AIP Activity 2: Studies of groundcover vegetation for improved sustainability and management of pests of grapes

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Vineyard groundcover vegetation influences the growth of grapevines and contributes to the management of grape pests. This project investigated the suitability of native and non-native plant species for vineyard groundcover vegetation, assessed the impact of different vegetation types on populations of grape pests and beneficial insects, evaluated its effects on vine growth and fruit quality, and measured effects on populations of beneficial and harmful soil microbes. A large multi-year study (objective A2.1) conducted in 98 commercial vineyards showed a strong correlation between increased drive row plant species diversity and decreased cutworm damage to the buds of grapevines. Certain plant species such as shepherd's purse were identified as contributing to the control.

The distribution, abundance and biology of the Lesser yellow underwing moth, *Noctua comes*, (A2.2) was completed with the collection of large numbers of larvae from the south Okanagan in the spring of 2017 following two years when populations were extremely low. With warmer winter conditions underwing larvae complete their development in spring before the buds of grapes are susceptible to feeding injury. The lesser underwing is now widely distributed throughout the Okanagan valley but largely absent from vineyards on the dry, sandy soils south of Oliver that are drip-irrigated. Feeding choice test and developmental bioassays showed that *N. comes* is less attracted to shepherd's purse than the native cutworm species and is able to complete development on this host plant. Differences in biology and variable developmental times will have to be considered for monitoring and management programs.

The suitability, beneficial properties, and vine crop performance impacts of groundcover vegetation (A2.3) was evaluated in commercial vineyards and in replicated experimental plots at Summerland RDC. In addition to repeated sampling of pest and beneficial insect species, replicated plots at SuRDC containing mixtures of various groundcover plant species were monitored for temperature and humidity by means of a microclimate mesh monitoring system. The growth of vines was evaluated based on pruning weights, and fruit measured for maturity. Results demonstrated the benefits of a dual irrigation system and greater plant species diversity for vine health and management of grapevine pests, with larger numbers of beneficial insects found in the plots with greater plant diversity. A bait attractive to cutworm larvae based on mustard seed oil and other components was developed in the lab and needs further development and assessment in the field.

Studies of the interaction of vineyard soil microbial populations with vegetation and vine physiology (A2.4) was completed successfully. Molecular diagnostic techniques were developed to assess populations of target microbial species (plant pathogens, AM fungi, entomopathogens) from soils collected from commercial vineyards and from the replicated research plots at SuRDC. In addition to assessments of vegetation, soils from the study plots have been analyzed and temperatures recorded

as additional parameters relating microbial populations to vegetation. The results of a successful greenhouse trial that compared microbial populations in soils from different drive row vegetation plots was published in a scientific journal and another manuscript outlining the results from the field trials is nearly complete. A living mulch trial established at SuRDC in 2016 was used to study the effects of vine row vegetation on microbial populations and vine performance.

Information has been developed regarding drought tolerant grass and legume species suitable for use in vineyard drive rows. The information generated from this research can be used to modify groundcover plant species mixtures to improve sustainability and contribute to the management of grapevine pests. Research has shown that greater plant species diversity is related to decreased cutworm feeding on the buds of grapevines in spring and greater numbers of beneficial insects and spiders. Findings have contributed to a better understanding of the importance of groundcover vegetation in the agroecology of vineyards and its role in vine health and pest management.

2. **Objectives/Outcomes**

Objective A2.1. Effect of plant species diversity on cutworm damage to grapevines.
Description: Complete the evaluation of the relationship of cutworm damage to vegetation diversity, particularly the presence of winter annual mustards, in commercial vineyards surveyed previously.
Outcome: Development of methods to control climbing cutworm pests of grapevines using winter annual mustards in the vine rows and increased plant species diversity in the vineyard drive rows will provide effective non-chemical control and contribute to greater sustainability.
Performance Assessment/Variance: To determine the effect of vegetation on levels of cutworm damage to the buds of grapevines, numbers of damaged buds in 98 large study plots established in commercial vineyards was correlated with types of vegetation and with the presence of specific plant species within the drive row and the vine row. Data analysis was finalized and a ten page report (Lowery and DeLury. 2016. Study of Vineyard Vegetation, Pests, and Beneficials) with seven tables was prepared for the BCWGC R&D Committee and for collaborating growers. A companion four page, seven table, report containing individualized data was sent to participating growers (~80) outlining findings from their particular study blocks. Numerous poster and oral presentations (e.g. Lowery and Vukicevich. 2017. Drive and vine row vegetation options. SuRDC – Viticulture Field Day, Summerland, Aug. 29. Oral presentation and field tour) have been provided to industry. Results showed that greater plant species diversity within the drive row was related to lower levels of cutworm damage. Reduced larval feeding damage was also correlated with the presence of certain plant species (e.g. common mallow) or plant families (i.e. legumes). Compared with grass monocultures, drive rows containing a mixture of grasses and broadleaf plants (forbs) was associated with lower levels of cutworm feeding injury to buds. Damage was also significantly lower when shepherd's purse was

present in the vine row. Additional statistical analyses will be conducted to determine the role of other parameters, such as pesticides and irrigation practices, on levels of cutworm damage, and a scientific article will be published shortly. This multi-year study conducted initially in 98 large vineyard study blocks has been completed successfully without any variance.

Objective A2.2. Distribution, abundance and biology of the lesser yellow underwing moth.
Description: Collect samples to establish the distribution and abundance of the new invasive lesser yellow underwing moth, *Noctua comes*, and determine population trends in relation to soil types and vegetation characteristics. Evaluate in the laboratory larval feeding preferences and the effects of shepherd's purse and spring draba on the growth and development of underwing larvae.
Outcome: Provide knowledge of the biology and population distribution and trends for this new invasive pest of grapevines required for monitoring and control.
Performance Assessment/Variance: Collection of cutworm larvae from grapevines at night was conducted a final time in spring 2017 from 16 cultivar blocks to complete the study. In contrast to the previous two years when there was little cutworm damage to the buds of grapevines, populations were high to extremely high in some locations, allowing for the collection of large numbers of larvae. In total, 36 lesser yellow underwing moth larvae were collected, which represented a very small proportion of the total. None, however, were present among the nearly 2,000 larvae from vineyards on sandy soils south of Oliver (Zone 5). In contrast, lesser underwing larvae comprised slightly more than 4% of those larvae collected from four vineyards in zone 2 (Naramata, Penticton, Summerland), with one vineyard having 11.1% (17/153) lesser underwing. We collected only one underwing larvae in 2016, none in 2015, and 12 in 2014, all from vineyards in zone 2. A significant number were collected in previous years from vineyards in the Kelowna area (Zone 1). The first underwing larvae were collected in the Okanagan in 2001, providing time for dispersal throughout the valley. The dry, sandy soils of the south Okanagan appear to be unfavourable for this species, but additional study to determine the effects of different irrigation practices is perhaps warranted. It is worth noting that the 12 underwing larvae collected in 2014 came from the same vineyard where the 17 were collected in 2017, perhaps indicating a preference for certain vineyard conditions.

The lesser yellow underwing colony was maintained at the Summerland RDC for completion of the planned laboratory studies. Larvae were also supplied to Dr. Deb Henderson, Kwantlen Polytechnic University, for inclusion in studies to determine the efficacy of commercial and native isolates of the entomopathogen *Beauvaria bassiana*. Our laboratory studies of *N. comes* growth and development were delayed somewhat due to a reduction in technical assistance, but we successfully showed that larvae have a longer developmental time than the native *Abagrotis* species. It also does not require the 6-8 week reproductive summer diapause of the native *Abagrotis* cutworm species. Damage to grapes by the invasive underwing moth is therefore more variable. The warmer weather in the winters of 2015 and 2016 allowed larvae to complete development before the grape buds had swollen and become susceptible to larval feeding. In contrast, completion of underwing larval development was synchronized with bud swell in the spring of 2017 following a colder winter.

Due to a reduced level of technical support to T. Lowery, a small portion of this study was not completed to our satisfaction. Determining the lower temperature threshold for larval development that could be used in a temperature-based developmental model would help predict the degree of bud damage. Because of their tolerance to cold temperatures (larvae are able to develop in the refrigerator), growth cabinets able to operate effectively and continuously below 5 degrees Celsius were not available at that time.

Objective A2.3: Determine the suitability, beneficial properties, and vine crop performance impacts of native and non-native plant species as groundcover vegetation in commercial vineyards.
Description: In commercial vineyards and replicated plots at SuRDC, assess native and non-native drought-tolerant plant species for their suitability as vineyard groundcovers and determine their effects on populations of grape pests and beneficial insects and on grapevine physiology and fruit quality.
Outcome: Determination of beneficial drought-tolerant plant species suitable for culture under drip irrigation will contribute to greater sustainability through the need for reduced irrigation, improved vine health and fruit quality, and by their contribution to the management of grape pests.
Performance Assessment/Variance: For objective 2.3, the suitability, beneficial properties, and vine crop performance impacts of groundcover vegetation was evaluated in commercial vineyards and in replicated experimental plots at Summerland RDC. Sweep net and leaf samples were again utilized to evaluate numbers of beneficial insects, and pitfall traps were again placed in the replicated vegetation study plots at SuRDC. Some plots established in commercial vineyards had to be relocated during the study due to the alteration or removal of drive row vegetation. In addition to repeated sampling of pest and beneficial insect species, replicated plots at SuRDC containing mixtures of various groundcover plant species were monitored for temperature and humidity by means of a microclimate mesh monitoring system**.** Treatments for the replicated vegetation study consisted of 1) dual irrigation (sprinkler & drip) with a grass/flower cover crop, 2) dual irrigation with a grass/legume cover crop, 3) drip only irrigation with a dry native grass cover crop and 4) sprinkler only irrigation with a non-native grass cover crop.
Monitoring of pests and beneficial insects showed an effect of vegetation type, with greater numbers of beneficial insects from plots with greater plant species diversity. During 2016 and 2017 ground dwelling spiders and predacious beetles were monitored by means of pitfall traps. Vegetation had a significant effect on total numbers of species and also the composition of species. Collection of cutworm larvae in 2017 showed significantly more in treatment 1 that contained flowering plants as part of the groundcover mix than all other treatments, and the lowest number in treatment 4 that was irrigated with sprinklers. We were not able to collect data on leafhopper numbers and parasitism rates from the replicated vegetation plot study at SuRDC in 2017 due to the application of an unknown pesticide to half the block sometime previously. The plots will be maintained for 2018 to allow for collection of data on bud damage and numbers of cutworm larvae to verify an observation that cutworm moths were feeding on flowers of plants that were flowering late in the fall of 2017.

Knowledge of cutworm damage in relation to the presence of late flowering plants can be included in the development of a risk assessment model for use in a monitoring and management program. Growers can encourage winter annual species that reduce cutworm damage (i.e. shepherds purse) and limit those that attract moths to deposit eggs in the fall.

Drive row vegetation coupled with irrigation method had a measurable impact on vine growth and fruit maturation. The biggest differences were found when comparing treatment 4 (non-native grass/sprinkler) with treatment 3, the native grass/drip irrigation treatment. In 2017 the native grass with drip irrigated vines had reduced yield and berry weight and increased soluble solids and titratable acidity. Vine senescence in the fall was also hastened by the native grass/drip irrigation treatment, but differences in bud hardiness were not significant. Bud hardiness improved in the fall when drip irrigated vines were compared to the other 3 irrigation/cover crop treatments. Among the two dual irrigated treatments (grass with forbs and grass with legumes) there were few differences in yield and fruit composition, and no difference in bud hardiness.

As for the replicated vegetation study at SuRDC, counts of pests and beneficial insects from commercial vineyard plots having different types of vegetation showed higher numbers of beneficial insects in plots with greater groundcover plant species diversity, particularly when flowering plants were present. Irrigation type (sprinkler versus drip) interacts with vegetation and it is difficult to separate their effects. Data on numbers of leafhoppers in relation to vegetation characteristics has not yet been analyzed. It is difficult to acquire meaningful data on numbers of pests in commercial vineyards due to the application of various production practices (e.g. pesticide applications).

Larvae from the laboratory colonies were used to evaluate in the laboratory the attractiveness of a wide range of potential materials as possible larval baits. This proved to be difficult for several reasons. A large proportion of the larvae failed to respond or sought to hide. Baits that have been used traditionally for control of other cutworms and armyworms, such as bran and molasses, were not attractive to climbing cutworm. Utilizing arena choice test bioassays, an olfactometer to measure attractiveness of cutworm larvae to released volatiles, and an electroantennogram to measure the response of moths to odours, we have developed a larval bait based on mustard seed oil and other components that we hope to evaluate for effectiveness in the field.

Assessment of the suitability of legume and grass species for inclusion as vineyard groundcover plants was completed successfully. Favourable species of drought tolerant grasses (e.g. blue grama) and legumes (e.g. birdsfoot trefoil) have been identified and information provided to industry on numerous occasions. Improvements to vineyard groundcover plantings will contribute to greater sustainability trough reduced irrigation, provision of nitrogen, and enhanced management of pests.

Objective A2.4 Interaction of vineyard soil microbial populations with vegetation and vine physiology.
Description: Determine the relationship between cover crop identity and diversity and soil microbial community structure and functioning, and correlate vine performance measures with differences in microbial populations.
Outcome: Contribution to an understanding of the effects of production practices, vegetation

characteristics and soils on vineyard microbial populations that impact vine health and pest management.

Performance Assessment/Variance: The greenhouse and field research has been conducted successfully and there are no variances to report. A greenhouse study performed by graduate student, Eric Vukicevich (co-supervised by Dr. Lowery and Dr. Miranda Hart UBC-Okanagan) to evaluate the effect of vineyard groundcover vegetation on the soil microbial community and vine growth was completed successfully. Rooted cuttings were grown in pots in the greenhouse in a potting mix containing soil from the replicated plots at SuRDC outlined in activity 2.3 above. Half of the vines were inoculated with the root rot pathogen *Ilyonectria* spp. Vine growth was measured, roots were inspected for damage, pathogens were cultured from the roots, and the soil was analyzed using molecular diagnostic techniques for pathogens and beneficial microbes. This project was completed in 2017 with publication of the article titled "Groundcover management changes grapevine root fungal communities and plant-soil feedback", Plant and Soil, January 2018. Major findings for this project were that groundcover identity can alter the composition of fungi inside vine roots as well as vine growth in a high pathogen environment.

Soil samples were collected from six field sites for the final time in the spring of 2017. Data collected included plant community characteristics, soil moisture and chemistry, and molecular quantification of *Ilyonectria* spp., *Beauveria bassiana*, and arbuscular mycorrhizal (AM) fungi. In total, 854 samples have been collected and over 2,500 molecular assays carried out between the summer of 2015 and spring of 2017. Model-based analyses are currently underway to determine how plant communities affect these groups of soil fungi. Preliminary analyses suggest that *Ilyonectria* spp., a plant pathogen, may be more associated with exotic plant species and forbs than native species or grasses, while *Beauveria bassiana*, a beneficial entomopathogen, may be more abundant under forbs. AM fungi may be more associated with the presence of legume species in the vineyard groundcovers. A scientific manuscript covering this research has been prepared for submission this spring.

Vines in the living mulch field trial completed their third year of growth in 2017, filling out the trellis for the first time. Vine measurements in 2017 included: shoot length at bloom, repeated measures of leaf greenness (SPAD), leaf water potential, and dormant pruning weight. Soil measurements included: soil moisture at two depths, soil chemistry, and abundance of target fungal groups (AM fungi, *Beauveria*, and *Ilyonectria*). Initial analyses show strong treatment effects on all plant responses, as well as some soil parameters such as C/N and C/P ratios, soil moisture, and abundance of AM fungi. Competition for nutrients from creeping fescue significantly reduced the growth of the vines compared with the clean vine row treatments.

The infectivity and community composition of entomopathogenic fungi naturally occurring in soils under different groundcover treatments in a replicated vegetation trial at SuRDC was assessed using a lab bioassay with the greater wax moth, *Galleria mellonella*, as the 'bait'. Initial results show that groundcovers consisting of drought-tolerant native plants had higher rates of infection and larval mortality compared to those consisting of exotic plants. Preliminary selective media assays also suggest that the community composition of entomopathogenic fungi vary widely among treatments.

Sequencing of isolates cultured from Galleria larvae has just recently been completed and will be analyzed to determine exactly how different these communities are.
The outlined work was completed on target and additional research involving the effects of living vine row mulches on vine performance and soil microbial populations added. There are no other variances to report.

3. Issues

- Describe any challenges or concerns faced during the project. How were they overcome or how do you plan to overcome?
- Describe any potential changes to the work plan and the budget. How were or how will they be managed?

Research in commercial vineyards has been disrupted on occasion. Of the 98 initial vegetation study blocks established in commercial vineyards as part of objective A2.1, we were only able to obtain accurate spray records for approximately 80. The database remained sufficiently large to enable accurate statistical comparisons, but repeated attempts to obtain the records delayed completion of this objective. For objectives 2.3 and 2.4, alteration of the production practices or removal of the drive row vegetation (i.e. tillage) in the commercial vineyards required relocation of the study plots. We were able, however, to successfully relocate to favourable sites that will provide the required data.
A reduction in technical assistance delayed completion of some laboratory activities related to objectives 2.2 and 2.3 and caused delays in data compilation, statistical analyses and production of manuscripts. Data will be fully analyzed and scientific publications submitted to scientific journals in the near future. Considering the overall size of the project and the challenges related to these field and laboratory studies, we were able with a great deal of effort to remain on schedule and complete most of the objectives to our satisfaction. There are no variances to report.