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# 2018 Wild Blueberry Project Reports

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THE UNIVERSITY OF MAINE

# 2018 Wild Blueberry Project Reports

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**ENTOMOLOGY**

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**1. TITLE:** Pest biology and IPM, 2018.

***Study 1.*** ***<u>The blueberry tip midge, a recent pest of wild blueberry and its impact on potential yield, a final report - 2018.</u>***

**OBJECTIVES:** Our objectives were: 1) document the spread and distribution of blueberry tip midge populations in Maine wild blueberry, 2) determine the effect of crop stage (vegetative or crop) on infestation, 3) evaluate the impact of infestation by blueberry tip midge on growth and development of flower bud clusters in the vegetative year, and subsequent development of flowers in the spring of the following (crop year) in wild blueberry in Maine, 4) construct an optimal sampling plan for estimating blueberry tip midge infestation (galls / m$^2$), and 5) determine economic injury levels for this pest on wild blueberry in Maine.

**METHODS:**

*<u>Spatial and temporal distribution of tip midge and Infestation in prune vs crop fields</u>*

Blueberry tip midge sampling in wild blueberry was conducted periodically since its discovery in 2003 in Columbia Falls, ME. Sampling of fields to determine blueberry tip midge infestation level was performed over a nine-year period (2003 (n=20 fields), 2004 (n=20), 2005 (n=10), 2006 (n=20), 2010 (n=12), 2012 (n=16), 2013 (n=12), 2014 (n=16), and 2018 (n=16)). Typical wild blueberry production consists of a two-year cycle. A field is pruned in the first year and grows in a vegetative stage (producing flower buds) the year after pruning. In the second year, the field comes into bloom and produces a crop (Yarborough 2015). A total of 142 fields were sampled over this period; 99 were pruned fields and 43 were crop fields. Blueberry tip midge density was estimated in each of the fields by counting the number of stems with and without galls, using 10 to 40 m$^2$ quadrats per field. Percent infestation was estimated by dividing the number of galled stems by the total number of stems in a quadrant.

*<u>Number of generations</u>*

In 2017, wild blueberry stems were sampled for tip midge gall infestation and galls were dissected for larval density estimation. This study was conducted in a prune field at the University of Maine's Blueberry Hill Experiment Station at Jonesboro, Washington County, ME (44° 38.532N, 67° 38.707W), Jonesboro, ME. Sampling was initiated with the first occurrence of galls on 22 May and continued every 7-14 days until 28 August. On each sampling date, 10 arbitrary stems were selected, cut and brought back to the laboratory where the percent of stems with galls was calculated. Galls were dissected and the number of blueberry tip midge larvae per stem were counted. Gall infestation rate and larval density over time was graphed. Visual inspection of the number of peaks displayed on the graphs was used to estimate the number of generations that occurred during the growing season.

*Prune vs crop cycle incidence*

In 2003, 2004, 2005, and 2006 sampling was conducted in 70 paired (2003 (n=20 fields), 2004 (n=20), 2005 (n=10), 2006 (n=20) blueberry fields in Washington Co., ME to determine if blueberry tip midge occurred in greater or less abundances dependent upon the crop cycle of the field. Each field was 5-7 acres in size. Of the 20 fields, ten were in the crop year and ten were in the vegetative or prune year; only ten crop fields were sampled in 2005. Fields within each "prune/crop cycle" pair were separated from each other by a windbreak of conifer trees. Blueberry tip midge density was estimated by counting the number blueberry stems with tip midge galls in ten, $m^2$ quadrats per prune or crop stage field.

*Reduced risk vs grower standard insecticide comparisons*

Each of the fields described above (prune vs crop cycle incidence) was selected to represent one of two insecticide tactic treatments. The treatments were the use of: 1) reduced risk insecticides, or 2) grower standard insecticides for insect pest management. The reduced risk insecticides used were: Confirm® (tebufenozide), Dipel® (*Bacillus thuringiensis* Kurstaki toxin), Botanigard® (*Beauveria bassiana* Bas. Vuil.), and Success® and GF-120® (spinosad). The grower standard insecticides used were: Imidan® (phosmet), Cythion® (malathion), Assail® (acetamiprid), Provado® (imidacloprid), and Sevin® (carbaryl). All fields were scouted weekly for pests utilizing sweep-net sampling (blueberry spanworm, blueberry flea beetle, strawberry rootworm, blueberry sawfly, and grasshoppers), transect walking (blueberry thrips), and insect traps (blueberry maggot). Action thresholds and recommended rates for the insecticides that growers used were based on an earlier version of Yarborough et al. (2018). Blueberry tip midge density was estimated by counting the number of blueberry stems with tip midge galls in ten, $m^2$ quadrats per field (crop stage (crop or vegetative) x insecticide treatment (reduced risk or grower standard)). All fields from 2003, 2004, and 2006 were included, resulting in a three-way (year, crop cycle, and insecticide tactic) randomized incomplete block experimental design.

*Effect of production system on tip midge density*

In 2010, 2012, and 2013, four wild blueberry prune fields were sampled each year located in either Hancock, Lincoln, Sagadahoc, Waldo, or Washington counties, ME. In each year, four production systems (organic, low input, medium input and high input) that fit along gradients of capital inputs and potential environmental effects in Maine wild blueberry were selected for sampling blueberry tip midge (Asare et al. 2017). Blueberry tip midge density was estimated by counting the number of blueberry stems with tip midge galls in 40, $m^2$ quadrats per field.

*Potential crop loss*

Potential crop loss refers to the reduction in flowers produced during the prune cycle that bloom and have potential to produce fruit during the crop cycle. Not all flowers, even in the best of years, produce marketable fruit. In order to determine the potential crop loss due to blueberry tip midge attack, seven trials were conducted over six-years between 2010 and 2018, with two trials conducted in 2011-2012. With the exception of a second trial conducted at Orland, Hancock Co. ME (44°32'57.16"N, 68°41'29.56"W) in 2012-13 (trial #4), the location for all trials was the University of Maine's Blueberry Hill Experiment Station at Jonesboro, Washington County, ME (44° 38.532N, 67° 38.707W). Colored flags were used to mark 50 vegetative wild blueberry stems, 25 with and 25 without tip midge infestation as evidenced by the presence or absence of characteristic wild blueberry tip midge galls (Collins and Drummond 2017). Treatments were paired within the same clone (a genetically distinct plant referred to as a genet (Bell et al. 2009). Stems were selected in late spring after the appearance of galls. In the fall of each year (5 October and 2 November), ten (trial #2, 2011-12) or 25 (all other trials) marked stems from each treatment were cut and brought into the laboratory where the numbers of flower-bud clusters per stem were recorded. In the spring of the following year (between 15 and 27 May), the remaining stems were cut and brought into the laboratory to determine the number of flowers that developed from individual flower buds within flower-bud clusters.

*Optimal sampling plan for prune fields*

Pattern of aggregation was described in accordance with Taylor's power law (Taylor 1961). Parameter estimates were derived with non-linear regression between the mean tip midge density (galls / $m^2$ / field) and the variance of tip midge density, of the form $S^2 = a + b * mean^c$. Using estimates of variance from the preceding relationship for a range of means and two precisions (se/mean rations of 0.10 and 0.25), the optimal sample size for sampling tip midge during the prune phase was estimated using the formula (Cochran 1977):

$n = (t_{(0.05)} * S^2) / (m^2 * P^2)$, where:

$t_{(0.05)}$ is 1.96 or the t-value for a = 0.05, when n approaches ∞
$S^2$ = predicted variance
m = mean tip midge density / field
P = level of precision as represented by the se/mean ratio (either 0.1 or 0.25)

*Predictive degree-day model - Blueberry tip midge first attack*

Using the developmental threshold for blueberry tip midge pupae of 10ºC (Roubos and Liburd 2010b (9.8ºC), Hahn and Isaacs 2012 (10ºC)) we determined if we could develop a precise degree-day model for predicting the date of the first tip midge gall appearance in a wild blueberry field. In 2015, 2016, 2017 and 2018; we recorded the date of first tip midge gall appearance in fields located at the University of Maine's Blueberry Hill Experiment Station in Jonesboro, ME. Daily maximum and minimum air temperatures were collected by a weather station located in the middle of blueberry fields at the farm. Starting on 1 March, for each year, the number of cumulative degree-days was calculated that coincided with the date of first observed galls.

*Determination of action thresholds*

Another focus of our investigations has been the development of action thresholds (Pedigo et al. 1986). Based upon the average amount of potential crop loss (reduction of flowers per stem) from tip midge infestations estimated over the seven trials (2010-2017), an estimate of the percent of stems infested relative to the cost of crop loss and the cost of insecticide control was determined to assess action thresholds. We assumed that a given percent loss of flowers corresponded to the same percent loss in yield. Our models are based upon a 50% loss of flowers, derived from data collected in seven trials described the previous Crop Loss section. These calculations were performed for three crop values ($0.75, $1.50, and $2.50 / kg of fruit) and three yield scenarios (1781 kgs / ha, 4453 kgs / ha, and 7125 kgs / ha) with a control cost of $125 / ha, not unrealistic for wild blueberry, based upon partial budgets developed by Asare et al. (2017). Economic losses ranging from 0 - $500 / ha were derived by using a range of infestation levels from 0 to 15% of stems.

*Statistical analysis*

Statistical analyses were performed by using the statistical software JMP® (JMP 2015). Frequency distributions of blueberry tip midge field-level densities (galls / $m^2$) across all sampling years for both prune and crop fields were constructed. A series of continuous probability density functions (log-normal, beta, Weibull, Johnson, etc.) were fit to the frequency data in order to determine a predictive empirical probability model. Akaike Information Criteria, and the Shapiro-Wilk W test were used to evaluate fit.

To test whether crop stage and insecticide treatment affected blueberry tip midge gall density, we used Poisson regression (log-link) with year (2003, 2004, 2006), crop phase (prune vs crop), and insecticide treatment (grower standard vs reduced risk) as independent variables. All hierarchical interactions were included in the model. The dependent variable was tip midge gall density (galls / $m^2$/ field).

The effect of wild blueberry production system (organic, low, medium, and high input) on blueberry tip midge density was determined using a two-way Poisson regression (log-link), with production system and year as fixed categorical independent variables. The dependent variable was tip midge gall density (galls / $m^2$ / field) in pruned fields. A post-hoc Student's t quantile test was used to separate treatment least square means.

We used a general linear model (GLM), linear regression, with year as a continuous independent variable (9 years) and square root transformed tip midge gall density ($\sqrt{}$ (galls / $m^2$ / prune field) to test the hypothesis that tip midge density has been increasing over time since 2003. We used only sampled prune fields since we earlier observed a difference in density among prune and crop fields and in addition, pest management must be conducted in prune fields since blueberry tip midge infestation in crop fields overlaps with bloom. We also conducted the same regression but without the 2014 data to determine if unusually high 2014 densities were responsible for the significant increase in gall density over time. A two-way Poisson regression with year as a statistical block and tip midge damage vs no tip midge damage as a categorical fixed effect were used to test the hypotheses that tip midge infestation results in a reduction in the number of flower-bud clusters in the year of damage and a reduction in the number of individual flowers produced the year following damage (the dependent variables). To avoid pseudo-replication, stems within each treatment were pooled and not represented as individual replicates. After we ran the fully saturated model, we ran individual Poisson one-way regressions by year for both dependent variables.

Non-linear regression (Quasi-Newton algorithm) was used to test if blueberry tip midge infestation can result in an exponential increase in flowers / stem when the difference in bud clusters per stem was equal to or less in non-infested stems compared to gall infested stems.

## RESULTS:

*Spatial and temporal distribution of tip midge and infestation in prune vs crop fields*

The frequency distributions of all the sampled prune and crop fields when pooled over all nine years (2003, 2004, 2005, 2006, 2010, 2012, 2013, 2014, and 2018) are shown in Figure 1. The average density of galls / $m^2$ in prune fields was 5.30 $\pm$ 0.92(se) and in crop fields was 0.48 $\pm$ 0.16. However, frequency distributions were highly left skewed. In prune fields, 50% (median) of the fields had densities less than 2.4 galls / $m^2$ and in crop fields 50% of the fields had less than 0.1 galls / $m^2$ observed. While a four-parameter beta density function fit both observed frequency distributions prune and crop fields, a log normal density function resulted in lower

Akaike Information Criteria and non-significant Shapiro-Wilk W tests ($P > 0.20$), suggesting that the empirical data were well described by log normal density functions.

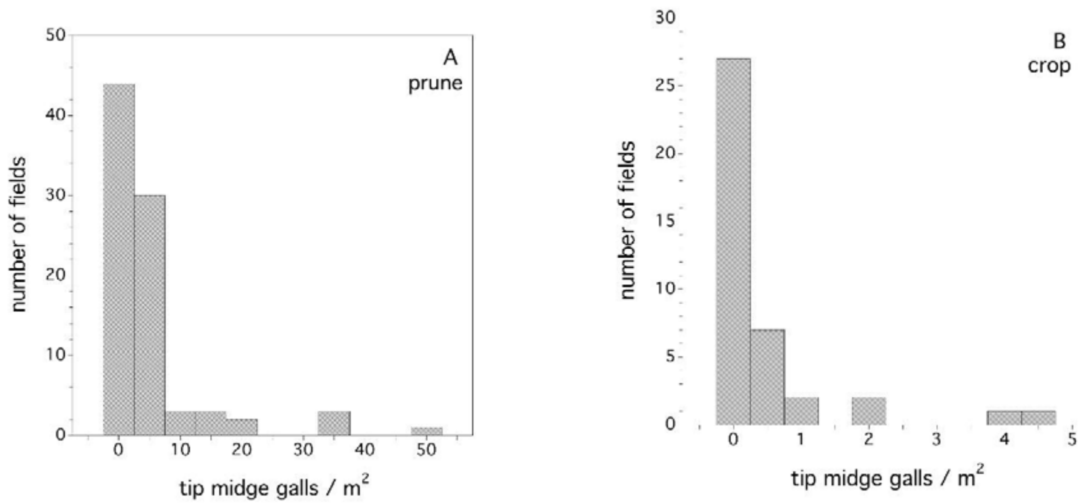



**Fig. 1.** Frequency distribution of blueberry tip midge gall densities in wild blueberry fields for prune fields (A, n=86) and crop fields (B, n=40).

In our controlled paired study where we had an equal number of prune and crop fields in each of three years (2003, 2004, and 2006), we observed that prune fields had higher densities of tip midge galls than crop fields (1.9 galls / $m^2$ vs. 0.6 galls / $m^2$, respectively). A generalized linear Poisson regression model fit to gall densities supported this observation ($X^2_{(1)} = 4.900$, $P = 0.027$) and that there was no year x crop phase interaction ($P = 0.206$). Figure 2a shows that the greater density in prune fields is consistent over the three years. There was a year effect of tip midge gall density with 2003 densities greater than 2004 and 2006 (($X^2_{(2)} = 19.730$, $P < 0.0001$). There was also no year x pest management interaction ($P = 0.998$), crop stage x pest management interaction ($P = 0.935$), nor year x crop stage x pest management interaction ($P = 0.919$). The main effect of pest management system (reduced risk vs grower standard) was also not significant ($P = 0.598$).

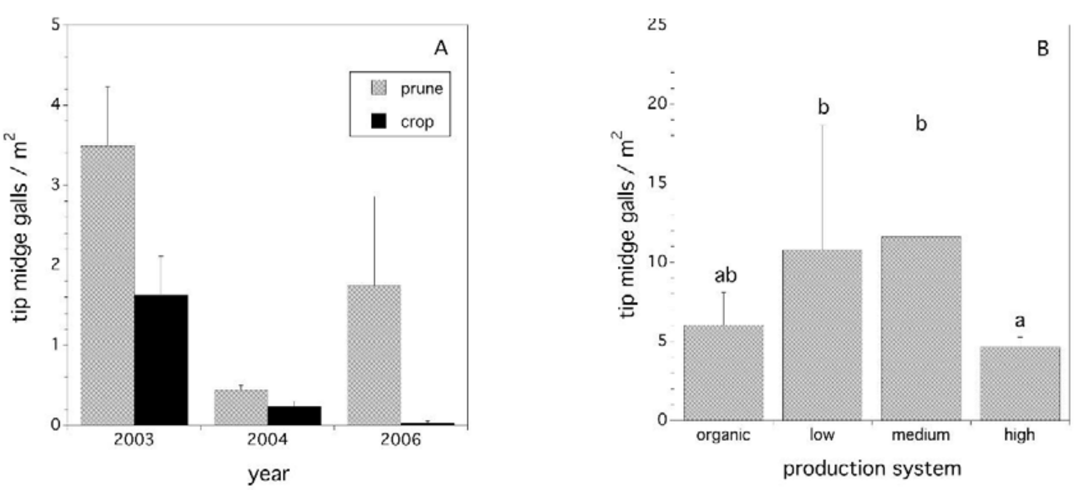


**Fig. 2.** Comparative densities of galls / $m^2$ in prune vs crop (A) wild blueberry fields and four production system types (B). Graph depicts non-transformed densities, analysis of variance conducted on square root transformed data.

During the years 2010, 2012, and 2013 there was a year effect ($X^2_{(2)} = 41.787$, $P < 0.0001$) and a production system effect ($X^2_{(3)} = 12.329$, $P = 0.006$), but no year x production system interaction ($P = 0.174$). Figure 2b suggests that the high input production system had the lowest density of tip midge infestation compared to the low and medium input systems. The organic production system is not different from any of the three conventional systems.

*Blueberry tip midge densities over time*

Blueberry tip midge is of most concern to growers during the prune cycle. Densities in crop cycle fields are low (Fig. 1B). We hypothesize this is due to tougher leaves encountered in crop fields at the time tip midge adults emerge in the spring. During the period 2003-2014, tip midge gall densities in prune fields increased (Fig. 3, $F_{(1,84)} = 14.149$, $P = 0.0003$). However, only 20.2% of the variance in gall density (square root transformed) was explained by year, suggesting that other factors besides time resulted in an increase in tip midge gall incidence in wild blueberry. To determine if high 2014 densities were responsible for the significant increase in gall density over time, a regression was fit by leaving out the 2014 data. Year was also significant in this regression suggesting that tip midge increased in density with time ($F_{(1,68)} = 4.053$, $P = 0.048$). Therefore, we conclude that tip midge populations increased from 2003 - 2014.

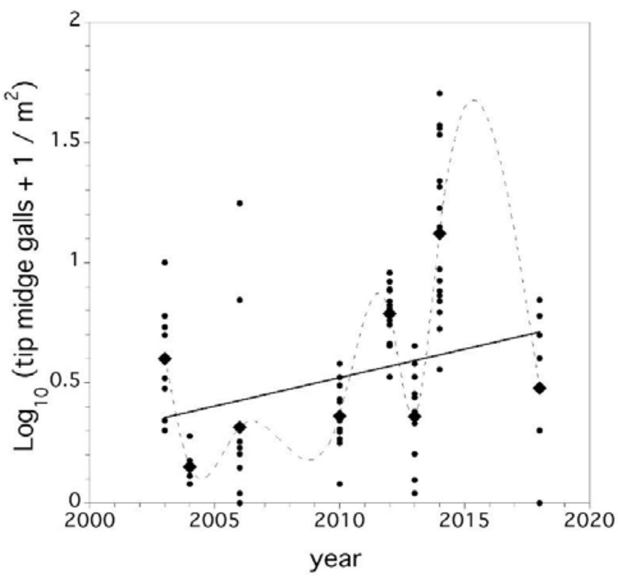



**Fig. 3.** Population increase of blueberry tip midge, as reflected by logarithm (base 10) transformed gall infested stems, in pruned fields (solid line is least square regression, dashed line is a cubic spline fit to the data). Filled circles are individual field mean gall infested stem densities and diamonds are mean field densities for each year.

In 2017 we assessed the occurrence of tip midge galls and gall larval density throughout the growing season in a prune field to determine the potential number of within-season generations that occur. Figure 4 provides evidence, based upon graphical inspection of both gall density (proportion of stems with galls) and tip midge larval density (larvae / gall), that three generations occur during the prune cycle. We do not know if the occurrence of three generations is consistent among years or if the number of generations varies depending upon the growing season.

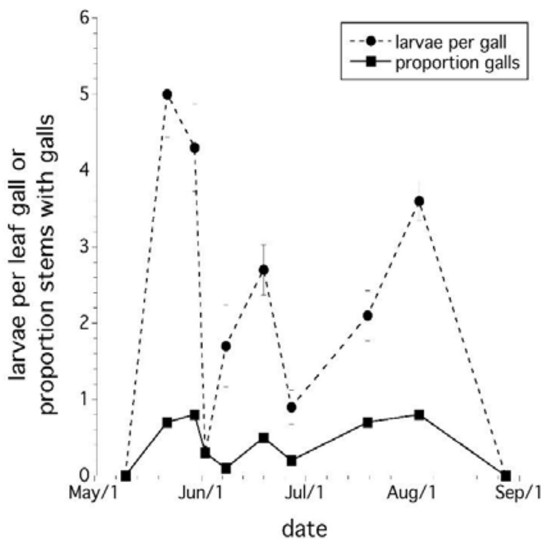
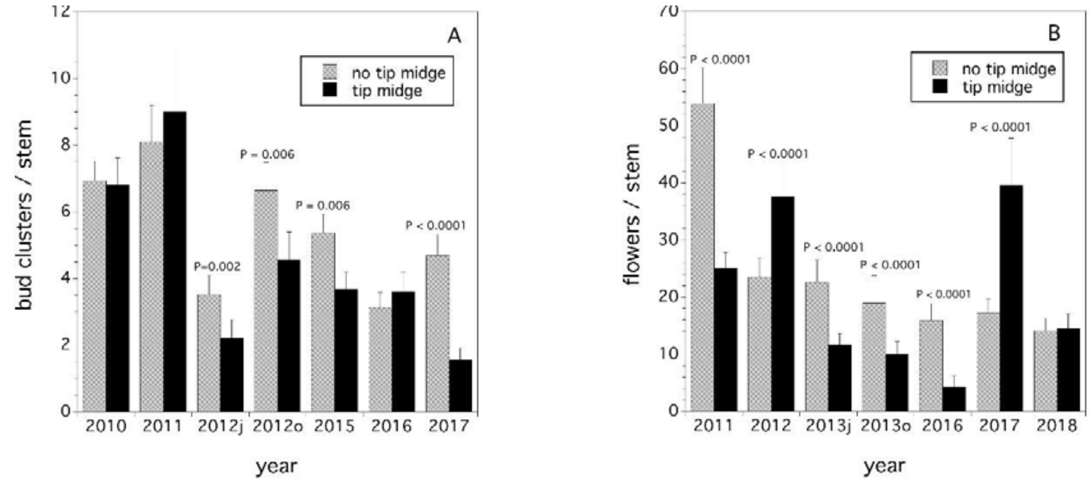



**Fig. 4.** Within season (2017) tip midge gall densities (proportion of stems per $m^2$ with galls) and tip midge larval densities (larvae / gall) in a prune cycle field. Error bars are standard errors.

*<u>Potential crop loss</u>*

We did find a significant difference in flower bud clusters due to treatment (no tip midge vs tip midge infested), but this effect varied by trial ($X^2_{(6)} = 41.072$, $P < 0.0001$, Fig. 5A, interaction of tip midge infestation x trial). In four of the seven studies (2012 J, 2012 O, 2015, and 2017, Fig. 5A) there was a significant reduction in the numbers of flower bud clusters produced on infested stems. Figure 5B shows the effect of the previous year's tip midge infestation on the number of flowers / stem during bloom. As with flower bud clusters there was a significant tip midge by trial interaction ($X^2_{(6)} = 868.966$, $P < 0.0001$, Fig. 5B). Four of seven trials showed a reduction in flowers per stem due to tip midge infestation. However, two trials were characterized by a significant increase in flowers per stem due to tip midge infestation. This suggests that while growers may suffer potential crop loss in some years from tip midge infestation, the effect is not consistent and may actually result in increased potential yield. Figure 5C shows that when bud clusters per stem are reduced due to tip midge infestation, a constant reduction in the number of flowers per infested stem is about 50% of the floral density in non-infested stems. However, when flower bud cluster number appears stimulated by tip midge infestation, floral density increases geometrically.



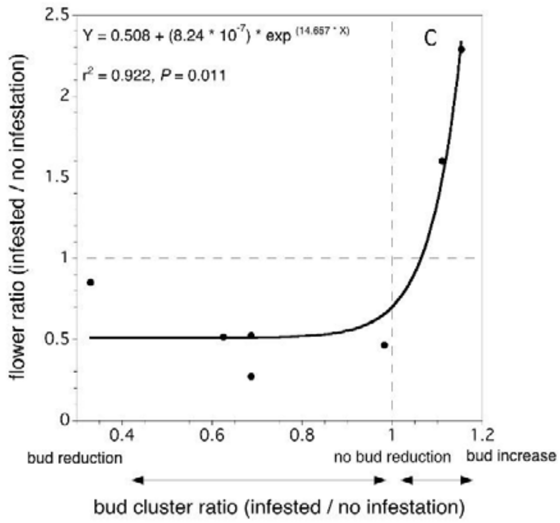




**Fig. 5.** Flower bud clusters / stem in each of the seven trials on infested and non-infested stems, at the end of the prune cycle (A). Flowers/ stem in each of the seven trials on infested and non-infested stems, at the start of the crop cycle just prior to bloom (B). All trials conducted in Jonesboro, ME, except in 2012. The 2012 J trial was conducted in Jonesboro, while the 2012 O trial was conducted in Orland, ME. Relationship between bud cluster ratio and flower ratio on infested and non-infested stems (C).

*Optimal sampling plan for pruned fields*

The mean to variance relationship (Taylor's power law) for blueberry tip midge is: $S^2 = 1.491 + 1.492 * \text{mean}^2$ ($F_{(1,41)} = 523.282$, $P < 0.0001$, $r^2 = 0.927$). The optimal sample sizes for estimation of the average blueberry tip midge densities that were observed between 2003 and 2014 in wild blueberry are 20, $m^2$ quadrat samples in a field for a precision of 25% (se / mean ratio) and 110 samples for a precision of 10% (Fig. 6).

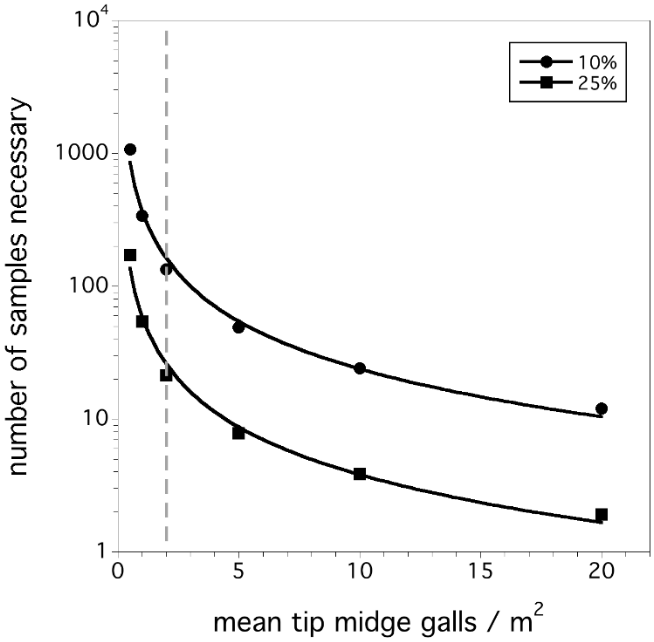



**Fig. 6.** Optimal sample size for blueberry tip midge in wild blueberry for a range of gall densities and two precisions (10% and 25%). The dashed line is the overall mean gall density between 2003 and 2014.

*Predictive degree-day model - Blueberry tip midge first attack*

The average number of cumulative degree-days (base = 10ºC, starting from 1 March for all 4 years) for predicting the occurrence of the first galls in a field was 58.5 $\pm$ 2.15 (se). This predictive degree-day model has high precision (3.7% measured as 100 * se/mean ratio).

*Determination of action thresholds*

The results of our economic threshold analysis are shown in Figure 7. The graphs show economic thresholds if, on average, crop loss due to infested stems is 50% (Fig. 5C). Currently, almost 80% of fields have less than 5% stem infestation by tip midge (Fig. 7A). Growers who tend to obtain lower than average yields (1781 kgs / ha) would use thresholds between 3 and 13% depending upon the price received by the grower (Fig. 7 B-D). Based upon infestation levels currently experienced by growers, most would not likely reach threshold levels in their field and so the cost of control would often exceed any loss due to tip midge infestation. However, it can be seen that for the average level of production over the past five years in Maine of 4453 kgs / ha (Asare et al. 2017), the economic injury level ranges from 1.5 - 5% infestation (the level where the cost of control equals the cost of crop loss) when the price growers receive for blueberries ranges from $1.10 to $4.40 / kg (Fig. 7B-D) and growers who achieve high yields of 7125 kgs / ha would be advised to use thresholds ranging from 1 to 3 % infestation, depending upon the price of blueberries. Therefore, growers obtaining high yields in a given year would be likely to control blueberry tip midge as the cost of control would often be exceeded based upon typical infestation levels that might be experienced.

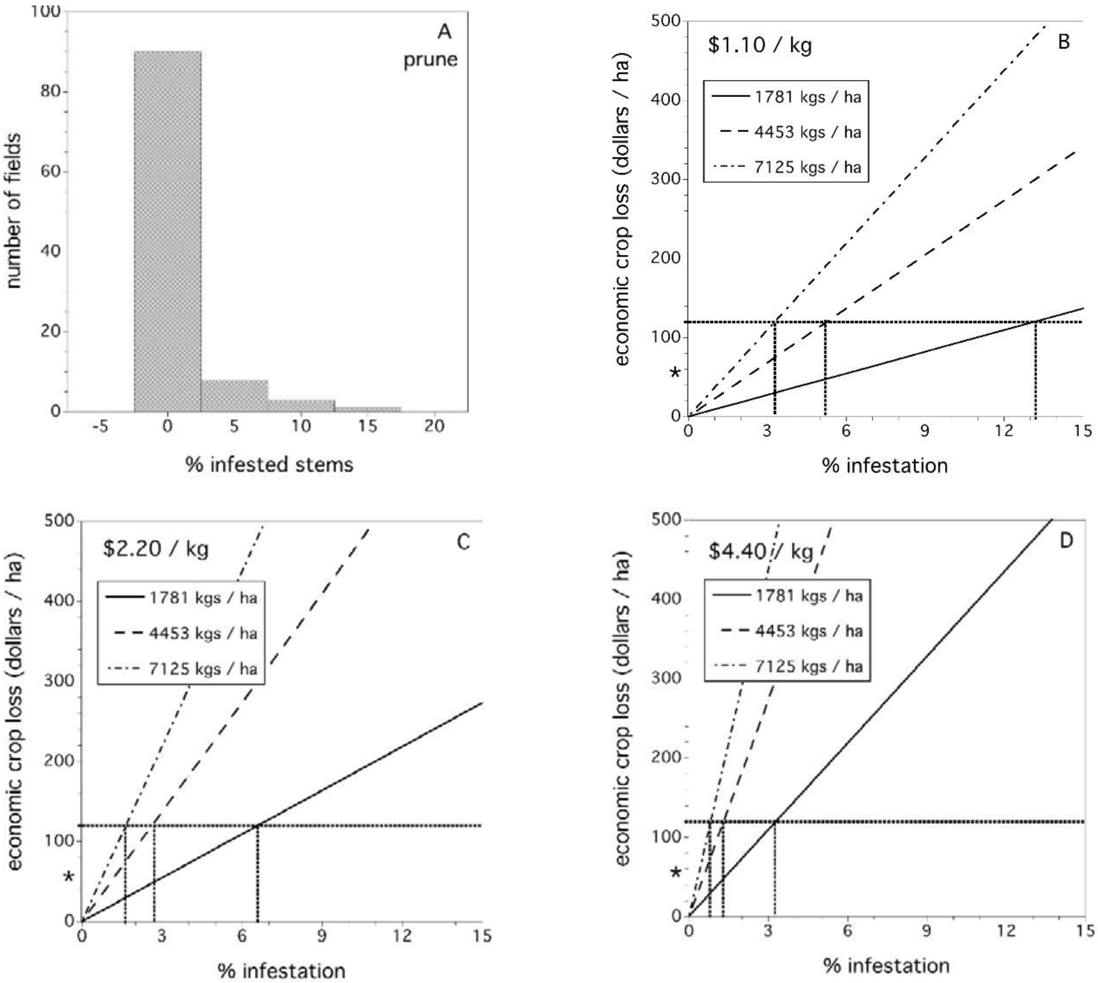



**Fig. 7.** Frequency distribution of blueberry tip midge infested fields (A) and economic threshold estimates for control costs at $120.00/ha under three yield scenarios representing low, medium, and high input production systems and three prices for the crop: $1.10/kg (B); $2.20/kg (C); and $4.40/kg (D).

**CONCLUSIONS AND RECOMMENDATIONS:** Blueberry tip midge is a new emerging insect pest in Maine and Maritime Canada wild blueberry production (Reekie et al. 2009, Cutler and Sproule 2011, Collins and Drummond 2017). Our sampling over the past decade shows that it appears to be increasing in occurrence and density across the Maine wild blueberry region. Little is known about its ecology in this crop and growers have limited experience managing it. In Maine it is a common and serious pest of cranberry that has been a challenge to control (Tewari 2013). Tip midge was common in cranberry decades prior to its discovery in wild blueberry. We do not know if this pest jumped from cranberry to wild blueberry to exploit this vast new host plant or if different races are associated with each host plant as reported in western North America (Cook 2011, Cook et al. 2011, 2012, Mathur et al. 2012).

We found that three generations are possible in Maine on wild blueberry, but we do not know if this number of generations is common or the exception. Anecdotally, observations during several of our insecticide control trials suggest that often only a single generation may occur since new galls cease to form by late June (Collins and Drummond 2013, 2014, 2016).

Data plotted in Reekie et al. (2009) of tip midge life stages on wild blueberry in Nova Scotia suggest that two (with a possible partial third) generations occur in Nova Scotia. Cook et al. (2012) provided evidence that tip midge may have three generations on highbush blueberry in British Columbia. Their data suggest a fair degree of overlap in generations and so it is difficult to determine the exact number of generations. In Michigan, Hahn and Isaacs (2012) provide gall and larval phenology data that suggest 3-4 generations occur in a growing season.

Predicting the initial emergence and attack of this pest has proved challenging. Optimal control with insecticides in wild blueberry occurs when timing of the first application is made at the first sign of gall appearance in a prune field (Collins and Drummond 2018). Predicting emergence and attack with traps in highbush blueberry appears to be an effective tool for pest management (Roubos and Liburd 2010a). We have found that trapping with yellow bowl traps has not resulted in a consistent means of predicting the onset of attack and gall occurrence (Drummond and Collins unpublished data). A degree-day model of 1300 degree days (base 10ºC (Hahn and Isaacs 2012), or base 9.8ºC (Roubos and Liburd 2010b)) for predicting the largest peak of adult emergence during the season might still be useful for Maine wild blueberry growers, but a more useful degree-day model is that for predicting first occurrence of attack. This is because the timing of the first insecticide application in wild blueberry for chemical control of blueberry tip midge is initiated at first sign of attack. We found that using the same base temperature of 10ºC provides a highly precise predictive model ($58.5 \pm 2.15$) under field conditions using air temperatures.

We found that field infestation of tip midge is significantly higher in prune fields than in crop fields. We have not found any mention in the literature that in cranberry or highbush blueberry older leaves with higher phenolic content tend to harbor significantly lower galls. In wild blueberry this appears to be the case in crop phase leaves (Drummond unpublished data), although the exact mechanism behind our finding of lower gall densities in crop fields compared to prune fields is unknown. We speculate that young vegetative meristems are more suitable for blueberry tip midge development and survival, because lateral branch development and the occurrence of active apical meristems are not abundant in crop stage plants unless flowers are removed early in the season or lacking and plant resources are shifted from reproductive growth (fruit production) to vegetative growth (Bajcz and Drummond 2017a). Hahn and Isaacs (2012) found that highbush blueberry cultivars had a profound effect on tip midge infestation, ranging from 1.8 to 30.9 percent infestation. This supports a hypothesis that host plant quality or phenology might be a basis for the differences in infestation that we observed between prune and crop stage fields.

The effect of production system does affect blueberry tip midge incidence. We found that the high input, more intensive production system, did have lower tip midge densities than the low or medium input. Interestingly, the organic system was not different from any of the three conventional production systems. We are not sure why this is the case; one might have expected that the organic production system would have the highest tip midge densities. Yarborough et al. (2017) showed that the significant factor affecting tip midge infestation levels were leaf nutrition. They found that as average field-level boron ppm and % phosphorus in prune field plant leaves increased, blueberry tip midge infestation increased linearly. This suggests that rapidly growing leaves that are of high nutritional content might be optimal for tip midge. Yarborough et al. (2017) did not find a production system effect in their study. In the high input system, we found that fields managed with grower standard insecticides had no difference in blueberry tip midge infestation compared to high input fields managed with reduced risk insecticides. Because of this, we speculate that management practices other than insecticides might be determining the differences in blueberry tip midge infestation that we found. Although, blueberry tip midge can be quite difficult to control with insecticides (Hahn 2011, Collins and Drummond 2013, 2014).

We found a high variation in percent infestation of both prune and crop fields (average density of galls / $m^2$ was 5.30 $\pm$ 0.92 and 0.48 $\pm$ 0.16, for prune and crop fields, respectively). In Michigan, highbush blueberry (Hahn and Isaacs 2012) infestation levels appear to be a bit higher than Maine wild blueberry prune fields at 7.2 $\pm$ 1.7, but these differences are not likely to be significant at an $\alpha$ level of 0.05. Therefore, it appears that blueberry tip midge in Maine as a new emerging pest is already at a comparable level to what is observed in a more established pest / host plant relationship in Michigan.

Potential crop loss, measured as a reduction in flowers per stem, may not always result in actual crop loss in fruit crops. Tewari (2013) found that tip midge damages the apical meristem resulting in fewer flowers the following year, a potential crop loss. Dernisky et al. (2005) showed that in rabbiteye blueberry (*Vaccinium ashei* Reade), tip midge damage resulted in damaged flowers, which resulted in reduced fruit set. Reduced fruit set is also a measure of potential yield loss since many flowering plants and shrubs can compensate for reduced numbers of viable flowers, especially in wild blueberry (Bajcz and Drummond 2017a, 2017b). Despite compensation properties of wild blueberry, Yarborough et al. (2017) and Asare et al. (2017) show that there is a strong relationship between fruit set and yield. Therefore, our finding that blueberry tip midge infestation may reduce flower bud clusters in the year of damage (prune year) and flower number per stem in the year following damage suggests that this pest can cause potential yield loss. We did find an infestation x year interaction showing that infested stems (stems with galls) did not always result in potential crop loss or the reduction of flower numbers per stem. Reekie et al. (2009) report that blueberry tip midge infestation of wild blueberry can lead to reduced number of flowers as we found, and premature bloom which we did not observe. What we found that was intriguing is that in some years, wild blueberry plants appeared to respond in a hyper compensatory manner that resulted in an increase in flower number per stem. A review article by Trumble et al. (1993) cites several studies that show herbivores may increase assimilate demand by previously existing or new sinks. This is possibly the case with blueberry tip midge and wild blueberry reproductive tissue in the form of floral primordia. In addition, Reekie et al. (2009) showed an increase in branching of infested stems. Increased branching will result in more flowers per stem and may be a mechanism of the overcompensation phenomenon that we document.

Belsky et al. (1993) suggest that plant compensation or overcompensation due to herbivory as a coevolved evolutionary phenomenon may not be a correct interpretation for increased plant growth or reproductive output after herbivory. These authors state “rapid plant re-growth is more likely to have evolved as a strategy to reduce the negative impacts of all types of damage, than as a strategy to increase fitness following herbivory above ungrazed levels.” Hendrix (1988), in a review of the effects of herbivory on plant reproduction, cites many examples of compensation and overcompensation in reproductive effort by plants. A few specific examples of compensation to herbivory are the studies by Hendrix (1979) on wild parsnip and Doust and Eaton (1982) on beans. However, Hendrix (1988) also states that weather and access to nutrients can modulate these plant compensatory responses. In all of these reviews we did not find any reported overcompensation reproductive responses in any *Vaccinium* species. Therefore, this may be a novel documented response in the genus *Vaccinium*.

Given that potential crop loss can result due to blueberry tip midge almost half of the time (3 out of 7 years), sampling and economic thresholds to determine a basis for control are important. In a review of the cranberry and blueberry pest management literature we found no documentation of quantitative sampling plan to assess the degree of tip midge infestation. We did find a report by Fitzpatrick et al. (2015) that determined an action threshold for cranberry of 30% upright infestation that would warrant an insecticide application. Most cranberry and blueberry pest management involves predicting peak emergence through degree-day models or bowl traps and applying insecticides when these triggers are reached (Roubos 2009, Hahn and Isaacs 2012). We developed economic thresholds for blueberry tip midge that incorporate yield potential, price expected by the grower, cost of control, and infestation level. The price scenarios we used cover both growers that sell fresh market and those that sell to processors of frozen fruit. Price can fluctuate greatly and rapidly. The price received by growers for processed berries has recently declined to a level that is just above production cost, but organic growers make much greater profit selling both frozen and fresh fruit (Yarborough pers. comm.). Sampling prune fields economically with an optimal sampling plan in combination with the use of an economic threshold can be the basis of an IPM program directed at controlling blueberry tip midge in the prune year. We have shown that the prune year is the crop stage in which damage is realized and it is the crop phase that will minimize or prevent insecticide residues on the fruit since fruit will not be harvested for 12-14 months after control tactics are implemented. Upon attaining the threshold, the grower can apply insecticides for control (Collins and Drummond 2018) to reduce further infestation. Another option that has more promise is to allow tip midge to infest stems until early summer (first half of July) and then prune the crop with mowing and / or burning. We have shown that a delayed prune will control the blueberry tip midge larvae within the galls (Collins and Drummond 2017) and as long as the delayed prune takes place before mid-July, minimal reduction of flower buds will result in the subsequent crop phase. (Drummond and Yarborough 2014). This strategy has been well adopted by blueberry growers for blueberry thrips in wild blueberry (Drummond et al. 2013).

Currently, many growers have not experienced blueberry tip midge, especially those in the easternmost part of the Maine production area. If this pest continues to increase, sampling plans and economic thresholds should allow growers to manage it in a sustainable and cost effective manner.

## REFERENCES:

Asare, E., A. K. Hoshide, F. A. Drummond, X. Chen, and G. K. Criner. 2017. Economic risk of bee pollination in Maine wild blueberry, *Vaccinium angustifolium* Aiton. J. Econ. Entomol. 110 (5): 1980 – 1992.

Bajcz, A. W. and F. A. Drummond. 2017a. Bearing fruit: Flower removal reveals the trade-offs associated with high reproductive effort for wild blueberry. Oecologia. 185(1): 13-26.

Bajcz, A. W. and F.A. Drummond. 2017b. Flower power: Floral and resource manipulations reveal the consequences of reproductive effort in wild blueberry (*Vaccinium angustifolium*). Ecology and Evolution. DOI: 10.1002/ece3.3109: 1-15.

Bell, D. J., L. J. Rowland, J. Smagula, and F. Drummond. 2009. Recent advances in the biology and genetics of wild blueberry. Maine Agric. For. Exp. Stn., University of Maine, Orono. Tech. Bull. 36 pp.

Belsky, A.J., W. P. Carson, C. L. Jensen, and G. A. Fox. 1993. Overcompensation by plants: herbivore optimization or red herring? Evol. Ecol., 7(1): 109-121.

Cochran, W. G. 1977. Sampling Techniques, 3rd ed. Wiley Eastern Ltd., N.Y. 428 pp.

Collins, J. and F. A. Drummond. 2013. Blueberry tip midge control with foliar applications of insecticides, 2012. Arthropod Management Tests 38 (1). doi.org/10.4182/amt.2013.C5

Collins, J. A. and F. A. Drummond. 2014. Blueberry tip midge control with foliar application of insecticides, 2013. Arthropod Management Tests 39 (1). doi.org/10.4182/amt.2014.C2

Collins, J. A. and F. A. Drummond. 2016. Blueberry tip midge control, 2014. Arthropod Management Tests 40 (1). doi: 10.1093/amt/tsv013

Collins, J. A. and F. A. Drummond. 2017. Blueberry tip midge. Fact Sheet No. 208, University of Maine Cooperative Extension, Orono, ME. https://extension.umaine.edu/blueberries/factsheets/insects/208-blueberry-tip-midge/

Collins, J. A. and F. A. Drummond. 2018. Blueberry gall midge control, 2017. Arthropod Management Tests 43 (1). doi: 10.1093/amt/tsy016.

Cook, M. A. 2011. *Dasineura oxycoccana* (Diptera: Cecidomyiidae) populations on cranberry and blueberry in British Columbia: Same species, host races, or sibling species? M.S. Thesis, Simon Frasier University, Vancouver, B.C. 87 pp.

Cook, M. A., S. N. Ozeroff, S. M. Fitzpatrick, and B. D. Roitberg. 2011. Host-associated differentiation in reproductive behaviour of cecidomyiid midges on cranberry and blueberry. Entomol. Exp. Appl. 141: 8-14.

Cook, M. A., S. M. Fitzpatrick, and B. D. Roitberg. 2012. Phenology of *Dasineura oxycoccana* (Diptera: Cecidomyiidae) on cranberry and blueberry indicates potential for gene flow. J. Econ. Entomol. 105(4) 1205-1213.

Cutler, C. and J. Sproule. 2011. Blueberry gall midge, also known as cranberry tipworm, tip midge. Nova Scotia Agricultural College Wild Blueberry Factsheet. Wild Blueberry Producers Association of Nova Scotia.

Dernisky, A. K., R. C. Evans, O. E. Liburd, and K. MacKenzie. 2005. Characterization of early floral damage by cranberry tipworm (*Dasineura oxycoccana* Johnson) as a precursor to reduced fruit set in rabbiteye blueberry (*Vaccinium ashei* Reade). Int. J. Pest Manag. 51(2): 143–148.

Doust, L. J. and G. W. Eaton. 1982. Demographic aspects of flower and fruit production in bean plants, *Phaseolus vulgaris* L. Am. J. Bot. 69: 1156-1164.

Drummond, F. A. and D. Yarborough. 2014. Growing season effects on wild blueberry (*Vaccinium angustifolium*) in Maine and implications for management. Acta Horticulturae 1017: 101-108.

Drummond, F. A., J. A. Collins, and D. Yarborough. 2013. Blueberry thrips. Fact Sheet 202, UMaine Extension No. 2373, Univ. Maine, Orono, ME.

http://umaine.edu/blueberries/factsheets/insects/202-blueberry-thrips/ Last accessed 12 September, 2018.

Fitzpatrick, S. M., M. Elsby, W. Wong, and S. Mathur. 2015. Best Management Practices for cranberry tipworm in western Canada. BC Cranberry Marketing Commission

Hahn, N. 2011. Biology and management of blueberry gall midge and scale insects in Michigan blueberries. M.S. Thesis, Michigan State Univ., East Lansing, MI. 91 pp.

Hahn, N. G. and R. Isaacs. 2012. Distribution and phenology of *Dasineura oxycoccana* (Diptera: Cecidomyiidae) in Michigan blueberries. Environ. Entomol. 41(3): 455–462.

Hendrix, S. D. 1979. Compensatory reproduction in a biennial herb following insect defloration. Oecologia 42: 107-118.

Hendrix, S. D. 1988. Herbivory and its impact on plant reproduction. *In:* Plant Reproductive Ecology: Patterns and Strategies. J. L. Doust and L. L. Doust, eds. Oxford University Press, N.Y. 344 pp.

JMP®. 2015. Version 12. SAS Institute Inc., Cary, NC, 1989-2007.

Mathur, S., M. A. Cook, B. J. Sinclair, and S. M. Fitzpatrick. 2012. DNA barcodes suggest cryptic speciation in *Dasineura oxycoccana* (Diptera: Cecidomyiidae) on cranberry, *Vaccinium macrocarpon,* and blueberry, *V. corymbosum.* Fla. Entomol. 95(2): 387-394.

Pedigo, K. P., S. H. Hutchins, and L. G. Higley. 1986. Economic injury levels in theory and practice. Annual Review of Entomology 31:341-368

Reekie, M., K. MacKenzie, and B. Lees. 2009. The biology and pest potential of cranberry tipworm (Diptera, Cecidomyiidae) on wild blueberry. Acta Hort. 810: 401-410.

Roubos, C. R. 2009. Monitoring and managing blueberry gall midge (Diptera: Cecidomyiidae) in rabbiteye blueberries. PhD. Dissertation, Univ. Florida. Gainesville, FL. 117 pp.

Roubos, C. R. and O. E. Liburd. 2010a. Evaluation of emergence traps for monitoring blueberry gall midge (Diptera: Cecidomyiidae) adults and within field distribution of midge infestation. J. Econ. Entomol. 103: 1258-1267.

Roubos, C. R. and O. E. Liburd. 2010b. Pupation and emergence of blueberry gall midge, *Dasineura oxycoccana* (Diptera: Cecidomyiidae), under varying temperature conditions. Fla. Entomol. 93: 283-290.

Taylor L. R. 1961. Aggregation, variance and the mean. Nature.189:732–735.

Tewari, S. 2013. Interactions between a gall making fly, *Dasineura oxycoccana* (Diptera: Cecidomyiidae), and its host plant, cultivated cranberry (*Vaccinium macrocarpon*). M.S. Thesis. Univ. Mass. Amherst, MA. ScholarWorks@UMass Amherst. 118 pp.

Trumble, J. T., D. M. Kolodny-Hirsch, and I. P. Ting. 1993. Plant compensation for arthropod herbivory. Ann. Rev. Entomol. 38(1): 93-119.

Yarborough, D. E. 2015. Wild blueberry culture in Maine. Fact Sheet No. 220, UMaine Extension No. 0288. University of Maine Cooperative Extension, Orono, ME.

https://extension.umaine.edu/blueberries/factsheets/production/wild-blueberry-culture-in-maine/ Last accessed 12 September, 2018.

Yarborough, D., F. Drummond, S. Annis, S. and J. D'Appollonio. 2017. Maine wild blueberry systems analysis. Acta Hort. 1180:151-160

Yarborough, D. E., F. Drummond, and J. A. Collins. 2018. Insect control guide for wild blueberries. Fact Sheet No. 209, UMaine Extension No. 2001. University of Maine Cooperative Extension, Orono, ME. https://extension.umaine.edu/blueberries/factsheets/insects/209-insect-control-guide-for-wild-blueberries/ Last accessed 12 September, 2018.

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## ENTOMOLOGY

**INVESTIGATORS:** F. A. Drummond, Professor of Insect Ecology/Entomology
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E. Ballman, Research Associate in Invasive Species/Entomology

**2. II. TITLE:** Biology of spotted wing drosophila, 2018.

### *Study 1.* ***Modeling internal fruit temperature as a predictor of first occurrence of spotted wing drosophila (SWD) in wild blueberry***

**OBJECTIVE:** Currently, a good simulation model and a predictive phenological model exist for SWD. These have been developed by research scientists in the western U.S. Both of these tools are driven by air temperature during the growing season. We evaluated the degree-day phenological model last year for predicting first occurrence of SWD in wild blueberry fields and found that its accuracy was only marginal. Therefore, in 2018 we decided to see if instead of air temperature, internal fruit temperature would be better to drive the models once infestation began. We report on the fruit temperature relative to air temperature in two blueberry growing regions in Maine.

**METHODS:** Internal fruit temperature and fruit diameter were measured at two sites in 2018 (Hope and Jonesboro, ME). Fruit temperatures were evaluated three times at the Jonesboro site (31 July, and 8 and 15 August) and twice at Hope (25 and 27 July). On each sample date, we selected 20 ripe berries from each of five clones; 10 berries were high on the stem and unshaded and 10 were lower on the stem and shaded by leaves. Internal temperature of each berry was measured using an Omega® Handheld Digital Thermometer. After measurements were completed for each clone, we estimated percent cloud cover and determined air temperature using both the Omega® Handheld Digital Thermometer and a Kestrel® 3000 wind meter. Fruit diameter was measured on 25 and 31 July at Hope and Jonesboro, respectively. Approximately one pound of fruit was collected at each site and brought back to the laboratory. The diameter of 100 randomly selected berries was measured using an SE® 784EC 6" Electric Digital Caliper.

Berry size was modeled by a Weibull distribution and Weibull regression was used to compare berry size between the two study sites. General linear models (ANOVA) were used to determine if site, clone, and berry location on the stem (sunny vs. shaded) determined internal fruit temperature. Two additional models were used to assess which environmental variables explained internal fruit temperature for sunny and shady locations separately. A final general linear model was used to determine if internal fruit temperature differed from air temperature.

**RESULTS:** A Weibull probability density function described both the Hope and Jonesboro berry-size frequency distributions. A Weibull regression showed that berry size (diameter) was not significantly different between the two blueberry fields in Hope and Jonesboro ($X^2_{(1)}$ = 0.079, $P$ = 0.779, Fig. 1.).

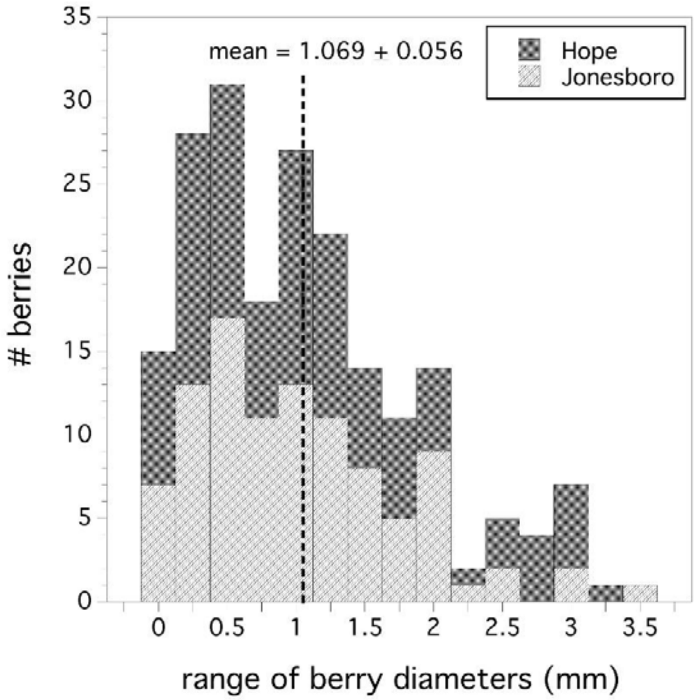


**Fig. 1.** Frequency distribution of wild blueberry diameter size in Hope and Jonesboro study fields (n=498 berries).

Wild blueberries in the sunny position of the stem were significantly warmer than shaded berries (location within cone, $F_{(5,484)}$ = 2.917, $P$ = 0.013). Site, and clone, or their interactions, were not significant factors ($P$ > 0.05) in determining differences in internal berry temperature. Overall, sunny berries were 1.03ºC warmer than shaded berries. When site, clone, air temperature, amount of cloud cover, and relative humidity were assessed to determine the main predictors of berry temperature for shaded berries, cloud cover was the only significant predictor ($P$ = 0.03); although, a cloud cover X air temperature interaction was marginally significant ($P$ = 0.057) suggesting that internal fruit temperature was not as affected by a reduction in cloud cover at high air temperatures. Site and clone were not significant; the variation in shady berry internal temperature explained by these two predictors was 85.5%. Sunny internal berry temperature was determined by site, cloud cover, and air temperature. The variation in sunny internal berry temperature explained by these three predictors was 90.7%.

**CONCLUSIONS AND RECOMMENDATIONS:** Despite finding small (1ºC, less than 2-3%) differences in internal fruit temperature between shaded and sunny fruit, we did not find a significant differential between air and internal fruit temperature by site, clone, or location. Therefore, it should not be necessary to construct a complex biophysical model of the internal temperature of wild blueberries in order to accurately predict development of the immature stages of spotted wing drosophila.

***Study 2. Validation of the spotted wing drosophila male trap capture threshold. 2018, year three***

**OBJECTIVE:** Previous work has shown that spotted wing drosophila male fly trap-captures can be used as a reliable method for determining when fields are at risk from larval infestation. Excellent validation of this risk-based threshold resulted from work in 2016 and 2017. In 2018 we trapped flies, recorded the cumulative number of male SWD, and made weekly assessments of fruit infestation. These data were then used to estimate the level of fruit infestation relative to male fly capture rates.

**METHODS:**

*Adult and larval abundance*

Cooperating growers allowed us to trap adult SWD and sample fruit for larval infestation on a weekly basis. The fields were maintained by the growers using typical wild blueberry production practices. Traps were placed in 20 wild blueberry fields in Downeast and Mid-coast, Maine (10 per region). Trapping for SWD began early July and continued until larval infestation of fruit was detected or until fields were harvested. Traps were monitored at five to nine day intervals for the presence of SWD adults. All traps were constructed from Solo®, 16 fl. oz, red polystyrene cups with light-blocking lids. Seven to ten, 3/16-inch holes were punched on the side of each container near the top, evenly spaced around the rim. Bait consisted of live yeast (1tbsp) + sugar (4tbsp) + 12oz water (makes enough for four traps). Three traps were placed at each site and were hung 1-2 ft above the top of the canopy using 36 inch plant stands. Throughout the study and on each sample date, traps set the previous week were collected and returned to the laboratory where male, female, and total abundance of SWD adults were determined and recorded. New traps were deployed weekly. Using these data we calculated the total number of SWD and SWD males per trap captured from each site on each date and the mean cumulative number of SWD and SWD males over the collection period.

To compare adult abundance with larval infestation, weekly fruit samples were taken from the 20 wild blueberry fields from mid-July until the fields were harvested. The samples were processed using the Salt Extraction Method described in Maine wild blueberry factsheet #210 (http://umaine.edu/blueberries/factsheets/insects/210-spotted-wing-drosophila/). Each sample consisted of a ca. 1-cup sample collected from the vicinity of each of the three adult traps (three samples per field). Using these data we calculated the mean number of larvae each site on each sample date. These data were compared with the adult abundance data collected over the same time period.

**RESULTS:** The 2018 growing season was atypically hot during the SWD buildup period of July and August in both the Downeast and Coastal growing areas. Figure 1 shows a NWS map of summer daily temperatures from Bangor, depicting the unusually hot weather. During the field season we noted that atypical SWD dynamics of population buildup were taking place. SWD trap captures occurred earlier Downeast (mid-July) compared to Coastal fields (early – mid August). This is a phenomenon that we have not witnessed since our trapping began in 2012. Four of the 20 fields that we monitored were harvested early before any male SWD were captured; one field had one male captured in three traps (or 0.33 males / trap) and no infestation of fruit occurred (30 July – 8 August).

Two fields were harvested early (17 July and 8 August) with no infested fruit and only a very low number of male SWD detected (0.33 and 0.67 males per trap, respectively). Thus, early harvest is still a viable strategy to avoiding SWD infested fruit (Table 1).

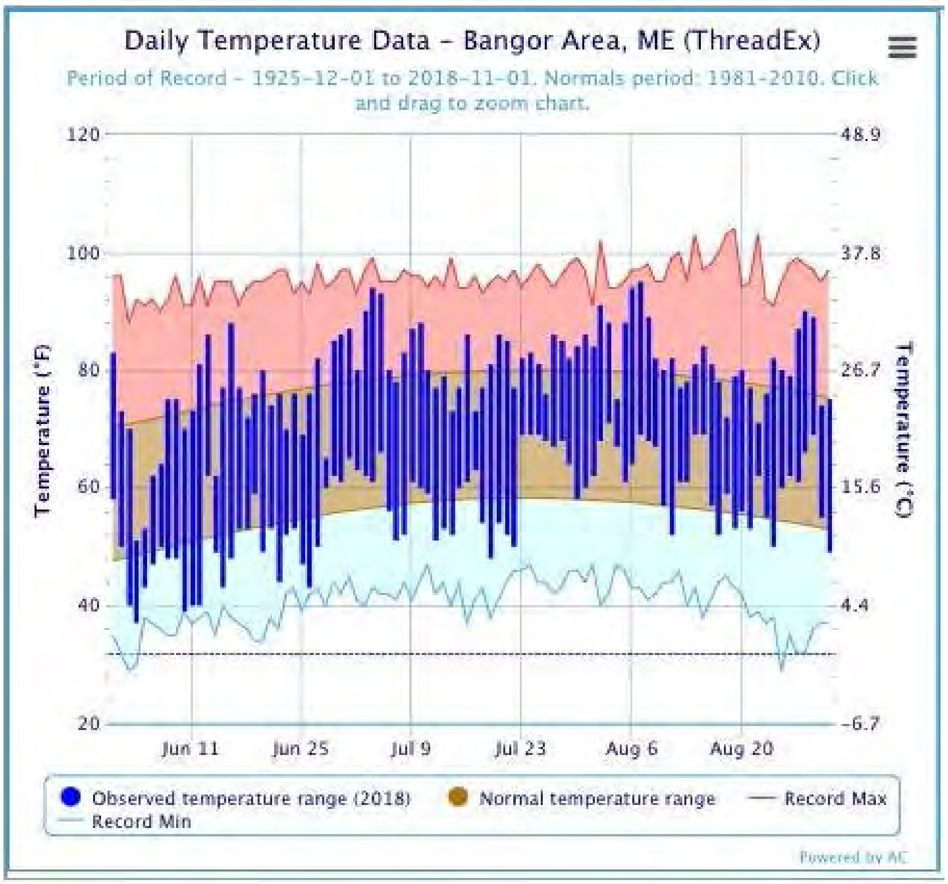


**Fig. 1.** Daily maximum and minimum air temperatures in Bangor, ME for June, July, and August 2018. Brown band is normal temperature range (1981 – 2010) during the Maine summer.

**Table 1.** Early harvested fields* that had no or extremely low male SWD trap captures.

| Region | Harvest date | Male SWD / trap[1] | % infestation at harvest |
|---|---|---|---|
| Coastal | 6 August* | 0.0 | 0.0 |
| Coastal | 6 August* | 0.0 | 0.0 |
| Downeast | 30 July* | 0.0 | 0.0 |
| Downeast | 8 August* | 0.33 | 0.0 |
| *Fields harvested later with no or few male SWD captured and no infestation* | | | |
| Downeast | 15 August | 0.67 | 0.0 |
| Downeast | 15 August | 0.0 | 0.0 |

[1] based upon three traps per field

The 14 remaining fields were not harvested until male SWD were being captured in much higher numbers. Table 2 summarizes the cumulative male trap captures and the observed and expected (based upon predictive model) proportion infestation of fields for groups of thresholds. It can be seen that the predicted probabilities for likelihood of field infestation based upon the cumulative male SWD trap captures the week prior to infestation (based upon field data collected from 2012-2017) were not similar to what we observed in 2018. A high percentage of fields were characterized by infested fruit prior to harvest, even when the number of male SWD trap captures were low. This may have been due to the unusual explosive increase in SWD trap captures over short periods of time in 2018. The rate of increase of male SWD trap-capture from the week prior to detected fruit infestation and the following week was 567.8 $\pm$ 154.6 %. This phenomenal increase in males over a one-week period was most likely due to the extreme hot weather during late July and the first half of August. This increase in males reflects a large increase in total SWD and thus the rapid potential for fruit infestation.

Because our predictive model SWD thresholds did not do well at predicting infestation a week following the male SWD trap captures, we decided to see if the model would predict the infestation that occurred the SAME week as the SWD male trap captures for various threshold levels. Table 3 shows the infestations observed in the field the same week as the SWD male trap captures for various thresholds and the predicted infestations that would be expected the following week (same as Table 2). Table 3 shows better prediction, but still not a good prediction of the infestation of fruit between male SWD trap captures and the percentage of fields that became infested in the same week. We suspect that the poor performance of the model for predicting the probability of fruit infestation might be due to the rapid potential for infestation under hot temperatures. We base this speculation on the observation that the predictions were better when male SWD trap captures were associated with the infestation in the same week rather than the following week which the model was based upon. Rapid explosive infestation rates are typical in fruit production systems in States south of Maine where hot summer temperatures are more common when ripe fruit occurs prior to harvest.

**Table 2.** Observed and predicted fruit infestation associated with average cumulative male SWD thresholds in 14 fields the week prior to infestation.

| **Threshold class - cumulative male SWD / trap** | **# fields** | **Observed proportion fields infested** | **Predicted[1] Probability of fields infested following week** |
|---|---|---|---|
| 1 | 3 | 66% | 1% |
| 3.5 | 6 | 83.3% | 10% |
| 7 | 2 | 50% | 25% |
| 17 | 3 | 100% | 50% |

[1] probability of a field being infested with the associated male threshold class. See SWD factsheet # 210-Spotted Wing Drosophila: Pest Biology and IPM Recommendations for Wild Blueberries for explanation of the predictive SWD threshold model.

**Table 3.** Observed fruit infestation associated with the average cumulative male SWD thresholds in 14 fields the week of detected infestation compared to the predicted probability of infestation a week later based upon the SWD threshold model.

| **Threshold class - cumulative male SWD / trap** | **# fields** | **Observed proportion fields infested** | **Predicted[1] Probability of fields infested following week** |
|---|---|---|---|
| 7 | 3 | 66.6% | 25% |
| 17 | 5 | 100% | 50% |
| 30 | 3 | 66.6% | 75% |
| 50 | 3 | 100% | 95% |

[1] probability of a field being infested with the associated male threshold class. See SWD factsheet # 210-Spotted Wing Drosophila: Pest Biology and IPM Recommendations for Wild Blueberries for explanation of the predictive SWD threshold model.

Figure 2 illustrates SWD population increase during the growing season and shows why fields harvested prior to mid–August escaped damage. In fact, during mid-August the SWD population increase stopped and then started again very explosively by August 20. Male SWD captures predicted overall SWD population increase (Fig. 3) and overall SWD populations were highly related to the actual fruit infestation levels that we observed in each field before harvest (Fig. 4).

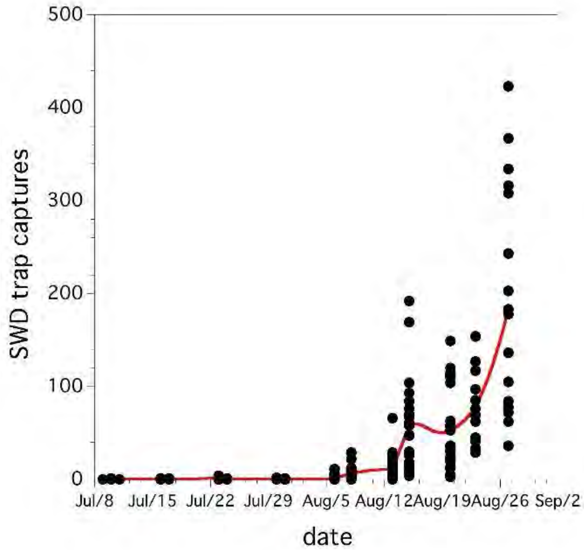


**Fig. 2.** Spotted wing drosophila population increase during the 2018 growing season.

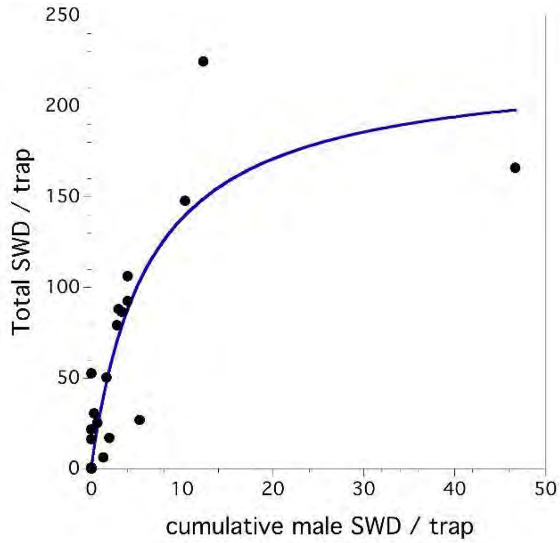


**Fig. 3**. Relationship between cumulative male and total SWD trap captures.

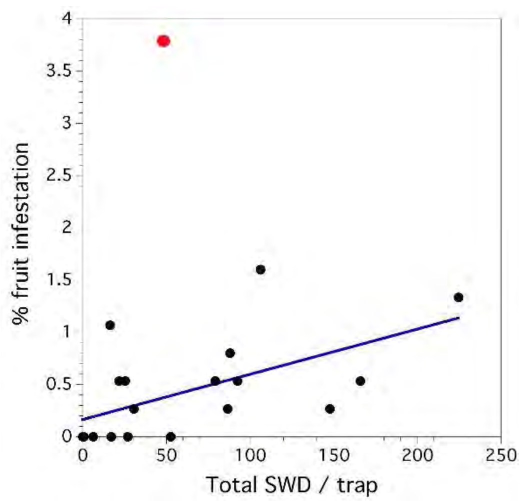


**Fig. 4.** Relationship between total SWD trap captures and % fruit infestation per field. Red data point is an outlier, a particular field with a high level of fruit infestation.

**CONCLUSIONS AND RECOMMENDATIONS:** In conclusion, the SWD threshold system appears to have broken down in 2018. Early harvest still avoided SWD infestation, but fields harvested starting in mid-August did not show a delay between the male SWD threshold and fruit infestation. In 2018, many threshold levels that in the past would suggest a low probability of fruit infestation actually became infested. Whether this is due to the extreme hot temperatures in mid to late summer is unknown. If it is, and hot summers continue to characterize the Maine growing season, then the current threshold system for spotted wing drosophila may not perform adequately for determining if fields need to be immediately harvested or protected with an insecticide.

An inspection of the past seven years of trapping data (2012 – 2018) does show an unexpected trend in SWD sex ratio (Fig. 5). It can be seen that a continual decline in male to female sex ratio has occurred since the onset of the SWD invasion. This could be a problem if growers rely on a threshold based upon cumulative male flies; although a similar sex ratio was witnessed in 2017 and the threshold model validated very well. There are at least two possible reasons for this trend. The first possibility is that male SWD are more sensitive to environmental hazards. We know this to be true of winter temperatures and insecticide exposure. Therefore, it could be that a summer such as the one we experienced in 2018 with very hot daytime temperatures might differentially shorten male longevity more than female longevity thus producing an unbalanced sex ratio compared to the expected 1:1.

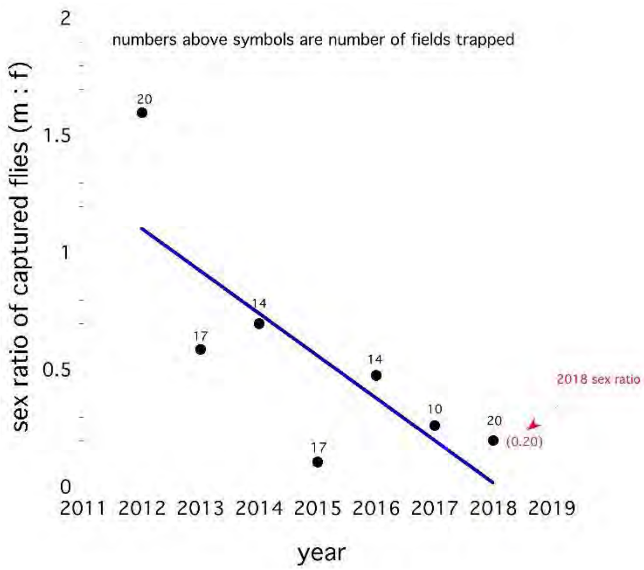

**Fig. 5.** Male to female SWD sex ratio from 2012 – 2018.

Another cause of such a trend might be increasing infection by a parasitic bacteria, *Wolbachia* spp. Species of this genus can infect a large number of insect species, and in some can result in what is known as cytoplasmic incompatibility which leads to the death of males prior to their birth. It has been assumed that none of the biotypes of SWD in the U.S. are infected by *Wolbachia,* and that cytoplasmic incompatibility does not occur in infected SWD females. However, this is an area that warrants investigation because high levels of infection in other insects has eventually led to population crashes due to the lack of viable males for mating. THIS OF COURSE IS A RESEARCH PROJECT WAITING FOR A NEW WILD BLUEBERRY ENTOMOLOGIST.

***Study 3.*** ***<u>Effects of the abundance of wild fruits and pupal predation on spotted wing drosophila populations in wild blueberry fields</u>***

**OBJECTIVE:** We have previously shown that spotted wing drosophila utilize wild non-blueberry fruits along field edges to build up their populations prior to blueberry ripening. We have also shown that predation of SWD pupae in wild blueberry fields can be quite high and appears to be mostly associated with insect predators, especially crickets. This study was designed to assess if wild fruit utilization and predation affect the SWD population buildup in fields.

**METHODS:**

*Adult and larval abundance*

Cooperating growers allowed us to trap adult SWD and sample fruit for larval infestation on a weekly basis. The fields were maintained by the growers using typical wild blueberry production practices. Traps were placed in 20 wild blueberry fields in Downeast and mid-coast, Maine (10 per region). Trapping for SWD began early July and continued until larval infestation of fruit was detected or until fields were harvested. Traps were monitored at five to nine day intervals for the presence of SWD adults. All traps were constructed from Solo®, 16 fl. oz, red polystyrene cups with light-blocking lids. Seven to 10, 3/16-inch holes were punched on the side of each container near the top, evenly spaced around the rim. Bait consisted of live yeast (1tbsp) + sugar (4tbsp) + 12oz water (makes enough for four traps). Three traps were placed at each site and were hung 1-2 ft above the top of the canopy using 36 inch plant stands. Throughout the study and on each sample date, traps set the previous week were collected and returned to the laboratory where male, female, and total abundance of SWD adults were determined and recorded. New traps were deployed weekly. Using these data we calculated the total number of SWD and SWD males per trap captured from each site for each date and the mean cumulative number of SWD and SWD males over the collection period.

*Field predation of spotted wing drosophila pupae*

Spotted wing drosophila pupae were removed from our laboratory colony, rinsed under running water to remove media, and examined under magnification to verify the presence of a developing fly. All pupae were frozen for 24 h prior to the start of the experiment. Killed pupae were affixed to 9 cm white-painted Petri dishes by two, 7 cm rows of double-sided tape. Each piece of tape had 10 pupae for a total of 20 pupae per plate.

At each field site, three plates were placed along the field edge 3 m apart and lightly covered with duff collected from the field. Plates were placed at a total of 20 fields, 10 in the Mid-coast region and 10 in the Downeast growing region. All plates were left in the field for 24 hours and then retrieved. The number of intact pupae were counted in the lab under magnification. Pupae that were obviously chewed, but not completely consumed, were still counted as predated.

*Abundance of wild fruit*

Wild fruit was evaluated along the edges of wild blueberry fields in the Downeast and Mid-coast growing regions. Wild fruit was surveyed up to three times in blueberry fields in late July, early August, and late August. Wild fruit evaluations were not repeated once a field was harvested. To evaluate wild fruit, three 100 ft transects were set up along each field edge. The presence or absence of wild fruit was recorded at every other foot along each transect for a total of 50 observations per transect. The types of wild fruit along each field were also recorded.

We constructed a predictive statistical model (general linear model) to determine the field level factors that explained the variation in the end of season total (male + female) SWD trap captures per trap at each field. The potential predictors that were considered for the model were: field size (acres), production system (organic; low, medium, and high conventional), the amount (%) of non-crop wild fruit along the edges of the field, and the intensity (%) of predation on

SWD pupae in the field. In addition, we included all of the two and three-way interactions in the initial modeling.

**RESULTS:** We found considerable variation in SWD trap captures, wild fruit abundance and predation levels among the 20 fields that we surveyed. This was desired because a large range in these three measures allows us to investigate the potential effects of wild fruit abundance and percent pupal predation. Figure 1 shows the range of each of these measures and the number of fields that represented each of the levels of SWD trap captures, wild fruit, and predation. In addition field size in acres is depicted.

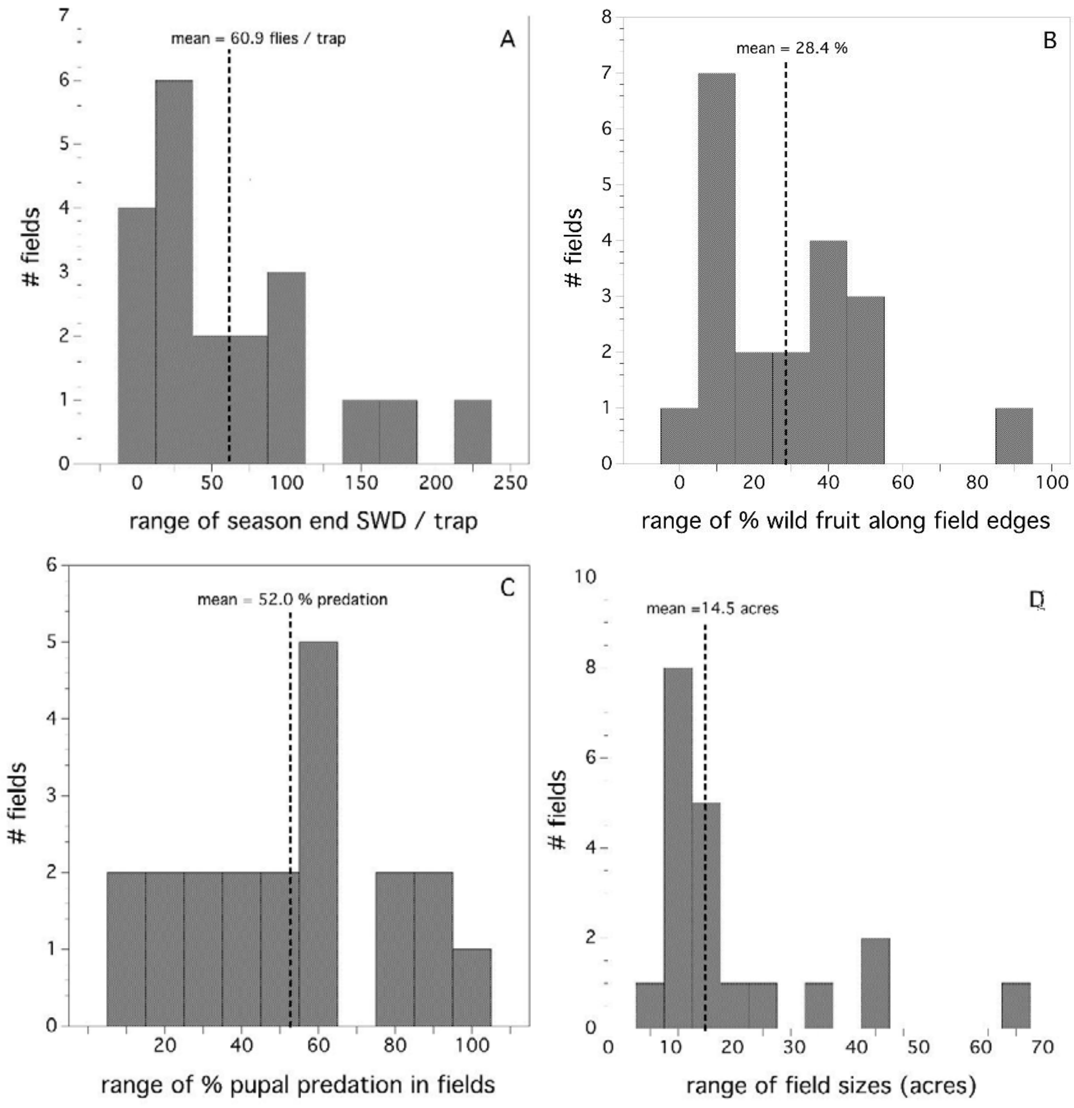


**Fig. 1.** Frequency distributions of sampled SWD flies / trap (A), % wild fruit along field edges (B), percent SWD pupal predation (C), and field size (D) of the 20 wild blueberry fields.

The end of season total (male + female) SWD trap captures per trap in our sampled fields were explained by the percent of non-crop wild fruit along the field edge and the percent of SWD pupal predation in the field ($F_{(3,16)}$ = 6.258, $P$ = 0.005). A strong predictive model resulted; 53.9% of the variation in the total SWD population abundance across all fields was accounted for by the two predictors. The model estimates and significance are shown in Table 1.

**Table 1.** Predictive model for determining abundance of SWD by the end of season.

| Terms in model | Estimate[1] | S.E.[2] | T-ratio | Probability[3] |
|---|---|---|---|---|
| Intercept | 11.688 | 32.669 | 0.36 | 0.725 |
| % Wild fruit | 1.359 | 0.565 | 2.40 | **0.029** |
| % Pupal predation | -0.024 | 0.430 | -0.06 | 0.956 |
| % Wild fruit X % pupal predation | -0.063 | 0.018 | -2.22 | **0.042** |

[1] estimate of model coefficient
[2] standard error or precision of the coefficient
[3] probabilities in bold denote a significant term or coefficient

An inspection of Table 1 suggests that the two predictors do not operate independently, in fact, % pupal predation is ONLY of value in explaining SWD abundance in the context of the wild fruit condition along the edge of the blueberry field. The abundance of wild fruit, however, is a strong predictor on its own (explaining 39.5% of the variation in SWD population abundance). Figure 2 depicts this interaction between the two predictors. Inspection of this figure shows that the observed SWD abundance increases from low (dark blue) to high (bright red) as the % wild fruit in a blueberry field increases (left to right of graph). However, an increase in % predation (bottom to top of graph) only results in a decrease in SWD abundance when the percent wild fruit abundance is high or greater than 50%. This is the interaction; % predation only appears to "kick in" and reduce SWD abundance in fields with high levels of wild fruit, which are also fields that end up having higher abundances of SWD.

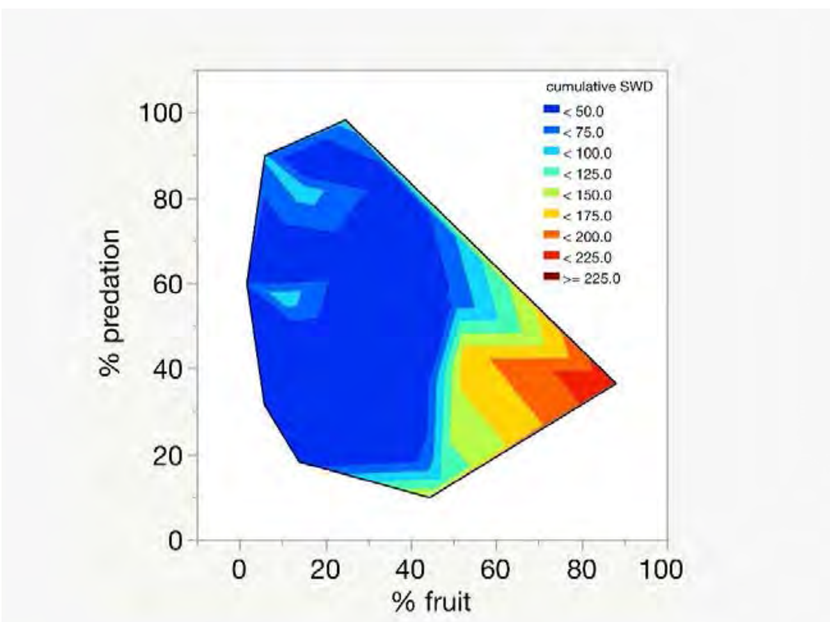


**Fig. 2.** A contour model of the interaction of % wild fruit along the field edge and the % pupal predation in the field.

**CONCLUSIONS AND RECOMMENDATIONS:** In summary, we did not find that the production system (organic, low input, medium input, high input) or field size had any impact on SWD abundance. We DID find that the intensity of SWD pupal predation and the abundance of wild fruit along the edge of blueberry fields both determine SWD season long abundance in wild blueberry fields. The amount of wild fruit is the strongest predictor. Predation is important in reducing SWD populations, but only in fields that are destined to be the most susceptible to SWD population explosions, those fields with an abundance of wild fruit along their edges. As far as we know (although we don't know much) this is the FIRST and ONLY quantification of how important these field level attributes are to the population increase and ultimately, the risk of fruit infestation in wild blueberry. Our previous research has determined the wild fruit species along wild blueberry field edges that are most utilized by SWD (raspberry, blackberry, and Japanese honeysuckle being the most important) (Ballman and Drummond 2017) and the predator species that contribute to predation (ground beetles and crickets being the most important) (Ballman et al. 2017).

**REFERENCES:**

Ballman, E. S., and F. A. Drummond. 2017. Infestation of wild fruit by *Drosophila suzukii* surrounding Maine wild blueberry fields. J. Agric. and Urban Ent. 33(1): 61-70.

Ballman, E. S., J. A. Collins, and F. A. Drummond. 2017. Predation on *Drosophila suzukii* (Diptera: Drosophilidae) pupae in Maine wild blueberry fields. J. Econ. Ent. 110(6): 2308-2317. doi: 10.1093/jee/tox233.

***Study 4. <u>Lure testing for spotted wing drosophila</u>***

**OBJECTIVE:** Spotted wing drosophila (SWD) is an invasive insect that can cause significant crop damage in wild blueberries. In Maine, SWD first appears during the late summer, but crop loss can be greatly reduced when using economic thresholds to time treatments and harvest. Currently, home-made yeast-sugar bait is recommended in Maine to attract SWD to red Solo® cup monitoring traps. Growers have expressed an interest in commercial products that allow for quicker deployment and subsequent SWD counting. This study is a continuation of the 2016 and 2017 lure studies and tests a commercial lure in two different traps as well as our traditional red Solo® cup with sugar/yeast bait. This study was conducted to determine which lure and trap design is the most effective at catching SWD while limiting capture of other drosophila species.

**METHODS:** The trial was run at the University of Maine's Wild Blueberry Farm in Jonesboro, Maine (Downeast) and at an unmanaged blueberry farm in Union, Maine (Mid-coast). Mid-coast traps were initially set up in an organic field in Stockton Springs, but because of an early harvest, traps were moved to the location in Union for the duration of the study. Two different traps were used in conjunction with the commercially available Scentry® lure (Fig. 1). Scentry® lures were either hung inside of a 32 oz deli cup with 12 evenly spaced 5 mm holes around the rim and filled with 200 ml soapy water, or hung from a red, doubled-sided sticky trap (Great Lakes IPM). Control traps were an empty deli cup filled with soapy water and the same sticky panel trap without an attached lure. We also deployed a red Solo® cup with our standard sugar/yeast bait. Three replicates of each trap type were deployed in three separate blocks at each location for a total of 15 traps per location. Traps were spaced 10 m apart and blocks were spaced 15 m apart. Traps were arranged in a single row along the wooded edge of the blueberry fields and were hung 1 m high (either from tree limbs or fence panels).

**Fig. 1.** Scentry® lures attached to deli cups and sticky panel traps in the field.

Traps were replaced every week and were randomly re-ordered each time. Scentry® lures were replaced after one month of deployment. Traps were deployed in Jonesboro on 8 Aug and 3 Aug in Stockton Springs, and deployed in Union starting on 13 Aug. The trials Downeast and Mid-coast were run for a total of five weeks. Each week, insects were strained from liquid traps and male and female SWD and non-SWD drosophila were counted. Liquid traps that had more than 100 SWD were subsampled using a gridded petri dish. To subsample, trap catches were spread across as many dishes necessary to have a single layer of flies. Flies were counted in ¼ of the grids in the dish and the number of flies was multiplied by four to estimate the total fly capture. Panel traps were covered with plastic sheeting to transport them back to the lab and then only male and female SWD were counted.

A one-way ANOVA was conducted to measure differences between treatments. Tukey's test was conducted on least square means to measure differences between individual treatments across sites. All analyses were conducted using JMP® 14 statistical software.

**RESULTS:** The two sites were significantly different for SWD males ($F_{(1, 18)} = 279.43$, $P < 0.0001$), SWD females ($F_{(1, 18)} = 35.85$, $P < 0.0001$), and total SWD ($F_{(1, 18)} = 127.27$, $P < 0.0001$), but not for non-SWD Drosophila ($F_{(1, 18)} = 1.77$, $P = 0.21$). Because there was a significant site X treatment interaction for male SWD, female SWD and total SWD ($P > 0.0001$), we ran the trap captures analyses by site. In Union, there was a significant difference between treatments for male SWD captures ($F_{(4, 8)} = 14.63$, $P = 0.0009$), female SWD captures ($F_{(4, 8)} = 95.58$, $P < 0.0001$), total SWD captures ($F_{(4, 8)} = 31.81$, $P < 0.0001$), and non-SWD drosophila captures ($F_{(2, 4)} = 45.81$, $P = 0.0017$). In Jonesboro, there was a significant difference between treatments for male SWD captures ($F_{(4, 8)} = 424.05$, $P < 0.0001$), female SWD captures ($F_{(4, 8)} = 32.99$, $P < 0.0001$), total SWD captures ($\mathrm{F}_{(4, 8)} = 110.04$, $\mathrm{P} < 0.0001$), and non-SWD drosophila captures ($F_{(2, 4)} = 61.20$, $P = 0.001$).

The deli cup with the Scentry® lure caught the most SWD and non-SWD Drosophila across both sites (Tables 1 & 2). The control deli cups and panel traps caught almost no SWD which indicates it was the lure itself that attracted the SWD to the traps. Trap capture increased over the season with some traps capturing over a thousand SWD in a one week period (Figs. 2, 3). While both field locations started with no infestation in blueberry fruit, all fields ultimately had infestation in the fruit (Figs. 4, 5).

**Table 1.** Jonesboro cumulative trap catches per trap across all dates, letters designate statistical differences within each column.

| Lure | Male SWD | Female SWD | Total SWD | Non-SWD Drosophila |
|---|---|---|---|---|
| Deli Cup Lure | 355.40 a | 227.87 a | 583.27 a | 231.60 a |
| Deli Cup Control | 0 d | 0.27 c | 0.27 c | 0.40 b |
| Panel lure | 130.33 b | 43.07 bc | 173.40 b | N/A |
| Panel Control | 0.07 d | 0 c | 0.07 c | N/A |
| Red Yeast Sugar Cup | 52.07 c | 113.07 b | 165.13 b | 13.97 b |

**Table 2.** Union cumulative trap catches per trap across all dates, letters designate statistical differences within each column.

| Lure | Male SWD | Female SWD | Total SWD | Non-SWD Drosophila |
|---|---|---|---|---|
| Deli Cup Lure | 80.25 a | 61.5 b | 141.75 a | 175.50 a |
| Deli Cup Control | 0 b | 0 c | 0 b | 0 b |
| Panel lure | 23.22 b | 8.0 c | 31.22 b | N/A |
| Panel Control | 0.11 b | 0 c | 0.11 b | N/A |
| Red Yeast Sugar Cup | 36.25 b | 88.75 a | 125.00 a | 23.67 b |

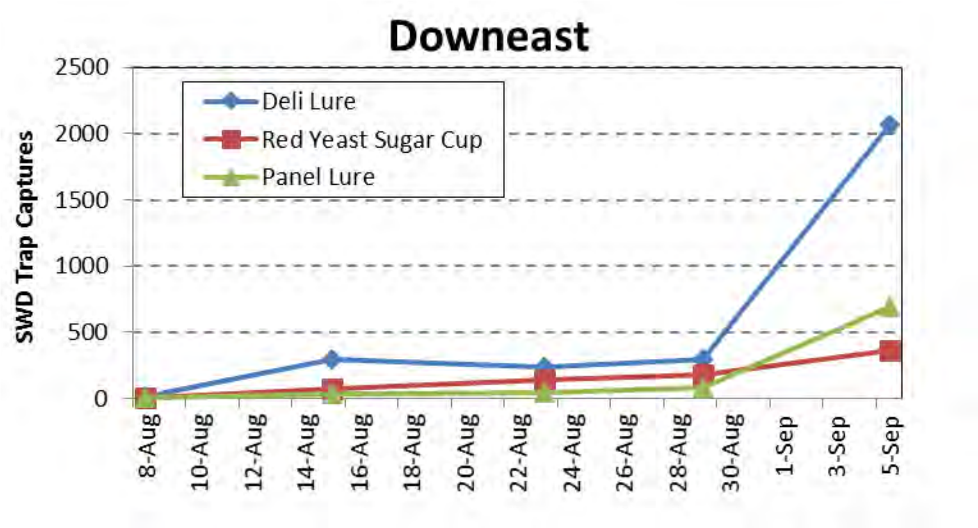


**Fig. 2.** Average SWD trap captures from baited traps from each of the five sampling dates conducted Downeast in Jonesboro, Maine.

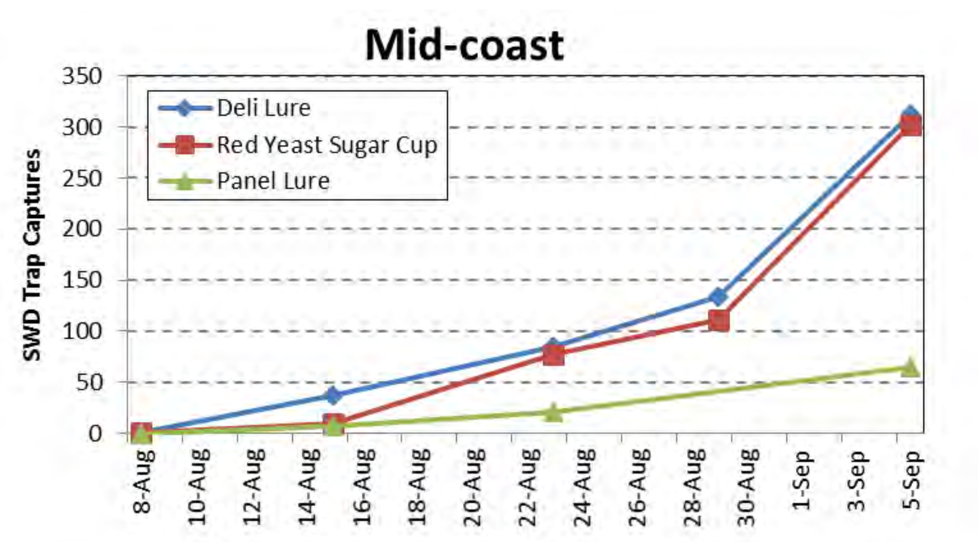


**Fig. 3**. Average SWD trap captures from baited traps from each of the five sampling dates conducted in Mid-coast Maine.

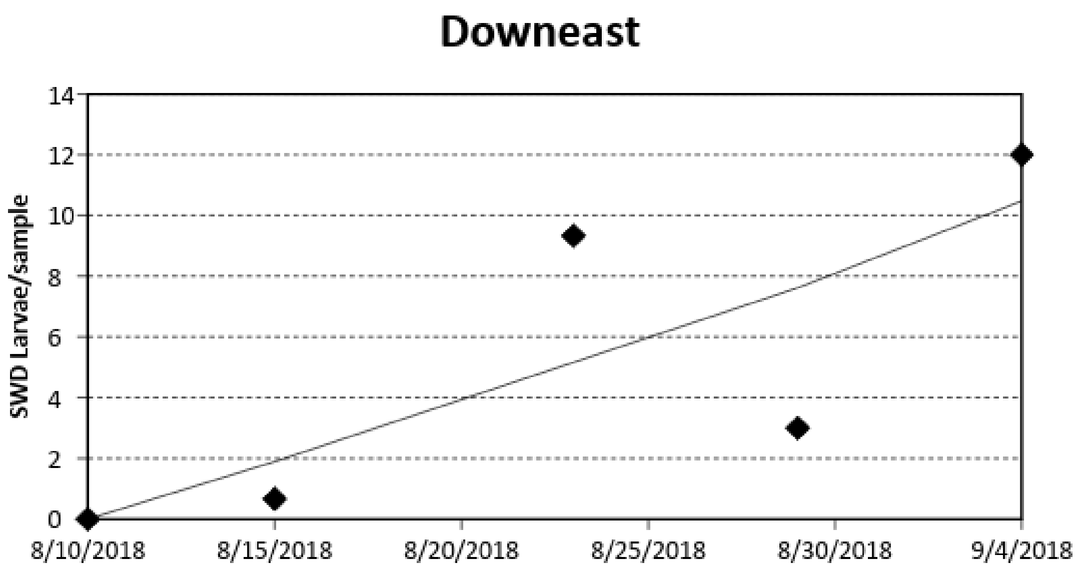


**Fig. 4.** Total SWD larvae infestation in fruit per sample date in Downeast Maine.

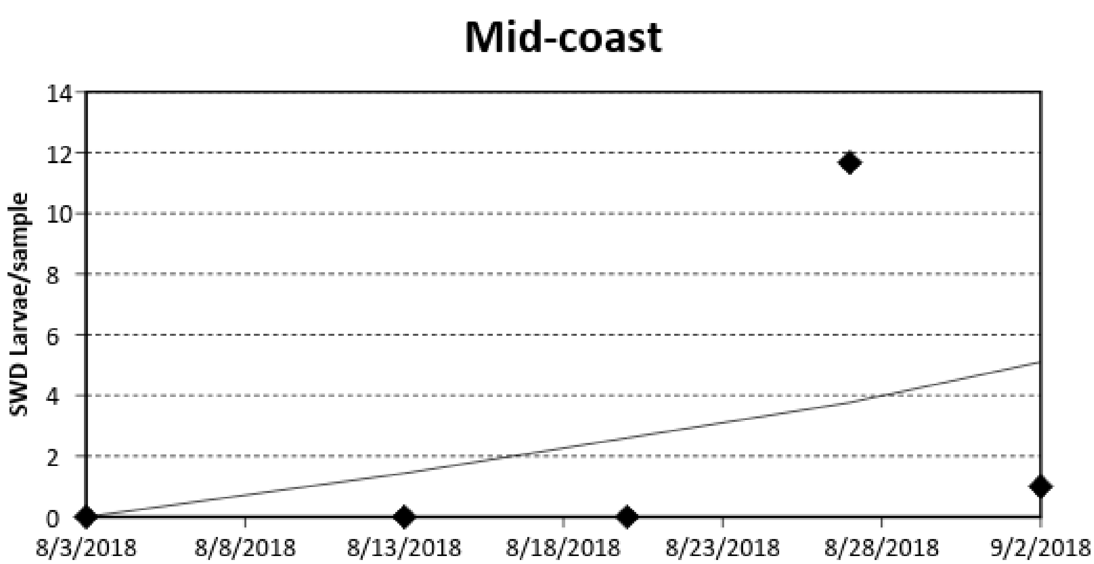


**Fig. 5.** Total SWD larvae infestation in fruit per sample date in Mid-coast Maine.

**CONCLUSIONS AND RECOMMENDATIONS:** The Scentry® lure appeared to be very effective at capturing SWD, although it also captured a large amount of non-SWD Drosophila. The deli cup was much easier to work with compared to the sticky panel. The small holes in the side of the deli cup prevented larger insects from entering the trap, while the panel trap was often obscured by wings and body parts of larger insects. The deli cups were also easier to handle, especially in windy conditions. If growers wish to utilize commercial pre-made bait, the Scentry® lure in combination with the deli cup may be a good option. However, because economic thresholds in Maine are based on captures in red Solo® cups with sugar/yeast bait, and because SWD captures can vary significantly between trap types, more research is needed to determine how economic thresholds recommendations might vary with the use of the Scentry®

lure. Scentry® lures also lose their effectiveness over time, so trap captures may also vary depending upon the age of the lure.

### *Study 5. __Influence of trap size on capture of spotted wing drosophila__*

**OBJECTIVE:** In 2018, an experiment was conducted to evaluate the effect of the physical trap size, as perceived by the spotted wing drosophila, on trap capture efficacy. Two different size red Solo® cups (29.6 ml and 473.2 ml) were evaluated for trap efficacy.

**METHODS:** Standard and miniature traps were constructed from red Solo®, 88.7 ml and 473.2 ml polystyrene cups with light-blocking lids constructed from a piece of red foam hot glued to the lids. Seven to ten (standard) or four (miniature), 6.4 mm diameter holes were punched on the side of each cup near the top, evenly spaced around the rim. Bait for both trap sizes consisted of live yeast (1tbsp) + sugar (4tbsp) + 12oz water (makes enough for four standard-size traps). All traps were hung 0.4 – 0.7 m above the top of the canopy using 0.9 m metal plant stands. Miniature traps were attached to the stands with rubber bands (Fig. 1) and standard traps were placed into the stand holder. There were four replications of each trap type set in pairs (statistical blocks) along the perimeter of a fruit-bearing wild blueberry field at the University of Maine Blueberry Hill Farm in Jonesboro, ME, which previous monitoring had shown to be infested with spotted wing drosophila. Throughout the study, on each sample date, traps set the previous week were filled with fresh bait and flies were collected and returned to the laboratory for identification of male and female spotted wing drosophila. Traps were initially deployed on 8 August 2018 and checked weekly for three weeks.

Multiple analysis of variance (MANOVA, RCB) was used to compare male, female, and total (male + female) abundance of adults captured in each trap over the three dates. Two additional sets of models were run with adjusted trap captures. The two adjustments were used to account for the difference in trap size as potentially perceived by searching flies (120.9 $cm^2$ vs 22.6 $cm^2$) and for the difference in the amount of yeast/sugar bait in each trap type (29.6 ml in each miniature trap compared with 88.7 ml in each standard trap). The adjustment was made by multiplying the trap captures in each miniature trap by 120.9 $cm^2$ / 22.6 $cm^2$ = 5.35 and 88.7 ml / 29.6 ml = 3.0, for size and bait adjustments, respectively.

**Fig. 1.** Miniature and standard size Solo® red cup traps, 2018.

**RESULTS:** There was a significant difference between the two trap sizes (Fig. 2). More males ($F_{(1,2)}$ = 9.865, $P$ = 0.047), females ($F_{(1,2)}$ = 86.572, $P$ = 0.006), and total flies ($F_{(1,2)}$ = 85.955, $P$ = 0.011) were captured in the standard traps compared to the miniature traps. There was no significant interaction ($P > 0.05$) between sample date and trap size in any of the three models. When all dates were combined, miniature traps captured 39.67% as many female SWD compared to standard traps, 42.25% as many males, and 47.74% as many total (males + females) flies.

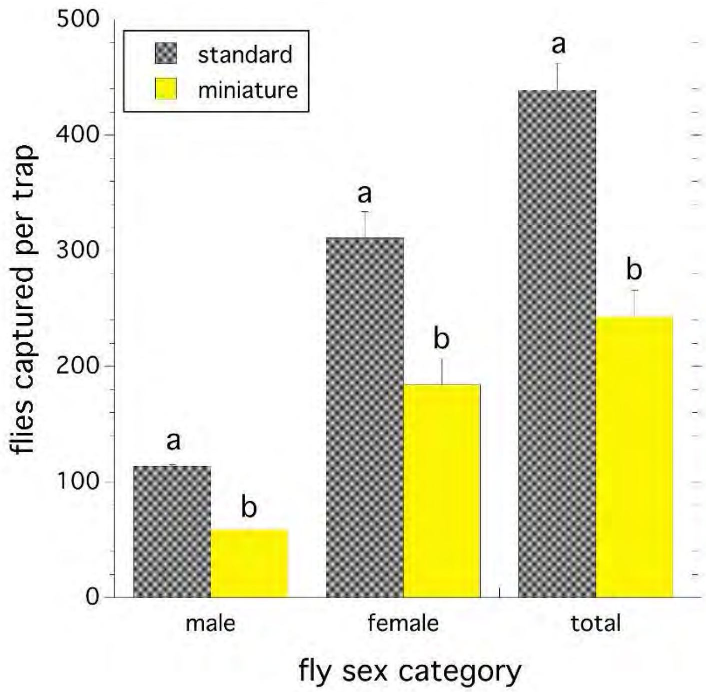


**Fig. 2.** Average fly trap-captures for two trap sizes (observed means and standard errors plotted), 2018.

However, when total fly captures in the miniature size traps were adjusted for the amount of yeast/sugar bait in each trap type (29.6 ml vs. 88.7 ml) there was no significant difference between miniature and standard traps ($F_{(1,2)}$ = 8.611, $P$ = 0.099), but there was a sample date by trap size interaction ($F_{(2,4)}$ = 25.315, $P$ = 0.015, H-F epsilon adjustment) (Fig 3). The interaction suggests that there was little difference in the bait volume adjusted trap captures for the first two dates and then at the third date, bait volume adjusted miniature trap capture was much higher (173%) than the unadjusted standard trap captures of total flies. When total fly captures of miniature size traps were adjusted for differences in size, there was a significant difference in adjusted miniature trap captures compared to the standardized trap captures. The size adjusted miniature trap captures were greater than the standard trap captures ($F_{(1,2)}$ = 16.989, $P$ = 0.028). There also was a sample date by trap size interaction ($F_{(2,4)}$ = 32.509, $P$ = 0.003, H-F epsilon adjustment) (Fig 3). The interaction suggests that there was a significant difference in the size-adjusted trap over all three dates, but this difference was very large at the third date. On the third date, size-adjusted miniature trap capture was much higher (310%) than the unadjusted standard trap total captures.

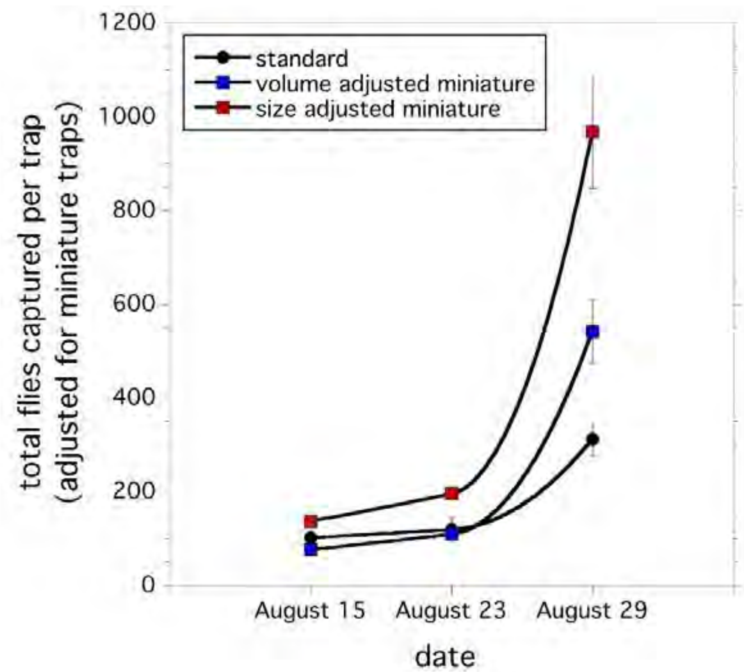


**Fig. 3.** Mean (±SE) spotted wing drosophila captured in miniature (adjusted for bait volume and trap size) vs. standard cup traps over the duration of the study. Means are for total (males + females) spotted wing drosophila.

**CONCLUSIONS AND RECOMMENDATIONS:** While trap size has not been investigated specifically (only when confounded with different trap types and baits), it might have important implications for IPM. We found that trap size of the red Solo® cup trap does affect trap capture abundance; although, when considering a per volume bait amount or a per two-dimensional trap area, the small trap size that we compared to the standard trap size was actually more efficient. The important implications of our study suggest that when the traps are used to assess threshold levels for spotted wing drosophila, a standard trap size is important as trap size determines the abundance of flies captured. This is especially important for the Maine wild blueberry agro-ecosystem where thresholds are based upon the capture of male flies and risk of fruit infestation increases with increasing cumulative male fly capture. We believe that we have an optimal trapping system for the spotted wing drosophila and unless more traps and baits are developed, the red standard Solo® cup trap with a live yeast bait will provide growers with an adequate tool for assessing the risk of spotted wing drosophila.

***Study 6. Rapid resistance monitoring for spotted wing drosophila***

**OBJECTIVE:** This protocol was developed based on dose-response assays conducted by Michigan State University and the University of Georgia as part of the SCRI-SWD project. It is intended to provide a rapid assessment of the susceptibility of SWD to insecticides using a simple test that can be widely used by Extension staff without insect colonies and laboratories. The objective of the study was to 1) compare response of SWD across the United States to $LC_{50}$ levels of insecticides, and 2) to determine whether any SWD populations exhibit survival at concentrations that will kill 100% of susceptible SWD.

**METHODS:** Two materials were tested (Malathion® 8F and Entrust® SC). Assays were completed on adult SWD collected from two locations. One site was in Washington Co. (Jonesboro – BBH) and one site in Waldo Co. (Stockton Springs - HF). For each site to be assessed, SWD adults were collected from live traps placed at that site. Field collected flies were reared on drosophila diet (Instant Drosophila Medium, Carolina Biological Supply Co., Burlington, North Carolina) in the laboratory for one generation (designated as F1). Flies used for all assays were 3 to 5 days old.

For each assay, a 20 ml glass scintillation vial was treated with 1 ml of a Malathion 8F or Entrust SC solution prepared as outlined in Tables 1 and 2; respectively. Once the solutions were added to vials, caps were tightly closed and the vial was shaken a few times to distribute the solution, the excess solution was then poured out and the vials and lids were placed in a fume hood to dry. The next morning, 5 female and 5 male adult SWD flies from the sampled location were placed in each vial and held in a growth chamber at 23 ± 2°C and 74% RH to reduce control mortality. Vials were kept on their sides for the duration of the experiment. For each assay there were three or four replications for each LC level + three or four non-treated controls. After 6 (Malathion) or 8 (Entrust) hours in the vials, we evaluated mortality. Flies were classified as either alive, dead, or moribund.

**Table 1.** Serial dilutions for Malathion 8F; * designates dilutions used for assays. Solutions of this insecticidal formulation were made by using acetone as a solvent. Stock Solution (500 ppm): dissolve 52.16 µl product in 100 ml acetone.

| PPM | Serial Dilutions |
|---|---|
| *102.9 ($LC_{90X8}$) | 20.58 ml of 500 ppm (stock) + 79.42 ml acetone |
| 20 | 19.44 ml of 102.9 ppm +80.56 ml acetone |
| *10 | 50.0 ml of 20 ppm + 50.0 ml acetone |
| 7 | 70.0 ml of 10 ppm + 30.0 ml acetone |
| *6.16 ($LC_{50}$) | 88.0 ml of 7 ppm + 12.0 ml acetone |
| 4 | 64.94 ml of 6.16 ppm + 35.06 ml acetone |
| *3 | 60.0 ml of 4 ppm + 20.0 ml acetone |
| *1 | 16.67 ml of 3 ppm + 33.33 ml acetone |

**Table 2**. Serial dilutions for Entrust SC; * designates dilutions used for assays.
Stock solution (1000 ppm): add 253.5 µl of product to 60 ml dd$H_2O$ with Induce® as a sticker (190 µl/150 ml dd$H_2O$).

| PPM | Serial Dilutions |
|---|---|
| *848.74 ($LC_{90X8}$) | 84.87 ml of 1000 ppm (stock) + 15.13 ml water |
| 500 | 58.91 ml of 848.84 ppm + 41.09 ml water |
| *300 | 60.0 ml of 500 ppm + 40.0 ml water |
| 200 | 66.67 ml of 300 ppm + 33.33 ml water |
| *100 | 50.0 ml of 200 ppm + 50.0 ml water |
| 30 | 30.0 ml of 100 ppm + 70.0 ml water |
| *16.67 ($LC_{50}$) | 55.57 ml of 30 ppm + 44.43 ml water |
| *3 | 14.4 ml of 16.67 ppm + 65.6 ml water |
| *1 | 16.67 ml of 3 ppm +33.33 ml water |

**RESULTS:** Overall, we found that there was a site (Stockton Springs vs Jonesboro) effect ($X^2_{(1)}$ = 4.438, $P$ = 0.035) on the susceptibility of total (males + females) SWD adults to the insecticides (Entrust and Malathion). This suggests that geographic regions vary as to the effectiveness of these insecticides. The dose (ppm) determined mortality ($X^2_{(1)}$ = 958.557, $P$ < 0.0001). There was also a site x insecticide interaction suggesting that the relative effect of Entrust compared to Malathion varied by site ($X^2_{(1)}$ = 9.579, $P$ = 0.002).

Males were more susceptible than females to Malathion, but not Entrust. The $LD_{50}$ (the dose that kills 50% of the population) estimates for males compared to females for both insecticides is shown in Table 3.

**Table 3.** Susceptibility of male vs female spotted wing drosophila to the insecticides Entrust and Malathion.

| SWD sex | Insecticide | $LD_{50}$ and 95% confidence interval | P – value[1] |
|---|---|---|---|
| male | Malathion | 5.548 ppm (4.767 – 6.465) | 0.0003 |
| | Entrust | 94.528 ppm (79.030 – 114.797) | 0.664 |
| female | Malathion | 7.418 ppm (5.783 – 10.346) | |
| | Entrust | 104.221 ppm (87.926 – 125.629) | |

[1] P – value for comparison between males and females for each of the two insecticides.

When the total (males + females) SWD susceptibility was investigated we found that for Malathion there was a dose x site interaction ($X^2_{(1)}$ = 9.273, $P$ = 0.002). This means that the susceptibility varied by site. The $LD_{50}$ for Malathion in Jonesboro was 5.570 ppm (4.813 – 6.456) and in Stockton Springs was 8.193 ppm (6.084 – 13.104). Therefore, the flies from Jonesboro only needed 67.9% of the dose of Malathion that the Stockton Springs flies were exposed for 50% mortality to occur. When we looked at the responses of flies to Entrust we also found that there was a dose x site interaction ($X^2_{(1)}$ = 8.777, $P$ = 0.003). The $LD_{50}$ for the total SWD (males + females) in Entrust in Jonesboro was 124.263 ppm (105.342 – 148.300) and in Stockton Springs was 75.085 ppm (63.242 – 90.279). Therefore, the flies from Jonesboro needed 165.5% more of the dose of Entrust than the Stockton Springs flies for 50% mortality to occur. Thus, flies in Jonesboro were more susceptible to Malathion, but less susceptible to Entrust than the Stockton Springs flies.

**CONCLUSIONS AND RECOMMENDATIONS:** Our initial hypothesis was that flies captured at an organic farm in Stockton Springs would be more susceptible than flies captured in Jonesboro where insecticides are used. What we found did not support that hypothesis entirely. We did find that to be the case with Entrust, but not with Malathion. One explanation for this is that flies captured at each of the sites could have migrated from a long distance and thus were not resident flies from the farms that they were trapped at. In 2017 we found that when high rates of Malathion were used in testing susceptibility of SWD from four sites in Maine, that there was no evidence of resistance developing at any of the sites. In February of 2018 we conducted a test with Malathion on flies collected at three farms: an organic farm, a low input conventional farm, and a high input conventional farm. Figure 1 shows the results of total fly (males + females) mortality as a function of dose and farm.

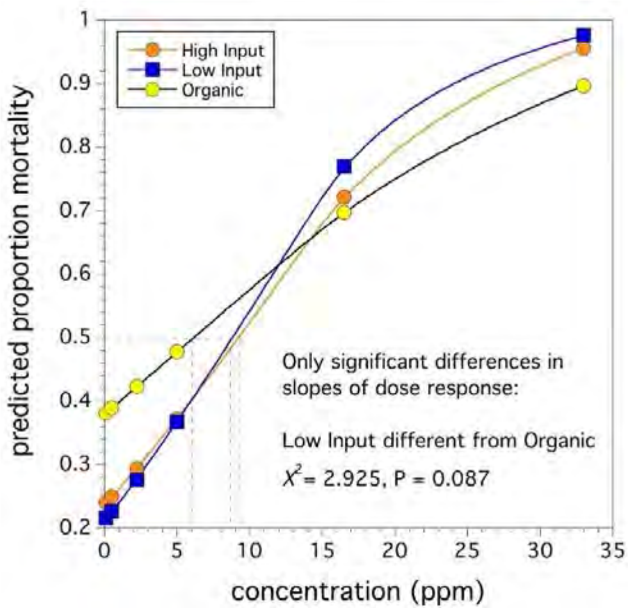


**Fig. 1.** Relationship between farm site of fly collection and exposure dose of Malathion, winter 2018.

Our results in this study determined that the flies captured at the organic farm were more sensitive to Malathion ($LD_{50}$ = 6.099 ppm (1.593 – 10.350)) than flies captured at the Low input conventional farm ($LD_{50}$ = 8.564 ppm (6.177 – 11.700)). These $LD_{50}$ levels are well within the levels that we describe above in our most recent study. These two studies do NOT provide evidence that tolerance or resistance by SWD to insecticides is occurring on farms in Maine. However, our results do suggest that heterogeneity in susceptibility exists across different wild blueberry growing regions in Maine. This heterogeneity could be due solely to natural genetic variation in the SWD population and not necessarily the historical use of insecticides. As I (Dr. Frank Drummond) am retiring soon, one take home message from this research is that resistance monitoring should be continued every few (2-3) years to ensure that a pattern in loss of insecticide effectiveness does not begin to develop. If this does occur, then a rotation to insecticides of different modes of action must be incorporated into farm management plans.

***Study 7. Winter survival of spotted wing drosophila***

**OBJECTIVE:** This is the second and final year of testing the winter survival ability of spotted wing drosophila. This is part of a multi-state experiment that was run in cold northern climates like Maine, New York and Michigan, as well as warmer states such as Georgia and California. Spotted wing drosophila (SWD) population densities in the spring and summer are likely dependent upon their ability to overwinter and travel from other areas of infestation. Studies from the winter of 2016-2017 showed that while SWD were able to survive freezing temperatures for periods of time, they were unable to survive the entire winter in Maine. This experiment was repeated in 2017-2018 to see if this pattern held across an additional year.

**METHODS**:

*Establishing SWD colony*

Adult SWD were acquired by live trapping in an organic wild blueberry field in Stockton Springs, ME in the fall of 2017. Live traps consisted of a commercial yellow jacket trap (Victor® Model # M362) with a lab-created fermentation lure snapped to the inside of the lid and with a

Drosophila culture tube that contained Instant Drosophila Medium formula 4-24 (Carolina Biological Supply Co., Burlington, N.C.). Fifteen traps were deployed along the field edge and were changed daily for one week. Each day, flies in the containers were gassed with $CO_2$ and inspected to verify that they were SWD. All confirmed SWD were placed into 9.3 X 2 cm Drosophila tubes with Instant Drosophila Medium and placed in a 25°C growth chamber with a 18:6 L:D cycle. Flies were transferred to new media tubes every two weeks. Two weeks before placing flies in the field, flies were moved to 10°C within 48 h of pupal emergence and held at 10°C for a minimum of one week.

*Design of field experiment*

A field site was set up along a wooded edge at the University owned Rogers Farm in Old Town, ME (the same location as the 2016-17 study). Twenty four holes were dug using a fence post digger. The soil plug was placed into a 36 oz deli cup leaving 1-2 cm at the top open. The empty space at the top of the deli container was filled with organic matter from the site (old leaves, twigs, etc.). A 1/8 piece of apple was set on top of the organic matter and 50 chilled male and female SWD (total of 100 flies) were added to the organic matter and covered in 2-3 cm of dead leaves. A double layer of 1 mm mesh was secured over the top of the deli cup and held in place with rubber bands. The deli cup was then placed into the hole so that the lip of the deli cup was level with the ground. The mesh was tucked into the ground around the cup and then covered with surrounding leaf litter.

Every two weeks, a set of four cups were dug up, transported back to the lab and held in mesh cages at room temperature. The apple piece was discarded, the mesh was removed, and all dead flies were counted in the cage after a two week holding period. The first set of four cups were brought back the same day the experiment was launched to serve as a control. This experiment ran for 10 weeks beginning on 7 December 2017.

Temperature at the field site was recorded using Hobo® data loggers. Four loggers were suspended from nearby tree branches to measure air temperature, and loggers were placed in-between the soil and leaf litter in four pots to measure the temperature to which SWD flies were exposed. Data loggers recorded temperatures every hour for as long as the cups remained in the field.

*Monitoring wild SWD in the field*

Flies were trapped during the experiment using a Scentry® commercial baited trap. Two traps were deployed along the field edge at the start of the experiment and were checked every two weeks for SWD. The traps had a drowning solution that was comprised of 90 g salt, 250 mL water and one drop of unscented dish soap. The flies were strained out of solution, identified as SWD, and counted. The drowning solution was changed every two weeks and the commercial baits were replaced every six weeks.

**RESULTS:** No wild flies were captured in our drowning traps during this study. Survival began at 76% (males 75%, and females 77%). Survival dropped to 8.5% after two weeks with 3% survival in males and 14% in females. There was a significant difference in survival between sexes in week two ($t_{(6)} = 4.37$, $P = 0.005$)(Student’s t-test). No flies survived beyond the first two weeks (Fig. 1).

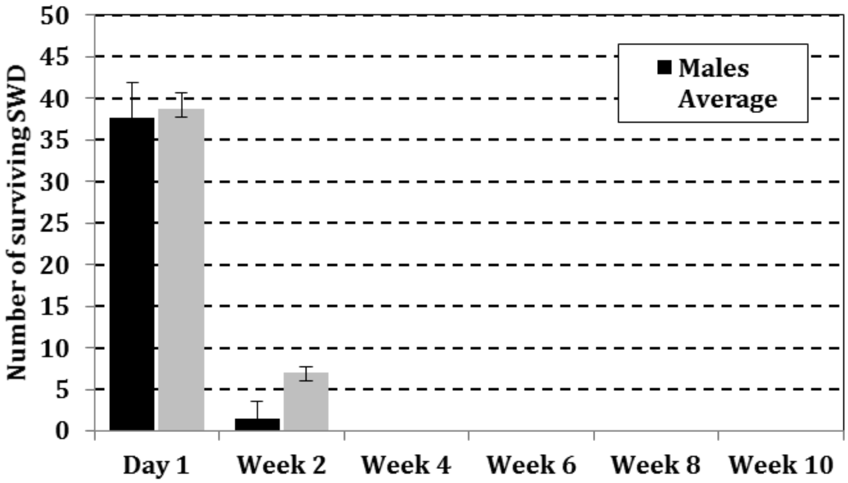

**Fig.1.** Survival of adult SWD in cups over time, 2017.

**CONCLUSIONS AND RECOMMENDATIONS:** The 2017 overwinter study began later than the 2016 study. It was colder and with more snow early in the 2017 experiment compared to 2016. This may be why we had lower survival and adult captures. It snowed within a few days of launching this experiment, which may be why no wild adult flies were ever captured. After two years of overwintering data, it appears that SWD are either unable to survive Maine winters or survive at very low numbers. SWD in Maine may be the result of fly migrants from warmer locations, and may be why we do not see SWD until later in the season, mid to late July. Genetic analysis currently being conducted by our research colleagues may be able to shed more light on the ability of SWD to overwinter.

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**ENTOMOLOGY**

**INVESTIGATORS:** F. A. Drummond, Professor of Insect Ecology/Entomology
J. A. Collins, Assistant Scientist of Insect Pest Management
E. Ballman, Research Associate in Invasive Species/Entomology

**3. III. TITLE:** Biology of blueberries, beneficial insects, and pollinators, 2018.

***Study 1. Effect of supplemental feeding on honey bee colony health and pollen foraging, a study conducted in 2013.***

**OBJECTIVE:** This study was conducted as a preliminary investigation into both the health and pollination effects of supplemental feeding of honey bee colonies during blueberry bloom. In 2006, most U.S. beekeepers started experiencing high rates of colony losses and tried to counter these losses through supplemental feeding. One of the questions that we had was whether supplemental feeding of pollen substitute reduces foraging activity by honey bees. This is important since foraging is the basis of pollination. In 2013 we conducted a preliminary study to determine if a relationship exists between foraging strength and supplemental feeding of colonies during bloom.

**METHODS:** The study was conducted with eight colonies overwintered successfully in the 2012/2013 winter. In early May, the eight colonies were equalized so that they all had six frames of sealed brood and 10 frames of workers. The hives were moved in two hive bodies to Jonesboro, ME on 15 May 2013. Upon arrival in Jonesboro, one-half (4) of the hives were randomly selected for supplemental feeding. The treatment group colonies were fed both pollen patties (MegaBee®) and 1:1 sugar syrup in a top feeding tray. Feeding was performed twice weekly from 15 May until 15 July 2013. Foraging strength for each colony was assessed by recording the number of worker bee foragers returning to a hive during a 1-minute period. Three replicate measurements of foraging were conducted at peak bloom. In addition, three additional measurements were made of the number of returning foragers in 1-minute that had visible amounts of blueberry (*Vaccinium* spp.) pollen on their legs. This measure was also repeated three times for each colony. Hives were moved back to Orono, ME on 15 July 2013 and managed for honey production. In mid-August each colony was assessed for population strength by measuring the number of workers covering all the frames in the hive and the number of frames in each hive that had capped honey. The percent of frames covered by workers was converted to total number of worker bees using the formulae in Burgett and Burikam (1985), and the number of frames with capped honey was converted to the number of deep hive supers present. Analysis of variance (CRD) was used to test the effects of supplemental feeding on worker population and honey production by the end of the summer and during bloom, the foraging force, and pollen carrying foragers returning to the hive.

**RESULTS:** We did not find any significant differences in any of the measures that we made on the hives; however, potential trends ($P = 0.10$) were found between feeding supplements and not feeding them. Figure 1 depicts these trends. The worker population and honey production tended to be higher for those hives that were provided supplemental feeding. We also found that colonies fed supplemental pollen patties and syrup tended to forage less and bring back less blueberry pollen than colonies that were not fed.

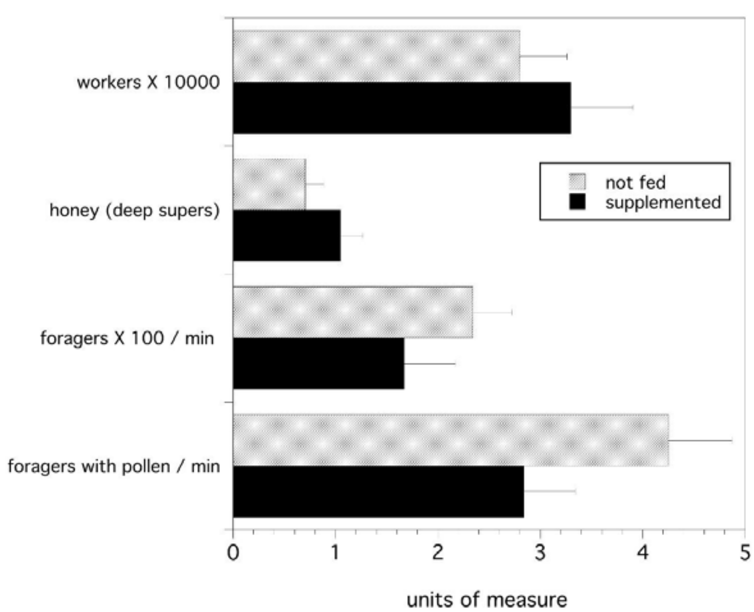



**Fig. 1.** Mean and standard errors (n=4 colonies per treatment) for worker population size and honey stores measured at the end of the summer, worker foragers returning to the hive entrance in a one minute period and worker foragers returning to the hive with presumed blueberry pollen in a one minute period (*Vaccinium* spp.).

**CONCLUSIONS AND RECOMMENDATIONS:** In conclusion, our preliminary study suggests that feeding supplemental protein to honey bee colonies during bloom may reduce foraging and the number of bees that transfer pollen in pollination. However, we need to be cautious with our conclusions because significant differences were not found, only trends. The evidence that we provide suggests that this study should be repeated with a larger sample size. Previous studies that we have conducted suggest that a sample size of 10-12 colonies per treatment is adequate for various measures. Based upon the trends discussed in this report, we recommend that growers renting colonies that are being fed might want to factor in that these colonies may provide slightly less pollination.

**REFERENCES:**

Burgett, M. and I. Burikam. 1985. Number of adult honey bees (Hymenoptera: Apidae) occupying a comb: A standard for estimating colony populations. J. Econ. Ent. 78(5): 1154–1156.

## *Study 2.* ***<u>Influence of bees on the spread of mummy berry secondary infection in wild blueberry</u>***

**OBJECTIVE:** Mummy berry disease, *Monilinia vaccinii-corymbosi* (Reade), is a fungal disease that attacks wild blueberry in the spring. During primary infection, spores kill developing leaf and flower tissue, and then these areas of infection produce conidia. These mats of conidia have floral aromas, are UV reflective, and produce sugars, all of which are attractive to bees. During secondary infection, bees visit these areas of infection and inadvertently pick up conidia and transmit them to healthy flowers. When conidia enters the germ tube of a flower instead of pollen, this creates a shriveled piece of fungal tissue also known as a mummy, which starts the cycle over again. This is a continuation of a study initiated in 2016 and repeated in 2017 that included measurements of conidia contamination on three taxa of common blueberry bee pollinators, and a cage study that measured transmission rates of conidia picked up by bees and transmitted to healthy flowers resulting in secondary infection.

**METHODS:**

*<u>Conidia on field bees</u>*

All field experiments were conducted in a commercial wild blueberry field in Hope, Maine. This is the same field that was used in 2016 and was not treated with any fungicides during the course of this study. We collected the three most common bee taxa involved with blueberry pollination: bumblebees, honey bees, and Andrenid bees. Bees were collected in the field once a week for three weeks during bloom on 17, 24, and 31 May. During each collection period we collected 20 of each bee type for a total of 60 bees of each type over the study. During each collection, bees were caught in 50 mL centrifuge tubes and immediately put onto ice to chill them. Half of the bees were gassed with $CO_2$ in the field and then their heads were cut off with sterilized scissors so that their heads and the remaining parts of their bodies (thorax and abdomen) were in separate tubes. We did this so that we could analyze the number of spores on a total of 30 whole bees per taxa, as well as the spores on an additional 30 bee heads and bodies per type. Bees were brought back to the lab, held in the refrigerator overnight, and processed the following day.

To remove spores from bees or bee body parts, 4 mL of tween solution was added to each tube and vortexed for 30s. The bee or bee body part was removed from the solution and discarded. Then, 1430 µL glycerol was added to each tube, vortexed for 30s, and frozen at -80°C until they could be concentrated and counted. To concentrate the bee spore solution, the samples were defrosted, centrifuged at 12,000 RPM for 5 minutes and 4800 µL of the supernatant was removed from the sample.

To count spores, the samples were vortexed for 30s, and then two, 10 µL aliquots were added to each side of a hemocytometer slide. All spores within the grid were counted (samples that had large numbers of spores were subsampled using the four corners and middle of the grid). Each bee or bee body part had two counts which were averaged and then extrapolated to determine the total number of spores in the sample.

To test for differences in number of spores, we combined data from whole bees and bee parts and transformed the number of spores per bee using a base 10 logarithmic transformation. Bees that had no spores were excluded from the analyses. Because the data did not follow parametric assumptions, we used the non-parametric Wilcoxon test to test for differences between bee species, and study type (whole vs bee parts). To test for differences in spore frequency among whole bees, we ran a nominal logistic regression.

To test for differences in spore frequency on heads versus bodies, we ran a nominal logistic regression. We excluded the six bees out of 90 that had spores on both their heads and bodies. To test the difference in the number of spores on heads and bodies, we ran a linear regression on the number of spores on heads and bodies using a base 10 logarithmic transformation. We excluded any bees that had no spores, and excluded the two highest outliers.

*Bumblebee conidia transfer*

Four, 1.8 x 3.0 m mesh flight cages were set up in a newly mown grass field. Two commercial bumblebee (*Bombus impatiens*) hives, and two small honey bee hives were individually placed inside the back of each flight cage. Two days before the experiment, a flat of healthy blueberries was added to each cage, and the cages were shut so that bees were only able to forage on blueberry. The day before the experiment, 240 stems with sporulating mummy berry infection were collected from the blueberry field in Hope, wrapped in damp paper towels, and transported back to the University. The sporulating stems were evenly divided into 24, 100 mL beakers filled halfway with water so that there were 10 stems per beaker. Six beakers were placed into the middle of each cage on a cinder block for a total of 60 stems per cage. The cages remained closed so that the bees were only able to forage on the infected stems for 24 h.

Prior to the start of the experiment, six sods of wild blueberry plants were dug up from the University of Maine's Blueberry Hill Farm, transported back to the University, and stored in cold storage until ready to use. The day before the experiment, the sods were brought into the lab at room temperature, and all open flowers were cut from the plants and discarded. The following day, single stems that had a newly opened flower were cut and placed into a 10 x 75 mm glass vial with water.

During the experiment, bees were offered a stem with a newly opened flower. If the bee foraged on the flower, the bee was immediately caught in a 50 mL centrifuge after its foraging was complete and placed in a cooler with ice. After a bee visit, the flower was removed from the cage and placed in a plastic tote to prevent any other insects from visiting it. The bees were processed for conidia using the same protocol as field captured bees. A total of 40 honey bees and 43 bumble bees were involved in the study.

After a bee visit, the flower stem was placed in water and held at room temperature for three days. After three days the flower was placed in 1M KOH and autoclaved for 15 m. Styles were carefully removed from tubes, placed on a slide and then stained with aniline blue (0.05% aniline blue in 0.067M $K_2HPO_4$, pH 9). The styles were examined at 200x under fluorescence using an Olympus BH-2 microscope with a 360 nm excitation filter, a 420 nm transmission barrier and a UVA filter of 360 nm to 380 nm. The number of spores observed, germinated, and the number of spores with germ tubes growing down the style were counted.

## RESULTS:

*Conidia on field bees*

Results in 2018 differed from a trend that we saw over the past two years, honey bees being more likely to have spores and greater numbers of spores than the other two bee taxa (bumblebees and sand bees). When combining data from bee body segments (head vs. thorax and abdomen) and whole bee trials, there was a significant difference in spore loads among bee types ($X^2_{(2)} = 24.36$, $P < 0.0001$) with Andrenid and bumble bees carrying the most spores and honey bees the least (Fig. 1). There was no difference in the amount of spores between whole bee and bee part trials ($X^2_{(1)} = 0.36$, $P = 0.55$). We also observed a significant difference in the likelihood of having spores between bee taxa ($X^2_{(2)} = 6.94$, $P = 0.031$). Honey bees had significantly less likelihood of having spore contamination on their bodies than bumblebees. Andrenids were not significantly different from honey bees or bumble bees in the likelihood of spore contamination.

The amount of spores on bee heads versus bodies were statistically different ($F_{(1, 57)} = 12.43$, $P = 0.0008$) with more spores on bodies compared to heads (Fig. 2). The frequency of spores on heads vs bodies was also statistically significant ($X^2_{(1)} = 69.22$, $P < 0.0001$) with spores more often on bodies than heads. Interestingly, there were only six out of 90 collected bees that had spores on both their heads and bodies.

*Bumblebee conidia transfer*

Unlike previous years, we saw masses of pollen grains in all of our samples. We did not see any mummy berry conidia in any of the bumblebee samples, and so therefore only sampled ¼ of the honey bee samples (10), and those also did not contain any spores.

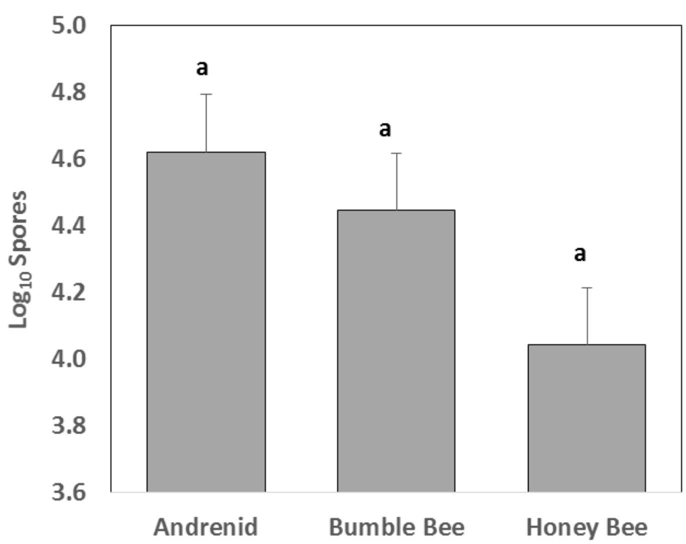



**Fig. 1.** The relationship between bee taxon and the number of spores (transformed using a $\log_{10}$ transformation) per bee for those bees that had contacted lesions and picked up spores. Combined data from whole bee and bee part studies.

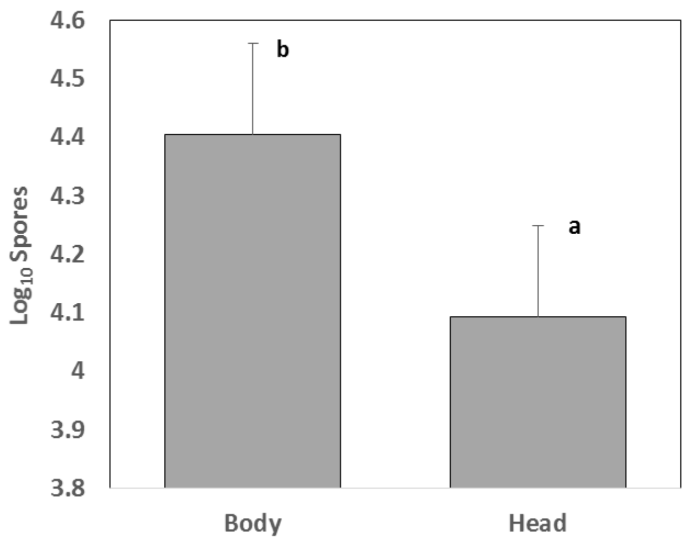



**Fig. 2.** The number of spores ($log_{10}$ transformation) on bee heads and bodies averaged across all bee taxon.

**CONCLUSIONS AND RECOMMENDATIONS:** Our previous studies in 2016 and 2017 found that honey bees had more conidia than bumblebees or Andrenids. While more bees carried spores in 2018 than in 2017, we did not find the same trend from the previous two years to hold true in 2018. This year, Andrenid and bumble bees had more spores than honey bees. This indicates that spore loads are not bee taxon dependent. We did see a trend that more spores are carried on bodies compared to heads. This may prevent visiting bees from depositing as many spores onto the flower's stigma, compared to a situation where the bee's head has more spores. The thought behind this is that it is most frequently the bee's head rather than the body that contacts the stigma.

In previous years, we saw that conidia transfer was rare (about 8% of the floral visits), but did happen. This year we did not see any conidia in our samples, though we did see many pollen grains, which were only rarely present in samples from the first two years. This phenomenon could be due to a number of reasons. It is possible that conidia were not transferred to any plants this year, either because bees were not picking up conidia, or the pollen was interfering with the transfer process. It is also possible that conidia were transferred, but were obscured by the large amounts of pollen.

## DISEASE MANAGEMENT

**INVESTIGATORS:** Seanna Annis, Associate Professor and Associate Extension Professor
Rachael Martin, Research Assistant
Nghi Nguyen, MS Graduate Student, School of Biology and Ecology
Jennifer D'Appollonio, Assistant Scientist, School of Food and Agriculture

**4. TITLE:** Research and control of leaf spot diseases, 2018.

**OBJECTIVE:** Improve control of various leaf spots, Septoria leaf spot (*Septoria* sp.), powdery mildew *(Erysiphe vaccinii*), and leaf rust (*Thekopsora vaccinii*) using field and lab research.

**METHODS:**

*Survey of weather and levels of disease in wild blueberry fields*

Seven blueberry fields with weather stations were rated for leaf spot diseases, powdery mildew, Septoria, and leaf rust, between October 10th and 25th, 2018. Five fields were not rated (four due to the field having been pruned and one due to removal of the weather station at harvest). Two stations had problems with their modems and were pulled from the field. One station was deployed in Blueberry Hill Research Farm (BBHF) later in the season. Five sampling plots of $0.25m^2$ were rated by one surveyor visually estimating percentages of blueberry coverage, blueberry leaf loss, blueberry stems with *Phomopsis*, and blueberry leaf area with the following leaf spot diseases: Septoria leaf spot, powdery mildew, and leaf rust. Any red leaf and false Valdensia disease were also noted. Fall disease ratings were averaged across the five sampling plots within a field.

*Spore dispersal of selected fungi*

Spore traps were placed at the edge between a crop and prune field near Deblois and in the upper crop field at BBHF in Jonesboro, ME on May 1, 2018. A repaired spore trap was placed in the lower prune field at BBHF on August 24th and was removed October 25th. We collected spore trap tapes containing the trapped airborne spores every week. The spore trap in the Deblois field had intermittent problems throughout the season and was removed from the field October 3rd. The upper crop field was pruned on October 3rd, so the spore trap was removed. Spore trap tapes were cut in half, and half was frozen for future DNA work while the other half was mounted on glass slides. Rust spores were counted for each hour from the tapes.

Disease assessments occurred weekly in the spore trap fields when the spore trap tapes were collected. Five sampling plots of $0.25m^2$ were rated by visually estimating percentages of blueberry coverage, blueberry leaf loss, blueberry stems with *Phomopsis*, and blueberry leaf area with the following leaf spot diseases: Septoria leaf spot, powdery mildew, and leaf rust.

Leaf rust and powdery mildew samples were collected for DNA extraction and sequencing. The spores or spore producing structures were collected from infected stems using a vacuum and extracted for DNA.

*Fungicide trial*

A split-plot complete randomized block experiment was established in a lowbush blueberry field at the Blueberry Hill Research Farm in Jonesboro, Maine, where high levels of leaf spots had been previously reported. Fungicides (Table 1) were randomly assigned to 6' x 30' plots with a 3' buffer lane between each plot and replicated in eight blocks. Plots were divided in half, and treatments were randomly assigned to one of two application timings (June 15 or June 22). Fungicides were applied at volumes equivalent to 20 gallons per acre at 35 psi with a $CO_2$ backpack sprayer equipped with a 4ft nozzle boom, 8002VS Tee Jet tips and '50 mesh' screens. Control plots received no spray applications.

Disease symptoms and leaf loss were rated three times: the end of July, August and September. A 30' rope with 20 evenly spaced markings was stretched along a transect through each plot and the stem closest to each marking was cut and bagged. The next day, leaves were rated for disease symptoms. The total number of leaves, nodes lacking leaves (leaves fallen) and the estimated percent coverage of each disease on remaining leaves was noted per stem. Per treatment, 160 stems (20 stems per plot) were rated. Phytotoxicity was also rated at the same time disease assessments were made. In the September rating, the numbers of flower cluster buds were also counted. The number of opening flower buds will be counted in the spring of 2019. The first stems were collected July 31$^{st}$ and rated August 1$^{st}$-3$^{rd}$. Stems were collected again on August 28$^{th}$ and rated August 29$^{th}$-31$^{st}$. A third collection of stems occurred on September 25$^{th}$ and was rated September 26$^{th}$-28$^{th}$.

Data were analyzed by plot averages in SAS (Statistical Analysis Software - SAS Cary, NC) using mixed model procedures (PROC GLIMMIX). Proportional data was transformed with arcsin square root method. Least Square means were used to determine specific differences among treatments ($\alpha = 0.05$).

## RESULTS:

*Weather station fields*

Weather station fields were rated later than in past years, and more leaves showed signs of senescence. There were many small black sunken lesions, which were hard to distinguish between Septoria or leaf rust (Figure 1). In most years, Septoria lesions are not seen into October since the infected leaves are typically the lower leaves that have fallen off. These lesions may be Septoria or leaf rust with no spore production. Lesions with leaf rust spore production were rated as leaf rust. Most weather station fields had some Septoria-like symptoms on leaves. There were low levels of lesions producing leaf rust spores and only some fields with powdery mildew symptoms. Fields also varied in their leaf loss, and this was not related to when the field was rated (Figure 2).

*Spore trap project*

There were different patterns of leaf loss and diseases between the two crop fields (Figure 3). In the Deblois field, there was a large increase in leaf loss from September 4$^{th}$ to September 18$^{th}$, and there was a drop off in Septoria-like symptoms from mid-August to end of September and an increase in leaf rust through September. One clone in particular was heavily infected by leaf rust near the spore traps. The upper crop field at BBHF had steadily increasing leaf loss and Septoria symptoms until September 4$^{th}$. Rust lesions were only visible after September 18$^{th}$.

Spores are currently being counted from spore trap tapes. Nghi Nguyen is developing a molecular method of identifying blueberry leaf rust. She has designed and screened eight sets of DNA primers for their ability to identify leaf rust DNA and their detection limits. She has tested two methods and found one method, LAMP, worked well for identification, but qPCR was better for quantification. She has extracted total DNA from weekly sections of spore trap tapes, which were identified by microscope to have leaf rust spores. She is currently testing the molecular methods on their ability to detect spores on the spore trap tapes.

*Fungicide efficacy trial*

Phytotoxicity was not observed at any of the rating times. In all of the disease ratings, there were no significant differences between the early and late application timings and no interaction between timings and treatments. All of the fungicides significantly decreased leaf loss compared to the check plot in July, August and September (Figures 4, 5 and 6). All three fungicides were similar in their effect on leaf loss in July and August. By the end of September, Bravo had significantly less leaf loss than Proline or Aprovia (Figure 6).

In July, it is difficult to distinguish between Septoria and leaf rust symptoms since both fungi produce symptoms of small, black necrotic lesions. Later in the season, rust lesions start to produce their orange colored uredospores on the underside of leaves and so can be distinguished from Septoria symptoms. We did not find any rust spore producing lesions on the plants in our trials in August or September so we conclude the majority of the small, black necrotic lesions were probably due Septoria infection (Figures 7, 8, and 9). All fungicides significantly decreased Septoria symptoms in July (Figure 7). In August and September, Aprovia and Bravo significantly decreased Septoria symptoms compared to the check plot (Figure 8 and 9). There were negligible powdery mildew symptoms in July (data not shown) and low levels in August and September (Figures 10 and 11). There was no effect of the treatments or their timings on powdery mildew symptoms suggesting they were not applied at suitable timings for this disease.

There were significant interactions among timing and treatment on the number of flower cluster buds present at the end of September (Figure 12). Later treatments of Proline and Bravo had significantly more flower buds compared to the earlier treatments of the same materials but not significantly more buds than the early check, which did not receive any treatment. We will count produced flowers in the spring to see if this difference in flower buds results in differences in flower numbers.

**RECOMMENDATIONS:** We will be recommending Aprovia for control of leaf spots in wild blueberry for 2019. Proline is already recommended but was not as effective as Aprovia and Bravo.

**Table 1.** Fungicides tested in 2018 for their efficacy to control leafspots.

| Treatment (Trade Names) | Material | Application Rate (per acre) | Manufacturer | FRAC group | EPA Registration Number | Reg. on Wild Blue-berry |
|---|---|---|---|---|---|---|
| Proline | Prothioconazole | 5.7 fl oz | Bayer Crop Science | 3 | 264-825 | yes |
| Aprovia | Solatenol® (Benzovindiflupyr) | 10.5 fl oz | Syngenta | 7 | 100-1471 | yes |
| Bravo Ultrex | Chlorothalonil (tetrachloroiso-phthalonitrile) | 3.6 lbs | Syngenta | M5 | 50534-201-100 | yes |

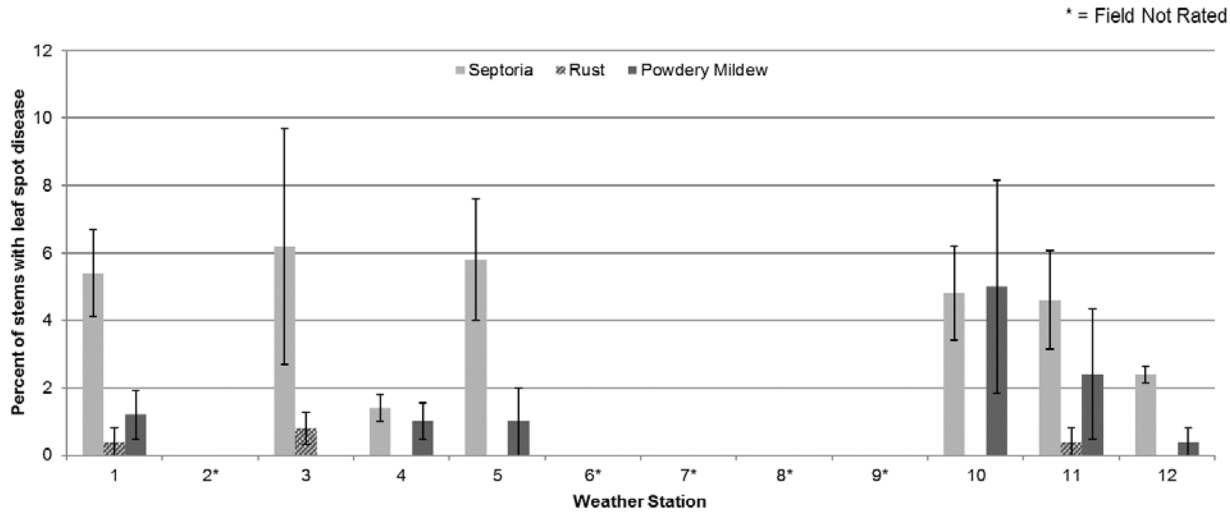



**Figure 1.** Percentage of leaf area with Septoria (light gray bars), powdery mildew (dark grey bars) and rust (striped bars) at each of the weather station fields. Error bars indicate standard error of the mean.  *Five fields were not rated, four due to early pruning and one due to early weather station removal.

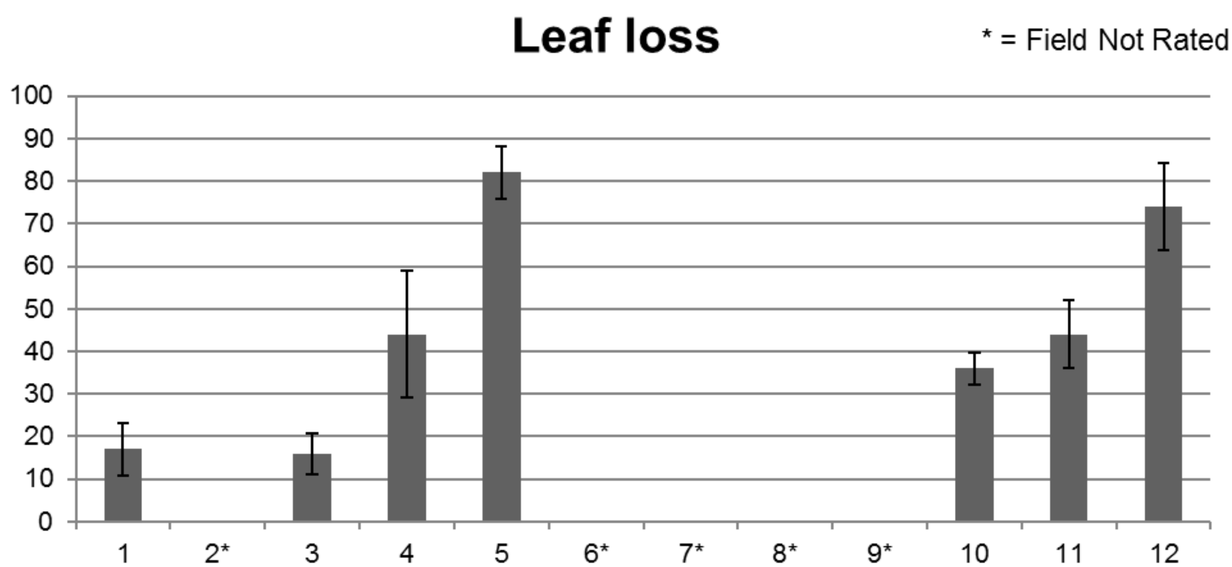
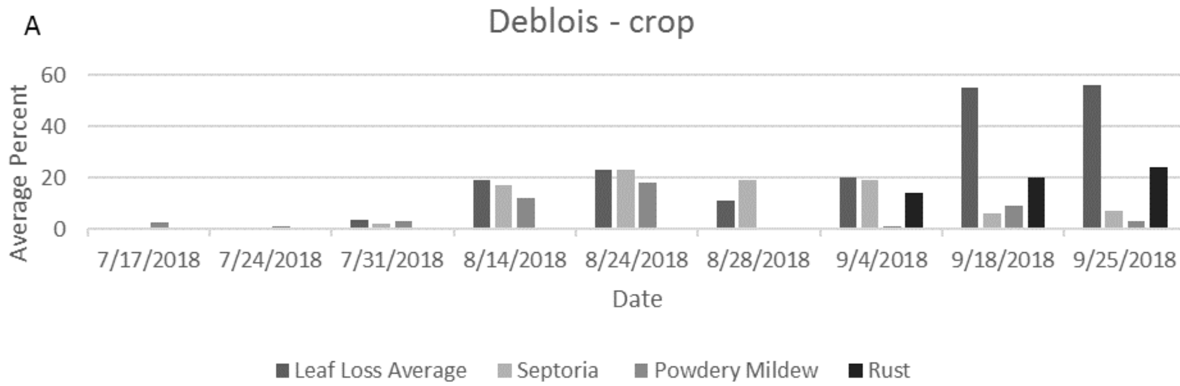



**Figure 2.** Leaf loss in weather station fields rated from October 10 to October 25.  Error bars indicate standard error of the mean.



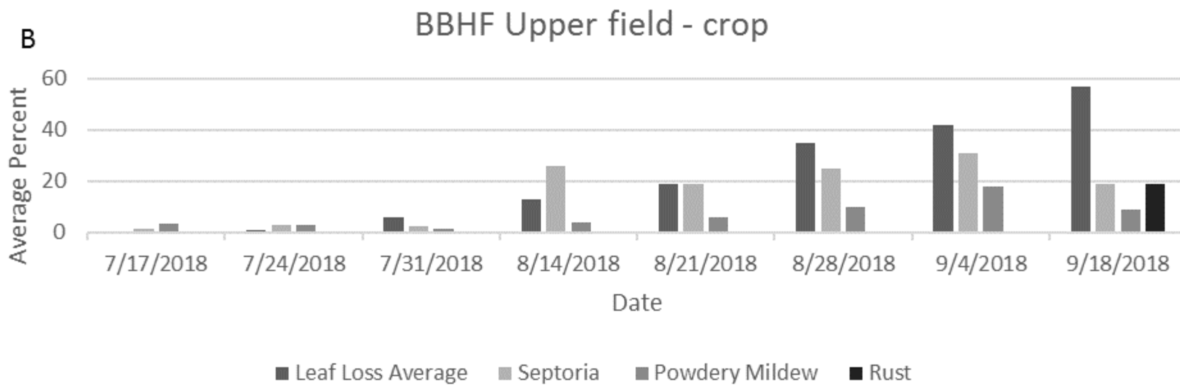




**Figure 3.** Leaf loss and symptoms of leaf spots (powdery mildew, Septoria and rust) rated each week in crop fields near Deblois, ME (A) and Blueberry Hill Farm in Jonesboro (B) where spore traps were placed.

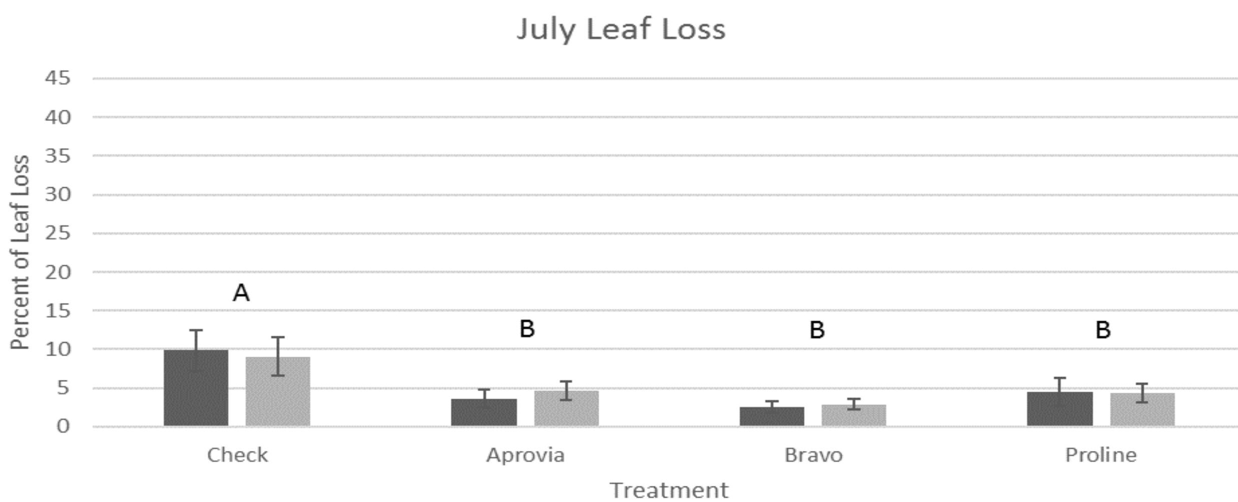



**Figure 4.** Percentage of leaf loss in July. Dark bars represent the early timing (June 15) and pale grey bars the later timing (June 22) of fungicide application. There were no significant differences in the timing of treatments. Bars with different letters indicate statistically significant differences at α =0.05.

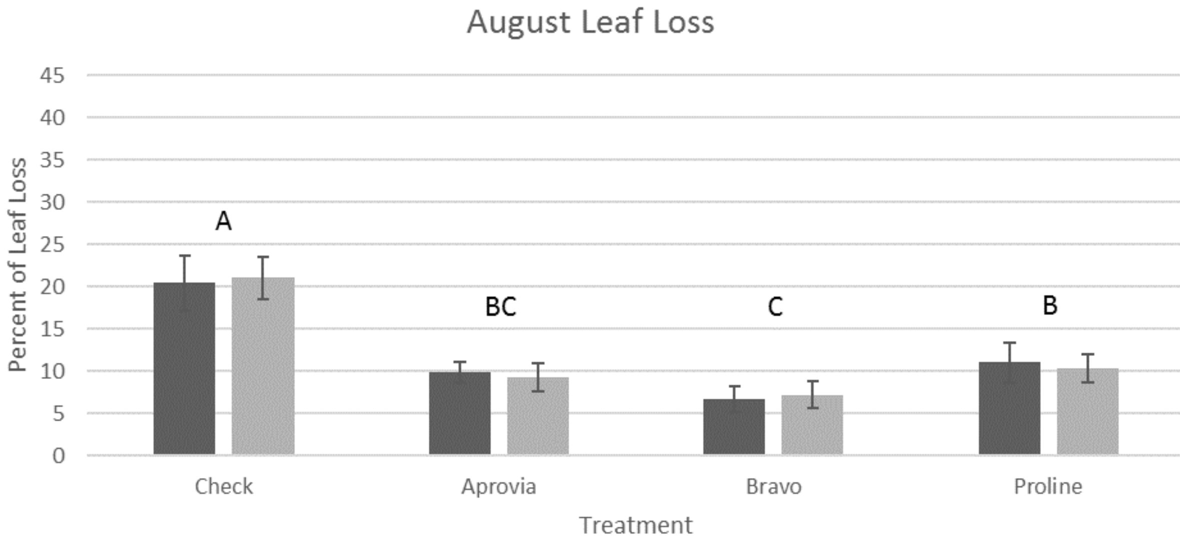



**Figure 5.** Percentage of leaf loss in August. Dark bars represent the early timing (June 15) and pale grey bars the later timing (June 22) of fungicide application. There were no significant differences in the timing of treatments. Bars with different letters indicate statistically significant differences at α =0.05.

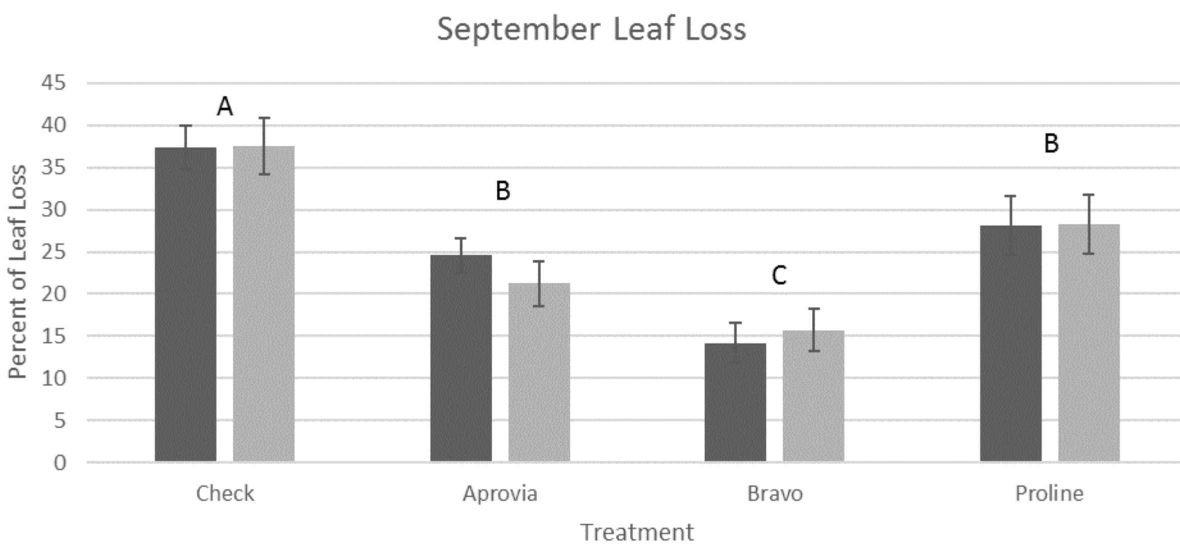



**Figure 6.** Percentage of leaf loss in September. Dark bars represent the early timing (June 15) and pale grey bars the later timing (June 22) of fungicide application. There were no significant differences in the timing of treatments. Bars with different letters indicate statistically significant differences at α =0.05.

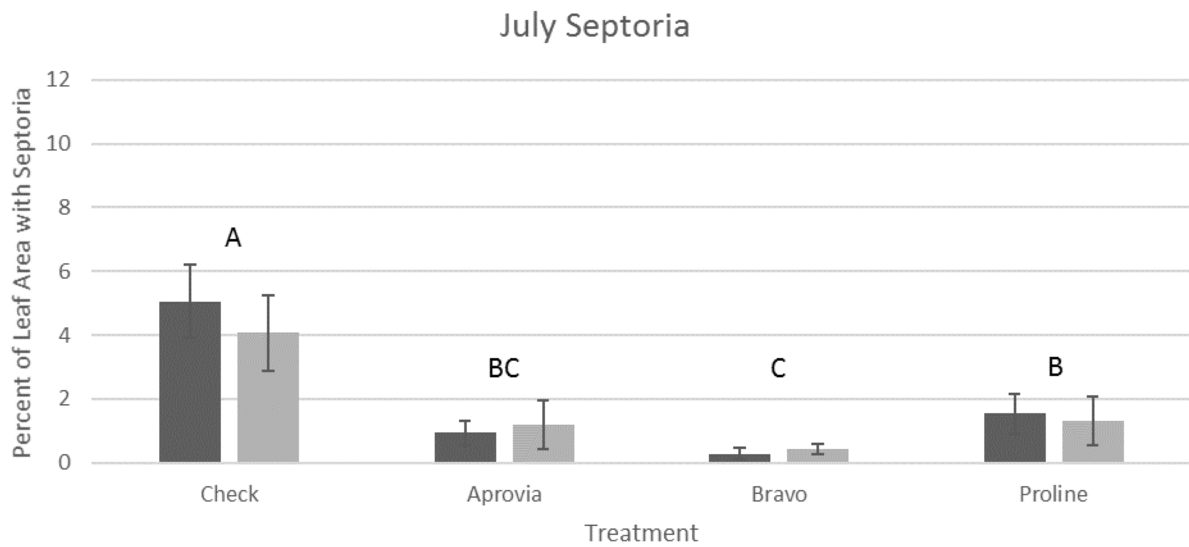



**Figure 7.** Percentage of leaf area with Septoria by treatment and application timing in July. Dark bars represent the early timing (June 15) and pale grey bars the later timing (June 22) of fungicide application. There were no significant differences between treatment timings. Bars with different letters indicate statistically significant differences at $\alpha = 0.05$.

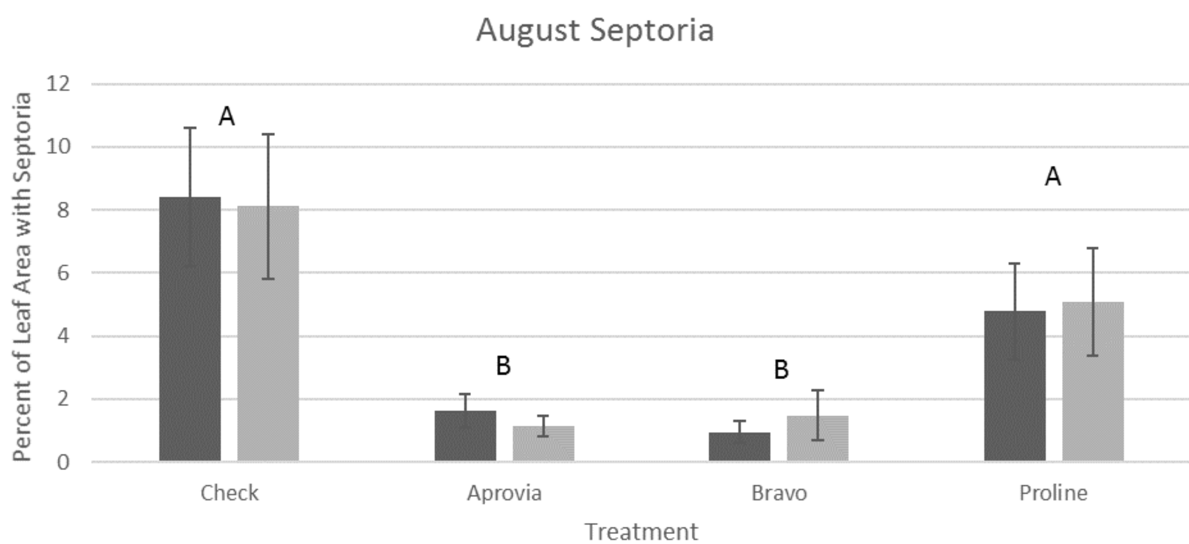



**Figure 8.** Percentage of leaf area with Septoria by treatment and application timing in August. Dark bars represent the early timing (June 15) and pale grey bars the later timing (June 22) of fungicide application. There were no significant differences between treatment timings. Bars with different letters indicate statistically significant differences at $\alpha = 0.05$.

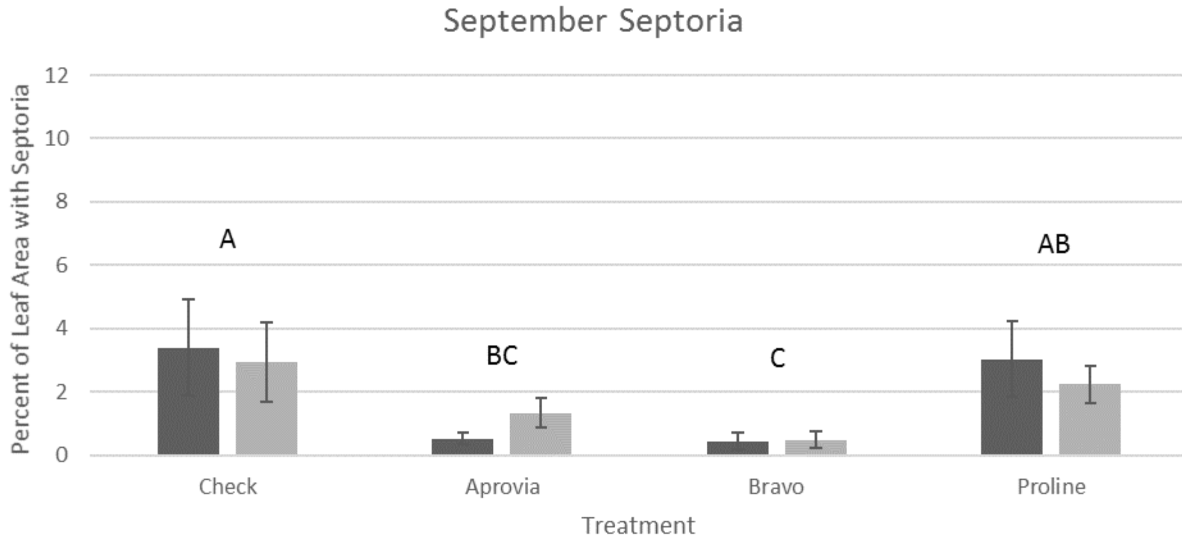



**Figure 9.** Percentage of leaf area with Septoria by treatment and application timing in September. Dark bars represent the early timing (June 15) and pale grey bars the later timing (June 22) of fungicide application. There were no significant differences between treatment timings. Bars with different letters indicate statistically significant differences at $\alpha = 0.05$.

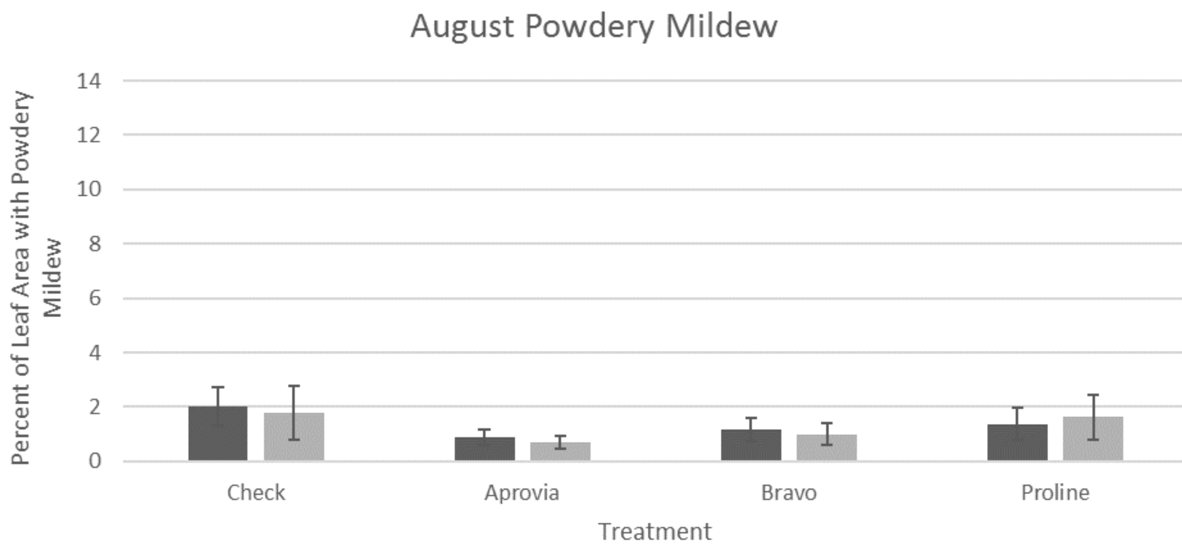



**Figure 10.** Percentage of leaf area with powdery mildew in August. Dark bars represent the early timing (June 15) and pale grey bars the later timing (June 22) of fungicide application. There were no significant differences in treatments or treatment timing and no significant interactions.

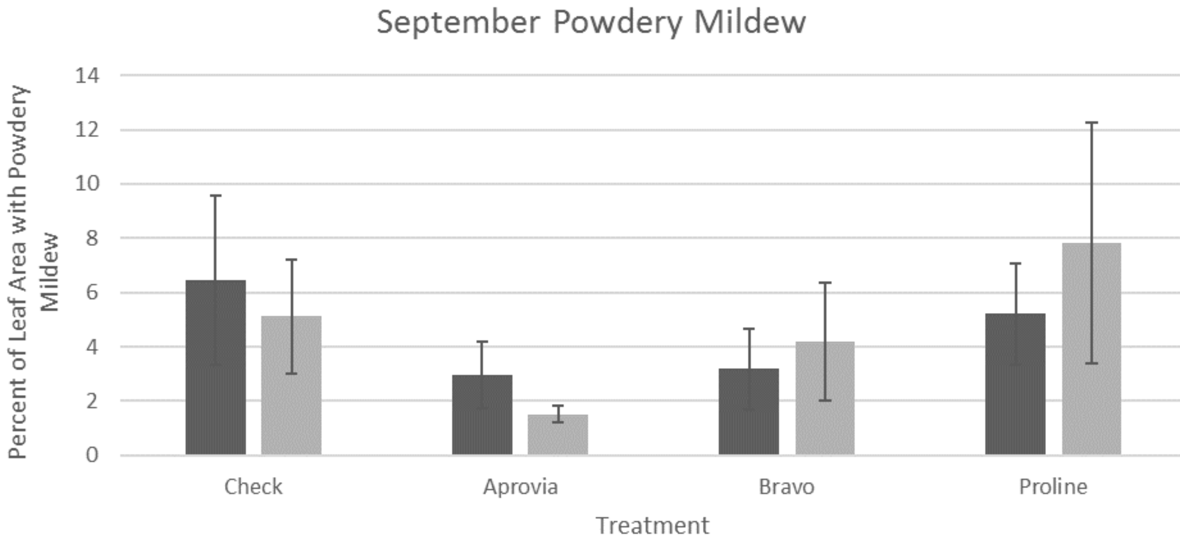



**Figure 11.** Percentage of leaf area with powdery mildew by treatment and application timing in September. Dark bars represent the early timing (June 15) and pale grey bars the later timing (June 22) of fungicide application. There were no significant differences in treatments or treatment timing and no significant interactions.

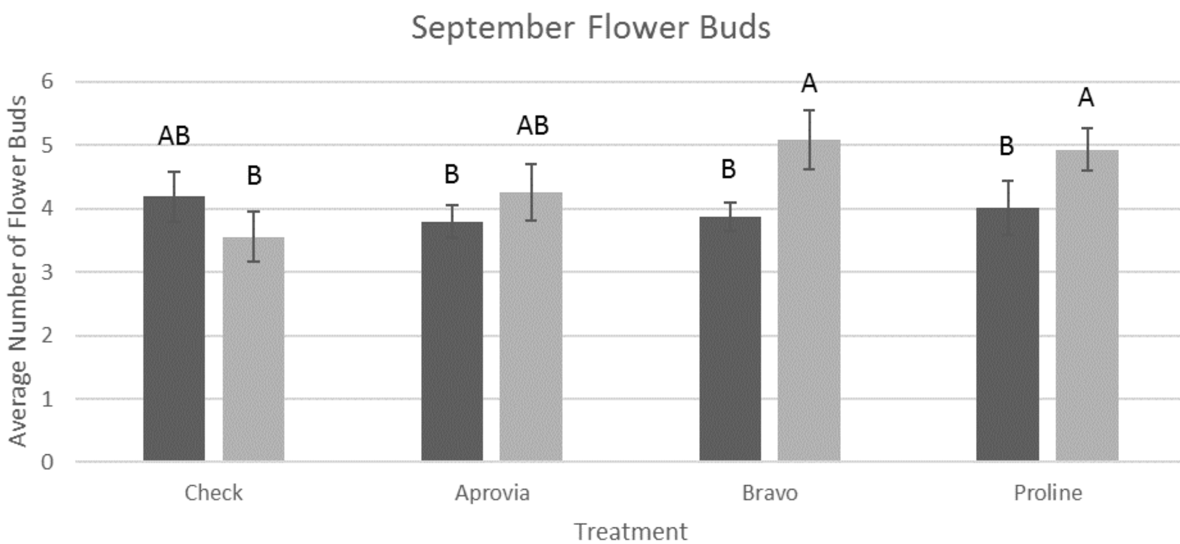



**Figure 12.** Average number of flower buds in September. Dark bars represent the early timing (June 15) and pale grey bars the later timing (June 22) of fungicide application. There was a significant interaction between treatments or treatment timing. Bars with different letters indicate statistically significant differences at α =0.05 between each treatment and timing combination.

## DISEASE MANAGEMENT

**INVESTIGATORS:** Seanna Annis, Associate Professor and Associate Extension Professor, School of Biology and Ecology
Rachael Martin, Research Assistant, School of Biology and Ecology
Jennifer D'Appollonio, Assistant Scientist, School of Food and Agriculture

**5. TITLE:** Research and control of mummy berry, 2018.

**OBJECTIVE:** Improve control of mummy berry, caused by *Monilinia vaccinii-corymbosi* (MVC) and Botrytis blight, caused by *Botrytis cinerea*, through research and the deployment and operation of a disease forecasting system using weather stations.

**METHODS:**

*Weather stations and edge effects on mummy berry*

From mid-April in 2018, fifteen weather stations, connected to the internet via cellular modems, were deployed in blueberry growers' fields around Maine from Waldoboro, Lincoln County to Crawford, northern Washington County (Figure 1). All of the weather stations had been updated with new modems. Twelve locations also had MVC mummy berry (pseudosclerotia) plots.

Twelve fields with weather stations were rated for mummy berry between May 21st and June 6th, 2018. Four 30-m transect ropes with 30 evenly spaced marks were randomly placed in the field around the weather station, or 1, 6, 12 and 24 m in from the edge of the field adjacent to the woods or a prune field. The stem closest to each mark on the rope was rated for mummy berry and Botrytis symptoms and the presence or absence of each disease was noted. Stems with top kill, frost, tip midge and red leaf were also recorded. Four additional fields were rated for the edge effect study. A total of six fields were rated at their forest edge and seven fields at their prune edge. To normalize the data, percent data were converted to proportion and arcsin transformations of the square root were performed. Mixed models using distance and least mean square comparison were used to compare locations in SAS 9.4 (SAS institute Inc.).

*Fungicide efficacy trials*

Field trials were set up in two lowbush blueberry fields with histories of mummy berry. One field was near Deblois and the other in Township 19, Maine. The plots were set up in a complete randomized block design of eight blocks per field. Fungicides (Table 1) were randomly assigned to 6' x 30' plots with a 3' buffer lane between each plot and replicated in each of the eight blocks per field. Fungicide applications were timed using the Mummy Berry Disease Forecast according to locally monitored conditions of fungal and plant development and weather conditions favoring disease development. More information about the Mummy Berry Forecast method can be found in UMaine Cooperative Extension Bulletin #217, and the forecasts for 2018 are available at https://extension.umaine.edu/blueberries/blog/. Fungicides were applied on May 9th at both field locations. Fungicides were applied at volumes equivalent to 20 gallons per acre at 35 psi with a $CO_2$ backpack sprayer equipped with a 4ft nozzle-boom, 8002VS Tee Jet tips and '50 mesh' screens. A negative control (check) plot received no spray applications. Weather stations were located within three miles of the test fields and measured air temperature and leaf wetness approximately 4” off the ground, soil temperature at 1” below the surface and soil moisture at 1” to 5” below the surface (where most of the blueberry roots are located).

Disease and frost ratings were made in the Deblois field on May 29th and the Township 19 field on June 6th. The Township 19 field showed early symptoms on May 29th, so we delayed the disease rating. The Township 19 field experienced frost conditions overnight from June 3rd to June 4th. In each field, ratings consisted of presence/absence of mummy berry symptoms, Botrytis, and frost on 40 blueberry stems in each plot rated as above. The number of markings at bare places (missing data) was also recorded. The percentage of infected stems was calculated as the number of counted, infected stems divided by the total number of rated stems (40 minus the number of bare locations) for each plot. Phytotoxicity was also rated at the same time disease assessments were made.

Blueberries were harvested on August 10th, 2018. Harvesting occurred in a 2-foot strip down each plot center with a mechanical harvester, and fresh weight was measured.

To normalize the disease measurements, percent data was converted to proportion and then an arcsine transformation of the square root was performed. The yield data had a normal distribution. Data were analyzed by plot averages in SAS (Statistical Analysis Software - SAS Cary, NC) using mixed model procedures (PROC GLIMMIX). Least Square means were used to determine specific differences among treatments ($\alpha = 0.05$).

*Timing of ascospore release*

Two spore traps were placed in crop fields from May 1st, 2018. One field was near Deblois and the other at Blueberry Hill Research Farm (BBHF) in Jonesboro, ME. Both fields had weather stations. The number of *Monilinia* ascospores and conidia were counted for each hour interval on the spore trap tape under a microscope at hourly intervals from May 1st to May 26th, 2018.

*Leaf loss study*

While we know that mummy berry can cause direct effects on yield by infecting developing fruit, it is still not clear what effect leaf loss due to mummy berry has on yield. An experiment to determine the effect of different levels of leaf loss on yield was set up. On May 25th, ten clones at BBHF were chosen, and five stems per clone with flowers were used, for each of four treatments: no leaf loss, 25%, 50% and 75% of branches removed. Total number of flowers and branches were counted and the appropriate number of branches were removed. The field experienced an overnight frost from June 3rd to 4th. On June 26th, the number of healthy set fruit, dead fruit, and branches were counted. On Aug 6th, stems were harvested and the number of branches, blue fruit, green fruit and undeveloped fruit were counted.

## RESULTS:

*Weather stations*

The weather stations with new modems worked well in some fields and not in others. There was some breakdown in the modems, and in some fields, suitable internet connection was difficult to obtain. Three stations were not operational during the mummy berry season. In August, updated modems were installed at five stations where they worked for the rest of the season. We will replace all the rest of the modems with updated ones before next season.

Mummy berry infection periods started about April 26th in the Midcoast region and May 1st in the Downeast region. Plant and fungus activity was delayed with the cool spring. In the Downeast fields, there were a number of wet periods overnight from temperatures dropping from the 70s °F during the day to the 30s. If the temperatures were high enough (40s °F), these wet periods produced possible infection periods in some fields (Figure 2). Mummy berry incidence levels closely matched severity, and both varied a great deal depending upon field conditions and grower fungicide applications (Figure 3). Overall, mummy berry was not as severe, on average 13% stems infected, compared to last year when 30% stems were infected.

*Fungicide efficacy trial*

There was a long, cold spring, so development of plants and MVC were delayed until early May at our test sites. Plants in Township 19 were a bit behind plants in the Deblois field. Apothecia of MVC were present by May 4th in many fields, but plants were not developed enough to have a lot of susceptible tissue. Due to weather conditions, the fungicide application was delayed until May 10th, which was probably after the first infection period. Because most MVC apothecia had dried up by May 19th, only one fungicide application was applied. The original experimental plan also included two single propiconazole application timings (first application only; "Propimax 1"and second application only "Propimax 2") to contrast with the typical two-applications of this fungicide made most years. The Propimax and "Propimax 1" treatments are identical since they both have only one application of fungicide and the Propimax 2 application was not made. Both treatments are presented in the results and provide an idea of the variability possible between two identical treatments. Disease symptoms were rated in the Deblois field on May 29th, but were just starting to develop in the Township 19 field by that date. On the night of June 3rd to June 4th, the Township 19 field had a severe frost with temperatures dropping to below 32°F for at least one hour. Frost severely affected lower lying blocks, resulting in approximately 45 to 50 % of the stems in each treatment having frost damage (Figure 4). Distinguishing between the death of flowers due to frost or mummy berry can be difficult and may have affected disease ratings in the Township 19 field.

None of the materials displayed phytotoxicity. Symptoms of Botrytis were also not seen. Plots treated with Proline, Luna Tranquility and Propimax had significantly less mummy berry disease incidence than the untreated check-plot and plots treated with Pristine at the Deblois site (Figure 5). The same pattern was observed in the Township 19 field, but there were no significant differences among the treatments (Figure 6). There was no effect of the treatments on yield in the Deblois field (Figure 7). The Township 19 field was not harvested due to the loss in potential yield from frost damage.

*Timing of ascospore release*

In the Deblois area, *Monilinia* apothecia were observed from about April 30th to May 17th, 2018. Only one mummy berry plot produced apothecia at BBHF. Very low counts of ascospores were detected in the Deblois field from May 1 to May 15th (data not shown). The low levels of ascospores are suspected to be due to problems with the spore trap, which we found was not producing enough suction near the end of May. At BBHF, a large peak of ascospores was found from May 1st to 2nd followed by a series of peaks until May 16th (Figure 8). There were lower levels of spores captured during times of higher leaf wetness, which may be due to rain pulling spores out of the air column. Peak spore production appeared to be in the morning, but this appearance of a peak may be affected by the occurrence of rain (Figure 9). We again found a peak of spores from May 23rd to May 27th that looked similar to *Monilinia* ascospores, but they occurred after *Monilinia* apothecia were reported to be finished (data not shown). We will use molecular methods to try to identify this fungus.

*Effects of field edges on mummy berry incidence*

There were no significant differences in the level of mummy berry infection at different distances from the prune field/crop field edge or from the forest edge (Figure 10). The highest levels of infection were at the forest edge this year, in contrast to the prune edge in 2016 and 2017. Only 6 fields with forest edges and 7 with prune edges were rated this year. There has been no conclusive effect of field edges on mummy berry incidence levels over the three years. Different fields were used in each year and different levels of mummy berry infection occurred each year.

**RECOMMENDATIONS:** Proline and Luna Tranquility will be added as recommended fungicides for control of mummy berry in the 2019 fungicide fact sheet. We are still looking for organic material controls of mummy berry.

**TABLES:**

**Table 1.** Fungicides tested in 2018 for control of mummy berry.

| Treatment (Trade Names) | Material | Manufacturer | EPA Registration Number | Application Rate (fl.oz/ acre) |
|---|---|---|---|---|
| Pristine | pyraclostrobin and boscalid | BASF Corporation | 7969-199 | 18.5 |
| Proline | prothioconazole | Bayer Crop Science | 264-825 | 5.7 |
| Luna Tranquility | fluopyram and pyrimethanil | Bayer | 264-1085 | 16 |
| Propimax | propiconazole | Syngenta | 100-617 | 6 |

**FIGURES:**

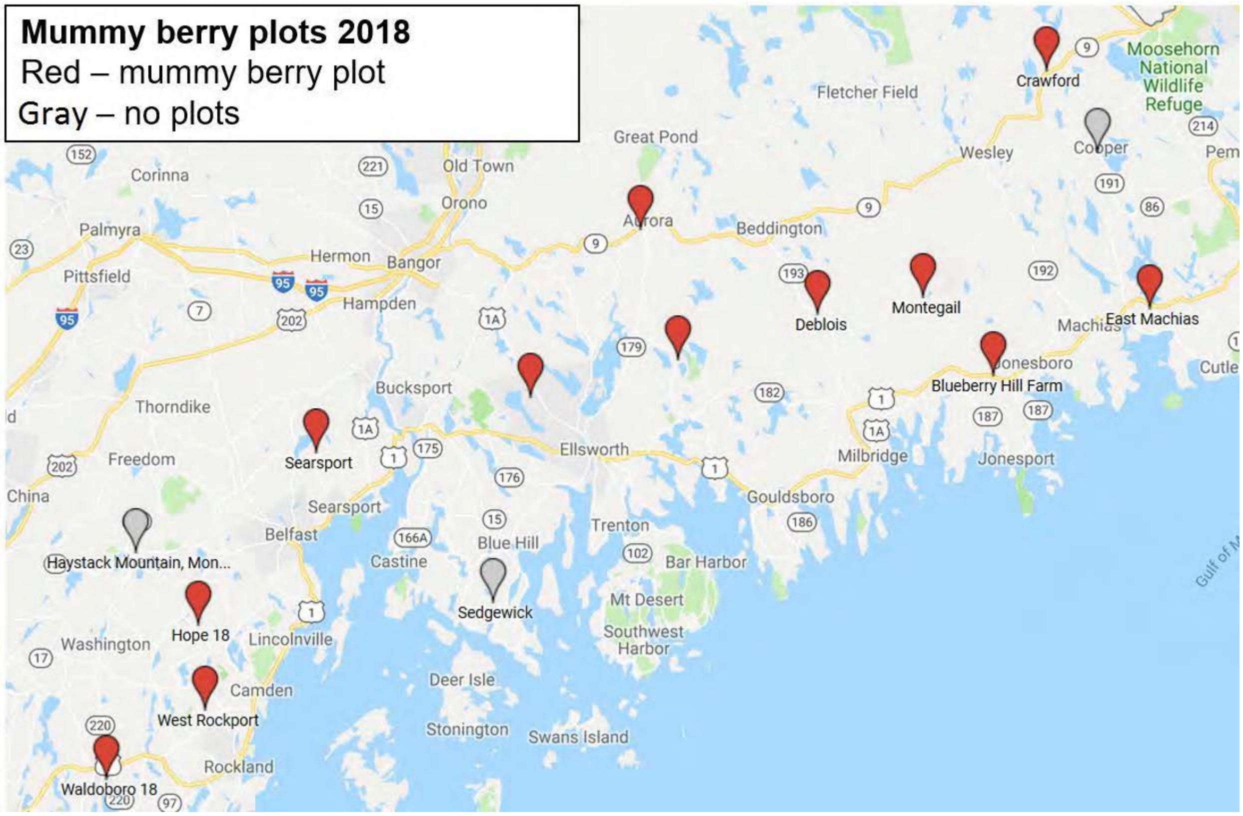



**Figure 1.** Locations of weather stations and mummy berry plots for 2018. Sites with red markers had a mummy berry plot; sites with gray markers did not.

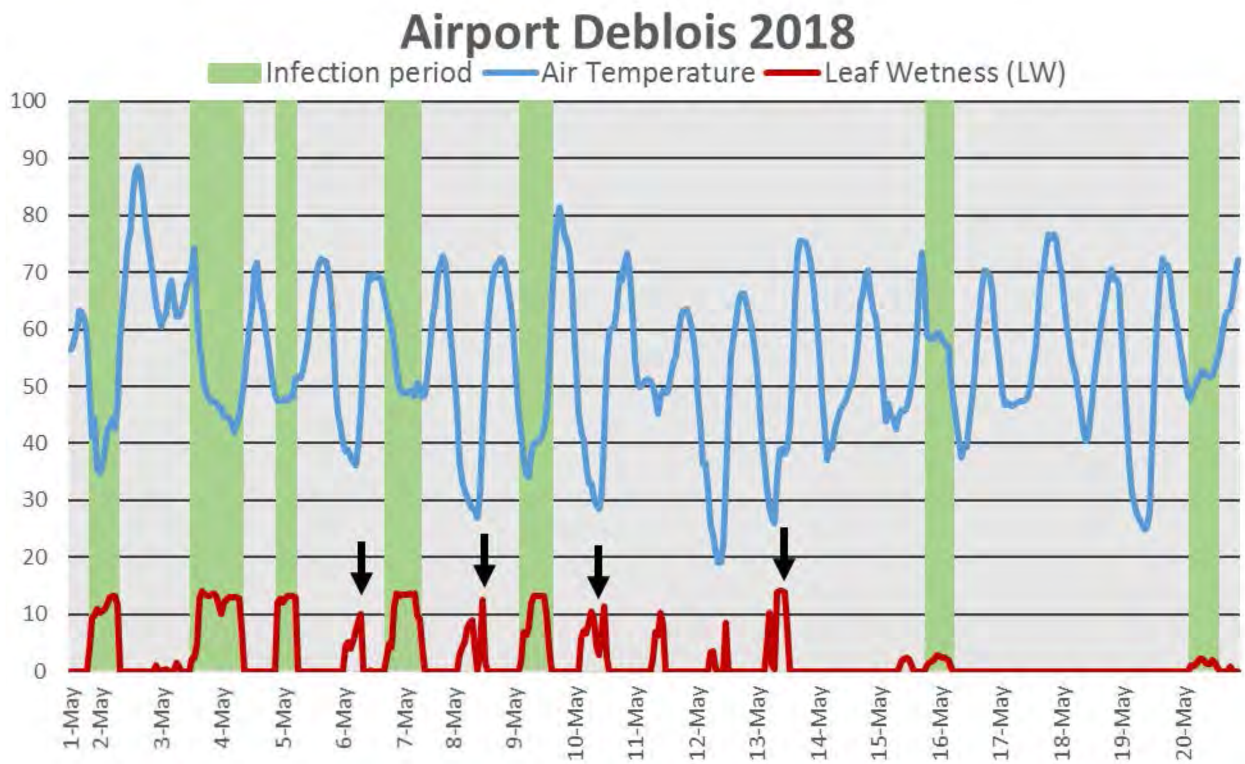



**Figure 2.** Infection periods at the Deblois site in 2018. Blue line is air temperature and Red line is leaf wetness, which were used to determine infection periods (green vertical bars) for *Monilinia vaccinii-corymbosi.* Apothecia were present from May 1st to May 20th. Arrows indicate overnight leaf wetness events that were too cold for infection to occur.

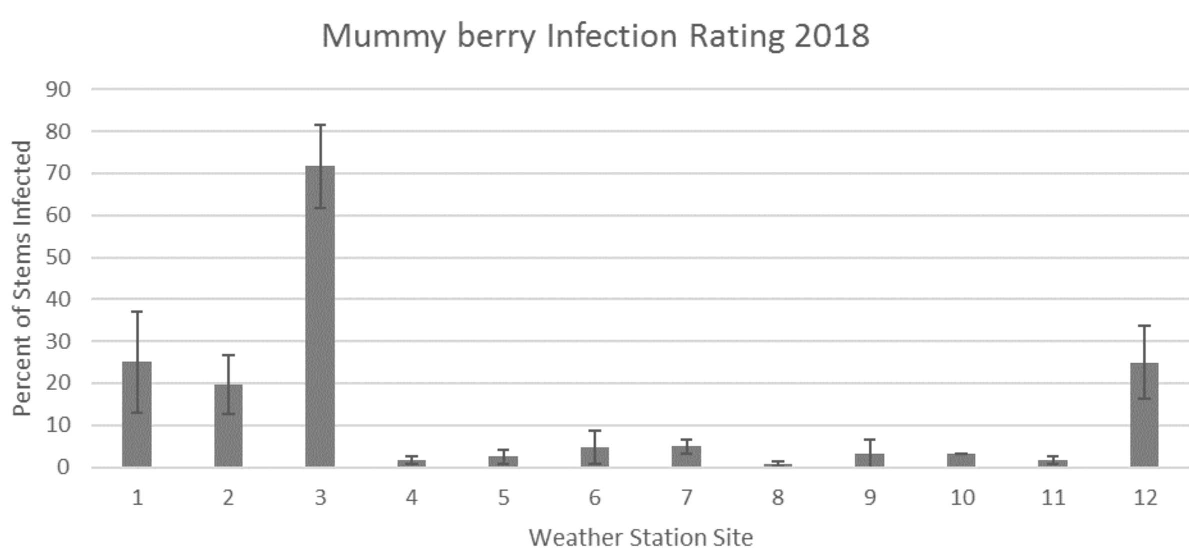



**Figure 3**. Percentage of stems infected with mummy berry at each of twelve weather station sites. Error bars indicate standard error of the mean.

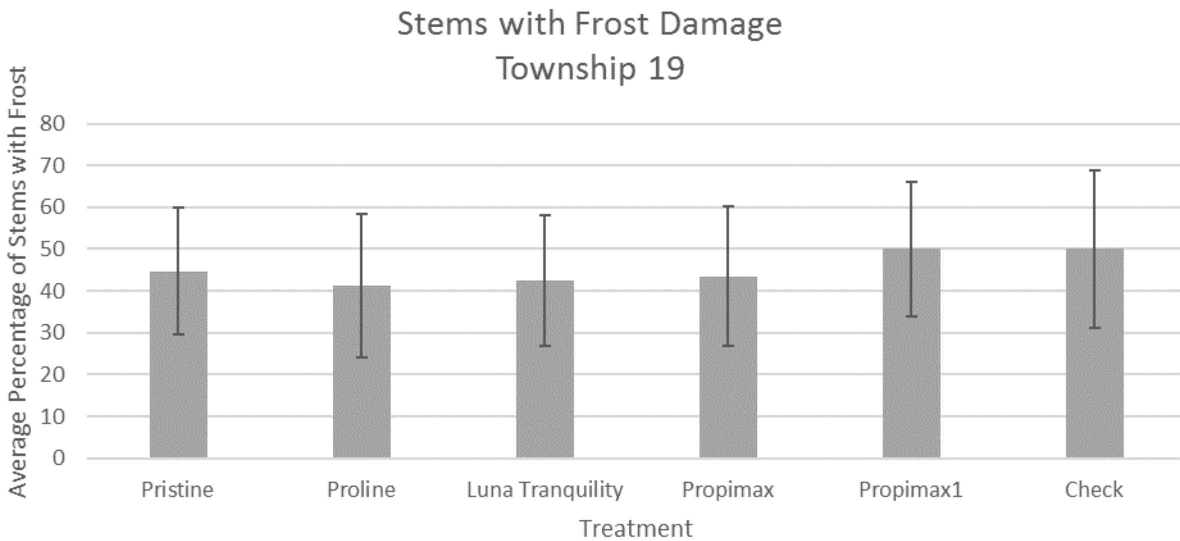



**Figure 4.** Average percentage of stems with symptoms of frost in Township 19 field. Error bars represent standard error of the mean of eight replicates. There were no significant differences among treatments.

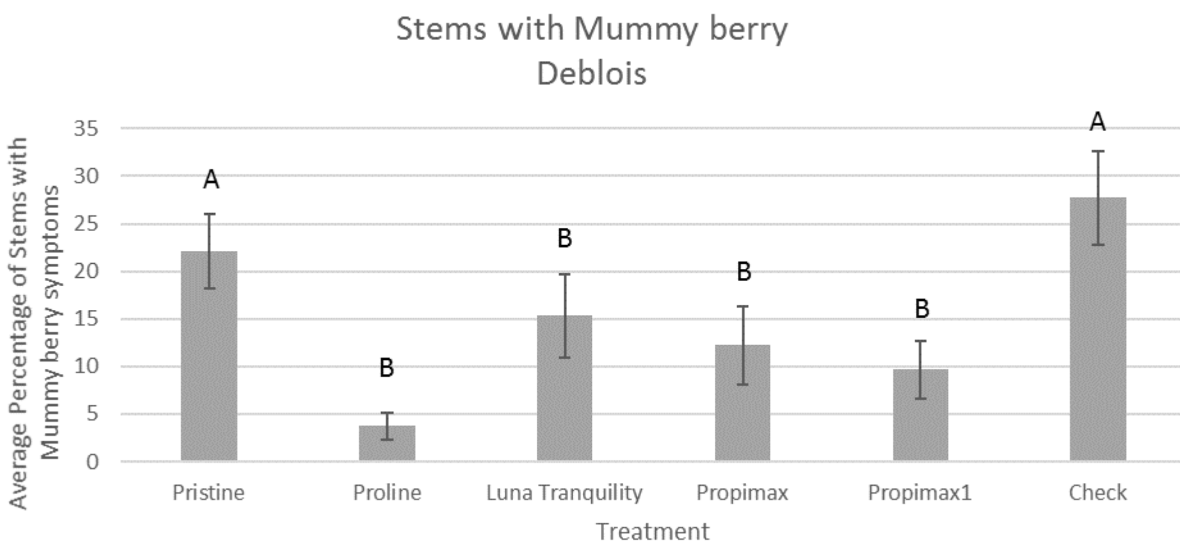



**Figure 5.** Average percentage of stems with symptoms of mummy berry in fungicide trials at Deblois field. Error bars represent standard error of the mean of eight replicates. Bars with different letters were significantly different at $p<0.05$ within the fields.

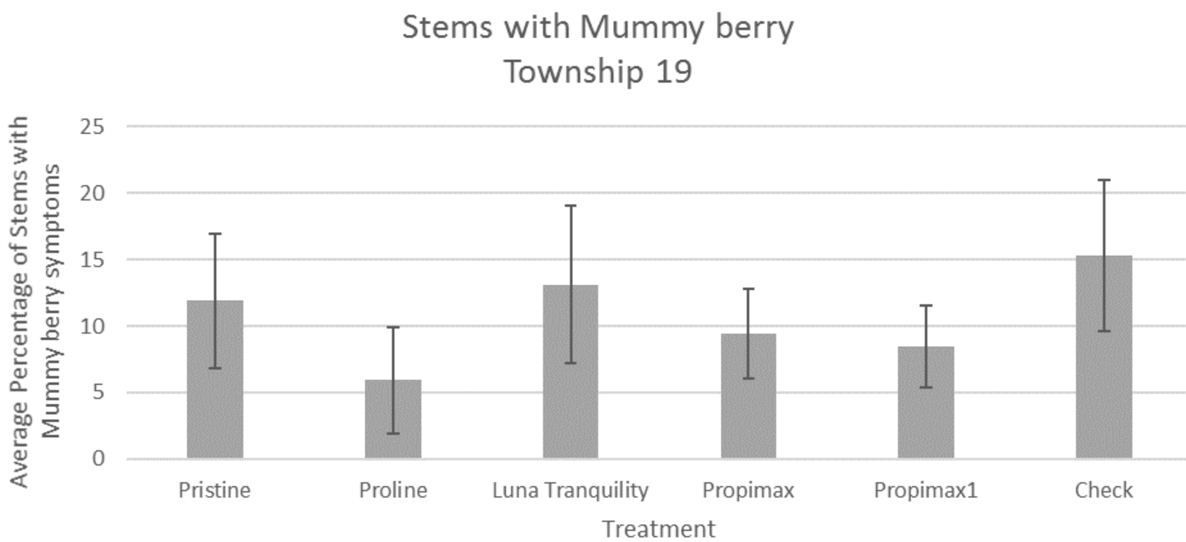



**Figure 6.** Average percentage of stems with symptoms of mummy berry in fungicide trials at Township 19 field. Error bars represent standard error of the mean of eight replicates. There were no significant differences among treatments.

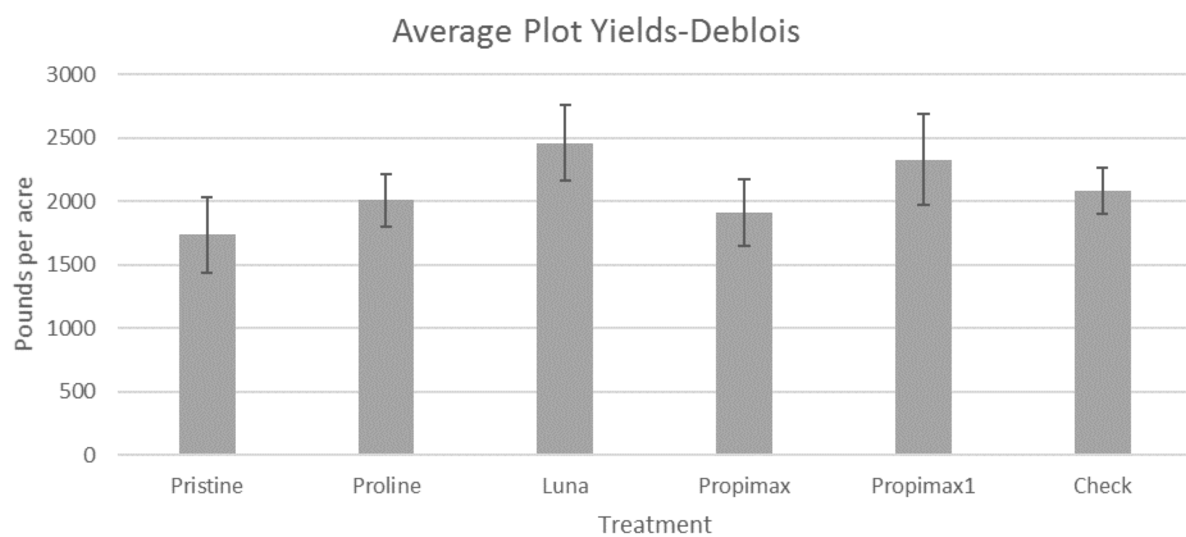



**Figure 7.** Average blueberry yield in pounds per acre for treatments in fungicide trial in Deblois field. Error bars represent standard error of the mean of eight replicates. There were no significant differences among treatments.

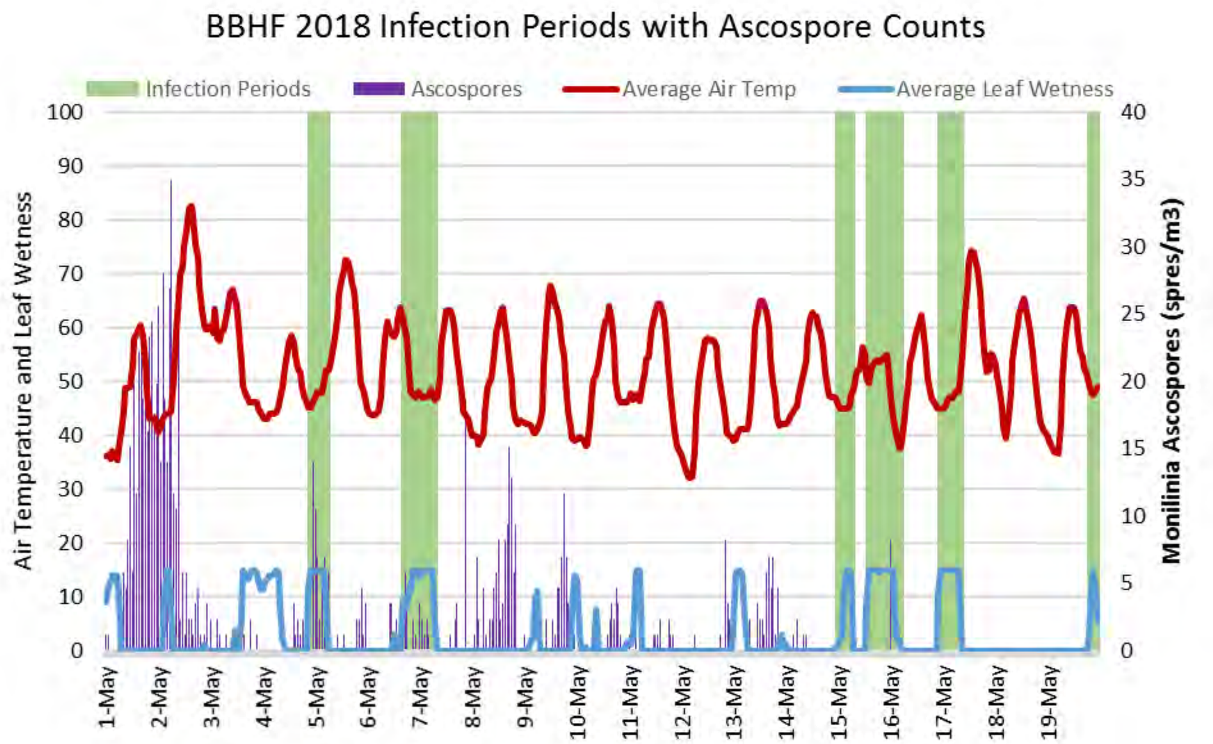



**Figure 8.** *Monilinia* ascospore counts in a crop field at Blueberry Hill Farm in Jonesboro from May 1st to May 20th, 2018. Air temperature (red line) and leaf wetness (blue line), ascospore count (purple bars), and infection periods (green bars) extending whole graph are shown.

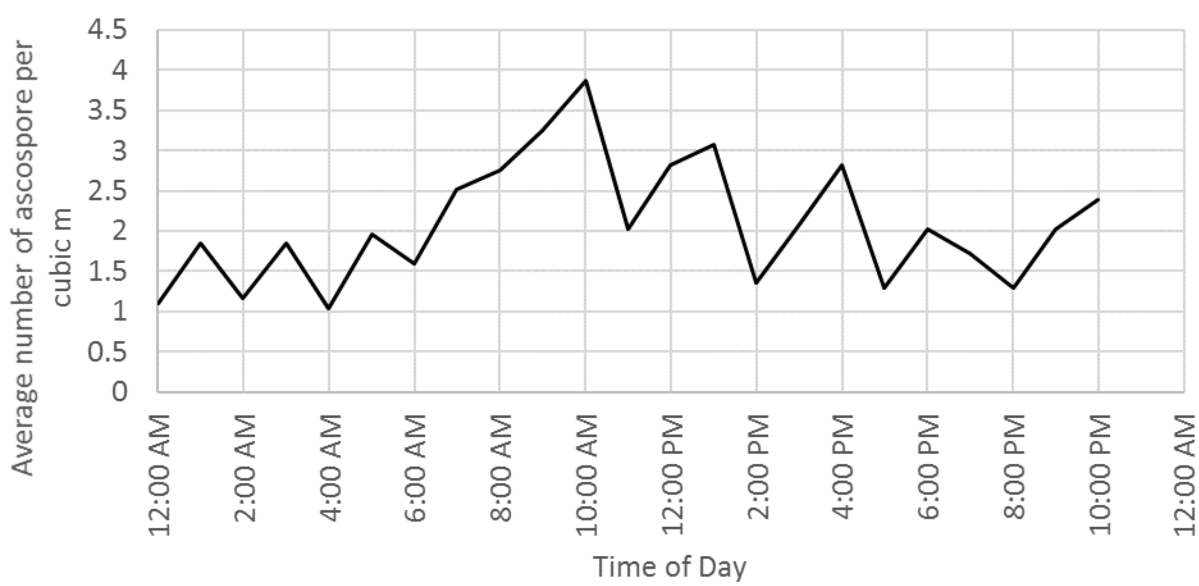



**Figure 9.** Average number of ascospores released per hour from May 1st to May 16th, 2018 in the crop field at Blueberry Hill Farm in Jonesboro.

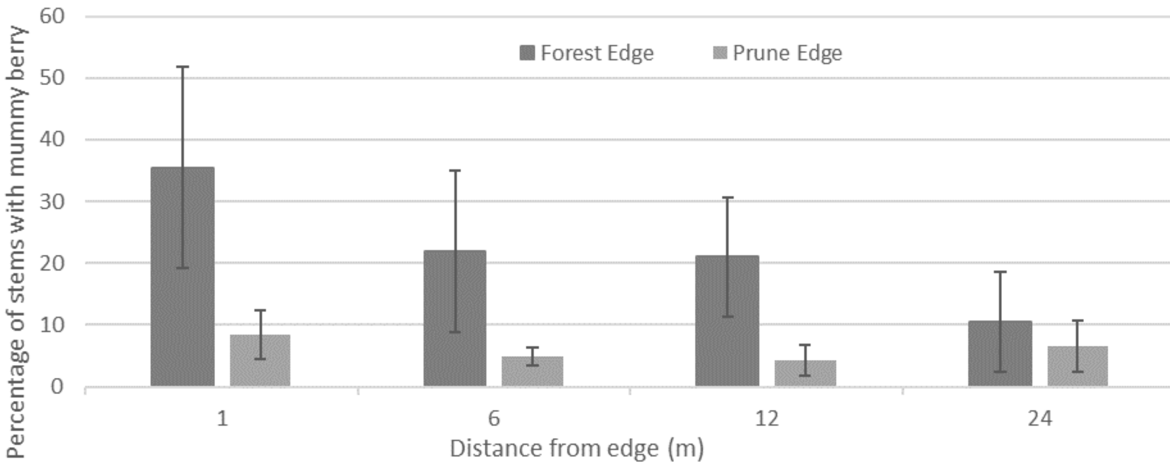



**Figure 10.** Percentage of stems infected with mummy berry along transects placed at 1, 6, 12, and 36m from the crop field edge bordering a forest edge (dark grey bars) or a prune field (light grey bars). There was no significant difference among the transects in the crop/prune edge or forest edge.

## WEED MANAGEMENT

**INVESTIGATORS:** David E. Yarborough, Professor of Horticulture
Jennifer L. D'Appollonio, Assistant Scientist

**6. TITLE:** Fall versus spring application of Zeus Prime XC for weed control in wild blueberry fields, 2016-18 – crop year results.

**METHODS**: Since spring 2016, we have been testing the Group 14 herbicide Zeus Prime XC (carfentrazone + sulfentrazone) for weed control efficacy in wild blueberry. In fall 2016 we set up a trial on Wyman's EO Morse field to compare fall post-pruning versus spring pre-emergence application of Zeus. A Completely Randomized Design was replicated ten times per treatment with 1 $m^2$ plots containing Zeus plus COC 1% v/v applied on 1 November 2016 or 3 May 2017. The maximum rate of Zeus, 15.2 oz/a, was supposed to be applied to the treated plots, but due to a calculation error the actual fall 2016 applied rate was 9.12 oz/a so the same rate was applied to the spring 2017 plots. This rate is between the "low" (7.7 oz/a) and "mid" (12.5 oz/a) rates set by the manufacturer in the 2016 Zeus Prime XC Trial. In 2018 the plots were evaluated for wild blueberry cover, broadleaf weed cover, grass cover and red sorrel (*Rumex acetosella*) cover on 20 July and were harvested by hand-raking on 31 July. Cover data were determined by using the Daubenmire Cover Scale converted to percent; yields were weighed in ounces on an analog scale and converted to lbs/acre. T-tests were performed on cover data for significant treatment differences, Bonferroni adjusted to $\alpha$=0.0167. Yields were compared using a Tukey's test ($\alpha$=0.05).

## RESULTS AND DISCUSSION:

*Wild blueberry and weed cover*

As in the prune year, there were no significant differences in wild blueberry cover, red sorrel cover, other broadleaf weed cover or grass cover in the crop year (Figures 1-2). Wild blueberry cover increased slightly from the prune to crop year (see 2017 WBAC Report #9), with Fall Zeus treatment resulting in the highest crop year cover. However, red sorrel cover had differing responses from July of the prune year compared to July of the crop year. In the untreated check cover fell from approximately 24% in the prune year to 10% in the crop year, and in the Fall 2016 Zeus treatment cover fell from approximately 27% to 14% cover (Figure 1). By contrast, red sorrel cover in the Spring 2017 Zeus treatment increased slightly from 9% in the prune year to 16% in the crop year. This is likely due to red sorrel's growth habit. Red sorrel has basal rosettes that persist dormant over the winter and bolt and flower the next year, as well as one or more new generations that germinate, bolt and flower that following year. The untreated check and Fall Zeus treatments contained overwintering rosettes that were not sprayed in spring 2017, whereas the Spring Zeus treatment was sprayed in May which killed any overwintering rosettes. Therefore, the overwintered plants in the former two treatments were able to grow over the summer of 2017, resulting in more cover in July 2017 than 2018 because the overwintered plants senesced and only the smaller later generation(s) and winter 2017-18 overwintering rosettes contributed to 2018 cover values. The overwintered plants in the Spring Zeus treatment were suppressed or killed, which resulted in lower cover compared to the other treatments in July 2017, but the later generation(s) and winter 2017-18 rosettes remained. We believe this is why cover increased from 2017 to 2018 in the Spring Zeus treatment but decreased in the other treatments, making cover among all three treatments comparable in July 2018. The red sorrel plants in the Spring Zeus treatment were also slightly larger compared to individuals in the other treatments (Photos 1-3). When 2017 photos of the plots were compared to 2018 photos, it appeared as though the suppression/elimination of the overwintered plants in the Spring Zeus treatment resulted in more light, space and other resources for the later generation(s) to utilize, allowing them to grow more relative to the later generation(s) in the other treatments (Photos 3-4).

As in 2017, in 2018 red sorrel was the only broadleaved weed of note present in the trial area, and wild oatgrass (*Danthonia spicata*) was the only grass. Broadleaf weed cover remained constant from July of the prune to crop year at ≤2% overall, while grass cover increased in all treatments from 2017 to 2018 (Figure 2). Although the differences were not significant, the relationships in grass cover remained constant, with the untreated check having the highest cover and spring Zeus the lowest cover in both years. The relative reduction in grass in the Spring Zeus treatment is more likely due to the herbicide than competition with red sorrel. Although wild oatgrass is not listed as being a species controlled by Zeus, Zeus does control some grasses, including some species or genera found in wild blueberry such as common barnyard grass (*Echinochloa crus-galli*), green foxtail (*Setaria viridis*), annual bluegrass (*Poa annua*), red fescue (*Festuca rubra*), fall panicum (*Panicum dichotomiflorum*) and witchgrass (*Panicum capillare*). All of these species are annuals except for red fescue, which is perennial like wild oatgrass, but it does show that Zeus can have action on perennial grasses. As seen in photos 1-3, the wild oatgrass in the plots was much larger than the red sorrel by July 2018 and there was still space available, so the grass wasn't shaded or crowded out by the sorrel.

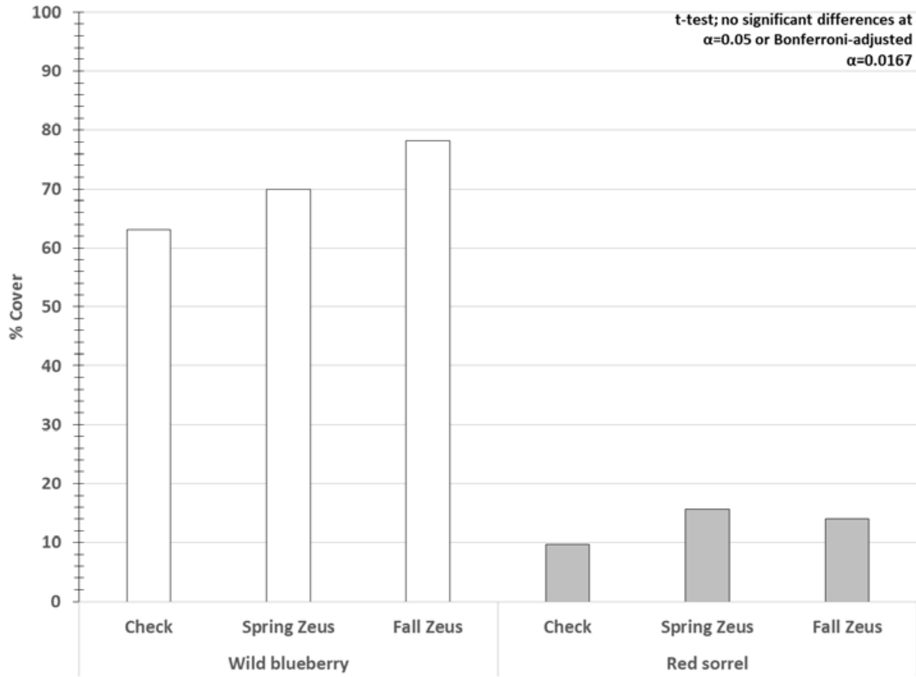



**Figure 1**. Wild blueberry cover and red sorrel cover in the crop year for fall versus spring applied Zeus (α=0.0167).

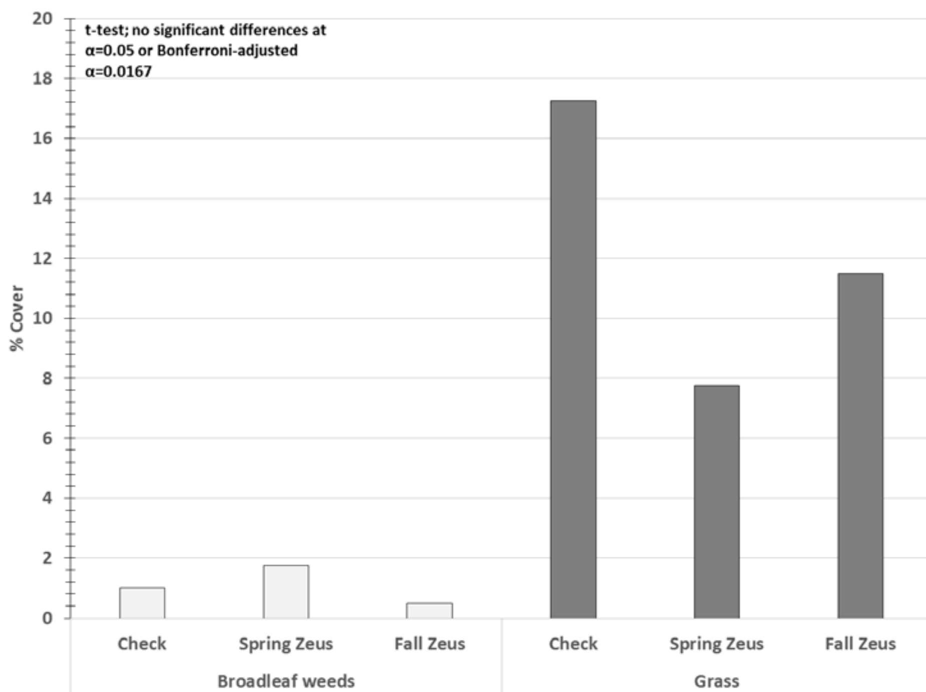



**Figure 2**. Broadleaf weed cover and grass cover in the crop year for fall versus spring applied Zeus (α=0.0167).

**Photo 1**. An untreated check plot in July 2018, with wild oatgrass and small red sorrel plants in the understory (bottom half of plot).

**Photo 2**. The Fall Zeus treatment in July 2018, with small red sorrel plants in lower left of plot.

**Photo 3**. The spring Zeus treatment in July 2018; note red sorrel plants throughout plot. See photo 4 for the same plot in 2017.

**Photo 4**. The Spring Zeus treatment in July 2017. The spring Zeus application almost eliminated red sorrel (note red sorrel outside plot border); the plant in the plot is a new seedling.

*Yield*

There were no significant differences among treatments for yield (Figure 3). The untreated check had the lowest yield, while the Spring and Fall Zeus yields were within 100 lbs/a.

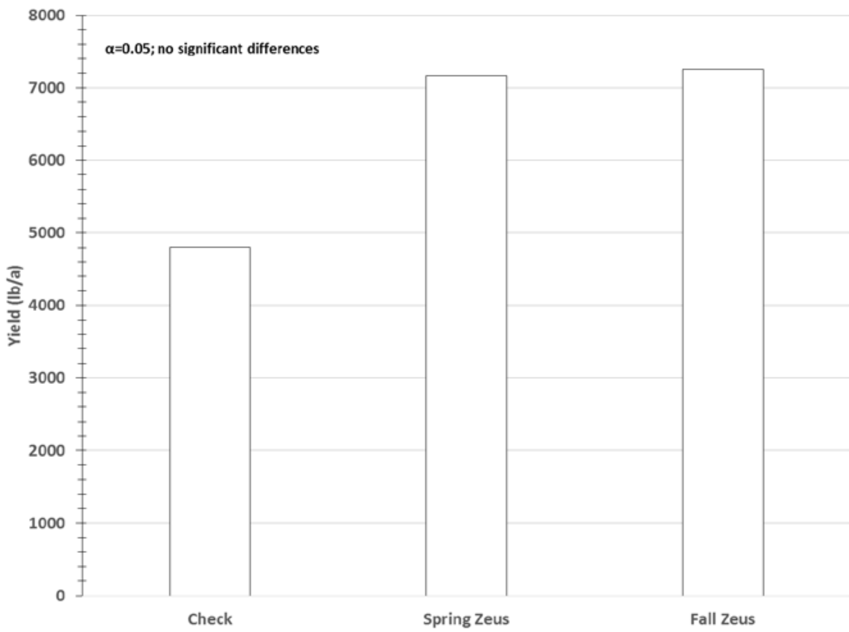



**Figure 3**. Yield in crop year 2018 (α=0.05).

**CONCLUSIONS:** In 2017 we concluded that Zeus application did not result in a reduction in wild blueberry cover or injury to wild blueberry, and the same held true in the crop year. The results of both years indicate that Zeus does appear to suppress wild oatgrass, but crop year results show that the spring application more effectively controlled oatgrass than a fall post-pruning application. No conclusions can be made regarding broadleaf weeds because of the low cover but some conclusions can be made regarding red sorrel. In the prune year, the spring application was more effective than fall post-pruning application. In the crop year, carryover control was slightly better from the fall application and blueberry cover was slightly higher; however, red sorrel cover was within 2% and blueberry cover within 10% of each other so the differences were negligible. Furthermore, yield was not affected by spring versus fall application, but both had increased yield compared to the untreated check. Therefore, either fall or spring Zeus application would be effective, but red sorrel doesn't usually occur alone in wild blueberry fields and control of other species must be taken into account, so the spring application would likely be more effective if grasses are present.

It should be noted again that the Zeus rate applied was between the low and mid-rate recommended by the manufacturer, and that applying the maximum rate of 15.2 oz/a could control red sorrel and other weeds better, but may also result in more injury to wild blueberry. See WBAC Report Nos. 7, 9 and 13 for further discussion of Zeus rates and concomitant crop injury.

**RECOMMENDATIONS**: Repeat using maximum Zeus rate on red sorrel to evaluate a fall versus spring application, especially if the field has grass.

**WEED MANAGEMENT**

**INVESTIGATORS:** David E. Yarborough, Professor of Horticulture
Jennifer L. D'Appollonio, Assistant Scientist

**7. TITLE:** Comparisons of pre-emergence applications of Zeus Prime XC and Rely 280 for weed control in wild blueberry fields – crop year results.

**METHODS**: We have been testing Zeus Prime XC, a Group 14 herbicide with carfentrazone and sulfentrazone as the active ingredients, for its effects on wild blueberry and weeds over the last three years. We currently have only one other Group 14 herbicide registered for wild blueberry which must be applied the year before to prevent blueberry injury, so Zeus has the potential to be a good fit for a resistance management program. We also began testing Rely 280, a glufosinate product in Group 10, for its effects on red sorrel, other weeds and wild blueberry. Unlike glyphosate (Group 9), glufosinate is only a contact herbicide, but we currently do not use any Group 10 herbicides so it also has the potential to be a tool for resistance management.

In 2017 we initiated a trial examining the effects of Zeus and Rely on weeds in general, both alone and in various tank mixes. Part of the trial was to evaluate a new formulation of Velpar DF CU to determine if there were any differences with the new formulation. Three sites were chosen to encompass a range in weeds and soil conditions: Clary Hill, Union; Blueberry Hill Farm, Jonesboro; and Joan's Lot, in Wesley. A partially Randomized Complete Split Block Design was replicated six times on each site with 12'x 60' plots and 5' alleys, some of which were split in half with Velpar L 1 lb/a applied to one half of each block (Figure 1). All treatments were applied pre-emergence on 12, 17 and 18 May 2017 as follows:

1. Untreated check (split with Velpar L);
2. Zeus Prime XC 12.5 oz/a (*Zeus,* split with Velpar L);
3. Zeus Prime XC 12.5 oz/a + Rely 280 29 oz/a + ReQuest AMS 2 pt/a (*Zeus+Rely,* split with Velpar L);
4. Sinbar WDG 2 lb/a + Velpar DF 1 lb/a + diuron 2 lb/a (*Trimix,* no split);
5. Sinbar WDG 2 lb/a + Velpar DF 1 lb/a (*Sinbar+Velpar,* no split);
6. Velpar DF 1 lb/a + Matrix 4 oz/a + diuron 2 lb/a (*Matrix mix,* no split); and
7. Velpar DF 1 lb/a + Rely 29 oz/a + diuron 2 lb/a + ReQuest AMS 2 pt/a (*Rely mix,* no split).

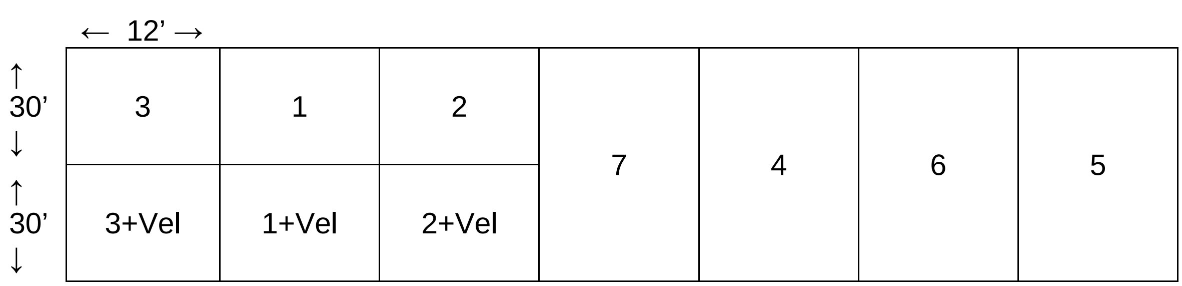



**Figure 1**. Example of a block layout.

In crop year 2018, the plots were evaluated for wild blueberry cover, broadleaf weed cover and grass cover on 13 (Union), 25 (Wesley) and 27 (Jonesboro) July and yields were taken on 8 (Union) and 17 (Jonesboro) August. No yields were taken in Wesley as the field was mowed because it was not going to be harvested by the grower. Cover data were determined by using the Daubenmire Cover Scale converted to percent. Yields were assessed by hand-raking two 1 $m^2$ quadrats per plot, weighing on an analog scale, and converting total ounces to lbs/acre. As in 2017, we found a significant difference in overall broadleaf weed cover among the sites due to site differences (see Table 1 for soil conditions); therefore, the sites were again analyzed individually. All treatments (the Velpar and no-Velpar split main treatments were considered separate treatments for analysis) were compared to each other with using Tukey's tests (α=0.05). T-tests were also performed for significant differences between no-Velpar and Velpar for each main split treatment (α=0.05).

**Table 1**. Differences in soil conditions among the three trial areas: Union, Jonesboro and Wesley.

| | pH | % OM | % sand | % silt | % clay | Soil texture |
|---|---|---|---|---|---|---|
| **Union** | 5.3 | 2.8 | 69 | 25 | 6 | sandy loam |
| **Jonesboro** | 4.7 | 9.8 | 71 | 24 | 5 | sandy loam |
| **Wesley** | 5.0 | 12.8 | 50 | 43 | 7 | loam |

**RESULTS AND DISCUSSION**:

*All-treatment comparisons*

*Crop year wild blueberry cover*

Crop year blueberry cover was comparable among sites, and there were no significant differences among treatments (Figure 2). Furthermore, cover in July of the crop year was similar to July of the prune year for all of the treatments.

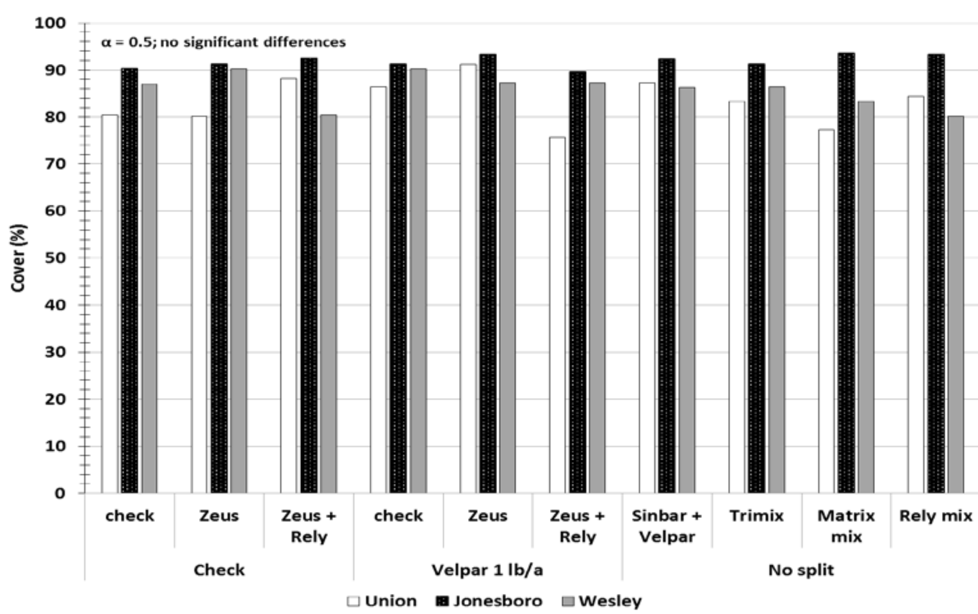



**Figure 2.** Crop year wild blueberry cover in Union, Jonesboro and Wesley following prune year pre-emergence applications of Zeus Prime XC alone and in combination with Rely, split with Velpar L; as well as tank mixes with no split (α=0.05, no significant differences).

*Crop year broadleaf weed cover*

In the crop year, the most common broadleaf weeds at the Union site included goldenrods (*Solidago* spp.), Queen Anne's lace (*Daucus carota*), slender vetch (*Vicia tetrasperma*), clover (*Trifolium* spp.) and arrow-leaved violet (*Viola sagittata*); the goldenrod and clover were also dominant in the prune year. In Jonesboro, the site was dominated primarily by spreading dogbane (*Apocynum androsaemifolium*), and secondarily by black chokeberry (*Aronia melanocarpa*) and bunchberry (*Cornus canadensis*); dogbane and chokeberry were also dominant in the prune year. The most common weeds at the Wesley site included St. Johnswort (*Hypericum perforatum*), northern bedstraw (*Galium boreale*), violet (*Viola* spp.), cow vetch (*Vicia cracca*), blue toadflax (*Nuttallanthus canadensis*) and red sorrel (*Rumex acetosella*); all except blue toadflax were also dominant in the prune year (in the prune year, *G. boreale* was misidentified as *G. mollugo*). Virginia creeper (*Parthenocissus quinquefolia*) was noted in the prune year creeping out from an old cellar hole next to the Wesley trial area but is not a common problem in wild blueberry fields. Although *Galium* species are more commonly seen in blueberry fields, the northern bedstraw at the Wesley site seems to also have originated from the cellar hole. It was probably planted at the site because it is edible, has historically been used in landscaping, and in New England usually occurs naturally in moister soils with neutral to high pH (see Table 1). Both species had spread across approximately half of the trial area and showed no carryover control effect in any treatment (Photos 1-2). Virginia creeper is a vigorous creeper/climber, and the leaves sprayed in the plots were probably rooted outside the trial area, so the vines either recovered from the herbicides or sent out new shoots into the trial area. Northern bedstraw is a rhizomatous perennial, and it likely had a similar response to herbicide as Virginia creeper.

**Photo 1**. The Wesley site, from the corner of the trial area adjacent to the cellar hole; note the continuous canopy of Virginia creeper in the foreground.

**Photo 2.** A plot in the Trimix treatment, looking across the trial area; the greenish yellow plants in the foreground extending to the tall green goldenrods in the background are an almost continuous canopy of northern bedstraw.

In Union, Zeus alone resulted in higher crop year broadleaf weed cover than the check; the only Zeus treatment significantly lower than the check was Zeus+Velpar at ~3% cover (Figure 3). The Zeus+Velpar treatment was also the only treatment in general significantly lower than the check, but Sinbar+Velpar (~4% cover), Zeus+Rely with Velpar, and Rely mix (both ~9%) carryover control was almost as good. The Jonesboro site had the least overall broadleaf weed cover among the sites, and there were no significant differences among treatments. Zeus alone and the three Velpar treatments resulted in the lowest crop year cover. In Wesley, the Rely mix resulted in the highest crop year broadleaf weed cover, but it was only significantly higher than the Zeus+Velpar treatment. At both Union and Wesley, Zeus+Velpar had the lowest broadleaf weed cover, and Zeus+Rely with Velpar was comparable, but at the Wesley site Rely mix and Sinbar+Velpar had the highest and second highest cover instead of the lowest and second lowest, respectively. The soil pH was comparable between sites, and soil texture was somewhat heavier but organic matter was considerably higher in Wesley. Soil texture and organic matter appear to be what drove the difference in broadleaf weed response (Table 1; see Conclusions).

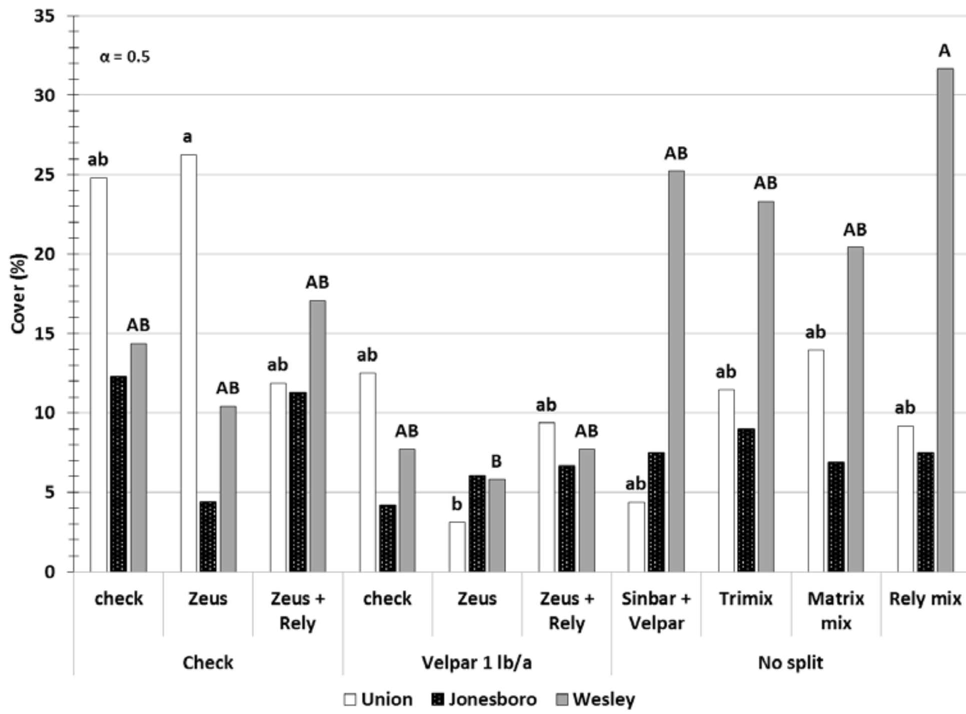



**Figure 3.** Crop year broadleaf weed cover in Union, Jonesboro and Wesley following prune year pre-emergence applications of Zeus Prime XC alone and in combination with Rely, split with Velpar L; as well as tank mixes with no split (only significant differences at α=0.05 denoted by different letters).

*Crop year grass cover*

In the crop year as in the prune year, there was 3% or less grass cover at the Union site. The only species found in multiple plots were colonial bentgrass (*Agrostis capillaris*), quackgrass (*Elymus repens*) and Canada bluegrass (*Poa compressa*); and only the bluegrass was dominant in the prune year. Most grass cover was found at the Jonesboro site, and was almost exclusively wild oatgrass (*Danthonia spicata*) with a few plots containing colonial bentgrass. In the prune year, wild oatgrass, colonial bentgrass and witchgrass were the dominant grasses. At Wesley, grass cover was also low; the predominant grass was quackgrass and second most common grass was colonial bentgrass. In the prune year, the dominant grass was redtop (*Agrostis gigantea*); the grass was still around the cellar hole in the crop year, but was not in the trial area.

As previously mentioned, grass cover was low in Wesley and very low in Union, and there were no significant differences among treatments (Figure 4). Treatment differences in Jonesboro were driven by wild oatgrass. The Zeus treatment resulted in the highest grass cover and was similar to the check. Grass cover in the Zeus with Velpar and Zeus+Rely with Velpar treatments were significantly lower compared to Zeus alone, as were all of the no split treatments, but only Sinbar+Velpar, Trimix and Rely mix were significantly lower than the check. The split with Velpar and no split treatments were not different from each other and they all contained a combination of Velpar, Sinbar and/or diuron.

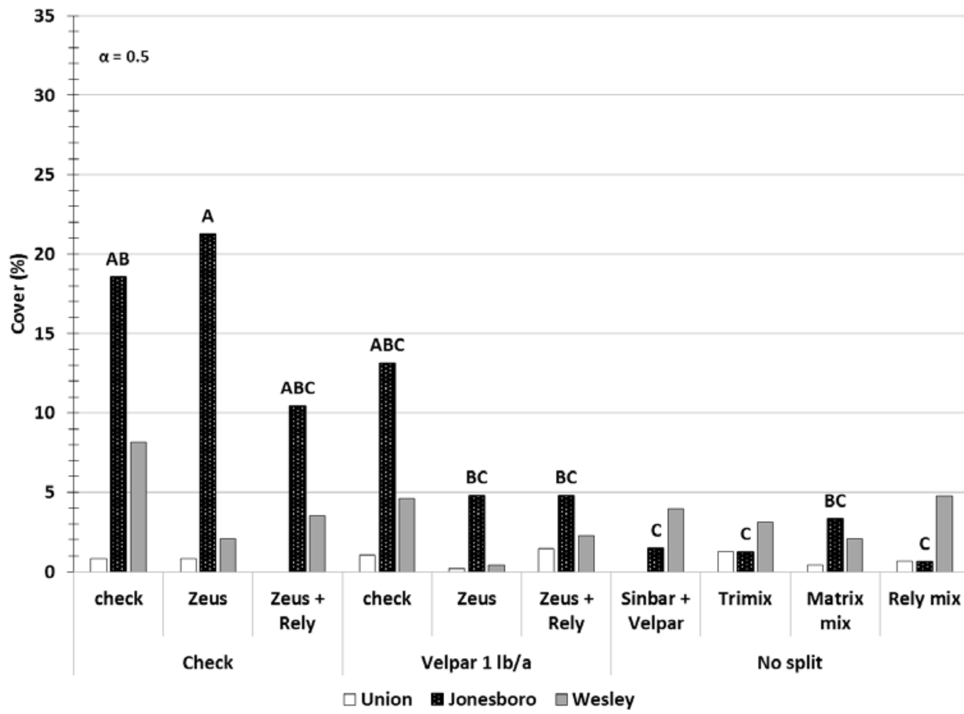



**Figure 4.** Crop year grass cover in Union, Jonesboro and Wesley following prune year pre-emergence applications of Zeus Prime XC alone and in combination with Rely, split with Velpar L; as well as tank mixes with no split (only significant differences at α=0.05 denoted by different letters).

<u>*Yield*</u>

Only two sites could be harvested for yield comparisons. When we arrived at the Wesley site to harvest the plots, we discovered that a company worker had bush-hogged our trial. Therefore, only the results of yields taken in Union and Jonesboro are presented here.

There were no significant differences among treatments at either site, but yields in Jonesboro were higher than those in Union for all treatments (Figure 5). Figure 2 shows that blueberry cover was slightly higher in Jonesboro than Union, but the vines were taller, more robust and more fecund overall (Photos 3-4). The Jonesboro site also had three hives/acre for pollination versus 0.75 hives/acre in Union.

**Photo 3.** Blueberry vines in the Zeus+Rely treatment at the Jonesboro site.

**Photo 4**. Blueberry vines in the Zeus+Rely treatment at the Union site.

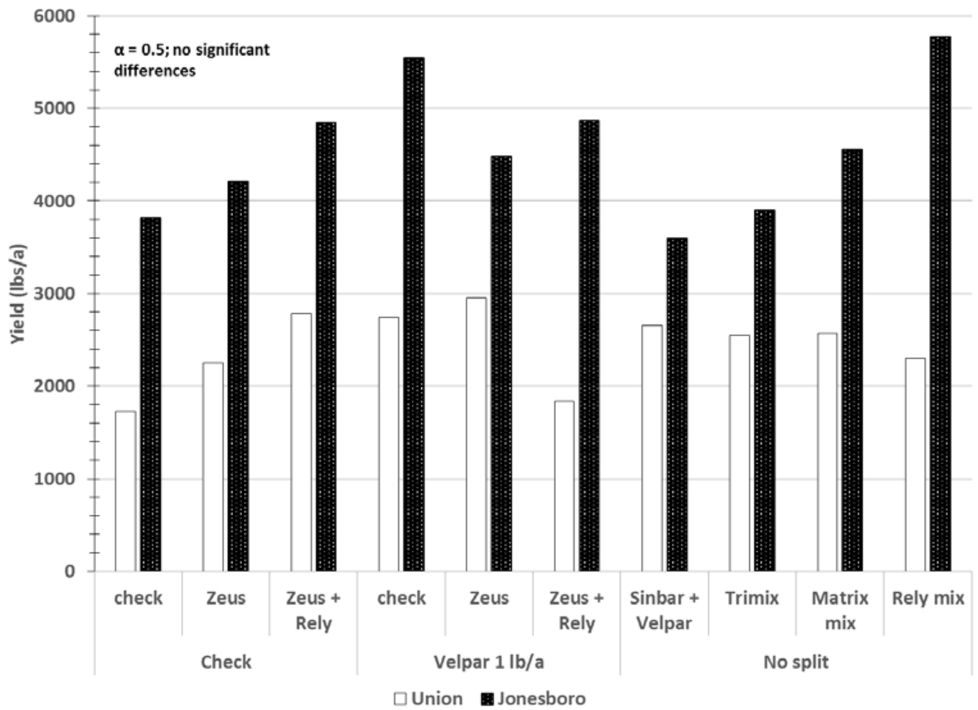



**Figure 5.** Yields in Union and Jonesboro following prune year pre-emergence applications of Zeus Prime XC alone and in combination with Rely, split with Velpar L; as well as tank mixes with no split (α=0.05; no significant differences).

*T-tests*

As in the prune year, T-tests were performed for no Velpar versus Velpar within each split treatment and only the significant results are presented here. There were no significant differences in blueberry cover for any site in the crop year.

Last year all three sites had significant differences in broadleaf weed cover. In the crop year in Union, Zeus+Velpar had significantly fewer broadleaf weeds than Zeus alone (Figure 6; last year there was no difference). In Jonesboro, Velpar had significantly fewer weeds than the untreated check in the crop year as in the prune year. Overall grass cover was very low in Union and Wesley, but there was a significant reduction in grasses for Zeus+Velpar versus Zeus alone at Wesley (Figure 7). In Jonesboro grass cover was highest in the Zeus treatment and was significantly lowered when Velpar was added. In the prune year, there were no significant differences in grass cover at any of the sites.

Finally, yields were not significantly different in Jonesboro with the addition of Velpar, but in Union yield was significantly reduced when Velpar was added to Zeus+Rely (Figure 8). By contrast, yield was not increased when Velpar was added to the untreated check or Zeus alone.

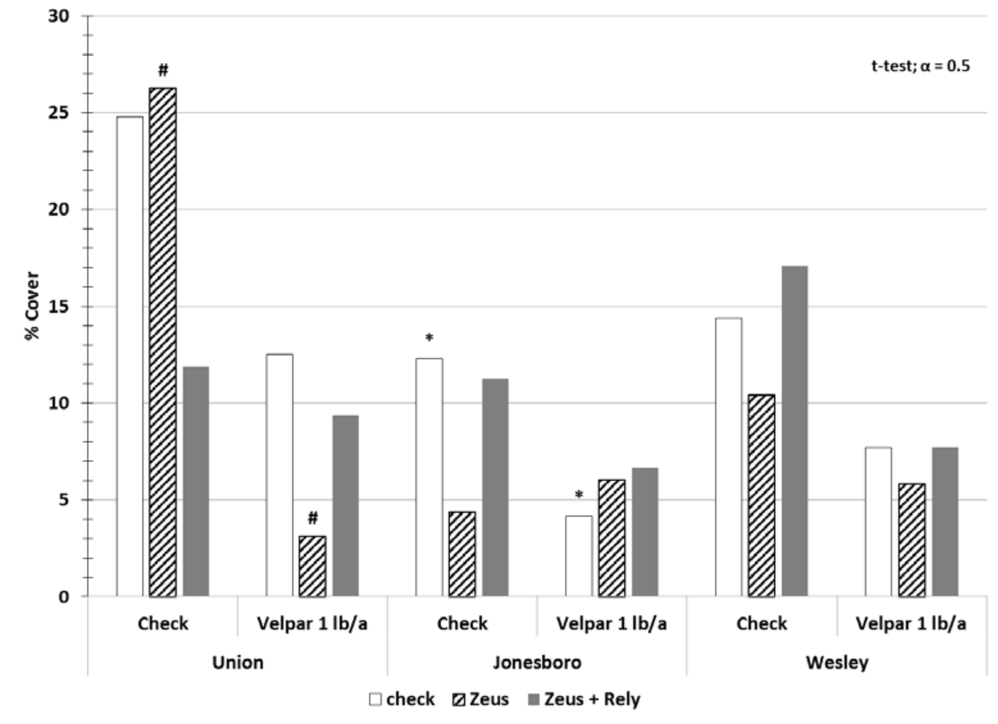



**Figure 6.** Comparison of broadleaf weed carryover control in the split treatments with and without Velpar in the crop year (α=0.05).

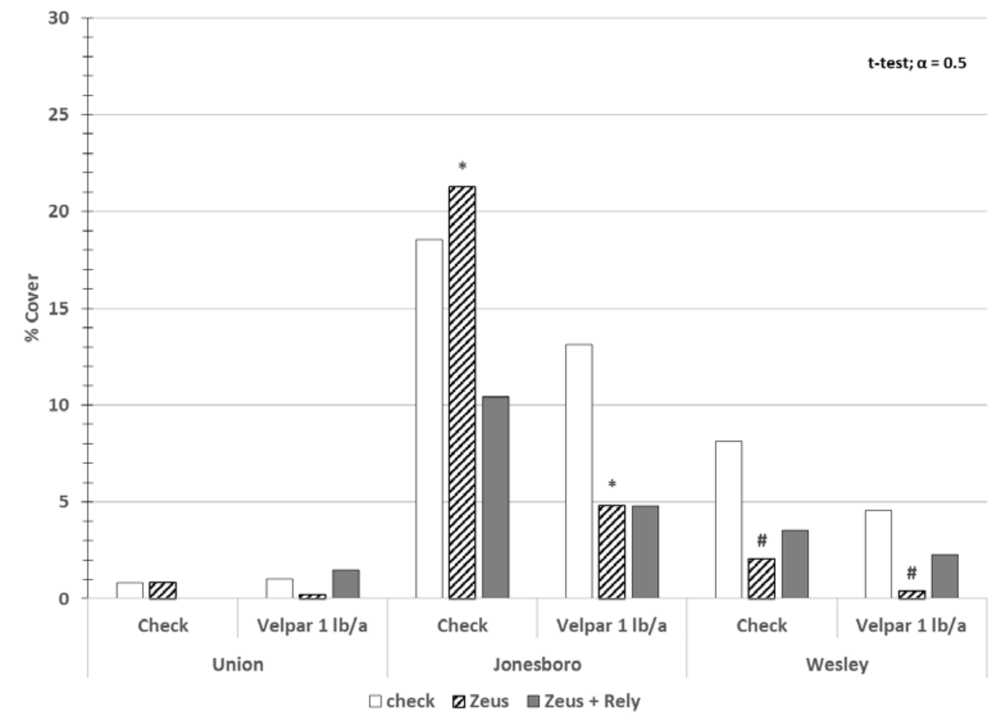



**Figure 7.** Comparison of grass carryover control in the split treatments with and without Velpar in the crop year (α=0.05).

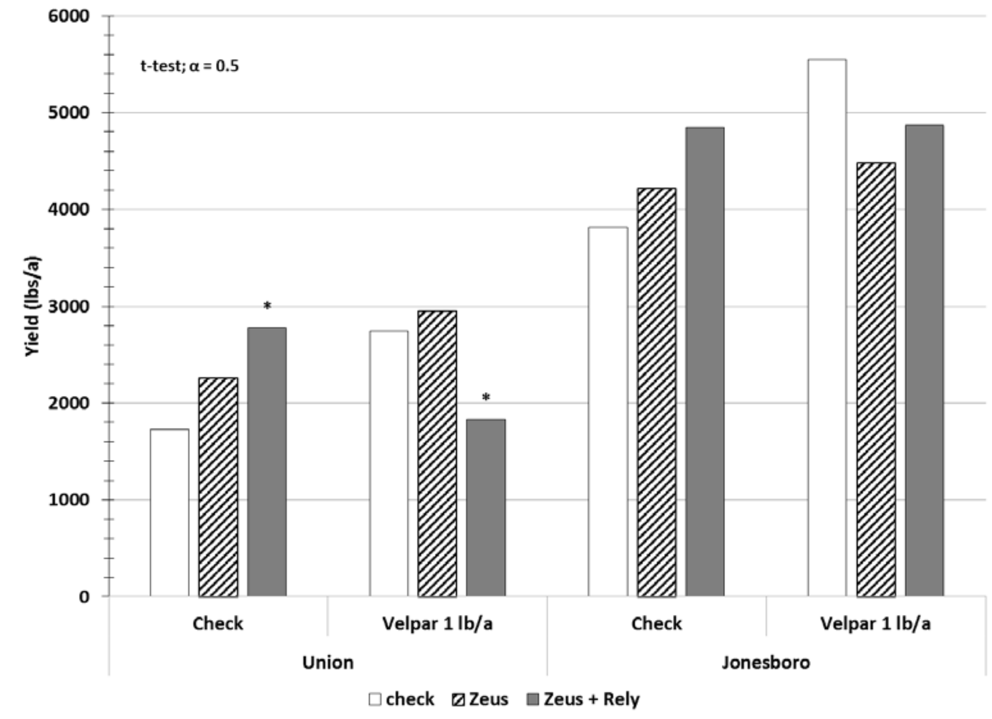



**Figure 8.** Comparison of yields in the split treatments with and without Velpar (α=0.05).

**CONCLUSIONS**: In Jonesboro, several grass responses to herbicide were the reciprocal of broadleaf weed responses. For example, broadleaf weeds were reduced but not significantly so in the Zeus treatment compared to the check, but grass cover increased. Also, adding Zeus or Zeus+Rely slightly increased broadleaf weeds compared to Velpar alone, but grass cover was not reduced significantly. In this trial, there appears there may be a correlation between broadleaf weed cover and grass cover in Jonesboro (Figures 2-3). In the split treatments without Velpar ("check"), Zeus had the lowest broadleaf weed cover and highest grass cover. In the split with Velpar ("Velpar 1 lb/a"), broadleaf weed cover was lowest in Velpar alone but grass cover was highest. Finally, in the non-split treatments ("no split"), broadleaf weed cover was lowest in the Matrix mix but grass cover was highest. We posit that this was because Jonesboro had the lowest weed diversity of the sites and therefore correlating responses of weeds were easier to detect. Two of the four dominant weed species, spreading dogbane and black chokeberry, were found only at this site, and the other two (bunchberry and wild oatgrass) were much more common in Jonesboro than at the other sites.

Last year we hypothesized that the Zeus rate may be too high on sandier sites, because the heavier soil in Wesley tied up some of the Zeus and phytotoxicity was lower but broadleaf weed control was comparable. The crop year results (Figure 3) don't necessarily bear this out. In the four Zeus/Zeus+Rely treatments, Jonesboro had equal or slightly better carryover control and Union had worse carryover control. Both Jonesboro and Union are sandier than Wesley and their soil textures are almost identical (Table 1). However, pH in Union is more than half a unit higher and organic matter is over 3x lower. The Zeus label states that "Zeus Prime XC adsorbs to the clay and organic matter fractions of soils; effectively limiting the amount of active ingredient immediately available to control weeds…soil pH also exerts a dramatic effect on Zeus

Prime XC availability in the soil solution. As soil pH increases, Zeus Prime XC availability increases" (FMC 2014). Jonesboro had the lowest soil pH and Union the highest, and Union had the lowest % organic matter and Wesley the highest. According to the label, Union should have consistently had the least weeds in the Zeus treatments but it did not. If soil pH was the main driver, Jonesboro should have had the most broadleaf weeds but it had the least, indicating that organic matter is likely a more important component of Zeus efficacy than soil pH. Soil texture is likely an important component as well, since heavier soils have more cation exchange and can also bind to herbicides. The organic matter in Jonesboro may have tied up some Zeus so that it wasn't all immediately available, but released over time via leaching and was more available in the mineral soil layer because of its sandier composition compared to Wesley. Wesley had the finest soil texture and the most organic matter; the Zeus released over time from the organic layer was more likely to be tied up in the siltier mineral layer which resulted in less carryover control. Union had comparable soil to Jonesboro but little organic matter, so Zeus on this site may have been more immediately available but leached out of the soil more quickly, leading to reduced carryover control.

Also, in the prune year we concluded that this trial confirmed that soil composition can result in marked differences in weed responses when using soil applied herbicides. Not only do the crop year Zeus results bear this out, but the crop year results for carryover broadleaf weed control in the four non-split treatments also bear this out. All four treatments contained Velpar DF, three contained diuron, and two contained Sinbar WDG. In the prune year, the heavier soil in Wesley prompted a release of broadleaf weeds in the four non-split treatments instead of a reduction, with the exception of the Matrix mix. In the crop year, all four treatments had higher broadleaf weed cover than the untreated check and cover was higher in Wesley compared to the sandier Jonesboro and Union sites. Last year we concluded that on sites with heavier soil, using Sinbar, Velpar and diuron could increase broadleaf weed cover when combined with a contact herbicide such as Rely which would only control those weeds that were emerged early in the season. The crop year results confirm this, as the Rely mix at Wesley had the highest broadleaf weed cover of all treatments at all sites.

Conclusions about carryover grass control could not be made for Wesley or Union due to low overall cover. In Jonesboro, long-term grass control was effective (although not necessarily significantly so) in all four non-split treatments and by Zeus and Zeus+Rely when combined with Velpar. Zeus+Rely was less effective without Velpar and Zeus alone actually released grasses, indicating that on sites with a grass issue, Zeus and/or Rely should not be applied without an additional herbicide for grass control.

In the prune year we highlighted visual observations of weed responses to Zeus and/or Rely; here we compare the dominant weeds in the crop year to their responses in the prune year. Last year Zeus reduced northern bedstraw, but it did not have any carryover effect into the crop year. There were several weeds Zeus did not control in the prune year, including colonial bentgrass, redtop, St. Johnswort, red clover, goldenrods and violets. All of these species were also dominant in the crop year, with the exception of redtop, which was still adjacent to the trial area but no longer in it. Bluegrass, wild oatgrass, spreading dogbane and cow vetch had varying responses in the prune year; in the crop year the latter three species were dominant, but bluegrass was only found in one plot. When Rely was added to Zeus in the prune year, control of bunchberry, blue toadflax, red sorrel and wild oatgrass was improved. In the crop year, all except blue toadflax were found in most plots, as were the goldenrods, violets, clovers, vetch, spreading dogbane, St. Johnswort and colonial bentgrass recorded in the Zeus only plots.

Finally, the Rely mix controlled wild oatgrass, quackgrass, blue toadflax and Canada goldenrod over the prune year growing season, but in the crop year, quackgrass cover was very low and only in Wesley. Blue toadflax and wild oatgrass persisted in low numbers at multiple sites, and Canada goldenrod was not present. As stated in the prune year conclusions, the visual observations reveal that a follow-up post-emergence herbicide or mid- to late-season contact herbicide application may be needed for continued weed control when applying Zeus and/or Rely pre-emergence.

None of the treatments adversely affected wild blueberry into the crop year. The difference in overall yield for Union versus Jonesboro appears driven by a couple of factors. Table 1 shows that pH was higher and organic matter much lower in Union. The higher pH is more favorable for weeds, and was reflected by both the higher overall broadleaf weed cover (Figure 3) and diversity recorded at the Union site. The Union site was managed less intensively than the Jonesboro site and so had shorter, weaker blueberry vines (Photos 3-4). Organic matter was also much higher in Jonesboro, which is favorable for wild blueberry. However, we believe the lower yields in Union to be attributed mostly to the lack of pollinations, as only 0.75 hives per acre were used in Union versus Jonesboro which used 3 hives per acre.

**RECOMMENDATIONS**: Since there was phytotoxicity and delay in emergence of wild blueberries observed with Spring Zeus treatments, evaluations of fall applications are currently underway to determine if they are as effective in controlling weeds with less or no injury to the wild blueberry plants. Last year we recommended that we also look at lower rates on sandy sites, both fall and spring on the same site, but pursuant to the crop year results the recommendation has been amended to look at the effect of different rates on weeds on sites with comparable pH but different soil textures and high versus low organic matter.

**LITERATURE CITED:**

FMC. 2014. Zeus Prime XC Herbicide Label, Label Code 02-26-14. FMC Corporation, Philadelphia, PA. 8 pp.

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**WEED MANAGEMENT**

**INVESTIGATORS:** David E. Yarborough, Professor of Horticulture
Jennifer L. D’Appollonio, Assistant Scientist

**8. TITLE:** Application timings of Rely 280 and Chateau for red sorrel control in wild blueberry fields, 2017-19.

**METHODS:** For the past several years, we have been investigating different rates and timings of various herbicides for efficacy in controlling red sorrel (*Rumex acetosella*) in wild blueberry. In previous research targeting this weed, Chateau (flumioxazin) was most effective of the herbicides tested in controlling red sorrel over the entire crop cycle. In this follow-up study, Chateau and Rely 280 (glufosinate), a burn-down contact herbicide, were applied at the same rate but different timings and crop cycles in 2017 to further determine efficacy on red sorrel.

The treatments were as follows:

***2017 Non-crop/2018 Crop (C18)***

1. Untreated check (*C18 check*);
2. Rely 280 29 oz/a **spring pre-emergence** (*C18 Spring Rely*);
3. Rely 280 29 oz/a **fall of non-crop year** (*C18 Fall Rely*);
4. Rely 280 29 oz/a + Velpar 1 lb/a **spring pre-emergence** (*C18 Rely+Velpar*);
5. Chateau 12 oz/a **fall of non-crop year** (*C18 Chateau*);

***2017 Crop/2018 Non-crop/2019 Crop (P18)***

6. Untreated check (*P18 check*);
7. Rely 280 29 oz/a **fall post-pruning** (*P18 Rely*); and
8. Chateau 12 oz/a **fall post-pruning** (*P18 Chateau*).

Table 1 shows a timeline of all past and/or upcoming spray applications, evaluations and harvests over the course of the trial. The spring treatments were sprayed on 3 May 2017, and the fall treatments were sprayed on 15 November 2017. For the 2018 Crop plots, wild blueberry cover, red sorrel cover, broadleaf weed cover and grass cover were assessed on 20 July 2018 and were harvested by hand-raking on 1 August. Phytotoxicity data were not collected because the herbicides had been applied the previous year, and there was no visible injury to wild blueberry or red sorrel. The 2018 Non-crop plots were assessed mid-season on 29 June 2018 for wild blueberry cover and phytotoxicity, red sorrel cover and phytotoxicity, broadleaf weed cover and grass cover. Cover data were determined by using the Daubenmire Cover Scale converted to percent; phytotoxicity was assessed by using a scale of 0-10 (0=no damage, 10=100% damaged/dead) converted to percent. Yields were weighed in ounces on an analog scale and converted to lbs/acre. Because of the 2017 Crop/2018 Non-crop treatment fall timing, and because Rely is a contact-only herbicide with no residual action and was applied after mowing, one mid-season evaluation was performed on 29 June 2018. All treatments were compared to each other within each cycle using Tukey's tests ($\alpha$=0.05), as were yields in the 2018 Crop cycle. T-tests ($\alpha$=0.05) were also conducted to compare: Rely spring pre-emergence versus fall of non-crop year, in the crop year (C18 Spring Rely vs C18 Fall Rely); Rely spring pre-emergence versus fall post-pruning, in the non-crop year (C18 Spring Rely, 2017 data vs P18 Fall Rely; see Table 1); Rely fall of non-crop year versus fall post-pruning (C18 Fall Rely vs P18 Fall Rely); and Chateau fall of non-crop year versus fall post-pruning (C18 Chateau vs P18 Chateau).

**Table 1.** Timeline for trial spray applications, evaluations and harvests over the 2017-2019 trial period.

| **2017** | | | | | | | | | **2018** | | | | | | **2019** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **J-A** | **M** | **J** | **J** | **A** | **S** | **O** | **N** | **D** | **J-A** | **M** | **J** | **J** | **A** | **S-D** | **J-A** | **M** | **J** | **J** | **A** | **S-D** |
| ↗ | ↑ | | ↑ | | | ↑ | | | | | ↑ | ↑ | ↖ | | | | ↑ | | ↑ | |
| **C18 S appl** | **C18 eval 1** | | **C18 eval 2** | | | **C18, P18 F appl** | | | | **P18 eval** | | **C18 eval** | **C18 har-vest** | | | **P18 eval** | | **P18 harvest** | | |

## RESULTS AND DISCUSSION:

*All-treatment comparisons – 2018 Crop (C18)*

There were no significant differences among treatments for wild blueberry cover or red sorrel cover (Figure 1). Although not significant, Rely applied in the fall of the non-crop year resulted in lower blueberry cover (56%) than either spring pre-emergence Rely alone (80%) or with Velpar (77%), and was lower than the untreated check (76%). Fall Rely also resulted in the highest crop year red sorrel cover of all treatments, only slightly lower than the untreated check, while Chateau resulted in the lowest crop year red sorrel cover. Although both treatments were applied pre-emergence in the spring, Spring Rely (18%) had less red sorrel than Rely+Velpar (29%). The factors contributing to this are unclear; blueberry cover was within 3% of each other, and both treatments had approximately 2% other broadleaf weed cover and <2% grass cover, so red sorrel wasn't released by control of other weeds.

Wild oatgrass (*Danthonia spicata*) was the only grass present, and grass cover was minimal in the crop year (Figure 2). Overall other broadleaf weed cover was <10% overall; there were no significant differences among treatments, but Chateau had the highest cover at almost 3x the other treatments (Figure 2). It should be noted that Chateau and Spring Rely had almost identical red sorrel cover, but Spring Rely had almost 15% more blueberry cover and 4x lower broadleaf weed cover. This is likely because Chateau was applied the previous fall, while the Spring Rely treatment burned down spring-emerged weeds such as spreading dogbane (*Apocynum androsaemifolium*), cow vetch (*Vicia cracca*) and black sedge (*Carex nigra*), which also allowed more resources for early season blueberry growth.

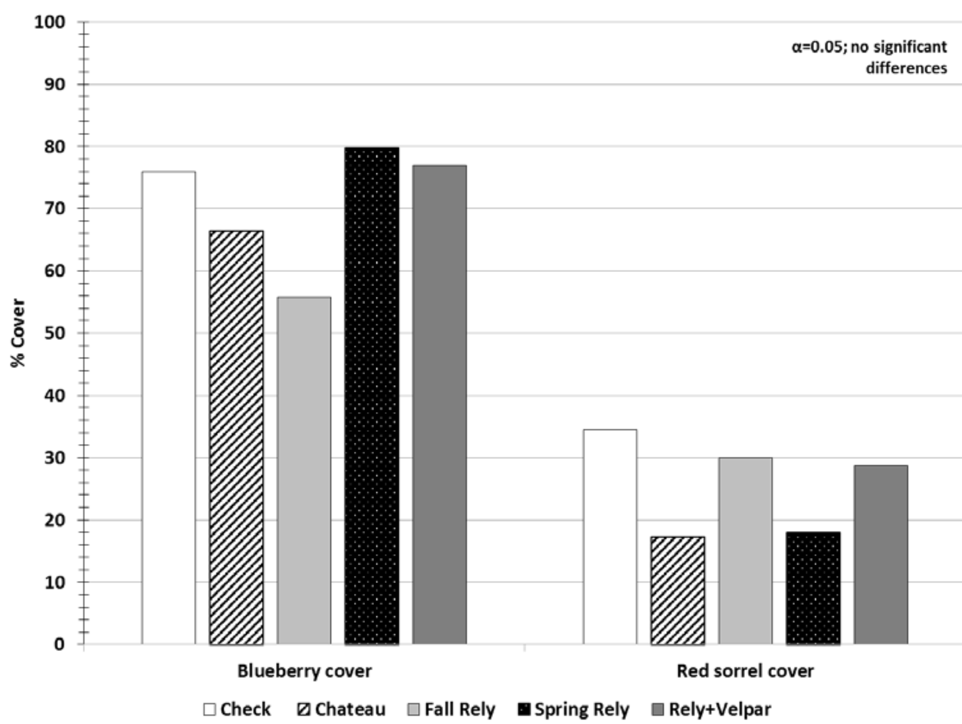


**Figure 1.** Wild blueberry and red sorrel cover in the 2018 crop year for Chateau and Rely (α=0.05; no significant differences).

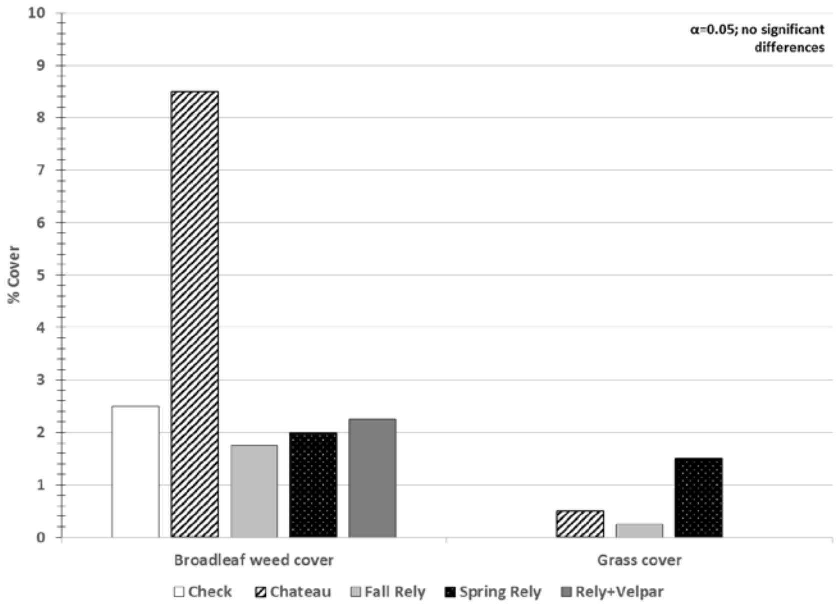


**Figure 2.** Broadleaf weed and grass cover in the 2018 crop year for Chateau and Rely (α=0.05; no significant differences).

*Yield – 2018 Crop (C18)*

Yields ranged from 3,022 lbs/a in the Fall Rely treatment to 5,716 lbs/a in the Spring Rely treatment, but there were no significant differences (Figure 3). Chateau, Fall Rely and Rely+Velpar reduced yield compared to the check, while Spring Rely was slightly higher. It is unclear as to why yield was reduced in Rely+Velpar; Chateau and Fall Rely were both applied in fall of the non-crop year, so they may have affected flowering in the crop year. Chateau is systemic and is taken up by the blueberry plants, but Rely is contact only, so we can only posit that although the flower buds were dormant at the time of application, Rely may have physically damaged them.

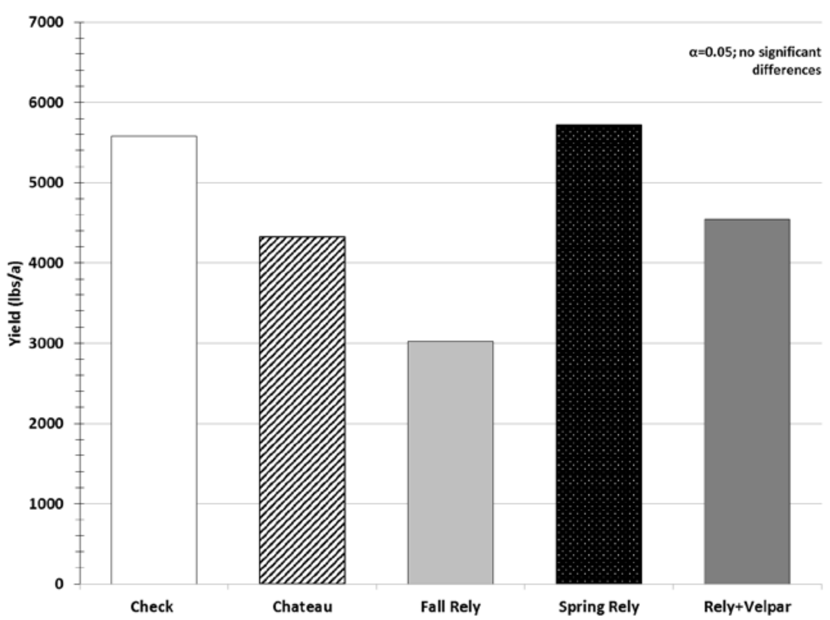


**Figure 3**. Wild blueberry yield in crop year 2018 for non-crop year Chateau and Rely treatments (α=0.05; no significant differences).

*All-treatment comparisons – 2018 Non-crop (P18)*

There were no significant differences among treatments for wild blueberry cover or phytotoxicity (Figure 4). In contrast to the Crop 2018 plots, where Fall Rely had lower blueberry cover than the Chateau, Fall Rely had higher cover than the Chateau treatment in the Non-crop 2018 plots. Fall Rely was also was the only treatment with phytotoxicity, but at 3% injury was negligible. There were also no significant differences in red sorrel cover or phytotoxicity (Figure 5). It is interesting to note that in both the P18 and C18 plots, Fall Rely had more red sorrel than Chateau, and % cover was almost identical between cycles (Figures 1, 5. Chateau: 17% C18, 19% P18; Fall Rely: 30% C18, 28% P18). This indicates that regardless of whether Chateau and Rely are applied in the fall of the non-crop year or post-pruning in the crop year, red sorrel response was consistent. Fall Rely application resulted in negligible injury to red sorrel, and Chateau produced less than 15% injury to red sorrel.

There were no significant differences among treatments for other broadleaf weeds or grass cover (Figure 6). Fall Rely resulted in the least grass but most broadleaf weeds. The non-significant difference in grass cover appears driven by fineleaf sheep fescue (*Festuca filiformis*), which was present in more plots and in denser cover in the check than the treatments. The difference in broadleaf weed cover appears driven by the specific weeds present; most were biennials/perennials such as raspberry (*Rubus* spp.), spreading dogbane, rough cinquefoil (*Potentilla norvegica*) and dwarf cinquefoil (*Potentilla canadensis*) which can regenerate from root reserves after treatment with a contact herbicide. Chateau was most effective on broadleaf weeds in general, which was to be expected as it is a systemic herbicide with residual action.

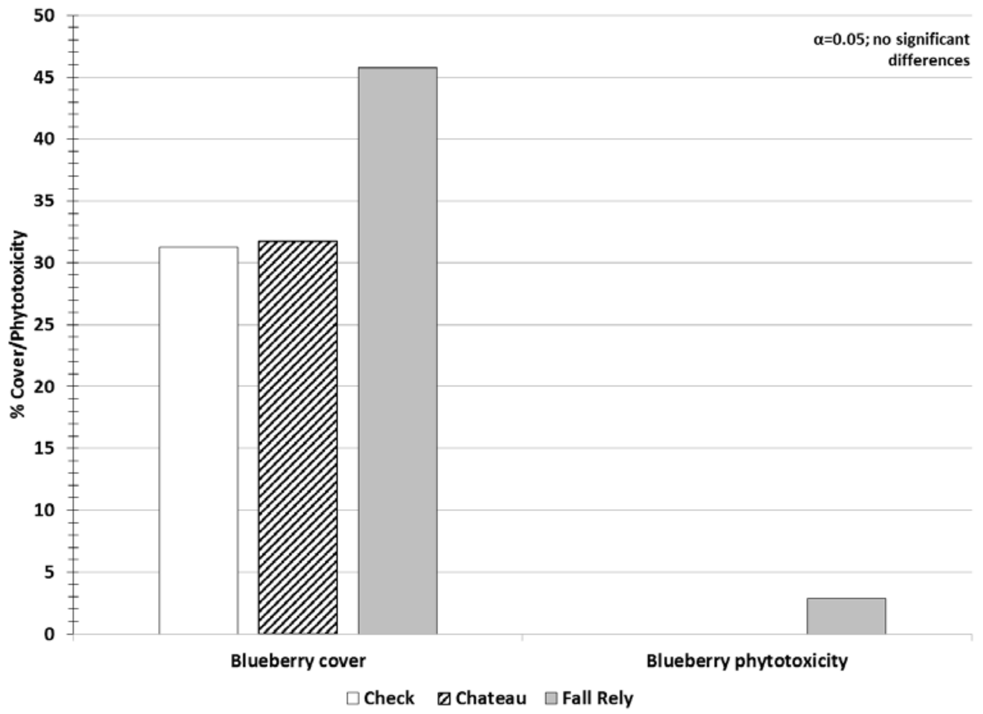


**Figure 4.** Wild blueberry cover and phytotoxicity in non-crop year 2018 for post-pruning fall application of Chateau and Rely (α=0.05; no significant differences).

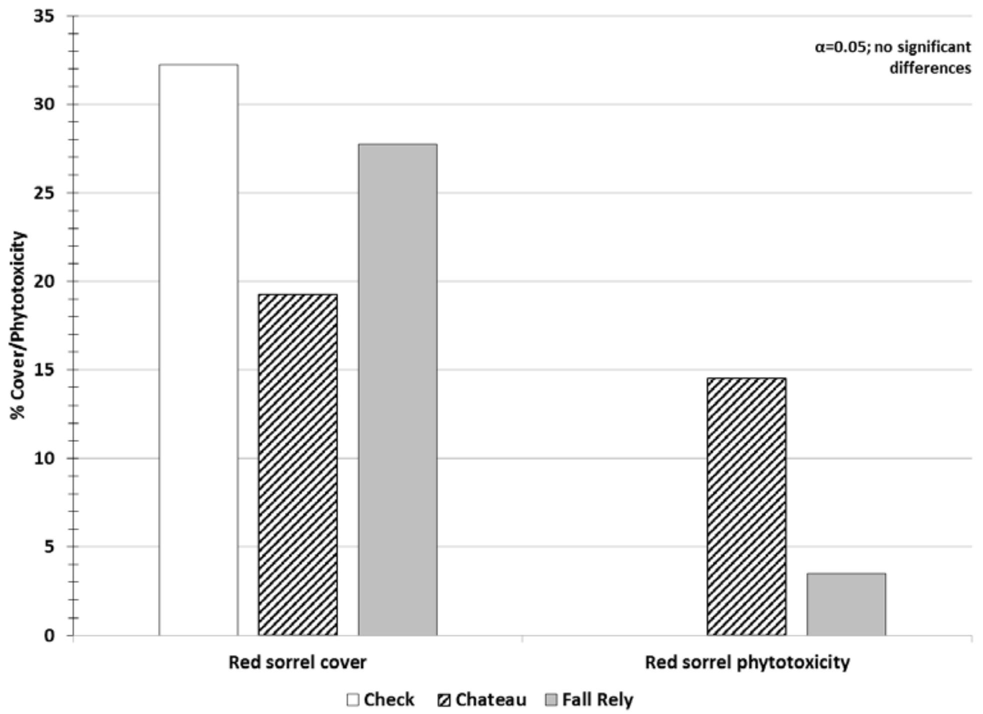


**Figure 5.** Red sorrel cover and phytotoxicity in non-crop year 2018 for post-pruning fall application of Chateau and Rely (α=0.05; no significant differences).

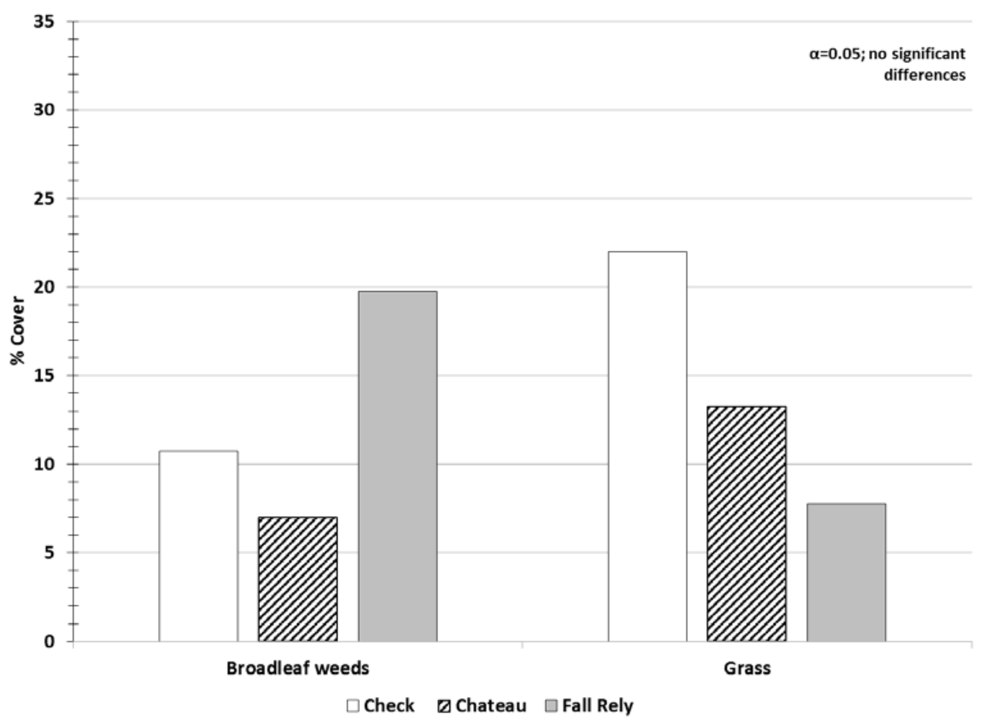


**Figure 6.** Broadleaf weed cover and grass cover in non-crop year 2018 for post-pruning fall application of Chateau and Rely (α=0.05; no significant differences).

*T-tests*

A t-test performed on crop 2018 data for differences between non-crop year spring and fall Rely application in the crop year revealed no significant differences in red sorrel or other weeds, but wild blueberry cover in the Spring Rely treatment was significantly higher than in Fall Rely (Figure 7). The reason for this is unclear; the blueberry plants were completely dormant at the fall application date of 15 November 15 2017, and overall weed cover was not dense, so these effects in the crop year were not expected.

The t-test performed on non-crop year data (pre-emergence Spring Rely 2017 data and post-pruning Fall Rely 2018 data) for differences between spring versus fall Rely application regarding effects on blueberry and weeds showed no differences in wild blueberry or grass cover, but red sorrel was significantly higher and other broadleaf weed cover was significantly lower with the Spring Rely treatment (Figure 8). The difference in red sorrel was highly significant at α=0.0086; there was 55% red sorrel cover in the Spring 2017 Rely treatment in July 2017, but there was less than 30% red sorrel cover in July 2018 after Fall 2017 Rely application. This is likely due to the other weeds being sprayed and therefore controlled early in the non-crop year, allowing red sorrel to take advantage of better growing conditions, as opposed to having competition over the non-crop year growing season and all being sprayed in the fall. As illustrated in Figure 7, spring pre-emergence carryover control of red sorrel was better in the crop year.

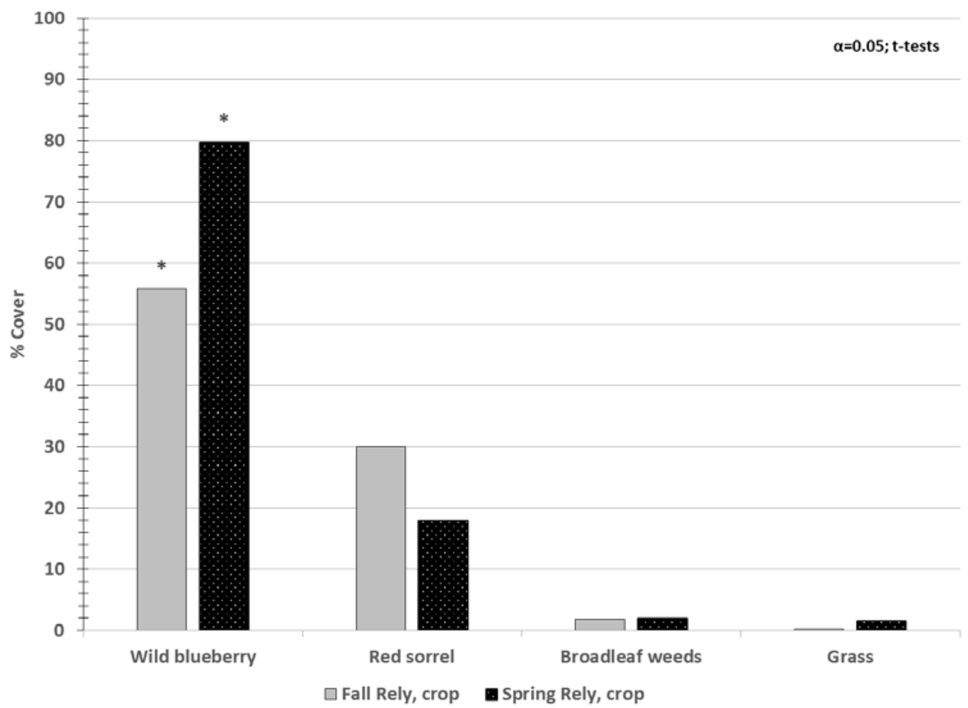


**Figure 7**. Non-crop year Spring versus Fall Rely application; wild blueberry and weed differences in the crop year (α=0.05).

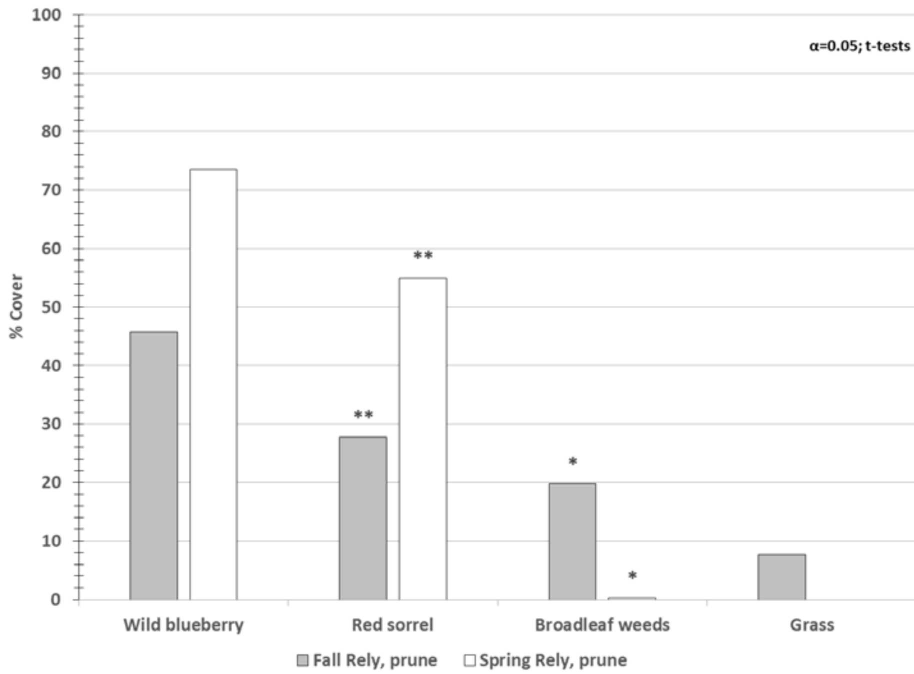


**Figure 8**. Non-crop year Spring versus post-pruning Fall Rely application; wild blueberry and weed differences in the non-crop year (α=0.05).

When crop year data for Rely application in the fall of the non-crop year was compared to non-crop year data for Rely application in the fall post-pruning (C18 vs P18, respectively, aka the growing season following the applications), there were no significant differences in wild blueberry cover or weed cover (Figure 9).

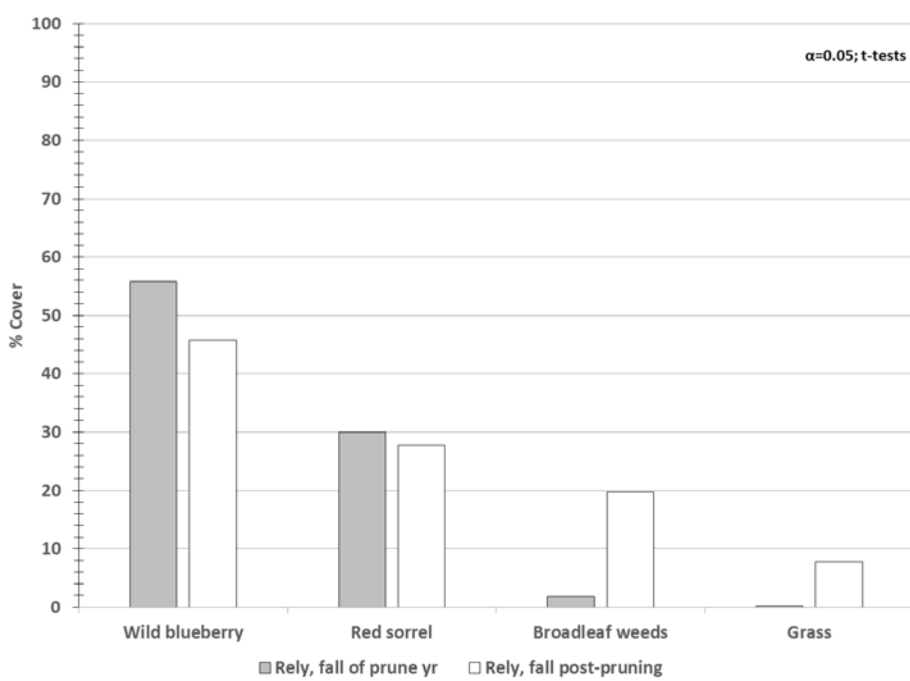


**Figure 9**. Fall Rely application in fall of the non-crop year versus fall post-pruning; wild blueberry and weed differences in the growing season following application (α=0.05).

A t-test was also performed to compare Chateau crop year data for application in the fall of the non-crop year with Chateau non-crop year data for application in the fall post-pruning, as for Rely above (Figure 10). In this analysis, red sorrel cover and other broadleaf weed cover were not significantly different, but wild blueberry cover was significantly higher in the C18 treatment than in the P18 treatment, and grass cover was higher in the P18 treatment (highly significant at $P = 0.0042$).

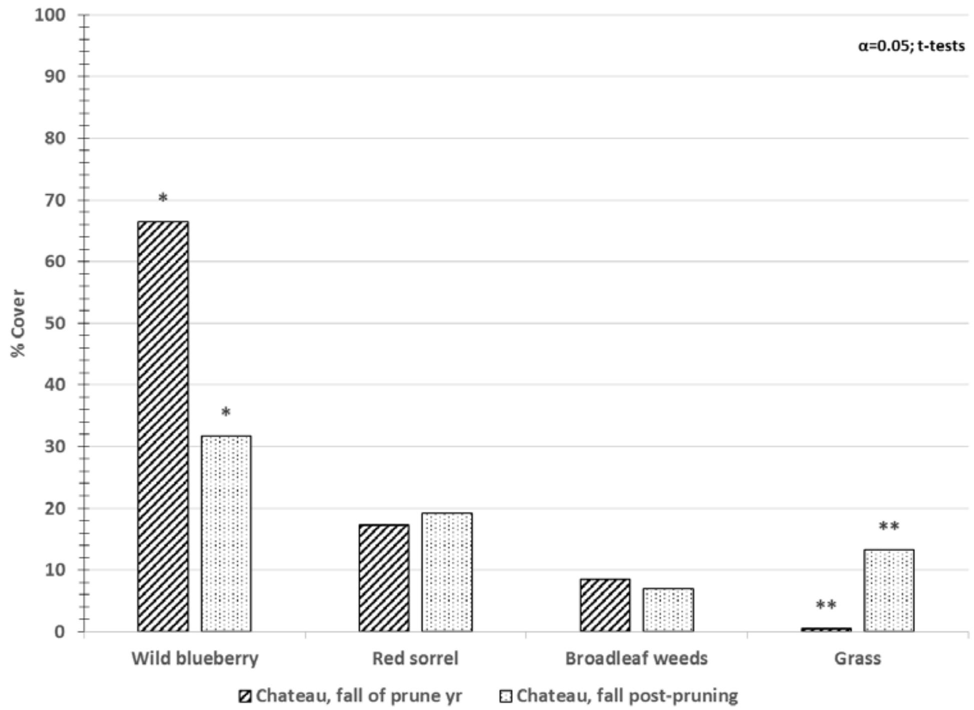


**Figure 10**. Chateau application in fall of the non-crop year versus fall post-pruning; wild blueberry and weed differences in the growing season following application (α=0.05).

**CONCLUSIONS**:

*2018 Crop (C18)*

Spring Rely resulted in the highest wild blueberry cover and yield, and lowest red sorrel cover, in both the non-crop and crop years. Spring application was more effective on weeds and resulted in a higher yield vs the fall application which reduced yield to almost half that of the untreated check. Last year, we stated that "Spring pre-emergence application of Rely, whether with or without Velpar, was not effective in significantly reducing or eliminating red sorrel. Some basal rosettes were killed, indicating that Rely did have an effect on red sorrel, but this weed has multiple generations in one growing season and Rely did not control individuals that germinated after application." Although no treatment in this trial eliminated red sorrel, Chateau and Spring Rely exhibited the best carryover control with no detrimental long-term effects on wild blueberry, although there was an approximately 1,000 lbs/a reduction in yield for Chateau compared to no treatment. Chateau did release some other broadleaf weeds compared to the Rely treatments, so after Chateau is applied in the fall, follow-up weed control in the crop year may be necessary, which may also ameliorate any reduction in yield.

*2018 Non-crop (P18)*

P18 Chateau and Fall Rely treatment resulted in the same amount of red sorrel cover in the non-crop year as seen in the crop year in the C18 plots, and red sorrel injury was less than 15%. This is initially more effective than the 2017 pre-emergence non-crop year treatments of Rely and Rely+Velpar, in which red sorrel cover ranged from 50-60% over the non-crop year before falling to approximately 20-30% in the crop year (see 2017 WBAC Report No. 12, Table 1 and Figure 1), with approximately 15% initial injury in the non-crop year. According to the red sorrel cover found in the C18 Chateau plots, we expect that red sorrel cover in the P18 Chateau plots will remain constant into the crop year. However, because P18 Fall Rely resulted in almost no injury to red sorrel, we cannot predict whether cover will remain constant (as reflected by % cover in the C18 plots vs P18 plots), will decrease (as seen in C18 plots, including the check, from non-crop to crop year), or increase.

As expected, post-pruning application of Chateau, a systemic herbicide, controlled broadleaf weeds better than Rely, a contact herbicide. It was not expected that Rely would control grass as well as Chateau in the long-term, but the effect was mainly due to control of fineleaf sheep fescue. White (2018) studied the biology of fineleaf sheep fescue and found that fresh seeds lacked dormancy and germinated in the spring and fall of the non-crop and crop years, and the seedlings were very susceptible to Chateau, Rely and the combination of both. Therefore, we can conclude that both of these herbicides are effective on fineleaf sheep fescue when applied in the fall of the non-crop year.

*T-tests*

When spring versus fall Rely non-crop year treatment was compared directly to each other in each year of the two-year blueberry cycle, Spring Rely resulted in higher blueberry cover in both years, better carryover control of red sorrel (even though there was more red sorrel in the non-crop year) and was more effective on other broadleaf weeds and grasses in the non-crop year as seen in Photos 1-4 (see Table 1 for timeline). When Fall Rely treatment was compared applying in fall of the non-crop year (Photo 2) versus fall post-pruning after harvest (Photo 4), neither one was significantly better, but the former treatment was slightly better for blueberry cover and weed control in general. So, we can conclude that a spring pre-emergence Rely treatment is most effective on red sorrel and other weeds, but if a fall treatment is necessary it should be applied in the non-crop year as well.

When Chateau treatment was compared applying in fall of the non-crop year versus fall post-pruning after harvest, the latter treatment was significantly less effective on grass and resulted in reduced blueberry cover, without improving control of red sorrel or other broadleaf weeds (Photos 5-6). Therefore, we can conclude that Chateau should also be applied in the non-crop year.

As mentioned above, differences in grass cover were driven by fineleaf sheep fescue, and White 2018 found that it was very susceptible to both Rely and Chateau. The results of the t-tests indicate that spring non-crop year Rely is most effective on fineleaf sheep fescue over the two-year blueberry cycle, but if a fall application is necessary it is more effective when applied in the non-crop year. Chateau was also more effective on fineleaf fescue when applied in the non-crop year.

**Photo 1.** Non-crop year Spring Rely treatment in crop year 2018.

**Photo 2.** Non-crop year Fall Rely treatment in crop year 2018.

**Photo 3.** Non-crop year Spring Rely treatment in non-crop year 2017; example showing poor red sorrel control.

**Photo 4.** Post-pruning Fall Rely treatment in non-crop year 2018, showing red sorrel mixed with other weeds.

**Photo 5.** Non-crop year Chateau application in the crop year.

**Photo 6.** Post-pruning Chateau application in the non-crop year; note red sorrel, other broadleaf weeds and fineleaf sheep fescue.

**RECOMMENDATIONS**: Non-crop year spring pre-emergence Rely is recommended for red sorrel control, and an application in fall should be avoided unless necessary. If necessary, apply Rely in the fall of the non-crop year, not the crop year. Chateau should also be applied in the non-crop year as opposed to the crop year; this recommendation is supported by the results of the 2015-16 red sorrel trial (2016 Report No. 14) and 2016-17 red sorrel trial (2016 Report No. 15), in which we concluded that a spring application of Chateau alone should be avoided, and a fall non-crop year application was more effective than a fall post-pruning application the first growing season after application. For fineleaf sheep fescue control using Rely, apply spring pre-emergence in the non-crop year unless a fall application is necessary, in which case apply in the non-crop year. Chateau should be applied in the non-crop year for fineleaf sheep fescue control as well.

The P18 plots will be evaluated for carryover weed control and yield effects in crop year 2019, and will be compared to the C18 crop year data (Table 1). The results of the P18 Chateau treatment will also be compared to the crop year results of the 2016-17 red sorrel trial (2017 Report No. 11) to examine whether efficacy and yield effects are consistent two growing seasons after application.

**LITERATURE CITED**:

White, S.N. 2018. Determination of *Festuca filiformis* seedbank characteristics, seedling emergence and herbicide susceptibility to aid management in lowbush blueberry (*Vaccinium angustifolium*). *Weed Research* 58:112-120.

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**WEED MANAGEMENT**

**INVESTIGATORS:** David E. Yarborough, Professor of Horticulture
Jennifer L. D'Appollonio, Assistant Scientist

**9. TITLE:** Combinations of pre-emergence Trellis SC with post-emergence Arrow for weed control in wild blueberry fields.

**METHODS**: We have been assessing the active ingredient isoxaben (trade name Gallery, solid) over the past several years. In 2013 we conducted a trial for general weed control at nine sites, but all but two had to be abandoned due to carryover weed control from the companies' own weed control programs. In 2015 we conducted a trial assessing efficacy on red sorrel, in which isoxaben did not perform significantly better than any other product tested. In both of the trials, isoxaben was applied pre-emergence in spring. In early 2018, Dow AgroSciences released a label for Trellis SC for application to dormant blueberry in the non-bearing year, with a maximum of two applications for a total of 1 lb/ai/a or 31 oz/a product per year. We initiated a trial in which we compared three rates of Trellis SC (half the max rate, max rate, and 2x max rate) with a Trellis tank mix, industry standard Trimix combination, Zeus and Callisto (mesotrione). All treatments except the Trellis mix and Trimix also received two applications of post-emergence Arrow (clethodim).

The treatments were as follows:

1. Untreated check (check);
2. Trellis 16 oz/a **pre-** + Arrow 6 oz/a 2x **post-** (*Trellis Low*);
3. Trellis 31 oz/a **pre-** + Arrow 6 oz/a 2x **post-** (*Trellis Mid*);
4. Trellis 62 oz/a **pre-** + Arrow 6 oz/a 2x **post-** (*Trellis High*);
5. Trellis 23 oz/a + Matrix 4 oz/a + diuron 2 lb/a **pre-** (*Trellis mix*);
6. Velpar 1 lb/a + Sinbar 1 lb/a + diuron 2 lb/a **pre-** (*Trimix*);
7. Zeus 10 oz/a **pre-** + Arrow 6 oz/a 2x **post-** (*Zeus*);
8. Callisto 6 oz/a **pre-** + Arrow 6 oz/a 2x **post-** (*Callisto pre*);
9. Callisto 3 oz/a 2x + Arrow 6 oz/a 2x **post-** (*Callisto post*);

The trial was set up at two sites: the Dean Dolham lot in Warren and Blueberry Hill Farm in Jonesboro. Each site contained six blocks with 6' x 30' plots and 3' alleys. The pre-emergence treatments were applied on 16-17 May and the post-emergence treatments were applied on 1 and 11 June and 20 and 26 June in Warren and Jonesboro, respectively, so that weed/crop development stages were comparable. A visual examination of phytotoxicity was conducted just prior to the first post-emergence treatment, and no crop injury was noted except for stunting and delay in emergence in the Zeus treatment; this is consistent with previous trials assessing Zeus. Therefore, the sites were sprayed twice with post-emergence Arrow and evaluations were conducted starting approximately two weeks after the second application (2 and 9 July, and 16 and 24 July for Warren and Jonesboro, respectively). Cover data were determined by using the Daubenmire Cover Scale converted to percent; phytotoxicity was assessed by using a scale of 0-10 (0=no damage, 10=100% damaged/dead) converted to percent. All treatments were compared to each other using Tukey's tests ($\alpha$=0.05) for significant differences, but due to site differences in weed cover, the sites were analyzed separately.

## RESULTS AND DISCUSSION:

*Wild blueberry cover and phytotoxicity*

In Jonesboro, there were no significant differences in blueberry cover at the first evaluation, but there was at the second evaluation in which the Trimix treatment had significantly more cover than Trellis Mid, but both were not significantly different from any other treatment (Figure 1). The Trellis Low (16 oz/a half rate) and Trellis mix (23 oz/a) treatments had slightly more cover than the Trellis Mid (31 oz/a max rate) or Trellis High (62 oz/a 2x max rate). Phytotoxicity at the first evaluation showed that Zeus had the most crop injury, expressed as stunting, and was significantly higher than all other treatments except Callisto post (Figure 2). By the second evaluation, phytotoxicity had declined in the Zeus treatment and mixes, but increased in the Trellis and Callisto treatments.

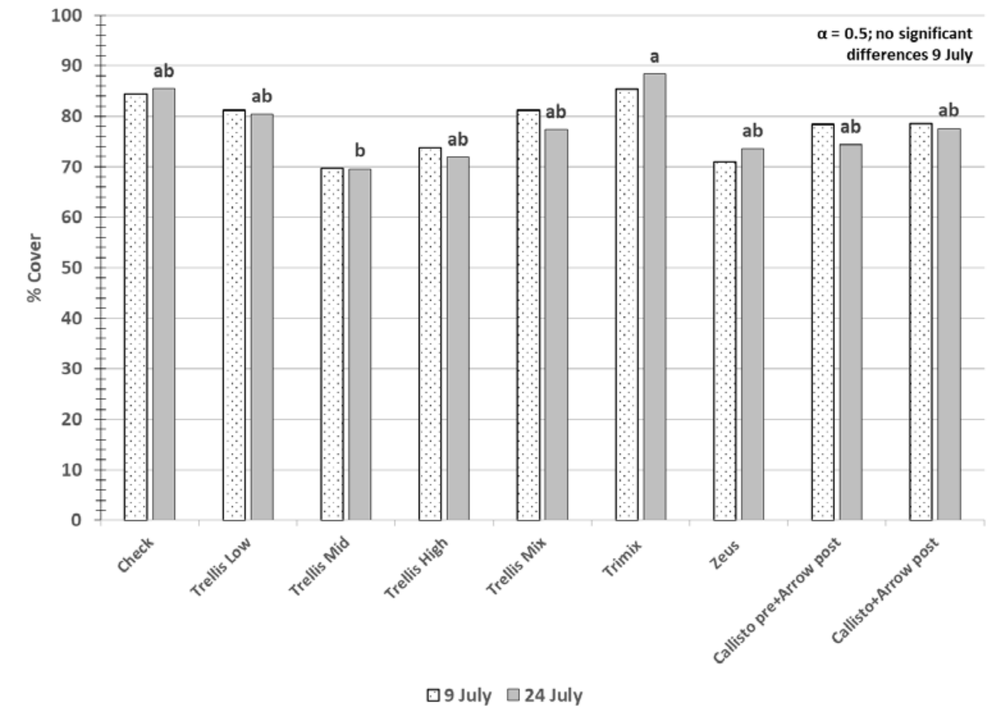


**Figure 1.** Wild blueberry cover in Jonesboro after pre-emergence and/or post-emergence applications of herbicides (α=0.05; only significant differences denoted by different letters).

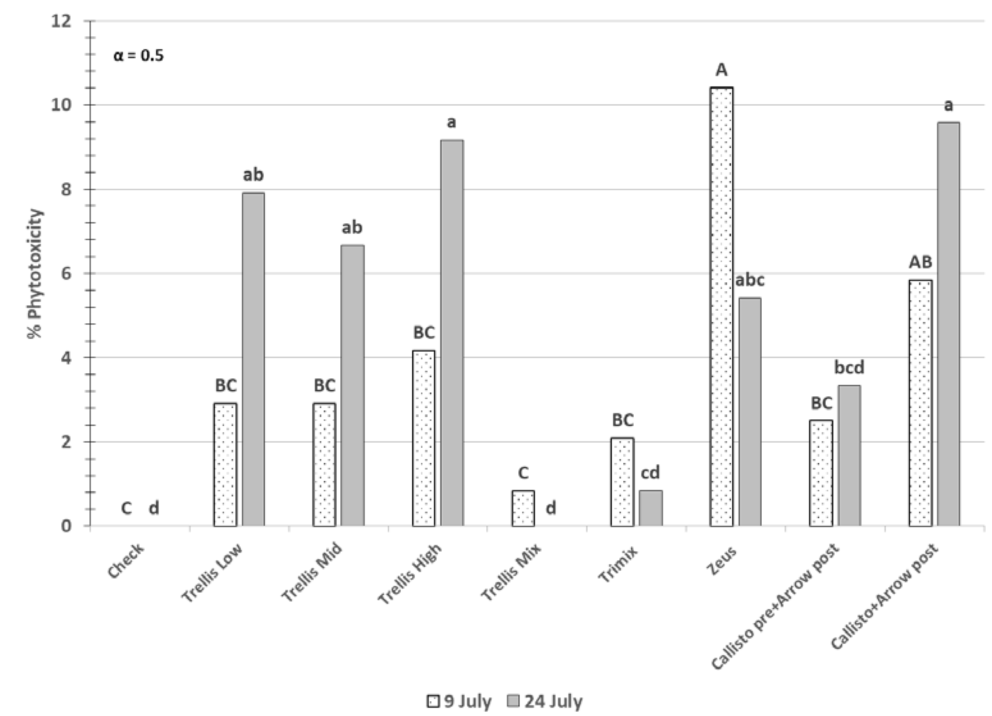


**Figure 2.** Wild blueberry phytotoxicity in Jonesboro after pre-emergence and/or post-emergence applications of herbicides (α=0.05; only significant differences denoted by different letters).

Wild blueberry cover in Warren followed roughly the same trend as in Jonesboro except that Trellis High had slightly more cover than Trellis Low, but there were no significant differences at either evaluation and cover was slightly lower overall (Figure 3). Zeus exhibited the same stunting effect as in Jonesboro, and phytotoxicity in this treatment was significantly higher than all other treatments at the first evaluation; Callisto post had higher phytotoxicity than all treatments except Zeus (Figure 4). At the second evaluation, injury had declined in all treatments except the Trellis Low, Mid and High, but at 2% or less was not a concern.

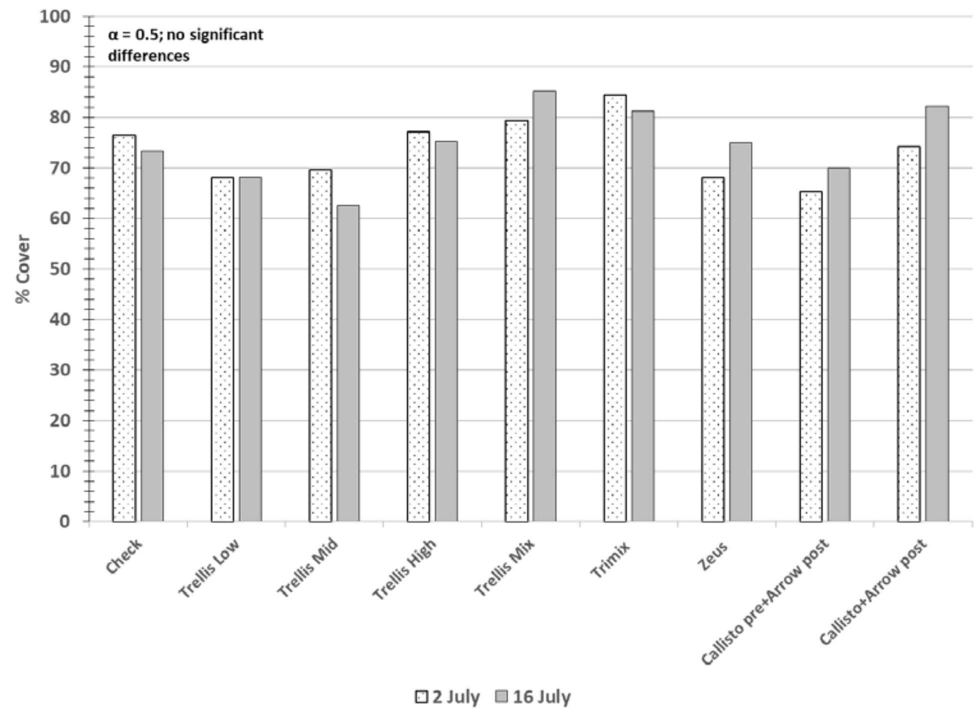


**Figure 3.** Wild blueberry cover in Warren after pre-emergence and/or post-emergence applications of herbicides (α=0.05; no significant differences).

At both sites, overall phytotoxicity did not exceed 12% and was well within acceptable limits. Furthermore, the phytotoxicity observed at the second evaluation, in all treatments but the two mixes which did not have Arrow, and so were due to the post-emergence Arrow application. Symptoms were epinastic twisting, slight stunting and yellowing of leaves and corresponded precisely with where the Arrow was applied (Photos 1-2). This type of injury from clethodim hadn't been observed in previous trials using the same container of Arrow, and the storage temperature log showed no excessively low or high storage temps, so we assume that the product had gotten old and one of the unnamed inert ingredients had degraded in such a way to cause injury. Therefore, the Arrow crop injury is not typical and will not be used to form conclusions, and new product will be procured.

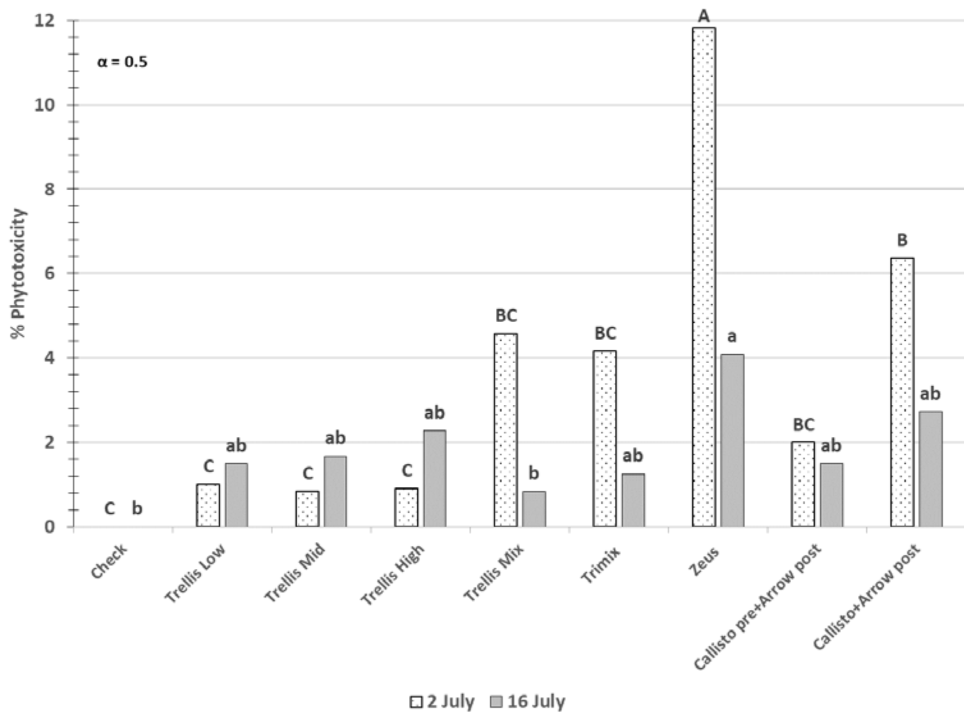


**Figure 4.** Wild blueberry phytotoxicity in Warren after pre-emergence and/or post-emergence applications of herbicides (α=0.05; only significant differences denoted by different letters).

**Photo 1.** Stunting of wild blueberry from post-emergence application of Arrow in a pre-emergence Callisto plot (neither product normally stunt blueberry).

**Photo 2.** Epinastic twisting of wild blueberry, bottom, from post-emergence application of Arrow in a post-emergence Callisto plot.

*Weed cover*

There were many more broadleaf weeds at Warren than Jonesboro, primarily because the Warren site had a large bare area with weeds but no blueberry across portions of Blocks 2, 3, 5, and 6. In Jonesboro, there were no significant differences in broadleaf weed cover at the first evaluation (Figure 5). At the second evaluation, Trellis Low and Zeus had the most broadleaf weeds, and both were significantly higher than Trimix which resulted in the best broadleaf weed control. Callisto post performed slightly better than Callisto pre and was also significantly lower than Trellis Low. Out of the four Trellis treatments, Trellis Mid was most effective on broadleaf weeds, while Trellis Low was least effective. In Warren, there were no significant differences at either evaluation (Figure 6). Once again, Trimix was most effective on broadleaf weeds overall. However, at this site Trellis Mid treatment had the highest weed cover of all treatments, and Trellis mix and Trellis High treatments gave the best broadleaf weed suppression of the four Trellis applications.

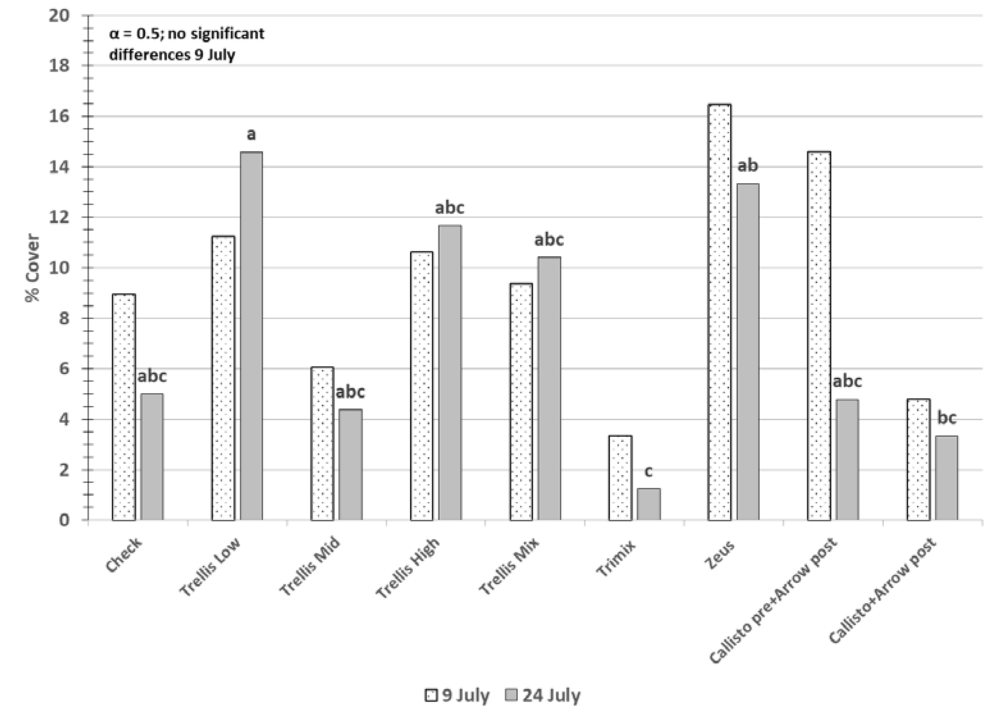


**Figure 5.** Broadleaf weed cover in Jonesboro after pre-emergence and/or post-emergence applications of herbicides (α=0.05; only significant differences denoted by different letters).

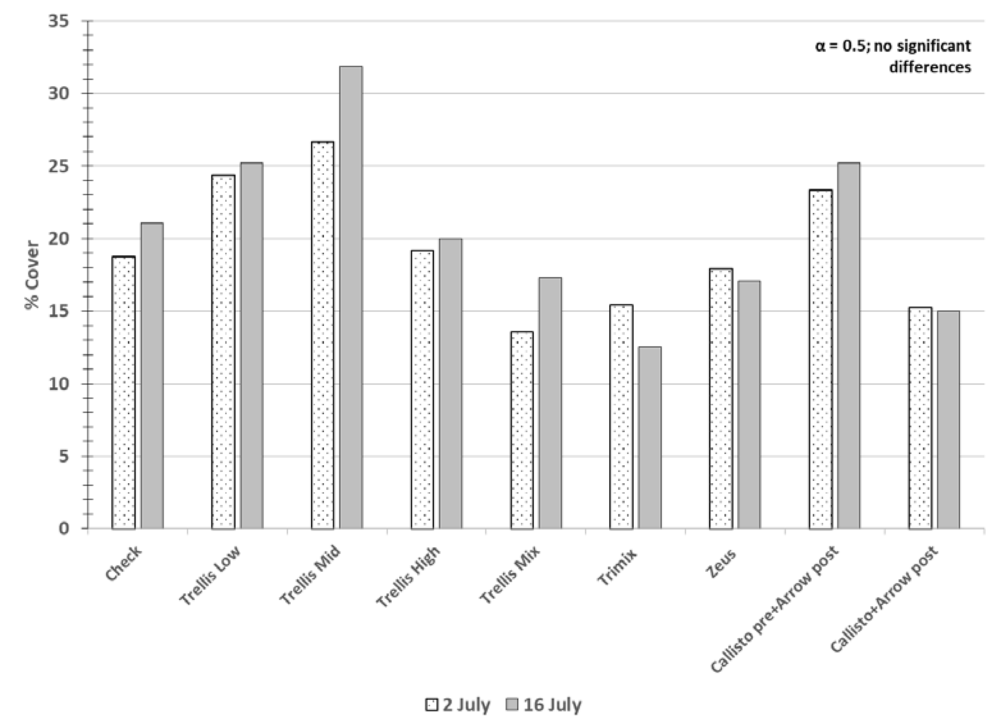


**Figure 6.** Broadleaf weed cover in Warren after pre-emergence and/or post-emergence applications of herbicides (α=0.05; no significant differences).

The difference in broadleaf weed response between sites does not appear directly related to grass cover. Grass cover was much higher in Jonesboro compared to Warren, and was dominated by bluegrasses (*Poa* spp.), fineleaf sheep fescue (*Festuca filiformis*) and wild oatgrass (*Danthonia spicata*) (Figure 7; also see photo 6). While not significantly different from the other Trellis treatments, Trellis Mid did have the lowest broadleaf weed cover and highest grass cover of the Trellis treatments; however, grass cover at the second evaluation was higher in Trellis High and mix than in Trellis Low, when the latter had the highest broadleaf weed cover. At this site, Trellis Mid, Trellis High and Callisto pre had the most initial grass cover and were significantly higher than only Trimix, also the only treatment containing Sinbar. By the second evaluation, grass cover declined or remained constant in the Trellis treatments but slightly increased in the Callisto treatments, and only Callisto pre and Trimix were significantly different. In Warren, there were no significant differences among treatments at either evaluation, and overall grass cover (almost exclusively quackgrass, *Elymus repens*) was so low that no definitive conclusions may be made comparing broadleaf weed response to grass cover (Figure 8).

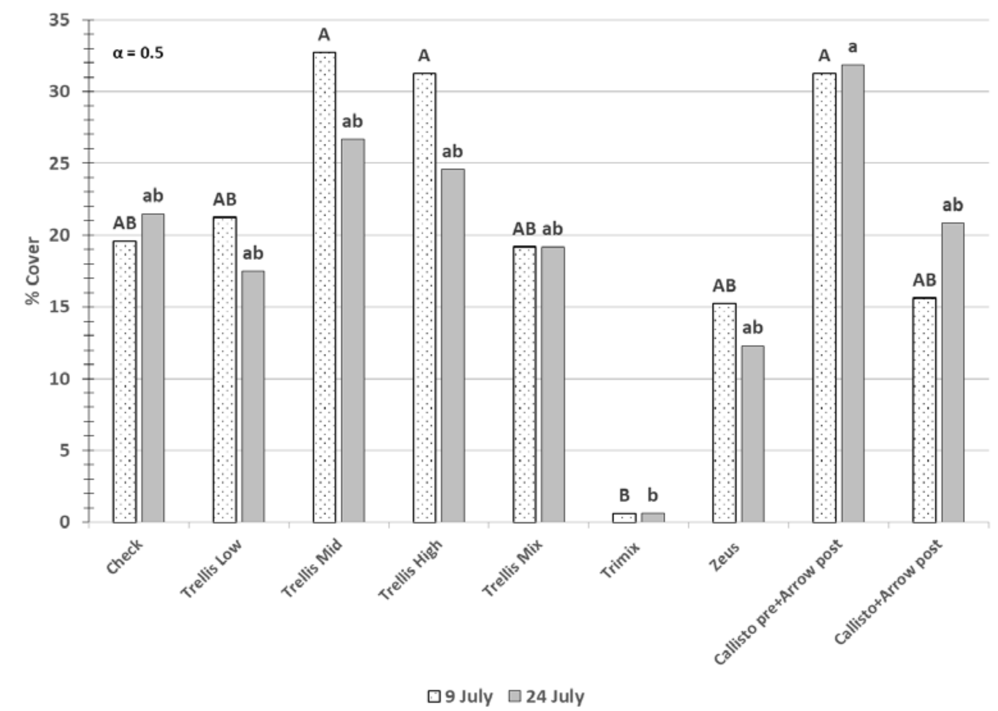


**Figure 7.** Grass cover in Jonesboro after pre-emergence and/or post-emergence applications of herbicides (α=0.05; only significant differences denoted by different letters).

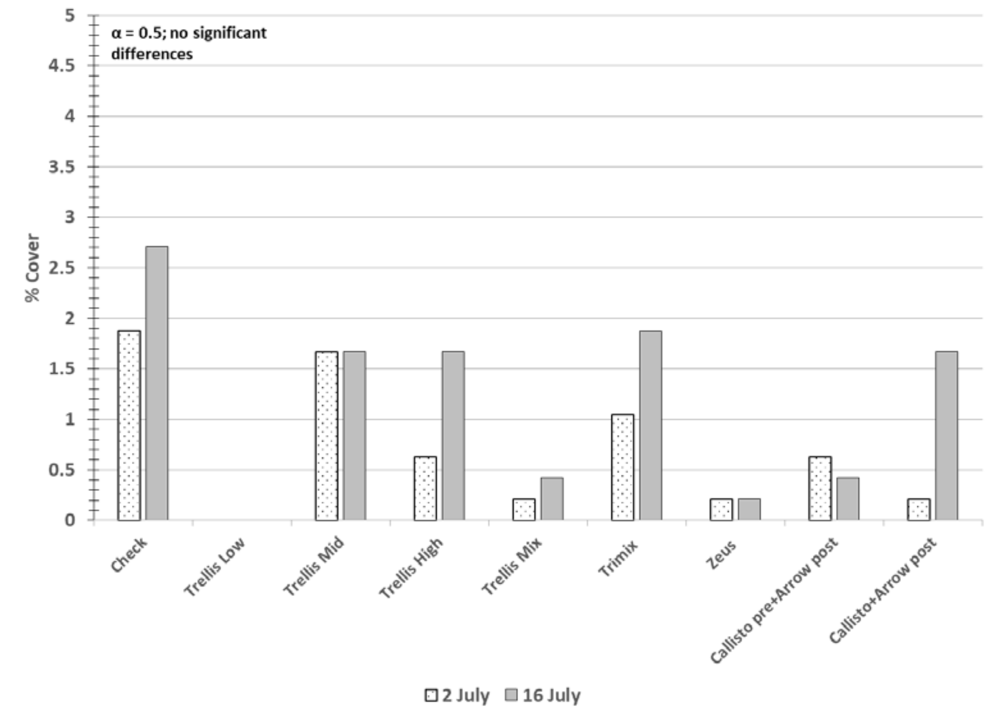


**Figure 8.** Grass cover in Warren after pre-emergence and/or post-emergence applications of herbicides (α=0.05; no significant differences).

The differences in broadleaf weed response between sites appears to be due more to site soil and weed species differences than corresponding grass cover. The Warren site has heavier soil and the trial area is between a productive hay field and wooded moist swale, while the Jonesboro site is sandier and drier. Although some species were present at both sites, there were several species only present at one site. For example, rattlesnake root (*Prenanthes* spp.), wild lettuces (*Lactuca canadensis* and *L. biennis*), pin cherry (*Prunus pensylvanica*), silverrod (*Solidago bicolor*) and broom sedge (*Carex* spp.) were only found at Jonesboro, and the site was dominated by red sorrel and goldenrods. Warren had a much greater diversity of weeds and many were only present here, including roses, Queen Anne's lace (*Daucus carota*), cow vetch (*Vicia cracca*), whorled loosestrife (*Lysimachia quadrifolia*), clovers (*Trifolium* spp.), ragweed (*Ambrosia artimisiifolia*), lesser stitchwort (*Stellaria graminea*), Canada St. Johnswort (*Hypericum canadense*), blackberry/raspberry (*Rubus* spp.), sessileleaf bellwort (*Uvularia sessilifolia*), spreading dogbane (*Apocynum androsaemifolium*) and oriental bittersweet (*Celastrus orbiculatus*) among others. Weed diversity was high, no particular weed(s) dominated the site, and weed pressure was so high in the bare area that not much weed control was evident regardless of treatment (Photo 3). Some species such as dogbane showed regrowth after treatment or lack of control; others such as raspberry, oriental bittersweet and bellwort had chlorosis from Trellis but did not die (Photo 4); and at least cow vetch (*Vicia cracca*) showed increasing injury with increasing Trellis rate but not consistently.

**Photo 3.** A Trellis plot in the bare area in Warren, with the wooded swale in the background. Heavy weed pressure obscured treatment effects.

**Photo 4.** A plot (not in the bare area) in the Trellis High treatment, showing poor control of species such as dogbane, goldenrods and oriental bittersweet at 2x max label rate.

**CONCLUSIONS AND RECOMMENDATIONS**: Wild blueberry was not adversely affected by the higher rates of Trellis in this trial at the max rate (Mid) or twice the max rate (High), but weed control was not significantly improved either. The inconsistent broadleaf weed responses by site indicate that soil texture, pH and/or specific weed species may drive efficacy of Trellis. Lack of rainfall to incorporate Trellis can cause Inconsistent results but over an inch of rain occurred within 10 days. At Jonesboro, the maximum rate of 31 oz/a (Trellis Mid) was most effective on predominantly red sorrel, goldenrods and wild lettuces. However, at Warren the max rate performed worst and the mix rate (23 oz/a) in a tank mix performed best on a wide variety of weeds.

As previously mentioned, grass cover at Warren was too low to allow for conclusions to be made, but the results in Jonesboro indicate that Trellis was not effective on grasses, even when followed by a grass control material. Although the Arrow injured blueberry, we did observe it slightly reduced grass cover in several treatments. There was a lot of grass residue in the trial area, more so in Blocks 4-6 compared to Blocks 1-3 (Photo 5-6). Overall Arrow injury was greater and overall weed cover was lower in Blocks 1-3, indicating that the thicker grass residue in Blocks 4-6 intercepted the herbicides before it contacted live foliage or the ground. This, as well as the overall poor weed control in the bare area in Warren, highlights the importance of consistent weed control and site preparation so that pesticides reach their intended targets.

**Photo 5**. A Trellis Mid plot in Block 1 in Jonesboro, showing little grass residue.

**Photo 6.** A Trellis Mid plot in Block 4 in Jonesboro, showing heavy grass residue and reduced weed control.

Finally, the Zeus treatment in this trial showed the same injury pattern to wild blueberry as in other trials, and Matrix was not as effective in a tank mix as Sinbar for general grass control or Velpar for broadleaf weed control. The Matrix results are consistent with past trials that indicate that effective control of weeds depends on the particular weed species present.

The trial will be carried over into 2019 for carryover weed control ratings and yield effects. In addition we will be including it in a trial with a fall application for winter annuals with a Trellis rate of 31 oz/a to determine if it will be effective in reducing weeds such as red sorrel in the following year.

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**WEED MANAGEMENT**

**INVESTIGATORS:** David E. Yarborough, Professor of Horticulture
Jennifer L. D'Appollonio, Assistant Scientist

**10. TITLE:** Evaluation of spring Express application on control of bunchberry (*Cornus canadensis*) in wild blueberry fields.

**METHODS**: Bunchberry (*Cornus canadensis*) is a major weed pest species in wild blueberry. It is a low-growing perennial that can form a dense understory and compete with blueberry plants for resources. It also has red berries at the same time as wild blueberry, and the harvesters pick up the bunchberries along with the blueberries so they have to be sorted out on the processing line. Express (tribenuron-methyl) is registered in the US for bunchberry control, but only as a summer/fall treatment in the prune year. Spartan (tribenuron-methyl), registered in Canada for bunchberry control, can be applied in either the spring or fall of the prune year, although a fall application is preferred due to better weed control and a wider application window. If a spring application is made, the New Brunswick Wild Blueberry IPM Weed Management Guide (NBDAAF 2017) notes the following. The majority of bunchberry leaves should be unfolded to a 45° angle but no later than when the first white blossoms appear. The plants turn pinkish red to yellow after application but may take several weeks to die down. If application is made too late, the plants turn red for the entire season and control is reduced; applied too early, and bunchberry regrowth can be expected later in the season. Application should be made before wild blueberry emergence exceeds 2 cm (approx. ¾"), and some height reduction and yellowing/reddening of leaves may be observed for 6-8 weeks post-application (more likely during prolonged cool temps or large temp fluctuations). Tribenuron-methyl should not be applied to spring-burnt fields or at later stages of blueberry development.

Wyman's of Maine manages land in both Canada and the US, and they requested that the University of Maine conduct a joint trial in which Wyman's would apply Express on a large scale to a mowed prune year wild blueberry field at different spring timings, and University personnel would evaluate its effects on blueberry and bunchberry. In spring 2018, Wyman's applied Express 1 oz/a + the surfactant Liberate 6.4 oz/a to sections of their Town Line West 3 field at three treatment timings: on 14 May (bunchberry plants emerged but no leaves expanded); 22 May (bunchberry leaves expanded at an angle <90°); and 31 May (bunchberry leaves fully expanded/flat but prior to flowering, blueberry emerged). So, the 2nd application was made at the timing recommended in New Brunswick (NB), the 1st application represented an earlier than optimal timing, and the 3rd application represented a later than optimal timing. After the applications were made, ten 1 $m^2$ plots containing blueberry and bunchberry were established in each treatment, as well as ten check plots in an untreated section of the field. Because all three applications were made adjacent to a tree line, the check plots were also located next to a tree line. Plots were assessed for wild blueberry and bunchberry cover and phytotoxicity on 21 June and 11 July. Cover data were determined by using the Daubenmire Cover Scale converted to percent; phytotoxicity was assessed by using a scale of 0-10 (0=no damage, 10=100% damaged/dead) converted to percent. Tukey's tests were conducted for significant treatment differences ($\alpha$=0.05).

**RESULTS AND DISCUSSION:** There were no significant differences in blueberry cover among treatments at either evaluation (Figure 1). Blueberry cover increased from the first to second evaluation in all treatments except the latest application timing, 31 May, with the highest cover in the 22 May treatment (optimal application timing). At the June evaluation, there was significantly more injury to blueberry in the first two application timings (14 and 22 May, Photo 1) compared to 31 May or the check (Figure 1, Photo 2), and injury was observed as reddened leaves and delay of filling in. At the July evaluation, the blueberry plants had essentially recovered in the 14 May and 22 May treatments and injury presented as having very small leaves compared to adjacent untreated plants (Photo 3), but the 22 May treatment still had significantly more phytotoxicity than the check. By contrast, phytotoxicity in the latest application timing treatment (31 May) increased from the June to July evaluation and was significantly higher than all other treatments. The blueberry plants in this treatment had small leaves but were also stunted. The stunting effect matches the Weed Management Guide which states that a reduction in height may be observed for 6-8 weeks, although the earlier applications were made when the weather was much cooler compared to the latest application and they were not stunted (stunting is more likely to occur under prolonged cool temps or large temp fluctuations near application date. The air temp was 79° F at the time of the 31 May application but it is unknown if there was large temp fluctuations). The Weed Management Guide language does not mention tiny blueberry leaves as a symptom, and personal communication with Gavin Graham, New Brunswick Dept. of Agriculture, Aquaculture and Fisheries who studies wild blueberry weeds and indicated that he had not seen this effect either. Differences in soil texture did not explain the phytotoxicity, as soils were the same throughout the field. The most likely explanation is that the blueberry plants were emerged at the 31 May treatment date.

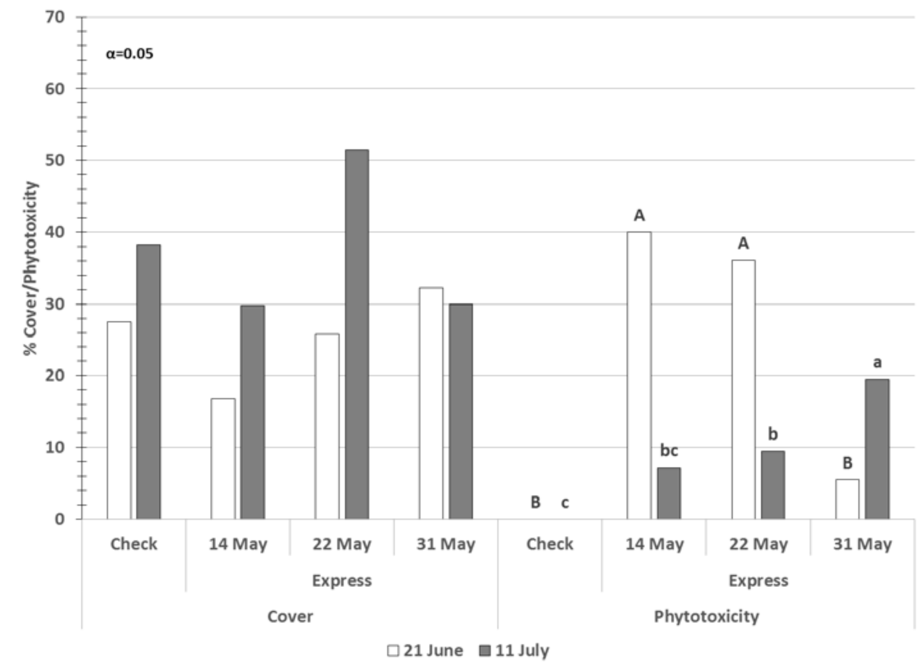


**Figure 1**. Wild blueberry cover and phytotoxicity after spring Express application at three bunchberry plant development timings (α=0.05).

**Photo 1.** Example of wild blueberry and bunchberry injury in the 22 May treatment in June. Blueberry injury presented as reddening of leaves and delay in filling in; bunchberry injury was reddening/yellowing of leaves, curling and necrosis.

**Photo 2.** An untreated check plot in June.

**Photo 3.** A 22 May treatment plot in July. Note the very small blueberry leaves, injured mature bunchberry in lower right, and new unaffected bunchberry in upper left.

In June there were no significant differences in bunchberry cover among treatments, but cover was highest in the check and the three Express treatments were within 5% cover (Figure 2). Bunchberry injury was greatest at the earliest application timing (Photo 4), and the 14 and 22 May treatments (Photo 3) had significantly more injury than the 31 May treatment or the check. This agrees with the NB IPM Weed Management Guide language stating that when applied too late, bunchberry control is reduced. However, the plants were only slightly reddened along the veins and leaf curling was more widespread (Photo 5). The bunchberry plants in the 14 and 22 May treatments were much more reddened and curled, and there was also widespread necrosis, which also agrees with the Weed Management Guide language stating that plants may take several weeks to die down (Photos 1, 4). This is borne out by the results of the July evaluation, in which the 14 May treatment increased in bunchberry cover and decreased in overall phytotoxicity, while the 31 May treatment decreased in bunchberry cover and increased in phytotoxicity. The 14 May application was too early and resulted in a flush of new growth; this presented as some plants having 90% injury while others in the same plot had new growth which was not affected (Photo 6). The 31 May application timing was no longer significantly different in cover or phytotoxicity from the other two timings; more injury to bunchberry was seen than in June, which was expected since it takes several weeks for bunchberry to die down. Although bunchberry cover among the three timings was not significantly different, the 22 May "optimal" timing resulted in a reduction of bunchberry cover plus the greatest injury by July. New unaffected plants also recovered in this treatment, but the average injury to the older plants (70%) was higher overall than in the 14 May pre-optimal timing (47%) or 31 May post-optimal timing (40%).

**Photo 4.** Bunchberry injury in the 14 May treatment in June. Symptoms are reddening, curling and necrosis.

**Photo 5.** Bunchberry phytotoxicity in June in the 31 May treatment. Symptoms are yellowing, only slight reddening and leaf curling.

**Photo 6.** A 14 May treatment plot in July. Note the extensive injury to older bunchberry plants, with a flush of new unaffected plants.

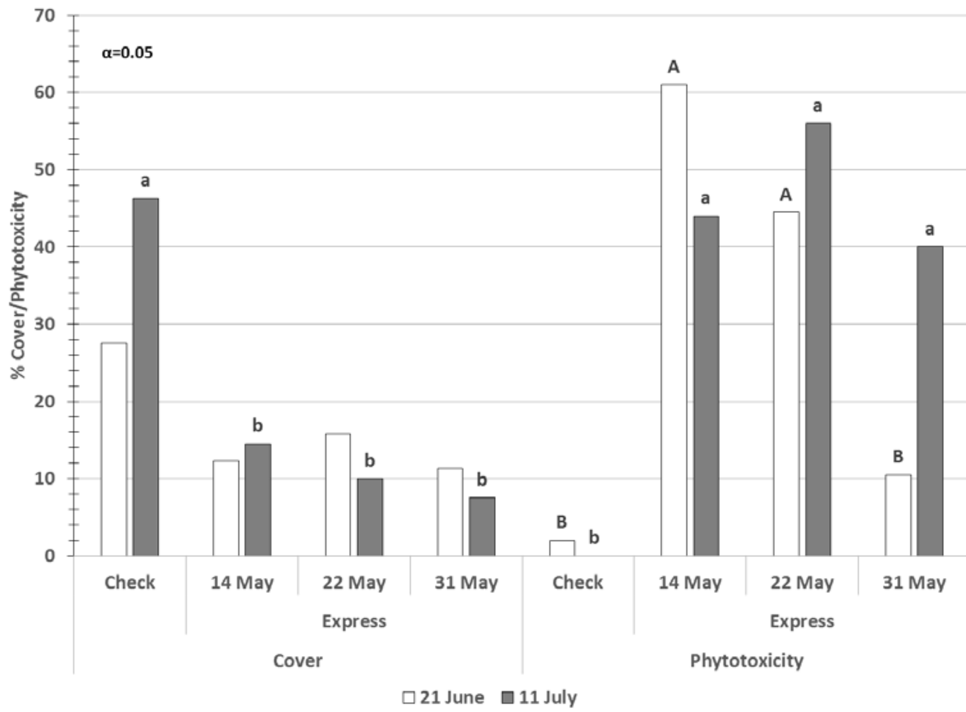


**Figure 2**. Bunchberry cover and phytotoxicity after spring Express application at three bunchberry plant development timings (α=0.05).

**CONCLUSIONS AND RECOMMENDATIONS**: In general, the results of this trial agree with the recommendations in the New Brunswick Wild Blueberry IPM Weed Management Guide for spring application of Express. The 22 May application timing, which correlates to the bunchberry leaves unfolded to roughly a 45° angle, resulted in the greatest long-term injury to mature bunchberry plants, while striking a balance between a new flush of growth from applying too early vs increased crop injury/reduced bunchberry control from applying too late.

It should be noted that there was a confounding edge effect in this trial. Because all of the treatments were applied adjacent to a tree line, it was difficult to separate early post-treatment phytotoxicity to wild blueberry from field edge effects. At the first evaluation, a delay of filling in by blueberry plant was noted, but it was initially unclear whether the effect was from the Express or shading by the tree line. We were ultimately able to find the “boom line” mark where crop injury effects ended, approximately 60’ into the field from the tree line (aka width of boom from tree line) and concluded that the delay in filling in was from the herbicide application (Photo 7). However, if this trial is repeated we recommend the following: the applications should be made away from the field edge, and the plots should be established prior to application. In this manner, edge effects are negated and a pairwise comparison of bunchberry cover could be made. Because of the flush of new growth, it would be better to know the amount of bunchberry cover present prior to treatment; then at intervals after treatment, cover can be tracked for both existing and new plants. It also would be beneficial to compare a fall vs spring treatment of Express to determine which is the most effective. Once all of these data and the data from the Express spot treatment trial are compiled and examined, we will likely pursue a label change to allow for spring applications.

**Photo 7.** "Boom line" mark in the 22 May treatment at the June evaluation, showing blueberry injury as delay of filling in (to left).

**LITERATURE CITED:**

NBDAAF. 2017. Wild Blueberry IPM Weed Management Guide. New Brunswick Department of Agriculture, Aquaculture and Fisheries Wild Blueberry Fact Sheet C.4.2.0. pp. 22-23.

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**WEED MANAGEMENT**

**INVESTIGATORS:** David E. Yarborough, Professor of Horticulture
Jennifer L. D'Appollonio, Assistant Scientist

**11. TITLE:** Evaluation of post-emergence Express application on control of target weeds in wild blueberry fields.

**METHODS:** Express (tribenuron-methyl) is registered in the U.S. for bunchberry control only, and only as a summer/fall treatment in the prune year. In Report No. 10, we discussed spring Express application effects on wild blueberry and bunchberry, but we also investigated whether Express would be effective as a post-emergence spot spray treatment on other broadleaf weeds. The New Brunswick Wild Blueberry IPM Weed Management Guide (NBDAAF 2017) notes that in New Brunswick, tribenuron-methyl may be used in the summer of the sprout year as a spot treatment for certain species such as alder, bracken fern, wild rose and yellow loosestrife. In all but bracken fern, the foliage turns yellow or red and the stem terminals die soon after application. Control of vetch, poplars, willows, goldenrods and fly honeysuckle has been erratic in their experience. With these parameters in mind, we scouted Downeast for prune year wild blueberry fields containing large enough populations of these species to support a spot treatment trial. We found three species to test on Wyman's land: cow vetch (*Vicia cracca*) on Town Line East; lance-leaved goldenrod (*Euthamia graminifolia*) on Town Line West 3; and whorled loosestrife (*Lysimachia quadrifolia*, closely related to yellow loosestrife) on Big Rock 1. The three trials were set up in a Completely Randomized Design with twenty 1 $m^2$ plots each containing both blueberry and the target weed, ten of which were sprayed with Express 1 oz/a + NIS 0.25% v/v on 15 June 2018. It should be noted that the weeds should have been small at the time of application. The goldenrod and loosestrife were 6" tall or less at the time of application, but the vetch had grown exponentially in the week between trial set-up and spray and were knee-high at the time of application, so reduced control was expected. Furthermore, the vetch only occurred in a large bare area with no blueberry plants, so effects on blueberry could not be assessed at this site. The loosestrife was located among large boulders on a small hill with very steep slopes, so the plots could not be completely randomized because the slope was too steep to be confident the correct Express rate would be applied to those plots. Therefore, seven of the ten check plots were on the steep slope, and seven of the ten treated plots were on top of the hill. The goldenrod tended to occur in low wet bare spots, so the plots were situated to encompass both the low-lying goldenrod and blueberry plants on dry hummocks.

The plots were evaluated for blueberry and target weed cover and phytotoxicity approximately two weeks (29 June) and four weeks (11 and 12 July) after Express application. Cover data were determined by using the Daubenmire Cover Scale converted to percent; phytotoxicity was assessed by using a scale of 0-10 (0=no damage, 10=100% damaged/dead) converted to percent. T-tests were conducted on each weed separately for significant treatment differences between Express and the untreated check ($\alpha$=0.05).

**RESULTS AND DISCUSSION:**

*Cow vetch*

As mentioned previously, the cow vetch was located in a large bare area with no blueberry plants, so only effects on the weed are discussed here. There were no significant differences in vetch cover between Express treatment and the check at either evaluation (Figure 1), and cover remained almost the same from the first to second evaluation. The vetch injury noted in the check was dead leaves in the vetch understory; the vetch had formed a solid mat about two feet above the ground and the leaves underneath had died from lack of light (Photo 1). This could not be separated from treatment effects so was recorded as background injury. Nevertheless, there was still significantly more injury in the Express treatment than the check at both evaluations (Figure 1). Phytotoxicity was expressed as a reduction in or lack of flowering. At the July evaluation the vetch was in full flower, but there were almost no flowers in the treated plots and plant height was slightly reduced (Photo 2). Some slender vetch (*Vicia tetrasperma*) was interspersed with the cow vetch, and showed the same responses to Express.

As a side note, it was observed at the July evaluation that the Express treatment killed red sorrel (*Rumex acetosella*) in the plots, but it is not known whether the overwintering rosettes were affected (Photo 3).

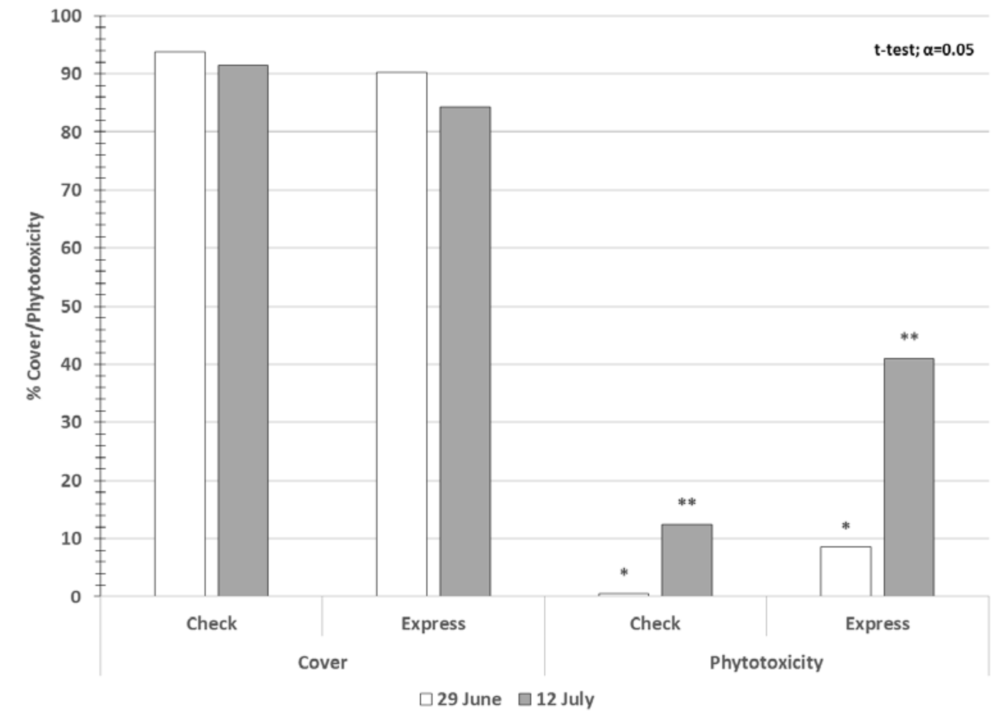


**Figure 1**. Cow vetch cover and phytotoxicity following a post-emergence spot treatment with Express (α=0.05).

**Photo 1.** Background injury in the untreated check, from lack of light.

**Photo 2**. An Express treated plot in July, showing reduced height and lack of flowering.

**Photo 3.** Red sorrel in the Express-treated plots was severely injured or killed.

<u>*Lance-leaved goldenrod*</u>

There was more blueberry cover overall in the Express plots compared to the check, but the difference wasn't significant at either evaluation (Figure 2). As previously mentioned, blueberry cover was low because the goldenrod was mostly in low-lying wet bare depressions, so most plots were situated on the border between the bare area with goldenrod and drier hummocks with blueberry. Blueberry phytotoxicity was significantly greater in the Express treatment at both evaluations, but at <10% the level of injury was minor and expressed mostly as reddened upper leaves (Figure 2, Photo 4). It was observed that *V. myrtilloides* was more affected than *V. angustifolium*, with more extensive reddening as well as twisting, but neither showed the stunting and very small leaves seen the bunchberry trial.

Lance-leaved goldenrod cover was initially comparable, but by July cover was significantly lower in the Express treatment (Figure 3). Phytotoxicity was significantly higher in the Express treatment at both evaluations, but did not exceed ~30% injury. Initial symptoms for goldenrod injury included minor stunting, chlorosis, curled tops and occasional necrosis. At the July evaluation the treated plants were yellowed, had apical twisting and necrosis, and did not have flowers while the untreated plants were in early flower (Photos 5-6). There was extensive orange-grass St. Johnswort (*Hypericum gentianoides*) cover in the trial area, but it appeared unaffected (see Photo 6).

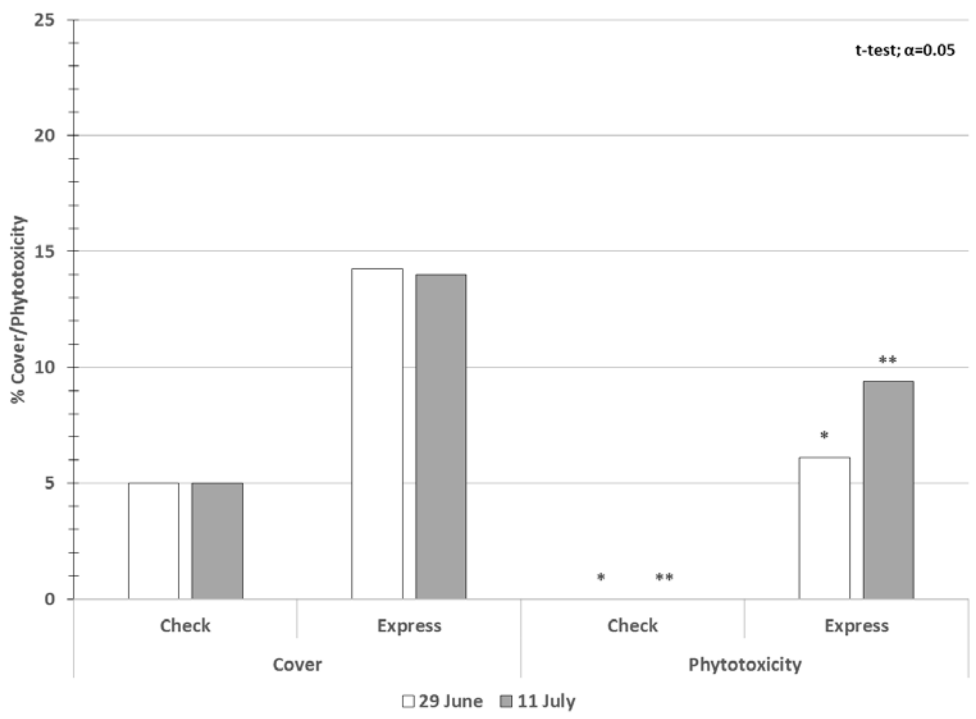


**Figure 2.** Wild blueberry cover and phytotoxicity following post-emergence Express spot treatment for control of lance-leaved goldenrod (α=0.05).

**Photo 4.** Wild blueberry initial injury from Express was reddened upper leaves.

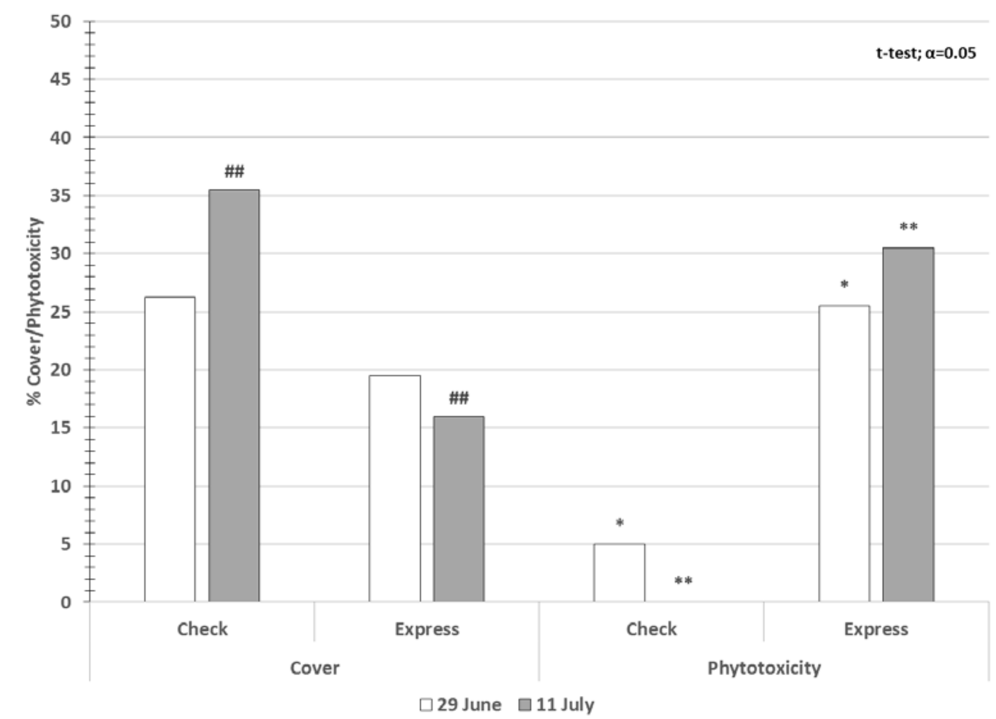


**Figure 3.** Lance-leaved goldenrod cover and phytotoxicity following post-emergence Express spot treatment (α=0.05).

**Photo 5.** An untreated check plot in July, in early flower.

**Photo 6.** An Express-treated goldenrod plant in July showing typical injury symptoms. The lower leaves are yellowed and the top is dead. Orange-grass St. Johnswort in the understory appeared unaffected.

*Whorled loosestrife*

Wild blueberry cover followed some of the same trends in this trial as in the lance-leaved goldenrod trial. There were no significant differences in wild blueberry cover between the check and Express treatment at either evaluation, cover was initially higher in the Express treatment and Express blueberry cover decreased slightly from June to July (Figures 2, 4). However, in this trial blueberry cover in the check increased from June to July, while cover in the goldenrod trial did not change. Blueberry phytotoxicity was significantly higher in the Express treatment, but was minor (Figure 4). Phytotoxicity in this trial ended up at the same level in July as in the goldenrod trial (~10 %), but the trend from June to July was the opposite (Figures 2, 4). In this trial, injury decreased from June to July, while in the goldenrod trial it increased. The difference may be because in this trial, we did observe the phytotoxicity expressed as very small leaves that we saw in the bunchberry trial, as well as leaf reddening (Photo 7). At the second evaluation, the leaf reddening seemed to be in plots with greater whorled loosestrife/other weed cover, and the small leaves tended to occur in plots with a more open canopy; the blueberry plants in the latter plots intercepted more spray than in the former plots.

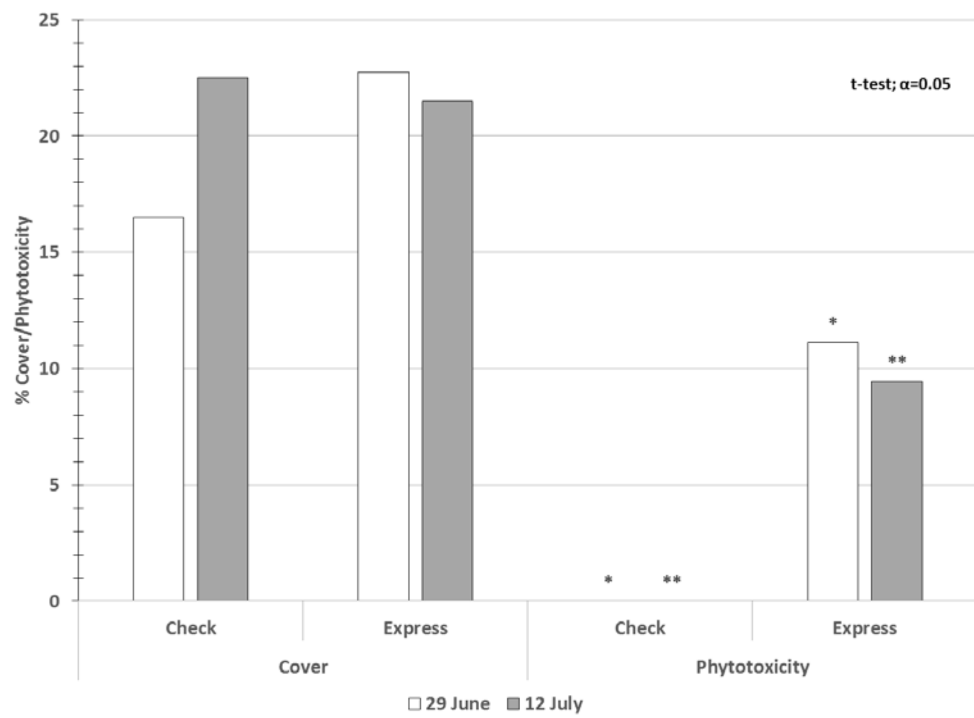


**Figure 4.** Wild blueberry cover and phytotoxicity following post-emergence Express spot treatment for control of whorled loosestrife (α=0.05).

**Photo 7.** Express injury to wild blueberry; note reddened and small terminal leaves (bottom).

Whorled loosestrife cover was reduced by roughly 10% in the Express treatment compared to the check at both evaluations, but the differences were not significant (Figure 5). However, phytotoxicity was significantly higher in the Express treatment at both evaluations, and increased from June to July until loosestrife injury exceeded 60%, so this species may not show full control until the following year. Initial phytotoxicity presented as shorter plants, and later symptoms included necrosis of upper leaves/stem and chlorosis of lower leaves (Photo 8, also Photo 9 for comparison to untreated plants). From the first to second evaluation, we observed necrosis spreading from just the upper leaves to the lower leaves as well. We also observed that wild strawberry (*Fragaria* spp.) showed reddening of veins (Photo 10), bunchberry was reddened but not killed (this matches NBDAAF (2017) which states that when applied too late, bunchberry is reddened throughout the season and control is reduced), and lambkill (*Kalmia angustifolia*) had apical twisting (Photo 11).

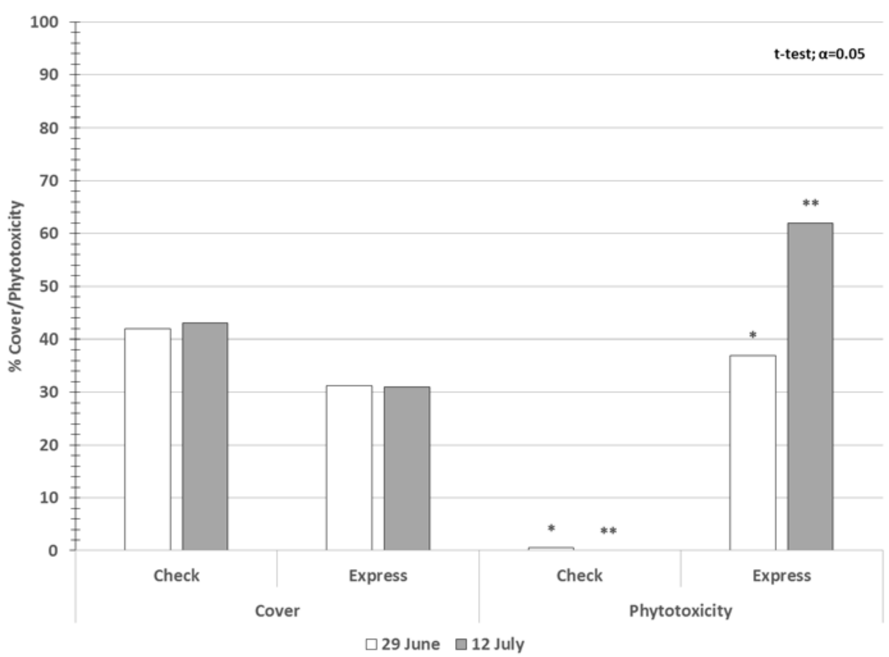


**Figure 5.** Whorled loosestrife cover and phytotoxicity following post-emergence Express spot treatment (α=0.05).

**Photo 8.** Whorled loosestrife injury in July, showing necrosis of upper leaves/stem and chlorosis of lower leaves.

**Photo 9.** An example of an untreated whorled loosestrife plot in July.

**Photo 10.** Symptoms of Express injury on wild strawberry in June.

**Photo 11.** Symptoms of Express injury on whorled loosestrife (yellowed plants), bunchberry and lambkill (taller green plants to left) in July.

**CONCLUSIONS AND RECOMMENDATIONS:** Because both cow vetch and lance-leaved goldenrod occurred in bare areas, wild blueberry yield effects could not reliably be determined and so the trial was terminated in fall 2018. Express was most effective on whorled loosestrife and least effective on lance-leaved goldenrod. Injury to the target weed was highest in the whorled loosestrife trial at 62% in July, compared to 41% in cow vetch and 30% in lance-leaved goldenrod. Injury symptoms were more severe over the entire loosestrife plant by July compared to cow vetch, which still had plenty of green unaffected tissue in July, and lance-leaved goldenrod, which had dead tops and slightly affected lower leaves. We expect that the whorled loosestrife was too damaged to recover, but both whorled loosestrife and cow vetch had naturally senesced by fall 2018 so we do not yet know if complete control of loosestrife will occur next year. The trial site will be examined visually in spring 2019 to determine if carryover effects are visible.

Therefore, if the label change discussed in the Express bunchberry trial allows for it, Express could be used as a post-emergence spot spray for whorled loosestrife control and control of the closely related yellow loosestrife listed in NDBAAF (2017). According to the stunting and lack of flowering observed in 2018, Express may be more effective on cow vetch if applied earlier to small plants. Express could also be used as spot spray on lance-leaved goldenrod and other goldenrods on a case-by-case basis; not all species will react the same so Express will have to be tested on a small area of the target goldenrod. Express may not kill the entire goldenrod plant, but it will kill the tops which will reduce height and prevent flowering.

Finally, the effects on non-target weeds such as red sorrel, wild strawberry and lambkill suggest that Express may be effective on them as well. Other species such as raspberry (*Rubus* spp.), common cinquefoil (*Potentilla simplex*), orange-grass St. Johnswort and bladder campion (*Silene vulgaris*) appeared unaffected, so control of weeds will have to be assessed on a case-by-case basis.

**LITERATURE CITED:**

NBDAAF. 2017. Wild Blueberry IPM Weed Management Guide. New Brunswick Department of Agriculture, Aquaculture and Fisheries Wild Blueberry Fact Sheet C.4.2.0. pp. 22-23.

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**WEED MANAGEMENT**

**INVESTIGATORS:** David E. Yarborough, Professor of Horticulture
Jennifer L. D’Appollonio, Assistant Scientist

**12. TITLE:** Crop year application of Select Max for grass control in wild blueberry fields.

**METHODS**: In 2017, Valent put out a supplemental label to allow for a crop year post-emergence application of Select Max on wild blueberry (expires 2 May 2019). The supplemental label lists a 45 day PHI (post-harvest interval) and states that the grower should verify crop tolerance by testing on a small area and monitoring for seven days before applying the same rate and NIS to the entire field. Therefore, we set up a trial at Blueberry Hill Farm in Jonesboro to compare crop year Select Max (clethodim) application with Poast (sethoxydim), a product currently registered for post-emergence grass control in the crop year. The trial was set up as a partially Randomized Complete Block Design with six replicates of 6' by 40' plots containing: 1. An untreated check, 2. Select Max 16 oz/a + NIS 0.25% v/v, and 3. Poast 2.5 pt/a + COC 2 pt/a. The blocks were partially randomized in that in each block, the Select Max and Poast plots were situated next to each other to facilitate direct comparison. The herbicide treatments were sprayed twice on 11 and 26 June 2018, and were evaluated for wild blueberry cover and phytotoxicity, broadleaf weed cover and grass cover on 9 and 19 July. Cover data were determined by using the Daubenmire Cover Scale converted to percent. T-tests were performed on cover data for significant treatment differences, Bonferroni adjusted to $\alpha$=0.0167. Yields were not assessed for this trial (see Results and Discussion), but a 1-gallon Ziploc bag sample was collected for MRL testing by Wyman's at a 45 day PHI.

**RESULTS AND DISCUSSION:** There were no significant differences among treatments at either evaluation. Wild blueberry cover fell slightly in all treatments from the first to second evaluation, but phytotoxicity was negligible (Figure 1). It should be noted that at the first evaluation, Poast treatment resulted in significantly more phytotoxicity compared to the check only ($\alpha$=0.0172), but at 2% injury it was well within acceptable limits.

Grass cover was initially reduced in both herbicide treatments, but slightly more so by Poast than Select Max (Figure 2). Grass cover also decreased from the first to second evaluation, but grass cover was within 5% of each other at the second evaluation with Select Max within 1% of the untreated check. Grass cover was predominantly prairie cordgrass (*Spartina pectinata*) and Kentucky bluegrass (*Poa pratensis*), with some Canada bluegrass (*Poa compressa*), wild oatgrass (*Danthonia spicata*) and quackgrass (*Elymus repens*). There was also initially lower broadleaf weed cover in the herbicide treatments compared to the check, but by the second evaluation Select Max and the untreated check were within 2% of each other, while Poast had more broadleaf weeds than the check (Figure 2). This is likely why wild blueberry cover decreased from the first to second evaluation. The trial area was dominated by large weeds such as prairie cordgrass, St. Johnswort (*Hypericum perforatum*), goldenrods (*Solidago* spp.), brackenfern (*Pteridium aquilinum*) and spreading dogbane (*Apocynum androsaemifolium*), all of which can form a tall dense canopy and shade or crowd out blueberry. It was also observed that the prairie cordgrass in the treated plots had reddened leaves (Photo 1) and did not flower, while those plants in the check and elsewhere were flowering by 19 July. Poast also provided some suppression of prairie cordgrass, although it appeared to be inconsistent; in some cases cover was reduced (Photo 2), while in other cases the leaves were merely reddened as in the Select Max treatment.

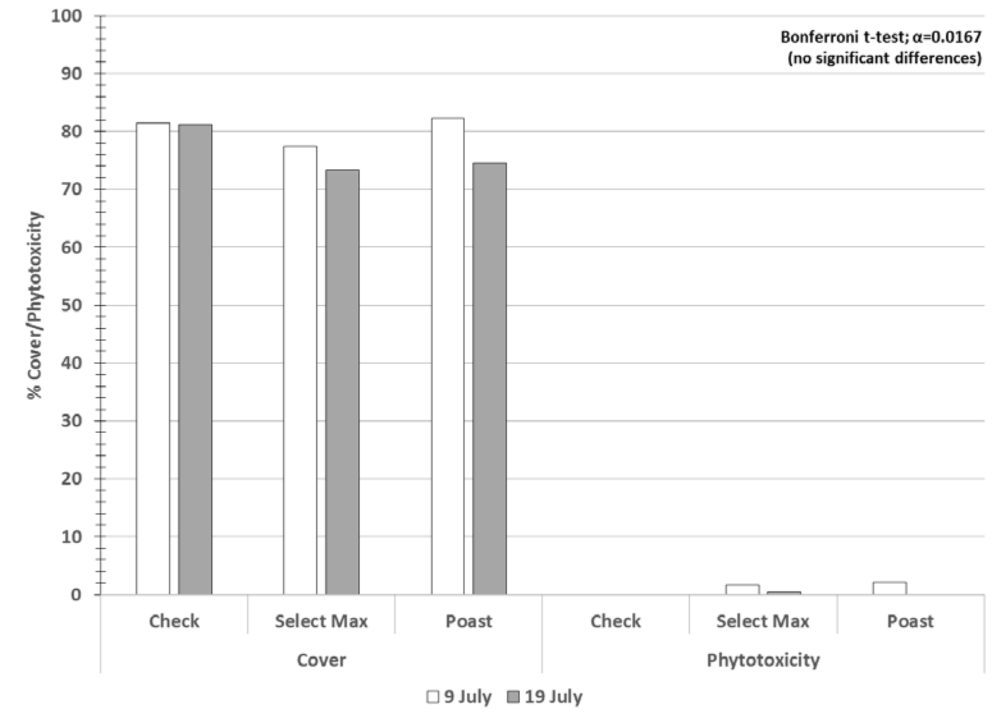


**Figure 1.** Wild blueberry cover and phytotoxicity following post-emergence crop year application of Select Max and Poast (α=0.0167).

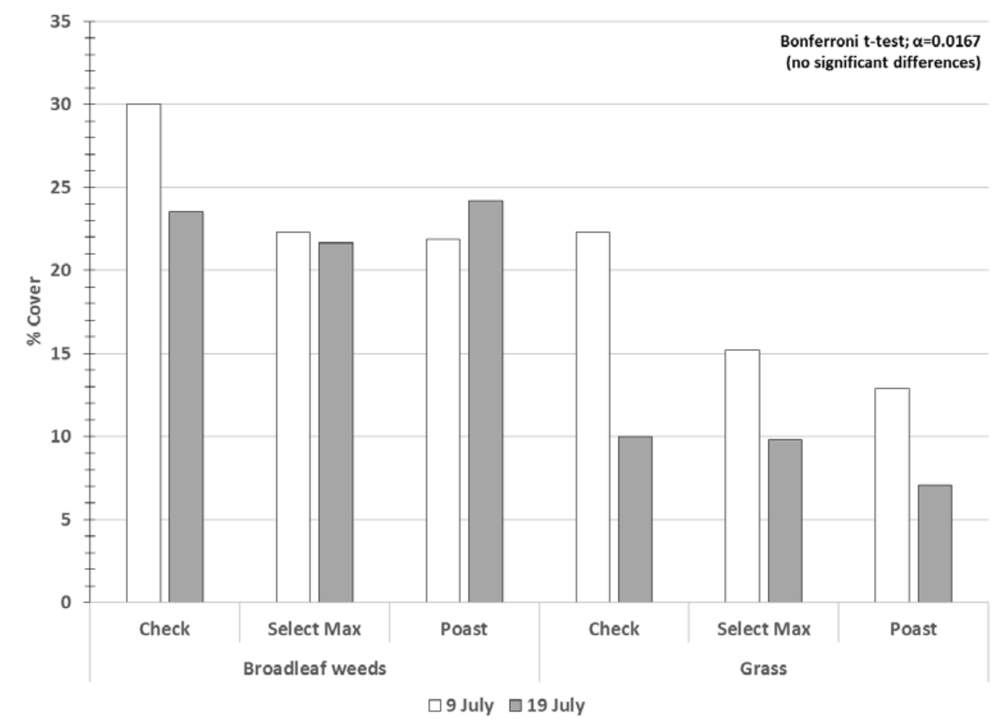


**Figure 2.** Broadleaf weed and grass cover following post-emergence crop year application of Select Max and Poast (α=0.0167).

**Photo 1**. Prairie cordgrass in a Select Max plot (R) versus outside the plot (L) on 9 July. Note reddening of treated leaves.

**Photo 2.** Prairie cordgrass in a Poast plot (R) versus outside the plot (L) on 9 July. Note reduction in cover.

**Photo 3.** A Select Max plot on 19 July just prior to harvest, showing large, dense and/or woody weed cover across the trial area.

By harvest time, no differences among treatments in either the blueberry plants or the amount of berries could be differentiated by the naked eye. There were so many tall/dense/woody weeds present that harvest would have been physically difficult, and it would have been impossible to separate yield herbicide treatment differences from weed competition effects (Photo 3). Therefore, yields were not assessed for this trial and it was determined that in this trial, Select Max yield effects would be comparable to Poast pursuant to visual inspection. Wyman's tested the Select Max berries for MRLs at the 45 day PHI listed on the label. They determined that when run on their processing lines and analyzed by their 3rd party lab, the results were favorable for sales to their specific markets, as some countries have unattainable tolerances. See below for recommendations.

**CONCLUSIONS AND RECOMMENDATIONS:** Crop year Select Max application was comparable to Poast in its effects on wild blueberry and weeds. The inability to harvest due to an overabundance of broadleaf weeds confirms that in order to get the full benefit of a post-emergence grass herbicide, broadleaf weed control must also be performed, which was not done in this trial. If Valent extends the supplemental label beyond May 2019, Select Max crop year use is recommended as long as broadleaf weed control is also performed. It should be noted that just as the supplemental Select Max label states that growers must test the herbicide for efficacy and crop injury on a small area before spraying an entire field, growers should also check with their processors to ensure that Select Max, at the 45 day PHI and/or >45 day PHI chosen to target certain markets, is approved for use by the processor before using it in the crop year. The processor should test for residues to determine if they fit MRLs for the countries they wish to sell to, from fruit obtained on their own processing line.

Prairie cordgrass is a native species not historically seen in wild blueberry, but in the past decade it has been observed "traveling" along wet roadside ditches from the Ellsworth area along Route 1 heading Downeast, and it can spread into wild blueberry fields from the ditches (as it has been in Blueberry Hill Farm's upper field for several years). It is a tall (6-8') perennial grass with rhizomes that can grow 5-10' per year and it can form dense stands (USDA NRCS 2006). It is usually found on poorly drained soils, but can live on seasonally drier sites as well. It is reduced in vigor by repeated mowing in one growing season, so multiple post-emergence applications of Select Max and Poast may be effective as a "chemical mowing" treatment on prairie cordgrass if it becomes problematic (see Photos 1-2 for effects after two applications).

**LITERATURE CITED:**

USDA NRCS Plant Materials Program and Bush, T. 2006. Plant Fact Sheet – Prairie Cordgrass *Spartina pectinata* Bosc ex Link. https://plants.usda.gov/factsheet/pdf/fs_sppe.pdf

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**WEED MANAGEMENT**

**INVESTIGATORS:** David E. Yarborough, Professor of Horticulture
Jennifer L. D'Appollonio, Assistant Scientist

**13. TITLE:** Evaluation of Zeus Prime XC fall application for control of poison ivy in wild blueberry fields.

**METHODS**: Poison ivy (*Toxicodendron radicans*) is not currently a major or chronic weed in wild blueberry fields, but its range has spread north in recent years and it is now found in wild blueberry growing regions where it previously did not exist. Areas infested with poison ivy cannot be harvested, because the oils can get onto the machinery and fruit and contaminate the berries. Wyman's of Maine had an infestation of poison ivy creeping into their EO Morse 6 field from a fire line on the field edge; they asked us to test Zeus Prime XC on it to determine if Zeus is effective on poison ivy because it was listed on the label as one of the weeds controlled. Therefore, a demonstration trial was set up in late September 2017. Eight 6' x 20' plots were staked on EO Morse 6 in the crop year after harvest, wild blueberry and poison ivy cover were assessed prior to flail mowing, and the four plots with the most poison ivy cover were treated with Zeus 15.2 oz/a on 15 November 2017. The stakes were marked with orange paint and pounded into the ground to just below the surface so that they would not be destroyed by flail mowing, and the plot corners were triangulated from markers along the adjacent fire line so that the plots could be re-staked in spring 2018.

Wild blueberry cover and phytotoxicity, poison ivy cover and phytotoxicity, broadleaf weed cover and grass cover were evaluated on 27 June 2018. Cover data were determined by using the Daubenmire Cover Scale converted to percent; phytotoxicity was assessed by using a scale of 0-10 (0=no damage, 10=100% damaged/dead) converted to percent.  T-tests were conducted for significant treatment differences (α=0.05).

**RESULTS AND DISCUSSION:** There were no significant differences between the check and Zeus treatment for wild blueberry, poison ivy, broadleaf weed or grass cover, and no differences in wild blueberry or poison ivy phytotoxicity (Figures 1-3). There was no injury to wild blueberry from Zeus application (Figure 1), but there was also very little injury to poison ivy (Figure 2). In this trial, Zeus decreased other broadleaf weeds slightly compared to the check but did not decrease grasses (Figure 3). Broadleaf weeds consisted of red sorrel (*Rumex acetosella*), spreading dogbane (*Apocynum androsaemifolium*) and yellow loosestrife (*Lysimachia terrestris*), and the only grass present was wild oatgrass (*Danthonia spicata*). Red sorrel, dogbane and wild oatgrass are problem weeds in wild blueberry; a separate trial investigating Zeus on red sorrel found that it suppressed both red sorrel and wild oatgrass, but they were controlled better long-term over the crop cycle by spring application than fall application.

After the June evaluation, we were contacted by the company because the Zeus had not effectively controlled the poison ivy and it was creeping further into the field, and they wanted to spray it with a product known to kill it before the infestation progressed. Therefore, the demonstration trial was terminated after the first evaluation.

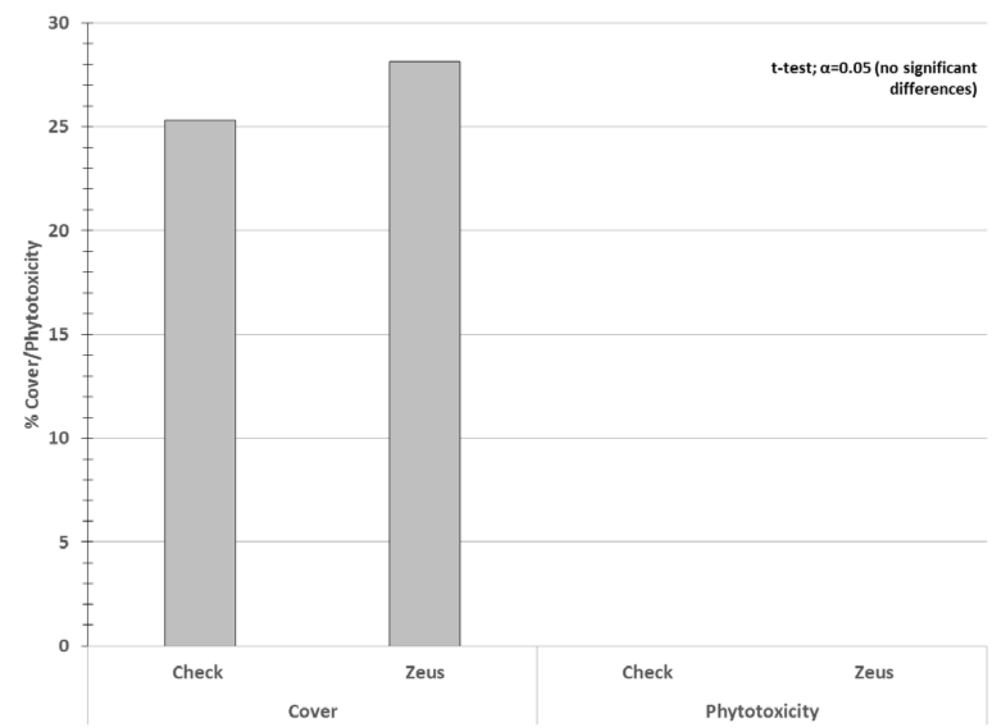


**Figure 1.** Wild blueberry cover and phytotoxicity in the prune year, following a fall post-pruning application of Zeus Prime XC.

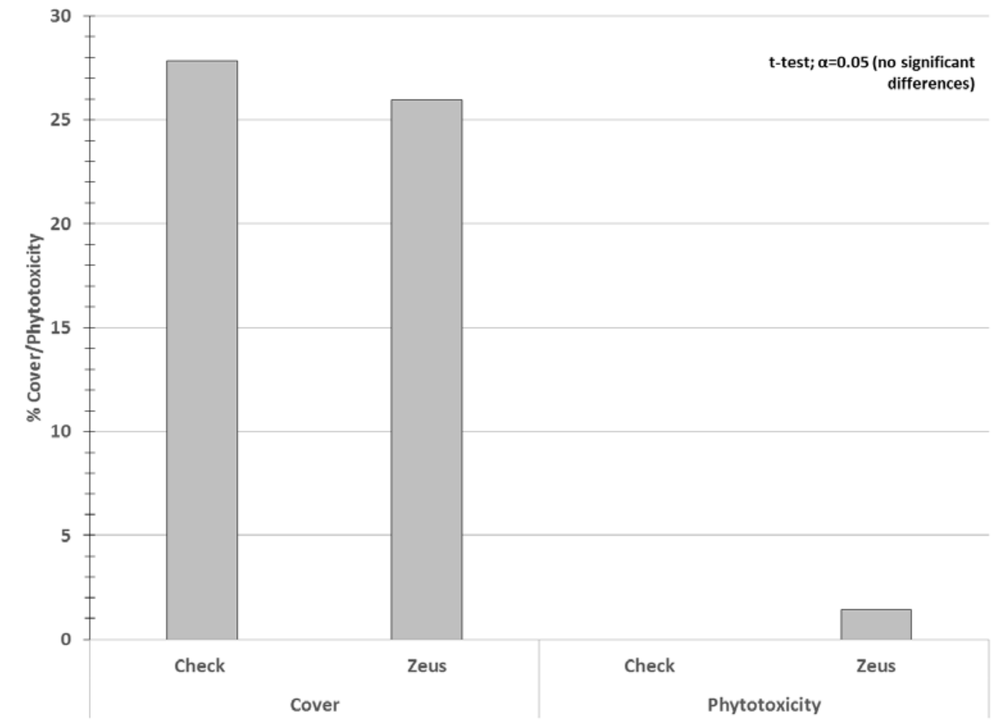


**Figure 2.** Poison ivy cover and phytotoxicity in the prune year, following a fall post-pruning application of Zeus Prime XC.

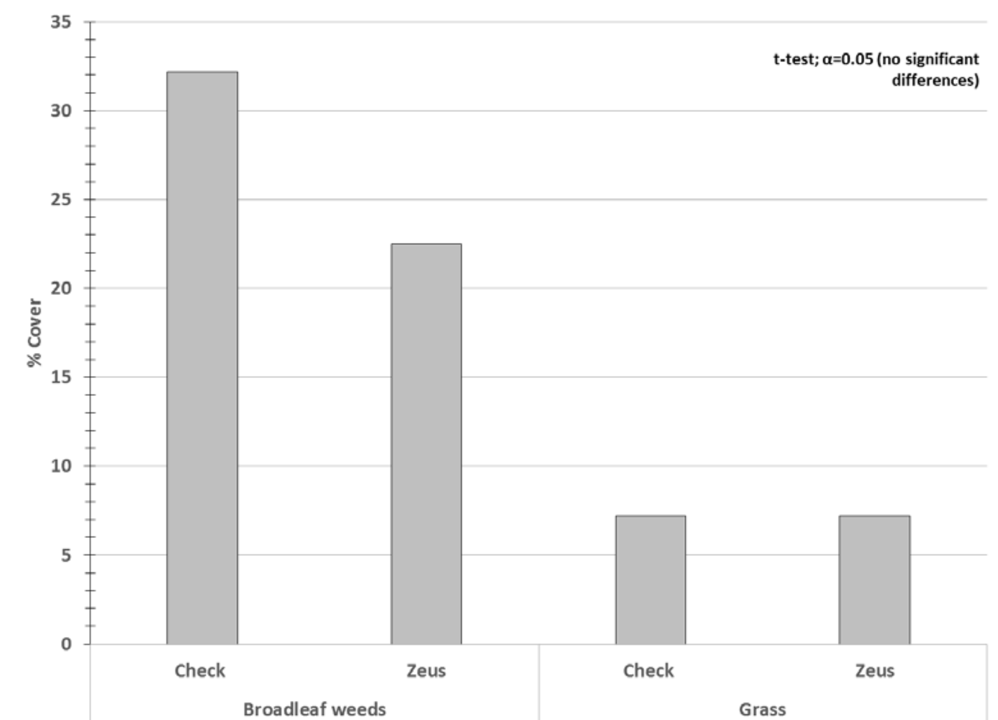


**Figure 3.** Broadleaf weed and grass cover in the prune year, following a fall post-pruning application of Zeus Prime XC.

**CONCLUSIONS AND RECOMMENDATIONS:** A fall application of Zeus did not effectively control poison ivy or other weeds in this trial. The latter conclusion supports the conclusions in the 2017-19 Fall Zeus Trial (Report No. 8). Zeus Prime XC, applied in the fall, is not recommended for poison ivy control.

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**WEED MANAGEMENT**

**INVESTIGATORS:** David E. Yarborough, Professor of Horticulture
Jennifer L. D'Appollonio, Assistant Scientist

**14. TITLE:** Evaluation of post-emergence Mission application on control of fineleaf sheep fescue (*Festuca filiformis*) in wild blueberry fields.

**METHODS**: Fineleaf sheep fescue (*Festuca filiformis*) is a problematic grass species in wild blueberry. It is a perennial bunch grass with a vigorous root system, and some populations have become resistant to commonly used herbicides. Previous research on herbicides such as foramsulfuron, linuron, rimsulfuron, clethodim and pronamide showed that: linuron, clethodim and spring pronamide were not effective on fescue (linuron reduced flowering height but didn't control the grass); and foramsulfuron exhibited good control but should not be used in a field with many broadleaf weeds. A fall pronamide or pre-emergence rimsulfuron application gave the most effective control of resistant fescue, but the rimsulfuron released certain other broadleaf weeds such as violets. In 2017 we received a request from the Advisory Committee to evaluate the effects of Mission (flazasulfuron) on wild blueberry and fineleaf sheep fescue. Mission is not labeled for any crops in the Eastern U.S., so this would have been a new crop use.

In spring 2018, a wild blueberry prune year field containing large amounts of fineleaf sheep fescue was located on Cherryfield Foods land in the T 25 Barrens. A trial was set up in a Randomized Complete Block Design with 6' x 40' plots and 6' alleys between blocks. Treatments consisted of an untreated check and Mission 2.8 oz/a + 0.25% v/v NIS applied post-emergence on 12 June 2018. Wild blueberry cover and phytotoxicity, fescue cover and phytotoxicity, broadleaf weed cover and grass cover was evaluated on 27 June and 11 July. Cover data were determined by using the Daubenmire Cover Scale converted to percent; phytotoxicity was assessed by using a scale of 0-10 (0=no damage, 10=100% damaged/dead) converted to percent. T-tests were conducted for significant treatment differences ($\alpha$=0.05).

**RESULTS AND DISCUSSION:** There was no significant difference in wild blueberry cover in June, but phytotoxicity was significantly higher in the Mission treatment (Figure 1). There was a background level of blueberry injury, due to CFF's Callisto application shortly prior to trial set-up; the injury expressed as minor chlorosis and disappeared from the untreated check plots by July. The blueberry plants in the Mission treatment were severely injured; plants were delayed filling in and there was extensive leaf reddening, necrosis and leaf drop (Photos 1-3). The injury was severe enough that at the July evaluation, although cover in the check increased, cover in the Mission treatment decreased and was significantly lower than the check. Blueberry injury also increased from June to July; plants in the Mission treatment barely grew in height or filled in (Photo 4).

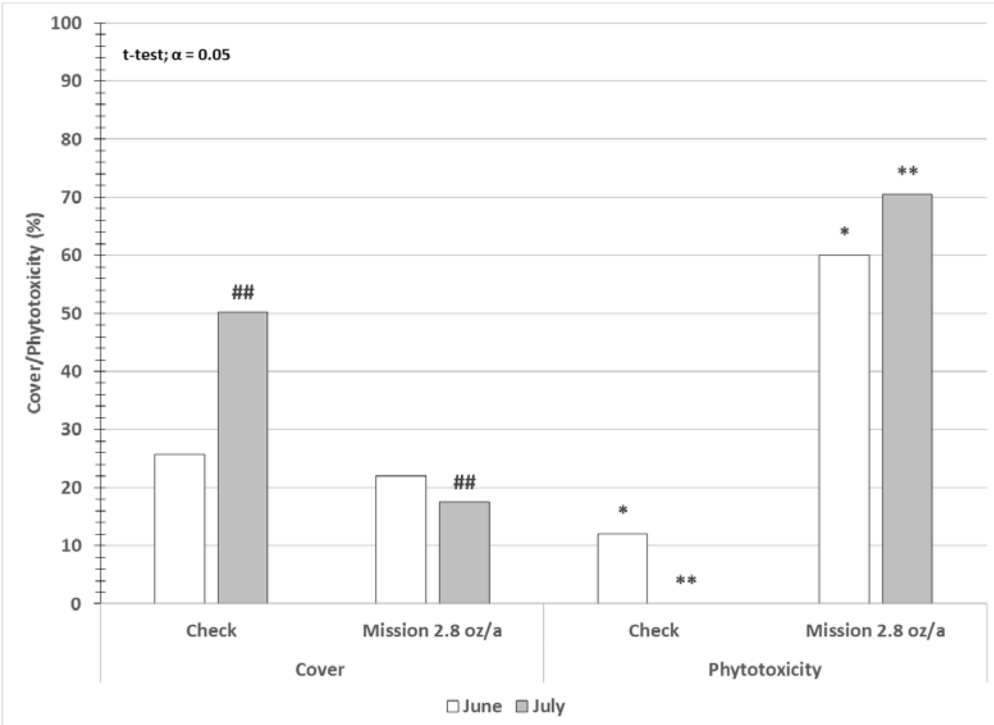


**Figure 1**. Wild blueberry cover and phytotoxicity in the Mission treatment versus the untreated check (α=0.05).

**Photo 1**. Wild blueberry phytotoxicity as chlorosis in the untreated check in June, from CFF's Callisto application.

**Photo 2.** Wild blueberry phytotoxicity in the Mission treatment in June; note reddening, necrosis, leaf drop and delay in filling in.

**Photo 3**. Wild blueberry cover at the June evaluation – Mission is on the left and the untreated check is on the right.

**Photo 4.** Wild blueberry phytotoxicity in the Mission treatment at the July evaluation (inside plot to left).

In June, fescue cover was comparable in both treatments; there was minor chlorosis in the check from CFF's Callisto treatment, but significantly more phytotoxicity in the Mission treatment (Figure 2). In July, fescue cover remained about constant but there were many more dead fescue leaves in both treatments, although Mission injury remained significantly higher than the check. In July, all fescue inflorescences had senesced and gone to seed. In the check, most of the leaves were green; in the Mission treatment, leaves were mostly dead on mature plants, but new small tufts that emerged after the application were green (Photos 5-7). We know from White 2018 that fresh fineleaf sheep fescue seeds lack dormancy and germinate readily in the spring and fall, so the small tufts were likely recently germinated plants from seeds dropped from the mature plants.

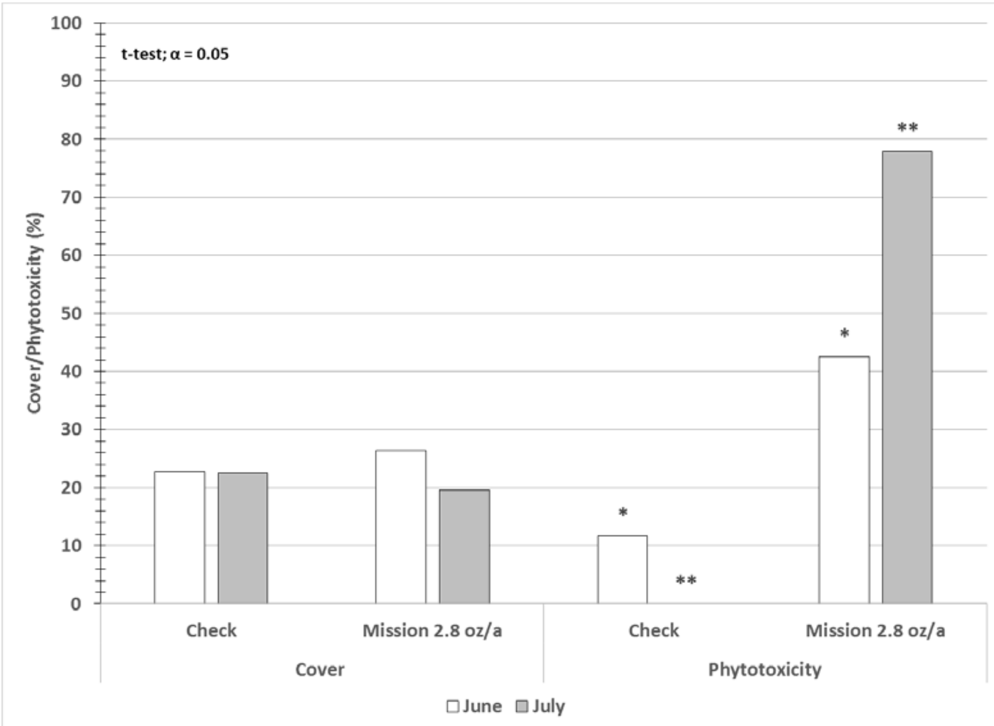


**Figure 2.** Fineleaf sheep fescue cover and phytotoxicity in the Mission treatment versus the untreated check (α=0.05).

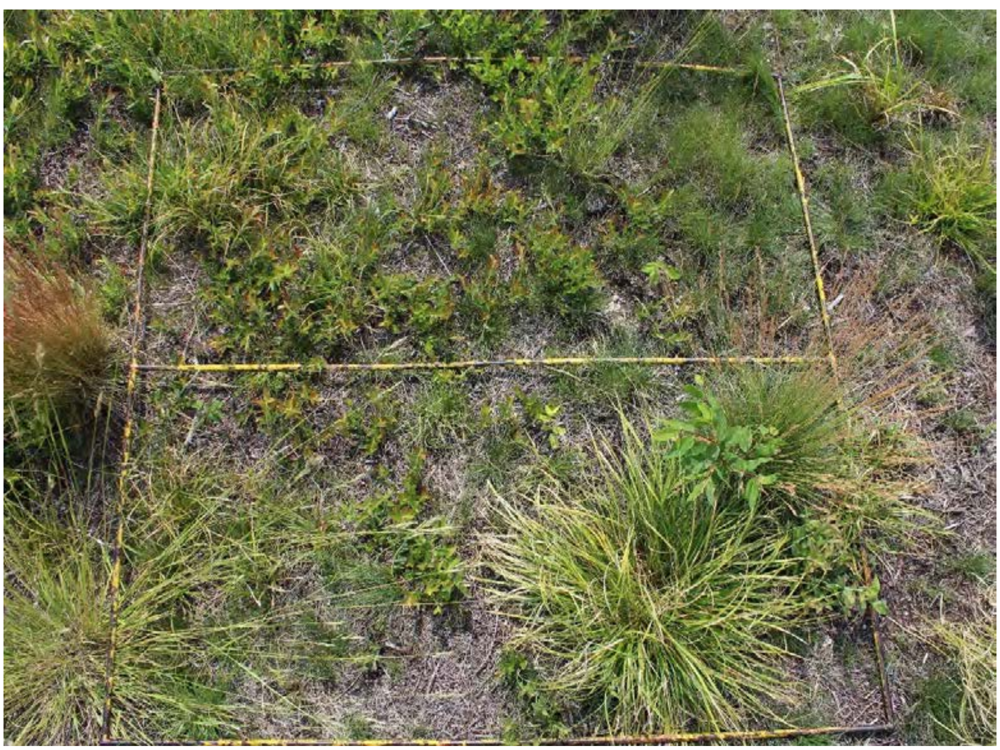

**Photo 5.** Untreated check plot at the July evaluation; note green mature fineleaf sheep fescue tuft with senesced inflorescences (lower right) and new small tufts throughout plot.

**Photo 6.** Fescue tuft in the Mission treatment at the July evaluation; note dead and green leaves.

**Photo 7.** Treated (L) versus untreated (R) plots at the July evaluation. Note dead and injured tufts in treated plot vs green tufts to right, with small new tufts in the foreground.

**CONCLUSIONS:** After the July evaluation it was clear that post-emergence Mission application resulted in unacceptable long-term injury to wild blueberry, and the level of fescue control was not good enough to justify the crop injury. Therefore, the trial was terminated after the July evaluation and will not be carried over into the crop year.

**RECOMMENDATIONS**: Mission is not recommended for use on wild blueberry. If flazasulfuron is ever registered in Maine, it may be worth it to investigate efficacy on red sorrel in problem areas not containing wild blueberry (e.g. spot treatment on large bare spots, as red sorrel tends to establish in bare areas and creep into wild blueberry stands).

**LITERATURE CITED:**

White, S.N. 2018. Determination of *Festuca filiformis* seedbank characteristics, seedling emergence and herbicide susceptibility to aid management in lowbush blueberry (*Vaccinium angustifolium*). *Weed Research* 58:112-120.

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**EXTENSION**

**INVESTIGATOR:** David E. Yarborough, Extension Blueberry Specialist

**15. TITLE**: Wild Blueberry Extension Education Program in 2018.

**OBJECTIVE**: To provide educational programing to bring research based knowledge to wild blueberry growers in Maine. To collaborate with Canadian researchers and to provide relevant information to Maine growers.

**METHODS**: Conduct an educational program that will stress the use of best management practices in an integrated crop management program, which will improve the efficiency of culture and minimize the use of unnecessary pesticides and fertilizers. Conduct spring grower meetings and field days to introduce and reinforce the use of best management practices, integrated crop management and sound business management principles. Provide management information through the Wild blueberry newsletters, fact sheets in the wild blueberry grower's guide both in print form and on the web at http://extension.umaine.edu/blueberries/, through telephone and correspondence, and conduct field visits as appropriate. Cooperate with the Wild Blueberry Advisory Committee Research, the Wild Blueberry Commission of Maine and the Wild Blueberry Association of North America on blueberry related matters. Cooperate with county (Soil and Water Conservation Districts), state (Department of Agriculture, Conservation and Forestry, the Board of Pesticides Control) and federal agencies (USDA, IR-4) on wild blueberry related matters. Needs are determined from the Wild Blueberry Advisory Committee Research and Extension priorities, Wild Blueberry Newsletter surveys, and from individual client contacts. The advisory committee gave priority to grower outreach, IPM, pesticide recommendations for weeds, insects and diseases, food safety and groundwater. Needs identified by the survey include weed management, economics/marketing, pest management, general information and fertilization. Needs identified by individual grower contact reinforce those previously identified, but also added was the need to evaluate cost effectiveness of crop inputs to manage fields with the current low prices.

**RESULTS:**

*Meetings attended:*

Northeastern Plant Pest and Soils Conference, Philadelphia, PA. January 9-11, 2018.

Organic Wild Blueberry Field Day, Chesterville, ME. July 16, 2018.

Wild Blueberry Producers of Nova Scotia Summer Meeting, Parsboro, NS. July 12, 2018.

Wild Blueberry Summer Field Day & Meeting, Jonesboro, ME. July 18, 2018.

North American Blueberry Research and Extension Workers Meeting, Orono, ME. August 12-15, 2018.

Wild Blueberry Association of North America Annual Meeting, Fredericton, NB. October 10-12, 2018.

Annual Meeting of the Wild Blueberry Producers Association of Nova Scotia, Truro, NS. November 15-16, 2018.

Wild Blueberry Production for Maine Agriculture in the Classroom blueberry taste test at McGraw Elementary, Hampden and Newburgh Elementary, Newburgh, December 13, 2018.

*Presentations:*

Comparisons of pre-emergence applications of sulfentrazone, carfentrazone and glufosinate for weed control in wild blueberry (*Vaccinium angustifolium*) fields. Northeastern Plant Pest and Soils Conference, Philadelphia, PA, January 9-11, 2018.

Wild Blueberry Overview and Wild Blueberry Production Trends 1996-2017. Maine Mobile Health Programs Group, University of Maine, Orono, ME, January 18, 2018.

Wild Blueberry Production Trends 1996-2017. PEI Blueberry Growers Association Marketing and Production Workshop, Charlottetown, PEI, January 24, 2018 (skype).

Smart Farming Opportunities for Wild Blueberries in North America. International Smart Farming Seminar, Dalhousie University, Truro, NS, March 15-16, 2018.

Blueberry crop trends 1996- 2017. Wild Blueberry Spring Meeting, Ellsworth, Waldoboro, Machias, April 3, 5, 7, 2018.

Wild Blueberry ICM Scouting Sessions, Warren, Orland and Machias, ME May 1, 2, 3, 22, 23, 24 and June, 26, 27, 28, 2018.

A Sweet Story of Maine's Wild Blueberry. St. Croix District Meeting Bar Harbor Garden Club, Northeast Harbor, ME, May 17, 2018.

Maine wild blueberry crop estimate for 2018. Wild Blueberry Producers of Nova Scotia Summer Meeting, Parsboro, NS, July 12, 2018.

Organic weed control and soil and leaf sampling. Organic Wild Blueberry Field Day, Chesterville, ME, July 16, 2018.

2018 weed management research plots and low input demonstration plot. Wild Blueberry Summer Field Day & Meeting, Jonesboro, ME. July 18, 2018.

Maine's Wild Blueberry. Ethos Eating on the Wild Side, Portland and Dresden, ME, July 31, 2018.

History of Maine's Wild Blueberry Industry. North American Blueberry Research and Extension Workers Meeting, Orono, ME, August 12-15, 2018.

Maine's Wild Blueberry. Skidompha Library Chats with Champions, Damariscotta, ME, August 21, 2018.

Wild Blueberry Pollination. NRCS farm tour, Waldoboro, ME, September 8, 2018.

Wild Blueberries in Maine. Big E, Springfield, MA, September 28-30, 2018.

Blueberry Production around the Globe and Is Climate Change Real? - The Effects of Climate Change on the Wild Blueberry. Wild Blueberry Association of North America Annual Meeting, Fredericton, NB, October 10-12, 2018.

Maine's Wild Blueberry Industry. Go Away Tours, Bar Harbor, ME, October 15, 2018.

Wild Blueberry Production. Maine Development Foundation Leadership Maine tour, Deblois, ME, October 15, 2018.

Blueberry Production around the Globe. Annual Meeting of the Wild Blueberry Producers Association of Nova Scotia, Truro, NS, November 15-16, 2018.

*Publications:*

Yarborough, D. 2019. History of Maine's Wild Blueberry Industry. Proceedings of the North American Blueberry Research and Extension Workers Meeting. DigitalCommons@Maine. *In press*.

D'Appollonio, J. and D. Yarborough. 2019. Comparison of multiple post-emergence Callisto applications for spreading dogbane (*Apocynum androsaemifolium* L.) control in wild blueberry fields. Proceedings of the North American Blueberry Research and Extension Workers Meeting. DigitalCommons@Maine. *In press.*

Yarborough, D. and J. D'Appollonio. 2019. Comparisons of pre-emergence applications of sulfentrazone, carfentrazone and glufosinate for weed control in wild blueberry (*Vaccinium angustifolium*) fields. Proceedings of Northeastern Plant Pest and Soils Conference. 3:79.

*Extension Publications:*

*Revised:*

Fact Sheet #209 2018 Insect Control Guide for Wild Blueberries
Fact Sheet #210 Spotted Wing Drosophila: Pest Biology and IPM Recommendations for Wild Blueberries
Fact Sheet #219 2018 Disease Control Guide for Wild Blueberries
Fact Sheet #224 Commercial Pollinators
Fact Sheet #239 2018 Weed Control Guide for Wild Blueberries
Fact Sheet #257 Weed Resistance Prevention Practices for Wild Blueberries
Wild Blueberry Crop Statistics web page
2018 Maine Wild Blueberry Pesticide Chart 1 of 3 Insecticides
2018 Maine Wild Blueberry Pesticide Chart 2 of 3 Fungicides
2018 Maine Wild Blueberry Pesticide Chart 3 of 3 Herbicides

*New:*
Fact Sheet #230 Management Strategies for Reduced Inputs

*Wild Blueberry Website:*

The Wild Blueberry website found at http://www.wildblueberries.maine.edu continues to be updated and is being revised to comply with the University of Maine content management system. It received 94,381 page views in 2018 and so it is well used world-wide. The wild blueberry blog is being used to update growers on current activities including insect (both pollinator and SWD), and disease (mummy berry monitoring) posts at: http://mainewildblueberries.blogspot.com/

*Other program activities:*

I am co-investigator with Seanna Annis for the SCBG project: *Optimizing Inputs for Wild Blueberry Weed and Disease Integrated Management (IPM)* (2017-2018). I am responsible for compiling the reports for the Wild Blueberry Advisory Committee, NRSP4 (IR-4 Program) for the REEport on-line database and the Extension MPRS logic model reporting system. I serve as the liaison for Maine in the IR-4, Minor Use Registration Program and convey project needs for all crops, as well as conduct trials for residue analysis. The objective of the program is to register least toxic alternative pesticides to replace materials that have been canceled so that our growers will be able to keep the minor crop production practices viable in Maine.

I serve on the peer review committee for Extension 2017-2019. I served on the graduate committees of: Tyler Case M.S. student, Major advisor Seanna Annis 2014 - 2018; and Nghi Nguyen M.S. student, Major advisor Seanna Annis 2017 – present.

**CONCLUSIONS:** Growers are participating in IPM programs in the four primary wild blueberry growing counties: Washington, Hancock, Knox and Lincoln. The skills survey results indicate that growers are learning new skills and making positive changes in their management practices. A high percentage of participating growers indicated they had learned new skills and changed their practices by rotating herbicides, thereby reducing weed resistance in wild blueberry fields. Growers are using the blight forecast provided on the Wild Blueberry Website Blog to be able to control blight more effectively with less applications, use the proper traps to detect and control insects such as the blueberry maggot fly and spotted wing drosophila and use leaf samples to determine fertilizer needs. Adoption of these management practices will enable growers to improve the efficiency of blueberry culture by reducing unnecessary pesticides and fertilizers. Developing alternative strategies for control of resistant weeds is necessary to prevent future losses in yield from weed competition. The introduction of the new pest, the spotted wing Drosophila, presents an additional challenge in monitoring, identification and control to prevent losses from this pest, but the recent development of an economic threshold will now reduce insecticide inputs. The addition of the new fact sheet *Management Strategies for Reduced Inputs* gives growers guidance to manage their fields during this time of low prices: https://extension.umaine.edu/blueberries/factsheets/production/230-management-strategies-for-reduced-inputs/.

The most recent survey conducted from the newsletter mailing list indicates that growers need the information provided by the meetings, fact sheets and newsletters. It also indicates that many growers are using integrated management techniques. Adoption of Best Management Practices will enable growers to improve the efficiency of blueberry culture by reducing unnecessary pesticides and fertilizers. More efficient management will result in greater returns and a stable, sustainable industry. In the short term, strategies to minimize costs with the current lower returns are being made. Two resources, the *Wild Blueberry Enterprise Budget* https://extension.umaine.edu/blueberries/factsheets/marketing-and-business-management/260-blueberry-enterprise-budget/ and the *Wild Blueberry Management Tool* https://extension.umaine.edu/blueberries/wp-content/uploads/sites/56/2010/06/Wild-Blueberry-Management-Tool-.xlsx provide the information needed to make informed decisions.

**RECOMMENDATIONS:** Continue to support the Extension program to provide for the continuation of research based knowledge to be delivered to wild blueberry growers in Maine. Growers benefit in maintaining efficient production practices that allow them to be competitive with cultivated and Canadian production, and the public will benefit from production practices that allow growers to produce wild blueberries at an affordable price and volume so that consumers will be able to afford to eat more healthy wild blueberries. The benefits of a healthier society are incalculable.

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**EXTENSION**

**INVESTIGATOR:** Lily Calderwood, Extension Wild Blueberry Specialist

**16. TITLE:** Lily Calderwood's Wild Blueberry Extension Program in 2018.

**OBJECTIVE:** To provide research-based education to Maine's wild blueberry growers.

**METHODS:**

- Conduct needs assessments (surveys, farm visits)
- Organize field meetings and indoor winter meetings
- Provide updated and organized research-based knowledge both on paper and online
- Seek external funding for future research and education based on needs assessment
- Connect growers and processors with each other and relevant resources

The current UMaine Extension Wild Blueberry Specialist, Dr. David Yarborough, is retiring April 30, 2019. I was hired to have a full year of overlap with him as his replacement. I shadowed Dr. Yarborough, Dr. Seanna Annis (Blueberry Plant Pathologist), and Dr. Frank Drummond (Blueberry Entomologist) through the 2018 season of field days and events to get up to speed on the crop and understand current programing. My current program goals fall into three categories: integrated pest and crop management, field perspectives on value-added products, and making resources available for aging farmers on land transfer options. Specifically, I aim to help the wild blueberry industry adapt their IPM (integrated pest management) and ICM (integrated crop management) programs to current and emerging needs. Working in partnership with stakeholders and growers, I aim to shed light on quality standards and connect growers with stakeholders for value-added products that benefit all growers and processors. I also aim to better understand the concerns of aging blueberry farmers and bring organizations in Maine together to educate wild blueberry growers on farm transfer options.

**RESULTS:**

*Workshops Held:*

- Decision Making for your Farm's Future; A Farm Succession Workshop (14 Attendees)
  Farm Succession for Wild Blueberry Growers. Machias, ME. I organized this event in collaboration with Maine Farmland Trust and Land for Good to educate the aging wild blueberry growers about the farm succession options and resources in Maine.
- Aging Blueberry Farmer Focus Group (5 Participants)
  Aging Farmer Focus Group, Bangor, ME. Dick Brzozowski received a grant to do a needs assessment of aging farmers from major commodity groups in Maine. I pulled together the wild blueberry grower focus group and attended the discussion.

*Meetings attended:*

- On-farm blueberry IPM twilight meetings (9 on Maine farms throughout the summer)
- Northeast Berry Calls (weekly spring calls with regional Extension specialists)
- Cavendish Blueberry Pesticide Credit Meeting (March 2018, Bangor, ME)
- Beginning Farmer Resource Network Meeting (May 2018, Bangor, ME)
- University of Maine Soil Health Field Day (June 2018 at Stonyvale Farm, Exeter, ME)
- University of Maine Extension Rogers Farm Day (June 2018, Old Town, ME)
- University of Maine Extension Presque Isle Field Crop Day (July 2018, Presque Isle, ME)
- Eating on the Wild Side; Blueberry Marketing and Field Walk (July 10, 2018 in Dresden, ME)
- Organic Wild Blueberry Annual Field Day (July 12, 2018 in Chesterville, ME)
- Annual Summer Blueberry Hill Farm Field Day (July 18, 2018 in Jonesboro, ME)
- Nova Scotia Wild Blueberry Field Day (July 21, 2018 in Amherst, NS)
- North American Blueberry Researchers and Extension Workers Conference (NABREW) (August 13-15, 2018 in Orono, ME)
- Wild Blueberry Association of North America (WBANA) Annual Meeting (November 2018, Fredericton, NB)
- Entomological Society of America (ESA) Annual Meeting (November 2018, Vancouver, BC)
- New England Vegetable and Berry Extension Team Meeting (December 2018, Fairlee, VT)

*Presentations:*

- **Calderwood, L.** Observations from the Field. 2018. Annual Summer Blueberry Hill Farm Field Day. Jonesboro, ME.
- **Calderwood, L.** Disease Management in Wild Blueberry. 2018. On-farm Twilight Meeting. Jonesboro, ME.
- **Calderwood, L.** Sustainable Weed Management. 2018. Maine Farm Day
- **Calderwood, L.** Wild Blueberries! 2018. Downeast Tourism Symposium; Balsam, Blueberries, and Bicycles. Machias, ME.

- **Calderwood, L.** Plant-Insect Interactions. 2018. Guest Lecture for BIO 327 Introductory Applied Entomology. Orono, ME.
- **Calderwood, L.** Wild Blueberry Production. 2018. Silvia Ross Home, Bangor ME.
- **Calderwood, L.** Kids Farm Day Wild Blueberry Booth. Windsor Fairgrounds, ME.

*Scientific Publications:* N/A

*Extension Publications:*

- Weed Management for Wild Blueberry (*revision in progress*, link has not been made yet)
- IPM Tactics to Reduce Pesticide Exposure to Honey and Native Bees. University of Maine Wild Blueberry Program for NRCS Collaboration. (Drummond, F. and L. Calderwood.) 2018. (https://extension.umaine.edu/blueberries/factsheets/bees/2009-ipm-tactics-to-reduce-pesticide-exposure-to-honey-and-native-bees/*)*

*Wild Blueberry Website:*

- My team and I regularly update the wild blueberry website which is currently undergoing the transition to a new format. (https://extension.umaine.edu/blueberries/)

*Awards:*

- University of Maine 2019 Faculty Fellow, Margaret Chase Smith Policy Center

*Grants Awarded:*

- **Calderwood, L.** Developing Precision Weed Management for Maine Wild Blueberry Production. Maine Food and Agriculture Center Research and Extension Grant. (5/1/2018-12/31/2019)

- Brzozowski, D., E. Depoy, and **L. Calderwood.** Determining the health and safety needs of farmers over 60. Northeast Center for Occupational Health and Safety. (09/1/2018-08/31/2019)

- **Calderwood, L.** Weed Management Tools for Wild Blueberry Growers in Maine. Maine Agriculture and Forest Experiment Station (MAFES). (01/01/2019-09/30/2020)

- **Calderwood, L.** Wild Blueberry Commission of Maine Grower Tax. (1/1/2019 – 11/15/2019)

- Annis, S. and **L. Calderwood**. Improving Wild Blueberry Production with IPM for Weeds and Diseases. State of Maine Specialty Crop Block Grant. (4/2019-3/2020)

- Zhang, Y., **L. Calderwood**, and S. Annis. Effects of Phenology and Fertilizer Applications on Wild Blueberry Production and Pests. State of Maine Specialty Crop Block Grant. (4/2019-3/2020)

*Other program activities*:

Needs Assessments

- 2018 Grower Needs Survey (paper and online, 63 respondents)

  Of respondents, 47% indicated that either grass or broadleaf weeds as their most challenging pest. Top 4 research interests were "Organic weed management," "native bees," "pruning method," and "value-added products." Of the respondents to my survey, 75% of growers indicated that their farm was not profitable in 2017. Seventy percent of respondents were over the age of 55 and 27.5% were over the age of 75. Forty-two percent indicated that they do not know what will happen to their farm when they are ready to stop farming.

- Organic Weed and Nutrient Management Survey (online, 27 respondents)

  Of respondents, 85% indicated organic nutrient management, and 92% indicated organic weed management as research needs.

- On-farm Visits (56 in-person visits, 42 of which were different farms)

  Approximately 80% of growers expressed an interest in changing the summer field meetings to include new information and different farms. Most aging blueberry farmers are not interested in adapting to new markets at this time. More adaptable growers are branching out into blueberry tea, dried bark, and wine. Many of the growers currently engaged in the Extension wild blueberry program are aging yet continue to farm.

**Table of Current Program Leadership**

| Educational Program and My Role | Collaborator's Name | Institution/Agency/Organization |
|---|---|---|
| Wild Blueberry ICM Program<br><br><br>*My role: Assuming Leadership* | Dr. Dave Yarborough<br>Dr. Frank Drummond<br>Dr. Seanna Annis<br>Dr. Yongjiang Zhang | Univ. of Maine Extension<br>Univ. of Maine<br>Univ. of Maine<br>Univ. of Maine |
| Berry Quality Project<br><br><br><br><br>*My role: PI on pending USDA grant* | Dr. James Meyer<br>Dr. Travis Esau<br>Dr. Beth Calder<br>Dr. Mary Camire<br>Dr. Jennifer Perry<br>Dr. Brian Perkins | Cornell Cooperative Extension<br>Dalhousie University<br>Univ. of Maine Extension<br>Univ. of Maine<br>Univ. of Maine<br>Univ. of Maine |
| Organic Weed and Nutrient Management Project<br>*My role: PI on pending USDA grant* | Dr. Seanna Annis<br>Dr. Yongjiang Zhang | Univ. of Maine<br>Univ. of Maine |
| Pollinator Protection Program Development<br><br>*My role: Co-leader* | Dr. Frank Drummond<br>Eric Venturini<br>Alice Begin | Univ. of Maine<br>NRCS Bangor/Xerces Society<br>NRCS Bangor |
| Food Safety for Wild Blueberry Processors and Growers<br>*My role: Co-leader* | Dr. Robson Machato | Univ. of Maine Extension |
| Working Group for Wild Blueberry Innovation<br>*My role: Leader/Organizer* | Bruce Hall<br>Josh Dixon | Wyman's of Maine<br>Foggy Hill Farm |
| Farm Succession for Blueberry Growers<br><br>*My role: Leader/Organizer* | Erica Buswell<br>Jo Barett<br>Severine von Tscharner Fleming | Maine Farmland Trust<br>Land for Good<br>The Greenhorns |