1.) PROJECT ACTIVITIES COMPLETED DURING THE REPORTING PERIOD. (Describe project progress specific to goals, objectives, and deliverables identified in the project workplan)

Objective I:  Improve and expand the current trapping networks for corn insect pests.
Ia) Black light trap network.  (Hutchison)
   • No field data generated this quarter.
 Ib) Pheromone trap networks.  (Hutchison/Potter)
   • No field data generated this quarter.

Ic) Corn rootworm sticky trap network. (Potter/ Hutchison/Ostlie)
   • 2019 trap results collected from non-seed industry cooperators

Objective II:  Develop a network of sentinel and on-farm survey plots for corn insect pests and corn diseases.

IIa) Corn disease and insect pest monitoring at U of M ROCs (Malvick and Potter)
   i.   Develop and use sentinel plots for determination of the annual prevalence of key corn pathogens and insects.
        • No field data generated this quarter
   ii.  Evaluate yield loss from corn foliar fungal pathogen losses at multiple locations by comparing fungicide applications with untreated controls
        • Yield data was obtained and preliminary analysis completed in Q3

IIb) On-farm corn insect and pathogen monitoring (fall survey for European corn borer and corn pathogens)
   i.   Conduct a statewide fall survey for overwintering larval corn borer populations to estimate annual geographic populations and project following year's risk. (Hutchison)
        • Field surveys were concluded in mid-October 2019, data compiled and used as a basis for a crop news article and poster and oral presentations.
ii. Use larvae collected during the statewide fall survey to determine geographic differences in corn borer voltinism biotypes. (Hutchison)
   - ECB larvae collected from infested 2019 survey fields are currently in environmental chambers until spring when they will be induced to break diapause. These will be assayed for the percentage uni-voltine vs. multi-voltine and presence of the Nosema pathogen.

iii. Conduct a statewide survey for corn diseases to determine annual prevalence of key species. (Malvick)
   - Field surveys were concluded in early October. Preliminary compilation of results was completed in Q3.

2.) IDENTIFY ANY SIGNIFICANT FINDINGS AND RESULTS OF THE PROJECT TO DATE.

Objective I: Improve and expand the current trapping networks for corn insect pests.

Ia) Black light trap network. (Hutchison)
   - None this quarter

Ib) Pheromone trap networks. (Hutchison/Potter)
   - Black cutworm – none this quarter
   - Corn earworm – none this quarter

Ic) Corn rootworm sticky trap network. (Potter/Hutchison/Ostlie)
   - Data compilation / analysis not yet completed.

Objective IIa) Corn disease and insect pest monitoring at U of M ROCs (Malvick and Potter)

i. Develop and use sentinel plots for determination of the annual prevalence of key corn pathogens and insects.
   - None this quarter

ii. Evaluate yield loss corn foliar fungal pathogen losses at multiple locations by comparing fungicide applications with untreated controls
   - Wet field conditions at planting and through the growing season affected corn stands and development. This prevented use of yield data from the Waseca and Morris sites. Fungicides did not produce significant yield differences (α = 0.05) at any of the remaining locations (Appendix I, Figure 1, 2, Table 1). Relative yield the hybrids varied by site.
   - Hybrids differed in moisture at all three sites. Relative moistures differed at the two southern sites.
   - Potential economic benefits for foliar fungicide applications to rotated corn during the 2017-2019 years of the study are given in Table 2. Only a single site year had a significant yield response (α=0.10).
   - The hand-harvested Physoderma study did not show differences in foliar disease levels or node rot but application timing effects on yield were observed (Appendix I, Figure 3). Because of the effect of green snap on viable ears and interplant competition it is best not assign a high degree of confidence to these results.
Objective IIb) On-farm corn insect and pathogen monitoring (fall survey for European corn borer and corn pathogens)

i. Conduct a statewide fall survey for overwintering larval corn borer populations to estimate annual geographic populations and project following year's risk. (Hutchison)
   • None this quarter

ii. Use larvae collected during the statewide fall survey to determine geographic differences in corn borer voltinism biotypes. (Hutchison)
   • None larvae from 2019 survey are still in diapause

iii. Conduct a statewide survey for corn diseases to determine annual prevalence of key species. (Malvick)

Tar spot was confirmed in Minnesota for the first time late in the 2019 growing season in four Minnesota counties. These confirmations were based on field observations and reports from cooperators. Although observations on tar spot were included in the fall corn borer survey, it was not detected. Survey timing or very low disease prevalence and/or disease incidence are probable reasons. These results reinforce the need for specialized survey techniques for certain pests and diseases. It also shows the importance of developing relationships with other private and public sector collaborators.

Corn disease was a consistent component of fall corn borer surveys in parts of SW, SC, WC, and to a lesser extent, elsewhere in Minnesota. The following examples may help illustrate the potential for collecting and maintaining historical data on corn insects and diseases in addition to corn borer.

• Bacterial leaf streak incidence appears reduced compared to previous years (Appendix I, Figure 4).
• Stalk rots were also somewhat lower than previous years (Appendix I, Figure 5). Part of this might be attributed to delayed corn maturities. Green snap was not included in these maps and many 2019 fields were surveyed before the high wind events in October.
• Physoderma node rot symptoms were observed over a wider area in 2019 (Appendix I, Figure 6).
• Northern corn leaf blight prevalence has remained relatively constant during the 2017-19 survey period. (Appendix I, Figure 7).

3.) CHALLENGES ENCOUNTERED. (Describe any challenges that you encountered related to project progress specific to goals, objectives, and deliverables identified in the project workplan.)

4.) FINANCIAL INFORMATION (Describe any budget challenges and provide specific reasons for deviations from the projected project spending.)

• Due to delays in implementing the survey, portions of funding for the corn rootworm objective may not be spent before the end of this fiscal year.
5.) EDUCATION AND OUTREACH ACTIVITIES. (Describe any conferences, workshops, field days, etc attended, number of contacts at each event, and/or publications developed to disseminate project results.)

Ib) Pheromone trap networks. (Hutchison/Potter)

- None this quarter

Ilb i) Conduct a statewide fall survey for overwintering larval corn borer populations to estimate annual geographic populations and project following year's risk. (Hutchison)

Newsletter articles:


Posters:


Grower and ag professional presentations:


B. Potter

UAT grower meeting (~70 growers)

Brown County Corn and Soybean Growers (~40 growers)

Renville/Redwood County Corn and Soybean Growers (~40 grower)

Ilb iii) Conduct a statewide survey for corn diseases to determine annual prevalence of key species. (Malvick)

Grower and ag professional presentations:

Some of the material from this portion of the project was presented by:

D. Malvick

- 2019 CPM Short Course in Minneapolis (~100 total ag professional attendees)
- 2020 Crop Management Input Seminar in Hutchinson (~90 grower and ag professional attendees).

B. Potter

- Same as Ilbi
Figure 1. Hybrid and fungicide effects on corn yield in two 2019 southern Minnesota sites.
Figure 2. Hybrid and fungicide effects on corn yield in a 2019 Northwest Minnesota site.

Figure 3. Corn yield response to timings of foliar fungicide (Delaro @ 8 fl. oz.) applications
Figure 4. Bacterial leaf streak observations during fall surveys 2017-19. Plants were counted as infected if diagnostic symptoms were readily observed on any leaf above ear.
Figure 5. Stalk rot observations during fall surveys 2017-19. These were not identified to causal agent/fungal genera but did not include green snap. Stalk rots were assessed using a “push test”.

Stalk Rot Incidence - 2017

Stalk Rot Incidence - 2018

Stalk Rot Incidence - 2019
Figure 6. Observations of node rot symptomatic of Physoderma during fall surveys 2017-19.
Figure 7. Observations of northern corn leaf blight during fall surveys (2017-19). This disease influenced by hybrid susceptibility as well as weather conditions. Plants were rated as positive if diagnostic lesions were observed on leaves at or above ear.
### Table 1. Individual and combined southern site data

**2019 UNIFORM FUNGICIDE MANAGEMENT TRIAL - CORN**  
FACTORIAL Analysis of Variance (FANOVA)  
YIELD @ 15.5% moisture and 56 lb./bu.

<table>
<thead>
<tr>
<th>Source</th>
<th>Prob &gt; F</th>
<th>LAMBERTON</th>
<th>WAUSECA</th>
<th>ROSEMOUNT</th>
<th>MORRIS</th>
<th>CROOKSTON</th>
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<td></td>
<td>COMBINED SITES §</td>
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*Combined site analysis of Variance (ANOVA) based on normalized yields (plot yield or moisture /site mean)
§Not included due to poor plot quality. Waseca site had planting/stand issues and Morris had nitrogen issues
§Crookston sites not included in combined site ANOVA due to unique row spacing and hybrids
Significant at alpha: * 0.20, ** 0.10, ***0.05 , ****0.01
### Table 2. Potential economic benefit from fungicide applications to rotated corn at multiple sites from 2017-2019

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<th>Location</th>
<th>Year</th>
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<th>ST+TR^3</th>
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<th>ST^2</th>
<th>ST+TR^3</th>
<th>$4.00</th>
<th>ST^2</th>
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<td>NSYB</td>
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<td>NSYB</td>
<td>NSYB</td>
<td>NSYB</td>
<td>NSYB</td>
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<tr>
<td>Waseca</td>
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<td>8.90</td>
<td>NSYB</td>
<td>NSYB</td>
<td>NSYB</td>
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<tr>
<td>Rosemount</td>
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<td>-11.50</td>
<td>NSYB</td>
<td>NSYB</td>
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<tr>
<td>Average*</td>
<td>2017</td>
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<td>0.1</td>
<td>NSYB</td>
<td>NSYB</td>
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<td>NSYB</td>
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<tr>
<td>Rosemount</td>
<td>2018</td>
<td>12.9</td>
<td>3.5</td>
<td>NSYB</td>
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<tr>
<td>Average*</td>
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<td>Waseca**</td>
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<td>3.5</td>
<td>NSYB</td>
<td>NSYB</td>
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<td>Morris</td>
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<td></td>
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</tr>
</tbody>
</table>

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1. The yields in the gray shaded cells were not statistically different from untreated (p = 0.10) NSYB = no significant yield benefit
2. Headline 3 2018-19 Delaro 4 Priaxor
3. Morris, Crookston not included in combined averages due to the use of different hybrids
4. ** Not included due to plot quality issues
Reducing Bt trait acres in 2020 Minnesota Corn Production? Implications for European corn borer

B. Potter, IPM Specialist; K. Ostlie, Extension Entomologist; W. Hutchison, Extension Entomologist, and A. Peltier, Extension Educator

Revised 11/21/2019

Bruce Potter, Extension IPM Specialist, Ken Ostlie, Bill Hutchison, Extension Entomologists, & Angie Peltier, Extension Educator

The economics of 2019-2020 corn production has challenged many farmers to minimize production costs. Hybrid selection is one way to reduce costs. Planting corn hybrids without Bacillus thuringiensis (Bt) proteins for protection against European corn borer (ECB), corn rootworm, or both will reduce seed costs. However, if not careful, farmers could inadvertently reduce crop revenues if they select hybrids without considering yield potential or insect populations in their fields.

Yield potential is the first thing to consider when selecting a corn hybrid. Bt traits protect the yield potential of a hybrid, but yield benefits only occur when targeted insects are above economic levels. When insect pressure is low or absent, economic benefit with trait-protected hybrids only occurs if higher costs are offset by greater yields. Switching to less-expensive non-Bt seed can be a good strategy when yields are comparable or when seed cost savings exceed any reduced yield potential plus prospective insect losses. In many 2019 fields, planting corn without a Bt trait can work well, if you recognize and account for your insect risk.

Historical, current, and future ECB populations

Since the adoption of Bt corn 24 years ago, Bt use rates in Minnesota have grown to as high as 85% of the total acres planted in 2017. During 2019, Bt hybrids declined to 82% of Minnesota corn acres (Figure 1). ECB populations in Minnesota and throughout most of the Midwest Corn Belt have been effectively suppressed by similar adoption rates of Bt. ECB populations continue to be low in Minnesota where Bt use has remained relatively high since 2007. Low ECB moth flights (Figure 2) parallel the low ECB larval populations detected in the fall surveys (Figures 3-6). Historically low ECB populations have also been documented in Wisconsin, where Bt adoption rates remain high as well (Figure 1).

During 2017-19, the MN Corn Research and Promotion Council provided funding to increase the number of fields surveyed for overwintering larvae (Figure 3) and ECB damage (Figure 4). As part of the project,
several farmer cooperators volunteered non-Bt field locations for the fall surveys. Importantly, this cooperation allowed us to sample fields that we knew in advance did not have above-ground Bt traits (*Figure 5, 6*). These unprotected fields greatly contributed to our understanding of the current spatial pattern of ECB in the state, revealing where ECB have a foothold in the state, and/or where ECB populations could begin to “rebound” in the next few years. During 2019, 248 commercial fields were evaluated, and thanks to farmers and other ag professional cooperators, this sample included 96 known non-Bt fields. The 2019 ECB infestation levels observed were similar to 2017-2018 (*Table 1, Figure 5*) and remain at historically low levels. For example, in the 96 non-Bt fields, we did observe a higher average of 0.0865 larvae/plant, whereas the randomly sampled fields (152) yielded only 0.0039/plant. These data compare to the state average overwintering larval number in random samples of 0.0080/plant in 2018, 0.0054/plant in 2017, and 0.016/plant in 2016. The average ECB population density in known non-Bt fields was 0.0386/plant in 2018 and 0.0288/plant in 2017. While higher than the density in fields at random, the average density in non-Bt fields remains much lower than the traditional economic thresholds levels for ECB (typically greater than 0.5 larvae/plant). It is important to remember that these numbers are state averages and the maps represent interpolated spatial data and do not reflect the densities within an individual field. In other words, they do not replace scouting for field-specific decisions.

From an area-wide and long-term resistance management view, it is prudent to maintain susceptible ECB in the state, which the non-Bt, “refuge” fields could produce. Any moths that emerge from non-Bt fields should theoretically have experienced less Bt selection pressure and ideally will most likely mate with the rarer resistant moths that survive from Bt fields. Such matings are therefore designed to assist in keeping the frequency of resistance genes low, and functionally recessive. The subsequent ideal outcome is that susceptible genes dominate over time and help conserve the Bt technology as long as possible. For ECB, this continues to be one of the ongoing success stories with Bt traits.

The risk of ECB developing resistance to Bt is not zero, however, and some continued monitoring of populations in Bt has value. For example, Bt resistance has appeared in ECB (this ECB biotype does not occur in Minnesota) in Nova Scotia, Canada, arising from intensive use of one Bt trait. In the case of “refuge-in-a-bag” fields, pollen shed between the Bt and refuge plants can lead to a mosaic of Bt expression in pollen and kernels, potentially reducing refuge efficacy. The effectiveness of the trait and insect biology makes this mosaic in kernel Bt expression a
concern for ECB, and other Lepidopteran pests such as fall armyworm (FAW) and corn earworm (CEW); there are several cases of Bt resistance with FAW and CEW globally on multiple crops.

**Managing ECB in the absence of Bt**

Going into 2020 summer, ECB populations will remain generally low. However, scattered reports of damage to non-Bt corn demonstrate ECBs are still present and thus always pose a potential threat in Minnesota. That said, a temporary increase in acres planted to non-Bt corn should not dramatically increase the risk of economic damage from ECB in the near-term, particularly if the non-Bt fields are surrounded by several Bt fields. However, this risk likely increases as the proportion of local fields planted to non-Bt increases, particularly where the local shift away from Bt dominates the locale for several years and where non-Bt corn is planted in large contiguous blocks. Most likely the higher fall ECB populations observed in some fields reflects local non-Bt dominance most often found in parts of SE, EC, C, WC and NW Minnesota (Figure 4). As growers choose to plant less Bt corn, these populations should be expected to increase.

Another variable to consider is that two biotypes of ECB continue to be present in Minnesota. A univoltine biotype that produces a single generation each year was the first type introduced into the U.S and historically predominated in the northern and central corn growing areas of the state. Multivoltine biotype moths emerge earlier in the growing season. In southern MN, they are capable of producing two, or rarely three, larval generations depending on temperature accumulation and photoperiod cues. Both strains overwinter as 4th or 5th instar larvae, pupate in the spring and moths begin emerging in mid-May or later.

Risk of yield loss from ECB can be reduced if you scout fields and apply a labeled insecticide where needed. Early and late-planted fields will be most attractive to egg-laying 1st and 2nd generation moths of the multivoltine biotype, respectively. These fields should be scouted for ECB if planted to a hybrid without an above-ground Bt trait. In contrast, it takes the univoltine larvae longer to complete development, so moths of this biotype produce an adult flight in-between the multivoltine 1st and 2nd generation moths. Where the univoltine biotype strain of ECB occurs, scouting should focus on fields from pre-tassel to near pollination when the flight is underway, typically mid-July to early August. In areas with biotype mixtures, mixed infestations can occur with overlapping and prolonged scouting windows.
Bt corn should also receive some scouting attention late season to detect potential ECB resistance and attack by other ear-feeding caterpillars. While ECB resistance to Bt has not been detected, several above-ground traits are now less effective against some corn earworm, western bean cutworm and fall armyworm populations. Occasionally, refuge plants may be attacked but look for ECB attack beyond the proportion of refuge plants. In particular, examine leaf feeding from first generation corn borers in earlier planted fields, stalk and ear tunneling in late-silking fields from univoltine and second generation corn borers, ear feeding from corn earworm and western bean cutworm, and late-whorl and ear feeding from fall armyworm. If you do detect an unusually high proportion of injured plants, confirm you planted a hybrid or hybrids with above ground Bt traits and notify your seed dealer. Independent confirmation is important so ask a trusted ag advisor to investigate or confirm your suspicions. Of course, we would appreciate a “heads-up.”

Notes on European corn borer, scouting and insecticide applications:

- Larvae are susceptible to insecticides for 10-14 days during each generation, from hatching to tunneling of third or fourth stage. This limited window means your scouting efforts must be timed well. This can be difficult in areas with mixed univoltine and multivoltine biotypes.

- As corn grows and the plant loses its whorl where larvae like to congregate, successive generations occupy leaf axils and ears lower in the corn canopy. End result: insecticide effectiveness declines with greater canopy interception by leaves above the larvae. Percentage control for well-timed applications declines from 85% (1st generation) to 70% (univoltine) to 50% (2nd generation). Expect control with insecticides, even if timed well, to be noticeably less effective than Bt traits (>99.5%).

- Larvae that tunnel into the stalk, ear shank, or ear are not susceptible to insecticide sprays and should not be considered in your spray decision. Re-evaluate the field closer to application if there is a scheduling or weather-related delay in getting the field sprayed to make sure the insecticide can still reach larvae.

- With aerial applications, water volume is critical… the more the better and 5 gpa is preferred. Performance is enhanced by heavy dew (favors movement into whorl or leaf axils) and diminished when using lower water volume, when leaves are dry (no
movement to leaf axils) and when hot temperatures increase evaporation of smaller spray droplets before they hit target.

When moving away from Bt traits to reduce costs, keep in mind three important considerations:

1. Bt traits are a form of insurance. Moving away from Bt traits means that you are assuming the risk of insect attack and timely scouting will be critical for optimal management.
2. Statewide, risk is generally low now for yield loss from European corn borer, but risk is not zero.
3. You can either choose to ignore the risk (and accept the potential yield loss in your fields) or minimize that risk through active management (scouting + insecticides).
Figure 1. Adoption of Bt corn hybrids. The Bt varieties include those that contain more than one gene that can resist different types of insects (e.g., European corn borer; corn rootworms) since 2000. Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service, June Agricultural Survey as published in the NASS report Acreage.
Figure 2. MN black-light trap ECB captures for 2019. The June peak corresponds to 1st generation and the mid-August to September flight corresponds to the 2nd generation. The 2nd generation ECB flight can overlap the univoltine moth flights that occur in July to August. Moths continued to be trapped at historically low numbers, for all locations. Source: MN Extension IPM Program: MN ECB black light trap captures.

Figure 3. Historical overwintering fall ECB populations (1995-1997) comparing a pre-Bt era infestation peak (1995), with the early years of commercialization (1996-1997), and with recent years (2017-2019). Source: MN Extension IPM Program (E.C. Burkness, W.D. Hutchison, & B.D. Potter).
Figure 4. Changes in ECB damage (tunneling) from 2017-2019. Source: MN Extension IPM Program (E.C. Burkness, W.D. Hutchison, & B.D. Potter).

Figure 5. Overwintering European corn borer populations (data interpolation) based on fall stalk dissections of MN field corn in randomly selected fields (upper row) and preselected known non-Bt and randomly selected fields combined (lower row), 2017-2019. MN Extension IPM Program (E.C. Burkness, W.D. Hutchison, & B.D. Potter; www.mnipm.umn.edu).
Figure 6. Relative location of fields sampled in 2019 for ECB (left) and those cooperator fields where Bt protection from corn borer was known to be absent (right).
Legend: White - no damage, Yellow – tunnels only (no larvae), Red –tunnels with larvae. (E.C. Burkness, W.D. Hutchison, & B.D. Potter).

Table 1. Statewide data for ECB larvae in field corn, Minnesota 2017-19

<table>
<thead>
<tr>
<th></th>
<th>Random Fields</th>
<th>Known Non Bt Fields only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>Mean #ECB larvae/plant (n)</td>
<td>Mean #ECB larvae/plant (n)</td>
</tr>
<tr>
<td>2017</td>
<td>0.0054 (149)</td>
<td>0.0288 (52)</td>
</tr>
<tr>
<td>2018</td>
<td>0.0080 (137)</td>
<td>0.0386 (70)</td>
</tr>
<tr>
<td>2019</td>
<td>0.0039 (152)</td>
<td>0.0865 (96)</td>
</tr>
</tbody>
</table>
Figure 7. Overwintering European corn borer larva and its feeding damage within the lower stalk. While stalk breakage or ear drop are readily visible, the extent of tunneling and physiological yield loss can be seen only after the stalk is split. Photo: Bruce Potter, University of Minnesota.


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Products are mentioned for illustrative purposes only. Their inclusion does not mean endorsement and their absence does not imply disapproval.

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