidacloprid provides commercial growers with a strong incentive to reduce field application rates. In the present study, we investigated the impact of reduced imidacloprid rates on aphid abundance and potato virus Y transmission within potato fields. In-furrow applications of imidacloprid provided better aphid control even at a reduced rate when compared to threshold-based foliar applications, but did not suppress the spread of the non-persistently transmitted potato virus Y. Virus transmission was significantly decreased in foliar-sprayed plots, possibly because foliar applications disrupted virus acquisition by aphid vectors. Despite these generally encouraging results, we still observed 2.3 – 2.7 fold increase in virus infection at foliar-treated plots at the end of the growing season.

Yang, P., D. Foote, A. Alyokhin, L. Lenz, and R. Messing. 2002. Distribution and abundance of mymarid parasitoids (Hymenoptera: Mymaridae) of the two-spotted leafhopper (Homoptera: Cicadellidae) in Hawaii. *Biological Control* 23: 237-244.

The abundance of mymarid parasitoids attacking the two-spotted leafhopper (*Sophonia*

rufofascia [Kuoh and Kuoh]), a polyphagous pest recently adventive to Hawaii, was monitored using yellow sticky cards deployed in several areas on the islands of Kauai and Hawaii. The yellow cards captured *Chaetomymar* sp. nr *bagicha* Narayanan, Subba Rao, & Kaur and *Schizophragma bicolor* (Dozier), both adventive species; as well as *Polynema* sp. Haliday, which is endemic to Hawaii (Hymenoptera: Mymaridae). The former two species were most abundant at all sites. On Kauai, there was a negative correlation between the captures of *C.* sp. nr *bagicha* and *Polynema* sp. Throughout the season, the increase in parasitoid numbers generally followed the increase in leafhopper numbers. *C.* sp. nr. *bagicha* and *S. bicolor* showed distinct habitat preferences. Removal of *Myrica faya* Aiton, an invasive weed that is a highly preferred two-spotted leafhopper host, decreased the overall numbers of captured parasitoids, but lead to a two-fold increase in the ratio of trapped parasitoids/hosts in weed-free areas.

Alyokhin, A. V., P. Yang, and R. H. Messing. 2001. Distribution and parasitism of two-spotted leafhopper eggs (Homoptera: Cicadellidae) in Hawaii. *Annals of the Entomological Society of America* 94: 664-669.
The two-spotted leafhopper, *Sophonia rufofascia* (Kuoh and Kuoh), is a recent invasive pest attacking a wide variety of plant species in Hawaii. We surveyed the distribution and parasitism of its eggs in a number of natural and agricultural habitats on the islands of Kauai, Oahu, and Hawaii. Egg density was fairly low, with egg distribution affected both by plant species and plant habitat. Approximately 40% of *S. rufofascia* eggs, averaged over all plants and sites, were parasitized by *Chaetomymar* sp. nr *bagichi* Narayanan, Subba Rao, & Kaur; *Schizophragma bicolor* (Dozier); and *Polynema* sp. Haliday (Hymenoptera: Mymaridae). Percent parasitism varied widely among different plant species and habitats. *Ch.* sp. nr. *bagichi* was the most abundant and widely distributed species, but the parasitoid guild varied depending on plant and on habitat. The implications of these results on decisions regarding classical biological control of two-spotted leafhopper in Hawaii are discussed.

Alyokhin, A. V., R. H. Messing, and J. J. Duan. 2001. Utilization of the exotic weed *Pluchea odorata* (Asteraceae) and related plants by the introduced biological control agent *Acinia picturata* (Diptera: Tephritidae) in Hawaii. *Biocontrol Science and Technology* 11: 711-718.
The flower-head feeding fly *Acinia picturata* (Diptera: Tephritidae) was deliberately introduced from Mexico into Hawaii in 1959 for biological control of the exotic weed *Pluchea odorata* (Snow) (Asteraceae). Neither field efficacy nor possible non-target effects of the fly have been evaluated in the 40 years since the introduction. We assessed the impact of the fly on both its target host and on 7 non-target plant species. The impact on the target weed was limited, with only 5 - 13% of the developing seeds in *P. odorata* flowerheads being destroyed by larval feeding. We did not detect any host range expansion of *A. picturata* onto flowerheads of 2 exotic or 5 endemic non-target plant species in the family Asteraceae.

Alyokhin, A. V. and R. H. Messing. 2001. Association of *Trupanea dubautiae* (Diptera: Tephritidae) with *Dubautia laxa* (Asteraceae) in Mt. Kaala National Area Reserve on Oahu. *Proceedings of the Hawaiian Entomological Society* 35: 137-139.
No abstract available

Yang, P., A. V. Alyokhin, and R. H. Messing. 2001. Patterns of oviposition and parasitism of eggs of *Kallitaxila granulata* (Homoptera: Tropiduchidae), a newly invasive planthopper

in Hawaii. *Proceedings of the Hawaiian Entomological Society* 35: 77-83.
Kallitaxila granulata (Stal) (Homoptera: Tropiduchidae), a recent invasive species in Hawaii, is a potential pest of agricultural and forest ecosystems. We present information on the planthopper's oviposition behavior, its egg distribution patterns, and the occurrence of egg parasitoids in Hawaii. There were no differences in the percentage of leaves containing *K. granulata* oviposition scars or in the number of eggs per scar among 4 different host plants (guava, hapuu, uluhe and kukui) at 3 different sites. However, there were substantial differences in patterns of egg distribution among the host plants. The planthopper preferred to lay eggs into the veins and to oviposit clutches of eggs in clusters on guava plants, while it tended to lay eggs singly into the veins on hapuu. On kukui, eggs were deposited equally in or off the veins, and were mostly deposited singly. On all 3 host plants, eggs conformed to a negative binomial distribution. Two species of parasitoids were reared from *K. granulata* eggs: *Chaetomymar* sp. near *bagicha* (a common parasitoid of the twospotted leafhopper, *Sophonia rufofascia*), and *Telenomus* sp. (Hymenoptera: Scelionidae). Total parasitism differed among host plants and sites with a range of 0 to 18.5%.

Alyokhin, A. V., R. H. Messing, and J. J. Duan. 2001. Abundance and mating behavior of Oriental fruit flies (Diptera: Tephritidae) in the vicinity of methyleugenol-baited traps. *Pan-Pacific Entomologist* 77: 161-167.
Methyleugenol-baited traps are used for Oriental fruit fly control through male annihilation, as well as for detection and monitoring of fly populations. However, if the males which come to these traps emit sex pheromones, attract females from the surrounding vegetation, and mate with them before being killed, then using such traps might in fact increase levels of fruit infestation. In the present study, we monitored fly abundance in an experimental orchard before, during, and after methyleugenol-baited trap deployment. We also recorded the numbers of flies recruited to the trees with and without traps, and quantified their sexual activity. The males attracted by methyleugenol in our experiments fed on the poisoned baits almost immediately upon their arrival, and did not attempt to emit pheromones or attempt copulations before entering the traps. No changes in female abundance in the vicinity of deployed traps were recorded. Because of their high specificity, low cost, and environmental safety, methyleugenol-baited traps might be a valuable tool for integrated management of Oriental fruit fly populations.

Alyokhin, A. V., C. Mille, R. H. Messing, and J. J. Duan. 2001. Selection of pupation habitats by Oriental fruit fly larvae in the laboratory. *Journal of Insect Behavior* 14: 57-67.
We performed a series of laboratory experiments to determine the effects of shade, soil moisture, and soil compaction on the selection of pupation habitats by wandering late instar Oriental fruit flies, *Bactrocera dorsalis* (Hendel). Larvae showed a strong preference towards pupating in shaded rather than brightly lit areas, in moist rather than dry soil, and in soil with larger particle sizes. These behavioral preferences are likely to lead to clumped distribution of Oriental fruit fly pupae in natural habitats. The implications of this for management of localized populations by chemical and biological methods are discussed.

Alyokhin, A. V, R. H. Messing, and J. J. Duan. 2000.Visual and olfactory stimuli and fruit maturity affect trap captures of Oriental fruit flies (Diptera: Tephritidae). *Journal of Economic Entomology* 93: 644-649.
An effective lure-and-kill trap is a potentially important instrument in monitoring and controlling

Oriental fruit flies, *Bactrocera dorsalis*(Hendel). A number of experiments were performed in a commercial guava (*Psydium guajava* L.) orchard to determine how fly captures are affected by combining visual and olfactory stimuli, and by the timing of trap deployment relatively to host phenology. Baiting sticky Ladd traps with hydrolyzed liquid protein significantly increased the number of captured flies. Mostly male flies were caught in the absence of mature guava fruit, while mostly female flies were caught when ripe fruit was abundant. These results suggest that an effective Oriental fruit fly trap should include both visual and olfactory lures, and that proper timing of trap deployment can be an important factor in monitoring female abundance in Oriental fruit fly populations.

Alyokhin, A. V., D. N. Ferro, C. W. Hoy, and G. Head. 1999. Laboratory assessment of flight activity displayed by the Colorado potato beetles (Coleoptera: Chrysomelidae) fed on transgenic and Cry3A toxin-treated potato foliage. *Journal of Economic Entomology* 92: 115-120.

Adults of full-sib Colorado potato beetle families were separated into three groups fed on different diets: transgenic potato foliage, potato foliage treated with a foliar formulation of *B. thuringiensis* endotoxin (12.37 µg of Cry3A δ-endotoxin per 1µl of mixture), and untreated potato foliage. After feeding for 3 hours, all the beetles were placed on a computer-linked flight mill system. The number of beetles that flew, duration of each flight, and the number of flights for each beetle were recorded. Feeding on transgenic foliage had a strong negative effect on the proportion of beetles that flew, as well as the average number of flights per flying beetle. Mean flight duration was not influenced by the beetle diet, but interaction between family and diet was highly significant, with pronounced family effects observed for the beetles fed on standard and treated foliage. Beetles from families that performed the longest flights when fed on untreated foliage performed the shortest flights when fed on transgenic foliage. Suppression of beetle flight as a result of endotoxin ingestion could keep beetles within transgenic fields, thus increasing selection pressure towards development of physiological resistance. One possible way to reduce this pressure is to provide refugia for susceptible beetles in close association with fields planted to transgenic potato.

Alyokhin, A.V. and D. N. Ferro. 1999. Electrophoretic confirmation of sperm mixing in mated Colorado potato beetles (Coleoptera: Chrysomelidae). *Annals of the Entomological Society of America* 92: 230-235.

Sperm precedence in the Colorado potato beetle, *Leptinotarsa decemlineata* (Say), was investigated using phosphoglucomutase (Pgm) allozymes as genetic markers. Females were mated to two males carrying different Pgm alleles, and the proportion of offspring sired by each male was determined by cellulose acetate gel electrophoresis. Our results indicate that Pgm alleles in the Colorado potato beetle are inherited in the Mendelian fashion, and there is no change in sperm utilization over time. We were also able to confirm that sperm precedence in this insect is incomplete, with about 72% of the larvae fathered by males at the second mating. Possible implications of incomplete sperm precedence for insecticide resistance management are discussed.

Alyokhin, A. V. and D. N. Ferro. 1999. Modifications in flight and oviposition of Bt-resistant and Bt-susceptible Colorado potato beetles as a result of exposure to *Bacillus thuringiensis* subsp. *tenebrionis* Cry3A toxin. *Entomologia Experimentalis et Applicata* 90:

93-101.
Laboratory strains of Colorado potato beetle, *Leptinotarsa decemlineata* (Say), physiologically resistant and susceptible to *Bacillus thuringiensis* (Berliner) subsp. *tenebrionis* Cry3A toxin were reared to adults on caged potato plants. Influence of three different diets (transgenic potatoes, regular potatoes, and regular potatoes followed by the transgenic potatoes) on beetle mortality, fecundity, and flight behavior were tested under laboratory conditions. A computer-linked flight mill system was used to quantify beetle flight, and dissections were performed to determine the level of flight muscle development. Susceptible beetles continuously fed on transgenic foliage suffered heavy mortality, did not develop flight muscles, and did not produce any eggs. Resistant beetles continuously fed on transgenic foliage were capable of flight and reproduction; however, it took them longer to initiate flight behavior, and their fecundity was lower than fecundity of other treatments. In both strains, detrimental effects became significantly less severe when the beetles were allowed to feed on regular foliage prior to toxin ingestion. In the resistant strain, ingestion of Cry3A toxin significantly increased flight activity, indicating that physiological resistance was probably reinforced by the behavioral escape from toxic environments. No such response was observed for susceptible beetles. When fed on regular foliage, resistant Colorado potato beetles engaged in significantly fewer flights than susceptible beetles. Behavioral differences between resistant and susceptible beetles observed in the present study are likely to affect gene flow between transgenic crops and adjacent refugia, and should be taken in consideration when designing resistance management plans for transgenic potato crops.

Alyokhin, A. V. and D. N. Ferro. 1999. Reproduction and dispersal of summer-generation Colorado potato beetle (Coleoptera: Chrysomelidae). *Environmental Entomology* 28: 425-430.
Colorado potato beetle dispersal and reproduction was investigated under field and laboratory conditions. Movement and mating of newly emerged summer-generation Colorado potato beetle adults was monitored in the field using a mark-recapture technique, and beetle mating within experimental plots was recorded. The number of degree-days (DD) required for the beetles to become reproductive was tested in an environmental chamber using 10° C as a developmental threshold. A computer-linked flight mill system was used to quantify the influence of mating on the flight behavior of male and female beetles. Adult dispersal started within the first 24 hours after eclosion from the pupae, but a significant proportion of newly emerged beetles stayed close to the place of their larval development until reaching reproductive maturity. The beetles required at least 34 DD before mating produced viable offspring, and females did not start laying eggs until a minimum of 51 DD after eclosion. Mating had a pronounced effect on beetle flight, decreasing flight activity of the females and increasing flight activity of the males. Enhancing gene flow between beetles surviving on transgenic plants and susceptible beetles in refugia should be advantageous in managing beetle resistance to transgenic plants.
Alyokhin, A. V. and D. N. Ferro. 1999. Relative fitness of Colorado potato beetle (Coleoptera: Chrysomelidae) resistant and susceptible to the *Bacillus thuringiensis* Cry3A toxin. *Journal of Economic Entomology* 92: 510-515.
Laboratory experiments were conducted to compare relative fitness of strains of Colorado potato beetle resistant and susceptible to *Bacillus thuringiensis* subsp. *tenebrionis* Cry3A toxin. Net replacement rates and intrinsic rates of population increase were calculated for resistant and susceptible populations. During the experiment, susceptible males on average copulated 13.3 ± 1.5 times, while resistant males copulated only 8.0 ± 1.0 times. Susceptible females produced an

average of 824.2 ± 68.1 eggs and 590.9 ± 58.5 larvae, which was significantly more than 484.6 ± 48.0 eggs and 334.9 ± 39.7 larvae produced by an average resistant female. As a result, both net replacement rate and intrinsic rate of increase were reduced for the resistant population. Furthermore, twice as many susceptible beetles as resistant beetles survived overwintering diapause. Our results clearly indicate that relative fitness of resistant individuals is reduced in the absence of *Bacillus thuringiensis* in the environment. Therefore, relaxation of selection pressure through refugia and insecticide rotation will favor decrease in the frequency of resistant alleles in beetle populations.

Alyokhin, A. V. and D. N. Ferro. 1999. Mating ability of Colorado potato beetle (Coleoptera: Chrysomelidae) males fed transgenic potato foliage. *Canadian Entomologist* 131: 539-540.

Thirty-three teneral Colorado potato beetle males were provided with non-transgenic foliage for 8 d, another 33 males were provided with non-transgenic foliage for 4 days, and then switched to transgenic foliage for another 4 d, and the remaining 33 males were provided with transgenic foliage for 8 days and then mated to females continuously fed on non-transgenic foliage only. Seventy-five percent of the males continuously fed transgenic foliage died during the first 8 d after eclosion. Only one of the females that mated to surviving males laid a single mass of fertile eggs, producing a total of 14 larvae. All the males from the other two treatments survived throughout the experiment. Ninety-four percent of the males fed non-transgenic foliage and 85% of the males fed both non-transgenic and transgenic foliage sired viable offspring. On average, one fertile female mated to a male fed non-transgenic foliage produced 353.3 eggs (SE=15.9) giving rise to 248.6 larvae (SE=15.9), and one fertile female mated to a male fed both on non-transgenic and transgenic foliage produced 322.9 eggs (SE=22.9) giving rise to 218.9 larvae (SE=18.1). Neither mean number of eggs, nor mean number of larvae was significantly different between the treatments. These results indicate that susceptible Colorado potato beetle males arriving in transgenic potato fields from refugia can mate with resident resistant females.

Ferro, D. N., A. V. Alyokhin, and D. B. Tobin. 1999. Reproductive status and flight activity of the overwintered Colorado potato beetle. *Entomologia Experimentalis et Applicata* 91: 443-448.

Mating behavior of post-diapause Colorado potato beetles, *Leptinotarsa decemlineata* (Say), was observed within an overwintering site, a rotated potato field, newly colonized potato plants, and under laboratory conditions. The influence of spring mating on beetle flight in the presence and in the absence of host plants was investigated using a computer-linked flight mill system. Diapause was terminated simultaneously in male and female beetles, and the first matings were observed as early as within the first 24 hours after the beetles emerged from the soil (60-90 DD accumulated). The beetles mated within the overwintering site, the potato field, and the fields rotated out of potatoes. Mating status did not affect flight behavior of overwintered beetles; however, unfed beetles displayed higher flight activity than fed beetles. Most flight activity took place soon after flight muscle regeneration, and then declined sharply by the 5th day after flight initiation. Mating in or near overwintering sites soon after diapause termination might be an important factor in providing gene flow between insecticide-resistant and insecticide-susceptible Colorado potato beetle populations, and should be considered in designing resistance management plans.