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2005 Wild Blueberry Project Reports

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2005 Wild Blueberry Project Reports

FOOD SCIENCE AND BIOSYSTEMS ENGINEERING

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1. TITLE: Evaluation of Emerging Disinfection Technologies for Wild Blueberry Processing

METHODS: Last year the major microbial species associated with wild lowbush blueberries were isolated and identified. Two species (*Enterobacter agglomerans* and *Pseudomonas fluorescens*) were found to comprise over 90% of the natural flora associated with wild lowbush blueberries. These two field isolates were used to determine the effectiveness of emerging disinfection technologies. Hydrogen peroxide is classified by the U.S. Food and Drug Administration as Generally Recognized as Safe (GRAS) for certain specified food applications (21CFR184.1366). A recent action by the U.S. Environmental Protection Agency exempts use of $\leq$ 1% hydrogen peroxide applied to all post-harvest agricultural food commodities from the requirement of a tolerance (40CFR180.1197). Therefore, if a treatment containing 1% hydrogen peroxide proved to be efficacious in inactivating surface microorganisms and human pathogens on lowbush blueberries, post-harvest applications of hydrogen peroxide would be beneficial to the blueberry industry in improving product quality. Additionally, several studies have reported that applications of hydrogen peroxide and hydrogen peroxyacetic acid are capable of reducing certain pesticides and chemical residues in solution; therefore, if hydrogen peroxide treatments are capable of reducing residual phosmet, blueberry processors in Maine would further benefit from this combination approach to improving product quality. Ozone has been given GRAS status by the FDA since no residual ozone is found on produce following treatment. Organic blueberries were used for all of these studies. For the pesticide residue study blueberries were sprayed with 46.25ppm Imidan 2.5EC prior to processing. For the microbiological study blueberries were inoculated with 10^7cfu/g of the field isolates prior to processing. All processing was performed on equipment designed by Dr. Russ Hazen using the Pilot Plant facilities in the Department of Food Science & Human Nutrition at the University of Maine. Contact time was 60 sec for the pesticide experiments and 60 and 120 sec for the microbiological studies except for the combination treatments where times were 60 sec. for each treatment. In addition to hydrogen peroxide and ozone, chlorine, UV, plant water and combination treatments were evaluated. All samples in the pesticide study were extracted by an internally validated laboratory protocol and were analyzed using a gas chromatograph equipped with an atomic emission detector (GC/AED). Samples of 50 g were taken initially and after each processing step. Survival of *Enterobacter agglomerans* and *Pseudomonas fluorescens* was determined by plating on MacConkey Agar and Pseudomonas Isolation agar, respectively.

All tests and treatments were performed in triplicate and plated in duplicate.

RESULTS: Results of experiments examining the effect of treatment on residual Imidan 2.5EC have proved interesting. The greatest reduction in residual pesticide levels occurred with 1ppm O_3 after a 60 sec contact time (Table 1). Chlorine at 100ppm was the second most effective treatment following a 60 sec contact time (Table 1). Overall reductions ranged from 9.78% for plant water to 57.65% for O_3. Field samples sprayed with a wetable powder formulation are currently being analyzed.

Results from the microbiological inoculation studies are shown in Tables 2 thru 5. Hydrogen peroxide at 1% and ozone at 1 ppm resulted in a greater than 2-log reduction in *Enterobacter agglomerans* and *Pseudomonas fluorescens*. A contact time of 120 sec didn't result in a greater destruction of these bacteria. Combination treatments were not significantly better than hydrogen peroxide or ozone by themselves. All spray treatments applied this year were conducted using the spray/conveyor system. This equipment allowed researchers to apply treatment volumes in a manner similar to current industrial processes. The use of this equipment further validates the results of the study should the industry begin using hydrogen peroxide or ozone in postharvest processing facilities. Incorporation of this technology should take place without extensive alterations to existing processing lines.

As governmental agencies such as the FDA Center for Food Safety and Applied Nutrition continue to mandate action plans to minimize foodborne illness, the validation of hydrogen peroxide's and or ozone's antimicrobial activity when applied to lowbush blueberries illustrates maximum progress towards this goal. The antimicrobial effectiveness of UV alone again showed promise for use in the fresh pack market. On individual samples treated with UV for 60 or 120 seconds, reductions in *Enterobacter agglomerans* and *Pseudomonas fluorescens* were between 1.2 and 1.4 logs. Since log reductions were achieved without the addition of any liquid treatment to the samples, this treatment shows potential for use on fresh pack blueberries. Furthermore, it was observed that the bloom on all UV-treated berries remained intact throughout treatment and storage. Mineralization studies are currently in progress in order to determine if the microflora associated with lowbush blueberries can reduce pesticide residues by using them as a nutrient source.

RECOMMENDATIONS: Based on just the microbiological data, it appears that hydrogen peroxide or ozone could be an effective agent in reducing the microbial load on wild blueberries. Given that the normal microbial level on lowbush blueberries is 10^3 to 10^4, a 2 to 2.5 log reduction will significantly reduce the microbial population on the fruit. Commercial ozone generating equipment may also prove of use in the generation of both aqueous and gaseous ozone for treating berries for the frozen and fresh markets, respectively. The selection of hydrogen peroxide or ozone should be based on economics. For ozone, there would be a capital expenditure for the equipment while for hydrogen peroxide there is the recurring cost of the chemical. Research with gaseous ozone will require designing and building a treatment chamber to fit over the conveyor system. This project has been put on hold until we have a pilot plant manager.

Table 1
Crop Year 2005 Pesticide Results: Organic Blueberries Sprayed with 46.25ppm Imidan 2.5EC

Reported as parts per million (mg/L) phosmet remaining following postharvest treatment

	Mean ppm	**Mean % Reduction**
Control – 60 Sec	**44.25 ± 2.56**	
100ppm Cl_2	23.85 ± 1.29	46.05
1% H_2O_2	32.23 ± 5.43	23.22
1% H_2O_2/UV	37.28 ± 4.44	13.70
100ppm Cl_2/UV	31.98 ± 4.80	27.68
Plant Water	39.90 ± 2.38	9.78
1ppm O_3	18.71 ± 5.57	57.65
UV	30.42 ± 6.65	31.18
1ppm O_3/1% H_2O_2/UV (60sec each)	25.15 ± 2.62	39.40

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Table 2
Crop Year 2005 Microbial Results: Organic Blueberries Inoculated with *Enterobacter agglomerans* (field isolate)

Reported as Log CFU/g[z] (Mean ± SD) and Log Reduction[y] Following Treatment Application

	Mean Log CFU/g	**Mean Log Reduction**
Control – 60 Sec	**7.22 ± 0.01**	
100ppm Cl_2	6.09 ± 0.11	1.13
1% H_2O_2	5.11 ± 0.16	2.11
1% H_2O_2/UV	4.92 ± 0.24	2.30
Cl_2/UV	5.74 ± 0.19	1.48
Plant Water	6.06 ± 0.23	1.16
1ppm O_3	5.07 ± 0.09	2.15
UV	5.93 ± 0.08	1.29
1ppm O_3/1% H_2O_2/UV (60sec each)	4.88 ± 0.05	2.34

[z] Treatments were performed in triplicate and plated in duplicate. All values obtained from analysis were converted to log CFU/g blueberries.

[y] Log reduction is the difference between microbial counts before and after treatment.

Table 3
Crop Year 2005 Microbial Results: Organic Blueberries Inoculated with *Enterobacter agglomerans* (field isolate)

Reported as Log CFU/g[z] (Mean ± SD) and Log Reduction[y] Following Treatment Application

	Mean Log CFU/g	**Mean Log Reduction**
Control – 120 Sec	**7.22 ± 0.01**	
100ppm Cl_2	6.00 ± 0.09	1.22
1% H_2O_2	4.68 ± 0.68	2.54
1% H_2O_2/UV	5.05 ± 0.27	2.17
Cl_2/UV	6.27 ± 0.01	0.95
Plant Water	6.12 ± 0.15	1.10
1ppm O_3	4.87 ± 0.22	2.35
UV	6.07 ± 0.15	1.15
1ppm O_3/1% H_2O_2/UV (60sec each)	5.00 ± 0.04	2.22

[z] Treatments were performed in triplicate and plated in duplicate. All values obtained from analysis were converted to log CFU/g blueberries.

[y] Log reduction is the difference between microbial counts before and after treatment.

Table 4
Crop Year 2005 Microbial Results: Organic Blueberries Inoculated with *Pseudomonas fluorescens* (field isolate)

Reported as Log CFU/g[z] (Mean ± SD) and Log Reduction[y] Following Treatment Application

	Mean Log CFU/g	**Mean Log Reduction**
Control – 60 Sec	**7.43 ± 0.31**	
100ppm Cl_2	6.19 ± 0.23	1.24
1% H_2O_2	4.86 ± 0.15	2.57
1% H_2O_2/UV	5.31 ± 0.29	2.12
Cl_2/UV	5.52 ± 0.46	1.91
Plant Water	6.18 ± 0.12	1.25
1ppm O_3	5.22 ± 0.10	2.21
UV	7.14 ± 0.13	0.30
1ppm O_3/1% H_2O_2/UV (60sec each)	4.97 ± 0.55	2.46

[z] Treatments were performed in triplicate and plated in duplicate. All values obtained from analysis were converted to log CFU/g blueberries.

[y] Log reduction is the difference between microbial counts before and after treatment.

Table 5
Crop Year 2005 Microbial Results: Organic Blueberries Inoculated with *Pseudomonas fluorescens* (field isolate)

Reported as Log CFU/g[z] (Mean ± SD) and Log Reduction[y] Following Treatment Application

	Mean Log CFU/g	**Mean Log Reduction**
Control – 120 Sec	**7.43 ± 0.31**	
100ppm Cl_2	6.13 ± 0.02	1.30
1% H_2O_2	5.19 ± 0.01	2.24
1% H_2O_2/UV	5.40 ± 0.11	2.03
Cl_2/UV	6.14 ± 0.11	1.29
Plant Water	6.39 ± 0.10	1.04
1ppm O_3	5.22 ± 0.10	2.21
UV	6.06 ± 0.38	1.37
1ppm O_3/1% H_2O_2/UV (60sec each)	5.08 ± 0.47	2.35

[z] Treatments were performed in triplicate and plated in duplicate. All values obtained from analysis were converted to log CFU/g blueberries.

[y] Log reduction is the difference between microbial counts before and after treatment.

FOOD SCIENCE AND BIOSYSTEMS ENGINEERING

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1A. TITLE: Incorporation of wild blueberry puree into a soy-based burger and its effect on sensory and chemical properties of the broiled burgers.

METHODS: Two prototype soy- wild blueberry burgers have been prepared according to the formulations in Table 1. Samples were broiled on an EmberGlo E24 electric charbrioler at 200 C to an internal temperature of 160 C. An informal sensory evaluation was performed in order to determine which of the formulations were preferred by individuals who regularly consume vegetable burgers. In addition, experiments to determine if addition of wild blueberry puree will prevent the formation of heterocyclic aromatic amines (HA) during charbroiling. Solid phase extraction followed by high performance liquid chromatography will be used to isolate and identify heterocyclic aromatic amines (Toribio et al. 1999).

RESULTS: Results from the informal sensory evaluation indicated that soy burgers formulated with 10 to 15% wild blueberry puree were preferred by the panelists. Sensory evaluation using these two formulations will be preformed during the winter of 2005/2006. Research to determine if wild blueberry puree can inhibit (HA) formation is currently on going. The food matrices of the soy-based burger have required that the published method be modified. Research with HAs will also be preformed in ground beef burgers formulated with wild blueberry puree.

RECOMMENDATIONS: Research on development of a soy-wild blueberry burger will be completed during the summer of 2006. This will include the sensory evaluation, chemical, and physical characteristics of the burgers.

TABLE 1
Soy-Wild Blueberry Burger Formulations

Ingredient	10% Puree	15% Puree
Texturized soy protein	125.7g	108.6g
Wild blueberry puree	34.1g	51.1g
Canola oil	89.1ml	89.1ml
Soy sauce	59.4ml	59.4ml
Chopped garlic	14.2g	14.2g
Dried onion	14.2g	14.2g
Sesame oil	3.7ml	3.7ml
Guar gum	7.1g	7.1g

FOOD SCIENCE AND BIOSYSTEMS ENGINEERING

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2. TITLE: Detection of Infested Blueberries using Near-Infrared Spectroscopy

OBJECTIVE: Exploratory research examining Near-Infrared Spectroscopy (NIRS) as a method to detect maggot-infested blueberries in an IQF processing line.

METHODS:

1. Sample preparation

Limited opportunities this season for artificial infestation, led to the use of naturally infested blueberries that were picked and used for NIR testing. Organic blueberries were obtained from several different Maine locations, where spots with high infestation where reported. These locations included Jonesboro (Blueberry Hill Farm and Hatch Knoll Farm), Stockton Springs and Amherst. All blueberries were raked from the fields near the tree line where the probability for infestation is highest. They were stored in a cool laboratory (approximately 22 C) for one week to allow for the maggot larvae growth. At the appropriate time the blueberries were prepared for near-infrared scanning as described below.

2. Near-infrared spectroscopy (NIRS) scanning and analysis

Samples were assigned names according to their origin (e.g., "Jonesboro") and the batch number corresponding to the week in which berries were picked. Each batch was separated in one to six subsets of 120 berries each and designated with a letter (A, B, C, D, E and F). For the 2005 season we have 21 sets. These berries were then counted and recorded on data sheets. Each scannable berry was further processed as described here.

The first step of the NIRS process was sizing the individual berries. Employing a sizing template device the berries were sized, stem side up, by fitting it through the appropriate slot indicating berry diameter in mm. Berries that were under 6 mm were not used. Each berry was sized and placed in an individually labeled tray, which depicted the date, batch number, set letter and berry number. Once these steps were completed the berries were held at laboratory refrigerator at ca. 4°C until they were scanned using the two NIRS systems. All berries in a single set were scanned on the same day and under the same conditions. Figure 1 gives a schematic of the basic overall berry scan procedure for both NIR systems at UMaine.

All sized berries were scanned at the Chemical and Biological Engineering laboratory at UMaine, with a prototype UV-NIR system from Ocean Optics, Inc. (Dunedin, FL) and a NIR system from Control Development, Inc. (South Bend, IN). In both cases a wide-spectrum (200 – 1700 nm) halogen light source was focused onto the individual berry at a distance from the culminating lens of approximately 25 mm and 80 mm for Ocean Optics NIRS (OO) and Control Development NIRS (CD). A culminating lens mounted at a 45 degree angle from light incidence allowed collection of light reflected from the berry; the reflected light was directed to an A/D converter via a fiber optic cable. After digital conversion, the sample data between 650 and 1100 nm (OO) or

900 – 1600 nm (CD) were graphed via the associated software program (OOIBase32, Ocean Optics, Inc. and Spec32, Control Development, Inc.). Replicate scans of each berry were collected and each set of berries was consecutively scanned on the two systems.

3. Prediction model analysis

First, individual spectra were imported into the modeling tool (either GRAMS®, version 6.00, Thermo Galactic, Salem, NH or MATLAB, version 5.3, MathWorks, Natick, MA) and training (data) sets were built from each set of 120 samples. Before building calibration models, the individual spectra were examined for anomalies, potential outlier samples or particular wavelengths of interest. Observed anomalies in the raw spectra were compared later with outlier spectra identified by statistical tests on the residuals (error terms) from Partial Least Squares (PLS) models.

PLS analyses were carried out on all spectra from previous years and on a number of data sets from 2005. PLS involves regression of the independent variations contained in the spectra against the measured reference data (infestation, size, water content etc.). All independent variations are captured in separate factors which may represent different physical or chemical properties of the samples such as water or sugar content, color, size etc. The first factors isolated during PLS modeling usually represent the largest variation contribution in the spectral data.

For developing calibrations, non-infested and infested blueberries were arbitrary assigned a value of -1 and 1 respectively (called constituent values). The threshold value was calculated as the arithmetic mean of the assigned arbitrary constituent values for each data set. Samples were considered infested if predicted constituent values were greater than the rejection threshold, and all others were considered non-infested.

Preprocessing methods that were used included mean centering, variance scaling, light scatter correction methods, and 1^{st} and 2^{nd} derivatives over 5 points. These methods are often used in spectroscopic data analysis (see Delwiche and Reeves, 2004; Walsh et al., 2004; Chen et al., 2002; Dardenne et al., 2000; Lammertyn et al., 2000) as they further enhance the PLS model calibration.

Data with replicate samples were transformed by averaging across replications. Spectral data sets from the same batch scanned with the same instrument and settings were joined to yeld combined data sets with large number of spectra. PLS was performed on these large combined data sets as well as on single data sets from the same batch and results were compared.

Cross validation was used in the analysis to estimate the robustness of the models. This algorithm attempts to predict unknown samples by using the training data set itself. The reduction in the standard error of cross validation (prediction), SECV, was used to determine the recommended number of PLS factors.

Spectral and concentration outliers were identified based on the residual plots after calculating the PLS models. Beta (calibration) coefficients from PLS were used to test for absorbance bands sensitive to differences between infested and non-infested berries.

4. Fourier Transform Infrared Spectroscopy (FT-IR)

The FT-IR methods followed standard protocols found in literature (Filip and Hermann, 2001) A number of frozen samples of infested and non-infested blueberries and maggots

were scanned by a Bruker FT-IR system in the 2,500 – 20,000 nm range. A small amount of each sample was spread on a zinc iodide (ZnI) crystal (90° from incident light) and the samples were left to dry under the light beam in the FT-IR instrument. Spectra were then measured by IR transmittance. Another set of samples were pressed into discs with potassium bromide (KBr) at approximately 250 atm and measured by IR transmission.

Although a destructive technique, FT-IR provides valuable information about functional groups in the samples by yielding spectra with defined signature.

5. Dehydration experiments

Oven drying. In order to examine the influence of water on the NIR signal and to determine water content, a number of blueberries were dried in a laboratory oven at 105 °C for 24 h. Each berry was kept in a marked aluminum weighing dish. For water content calculations, all berries were weighed before and after drying. The loss of mass after completion of drying at this temperature is due to the removal of most of the total bound and free water in each berry. NIR scans were also collected before and after drying and then compared to identify wavelengths and peaks in the spectra which are most influenced by dehydration.

Continuous drying in NIR system. Single berries were places under the halogen lamp of the CD NIRS and scanned continuously. The temperature under the lamp was measured to be approxmately 60 °C and spectra were collected every 30 min for 24 h.

Freeze-Drying. A set of berries were scanned by NIR while fresh and then the tray with the berries was covered with liquid nitrogen to initiate quick freezing. The samples were then freeze dried under vacuum for 24 h. All samples were rescanned by NIR immediately after freeze drying. Spectra of fresh and freeze dried berries were compared for each berry as well as compared to results from oven drying.

Humidity chambers. In order to obtain equal moisture content in each berry, a set of 120 berries was placed in a humidity chamber (AEWC, UMaine) for 24 h. The relative humidity was maintained at 80 %, equal to water content in fresh blueberries (Duke J.A., web resource), and temperature was 25 °C. All berries were scanned by NIR before and after the humidity chamber treatment and dissected after the last scanning to determine infestation.

6. Total protein concentration

Proteins were extracted from infested blueberries (with the maggot removed), non-infested blueberries and from maggots. The extraction methods consisted of modified standard procedures for protein extraction, precipitation and purification. The method for protein extraction was based on Fils-Lycaon, et al., (1996). General protein content was measured on the final purified extracts by Coomassie assay (Pierce Chemicals). A series of standard BSA dilutions were made ranging from 2.5 ug/ml to 2,500 ug/ml. Absorbance was measured at 595 nm fixed wavelength on UV/VIS spectrometer after adding the Coomassie dye to the standard solutions and samples. Protein concentrations of the samples were calculated from their absorbencies at 595 nm using the standard curve of protein concentration vs. absorbance.

RESULTS/CONCLUSIONS:

1. NIRS: data preprocessing, modeling and analysis

Data processing. By examining raw spectra, differences were found between stem and calyx scans. The regions where the two resulting spectra differed were 700-800 nm for the OO-generated spectra and 1400 - 1600 for the spectra from CD. These differences are potentially interesting for identification of berry orientation by NIRS.

Based on analysis of preprocessing methods, mean centering and variance scaling were applied to all 2005 PLS models and multiplicative scatter correction and 1st and 2nd derivatives were also tested. However, preprocessing rarely led to very significant improvement of the prediction results; this was suggested by other researchers (Delwiche and Reeves, 2004).

Modeling and analysis. In order to build balanced sample sets having approximately the same number of infested and non-infested samples, the spectra from all sets in a batch (picked and scanned during the same week) were combined together and equal number of infested and non-infested sample spectra was selected for building calibrations.

The preliminary results from PLS models from 2005 confirm findings from previous years i.e., models with small number of samples and low infestation ratio do not provide satisfactory infestation prediction. The low percentage of naturally infested berries (4-10%) in the 2005 sample sets led to unbalanced calibration models, and resulted in models are that were poor predictors. Therefore, larger number of samples have to be scanned before obtaining consistent and conclusive results. Currently the process of NIR scanning and data analysis has not completed for the 2005 season.

2.FT-IR spectra

During analysis of FT-IR spectra (data not shown) from blueberries and maggots, a number of peaks were identified that were different in the maggot spectra than the berry spectra. These peaks were at 2970 nm arising from polysaccharides, 5714 nm, from carbonyl groups (most likely part of an ester group) and at 6134 and 6450 nm, from amide bands. There were also differences in the baseline noise in the spectra due to water content variation. And the largest peak that appeared in the maggot spectra but not in the berry spectra was the one due to carbonyl groups. These results are in agreement with findings reported by other researchers, observing higher protein and amino acid content in infested fruit (see Drew R.A.I., 1988). These results were used as an initial step in designing of LS/MS analysis (in progress) of protein and amino compounds in blueberries and maggots.

3. Dehydration experiments

Oven drying. Ten random samples selected from berries picked at Hatch Knoll farm in Jonesboro, ME, were dried at 105 °C to determine water content. The average water content was 86 % with standard deviation of 1.5 %. These numbers are very similar to the 87 % total water in blueberries reported in literature (Duke J.A., web resource). Another 10 samples were dried at 70 °C for 3 h and the resulting water content was found to be 59 % and standard deviation of 8.4 %.

After comparing spectra of blueberries before and after oven drying at 105 °C with spectra from the other dehydration methods discussed further, they were found to be

very similar. Therefore, the results from continuous drying and freeze-drying apply to oven dried blueberries.

Continuous drying in NIR system. Spectra from a single blueberry dried and scanned continuously for 24 h under the NIR system light are presented in Figures 2 and 3. The largest change in the berry with drying time takes place in the first 3 h as the spectra at 0 h and 3 h are further apart. During this period, the water content of the blueberry decreases from 86 to 60 % as shown in the water content measurements discussed above. This water fraction is probably mostly free and located at the top portion of the berry directly exposed to the halogen light. Therefore, its removal has highest impact on the NIR signal. The water removal continues with less intensity between 3 h and 6 h when smaller baseline shift of the spectra can be seen. There is very little change that takes place between 6 h and 9 h of drying, and changes between 9 h and 24 h are negligible, since most of the free and bound water is already removed. Overall, during the drying process the spectra change more dramatically in the longer wavelengths than in the shorter wavelengths. Since the strongest absorption bands of water are in the longer wavelengths they are most affected by dehydration. Water absorption is weaker at multiple shorter wavelengths which are, therefore, less affected (see Figure 4). There is also change in color and possible changes in the other blueberry compounds, such as carbohydrates, due to heat which contribute to the change in NIR signal at shorter wavelengths.

As it can be seen from Figure 2, the slope and intensity of the peaks change as well, besides the baseline shift mentioned above. These changes are more clearly seen at the plot of the first derivatives of the spectra in Figure 3. As the first derivative takes into account the change in slope of the spectra, it is evident that with drying the slopes for all peaks between 900 nm and 1500 nm are reduced. There is a small shift in the peaks from 1250 to 1450 nm towards the longer wavelengths due to the loss of the plateau section on the top of the 1450 nm peak with drying (see Figure 2). It should be noted that there is a new peak appearing at 1550 nm not seen in the spectrum from a fresh berry. It is evident that the removal of water signal from the NIR spectra leads to the exposing of underlying signal which is in the absorption region of proteins and free amines (see Figure 4). This is an indication that the water signal may be interfering with the signal coming from proteins thus adversely affecting maggot detection by NIR. Since water absorbs in multiple wavelengths, dehydration leads to decrease in absorbance in the whole spectrum, observed as baseline shift and slope and peak reduction. However, it should be noted that dehydration leads to the exposure of underlying features in the spectra between 1500 and 1700 nm.

Freeze drying. Spectra from blueberries before and after freeze drying had identical peaks and features to spectra from continuous drying. Therefore, the above discussion applies to the raw spectra results from freeze drying. After freeze drying berries can be re-hydrated that would make dissection and PLS model analysis possible. This research is still in progress and results are preliminary.

Humidity chambers. The spectra from a single blueberry before and after humidity chamber treatment are presented in Figure 5. After examining a number of randomly selected spectra, it was concluded that there was not an identifiable trend in spectral baseline shift as displayed in Figure 5. For some samples absorption increased and for others it decreased. However, all samples exhibited a steep slope increase in the

spectra for wavelengths longer than 1650 nm. This is most likely due to the intake of free water from the surrounding air by the blueberries. Further experiments are planned with this method.

4. Total protein concentration

Proteins extracts from non-infested blueberries, infested blueberries and from maggots were prepared as described. The total protein concentration in the protein extracts, measured by Coomassie protein assay, were found to be 2.1 ug/ml for the non-infested blueberry and 3.5 ug/ml for the infested and 3.4 mg/ml for the maggot sample. The 95 % confidence intervals for protein concentrations of the non-infested sample was 1.8 – 2.4 ug/ml and for the infested sample was 3.3 – 3.7 ug/ml. From the results of means comparison through hypothesis testing the total protein concentration in infested blueberries was found to be higher than in non-infested blueberries. However, this concentration is much lower than the 1 % theoretical detection limit for NIR spectroscopy. Therefore, the PLS models are most likely detecting variation due to other factors than changes in the protein concentration in the blueberries.

The next step in this research is identifying more compounds and their concentrations by LC/MS which can potentially be source for variation detected by our PLS prediction models.

5. Volume ratios and NIR detection limit (Table 1).

For the purpose of this study, 20 berries and maggots were randomly selected and their volumes were calculated. Then volume ratios of maggot to berry were computed and results are presented in Table 1. It is evident that the weighted average ratio is approximately 0.6 % and the maximal obtainable ratio is approximately 5 %. Since light penetration in fruit is 3 to 5 mm, which means that roughly half of the berry volume is "seen" by NIRS, if the maggot is located at the half being scanned the average ratio would be approximately 1.2 %. It is believed that NIRS theoretical detection limit is 1% - the smallest concentration that the method can detect. Therefore, the average volume ratio (maggot : blueberry) is approximately at the NIR detection limit of 1 %. In order to increase the probability to detect the maggot we have been scanning each blueberry from to opposite directions – stem end and calyx end.

6. Conclusions

The above discussed results from dehydration experiments help us understand better the influence of water content in the blueberries on the NIR signal and ultimately on our infestation prediction models. Our goal is to identify methods for compensation for the high water content in the fruit and determine the highest prediction ration obtainable by NIR and PLS.

We can conclude that water content strongly influences blueberry NIR spectra. Further, the dominating water signal could have adverse effect on detection of proteins or amines due to maggot presence in the blueberry.

The presented results show that there are a number of factors that affect NIR signal and thus PLS prediction models. By identifying these factors we can propose methods for compensating for any adverse effects and improving PLS prediction. We are also able to determine the detection limit of our method and make recommendations

about prediction models' robustness and feasibility of NIR spectroscopy and PLS for maggot infestation detection.

RECOMMENDATIONS: Continue experiments providing information on factors affecting NIR spectra and PLS prediction models. Confirm sources of variation PLS models are detecting. Analysis of such results would assist in improving infestation models prediction. Further, recommendations for detection limit and reliability of our method for infestation detection by NIR spectroscopy and PLS regression could be made.

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Table 1. Volume ratios of maggot to blueberry. The ratio of the maggot with smallest volume to the berry with the largest volume in the sample resulted in the minimum. The maximum ratio is largest maggot to smallest berry. Weighted average ratio is equal to average maggot volume to average berry volume.

Volume ratios	Maggot : blueberry ratio	Percent (%)
MIN	0.0005	0.05
MAX	0.0494	4.94
Weighted average	0.0056	0.56

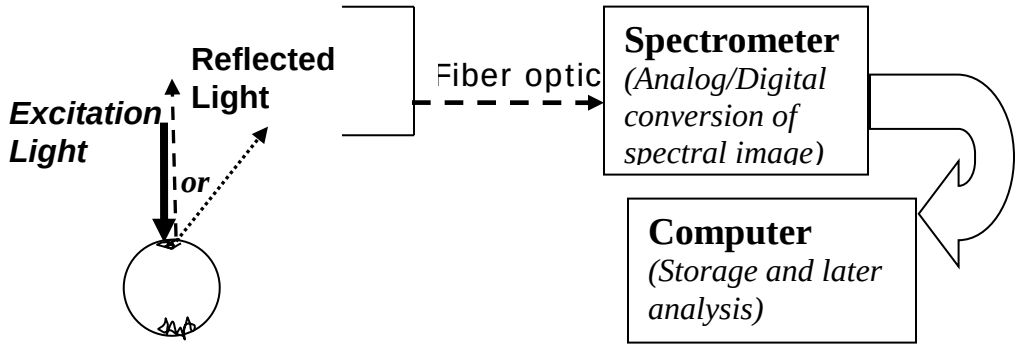

Figure 1. Flow schematic of equipment, light capture, spectrometer and computer. Reflected light will be at 45 or 360 degrees angle measured from the excitation light.

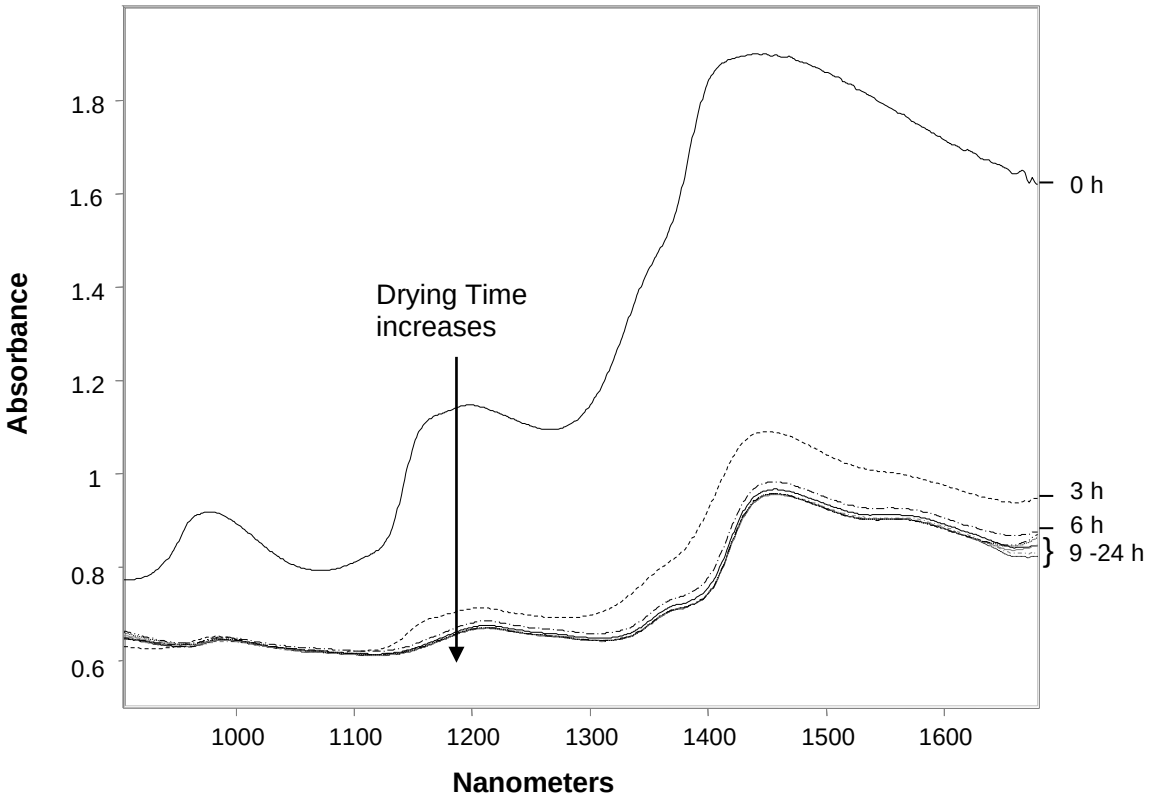

Figure 2. NIR spectra from the Control Development instrument from continuous drying of a single blueberry.

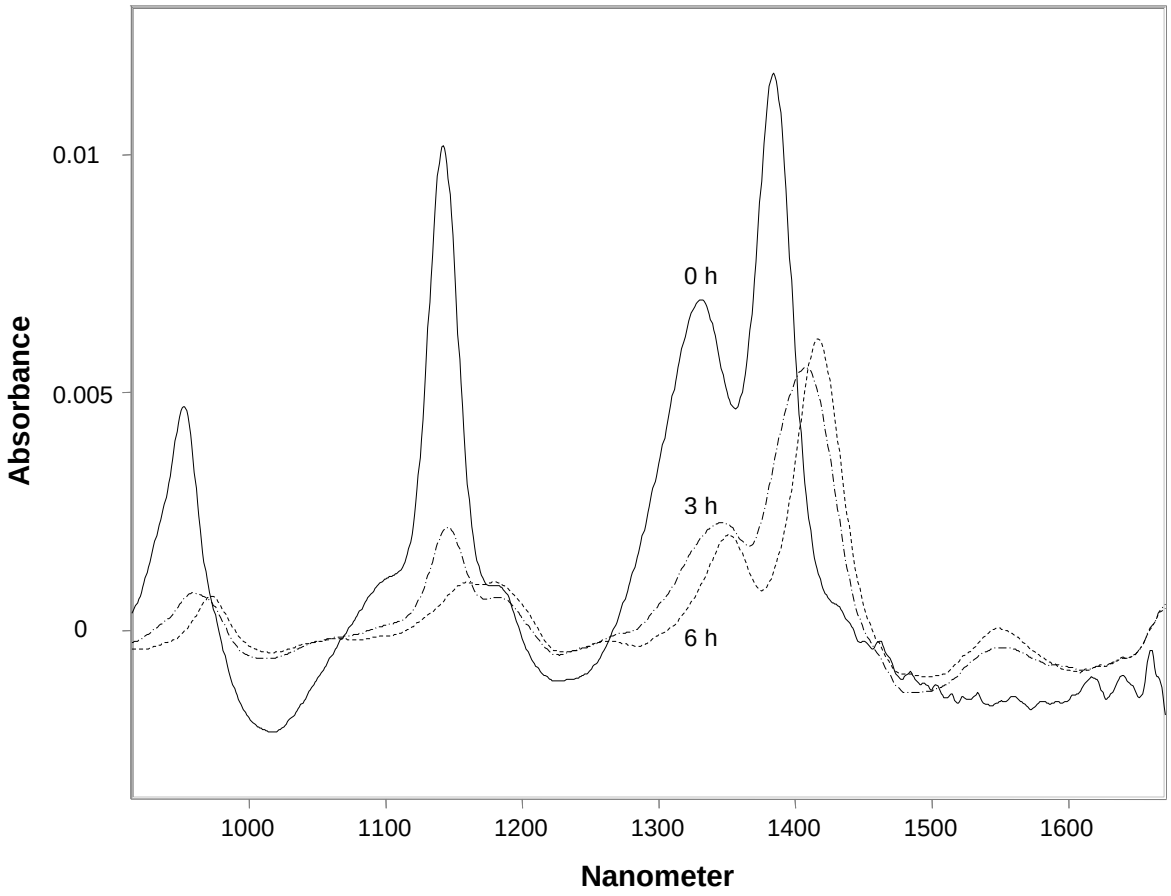

Figure 3. First derivative of NIR spectra from continuous drying of a single blueberry from the Control Development instrument.

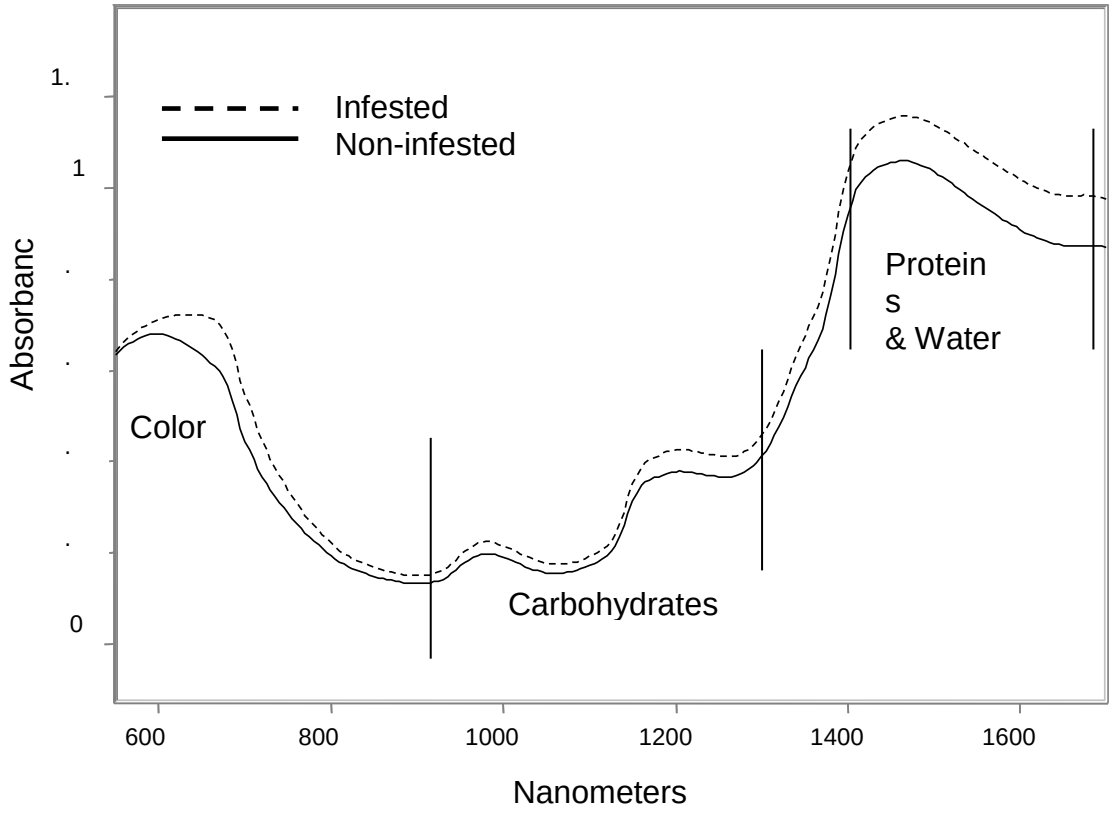

Figure 4. Absorption bands in typical blueberry NIR spectra

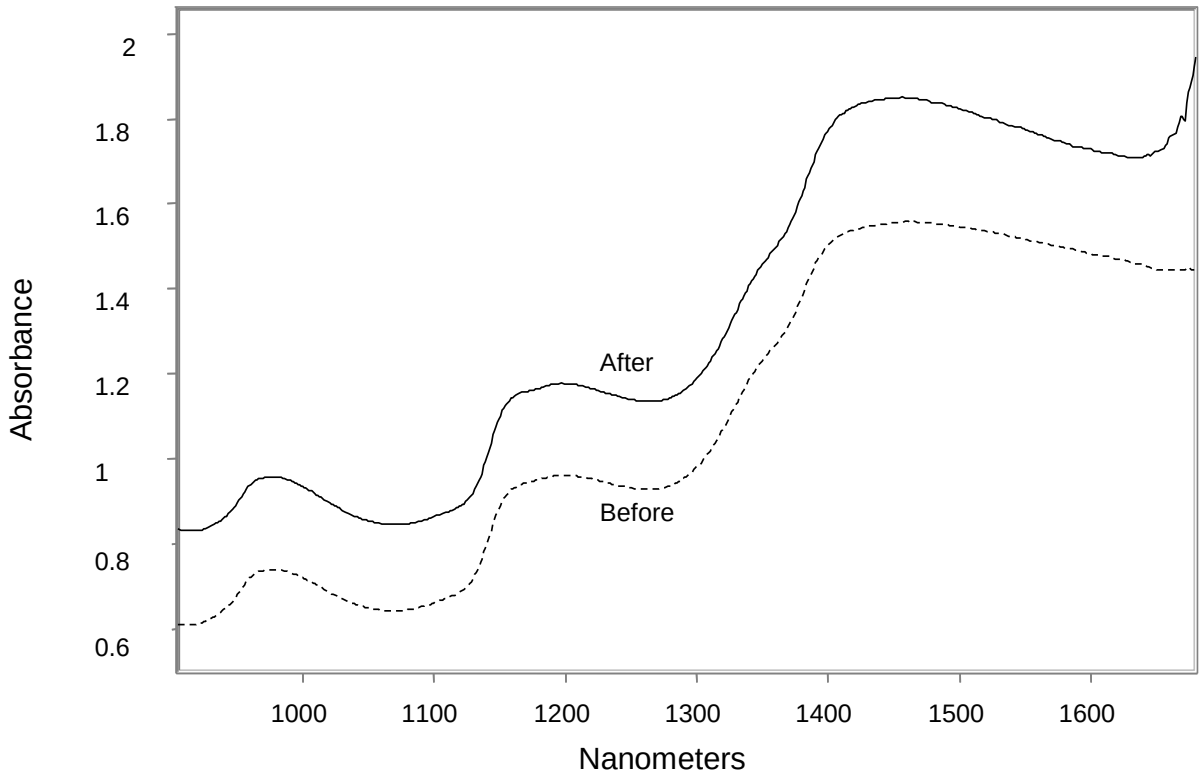

Figure 5. NIR spectra of a single blueberry before and after humidity chamber (80 % RH) treatment from the Control Development instrument.

FOOD SCIENCE AND BIOSYSTEMS ENGINEERING
INVESTIGATOR: Dorothy J. Klimis-Zacas, PhD., Professor of Clinical Nutrition

3. TITLE: Wild blueberries and Arterial Functional Properties

OBJECTIVE: to study the role of wild blueberry consumption on *vasodilation* during exposure to agonists such as acetylcholine (an endothelium-dependent vasodilator) and pinpoint the biochemical pathway by which wild blueberries may be acting after inhibition of the NO and COX pathways in Sprague-Dawley and Spontaneously Hypertensive Rats (SHR).

METHODOLOGY: Weanling male Sprague-Dawley (SD) and Spontaneously Hypertensive (SHR)(twelve in each group) were placed on the following diets for 8 weeks.

1. Control diet and
2. Control diet and blueberries

Rat weights and food intakes were measured throughout the experiment and rats were fed the above diets for 8 weeks. Rats were anaesthetized and blood and arteries were removed and arterial rings prepared. Aortae were excised, rings were prepared, and were immersed in tissue baths containing physiological saline solution (PSS) at 37 C, aerated with 95% O2 and 5% CO2 (pH 7.4). Following equilibrium and preconditioning under 1.5gm preload, rings were pre-contracted with a maximal dose of the alpha-1 adrenergic agonist L-Phenylephrine (L- Phe, $3x10^{-7}$) and relaxed with cumulative concentrations of acetycholine (Ach,10^{-9} to $3x10^{-6}$ M), a vasodilator which requires the endothelium to employ its effect and its action is mediated through NO. After washout, two rings were relaxed with Ach in the presence of the NOS (nitric oxide synthase) inhibitor, L-NMMA, and the other two rings with MFA, a COX pathway inhibitor.
The maximal force of relaxation was measured (Fmax) to determine the effect of blueberries on endothelium NO- and COX- mediated vasodilation. The maximum vasodilation of SD and SHR aortae to Ach as a percent of the initial precontraction before and after treatment with inhibitors was studied. Concentration-response curves were determined for the dilator acetylcholine and after inhibition with the inhibitor of NOS, L-NMMA, as well as with the inhibitor of the COX pathway, MFA. Thus the specific pathway that blueberries exert their action on the artery was identified in SHR (hypertensive rats). At the present time, data on the Sprague-Dawley rats (controls) are being analyzed.

CONCLUSION AND SIGNIFICANCE: Our studies in the past documented that wild blueberries affect the contractile machinery of the smooth muscle cell by decreasing arterial contractility in response to the stress hormone, epinephrine. From the present experiment we determined that when acetylcholine (which needs the intact endothelium for its action and operates through increasing the release of NO) is used as the compound to affect vasorelaxation, wild blueberries seem to potentiate greater vasorelaxation in the aortas of the animals that are under oxidative stress, the hypertensive animals, as compared to hypertensive animals fed normal diets. When NOS was inhibited in the

hypertensive animals, we observed greater vasorelaxation in the animals that were fed the blueberry-enriched diets, indicating the operation of alternate vasorelaxing factors (pathways) or increased NO bioavailability in the blueberry fed rats. COX inhibition induced reduced vasodilation in the hypertensive animals fed the blueberry-enriched diets suggestive of the possible role of blueberries in the COX pathway either reducing production of vasoconstrictor or increasing production of vasodilator prostanoids. Even though endothelium-dependent vasodilation was restored in the control diet animals it was less in the animals that ate the blueberry-enriched diets. Thus blueberries in the hypertensive animal operate through alternate pathways to affect arterial vasomotor tone. Results from the effect of blueberries on endothelium-dependent relaxation of the SD rat will be ready in the near future.

RECOMMENDATIONS: Future experiments will address the effect of blueberries on blood pressure regulation both in the SD and SHR, and determine whether blueberries may prevent blood pressure elevation in younger animals (6 weeks old) or may reverse it in older animals (14 week old). Nitric oxide bioavailability will be also be assessed by measuring eNOS (endothelial nitric oxide synthase) and iNOS (induced nitric oxide synthase). The involvement of blueberries on the COX pathway will be further verified by studying the activity of prostanoids such as TXA_2 and PGH_2.

Refereed Publications

Norton, C., Kalea, A.Z., Harris, P.D. and Klimis-Zacas, D. Wild blueberry-rich diets affect the contractile machinery of the vascular smooth muscle in the Sprague-Dawley rat. *Journal of Medicinal Food*. 8:8-13, 2005.

Kalea A.Z., Lamari F.N., Theocharis A.D., Cordopatis P., Schuschke D.A., Karamanos N.K., Klimis-Zacas D.J. Wild blueberry (Vaccinium angustifolium) consumption affects the composition and structure of glycosaminoglycans in Sprague-Dawley rat aorta. *Journal of Nutritional Biochemistry. Epub* Aug 17, 2005 (in print, available on line from sciencedirect).

Published abstracts:

Kalea A.Z., Norton C., Harris P.D. & Klimis-Zacas D. Whole wild blueberries suppress a1 adrenergic agonist induced contraction in rat aorta, *FASEB J*. 17(4): A334, 2003.

Norton C., Kalea A.Z., Harris P.D. & Klimis-Zacas D. Whole wild blueberries affect the vascular contractile machinery in the Sprague-Dawley rat, *FASEB J.* 16(4): A334, 2003.

Kalea, A.Z., Lamari F., Theocharis A.D., Karamanos N.K., and Klimis-Zacas, D. Wild blueberries affect the composition of the extracellular matrix in rat aorta, *FASEB J.* 19(4), A451, 2005.

Kalea, A.Z., Lamari F., Karamanos N.K., Klimis-Zacas, D. Wild blueberries affect the concentration and composition of aortic glycosaminoglycans in Sprague-Dawley rat.

Meeting of the Hellenic Society of Pharmacology, University of Patras, Greece, March 2004

Clark K., Kalea A.Z., Schuschke D, Harris P.D. & Klimis-Zacas, D. Effect of dietary blueberries on endothelium-dependent vasodilation in spontaneously hypertensive rats *(submitted for poster presentation in the FASEB-Experimental Biology 2006 Meeting, American Society of Nutrition, San Francisco, April 1st 2006)*

FOOD SCIENCE AND BIOSYSTEMS ENGINEERING

INVESTIGATOR: Vivian C. H. Wu, Ph.D., Assistant Professor, Dept. of Food Science & Human Nutrition
Alfred A. Bushway, Ph.D., Professor, Dept. of Food Science & Human Nutrition

4. TITLE: Practical Microbial Control Approach and Antimicrobial Properties Study for Wild Blueberries

OBJECTIVE:

1. Study of synergistic antimicrobial properties of wild blueberries in combination with cranberries for controlling foodborne pathogens (*Escherichia coli* O157:H7, *Listeria monocytogenes*, *Salmonella* Typhimurium, and *Staphylococcus aureus*)
2. Sanitation and microbial control for Maine wild blueberries using new pouch system of Chlorine Dioxide.

METHODOLOGY:

Objective 1

Four foodborne pathogens were used: *E. coli* O157:H7, *L. monocytogenes*, *S.* Typhimurium, and *S. aureus*. A pathogen cocktail was made by combining four individual cultures prior to use. Target concentration was 4 log CFU/ml. The "cocktail" system is chosen because studying individual pathogen will make the project too large to handle. Also in the natural environment mixed culture is the norm in most food systems.

According to our preliminary results, a berry concentrate mixture [5% (v/v) blueberry and 5% cranberry concentrate] was prepared in distilled water (DW) for the study of the bactericidal effect, and in Brain Heart Infusion (BHI) broth for the suppressive effect. Pathogen cocktail was inoculated (4 log CFU/ml) in both DW and BHI and incubated at 7°C or 21°C. Pathogen counts were made for the DW at 0, 1, 5, 7, and 24 hr, and for the BHI on day 0, 1, 3, and 5. A synergistic berry powder blend (10% w/v) was also evaluated.

Objective 2

A new chlorine dioxide (ClO_2) method for microbial decontamination was developed in this study. A sachet containing all necessary chemicals to generate 500 to 1000 ppm of chlorine dioxide in one liter of water was used. The concentration of ClO_2 was measured by a DPD method (N, N-diethyl-ρ-pheyl-enediamine) using a colorimeter (DR/820, HACH, CO). The decontamination efficiency was first tested in laboratory media before further study in berry samples. Four different bacteria (*Salmonella* Typhimurium, *Listeria monocytogenes*, *Yersinia enterocolitica*, and *Pseudomonas aeruginosa*) were studied individually. Chlorine dioxide solutions (5 ppm) or water (as a control, 4.9 ml, 23 °C) were deposited in test tubes wrapped with aluminum foil to prevent sunlight. Cell suspension (ca. 6-7 log-CFU/ml) of different bacteria was inoculated in water (control) and ClO_2 (5 ppm), and treated for 10 sec, 1 min, 2 min, 5 min, and 10 min. Five ml of Dey-Engley (DE) neutralizing broth (Neogen, MI) was added after treatment to achieve neutralization of potentially lethal residual chemicals and to adjust the pH to a range not

lethal to the pathogens after treatment. Viable cell counts of each bacterium after treatment were evaluated.

RESULTS:

Objective 1

Results (indicated from Figure 1 to 4) from the DW experiments showed that while no reduction of pathogens was observed in pure DW at 7 ^{o}C and 21 ^{o}C, significant bactericidal effects were observed except for *E .coli* O157:H7 at 21 ^{o}C. Starting from 7 h, no *L. monocytogenes* were recovered from the treatments at both 7 ^{o}C and 21 ^{o}C. BHI data indicated that the growth of all pathogens tested was reduced (4 to 9 log CFU/ml difference) compared to the negative control at both temperatures.

Objective 2

Results (Table 1) indicated that the new chlorine dioxide (ClO_2) method for microbial decontamination was achieved even in as short treatment time as 10 sec. After 10 second treatment, 2.43, 2.93, 3.09, and 1.9 log CFU/ml reductions were observed for *Salmonella* Typhimurium, *Yersinia enterocolitica*, *Pseudomonas aeruginosa*, and *Listeria monocytogenes*, respectively. The new ClO_2 method was the most effective on *Yersinia enterocolitica* and *Listeria monocytogenes*. After 1 min treatment with ClO_2, both *Listeria monocytogenes* and *Yersinia enterocolitica* were reduced to less than the detection limit. After 10 min treatment, all pathogens (about 6 log concentration) were reduced to the non-detectable level.

CONCLUSIONS: The synergistic effects of wild blueberries and cranberries have not only heath benefits but significant antimicrobial effects. They have multiple functions and can be further considered for food applications.

Our new ClO_2 method is a simple, cheap, and highly effective decontamination method to reduce foodborne pathogens.

RECOMMENDATIONS: Further application of combination of wild blueberries and cranberries in food system should be conducted. The sensory evaluation will also be needed. Our new chlorine dioxide (ClO_2) method should be further applied in the field study. Its application to the wild blueberries sanitation should also be evaluated through using it in cleaning up the equipment and the processing environment.

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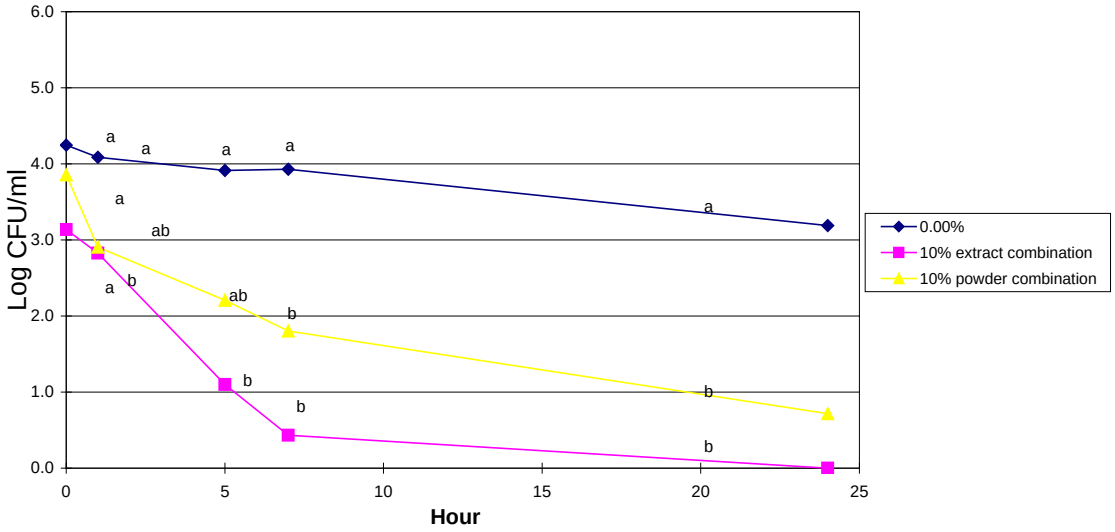
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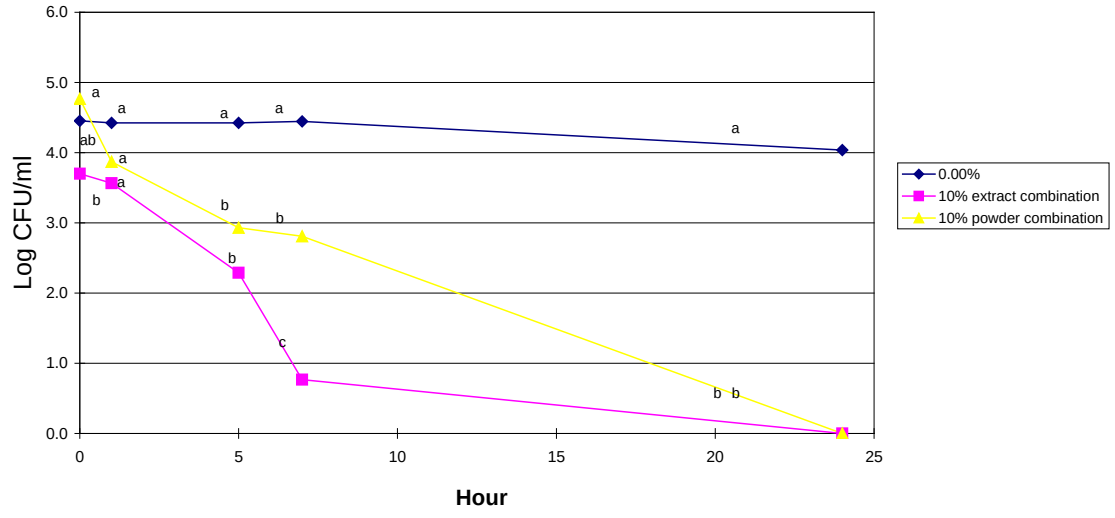
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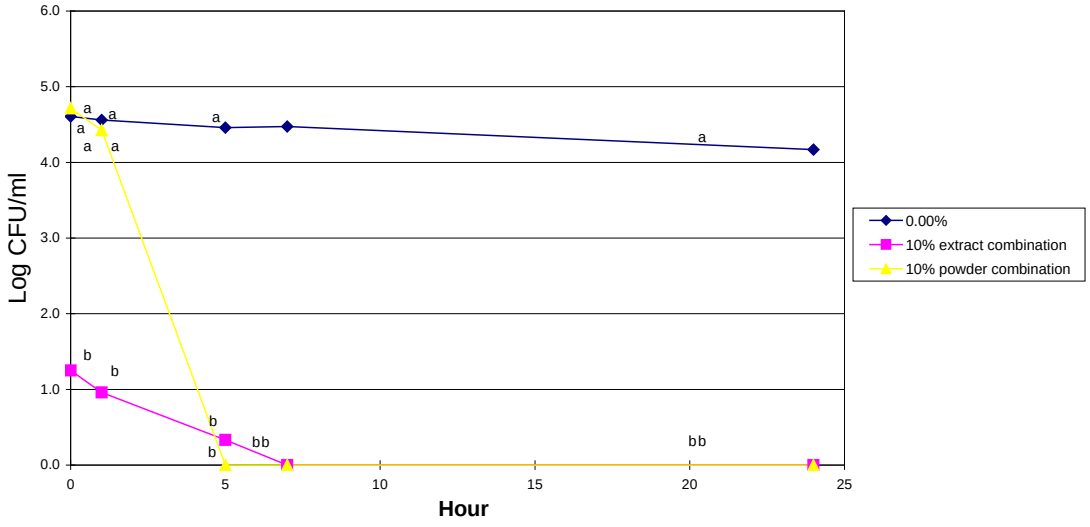
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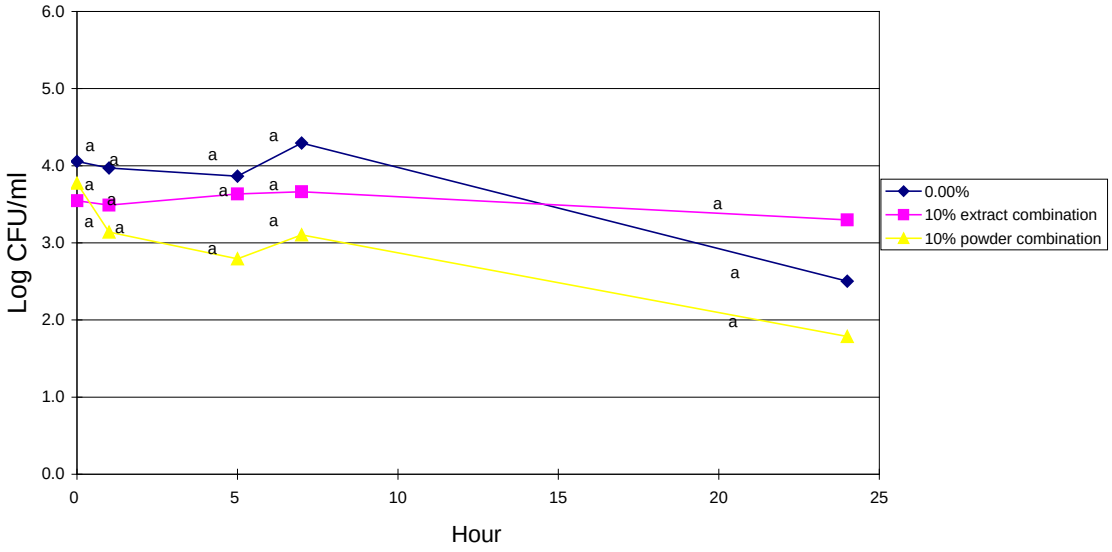
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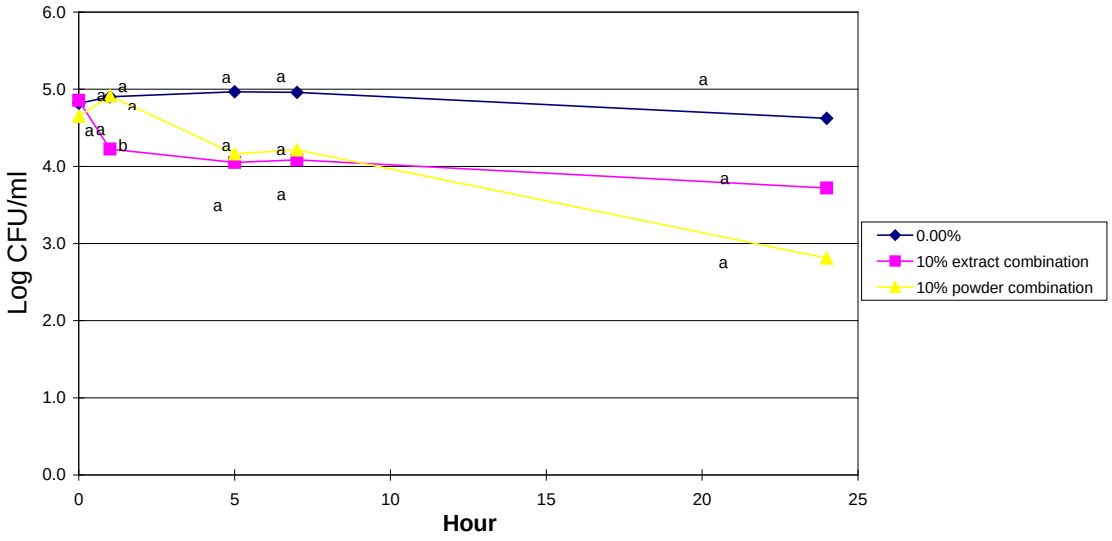

FIGURE 1. Antimicrobial effect of mixed cranberries and blueberries on *S.* Typhimurium (a), *S. aureus* (b), *L. monocytogenes* (c), *E. coli* O157:H7 (d), total pathogens (e) in water at 21^{o}C. Bars with different letters in the same sampling time indicate significant difference (P<0.05).

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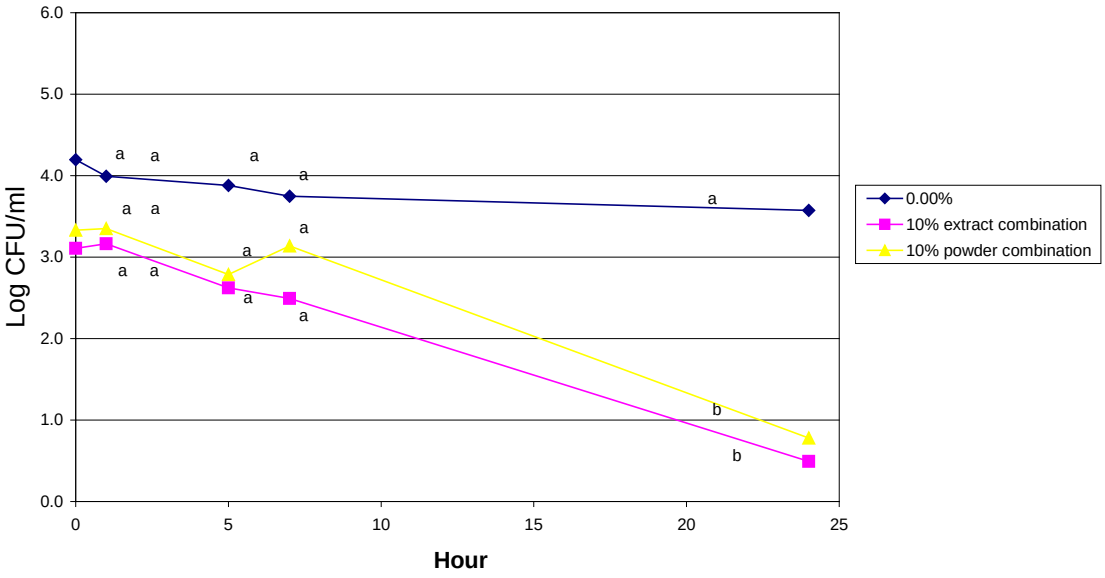
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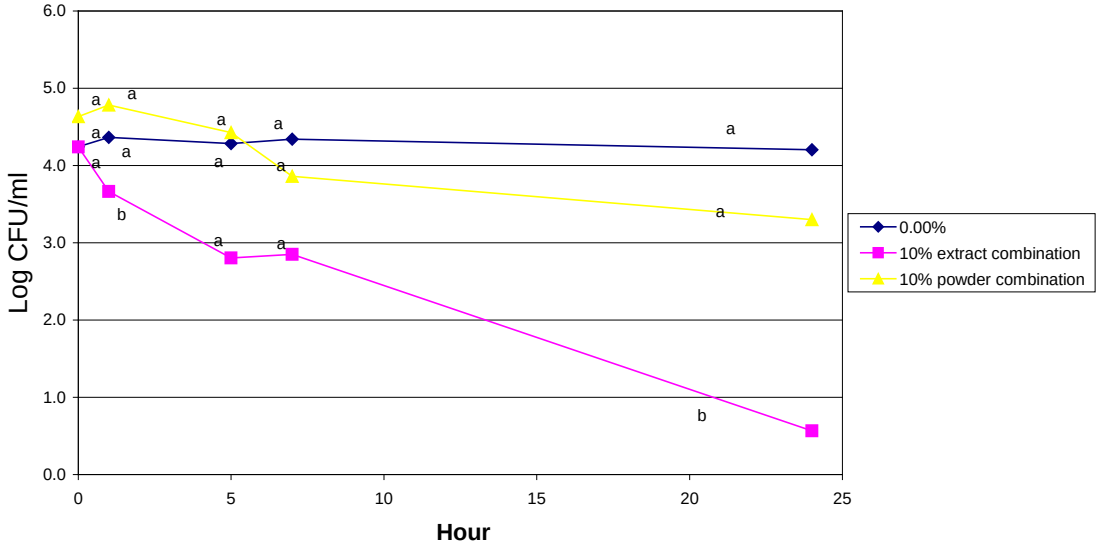
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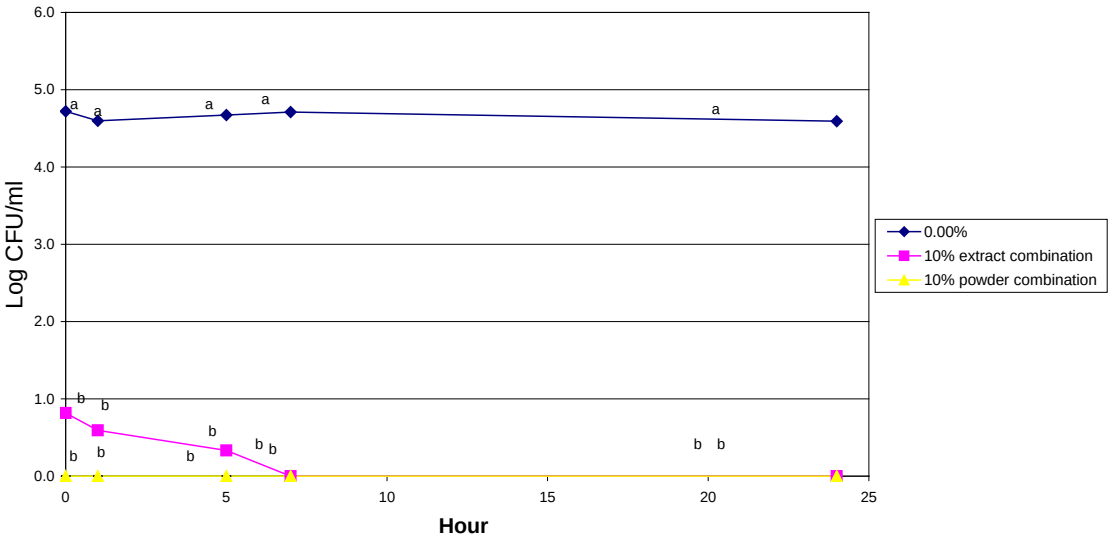
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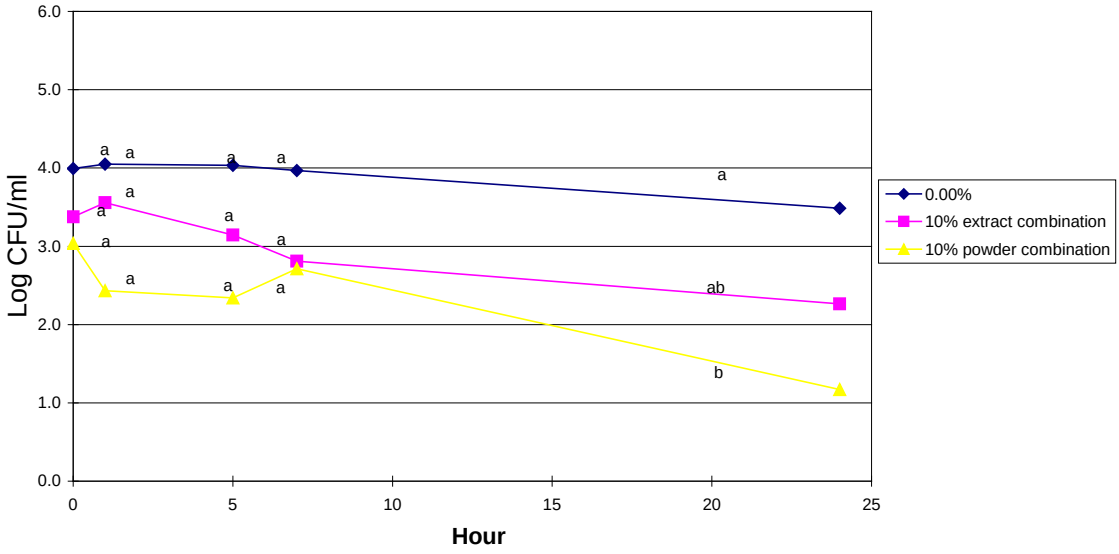
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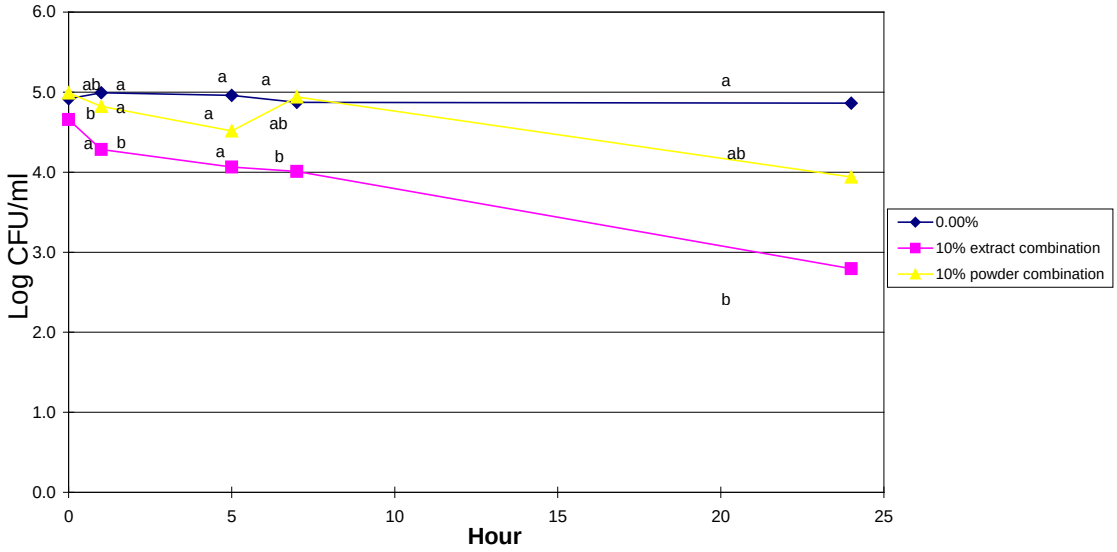
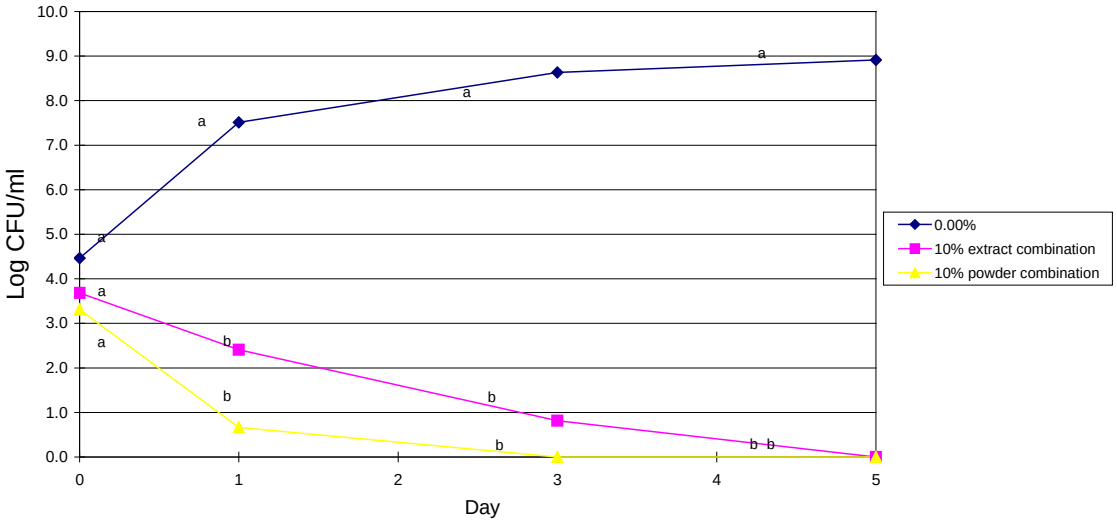


FIGURE. 2. Antimicrobial effect of the mixed cranberries and blueberries on *S.* Typhimurium (a), *S. aureus* (b), *L. monocytogenes* (c), *E. coli* O157:H7 (d), total pathogens (e) in water at 7^{o}C. Bars with different letters in the same sampling time indicate significant difference (P<0.05).

(a)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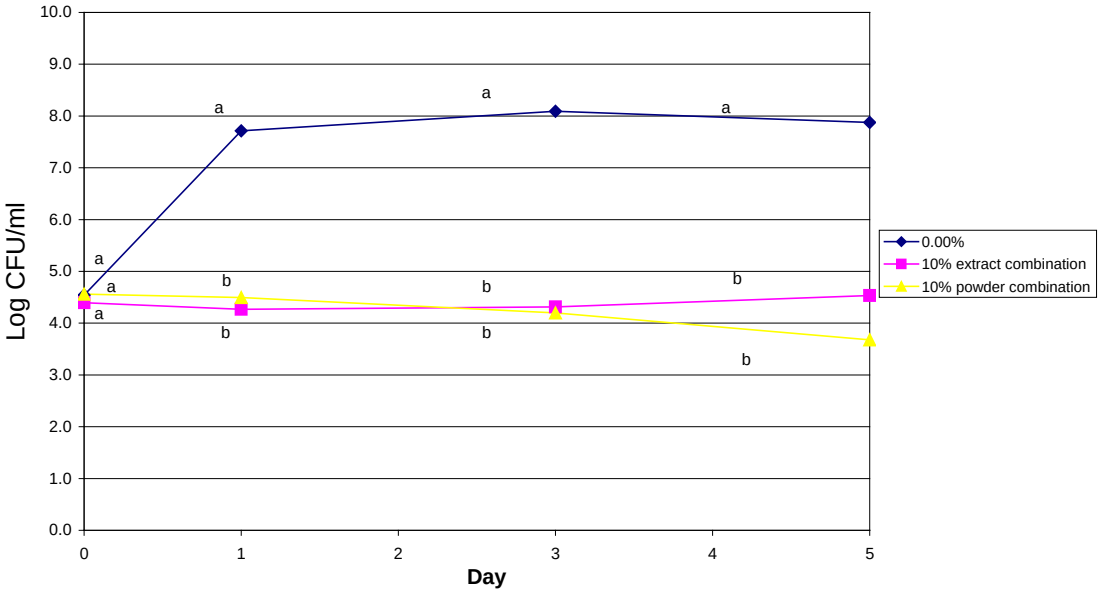
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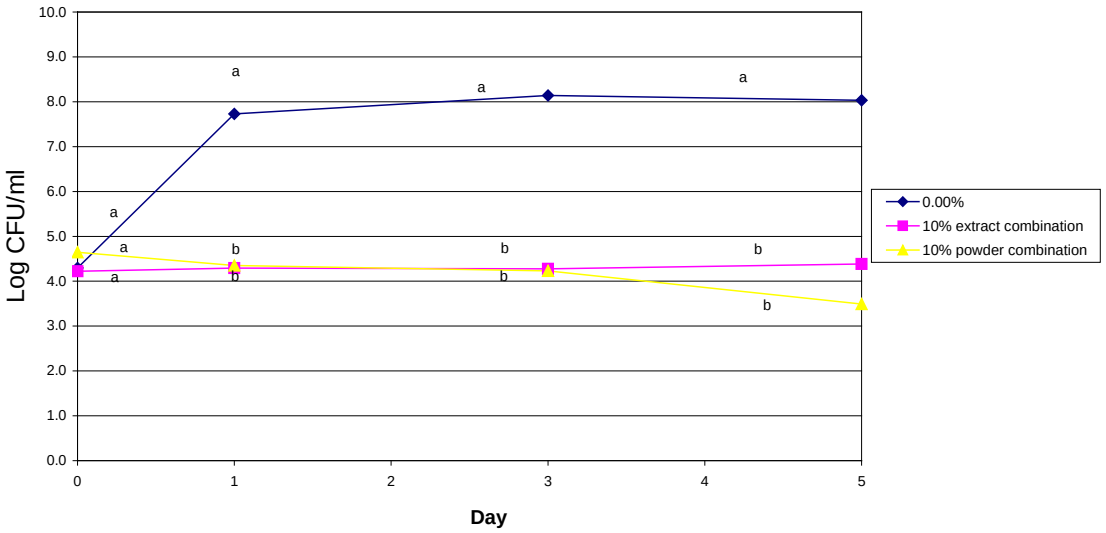
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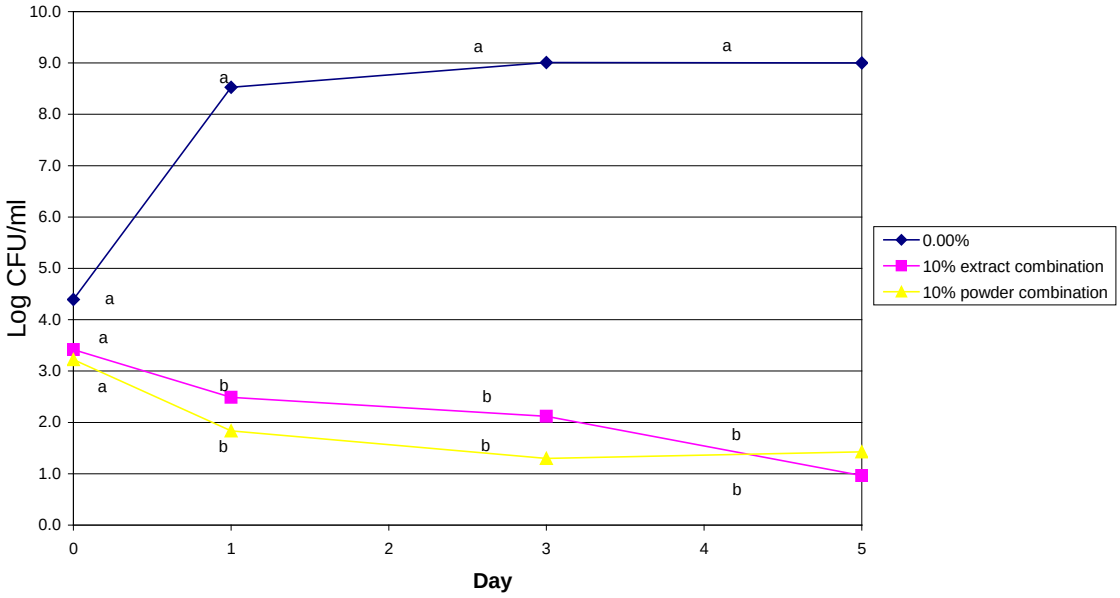
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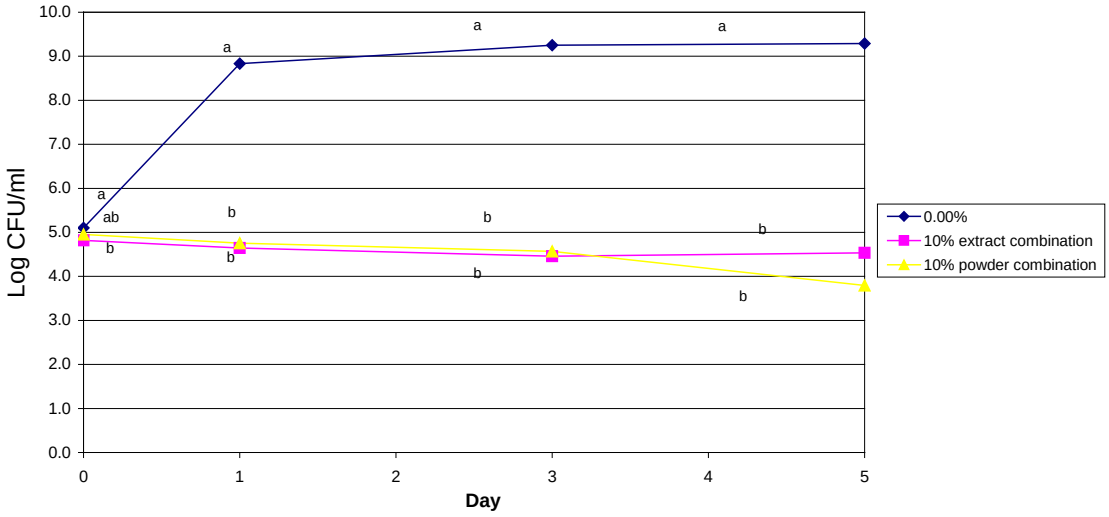
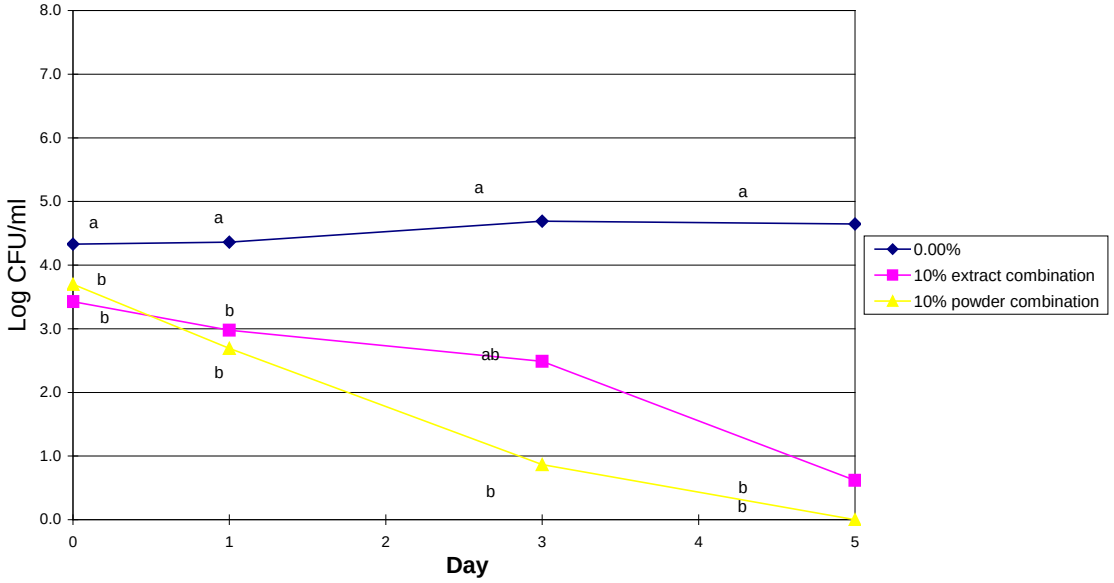


FIGURE 3. Antimicrobial effect of mixed cranberries and blueberries on *S.* Typhimurium (a), *S. aureus* (b), *L. monocytogenes* (c), *E. coli* O157:H7 (d), total pathogens (e) in BHI at 21 ^{o}C. Bars with different letters in the same sampling time indicate significant difference ($P<0.05$).

(a)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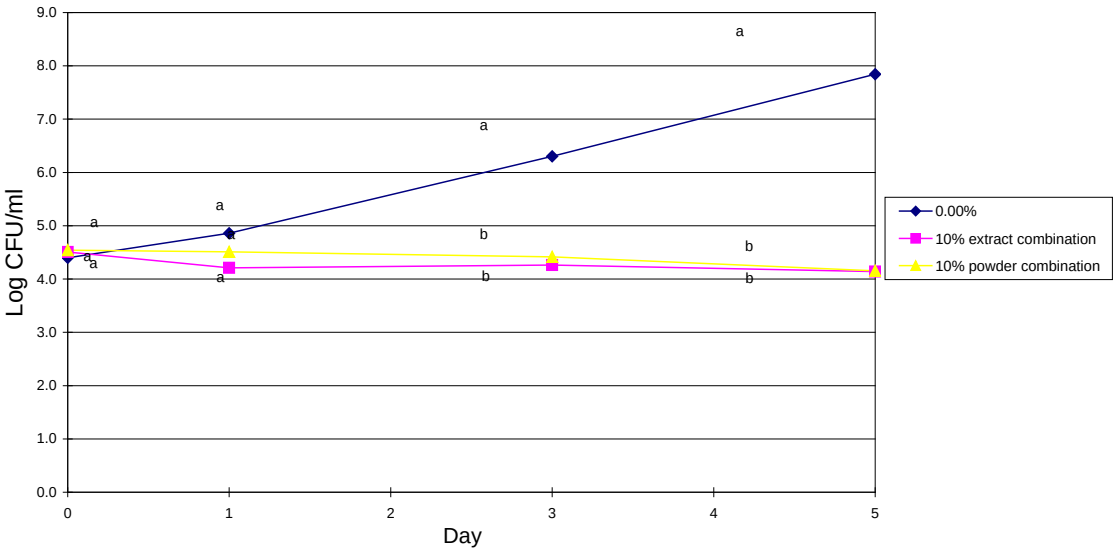
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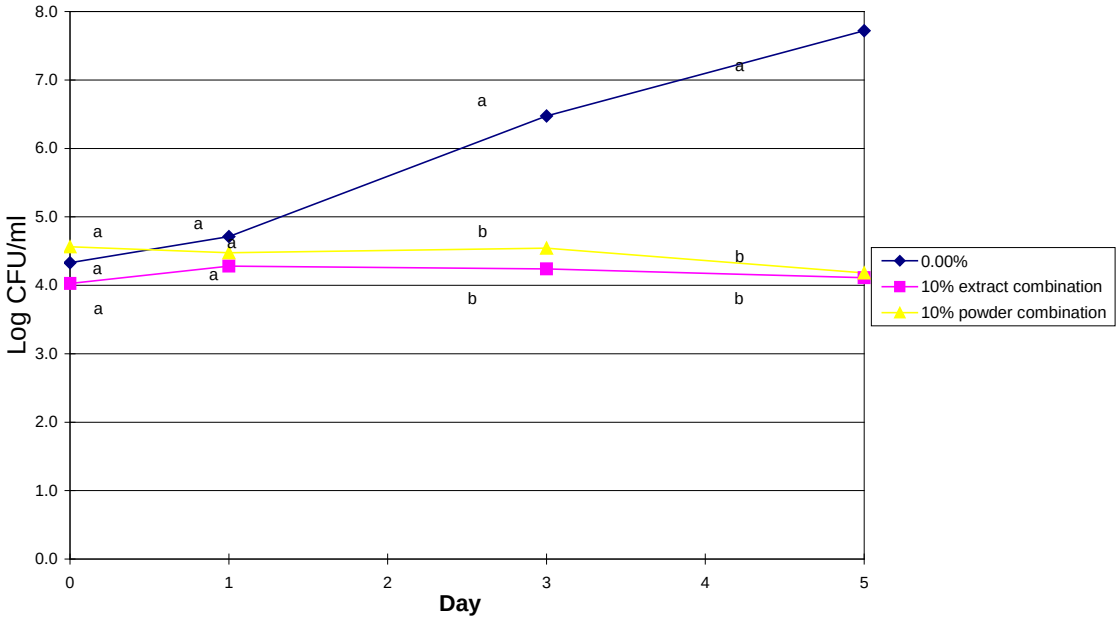
10% powder combination

(c)


8.0
7.0
6.0
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4.0
3.0
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10% extract combination
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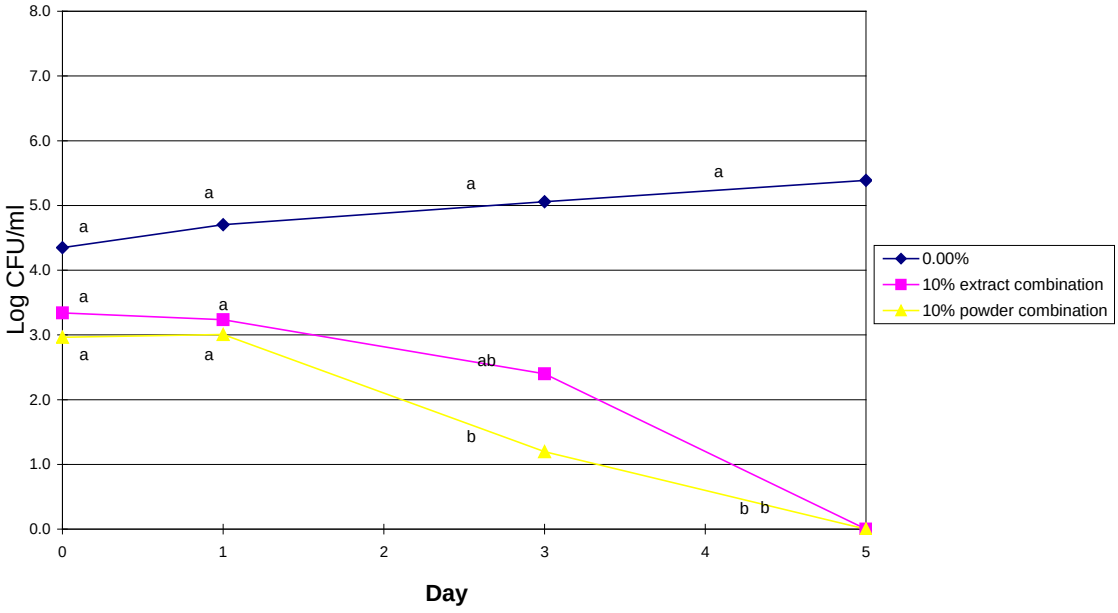
(d)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(e)

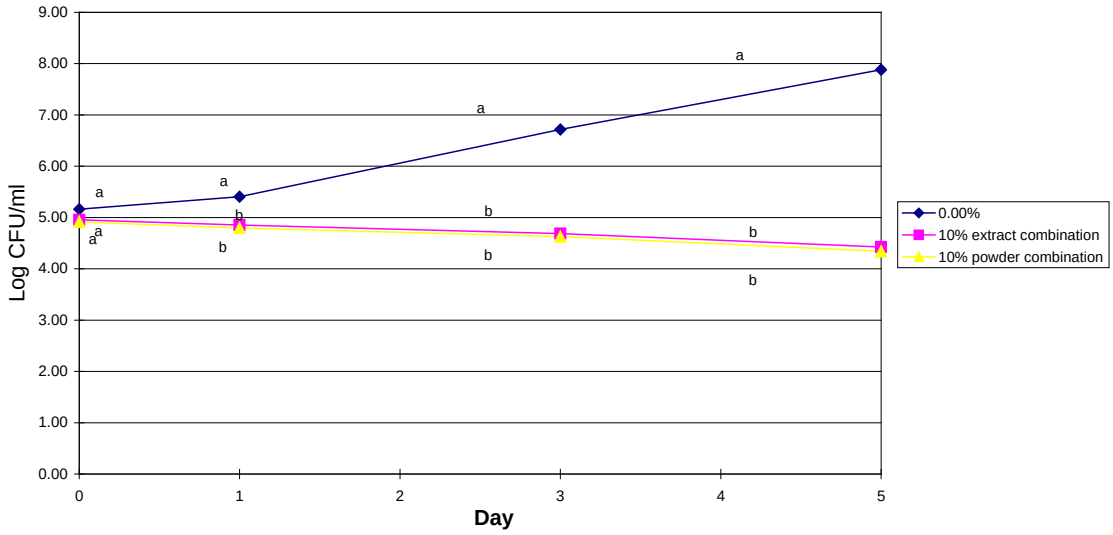


FIGURE 4. Antimicrobial effect of the mixed cranberries and blueberries on *S.* Typhimurium (a), *S. aureus* (b), *L. monocytogenes* (c), *E. coli* O157:H7 (d), total pathogens (e) in BHI at 7 ^{o}C. Bars with different letters in the same sampling time indicate significant difference ($P<0.05$).

Table 1. Populations of four pathogens recovered from water (control) and ClO_2 treatment (5 ppm).

			Populations (log CFU/ml)				
		pH	10s	1 min	2 min	5 min	10 min
Salmonella	Water	6.6	5.87				5.92
	ClO_2	4.3	3.44	2.85	2.04	0.69	<0.3
Yersinia	Water	6.5	6.0				6.04
	ClO_2	4.3	3.07	<0.3 [a]	<0.3	<0.3	<0.3
Pseudomonas	Water	6.6	6.5				6.32
	ClO_2	4.1	3.41	3.69	3.56	3.36	<0.3
Listeria	Water	6.1	6.54				6.51
	ClO_2	4.3	4.64	<0.3	<0.3	<0.3	<0.3

[a] less than detection limit (no colonies were observed after treatment)

IRRIGATION

INVESTIGATORS: Gordon Starr, Soil Scientist/Hydrologist
David Yarborough, Professor

6. TITLE: Irrigation Water Use in Wild Blueberry Production

EXECUTIVE SUMMARY

Grower experience indicates that the wild blueberry crop requires somewhere near one inch per week of water and that fog and dew aid production by supplying water. Results obtained in the period of 2002-2005 have substantially confirmed these beliefs. However, research is needed to improve the amount and timing of irrigation water applications across the blueberry growing region of southeast Maine. Research has progressed significantly since the inception of the project in 2002, and the 2005 dataset is the most complete of any thus far. In this report, we discuss progress on sites and methods, revisit results from 2002 and 2003 to provide background information, and then give a discussion of some unique features of the 2004 and 2005 datasets.

BACKGROUND: Diminishing supplies and competing interests for water have resulted in severe irrigation water supply shortages for the Wild Blueberry Industry. A meeting was held in November, 2001 with industry representatives, growers, and researchers to determine water related research priorities of the Wild Blueberry Industry. A collaborative study was initiated in 2002 by the USDA-ARS and University of Maine with funding provided by the Wild Blueberry Commission and field support from collaborating farmers. This ongoing study has the following objective:

OBJECTIVE: Develop efficient water management practices for wild blueberry production.

IMPACT OF RESEARCH/BENEFIT TO INDUSTRY: Growers will have better information and techniques for making proper irrigation decisions. Water will be conserved and made more available for other users that compete with irrigators for this valuable and limited water resource.

SITES AND METHODS

Weighing lysimeters (Figure 1) and devices for measuring soil water tension, soil water content, and meteorological variables have been used since 2002 for studying crop water use at Blueberry Hill farm in Jonesboro, ME and these have been complemented by lysimeters four additional sites. Installations in both crop and prune years were used at Jonesboro and Deblois, ME and an installation in crop only was used in Jonesport, ME. These sites were chosen to give a range of climate to evaluate fog and temperature effects on water use of wild blueberries as they vary with distance from the Atlantic Coast for the dominant sandy soils of the blueberry growing region. An installation located in Addison, ME was completed in 2004 and another completed in 2005 in Northfiled, ME. Both the Addison and Northfield installations are on finer textured soil.

2002 RESULTS

Evapotranspiration was determined by measuring the change in lysimeter weight per day for a 24 hour period from midnight to midnight on days having no rain and expressing this as an equivalent depth of water per week. This is illustrated in Figure 2 which shows daily rainfall and average lysimeter weight versus time from June 6 through June 25, 2002 at the Blueberry Hill site. The ET for days 159 and 160 averaged 0.48 in/wk whereas days 164 and 165 averaged only 0.10 in/week. On all four of these days, strong increases in nighttime lysimeter weight were evident. By contrast, the nighttime rise in lysimeter weight was not as pronounced for days 172 through 174 and ET averaged 1.0 in/wk.

The nighttime increases in lysimeter weight were a persistent feature seen in the data, particularly at the two sites nearest the coast. Figure 3 compares Blueberry Hill and Wyman's farm from July 11 through July 16. For days 194 and 195, it is the nighttime rise in weight that appears to make the difference between the 0.99 in/wk recorded at Blueberry Hill and the 1.25 in/wk (3.2 cm/wk) recorded at Wyman's farm. The difference in ET between Blueberry Hill (1.0 in/wk) and Kelley Point (0.61 in/wk) could not be entirely explained by nighttime rises in lysimeter weight (Figure 4). The nighttime rises were evident at both sites yet Blueberry Hill still had much higher ET (Figure 4). The daytime temperature has a strong effect on ET and the Kelley Point site is persistently much cooler than either of the other sites located further inland.

The nighttime rise in weight is clearly a significant flux of water and should be studied further. Researchers in Europe saw similar effects in their weighing lysimeters containing bare soil near the Mediteranean coast and attributed them to influxes of cool, moist air from the sea. The water vapor from the air was thought to adsorb directly into the soil. Increases in relative humidity characteristically accompanied decreases in air temperature (Figure 4) at the Blueberry Hill site, so it is reasonable to suspect the same phenomena are at work. The lysimeters in this study contain lowbush blueberry plants that will frequently collect heavy dew as moist evening air condenses on leaves and stems. It is not clear how much of the water deposited on the lysimeters at night comes from dew and how much (if any) is directly adsorbed into the soil. In an attempt to resolve this question in the future, leaf wetness sensors are being installed to determine the presence of dew deposition.

Initial results for this study suggest that water was being supplied to the crop at night through direct condensation on the plants and adsorption into the soil. This effect was more prevalent at the sites near the coast. Several years of additional data are needed to quantify water use of the crop over time and throughout the two year cropping cycle. However, the initial results suggest that water demand of wild blueberries will be greater at inland locations where temperature is greater, humidity is less, and coastal fog is less prevalent.

2003 RESULTS

In 2003, the measured parameters included: vapor deposition (VD), vapor uptake (VU), evapotransporation (ET), rainfall (R), drainage (D), relative humidity (RH), solar radiation (SR), air temperature (T), visibility (V), wind speed (W), and volumetric soil water content (θ_v) at Blueberry Hill. Changes in weight averaged over the four lysimeters

on an hourly basis were used to determine vapor transfers. The VD (hourly increase in weight) or VU (hourly decrease in weight) were calculated for only those hours when R = 0, D = 0, and irrigation = 0. Daily evapotranspiration was calculated using three different definitions: (1) daily change in weight (expressed as equivalent water depth) on days where R = 0, D = 0, and irrigation = 0; (2) depth equivalent daily change in weight minus daily R on days where D = 0 and irrigation = 0; (3) daily sum of VU minus sum of VD for all days.

It was a concern that only 74 of the total 115 days could be used with definition (1) and this might inject bias into the ET measurement. The ET was also calculated using definition (2) for 103 days and definition (3) for all 115 days. Using definitions (1), (2), and (3), ET averaged 0.31 cm, 0.27 cm, and 0.26 cm. Definition (1) gives a slightly higher average than definition (2) or (3), probably because by only using days with no rain, it represents a dry weather estimate for ET. Similary, by throwing out all hours with rainfall and irrigation, definition (3) may understate true evapotranspiration because it does not accurately quantify the rapid evaporation period immediately following wetting events.

Initial data from a study of soil water uptake and deposition indicate that vapor deposition accounts for about 22% of the total water uptake and 28% of ET (calculated using definition 2) at the blueberry hill site. The supplemental irrigation to provide a constant weekly rate (1 inch/week) matched measured crop year water requirements through about day 235 after which ET fell rapidly and 1 inch/week would be excessive. Given the high rates of water deposition in the absence of rainfall it is important to have further studies of these phenomena as it may confound traditional irrigation scheduling. The VD may have a profound influence on ET, both over time and spatially at varying distances from the coast. Daily composite data indicated net deposition was greatest between 7:00 and 9:00 a.m. Vapor deposition was weakly correlated with changes in soil water storage suggesting that deposition may be directed into the soil and not merely in the form of dew deposition on plants. Day to day variation in water uptake (ET) rates was substantial and was clearly related to the maximum daily temperature and solar radiation.

2004 RESULTS

In 2004 we had relatively complete datasets on plant water uptake at the three coarse textured sites. Thus, our initial analysis of these data focuses on dry weather plant water uptake (ET as calculated using definition 1) comparing crop and prune year data at various distances from the coast. Water uptake depended fairly predictably on distance from the coast (Figure 6). The inland site (Deblois) had the highest uptake, followed by Blueberry Hill, and the lowest was the coastal Kelley Point site. Uptake for all sites and years fell off fairly rapidly after the beginning of August. The prune (solid lines) vs. crop (dashed lines) comparison showed that prune water uptake was lower than crop at both blueberry hill and Deblois. As the season progressed, the two phases of the growing cycle approached one another and by the latter part of August were nearly identical.

Based upon these data, it is suggested that the prune year water requirements were in the range of 0.8 to 0.9 inches per week over most of the growing season (higher at Deblois than Blueberry hill). However, water requirements were reduced after mid August and reached values as low as 0.5-0.7 inches per week by mid September. Crop year water requirements were considerably higher at Deblois than elsewhere from mid

June through the latter part of July. There was a peak in crop year water uptake in late June at Deblois and Kelley point. The year 2004 is the first year that a full compliment of data is available for comparing water use at the various crop years and sites. Thus, future research is needed to confirm these results and establish long-term averages of crop water usage. Also, it should be cautioned that rainy days were not used in the 2004 calculations. As observed previously, rainy days, foggy days, and days with dew formation have generally lower water uptake and significant vapor deposition. Analysis is currently being conducted to establish corrections to water uptake curves to account for these phenomena.

2005 RESULTS

The 2005 crop years was the first in which data from a completed battery of research sites including sandy and finer textured soil is available. These data are currently being analyzed for crop water uptake rates and irrigation requirements. Two publications (one extension and one peer reviewed) are in preparation on this subject and these will be provided to the research committee. The analysis is being focused upon providing information on plant water demands that can be used in sizing and operating irrigation systems for maximum efficiency. In addition, the relationship between sod depth and water holding capacity has been investigated using soil water mapping technology and our lysimeters that cover a range of soil types and sod depths. Testing of water redistribution through the sod and rhizome network has been done by studying redistribution along a drip-tube transect. Irrigation water application amounts, crop water stress (by the canopy temperature method), and soil water content have been measured across transects as the water redistributes following irrigation. The crop water stress indicates how far away from the irrigated area the plants receive water through rhizomes.

Figure 1. A weighing lysimeter containing newly transplanted blueberry sod.

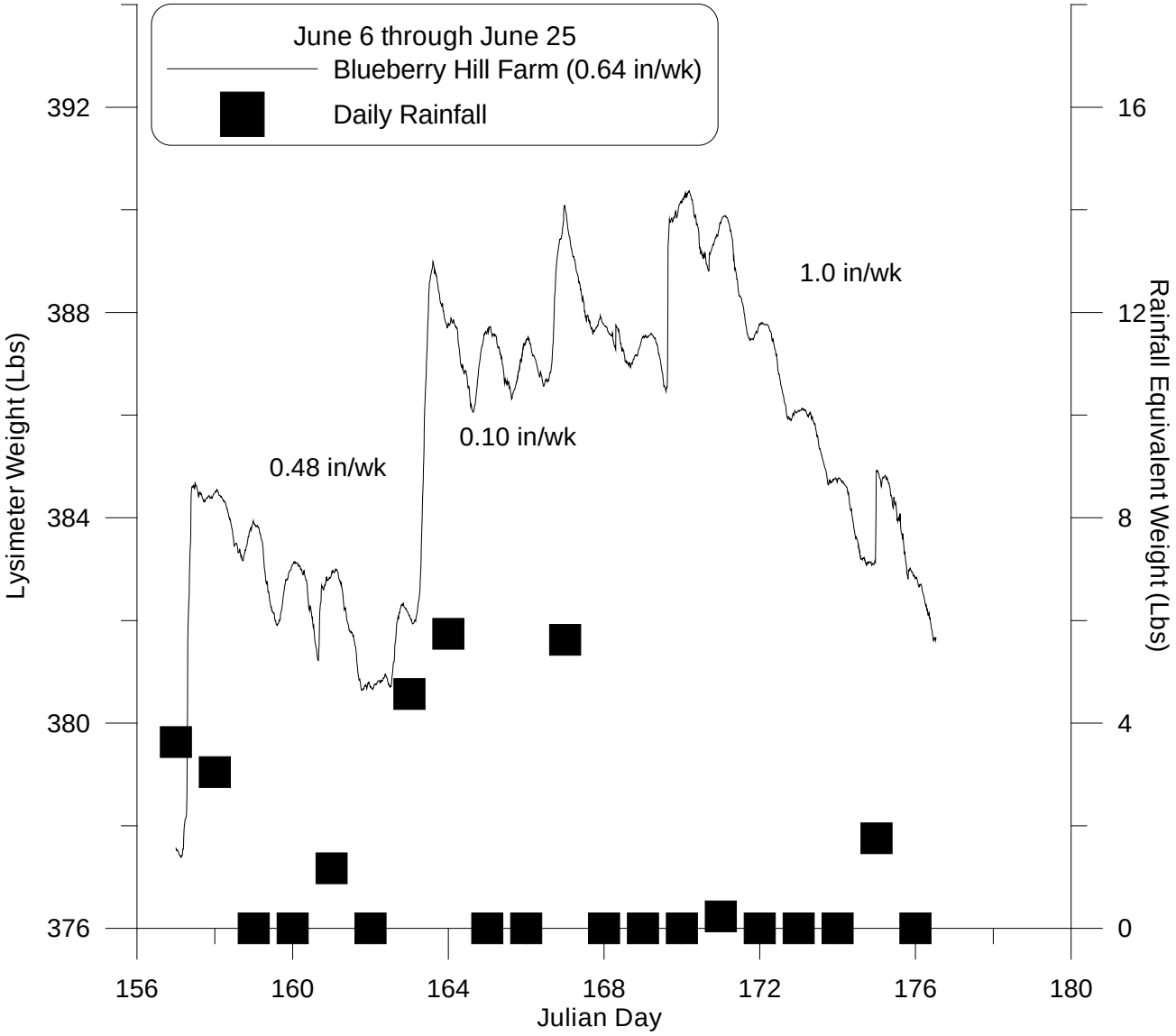


Figure 2. Rainfall equivalent weight and lysimeter weight versus the day of year (Julian Day) from June 6 through 25, 2002.

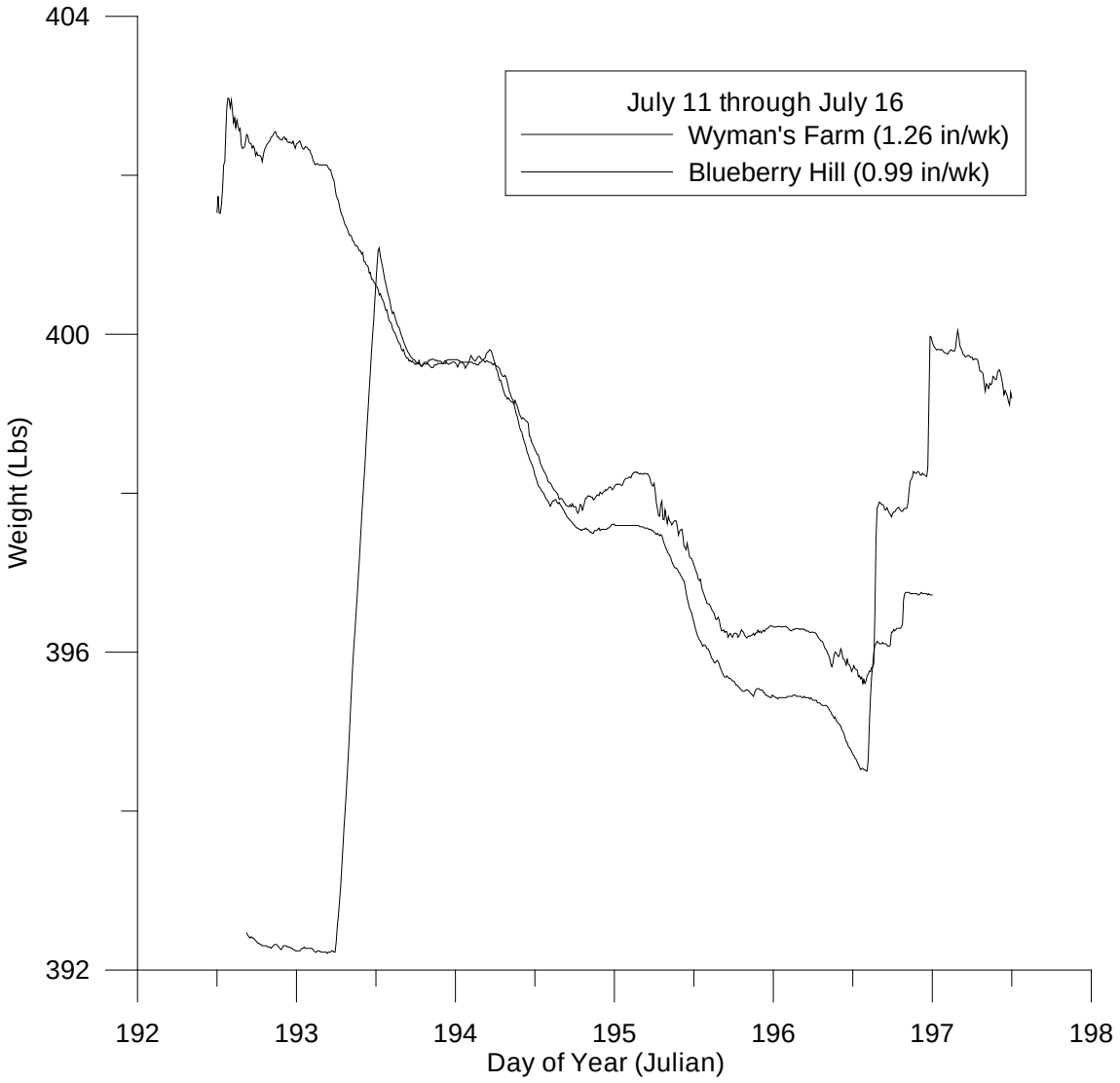


Figure 3. Lysimeter weight over time comparing Blueberry Hill and Wyman's Farm in 2002.

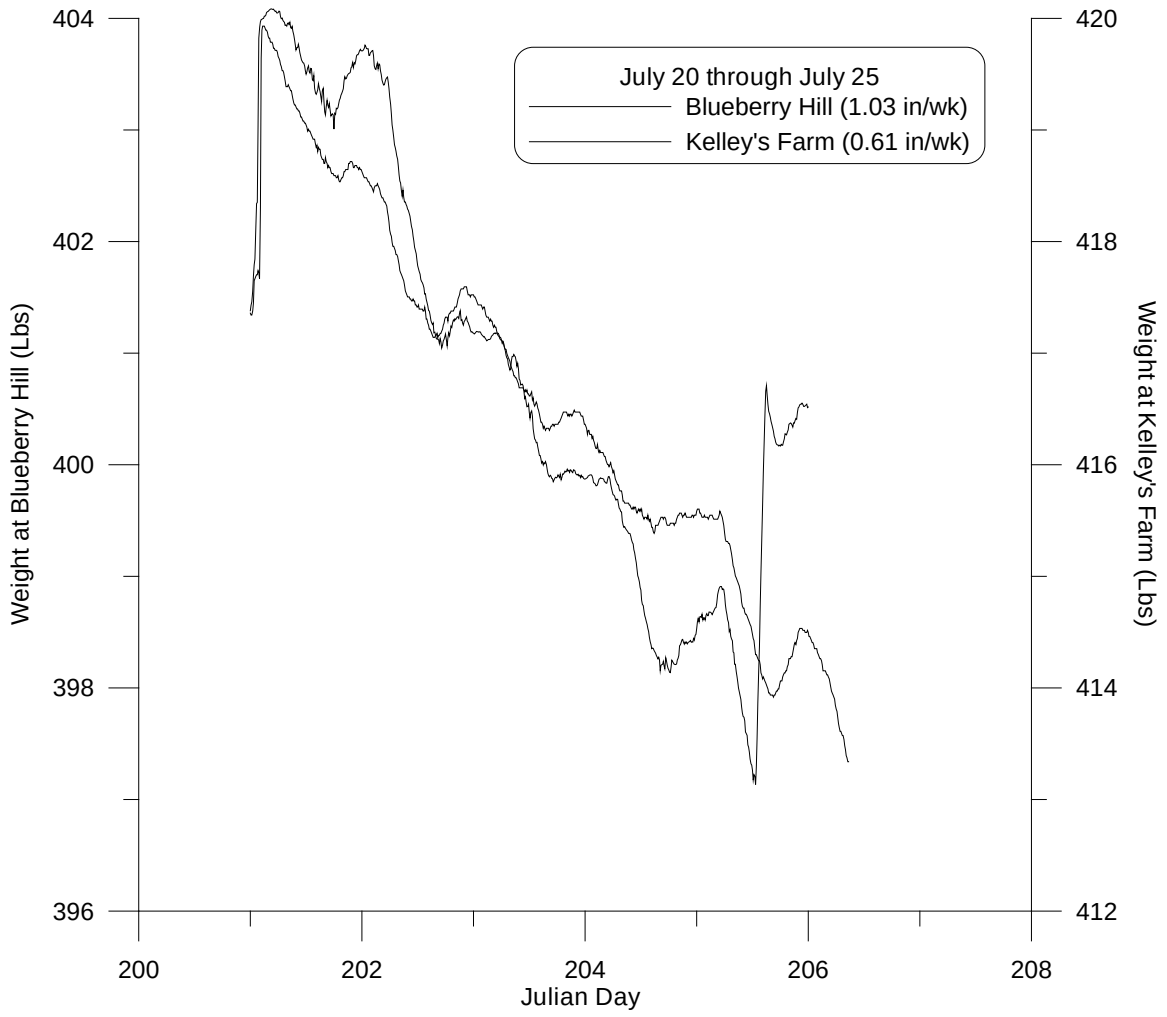


Figure 4. Lysimeter weight over time comparing Blueberry Hill and Kelley's Farm

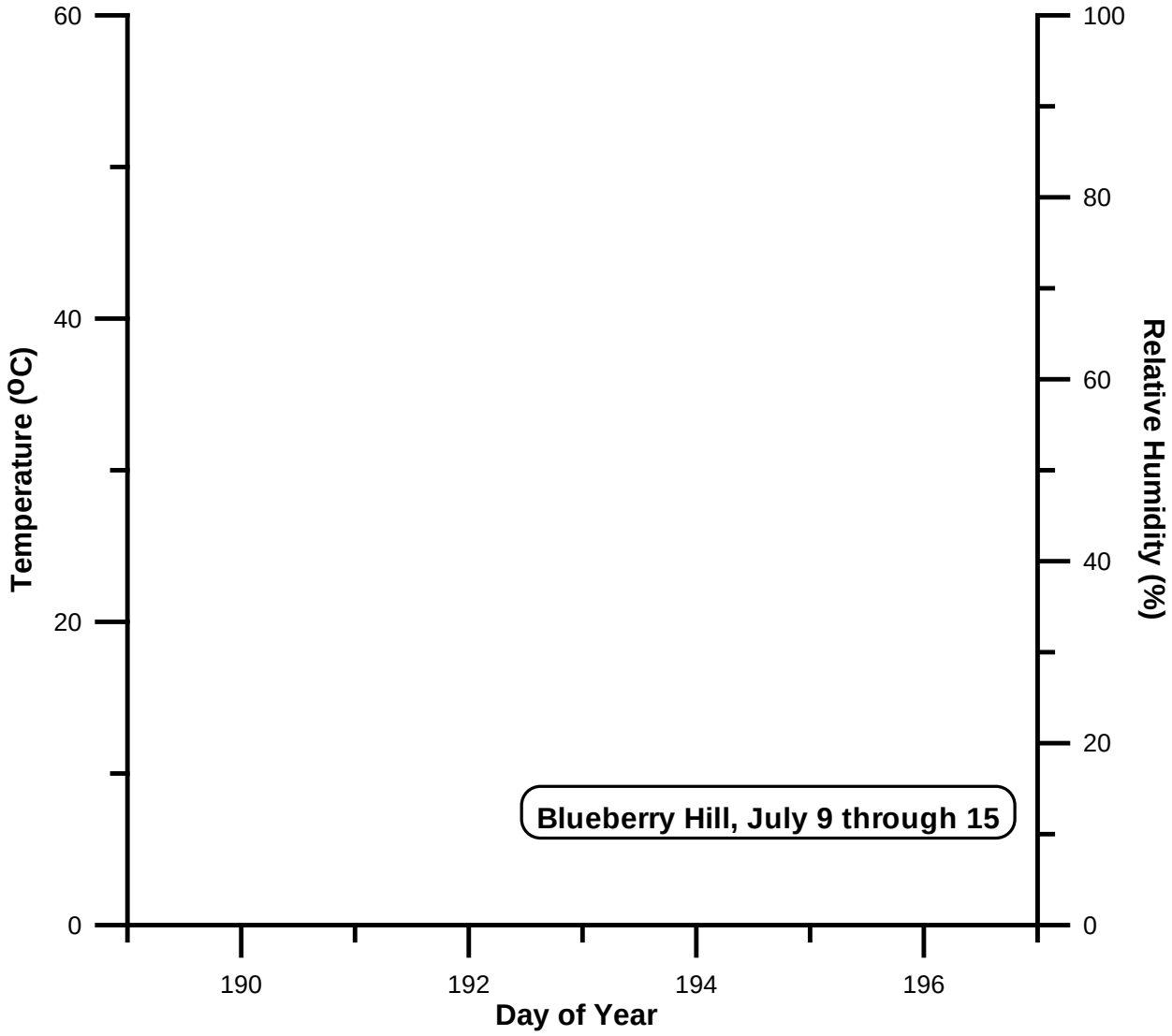


Figure 5. Daily temperature and relative humidity patterns at Blueberry Hill in Mid July, 2002.

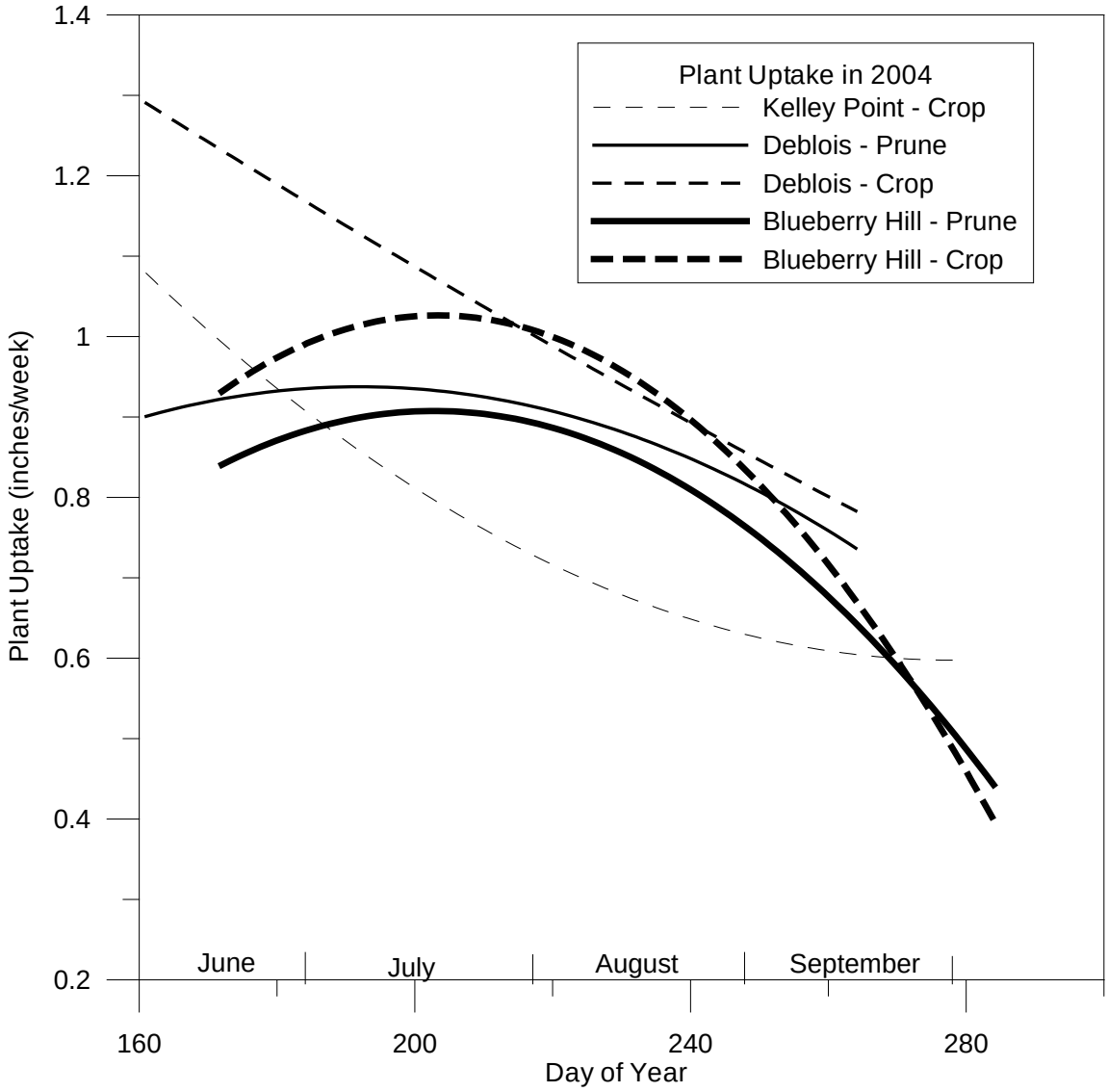


Figure 6. Plant water uptake curves for three sandy sites in prune and crop years.

ENTOMOLOGY – INSECT PEST MANAGEMENT

INVESTIGATORS: F. A. Drummond, Professor of Insect Ecology/Entomology
J. A. Collins, Assistant Scientist of Insect Pest Management

7. TITLE: Control Tactics for Blueberry Pest Insects, 2005

1. Laboratory screening of insecticides.

METHODS: Laboratory screenings were completed against blueberry spanworm (SW), blueberry flea beetle (FB), strawberry rootworm (SR), and red-striped fireworm (FW). Each treatment was applied in 25 gallons of water-mixture per acre with a CO_2-propelled, 80-inch boom sprayer (76-inch swath) equipped with four, flat-spray 8002VS TeeJet® nozzles operating at 35 psi and at a slow walking speed. Speed was regulated using a metronome. The materials were allowed to dry on the foliage. One treated stem was cut and placed in each cup. For the trial against red-striped fireworm, leaf curls containing FW larvae were collected from an infested field and placed individually in plastic cups. There were 25 insects per treatment. Treatments were applied directly onto the curls (in the cups). For all trials, the cups were held in a growth chamber at ca. 21°C and assessed for mortality at daily intervals for five days. Untreated blueberry foliage was added to each cup as needed.

RESULTS: The Product-Limit Survival (Kaplan-Meier) Method and Gehan-Wilcoxon Mean Separation were used to compare the mean days to death of each treatment to the untreated check within each trial (Table 1).

In Trial #1 against SW, Assail 30 SG, Avaunt 30 WG, Entrust 80 WP, and Intrepid 2 F were all significantly different from the check. As expected, mean days to death following application of the insect growth regulator Intrepid 2 F was longer then with the other materials, but still significantly less then the untreated check. Logistic Regression was used to compare % survival among the treatments. All four materials provided excellent control of SW. Figure 1 shows % survival of SW treated with each material. On day 4, 66.7% of larvae fed Intrepid-treated foliage were alive compared to 8.3, 0.0, and 13.3% of larvae fed foliage treated with Assail, Entrust, or Avaunt, respectively. Percent survival on day 5 was only 6.7% vs. 0.0% in the other treatments; 91.7% of the untreated check larvae remained alive at the conclusion of the trial.

All the materials were also significantly different from the untreated check in Trial #2 against FB larvae. The most effective materials were Assail 30 SG and SpinTor 2 SC; 50% of the larvae fed foliage treated with these materials were dead within one day. Assail 30 SG, Avaunt 30 WG, Novaluron 10 EC, and SpinTor 2 SC were all highly effective and significantly reduced % survival in comparison with the untreated check by the third day of the trial (Fig. 2).

Avaunt and Assail also gave excellent control of SR adults (Trial #3). SpinTor 2 SC, while not as effective in this laboratory trial, also performed well. Percent survival was significantly less then the untreated check (Fig. 3).

Entrust 80 WP provided the best control of FW larvae (Trial #4). Over 50% of larvae treated with Entrust were dead within 2 days of the application and only 12% of

the larvae were alive by day 14 of the trial. The application of Intrepid resulted in 52% mortality (Fig. 4).

CONCLUSIONS: Entrust 80 WP and Intrepid 2 F, as well as two materials not included in this trial, SpinTor 2 SC and Confirm 2 F, have all performed well in recent field tests against blueberry spanworm. We do not hesitate to recommend them for control of this insect. These materials are also considered "reduced-risk" and are generally less toxic to humans and the environment. However, Entrust and SpinTor in particular have a very short residual activity in the field and may require multiple applications. From the results of this laboratory trial, Avaunt and Assail appear to be very promising alternatives and warrant additional field tests.

Past field trials for flea beetle control suggest that SpinTor 2 SC, Entrust 80 WP, Imidan, and Mycotrol ES all perform very well. All of these insecticides are registered and currently recommended for use. Results of this laboratory trial indicate that Avaunt 30 SG, Assail 30 WG, and Novaluron 10 EC may also prove to be viable alternatives and should be included in future field tests.

Avaunt and Assail both gave excellent control of strawberry rootworm adults and warrant additional testing in the field. Several additional materials have proven effective in recent field trials. Entrust 80 WP, an organically approved formulation of spinosad (the active ingredient in SpinTor), gave excellent control in 2003. Imidan has also proven to be very effective.

When evaluated in the laboratory, both Entrust and Intrepid appear to have potential to control red-striped fireworm. Further evaluation of both these materials under field conditions is warranted.

2. Field evaluation of insecticides for control of secondary pest insects.

METHODS: Trials were completed against blueberry spanworm (SW) and blueberry thrips (BT). The test against SW was applied as a foliar spray to a fruit-bearing field. Pre- and postspray sweep-net samples were used to estimate control.

In the BT trial, Admire 2 F was applied as a spray to the soil in a pruned field prior to stem emergence; all other materials were applied as foliar sprays timed to stem growth. Efficacy was evaluated according to the number of blueberry stems with and without thrips' damage as evidenced by curled leaves.

RESULTS/CONCLUSIONS: Analysis of Variance (ANOVA) and Student-Newman-Keuls (SNK) Mean Separation ($P \leq 0.05$) were used to compare numbers of SW captured in sweep-net samples. Post spray counts were generally low in all plots. Cool and wet post spray conditions made sweep-net sampling difficult and may have confounded the results. However, all the materials did reduce seasonal densities of blueberry spanworm larvae in comparison with the untreated checks ($P = 0.0001$)(Table 2).

The pre-emergence application of Admire 2 F resulted in a 68% reduction in the average % stems with thrips curls; the difference was significant ($P = 0.0124$)(Table 3). There were also significantly fewer % stems with thrips curls in the plots treated with Assail 30 SG (5.2%) than in the untreated check plots (12.1%); this represents a 57%

reduction. One application of Novaluron 10 EC resulted in a 50% reduction; however, this was not significantly different from the untreated check. Entrust 80 WP was not effective. Additional trials should be completed with Novaluron; since some control was obtained with just one application. Entrust is a short-residual material requiring multiple applications, particularly following rainfall events; however, two applications of SpinTor 2 SC did provide excellent control in a 2003 field trial. Further tests should be conducted with both Entrust and SpinTor.

3. <u>Control of blueberry maggot with ground application of insecticides.</u>

METHODS: We conducted two trials against blueberry maggot (BMF). All materials were applied in 7.25 gallons of water-mixture per acre using a SOLO® 450 mist blower. Pre- and postspray populations of BMF adults were monitored with baited yellow Pherocon® AM traps. Efficacy was further evaluated based on the number of BMF pupae collected from berry samples.

RESULTS/CONCLUSIONS: In Trial #1, the effectiveness of three rates of Provado 1.6 F (4, 6, or 8 oz/acre) was evaluated. Analysis of Variance (Randomized Block Design) and LS Means Differences Tukey HSD ($P \leq 0.05$) were used to compare the seasonal density of BMF adults captured on Pherocon AM traps between treated and untreated check plots. There was a significant difference among the treatments ($P = 0.0354$)(Table 4). There was also a significant regression effect; BMF captures decreased with increasing rates of Provado ($P = 0.0064$). Significantly fewer BMF adults were captured in plots treated with Provado 1.6 F at the highest 8 oz/acre rate.

When the fruit was evaluated for infestation, a large number of pupae (35) were collected from one plot treated with Provado at the 4 oz rate. All other samples collected from Provado-treated plots (all rates) had 5 pupae or less. When this sample was included in the analysis, there was no significant difference among the treatments ($P = 0.1078$). When this sample was excluded from the analysis, ANOVA revealed a decrease in fruit infestation as determined by assessing the number of pupae found in berry samples. As application rate increased, there was an accompanying decrease in infestation levels ($P = 0.0103$) (Table 4 and Fig. 5). Data for number of pupae was transformed by sqrt prior to analysis. We are unsure how to explain the high level of infestation in one plot treated with a low (4 oz) rate. It is possible, but unlikely, that it can be attributed to a mechanical problem with the sprayer. The topography of the site is another possibility.

In Trial #2, the effectiveness of Prev-AM was evaluated. There was no significant difference in seasonal density of adults ($P = 0.4708$) or number of pupae ($P = 0.2197$). Prev-AM (sodium tetraborohydrate decahydrate) is a blend of borax, orange oil, and organic surfactants and is advertised as having both fungicidal and broad-spectrum insecticidal activity. However, this material appeared to be ineffective in controlling BMF in this trial.

4. <u>Control of blueberry maggot with GF-120 NF Fruit Fly Bait.</u>

METHODS: An ATV-mounted sprayer was used to apply 2:20-ft perimeter swaths of GF-120 NF Fruit Fly Bait at a rate of 1:5 v/v with water. Pre- and postspray populations of BMF adults were monitored with baited yellow Pherocon AM traps. Efficacy was further evaluated based on the number of BMF pupae collected from berry samples.

RESULTS/CONCLUSIONS: The effectiveness of applying GF-120 NF with different timings was evaluated. Analysis of Variance and LS Means Differences Tukey HSD ($P \leq 0.05$) were used to compare the seasonal density of BMF adults captured on Pherocon AM traps between plots treated with GF-120 NF on a weekly basis, plots treated with GF-120 as needed based on Pherocon trap counts, and untreated check plots. There was no significant difference among the treatments ($P = 0.3387$)(Table 5).

When the fruit was evaluated for infestation, there was no significant difference among the treatments ($P = 0.2563$). Data for number of pupae was transformed by sqrt prior to analysis.

RECOMMENDATIONS:

These trials represent the first year of testing with Assail 30 SG and Avaunt 30 WG. Both of these materials warrant further testing. Assail (acetamiprid) is a reduced-risk, broad-spectrum, neonicotinoid insecticide offering the advantage of low toxicity to beneficial insects and a longer residual than spinosad. Our initial trials have show it to have some effect against a variety of blueberry pest insects including blueberry spanworm, blueberry flea beetle, strawberry rootworm, and blueberry thrips. Avaunt 30 WG (indoxacarb) is one of a new class of materials called oxadiazines and offers similar advantages. It is a broad-spectrum material that appears to have at least some activity against a variety of blueberry pest insects. It is classified as a reduced-risk product with low toxicity to both honeybees and bumblebees once the material has dried on the foliage. And, it has a short pre-harvest interval (3 days).

There are currently no control recommendations for red-striped fireworm. This pest is becoming more of a concern with the adoption of perimeter sprays for control of blueberry maggot. Red-striped fireworm was generally controlled by full-field applications. This pest is becoming a contaminant problem for those growers that are exporting the harvest to Europe and Asia.

Mixed results have been obtained in trials with pre-emergence applications of Admire 2 F as a control for blueberry thrips over the past few years. Reductions of 38%, 26%, 100%, and 64% were observed following similar applications in 2000, 2002, 2003, and 2004, respectively. Based on these results, control of thrips will remain a potential problem. However, Admire 2 F would appear to be the best currently available alternative to diazinon.

This is the second year of trials with Provado 1.6 F (imidacloprid). It has proven effective in both years. Despite the promising results obtained in 2003 and 2004, GF-120 NF Fruit Fly Bait was ineffective in this 2005 trial. GF-120 is a short-residual material and may require frequent applications to maintain control. Further trials are needed to assess the long-term viability of this material as an alternative for BMF control.

1. Laboratory screening of insecticides.

Table 1. Laboratory screening of insecticides, mean days to death.

Material	Rate (oz/acre)	Mean days to death *	*Prob Chi*^{2} ≥< 0.05 ***
Trial # 1 – Blueberry Spanworm Larvae			
Assail 30 SG	5.3 oz	1.00	< 0.0001
Avaunt 30 WG	6.0 oz	2.00	< 0.0001
Entrust 80 WP	2.0 oz	1.00	< 0.0001
Intrepid 2 F	16.0 oz	5.00 *	< 0.0001
Untreated check	-	**	NA
Trial # 2 – Blueberry Flea Beetle Larvae			
Assail 30 SG	5.3 oz	1.00	< 0.0001
Avaunt 30 WG	4.0 oz	3.00	< 0.0001
Avaunt 30 WG	6.0 oz	2.00	< 0.0001
Novaluron 10 EC	9.6 oz	3.00 *	0.0003
SpinTor 2 SC	6.0 oz	1.00	< 0.0001
Untreated check	-	**	NA
Trial # 3 – Strawberry Rootworm Adults			
Assail 30 SG	5.3 oz	1.00	< 0.0001
Avaunt 30 WG	6.0 oz	3.00	< 0.0001
SpinTor 2 SC	6.0 oz	**	0.0362
Untreated check	-	**	NA
Trial # 4 – Red-striped Fireworm Larvae			
Entrust 80 WP	2.0 oz	1.5 *	0.0007
Intrepid 2 F	16.0 oz	8.0 *	< 0.0001
Untreated check	-	**	NA

* Biased estimate due to censored observations (live larvae) at end of study.
** Not possible to estimate because of > 50% survival.
*** Probability of treatment not different from untreated check.
NA Not applicable.

Fig. 1. Percent survival of blueberry spanworm larvae.

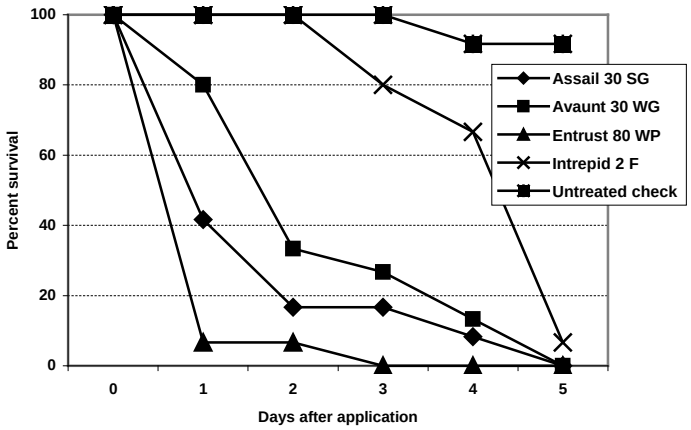


Fig. 2. Percent survival of blueberry flea beetle larvae.

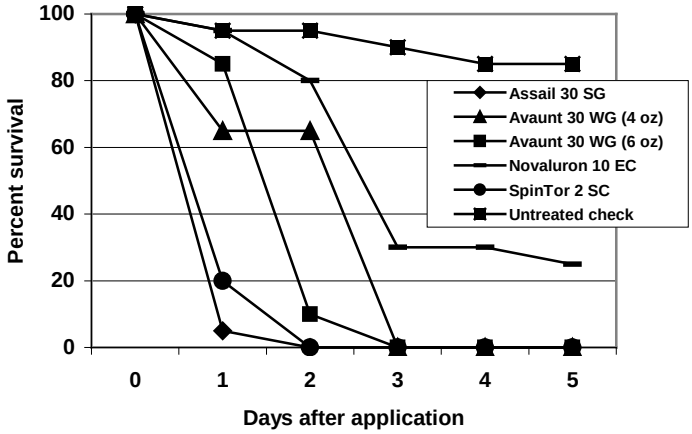


Fig. 3. Percent survival of strawberry rootworm adults.

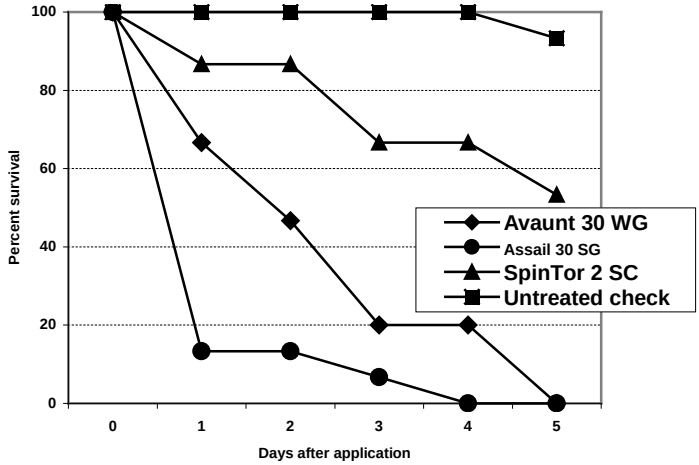
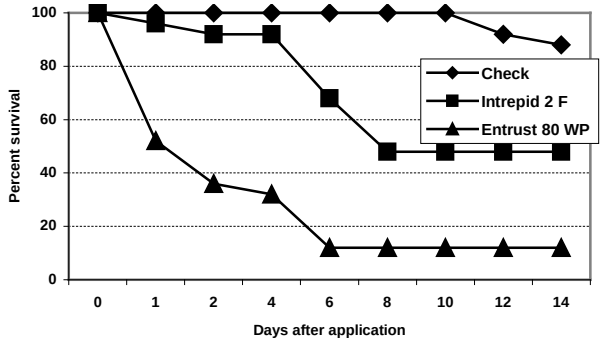


Fig. 4. Percent survival of red-striped fireworm larvae.



2. <u>Field evaluation of insecticides for control of secondary pest insects.</u>

Table 2. Field control of blueberry spanworm larvae with insecticides, summary.

Material	Amt. form./ acre	Larvae/10 sweeps Prespray 10 May	Post spray 11 May	13 May	17 May	20 May	Seasonal density	
Assail 30 SG	**5.3 oz**	**21.3 a**		**8.8**	**0.8**	**1.0**	**1.3**	**4.1 b**
Avaunt 30 WG	**4.0 oz**	**22.8 a**		**5.8**	**0.3**	**3.5**	**2.0**	**4.6 b**
Avaunt 30 WG	6.0 oz	24.5 a		3.5	1.5	5.0	0.0	4.9 b
Entrust 80 WP	**2.0 oz**	**23.8 a**		**1.8**	**0.5**	**3.3**	**2.8**	**3.4 b**
Intrepid 2 F	**8.0 oz**	**24.0 a**		**7.0**	**1.0**	**4.0**	**0.8**	**4.0 b**
SpinTor 2 SC	**6.0 oz**	**24.0 a**		**1.8**	**0.3**	**4.8**	**2.0**	**7.0 b**
Untreated check	**-**	**23.5 a**		**6.0**	**1.5**	**2.8**	**4.8**	**11.5 a**

Seasonal densities are trapezoidal integrals of densities over the season divided by the number of day's duration of the experiment. Means followed by the same letter(s) are not significantly different ($P \leq 0.05$, SNK).

Table 3. Field control of thrips with insecticides, summary.

Material (SE)	Amt. form./acre	Avg. # stems/	Avg. % stems with ft^2 (SE) curls/ft^2
Admire 2 F (pre-emergence)	16.0 oz	64.4 (10.7) a	3.9 (2.0) c
Assail 30 SG	5.3 oz	73.2 (4.4) a	5.2 (2.0) bc
Entrust 80 WP	2.0 oz	66.5 (6.8) a	10.8 (4.3) ab
Novaluron 10 EC	9.6 oz	69.8 (8.1) a	6.1 (2.3) abc
No insecticide	-	59.7 (9.5) a	12.1 (3.8) a

Means within each column followed by the same letter(s) are not significantly different ($P \leq$ 0.05, SNK).

3. Control of blueberry maggot with ground application of insecticides.

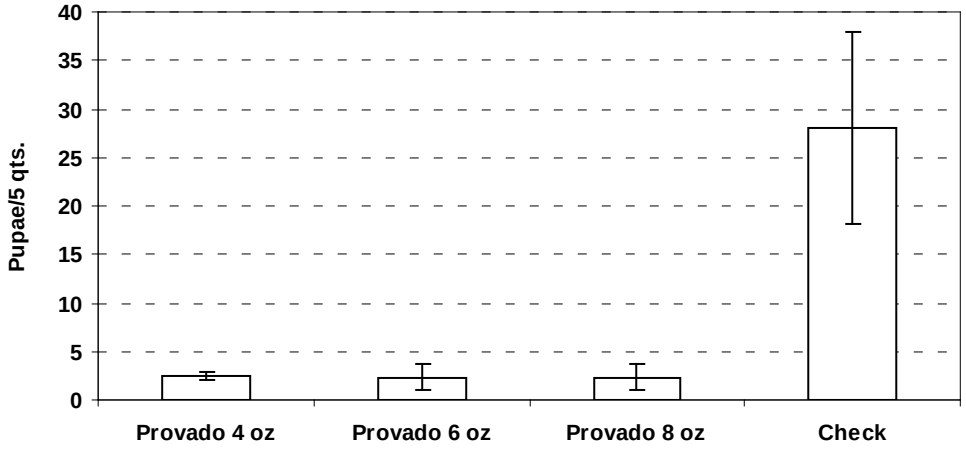
Table 4. Field control of blueberry maggot with Provado 1.6 F and Prev AM, summary.

	Amt. form./acre	Avg. pupae/5 qts	Avg. pupae/5 qts	Adults/trap seasonal density (SE)
Trial # 1				
Provado 1.6 F	8.0 oz	2.33 (1.31) b	2.33 (1.31) a	3.65 (0.21) b
Provado 1.6 F	6.0 oz	2.33 (1.31) b	2.33 (1.31) a	4.02 (0.24) ab
Provado 1.6 F	4.0 oz	2.50 (0.40)) b *	13.33 (10.67) a **	4.70 (0.94) ab
Untreated check	-	28.00 (9.84) a	28.00 (9.84) a	6.81 (0.48) a
Trial # 2				
Prev AM	4% sol.		34.00 (10.21) a	3.63 (0.69) a
Untreated check	-		17.33 (6.26) a	4.98 (1.84) a

* Data for number of pupae/5 qts in Provado (4 oz) based on 2 replications.
** Data for number of pupae/5 qts in Provado (4 oz) based on 3 replications.

Seasonal densities of adults are trapezoidal integrals of densities over the season divided by the number of day's duration of the experiment. Means within each column and trial followed by the same letter(s) are not significantly different ($P \leq 0.05$, LS Means Differences Tukey's HSD).

Fig. 5. Control of BMF with Provado 1.6 F, fruit infestation.



4. <u>Control of blueberry maggot with GF-120 NF Fruit Fly Bait.</u>

Table 5. Field control of blueberry maggot with GF-120 NF Fruit Fly Bait, summary.

	Treatment	Avg. pupae/5 qts	Adults/trap seasonal density (SE)
GF-120 NF	Weekly	51.2 (24.3) a	3.05 (0.68) a
GF-120 NF	As needed	21.4 (5.8) a	2.23 (0.96) a
Untreated check	-	31.2 (10.4) a	3.95 (1.28) a

Seasonal densities are trapezoidal integrals of densities over the season divided by the number of day's duration of the experiment. Means within each column and trial followed by the same letter are not significantly different ($P \leq 0.05$, LSMeans Differences Tukey's HSD).

ENTOMOLOGY – INSECT PEST MANAGEMENT

INVESTIGATORS: F. A. Drummond, Professor of Insect Ecology/Entomology
J. A. Collins, Assistant Scientist of Insect Pest Management

8. TITLE: Integrated Pest Management (IPM) strategies, 2005

1. Evaluation of feeding damage by blueberry spanworm larvae in the pruned year.

METHODS: In May 2005, five replications (blocks) were established in a pruned field at Blueberry Hill Farm. The field was burned in the fall of 2004. Five, 4-ft^2 plots were set in each block and one of five different densities of blueberry spanworm larvae was placed in each plot (0, 25, 50, 75, or 100 larvae). Two blocks were set on 6 May using 2^{nd} to 4^{th} instar larvae collected from an infested field. Three additional blocks were set on 11 May with 2^{nd} to 5^{th} instar larvae. Each plot was covered with a mesh cage (2.0 x 2.0 x 1.5 ft) and sealed with sand around the bottom to prevent movement of the larvae from the plots.

On 21 May, the cages were removed and the number of blueberry stems growing within each plot was counted and compared with the initial larval density.

On 21 November, 50 stems within each plot were cut and brought into the laboratory. The number of flower buds/stem was recorded at each density. Analysis of Variance (RCB) and Regression analyses were conducted comparing average flower buds/stem with initial larval density.

RESULTS/CONCLUSIONS: Figure 1 and Table 1 show the relationship between average number of blueberry stems and initial spanworm larval density. There was no significant difference in the number of stems among the densities (ANOVA, $P = 0.5788$). There was also no significant linear trend ($P = 0.9147$).

Subsequent fall flower bud production indicated a significant difference in flower bud production among the densities (ANOVA, $P = 0.0341$) (Table 1 and Fig. 2). There was also a significant linear trend ($P = 0.0001$). There was an apparent increase in flower bud production with increasing numbers of spanworm larvae.

Table 1. Comparison of blueberry stem production and subsequent flower bud production with spanworm larval density.

Initial spanworm larval density	Avg. number of stems/plot	Avg. flower buds/ stem
0	64.8 a	2.20 c
25	69.6 a	2.62 bc
50	68.0 a	3.19 abc
75	63.6 a	3.43 ab
100	66.2 a	3.82 a

Means within each column followed by the same letter are not significantly different ($P \leq 0.05$, LS Means Differences Tukey's HSD).

Fig. 1. Relationship between initial spanworm larval density and blueberry stem production.

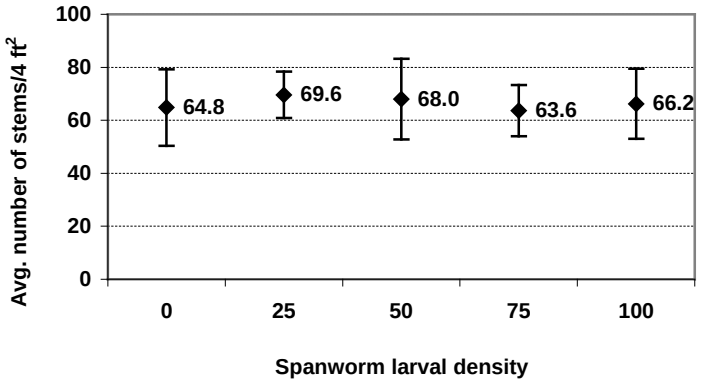
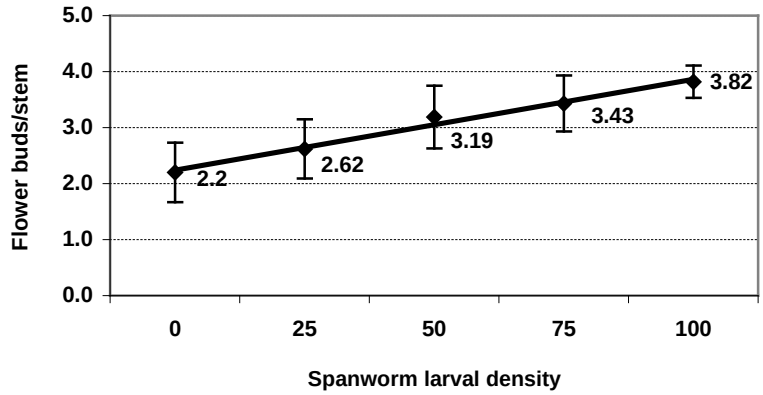


Fig. 2. Relationship between initial spanworm larval density and blueberry flower bud production.



2. Evaluation of feeding damage by blueberry flea beetle larvae in the pruned year.

METHODS:

On 11 May 2005, five replications (blocks) were established in a pruned field at Blueberry Hill Farm. The field was burned in the fall of 2004. Five, 4-ft^2 plots were set in each block and one of five different densities of field-collected, mid-instar blueberry flea beetle larvae was placed in each plot (0, 25, 50, 75, or 100 larvae). Each plot was covered with a mesh cage (2.0 x 2.0 x 1.5 ft) and sealed with sand around the bottom to prevent movement of the larvae out of the plots.

On 21 June, the cages were removed and the number of blueberry stems growing within each plot was counted and compared with the initial larval density.

On 1 December, 50 stems within each plot were cut and brought into the laboratory. The number of flower buds/stem was recorded at each density. Analysis of Variance (RCB) and Regression analyses were conducted comparing average flower buds/stem with initial larval density.

RESULTS/CONCLUSIONS:

Figure 1 shows the relationship between average number of stems and initial flea beetle larval density. There was a significant difference in the number of stems among the densities (ANOVA, $P = 0.0135$). There was also a significant linear effect ($P = 0.0036$), but no significant quadratic ($P = 0.6274$) or cubic ($P = 0.1914$) trend. Figure 1 suggests that low densities of flea beetle might stimulate stem production, but analysis of variance did not support this contention. The only significant trend found was a linear response, interpreted as follows: each individual increase in flea beetle larval numbers results in an incremental decrease in stem density per plot.

Subsequent fall flower bud production indicated a significant difference in flower bud production among the densities (ANOVA, $P = 0.0001$) (Table 1 and Fig. 2). There was an apparent linear trend; however it was not significant ($P = 0.0695$).

Table 1. Comparison of blueberry stem production and subsequent flower bud production with flea beetle larval density.

Initial flea beetle larval density	Avg. number of stems/plot	Avg. flower buds/ stem
0	94.0	3.36 ab
25	112.8	3.39 a
50	88.0	2.94 abc
75	62.2	2.60 c
100	65.8	2.88 bc

Means within each column followed by the same letter are not significantly different ($P \leq 0.05$, LS Means Differences Tukey's HSD).

Fig. 1. Relationship between initial flea beetle larval density and blueberry stem production.

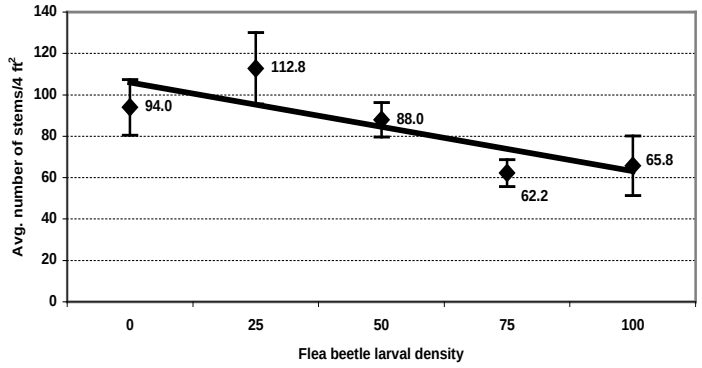


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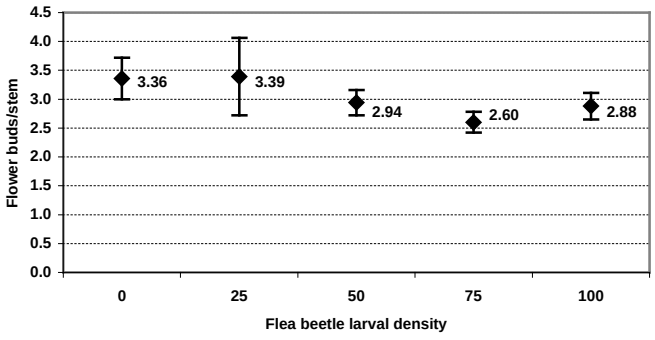
Fig. 2. Relationship between initial flea beetle larval density and blueberry flower bud production.



3. <u>Evaluation of two methods of estimating fruit infestation by blueberry maggot.</u>

METHODS:

On 8 August, we raked twenty quarts of blueberries from a field with a large population of blueberry maggot flies (BMF) as determined by monitoring with baited, yellow, Pherocon® AM traps. The berries were 90-95% ripening and turning blue.

Ten quarts were distributed in a 1 to 2-inch deep layer in screened boxes suspended over ca. 2 inches of fine sand (5 quarts of infested berries per box). Hardware cloth (0.25 inch) was used as a screening material. The BMF were allowed to develop, and in late September and mid-October, BMF pupae were separated from the sand by floating them in water using the protocol below.

Floatation Procedure for Collecting BMF Pupae:

1. Fill a 6 to 10-inch deep and 12 to 18-inch diameter container with water.
2. Place ca. 1 to 2 inches of sand with pupae in the bottom of the container.
3. Stir the sand gently to loosen any pupae and allow them to float to the top.
4. With a small brush, remove any floating pupae from the surface and place them on newspaper to dry.
5. Repeat steps 3 and 4 to insure that all pupae have been collected.

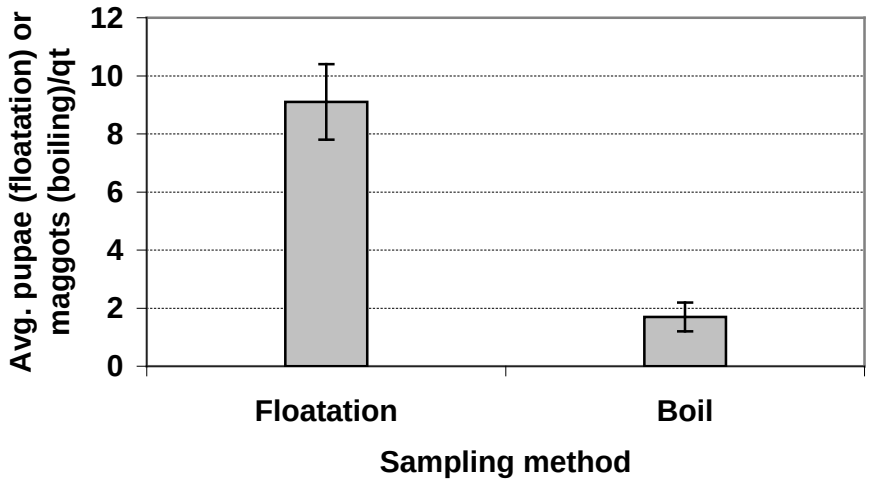
The remaining 10 quarts were stored in individual plastic bags and placed in the refrigerator prior to processing by boiling according the following protocol. The 10 quarts were processed within 2 weeks of collection.

Boiling Procedure for Collecting BMF Larvae:

1. Place 1 quart of fruit in a medium sized saucepan. Fill the pan 1/3 full of water and, stirring occasionally, bring to a boil over medium heat.
2. Simmer uncovered for 3 to 5 minutes or until the fruit has broken-down.
3. Empty mixture into a large kitchen sieve held over a black 9 x 13 inch baking dish.
4. Mash the mixture thoroughly then rinse with running water. Collect rinse water in the baking dish. Be careful not to let the water overflow.
5. Discard the pulp mixture.
6. Decant the rinse water being careful not to pour off the material in the bottom of the baking dish.
7. Repeat the process of filling the pan with water and decanting twice or until liquid runs clear.
8. Examine the contents of the baking dish and collect any larvae.

RESULTS/CONCLUSIONS: Analysis of Variance was used to compare the number of pupae collected using the floatation procedure with the number of larvae collected by boiling. Significantly more BMF were collected using the floatation method ($P = 0.0001$) (Fig. 1). Although floatation appears to be the more accurate method of estimating fruit infestation, it is probably best suited to scientific studies and is not a viable method in commercial settings. Development of the BMF to the pupal stage requires several weeks; the boiling method is a "same-day" estimate. Floatation is also more labor intensive and requires the construction of special "pupation boxes". Once built; however, these boxes can be reused many times.

Fig. 1. Estimate of fruit infestation.



4. Comparison of two barriers to emigration into fields by blueberry maggot.

METHODS: In 2005, we evaluated both pesticide-treated plastic spheres (PTS) and baited, yellow Pherocon AM traps (YPT) for control of blueberry maggot fly (BMF) in three blocked, untreated (no insecticide sprays) fruit-bearing blueberry fields. Pesticide-treated spheres and yellow panel traps were deployed in a manner to intercept BMF emigrating into fields from the surrounding forest and other blueberry fields. The treatment plots (PTS and YPT) of each field had either spheres or traps placed every 10 ft along the perimeter closest to the woods. The control (CON) plots had no spheres or traps deployed around the perimeter. In each treatment, seven baited, yellow Pherocon traps were placed throughout the field to monitor BMF penetration into the fields. Four of the traps were placed around the perimeter of each plot, and three traps were placed across the middle of each plot. Traps were checked twice per week during July and August.

Blueberries were raked from Pesticide-Treated Sphere, Yellow Panel Trap, and Control plots (1 quart from each edge and 3 quarts across the middle of each plot). Berries were placed on a wire platform over moist sand where they remained for a 1-2 months until the BMF had pupated into the sand. At that time, the sand was placed in a bucket with water and was agitated to dislodge pupae causing them to float. Floating pupae were removed and counted.

RESULTS/CONCLUSIONS: There was no significant difference in the number of BMF adults captured on yellow monitoring traps in PTS, YPT, or Control plots ($P = 0.273$), or in the number of BMF captured at the edge or in the middle of plots ($P = 0.482$). The field located in Township 19 had many more total BMF than either of the other fields (Fig. 1).

There was also no significant difference in the number of BMF pupae found in fruit collected from PTS, YPT, and Control plots ($P = 0.877$), or from the edge or middle of plots ($P = 0.229$). The average number of pupae per quart of blueberries in any treatment or location was between 1.8 and 4 (Fig. 2).

It does not appear that pesticide-treated spheres or yellow panel traps are successful at intercepting emigrating BMF. There was little difference in the number of BMF located on traps or found in berries between the edge and middle of all treatment plots, and there were similar numbers of flies found in control and treatment plots. Future research should concentrate on finding a way to attract BMF to perimeter traps to make them a more effective method for controlling BMF.

Fig. 1. Mean number of BMF captured per trap in Control, PTS, and YPT treatments by field and location.

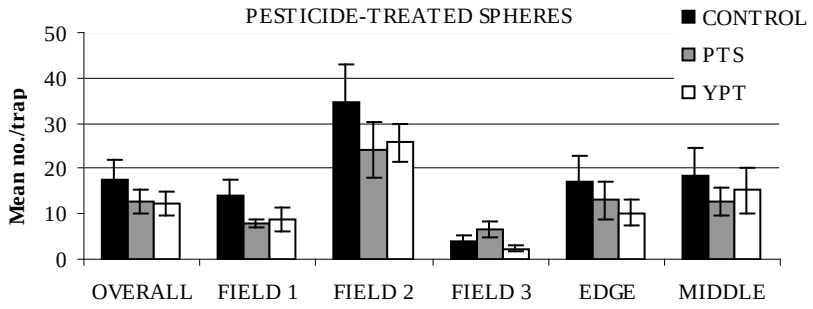
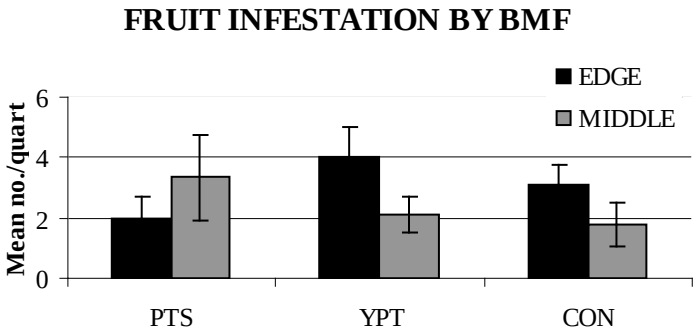


Fig. 2. Mean number of BMF pupae found per quart of blueberries at the edge and middle of each treatment plot.



5. Effect of date of pruning on flower-bud production in lowbush blueberry.

METHODS: In the fall of 2004, seven lowbush blueberry clones were selected and set with markers in a crop-year field at Blueberry Hill Farm. The minimum size of each clone was 20 x 20 ft. On 29 September a flail-mower mounted on an ATV was used to mow a minimum 2-m^2 plot within each clone. In the spring and summer of 2005, nine additional plots were mowed within each clone. Treatment dates were: 6 and 20 April; 3, 17, and 31 May; 15 and 29 June; 15 July; and 31 August 2005. In the spring of 2006, the number of flower buds will be counted on each of 100 lowbush blueberry stems from each plot. Regression analysis will be used to determine the relationship between date of pruning and flower-bud production.

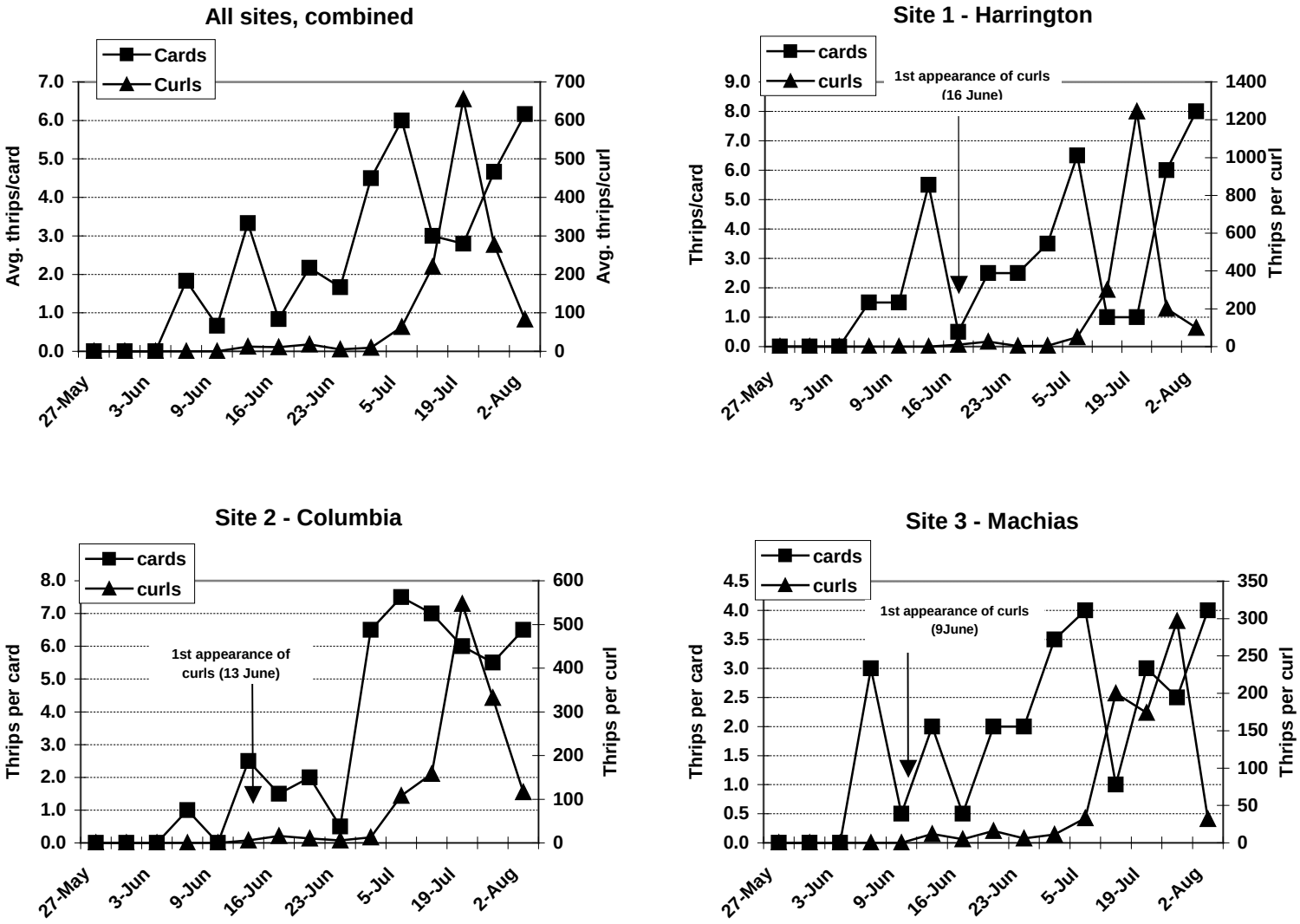
6. Monitoring populations of thrips in wild blueberry (pruned year) fields.

METHODS: *Yellow sticky cards*: On 24 May, two yellow sticky cards were placed in each of three pruned blueberry fields that had been infested with thrips in 2003. Each card measured 3 x 5 inches and was hung just above the ground from a wooden lathe. No blueberry plants had emerged at the time the cards were distributed in the field. All the cards were replaced at weekly intervals from 27 May to 2 August. The number of thrips on each card was counted using a dissecting microscope.

Examination of leaf curls: At weekly intervals beginning on 9 June when curls were first observed, 10 leaf curls were collected from each of the same fields and brought into the laboratory. The curls were examined and the number of thrips per curl was recorded. The thrips were collected and stored in 70% Ethyl alcohol for future identification.

RESULTS/CONCLUSIONS: Peak captures of blueberry thrips on yellow sticky cards were recorded on 5 July. The highest numbers of thrips in curls occurred on 19 July. As can be seen in figure 1, there was a lag between peak thrips per card and peak thrips per curl at all three sites. Our conclusion based on this study is that growers who are using foliar insecticide applications for blueberry thrips control should deploy sticky traps in early May and monitor the traps to determine when insecticide applications should be applied.

Fig. 1. Comparison of numbers of thrips captured on yellow sticky cards and thrips found in leave curls.



7. Development of a sequential sampling plan for blueberry spanworm larvae.

METHODS: Data used to develop a sequential sampling plan was based upon a historical data set collected in 16 blueberry fields between 1997 and 2005. The data consisted of larval (all instars) counts per set of ten 180º sweeps. The number of sets of ten sweeps varied between years and fields, ranging from 13 to 224 per field. Characterization of the spatial pattern of larvae within a field was performed by a Taylor power law regression, i.e. $S^2 = a\ m^{\ b}$, where S^2 = variance and m = mean for a given field; and a and b are regression coefficients for the intercept and slope. In addition, the parameters for the negative binomial distribution were estimated as follows:

$$P(x) = \frac{(k + x - 1)!\ p^{\ x}\ q^{-(x+k)}}{x!\ (k-1)!}$$

Where: □ = kp $S^2 = kp + kp^2$

With the spatial pattern characterized, an optimal sample size for a fixed sample plan was determined and sequential sampling guidelines using Wald's SPRT method were developed. To test the validity of the sequential sampling plan, a simulation model was used based upon the characterized spatial pattern of larvae in fields.

RESULTS: Figure 1 depicts the spatial pattern of blueberry spanworm larvae. It can be seen that larvae do not occur randomly, but instead are highly aggregated or clumped meaning where you find one larva you are very likely to find more. This aggregated distribution of larvae in a field results in a fixed sampling plan such that for precisions of 10 and 20% the estimated number of sets of sweeps necessary to accurately estimate larval abundance near threshold levels (10 larvae / set of 10 sweeps) are about 36 and 10 sets of sweeps, respectively (for levels of precision of 10% and 20%, with precision defined as the SE/mean ratio), (Fig. 2). Figure 3 illustrates that if one wants to be 95% confident in estimating larval densities near threshold levels, the necessary sample sizes for 10% and 20% precision are about 135 and 35 sets of sweeps per field. Figures 4, 5, and 6 are sequential sampling plans for blueberry spanworm larvae for error rates (precisions) of 20, 10, and 5%, respectively. These graphs provide the bounds for a field scout to decide when sampling can be stopped or if more samples need to be taken in order to determine whether the economic threshold has been exceeded or not. The idea in using these sequential sampling plans is that a field scout would take an initial series of samples, for example 5 samples, and then determine where they are on the graph as far as larval catch is concerned. The decision is made in accordance whether one finds themselves well below the threshold, well above the threshold, or in the area of uncertainty, in which case the sampler would take another series of samples and reassess where the data falls on the graph. Table 1 is the same sequential plan as figure 5, but in a more easily interpreted format. Table 1 includes an upper limit of 35 samples at which the scout would complete the field sampling and make a decision. This is to guard against continuous sampling in a field that is at or very close to the threshold. Table 2 illustrates how many samples would need to be taken for three simulated fields with populations of 18, 5, and 11 larvae / set of 10 sweeps. Only 5 samples would need to be taken for a field of 18 larvae / set of 10 sweeps in order to determine that the field exceeds threshold

levels of larvae and should be treated. Seven samples are necessary for a field that has only 5 larvae / set of 10 sweeps. In this case after seven samples the decision is not to treat. A field that has a population density very close to the threshold, 11 larvae / set of 10 sweeps, requires sampling 20 sets of 10 sweeps in order to determine that the field is above threshold and requires treating.

CONCLUSION: A fixed optimal sampling plan reveals that adequate sampling of a field requires anywhere from 10 to 35 sets of ten sweep samples or 35 to 135 samples if 95% confidence is required at precisions of 20 and 10%. The sequential sampling plan can save considerable time by setting an upper limit of 35 samples, but having many fields that might only require 5 – 7 samples.

Fig. 1. Taylor power law fit of the relationship between the variance and mean sweep-net numbers for each field.

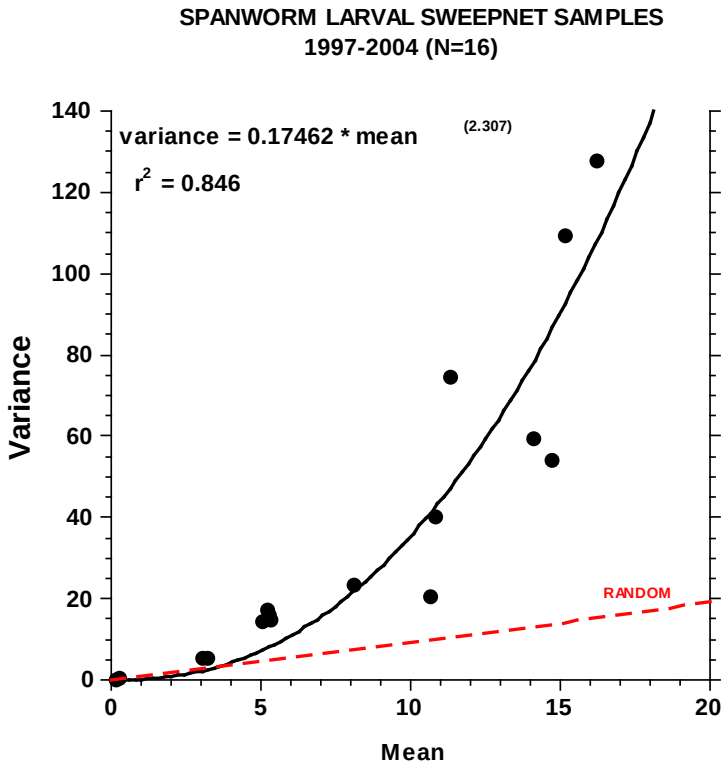


Fig. 2. Fixed optimal sampling plan for blueberry spanworm larvae at 10 and 20% levels of precision. Dotted line demarcates number of samples needed to accurately estimate spanworm larval numbers near the threshold.

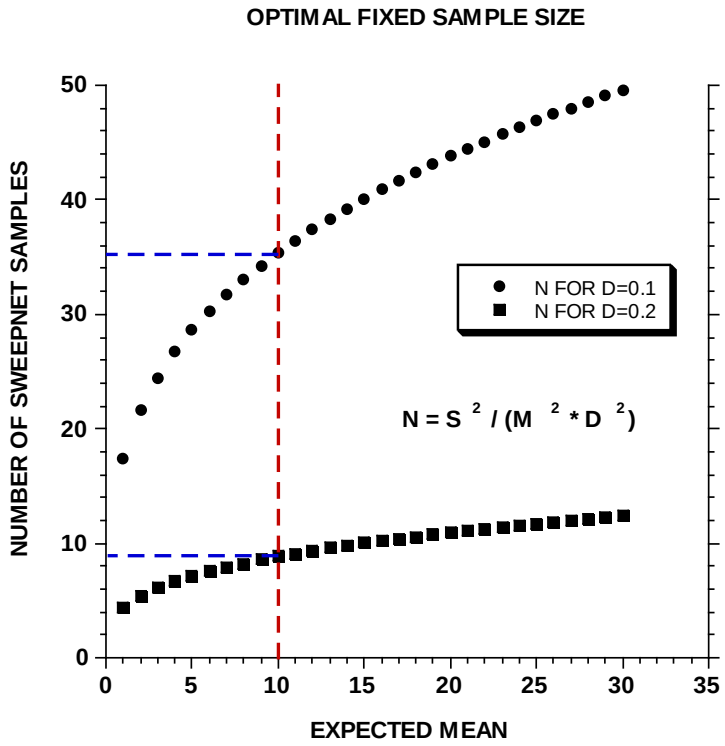


Fig. 3. Fixed optimal sampling plan for blueberry spanworm at 10 and 20% levels of precision and 95% confidence. Dotted line demarcates number of samples needed to accurately estimate spanworm larval numbers near the threshold.

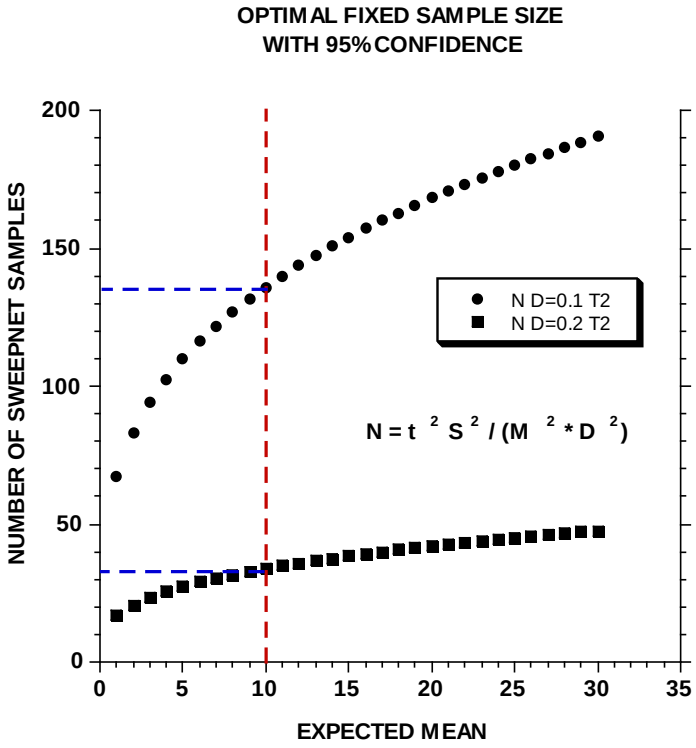


Fig. 4. Sequential sampling plan for 20% precision.

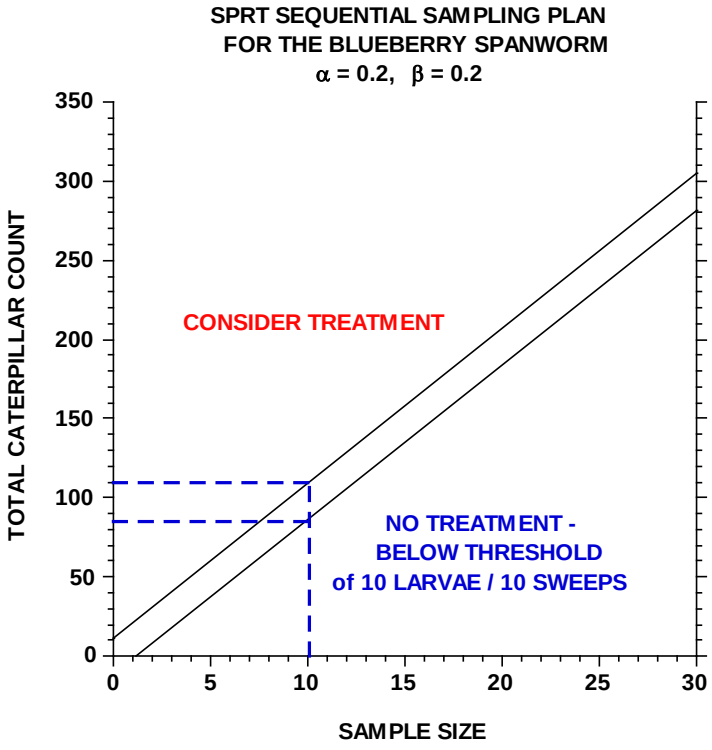


Fig. 5. Sequential sampling plan for 10% precision.

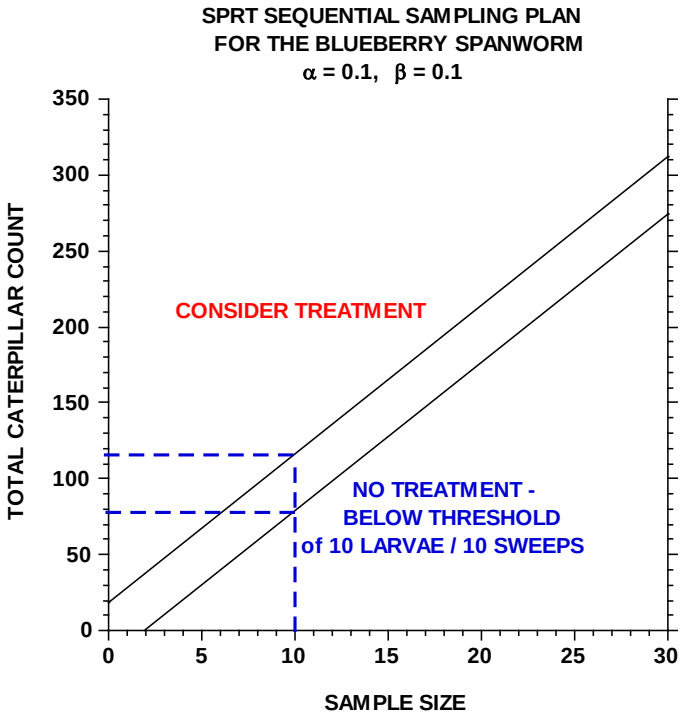


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Fig. 6. Sequential sampling plan for 5% precision.

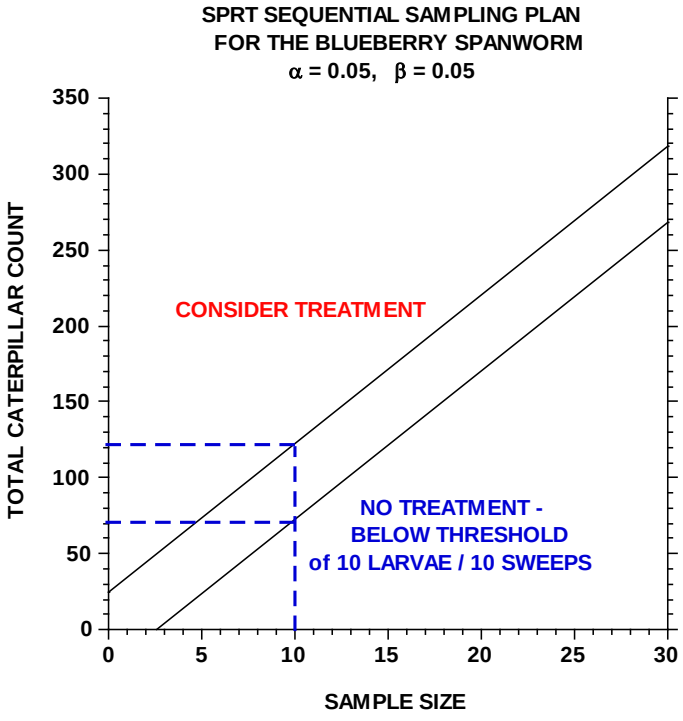


Table 1. Sequential sampling plan in a format suitable for field use.

# samples (α=0.1, β = 0.1)	if smaller, STOP: below threshold	if larger, STOP: above threshold
5	6.0	13.5
7	7.1	12.4
10	7.9	11.6
15	8.5	11.0
20	8.8	10.7
25	9.0	10.5
30	9.1	10.4
35*	STOP	STOP

* If get to 35 samples, stop and calculate mean…determine if above or below threshold of 10 larvae / set of 10 sweeps

Table 2. Simulation of three sinarios.

1) *true mean = 18*

   first 5 samples: 25, 41, 35, 5, 5…mean = 22.2…**cutoff 6.0 - 13.5**

   STOP: ABOVE THRESHOLD

2) *true mean = 5*

   first 5 samples: 11,8,7,5,3…mean = 6.8…**cutoff 6.0 - 13.5**

   first 7 samples: 11,8,7,5,3,2,4…mean = 5.7…**cutoff 7.1 - 12.4**

   STOP: BELOW THRESHOLD

3) *true mean = 11*

   first 5 samples:16,9,12,11,11…mean = 11.8… **cutoff 6.0 - 13.5**

   first 7 samples:16,9,12,11,11,8,11…mean=11.1 **cutoff 7.1 - 12.4**

   first 10 samples: 16,9…11,8,11,14,12,7…mean = 11.1 **cutoff 7.9 - 11.6**

   first 15 samples:16,9…12,7,25,7,10,3,6…mean = 10.8 .**cutoff 8.5 - 11.0**

   first 20 samples: 16…1,17,15,12,11…mean = 11.4 …**cutoff 8.8 - 10.7**

   STOP: ABOVE THRESHOLD

RECOMMENDATIONS: Efforts have been under way since 1997 to convert existing action thresholds for blueberry spanworm and blueberry flea beetle larvae in fruit-bearing fields to economic injury levels. The results of our recent experiments on defoliation by blueberry spanworm in pruned fields were quite surprising. They suggest two important points. First, that a large range of spanworm densities will not affect stem density by the end of the growing season. Second, the consumption of blueberry plant tissue by spanworm larvae may result in a stimulation of reproductive tissue production or follower buds. These results are very important and may suggest that if growing conditions are fine, spanworm should not be controlled in pruned fields. Only if blueberry plants are severely stressed will a reduction in potential yield result due to high larval densities during the prune year. This phenomenon needs to be repeated for several years to see if trends are consistent.

Likewise, it is apparent from our research that infestation by flea beetle in pruned fields can reduce blueberry-stem density. And, a large decrease in flower buds per stem due to increasing flea beetle density was observed in 2003. Our 2004 trial suggested that flea beetle larvae can defoliate a pruned crop, but we were not successful in demonstrating that high densities of 100 larvae/4-ft^2 plot can result in a decline in stem density, flower buds/stem, or flower buds/plot. Because it is suspected that the effect of flea beetle feeding on pruned blueberry plants is dynamic and depends upon the timing of blueberry flea beetle egg hatch and sprout emergence as well as environmental conditions such as rainfall and soil fertility, we plan on repeating these studies for at least two more cycles to determine if the pattern that we describe in this study is consistent over time.

Monitoring blueberry fields for pests is one of the foundations of integrated pest management. However, monitoring for insect pests can be expensive and time consuming. The sequential sampling plan developed for blueberry spanworm will be made available to blueberry growers soon. We recommend that growers adopt this sampling methodology as a means of arriving at precise estimates of blueberry spanworm population levels with reduced sampling effort.

The ability to detect thrips on sticky traps before leaf curls develop in the crop provides a useful pest management tool for timing foliar insecticide sprays. This is the second year that we have documented detection of thrips on sticky traps prior to leaf curl formation in the field. Our recommendation is that the first insecticide application should be made when the first thrips are detected on the traps followed by one or two more applications at 3 to 7 day intervals depending upon the insecticide and the weather conditions. Further research will be conducted to determine how late in the season insecticide applications need to be made to protect blueberry plants from infestation.

2006 will be the second year of a three-year study to evaluate the effect of date of pruning on flower bud production. In August 2005, 7 additional clones were selected and set with markers. The initial fall application for this second trial was applied on 1 November 2005.

ENTOMOLOGY – INSECT PEST MANAGMENT

INVESTIGATORS: F. A. Drummond, Professor of Insect Ecology/Entomology
J. A. Collins, Assistant Scientist of Insect Pest Management

9. TITLE: Control Tactics for Blueberry Pest Insects, 2005

1. Laboratory screening of insecticides.

METHODS: Laboratory screenings were completed against blueberry spanworm (SW), blueberry flea beetle (FB), strawberry rootworm (SR), and red-striped fireworm (FW). Each treatment was applied in 25 gallons of water-mixture per acre with a CO_2-propelled, 80-inch boom sprayer (76-inch swath) equipped with four, flat-spray 8002VS TeeJet® nozzles operating at 35 psi and at a slow walking speed. Speed was regulated using a metronome. The materials were allowed to dry on the foliage. One treated stem was cut and placed in each cup. For the trial against red-striped fireworm, leaf curls containing FW larvae were collected from an infested field and placed individually in plastic cups. There were 25 insects per treatment. Treatments were applied directly onto the curls (in the cups). For all trials, the cups were held in a growth chamber at ca. 21°C and assessed for mortality at daily intervals for five days. Untreated blueberry foliage was added to each cup as needed.

RESULTS: The Product-Limit Survival (Kaplan-Meier) Method and Gehan-Wilcoxon Mean Separation were used to compare the mean days to death of each treatment to the untreated check within each trial (Table 1).

In Trial #1 against SW, Assail 30 SG, Avaunt 30 WG, Entrust 80 WP, and Intrepid 2 F were all significantly different from the check. As expected, mean days to death following application of the insect growth regulator Intrepid 2 F was longer then with the other materials, but still significantly less then the untreated check. Logistic Regression was used to compare % survival among the treatments. All four materials provided excellent control of SW. Figure 1 shows % survival of SW treated with each material. On day 4, 66.7% of larvae fed Intrepid-treated foliage were alive compared to 8.3, 0.0, and 13.3% of larvae fed foliage treated with Assail, Entrust, or Avaunt, respectively. Percent survival on day 5 was only 6.7% vs. 0.0% in the other treatments; 91.7% of the untreated check larvae remained alive at the conclusion of the trial.

All the materials were also significantly different from the untreated check in Trial #2 against FB larvae. The most effective materials were Assail 30 SG and SpinTor 2 SC; 50% of the larvae fed foliage treated with these materials were dead within one day. Assail 30 SG, Avaunt 30 WG, Novaluron 10 EC, and SpinTor 2 SC were all highly effective and significantly reduced % survival in comparison with the untreated check by the third day of the trial (Fig. 2).

Avaunt and Assail also gave excellent control of SR adults (Trial #3). SpinTor 2 SC, while not as effective in this laboratory trial, also performed well. Percent survival was significantly less then the untreated check (Fig. 3).

Entrust 80 WP provided the best control of FW larvae (Trial #4). Over 50% of larvae treated with Entrust were dead within 2 days of the application and only 12% of

the larvae were alive by day 14 of the trial. The application of Intrepid resulted in 52% mortality (Fig. 4).

CONCLUSIONS: Entrust 80 WP and Intrepid 2 F, as well as two materials not included in this trial, SpinTor 2 SC and Confirm 2 F, have all performed well in recent field tests against blueberry spanworm. We do not hesitate to recommend them for control of this insect. These materials are also considered "reduced-risk" and are generally less toxic to humans and the environment. However, Entrust and SpinTor in particular have a very short residual activity in the field and may require multiple applications. From the results of this laboratory trial, Avaunt and Assail appear to be very promising alternatives and warrant additional field tests.

Past field trials for flea beetle control suggest that SpinTor 2 SC, Entrust 80 WP, Imidan, and Mycotrol ES all perform very well. All of these insecticides are registered and currently recommended for use. Results of this laboratory trial indicate that Avaunt 30 SG, Assail 30 WG, and Novaluron 10 EC may also prove to be viable alternatives and should be included in future field tests.

Avaunt and Assail both gave excellent control of strawberry rootworm adults and warrant additional testing in the field. Several additional materials have proven effective in recent field trials. Entrust 80 WP, an organically approved formulation of spinosad (the active ingredient in SpinTor), gave excellent control in 2003. Imidan has also proven to be very effective.

When evaluated in the laboratory, both Entrust and Intrepid appear to have potential to control red-striped fireworm. Further evaluation of both these materials under field conditions is warranted.

2. <u>Field evaluation of insecticides for control of secondary pest insects.</u>

METHODS: Trials were completed against blueberry spanworm (SW) and blueberry thrips (BT). The test against SW was applied as a foliar spray to a fruit-bearing field. Pre- and postspray sweep-net samples were used to estimate control.

In the BT trial, Admire 2 F was applied as a spray to the soil in a pruned field prior to stem emergence; all other materials were applied as foliar sprays timed to stem growth. Efficacy was evaluated according to the number of blueberry stems with and without thrips' damage as evidenced by curled leaves.

RESULTS/CONCLUSIONS: Analysis of Variance (ANOVA) and Student-Newman-Keuls (SNK) Mean Separation ($P \leq 0.05$) were used to compare numbers of SW captured in sweep-net samples. Post spray counts were generally low in all plots. Cool and wet post spray conditions made sweep-net sampling difficult and may have confounded the results. However, all the materials did reduce seasonal densities of blueberry spanworm larvae in comparison with the untreated checks ($P = 0.0001$)(Table 2).

The pre-emergence application of Admire 2 F resulted in a 68% reduction in the average % stems with thrips curls; the difference was significant ($P = 0.0124$)(Table 3). There were also significantly fewer % stems with thrips curls in the plots treated with Assail 30 SG (5.2%) than in the untreated check plots (12.1%); this represents a 57% reduction. One application of Novaluron 10 EC resulted in a 50% reduction; however,

this was not significantly different from the untreated check. Entrust 80 WP was not effective. Additional trials should be completed with Novaluron; since some control was obtained with just one application. Entrust is a short-residual material requiring multiple applications, particularly following rainfall events; however, two applications of SpinTor 2 SC did provide excellent control in a 2003 field trial. Further tests should be conducted with both Entrust and SpinTor.

3. <u>Control of blueberry maggot with ground application of insecticides.</u>

METHODS: We conducted two trials against blueberry maggot (BMF). All materials were applied in 7.25 gallons of water-mixture per acre using a SOLO® 450 mist blower. Pre- and postspray populations of BMF adults were monitored with baited yellow Pherocon® AM traps. Efficacy was further evaluated based on the number of BMF pupae collected from berry samples.

RESULTS/CONCLUSIONS: In Trial #1, the effectiveness of three rates of Provado 1.6 F (4, 6, or 8 oz/acre) was evaluated. Analysis of Variance (Randomized Block Design) and LS Means Differences Tukey HSD ($P \leq 0.05$) were used to compare the seasonal density of BMF adults captured on Pherocon AM traps between treated and untreated check plots. There was a significant difference among the treatments ($P = 0.0354$)(Table 4). There was also a significant regression effect; BMF captures decreased with increasing rates of Provado ($P = 0.0064$). Significantly fewer BMF adults were captured in plots treated with Provado 1.6 F at the highest 8 oz/acre rate.

When the fruit was evaluated for infestation, a large number of pupae (35) were collected from one plot treated with Provado at the 4 oz rate. All other samples collected from Provado-treated plots (all rates) had 5 pupae or less. When this sample was included in the analysis, there was no significant difference among the treatments ($P = 0.1078$). When this sample was excluded from the analysis, ANOVA revealed a decrease in fruit infestation as determined by assessing the number of pupae found in berry samples. As application rate increased, there was an accompanying decrease in infestation levels ($P = 0.0103$) (Table 4 and Fig. 5). Data for number of pupae was transformed by sqrt prior to analysis. We are unsure how to explain the high level of infestation in one plot treated with a low (4 oz) rate. It is possible, but unlikely, that it can be attributed to a mechanical problem with the sprayer. The topography of the site is another possibility.

In Trial #2, the effectiveness of Prev-AM was evaluated. There was no significant difference in seasonal density of adults ($P = 0.4708$) or number of pupae ($P = 0.2197$). Prev-AM (sodium tetraborohydrate decahydrate) is a blend of borax, orange oil, and organic surfactants and is advertised as having both fungicidal and broad-spectrum insecticidal activity. However, this material appeared to be ineffective in controlling BMF in this trial.

4. <u>Control of blueberry maggot with GF-120 NF Fruit Fly Bait.</u>

METHODS: An ATV-mounted sprayer was used to apply 2:20-ft perimeter swaths of GF-120 NF Fruit Fly Bait at a rate of 1:5 v/v with water. Pre- and postspray populations of BMF adults were monitored with baited yellow Pherocon AM traps. Efficacy was further evaluated based on the number of BMF pupae collected from berry samples.

RESULTS/CONCLUSIONS: The effectiveness of applying GF-120 NF with different timings was evaluated. Analysis of Variance and LS Means Differences Tukey HSD ($P \leq 0.05$) were used to compare the seasonal density of BMF adults captured on Pherocon AM traps between plots treated with GF-120 NF on a weekly basis, plots treated with GF-120 as needed based on Pherocon trap counts, and untreated check plots. There was no significant difference among the treatments ($P = 0.3387$)(Table 5).

When the fruit was evaluated for infestation, there was no significant difference among the treatments ($P = 0.2563$). Data for number of pupae was transformed by sqrt prior to analysis.

RECOMMENDATIONS:

These trials represent the first year of testing with Assail 30 SG and Avaunt 30 WG. Both of these materials warrant further testing. Assail (acetamiprid) is a reduced-risk, broad-spectrum, neonicotinoid insecticide offering the advantage of low toxicity to beneficial insects and a longer residual than spinosad. Our initial trials have show it to have some effect against a variety of blueberry pest insects including blueberry spanworm, blueberry flea beetle, strawberry rootworm, and blueberry thrips. Avaunt 30 WG (indoxacarb) is one of a new class of materials called oxadiazines and offers similar advantages. It is a broad-spectrum material that appears to have at least some activity against a variety of blueberry pest insects. It is classified as a reduced-risk product with low toxicity to both honeybees and bumblebees once the material has dried on the foliage. And, it has a short pre-harvest interval (3 days).

There are currently no control recommendations for red-striped fireworm. This pest is becoming more of a concern with the adoption of perimeter sprays for control of blueberry maggot. Red-striped fireworm was generally controlled by full-field applications. This pest is becoming a contaminant problem for those growers that are exporting the harvest to Europe and Asia.

Mixed results have been obtained in trials with pre-emergence applications of Admire 2 F as a control for blueberry thrips over the past few years. Reductions of 38%, 26%, 100%, and 64% were observed following similar applications in 2000, 2002, 2003, and 2004, respectively. Based on these results, control of thrips will remain a potential problem. However, Admire 2 F would appear to be the best currently available alternative to diazinon.

This is the second year of trials with Provado 1.6 F (imidacloprid). It has proven effective in both years. Despite the promising results obtained in 2003 and 2004, GF-120 NF Fruit Fly Bait was ineffective in this 2005 trial. GF-120 is a short-residual material and may require frequent applications to maintain control. Further trials are needed to assess the long-term viability of this material as an alternative for BMF control.

1. Laboratory screening of insecticides.

Table 1. Laboratory screening of insecticides, mean days to death.

Material	Rate (oz/acre)	Mean days to death *	*Prob Chi*^{2} ≥< 0.05 ***
Trial # 1 – Blueberry Spanworm Larvae			
Assail 30 SG	5.3 oz	1.00	< 0.0001
Avaunt 30 WG	6.0 oz	2.00	< 0.0001
Entrust 80 WP	2.0 oz	1.00	< 0.0001
Intrepid 2 F	16.0 oz	5.00 *	< 0.0001
Untreated check	-	**	NA
Trial # 2 – Blueberry Flea Beetle Larvae			
Assail 30 SG	5.3 oz	1.00	< 0.0001
Avaunt 30 WG	4.0 oz	3.00	< 0.0001
Avaunt 30 WG	6.0 oz	2.00	< 0.0001
Novaluron 10 EC	9.6 oz	3.00 *	0.0003
SpinTor 2 SC	6.0 oz	1.00	< 0.0001
Untreated check	-	**	NA
Trial # 3 – Strawberry Rootworm Adults			
Assail 30 SG	5.3 oz	1.00	< 0.0001
Avaunt 30 WG	6.0 oz	3.00	< 0.0001
SpinTor 2 SC	6.0 oz	**	0.0362
Untreated check	-	**	NA
Trial # 4 – Red-striped Fireworm Larvae			
Entrust 80 WP	2.0 oz	1.5 *	0.0007
Intrepid 2 F	16.0 oz	8.0 *	< 0.0001
Untreated check	-	**	NA

* Biased estimate due to censored observations (live larvae) at end of study.
** Not possible to estimate because of > 50% survival.
*** Probability of treatment not different from untreated check.
NA Not applicable.

Fig. 1. Percent survival of blueberry spanworm larvae.

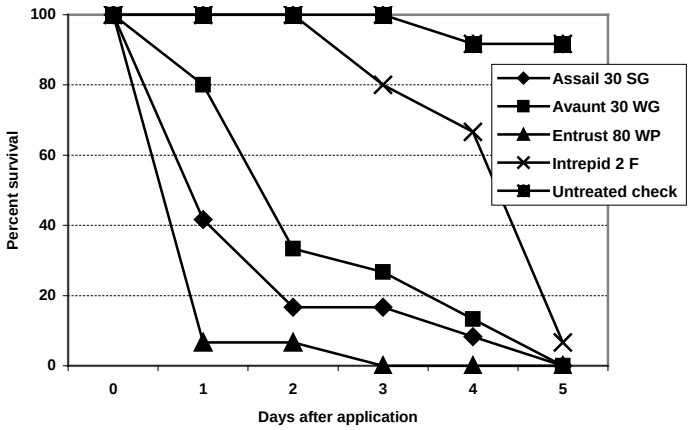


Fig. 2. Percent survival of blueberry flea beetle larvae.

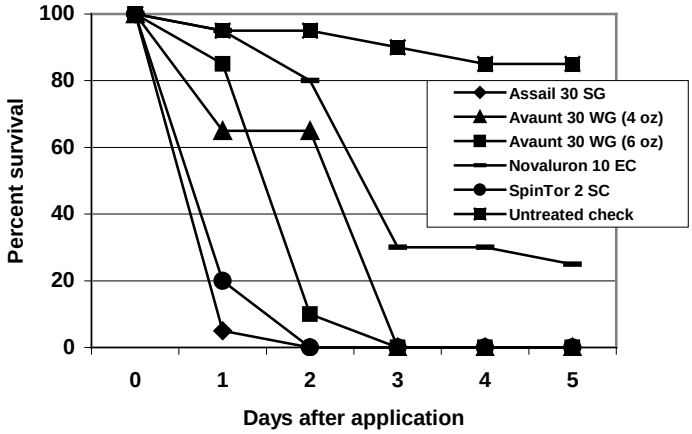


Fig. 3. Percent survival of strawberry rootworm adults.

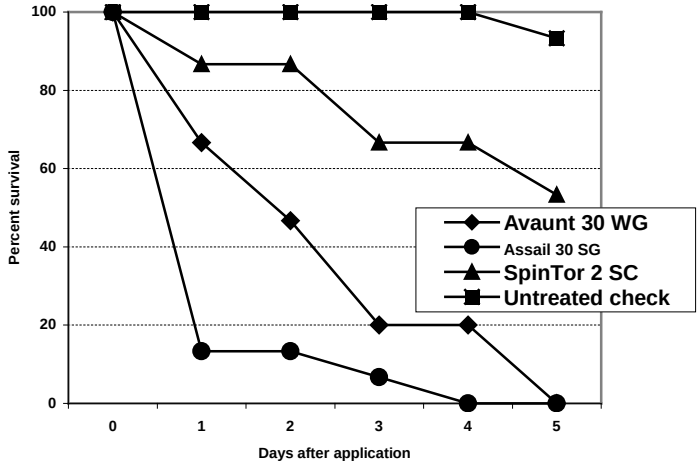
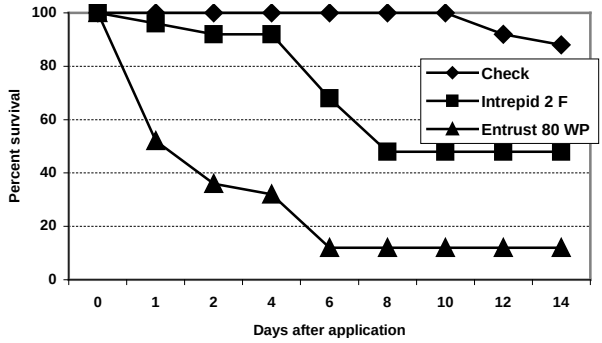


Fig. 4. Percent survival of red-striped fireworm larvae.



2. <u>Field evaluation of insecticides for control of secondary pest insects.</u>

Table 2. Field control of blueberry spanworm larvae with insecticides, summary.

Material	Amt. form./ acre	Larvae/10 sweeps Prespray 10 May	Post spray 11 May	13 May	17 May	20 May	Seasonal density
Assail 30 SG	**5.3 oz**	**21.3 a**	**8.8**	**0.8**	**1.0**	**1.3**	**4.1 b**
Avaunt 30 WG	**4.0 oz**	**22.8 a**	**5.8**	**0.3**	**3.5**	**2.0**	**4.6 b**
Avaunt 30 WG	6.0 oz	24.5 a	3.5	1.5	5.0	0.0	4.9 b
Entrust 80 WP	**2.0 oz**	**23.8 a**	**1.8**	**0.5**	**3.3**	**2.8**	**3.4 b**
Intrepid 2 F	**8.0 oz**	**24.0 a**	**7.0**	**1.0**	**4.0**	**0.8**	**4.0 b**
SpinTor 2 SC	**6.0 oz**	**24.0 a**	**1.8**	**0.3**	**4.8**	**2.0**	**7.0 b**
Untreated check	**-**	**23.5 a**	**6.0**	**1.5**	**2.8**	**4.8**	**11.5 a**

Seasonal densities are trapezoidal integrals of densities over the season divided by the number of day's duration of the experiment. Means followed by the same letter(s) are not significantly different ($P \leq 0.05$, SNK).

Table 3. Field control of thrips with insecticides, summary.

Material (SE)	Amt. form./acre	Avg. # stems/	Avg. % stems with ft^2 (SE) curls/ft^2
Admire 2 F (pre-emergence)	16.0 oz	64.4 (10.7) a	3.9 (2.0) c
Assail 30 SG	5.3 oz	73.2 (4.4) a	5.2 (2.0) bc
Entrust 80 WP	2.0 oz	66.5 (6.8) a	10.8 (4.3) ab
Novaluron 10 EC	9.6 oz	69.8 (8.1) a	6.1 (2.3) abc
No insecticide	-	59.7 (9.5) a	12.1 (3.8) a

Means within each column followed by the same letter(s) are not significantly different ($P \leq 0.05$, SNK).

3. Control of blueberry maggot with ground application of insecticides.

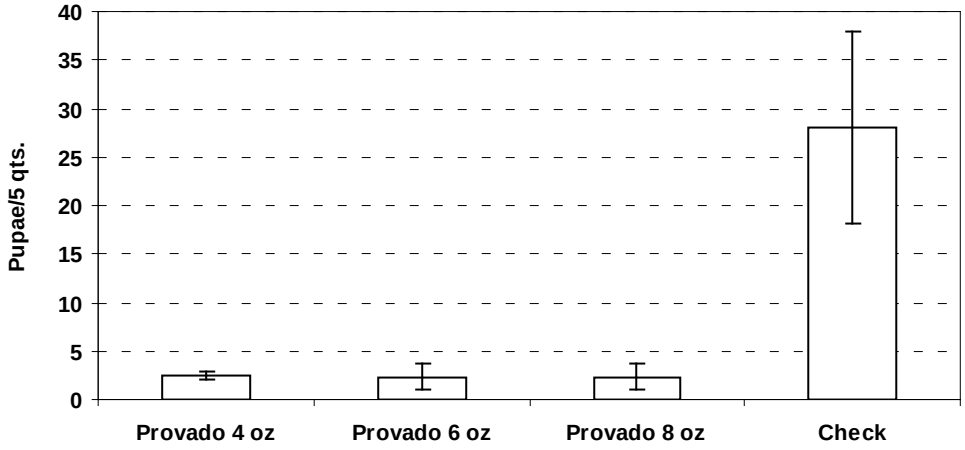
Table 4. Field control of blueberry maggot with Provado 1.6 F and Prev AM, summary.

	Amt. form./acre	Avg. pupae/5 qts	Avg. pupae/5 qts	Adults/trap seasonal density (SE)
Trial # 1				
Provado 1.6 F	8.0 oz	2.33 (1.31) b	2.33 (1.31) a	3.65 (0.21) b
Provado 1.6 F	6.0 oz	2.33 (1.31) b	2.33 (1.31) a	4.02 (0.24) ab
Provado 1.6 F	4.0 oz	2.50 (0.40)) b *	13.33 (10.67) a **	4.70 (0.94) ab
Untreated check	-	28.00 (9.84) a	28.00 (9.84) a	6.81 (0.48) a
Trial # 2				
Prev AM	4% sol.		34.00 (10.21) a	3.63 (0.69) a
Untreated check	-		17.33 (6.26) a	4.98 (1.84) a

* Data for number of pupae/5 qts in Provado (4 oz) based on 2 replications.
** Data for number of pupae/5 qts in Provado (4 oz) based on 3 replications.

Seasonal densities of adults are trapezoidal integrals of densities over the season divided by the number of day's duration of the experiment. Means within each column and trial followed by the same letter(s) are not significantly different ($P \leq 0.05$, LS Means Differences Tukey's HSD).

Fig. 5. Control of BMF with Provado 1.6 F, fruit infestation.



4. <u>Control of blueberry maggot with GF-120 NF Fruit Fly Bait.</u>

Table 5. Field control of blueberry maggot with GF-120 NF Fruit Fly Bait, summary.

	Treatment	Avg. pupae/5 qts	Adults/trap seasonal density (SE)
GF-120 NF	Weekly	51.2 (24.3) a	3.05 (0.68) a
GF-120 NF	As needed	21.4 (5.8) a	2.23 (0.96) a
Untreated check	-	31.2 (10.4) a	3.95 (1.28) a

Seasonal densities are trapezoidal integrals of densities over the season divided by the number of day's duration of the experiment. Means within each column and trial followed by the same letter are not significantly different ($P \leq 0.05$, LSMeans Differences Tukey's HSD).

DISEASE MANAGEMENT

INVESTIGATOR: S.L. Annis, Biological Sciences
COOPERATORS: D. Yarborough, Blueberry Extension Specialist
K. Guiseppe, Research Assistant
L. Kreider, Blueberry technician
K. McGovern, Masters graduate student

10. TITLE: The Effect of Fungicides and Cultural Treatments on *Monilinia* Blight, Yield and Post-Harvest Disease in Wild Blueberries

METHODS:

1) The effect of fungicides on *Monilinia* blight incidence and yield in the crop year.

In May of 2005, 48-240 ft^2 plots were established in two crop-year fields. Four replications of eight treatments were applied in a replicated block design: 1) control; 2) Orbit (6 oz/acre); 3) Bravo for the first two sprays (64 fl oz/acre) then Abound (15 oz/acre); 4) Pristine (18.5 oz/acre); 5) Serenade (3 lb/100 gal); 6) Sulforix at (3 gal/100 gal); 7) Abound (15.4 oz/acre); and 8) Indar (2 oz/acre). These were applied with a CO_2 backpack sprayer at a rate of 20 gallons per acre with 80002VS Tjet nozzles on May 4, May 11, May 31/June 1, and June 13. The proportions of stems with *Monilinia* blight were assessed in 4 random 6"x18" subsections of each plot on June 20. In early August, yield was estimated by harvesting a 17" wide strip down the center of each plot and weighing the berries.

2) The effect of fungicide treatments on post-harvest disease in wild blueberries.

A subsample of 300 healthy, ripe, uncrushed berries was reserved from each plot of the fungicide trial for post-harvest disease assessment. The berries were arranged, not touching each other, on a plastic grid in a tray with a small dish containing wet paper towels. The trays were covered with plastic wrap and kept at room temperature for three weeks. Each week the berries were examined and any infected berries were removed from the trays. Fungi causing the fruit rots were identified.

3) The effect of organic management on *Monilinia* blight and yield in wild blueberries.

Ninety-six 6'x 50' plots were established in eight blocks in a split-split-split-plot design. The treatments applied were 1000 lbs/acre of granular 90% sulfur or no sulfur, pruning by burning or by mowing, and 0, 20 or 40 lbs/acre of nitrogen from Pro-Holly (4-6-4), a granular organic fertilizer. The plots were pruned on May 5, 2004. Sulfur was applied on May 11 and fertilizer on May 27, 2004. In June 2005, the proportion of stems with *Monilinia* blight was assessed in four random 6"x18" subsections of each plot. A 24" width was harvested by machine down the center of each plot on August 10, 2005 and the berry weight was determined.

4) Possible organic controls of *Monilinia* blight in lowbush blueberries.

Two fields, one near Belfast and one near Milford, ME, were used to test the efficacy of organic treatments for mummy berry blight control. In each field, 28 2m x 20m plots were established during the crop year for application of 6 treatments and a control in four replications. The treatments included aerated and non-aerated compost teas, Serenade and Plant Shield. The compost teas were produced using 272 g compost in 7570 mL MilliQ water and incubated for 3 days for aerated and 7 days for non-aerated

teas and then applied as a dilute solution of 1 part compost tea to 4 parts water. Serenade contains *Bacillus pumilus (*AgriQuest) and was applied at a rate of 0.2qts/acre. Each of the above treatments were sprayed every 3-4 days, weather permitting. Plant Shield containing *Trichoderma harazinium* (BioWorks) was applied as 36 g per treatment area, mixed with approximately 10 gal of water and applied every 7 days, weather permitting. All treatments were sprayed with a CO_2 backpack sprayer at 20 gpa with 80002VS Tjet nozzles during the wild blueberry leaf development (mid April to mid May). In the third week of June, each plot was assessed for mummy berry blight by determining the proportion of infected stems in 4 sub-samples per plot.

RESULTS:

1) The effect of fungicides on *Monilinia* blight incidence and yield in the crop year

There was high mummy berry disease pressure in the spring of 2005 from the cool wet weather during April, May and early June. Levels of disease in both field sites were high with more than 10% infected stems (Fig. 1). The Township 19 field had significantly less disease than the Deblois field. None of the fungicide treatments had significantly less disease than the check plot. The treatments with Orbit, Bravo/Abound, Pristine or Serenade had lower levels of disease in both fields and will be retested again. The long infection period for mummy berry disease this spring may confound decisions of the effectiveness of these fungicides, since getting adequate cover and a "typical" spray timing was difficult due to the weather.

None of the yields from the treatment plots were significantly higher than those of the controls (Fig. 2). There was high variability among the blocks within a field due to weed cover and blueberry stand density. The Township 19 field had significantly less yield than the Deblois field even though it had less mummy berry disease. In the Deblois fields, all the treatments had higher yields than the control, but this was not significant due to the high variability between treatment blocks.

2) The effect of fungicide treatments on post-harvest disease in wild blueberries.

From 4 to 10% of the berries were infected with post-harvest fungal diseases, mainly *Botrytis*, one week after harvest (Fig. 3 and 4). A further 5 to 12% of berries were infected in the second week. *Botrytis* caused about 90% of the infections in the first week and about 40 to 75% of the infections in the second week with other fungi, *Pestalotia, Trichoderma, Alternaria, Colletotrichum, Phomopsis*, yeast and *Penicillium,* each causing from 5 to 30% of the infections in the second week depending upon the treatment. There were no significant differences in the post-harvest disease levels between the control and fungicide treatments, and many of the treatments had higher levels of disease than the control plots.

3) The effect of organic management on *Monilinia* blight and yield in wild blueberries.

Approximately 5% of stems had mummy berry blight in the Amherst field which is managed for transition to and maintenance with organic methods. There was no significant difference in the incidence of disease between mowing and burning methods of pruning (Fig. 5), but there were significantly higher yields in the burned versus mowed plots (Fig. 6). There was also significantly more disease in the highest fertilizer treatment (40 lb N/acre) than the control (0 lb N/acre) or low fertilizer treatment (20lb N/acre) (Fig. 7). The higher level of disease in the highest level of fertilizer did not affect yield (Fig. 8). The higher level of fertilizer may have made the plants more susceptible by

producing more succulent tissue during the infection period but also have provided nutrients for the plants to recover so the yield was not greatly affected.

4) Possible organic controls of *Monilinia* blight in lowbush blueberries.

There were much higher levels of mummy berry blight in the Belfast field, ranging from 38 to 52%, compared to the Milton field, ranging from 2% to 6% (Figure 9). There were no significant differences in the percentage of diseased stems between the control plots and the treatment plots. Some of the treatments, particularly the non-aerated compost teas, had higher levels of disease than the controls in both fields. The extremely high and low mummy berry disease pressure in the Belfast and Milton fields, respectively, make comparisons between the fields not possible. The large difference in disease pressure may also have affected how well the treatments performed since in Belfast there was a higher than average level of disease, making control of the disease difficult and in Milton, a below average level of disease making it difficult to determine if any significant control of the disease did occur.

CONCLUSIONS:

Mummy berry disease is a significant problem to the blueberry industry and evaluating new fungicides to control this disease must remain a priority. Some conventional and organic fungicide treatments should be re-evaluated next year to determine their effectiveness to control mummy berry disease since the unusually long infection period made it difficult to apply fungicides and achieve control of this disease. The development and implementation of a forecasting system in Maine to determine the risk of infection by mummy berry blight is a priority for improving control of this fungus. None of the conventional fungicides appeared to be effective against post-harvest diseases but this also may be affected by inadequate coverage of the plants during the infection periods during bloom. The high percentage of infected berries within the first week post-harvest will be a factor in developing a larger fresh-pack market for wild blueberries. Some diseases that were found infecting prune fields are being evaluated to determine the causal agents of the disease and the significance of these diseases to blueberry production.

RECOMMENDATIONS: Re-evaluate fungicides and organic methods for control of mummy berry disease and post-harvest disease. No organic method for control of mummy berry blight can be recommended at this time. Continue developing a forecasting system for risk of mummy berry blight. Determine the causal agent of stem blights observed in the prune year.

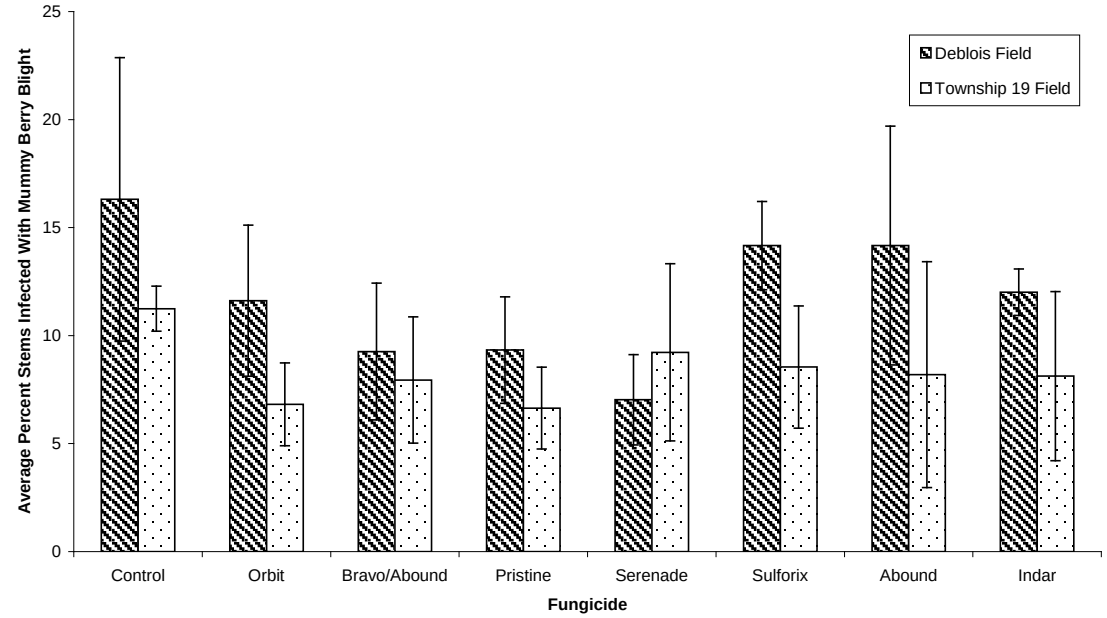


Fig 1. Control of mummy berry blight by fungicides in two fields in 2005. No significant difference among treatments.

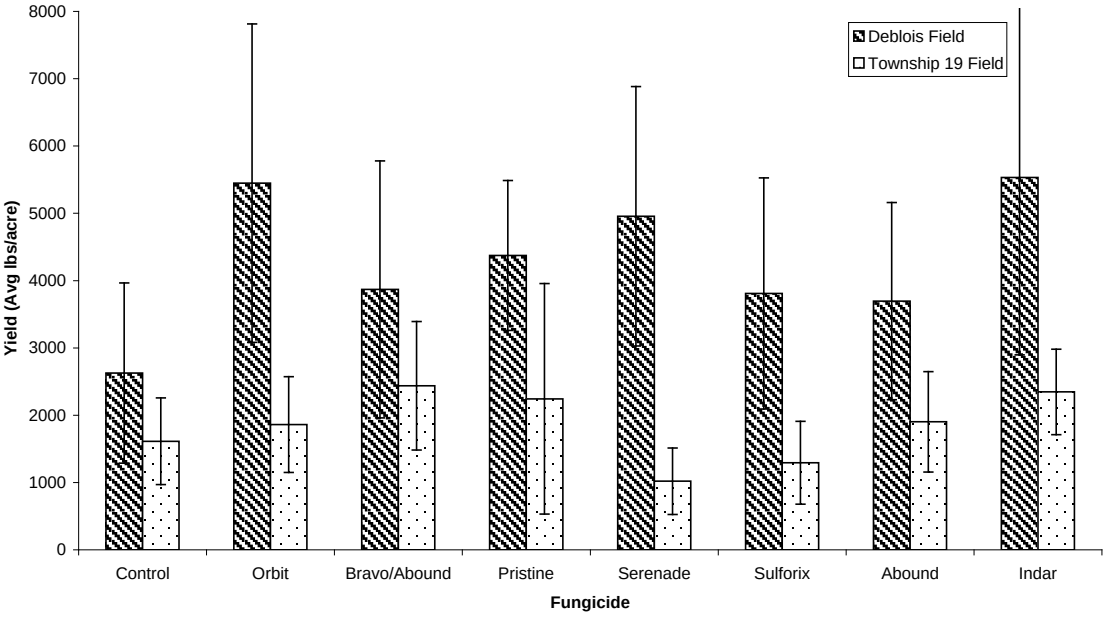


Fig 2. Effect of fungicide application on yield in two blueberry fields for 2005. No significant difference among treatments.

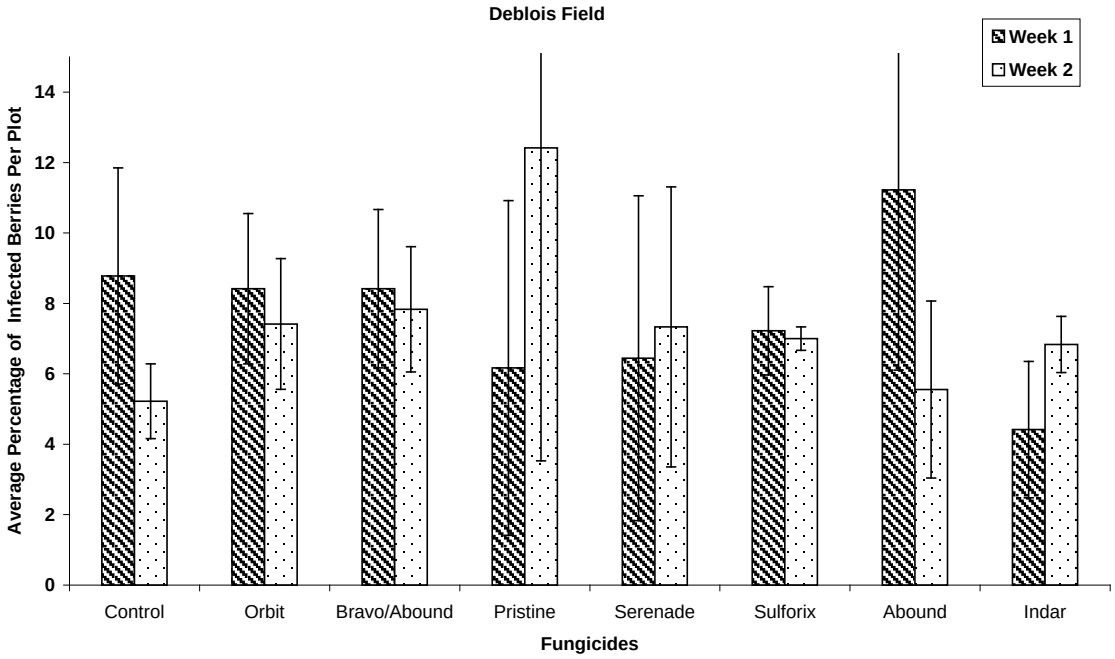


Fig 3. Effect of fungicides on post-harvest diseases in lowbush blueberries in 2005. No significant difference of percent infection

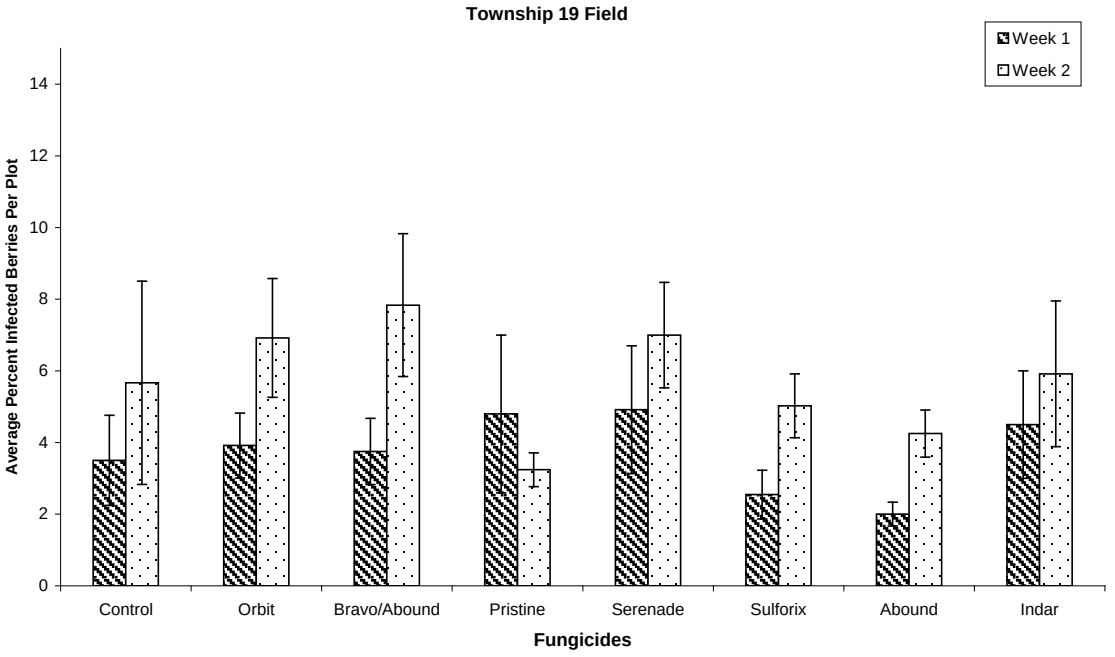


Fig 4. Effect of fungicides on post-harvest diseases in lowbush blueberries in 2005. No significant difference of percent infection

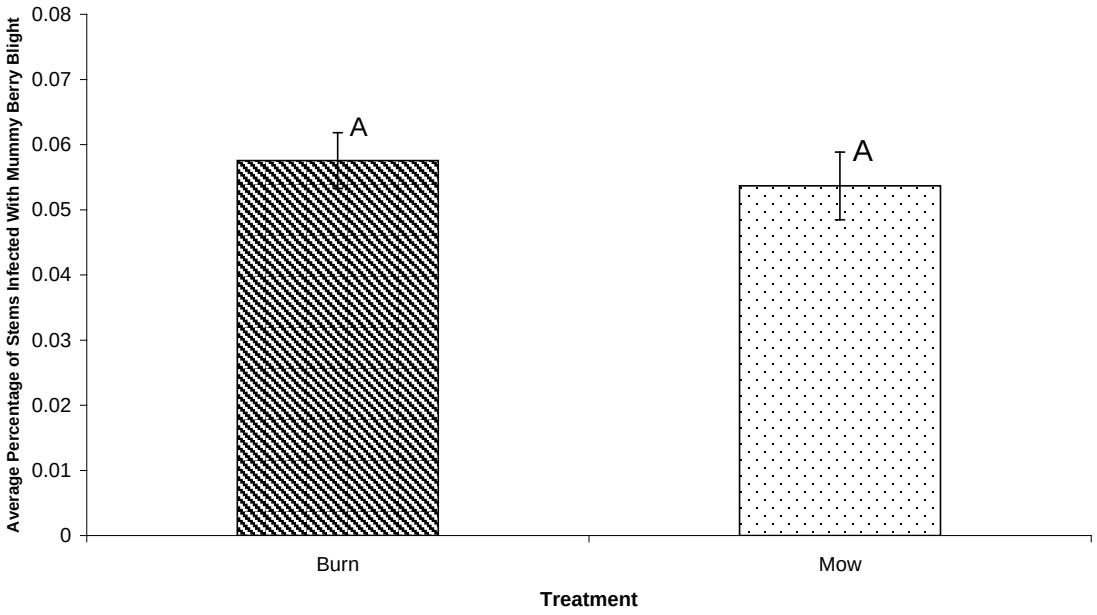


Fig 5. Effect of pruning treatment on mummy berry blight in organic blueberry field in 2005 (p= 0.691).

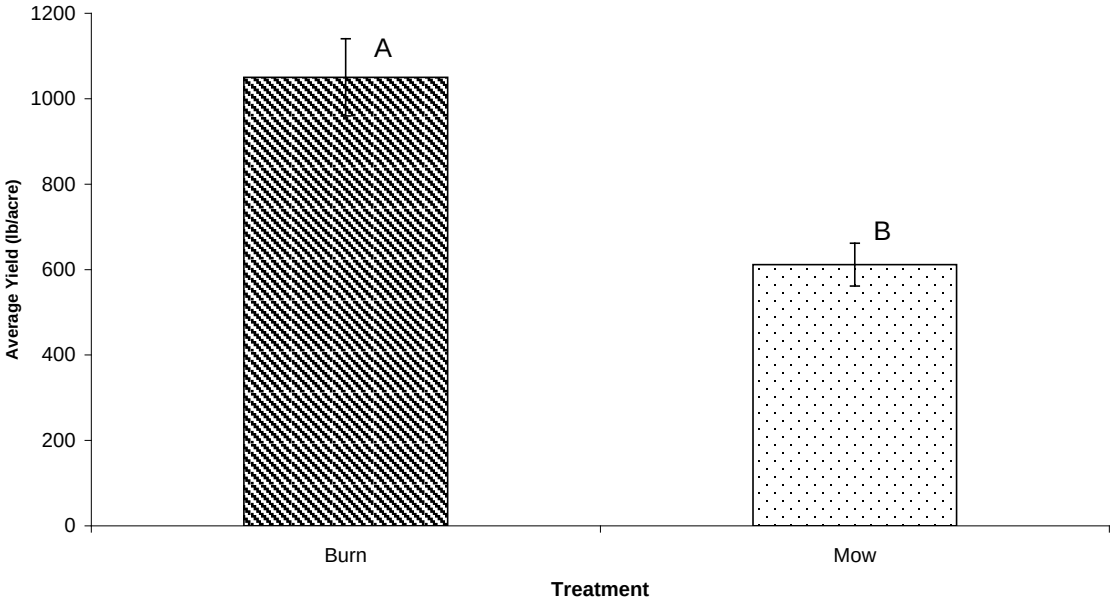


Fig 6. Effect of pruning treatment on yield in organic blueberry field in 2005 (p=0.023).

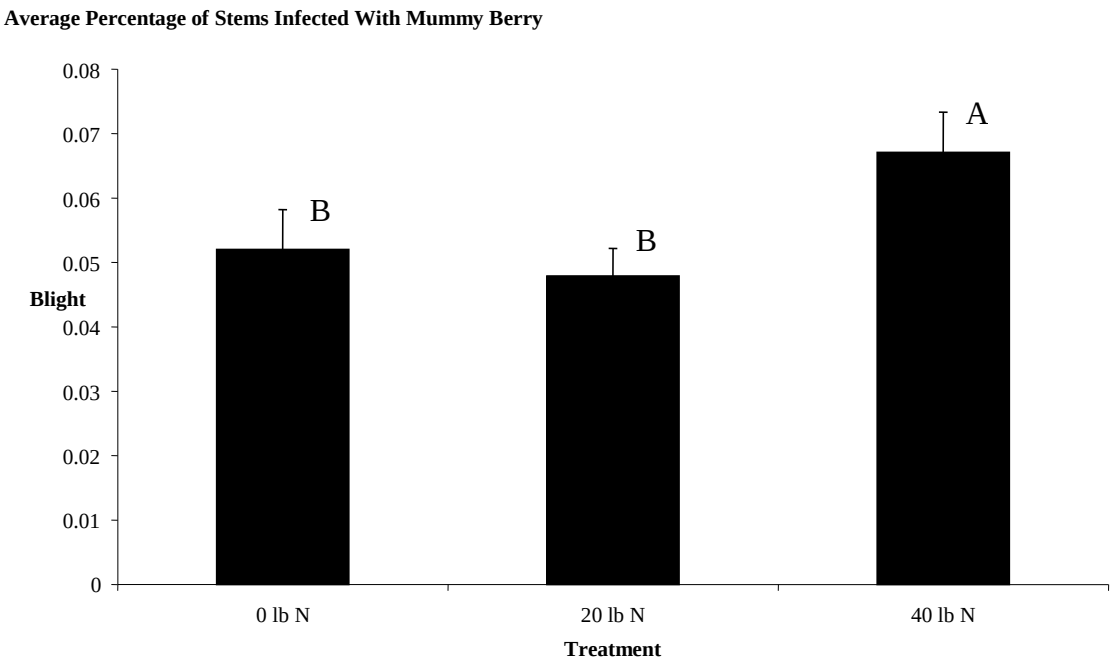


Fig 7. Effect of fertilizer treatment on mummy berry blight in organic blueberry field in 2005 (p=0.06).

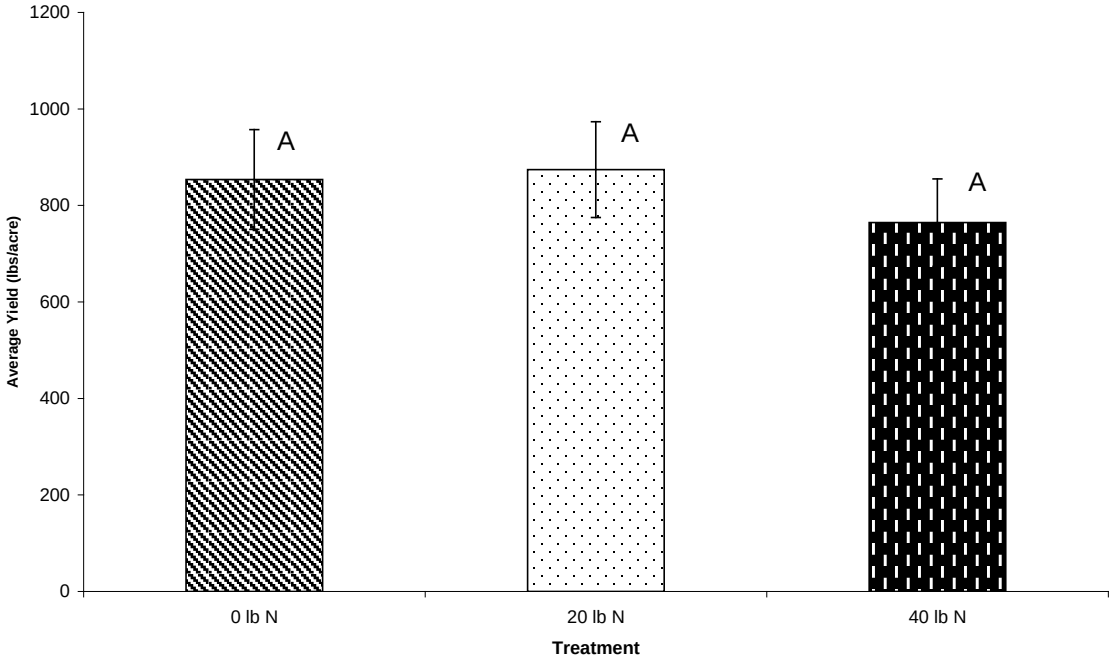


Fig 8. Effect of fertilizer treatment on yield in organic blueberry field in 2005 (p=0.38).

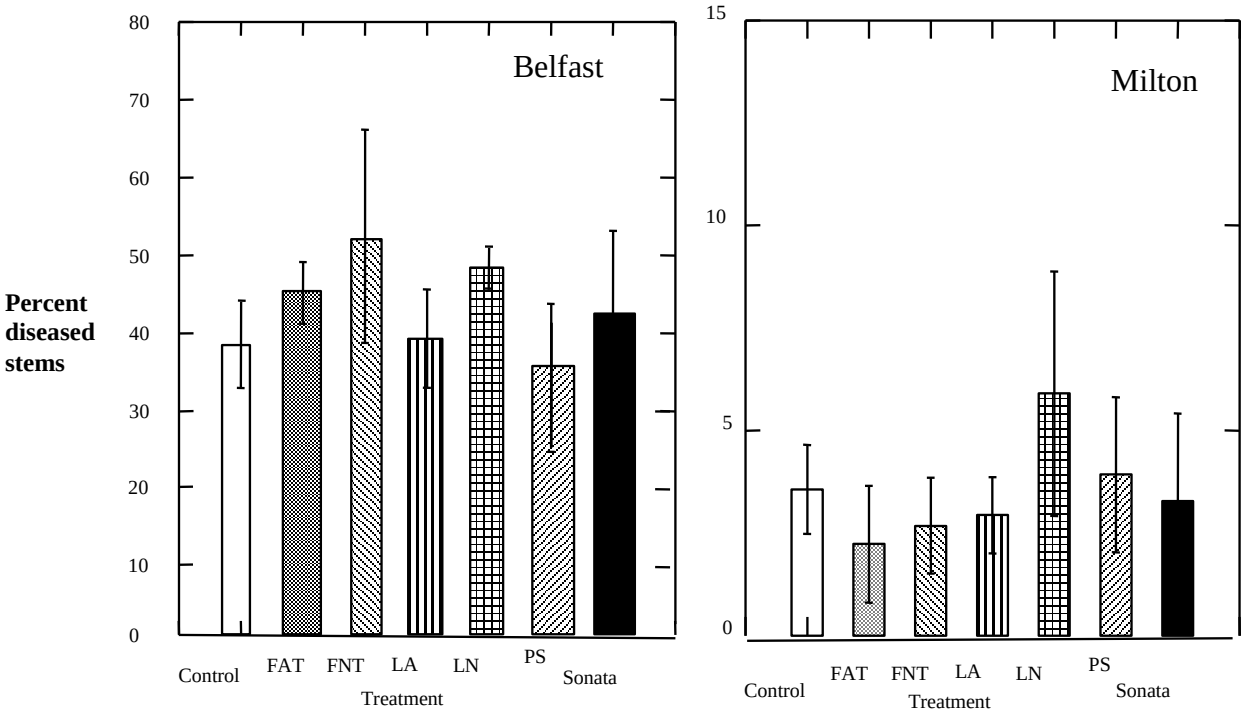


Figure. 9. Percentage of stems with mummy berry blight from two fields treated with FAT- fish and farm aerated compost tea, FNT- fish and farm non-aerated compost tea, LAT- lobster and manure aerated compost tea, LNT- lobster and manure non-aerated compost tea, PS- Plant shield (*Trichoderma*), Sonata- *Bacillus pumilis* by AgraQuest.

PLANT NUTRITION AND FERTILITY

INVESTIGATORS: John M. Smagula, Professor of Horticulture
Loretta Kreider, Scientific Technician

11. TITLE: Effect of Soil pH on Nutrient Uptake.

OBJECTIVES: To determine the effect of soil pH adjustment on nutrient uptake, available soil nutrients, plant growth and yield.

Brief Justification:

Many growers have soil pH values at the high end of the recommended pH range for growing wild blueberries yet they are recording high yields. They are reluctant to adjust their soil pH for fear of reducing yields. Yet, soil pH also has an effect on weed growth and lowering soil pH is recommended as a means of reducing weed pressure. These studies will provide data to support current recommendations for lowering soil pH to 4.6 or result in a reevaluation of these soil test recommendations.

pH Study - Blueberry Hill Farm

METHODS: Four clones were selected at Blueberry Hill Experiment Station Farm in Jonesboro. In each clone, eight 4 ft x 4 ft sections (plots) were identified for establishing four replications of two treatments. The perimeter of each plot was cut down to 6 inches to sever the rhizomes and isolate each plot. In August 1999, the plots were hand raked and the berry weight was not significantly different among potential treatment plots within each clone. Soil samples taken November 1999 from each clone indicated two had a pH of 4.5, one had 4.7 and one had a pH of 4.9. Since one ton of ground limestone will raise pH about 0.2 , treatment plots received an appropriate amount of limestone in May 2000 to adjust the soil pH to about 5.3 (Table 1). Control plots received gypsum ($CaSO_4$) to provide Ca in the amount that the limestone contributed**.**

Table 1
Treatment Summary

Clone	Treatment Number	Starting pH	Limestone $CaCO_3$ (lb/acre)	Gypsum $CaSO_4$ (lb/acre)
1	**1**	**4.7**	**0**	**6,693**
1	**2**	**4.7**	**7,000**	**0**
2	**1**	**4.9**	**0**	**4,784**
2	**2**	**4.9**	**5,000**	**0**
3	**1**	**4.5**	**0**	**8,608**
3	**2**	**4.5**	**9,000**	**0**
4	**1**	**4.5**	**0**	**8,608**
4	**2**	**4.5**	**9,000**	**0**

In this way, paired plots with the same plant material will have substantially different soil pH. Plant and soil nutrients will be monitored by leaf tissue and soil analysis. Soil pH and leaf nutrient concentrations will be related to yield during the crop year. Within each

treatment plots stems within randomly placed 1/6 ft^2 quadrats will be cut for stem density (stems/ft^2) and stem length, branching, and flower bud formation measurements.

RESULTS:

2001 Leaf Tissue Analysis

Treatment with limestone had an effect on a number of nutrient elements in leaf tissue samples taken July 2001 (Table 2**).** The leaf tissue concentrations of Ca, K, B, Cu , Zn and Mn were all lower in the plots receiving limestone ($CaCO_3$) compared to the control. Leaf Mg concentrations were raised by raising the soil pH. Control plot leaf Ca concentration was probably higher due to the greater solubility of $CaSO_4$ than $CaCO_3$.

Table2

Treatment	2001 leaf nutrient concentrations						
	Ca (%)	**K (%)**	**Mg (%)**	**B (ppm)**	**Cu (ppm)**	**Zn (ppm)**	**Mn (ppm)**
Control ($CaSO_4$)	**.721a**	**.481a**	**.208b**	**33a**	**4.2a**	**11.6a**	**1135a**
Limestone ($CaCO_3$)	**.676b**	**.451b**	**.256a**	**25b**	**4.0b**	**10.9b**	**629b**

2002 Leaf Tissue and Soil Analysis

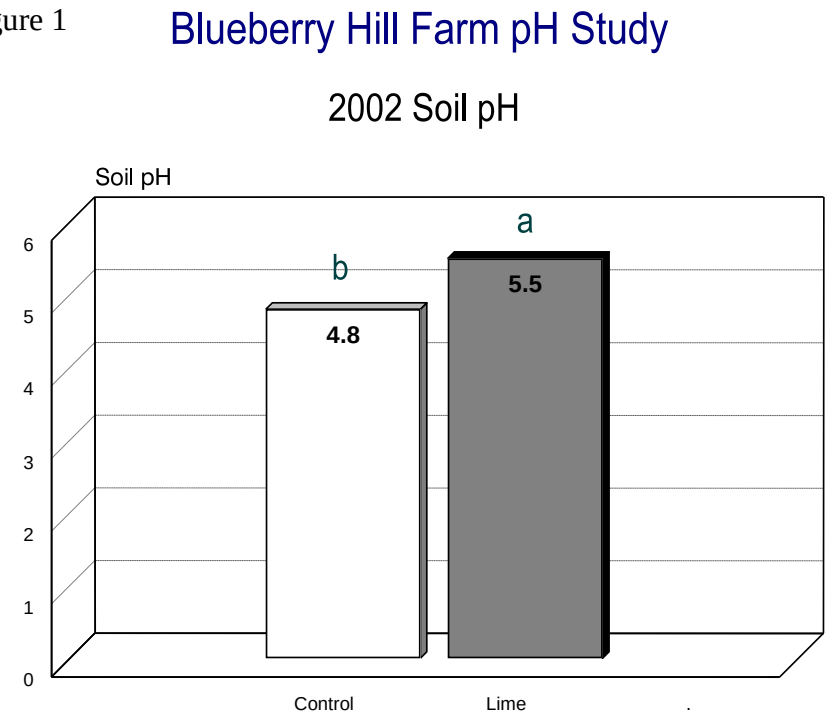
Crop year leaf samples (Table 3) showed different concentrations but similar trends to that found in 2001 prune year leaf samples. Leaf N, P, Zn, and Ca concentrations were not different between the control and limestone-treated plots, but leaf concentration of Mg increased and leaf K, B, Cu, Mn, Al, and Fe concentrations decreased in response to limestone application.

Table3

Treatment	2002 leaf nutrient concentrations						
	K (%)	**Mg (%)**	**B (ppm)**	**Cu (ppm)**	**Mn (ppm)**	**Al (ppm)**	**Fe (ppm)**
Control ($CaSO_4$)	**.398a**	**.150b**	**24a**	**4.42a**	**621a**	**80a**	**40a**
Limestone ($CaCO_3$)	**.380b**	**.168a**	**18b**	**4.19b**	**286b**	**71b**	**35b**

2002 Soil samples showed limestone treated plots had a higher pH than controls (Fig 1.).

Figure 1



Soil concentrations of Ca, Mg, B, Zn, and Mn were higher in the limestone-treated plots that had a higher pH compared to the control (Table 4). Liming resulted in a lower S soil concentration. Soil P, K, Cu, Fe, and Al were unaffected by the change in pH brought about by liming. Yield was not obtained in 2003 due to blossom damage and crop failure when a herbicide for grass control was applied to the field using the wrong oil adjuvant.

Table 4

2002 soil nutrient concentrations

Treatment	Ca (ppm)	K (ppm)	Mg (ppm)	P (ppm)	B (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)
Control ($CaSO_4$)	**535b**	**51a**	**16b**	**7.2a**	**0.06b**	**0.13a**	**1.8b**	**4.68b**
Limestone ($CaCO_3$)	**1709a**	**54a**	**79a**	**6.9a**	**0.08a**	**0.10a**	**3.1a**	**6.83a**

2004 Leaf Tissue and Soil Analysis

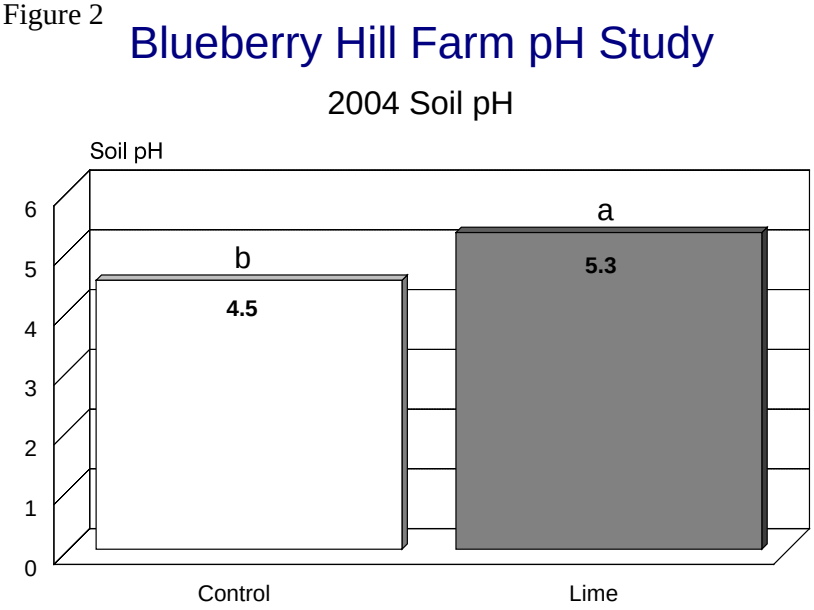
Prune year leaf samples (Table 5) showed different concentrations but trends did not reflect the data from 2002 (Table 3). Leaf N, Cu, Fe, Zn, concentrations were not different between control and limestone-treated plots, but leaf concentrations of Mg increased and leaf Ca, K, P, Mn, Al, and B concentrations decreased in response to limestone application.

Table 5

Treatment	2004 leaf nutrient concentrations						
	K (%)	Mg (%)	Ca (%)	P (%)	Mn (ppm)	Al (ppm)	B (ppm)
Control ($CaSO_4$)	**.513a**	**.142b**	**.416a**	**.164a**	**561a**	**54a**	**23a**
Limestone ($CaCO_3$)	**.490b**	**.155a**	**.383b**	**.141b**	**210b**	**48b**	**17b**

Soil samples taken in 2004 confirmed that limestone treated plots had a higher pH than controls. (Fig. 2)

Figure 2



Soil concentrations of Ca, Mg, B, Zn, and Mn were higher in the limestone-treated plots that had a higher pH compared to the control (Table 6). Soil K, P, Cu, Fe, and Al were unaffected by the change in pH brought about by liming.

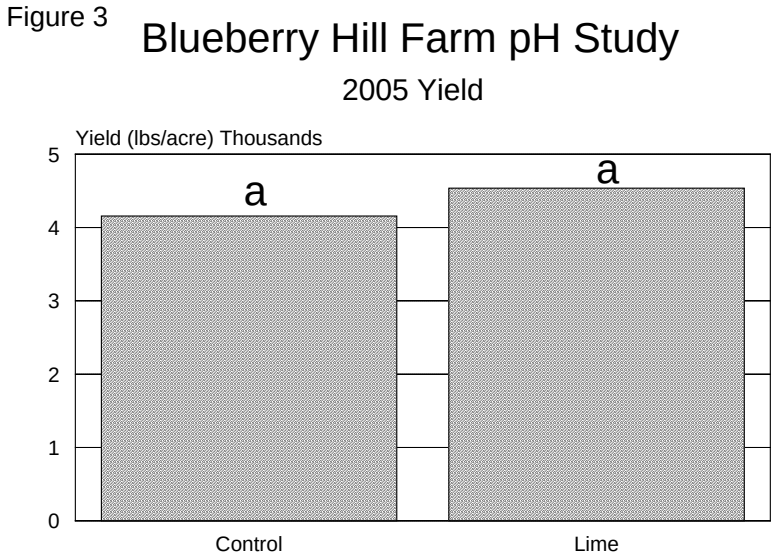
Table 6

Treatment	2004 soil nutrient concentrations							
	Ca (ppm)	K (ppm)	Mg (ppm)	P (ppm)	B (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)
Control ($CaSO_4$)	**511b**	**49a**	**30b**	**11.9a**	**0.15b**	**0.043a**	**1.6b**	**4.53b**
Limestone ($CaCO_3$)	**1578a**	**51a**	**86a**	**11.6a**	**0.22a**	**0.048a**	**2.3a**	**7.67a**

2005 Blueberry Yield

The yield of fruit within the 4 ft x 4 ft plots was not significantly different between the control and the limestone treatment (Fig. 3).

Figure 3



pH Study - Aurora

METHODS: Five discrete clones were selected in a commercial blueberry field in Aurora. Two 4 ft x 4 ft treatment plots were established in each clone and the perimeter of each was cut with a spade to isolate each plot. Soil samples indicated that the soil pH under these clones ranged from 5.1 to 5.5 (Table 5). Yield was collected August 2000 from each treatment plot within each clone and no difference was found between those randomly assigned treatment 1 (9,303 lbs/acre) or those assigned treatment 2 (9, 375 lbs/acre). Sulfur (S) was applied in June 2001 to plots assigned treatment 2 to adjust the soil pH down toward pH 4.6. This required from 550 to 990 lb S/acre, depending upon the pH under the specific clone (Table 5)**.** Soil and leaf samples were collected in July 2001 to establish base line data to compare changes as the soil pH changes. Stem samples were taken from each plot in October 2001 from a randomly placed 1/6 ft^2 quadrat for stem density, stem length and branching and flower bud formation measurements. Soil samples were taken July 22, 2002 to determine the effect on soil pH. Yield was collected August 7, 2002. The nutrient concentrations in leaf and soil samples collected each prune year will be document changes during the extent of the experiment. Measurements made on stem samples collected in the fall of each prune year will indicate changes in growth and development. Yield will be collected each crop year.

Table 5 Treatment Summary			
Clone	**Treatment Number**	**Starting pH**	**Sulfur lb/acre**
1	**1**	**5.3**	**0**
1	**2**	**5.3**	**770**
2	**1**	**5.2**	**0**
2	**2**	**5.2**	**660**
3	**1**	**5.5**	**0**
3	**2**	**5.5**	**990**
4	**1**	**5.4**	**0**
4	**2**	**5.4**	**880**
5	**1**	**5.1**	**0**
5	**2**	**5.1**	**550**

RESULTS:

2001 Leaf Tissue and Soil Analysis

Soil samples taken in July 2001 indicated that control and sulfur-treated plots had similar soil pH values of 5.18 and 5.16, respectively. Leaf nutrient concentrations were not significantly different between control and sulfur-treated treatment plots for all nutrients, except manganese (Mn). Leaf nutrients that might be expected to change with soil pH are given in Table 6.

Table 6

Treatment	2001 leaf nutrient concentrations						
	Ca (%)	**K (%)**	**Mg (%)**	**B (ppm)**	**Cu (ppm)**	**Zn (ppm)**	**Mn (ppm)**
Control	**.400a**	**.493a**	**.176a**	**28a**	**5.0a**	**15.0a**	**450b**
Sulfur (S)	**.412a**	**.471a**	**.174a**	**26a**	**5.2a**	**15.1a**	**580a**

Soil nutrient concentrations for control and sulfur-treated plots were not different for Ca, K, Mg, P, Al, B, Cu, Fe, Zn or Mn. The concentrations of most elements are presented in Table 7**.**

Table 7

Treatment	2001 soil nutrient concentrations							
	Ca (ppm)	**K (ppm)**	**Mg (ppm)**	**P (ppm)**	**B (ppm)**	**Cu (ppm)**	**Zn (ppm)**	**Mn (ppm)**
Control	**437a**	**96a**	**62a**	**9.4a**	**.17a**	**.11a**	**1.8a**	**12.4a**
Sulfur (S)	**524a**	**106a**	**77a**	**9.4a**	**.17a**	**.13a**	**2.1a**	**16.6a**

2001 Stem Characteristics

Stem density, stem length, and flower buds per stem were not affected by treatments (Table 8).

Table 8

2001 Stem Characteristics

Treatment	Density (Stems/ft^2)	Stem Length (in)	Branches (No)	Branch Length (in)	Flower buds/stem
Control	**34.8b**	**3.22a**	**1.76a**	**1.67a**	**1.42a**
Sulfur (S)	**53.8a**	**3.39a**	**0.77b**	**2.1a**	**1.42a**

2002 Crop-Year Soil Analysis

Soil pH was significantly lower in sulfur-treated plots one year after treatment (Fig.2) but only soil Zn, Mn, and S concentrations were higher in sulfur-treated plots (Table 9). S concentration was 190 ppm in sulfur-treated plots compared to 52 ppm for the controls.

Figure 2

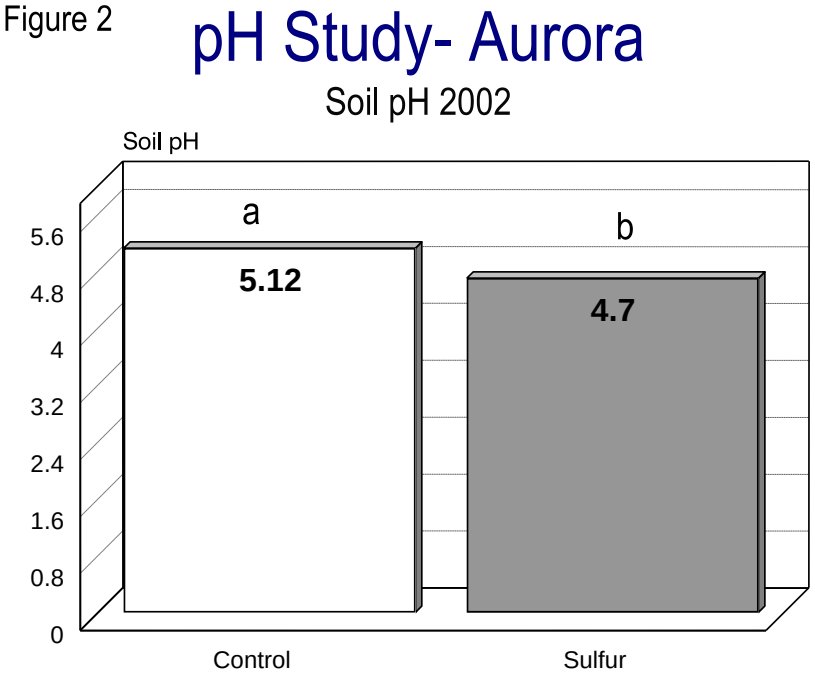


Table 9

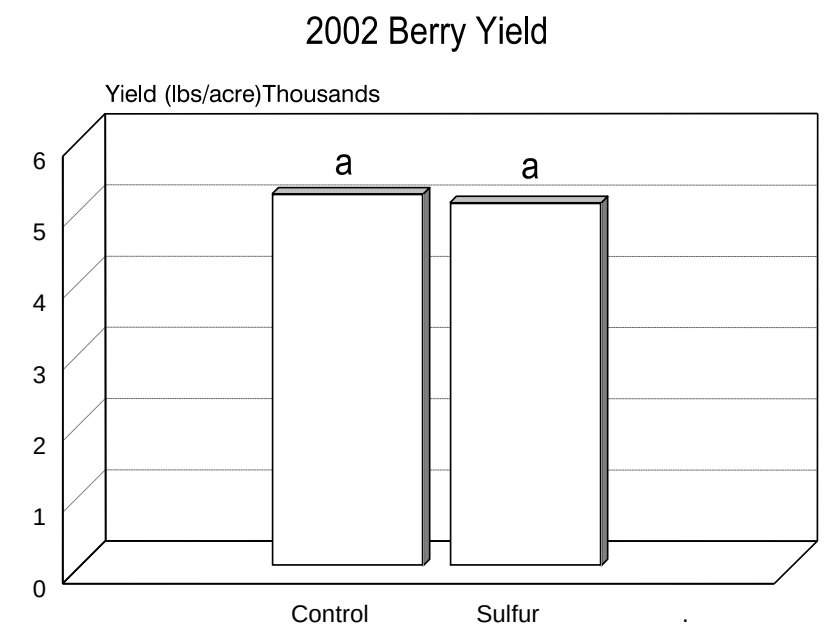
2002 soil nutrient concentrations

Treatment	Ca (ppm)	K (ppm)	Mg (ppm)	P (ppm)	B (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)
Control	**302a**	**83a**	**34a**	**6.4a**	**.06a**	**.17a**	**1.8a**	**5.8b**
Sulfur (S)	**331a**	**86a**	**37a**	**7.1a**	**.06a**	**.21a**	**2.2a**	**12.8a**

2002 Yield

Blueberry yield collected in August 7, 2002 was not affected by sulfur treatment (Fig. 3).

Figure 3 pH Study- Aurora



2003 Soil and Leaf Tissue Analysis

Prune-year leaf tissue levels were similar for control and sulfur-treated plots, except for leaf Mn concentrations (Table 10). Soil Mn concentrations were also higher in treatment plots receiving sulfur (Table 11). Soil pH values for treatment plots in 2003 (Fig. 4) were similar to those in 2002.

Table 10

2003 leaf nutrient concentrations

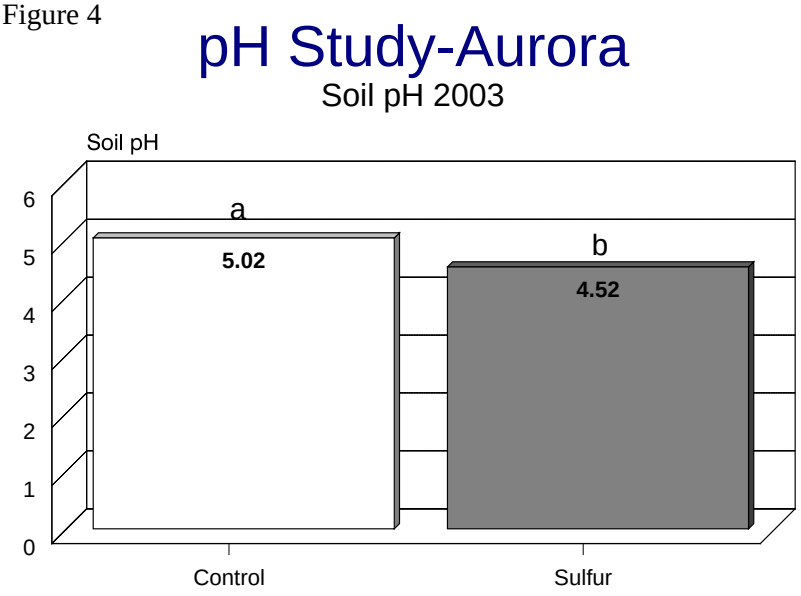
Treatment	Ca (%)	K (%)	Mg (%)	B (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)
Control	**.503a**	**.447a**	**.179a**	**28a**	**4.2a**	**28.2a**	**632b**
Sulfur (S)	**.504a**	**.501a**	**.171a**	**27a**	**4.0a**	**31.8a**	**1098a**

Table 11

2003 soil nutrient concentrations

Treatment	Ca (ppm)	K (ppm)	Mg (ppm)	P (ppm)	B (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)
Control	**452a**	**88a**	**53a**	**10.4b**	**.08a**	**.14a**	**2.1a**	**14.6b**
Sulfur (S)	**390a**	**83a**	**41a**	**12.1a**	**.07a**	**.16a**	**2.5a**	**21.2a**

Figure 4



2003 Stem Characteristics

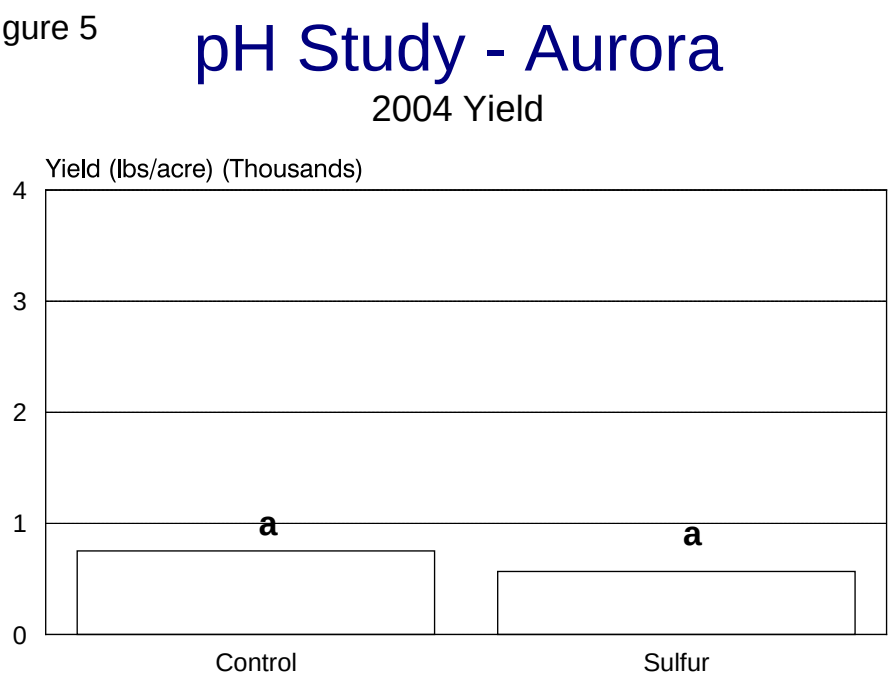
Stem density, length, branching and flower bud formation were not affected by soil pH (Table 12). Berry yield was extremely low due to severe winter injury across the state. There was no difference between the sulfur treatments and the controls (Fig. 5).

Table 12

2003 Stem Characteristics

Treatment	Density (Stems/ft^2)	Stem Length (in)	Branches (No)	Branch Length (in)	Flower buds/stem
Control	**40.27a**	**3.84a**	**0.54a**	**1.51a**	**0.85a**
Sulfur (S)	**38.38a**	**3.81a**	**0.57a**	**1.60a**	**0.85a**

Figure 5



2005 Soil and Leaf Tissue Analysis

Soil pH continues to show a difference between control and sulfur-treated plots (Fig. 6). Analyses of leaf tissue samples show Mn as the only nutrient that is different between the sulfur and control plots (Table 13). N and P concentration, 1.36% and 0.096%, respectively, were below the satisfactory range of 1.6% (N) and .125% (P).

Figure 6

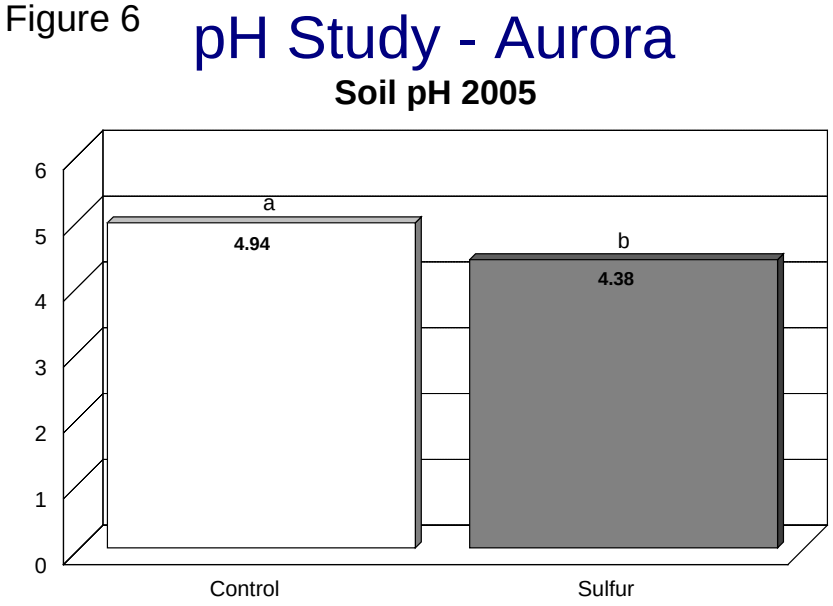


Table 13

2005 leaf nutrient concentrations

Treatment	Ca (%)	K (%)	Mg (%)	B (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)
Control	**.489a**	**.466a**	**.183a**	**23a**	**4.9a**	**16.1a**	**560b**
Sulfur (S)	**.498a**	**.475a**	**.170a**	**27a**	**5.2a**	**15.9a**	**1220a**

CONCLUSIONS: No conclusions can be made at this time.

RECOMMENDATIONS: No recommendations can be made at this time.

PLANT NUTRITION AND FERTILITY

INVESTIGATORS: John M. Smagula, Professor of Horticulture
Loretta Kreider, Scientific Technician
Qian Wang, Graduate Student

12. TITLE: Effect of Manganese on Growth and Yield of Wild Blueberry

OBJECTIVES: To determine the effect of raising leaf manganese (Mn) concentration on growth and yield of wild blueberry

Brief Justification

The lowbush blueberry exhibits a tendency to be a manganese accumulator, with leaf Mn concentrations occurring above 1000 ppm with no apparent adverse affects. The leaf Mn concentrations reported in highbush blueberry leaves are usually under 300 ppm, and it has been suggested that concentrations above 500 ppm are associated with toxicity symptoms. This study will determine if raising low leaf Mn concentrations (<750 ppm) in a commercial lowbush blueberry field will result in more growth and yield and higher fruit Mn concentrations, compared to untreated controls.

METHODOLOGY: A commercial wild blueberry field that had an average leaf tissue Mn concentration of < 750 ppm in a 2001 field sample was used for this study. Eight discrete clones were selected but one was eliminated from the study when it was found to be a mixture of two clones. Four treatments were replicated four times within each clone. The sixteen treatment plots (2 ft x 2 ft) were isolated from the rest of the clone by cutting through the blueberry sod to a depth of about six inches. Plots received a preemergent soil drench (750 ml/plot) containing 0, 1, 2, or 3 lbs Mn/acre from Citraplex (20% Mn) (Nortrace Co.). Composite leaf tissue samples were taken on July 6, 2004 from 15 stems in each treatment plot to determine leaf nutrient concentrations. Soil samples were also taken on July 6, 2004 to determine pH, organic matter content and nutrient concentrations. Stems were sampled November 26 and 27, 2004. All stems were cut at ground level in three randomly placed 1/9 ft^2 quadrats per plot to determine shoot number, length, and branching and the number of flower buds produced per stem. Berry yield will be determined in August 2005 by hand raking each plot. Samples of berries will also be analyzed for Mn concentrations.

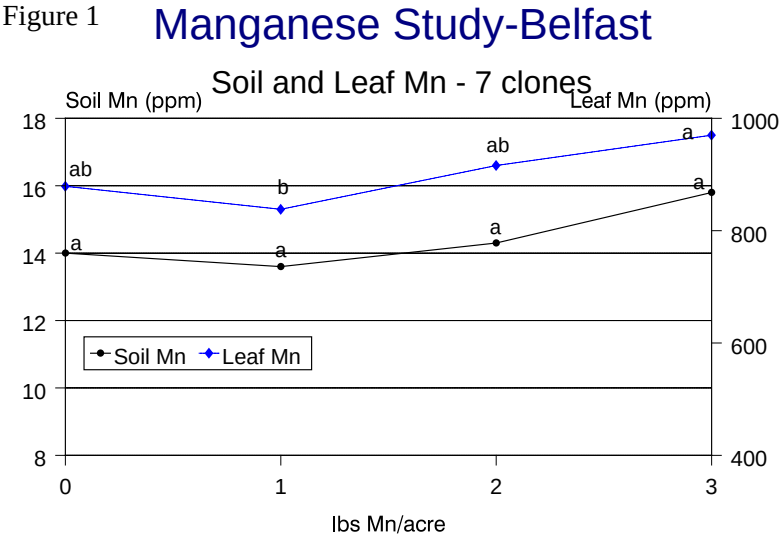
RESULTS: Changes in soil and leaf tissue Mn concentrations in response to Mn soil treatments showed a similar pattern (Fig. 1). There was a large variability even within clones and therefore changes in soil and leaf tissue Mn were not significant at the 5% level. At the 10% level, leaf Mn concentrations increased at the highest rate compared to the lowest rate. There was major difference in the leaf Mn concentration among clones (Fig 2), ranging from 588 to 1258 ppm. An interesting trend is observed when Mn concentrations are compared to other nutrients such as N (Fig. 3), P (Fig. 4), and K (Fig. 5); the clones having the lowest Mn concentrations had the highest N, P, and K concentrations. Variation in leaf nutrient concentrations were found among the seven clones (Table 1). Although there was no significant difference among clones for soil Mn concentration, leaf Mn concentrations varied among the 7 clones (Table 1). This means that some clones were able to absorb and transport to their leaves more Mn from the soil We measured the growth characteristics (Table 2) and the potential yield characteristics (Table 2b) of the seven clones and correlated them with leaf nutrient concentrations

(Table 3). Positive correlations were found between leaf Mn concentration and flower bud density and flower buds per stem.
Berry yield Berries were harvested from each plot, weighed for yield determination and the weight converted to the equivalent in lbs/acre. There was no significant difference among treatments (Fig. 6). The yield was low and differed dramatically among clones (Fig. 7). The leaf Mn concentrations are superimposed on the yield in this figure to show that there is a trend for clones with leaf Mn to have a higher yield.

CONCLUSIONS: While we have not been very successful in raising leaf Mn concentrations through foliar or soil applications of Mn, there are indications that clones with higher leaf Mn concentrations have the potential for higher yields.

RECOMMENDATIONS: No recommendations can be made at this time.

Figure 1



Citraplex (20%Mn) applied to soil pre-emergent. Mean Separation By Duncan's Multiple Range test, 10% level.

Figure 2

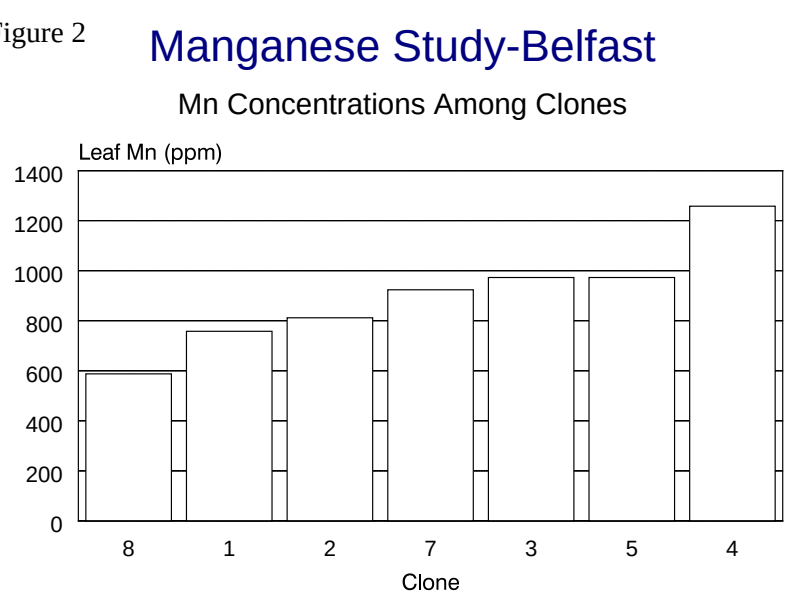


Figure 3

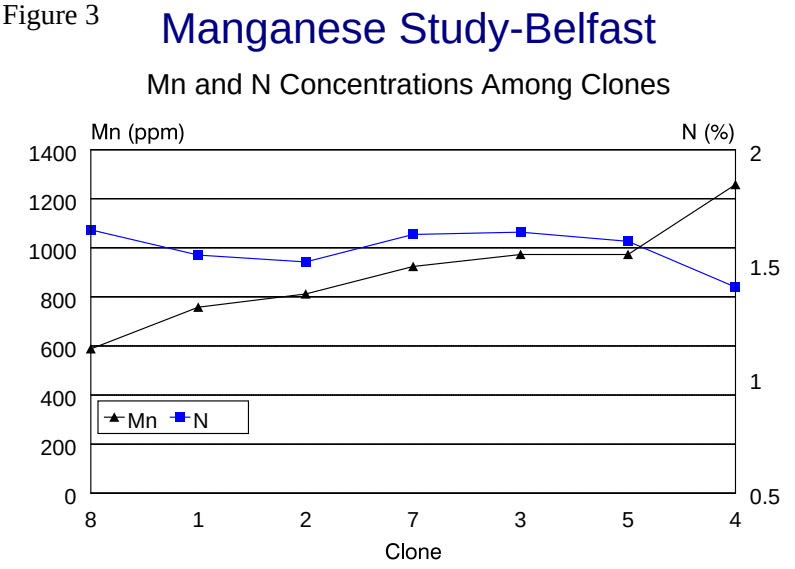


Figure 4

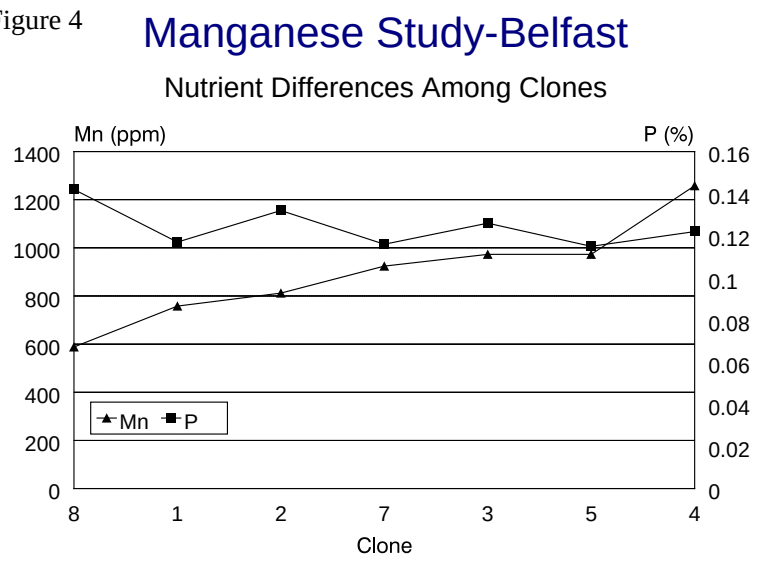


Figure 5

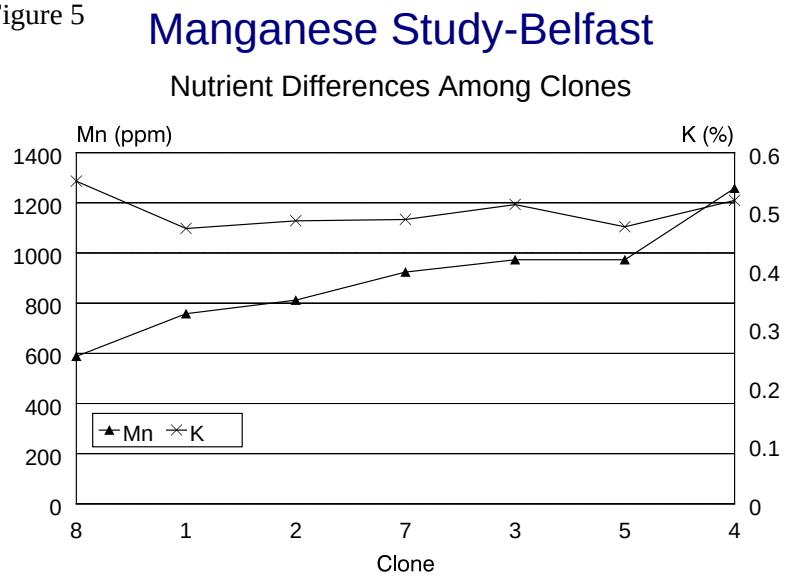


Table 1 Clonal differences in leaf nutrient concentrations averaged across all treatments

Clone	N	Ca	K	Mg	P	Al	B	Cu	Fe	Mn	Zn
	($g \cdot kg^{-1}$)					($mg \cdot kg^{-1}$)					
1	15.4 b	3.9 b	4.7 c	1.9 a	1.2 de	78 c	15.9 d	3.9 a	32.3 bc	758 c	13.9 c
2	15.1 b	3.8 b	4.8 c	1.6 e	1.3 b	95 a	22.7 b	3.7 ab	29.1 c	812 c	15.7 b
3	16.4 a	3.7 bc	5.1 b	1.8 b	1.3 c	96 a	18.9 c	3.4 abc	38.0 b	973 b	14.8 bc
4	14.0 c	3.6 c	5.2 b	1.5 e	1.2 cd	83 bc	23.4 b	3.2 bc	28.6 c	1258 a	14.7 bc
5	16.0 a	3.2 d	4.7 c	1.6 d	1.2 e	84 bc	15.7 d	3.3 bc	36.5 bc	993 b	17.9 a
6	16.3 a	3.8 b	4.9 c	1.6 de	1.2 e	80 c	23.8 b	3.0 c	38.3 b	924 b	17.5 a
7	16.5 a	4.1 a	5.5 a	1.7 c	1.4 a	91 ab	29.6 a	3.4 abc	54.3 a	559 d	17.3 a

Mean separation within columns by Duncan's multiple range test at $P \leq 0.05$.

Table 2. Growth characteristics of clones in prune year.

Clone	Stem or branch density (No./16 in^2)				Stem or branch length (in)				Branching (branches/stem)
	Stm[z]	US[y]	BS[x]	Brc[w]	Stm[z]	US[y]	BS[x]	Brc[w]	Bs[x]
1	13 b	13 ab	1 e	1 e	2.5 d	2.5 cd	1.3 d	0.4 d	0.6 c
2	17 a	15 a	2 d	2 de	2.2 e	2.1 e	1.9 c	0.67 c	1.0 b
3	16 a	14 a	2 cd	3 cd	2.4 d	2.4 cd	1.7 cd	0.67 c	1.0 b
4	15 ab	14 a	1 e	1 e	3.4 a	3.4 a	1.8 cd	0.70 c	0.7 bc
5	15 ab	10 c	5 a	8 a	2.8 c	2.6 c	3.3 a	1.18 ab	1.6 a
6	17 a	14 a	3 b	4 b	2.3 de	2.3 de	2.6 b	1.30 a	1.4 a
7	13 b	10 bc	3 bc	4 bc	3.0 b	2.9 b	3.1 ab	0.94 bc	1.4 a

[z]All the stems
[y]Unbranched stems
[x]Branched stems
[w]Branches
Means followed by different letters are significantly different by Duncan's multiple range test at $P \leqslant 0.05$.

Table 2b. Potential yield characteristics of clones in prune year.

Clone	Flower bud density (FB/103.2 cm^2)					Flower bud per stem/branch					Flower bud ratio (FB/cm)		
	Stm[z]	US[y]	BS[x]	BSM[w]	Brc[v]	Stm[z]	US[y]	BS[x]	BSM[w]	Brc[v]	US[y]	BSM[w]	Brc[v]
1	10 c	9 c	1 c	0 c	1 c	1 cd	0.8 bc	0.6 bc	0.3 c	0.3 c	0.1 cd	0.0 cd	0.1 b
2	10 c	8 c	1 c	1 c	0 c	1 d	0.6 c	0.6 bc	0.4 bc	0.2 c	0.1 d	0.1 bc	0.0 b
3	15 b	13 b	2 c	1 c	1 c	1 bc	0.9 b	0.8 bc	0.4 bc	0.3 c	0.1 ab	0.1 b	0.1 b
4	19 a	17 a	2 c	1 c	1 c	1.3 a	1.2 a	1.1 b	0.6 b	0.3 bc	0.1 bc	0.0 bc	0.1 b
5	18 ab	9 c	9 a	5 a	4 a	1.2 ab	0.9 b	1.9 a	1.0 a	0.5 ab	0.1 cd	0.1 a	0.2 a
6	19 a	14 ab	6 b	3 b	3 b	1.2 ab	1.0 b	2.0 a	1.1 a	0.6 a	0.2 a	0.1 a	0.2 a
7	5 d	3 d	1 c	1 c	1 c	0.4 e	0.3 d	0.4 c	0.2 c	0.1 c	0.0 e	0.0 d	0.0 b

[z]All the stems
[y]Unbranched stem
[x]Branched stem
[w]Major stem of branched stem
[v]Branch
Means followed by different letters are significantly different by Duncan's multiple range test at $P \leqslant 0.05$.

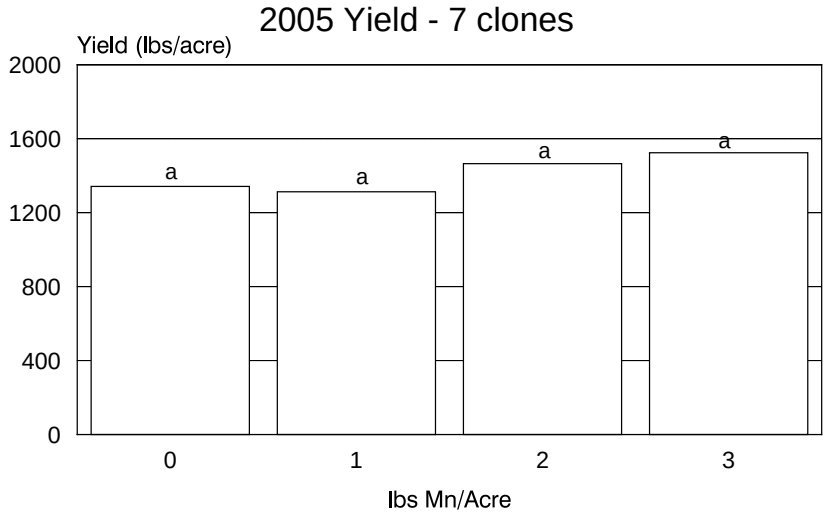
Table 3. Significant correlation coefficients between leaf nutrient concentrations and growth characteristics of the seven clones.

	Stem or branch density (No./103.2 cm^2)				Stem or branch length (cm)				Branching	Flower bud (FB) density (No./103.2 cm^2)					FB per stem or branch					FB ra (FB/c	
	Stm[z]	Ubs[y]	Bs[x]	Brc[w]	Stm[z]	Ubs[y]	Bs[x]	Brc[w]	Bs[x]	Stm[z]	Ubs[y]	B[v]	Bs[x]	Brc[w]	Stm[z]	Ubs[y]	B[v]	Bs[x]	Brc[w]	Ubs[y]	Bs[v]
N		-0.22	0.3	0.38	-0.2	-0.3	0.28	0.38	0.32		-0.26	0.24	0.2	0.26		-0.21					
Ca			-0.4	-0.38						-0.37		-0.48	-0.5	-0.37	-0.42	-0.28	-0.3	-0.32		-0.29	
K	-0.25				0.37	0.34				-0.25		-0.25	-0.24	-0.22	-0.21		-0.23		-0.26	-0.32	
Mg			-0.2	-0.23				-0.24		-0.28		-0.31	-0.35	-0.22	-0.29	-0.21	-0.25	-0.34			
P										-0.44	-0.32	-0.34	-0.32	-0.31	-0.42	-0.39	-0.24	-0.19	-0.25	-0.46	
Al										-0.3	-0.24	-0.19		-0.21	-0.3	-0.26	-0.22		-0.27	-0.22	
B			-0.2		0.27	0.26	0.19			-0.29		-0.32	-0.31	-0.27	-0.31	-0.24	-0.2		-0.25	-0.34	
Cu										-0.2					-0.19			-0.2			
Fe	-0.27	-0.34								-0.32	-0.37				-0.26	-0.32				-0.3	
Mn					0.36	0.37				0.46	0.49				0.47	0.52		0.23		0.37	
Zn			0.35	0.42			0.27	0.23	0.2			0.32	0.28	0.31							
Mn:Fe	0.25			-0.19	0.33	0.39	-0.21			0.46	0.57				0.42	0.51		0.19		0.34	

[a]All the stems
[y]Unbranched stems
[x]Branched stems
[w]Branches
[v]Major stem of branched stems

All correlations are significant at $P \leq 0.05$.

Figure 6 Manganese Study-Belfast



Citraplex (20%Mn) applied to soil pre-emergent. Mean Separation By Duncan's Multiple Range test, 5% level.

Figure 7 Manganese Study-Belfast

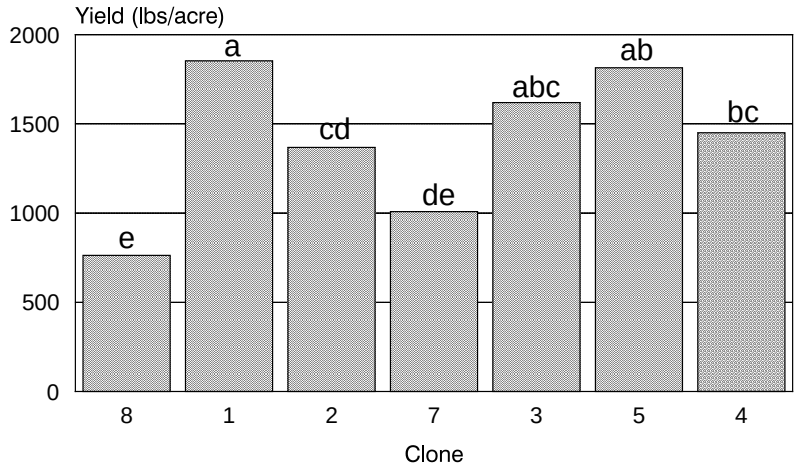
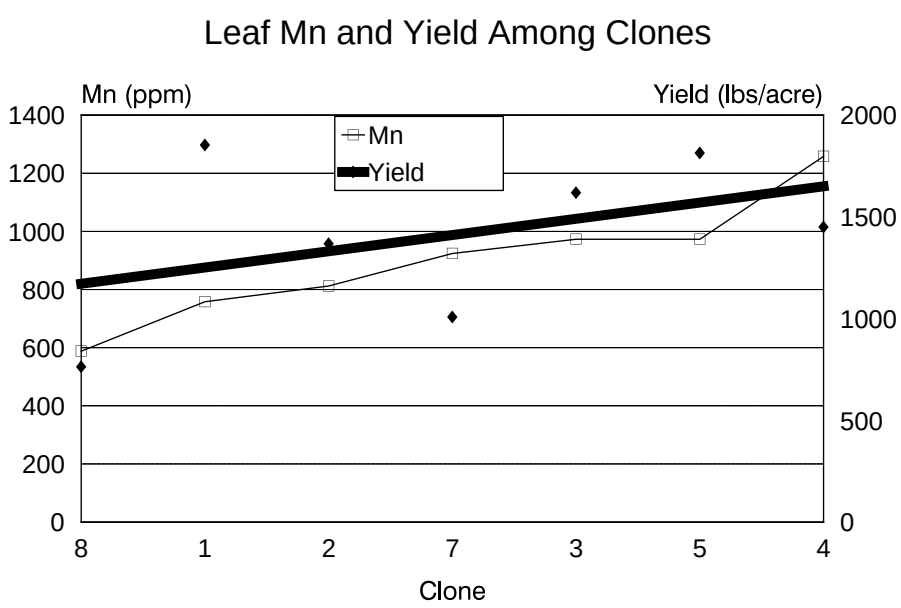


Figure 8

Manganese Study-Belfast



PLANT NUTRITION AND FERTILITY

INVESTIGATORS: John M. Smagula, Professor of Horticulture
Loretta Kreider, Scientific Technician

13. TITLE: Raising Foliar Nitrogen by Application of CoRoN™

OBJECTIVES: To determine an effective method of raising leaf Nitrogen concentrations that may increase growth and yield of wild blueberries.

METHODS: A commercial wild blueberry field that had a history of low leaf nitrogen (N) concentration was used in this study. CoRoN ™ (28% N) is a combination of polymethylene urea coupled with fast-release, low-biuret urea, designed to act as a slow-release foliar fertilizer. A Citrate-Phosphate buffer was used in treatments 2, 3, and 4 to control the pH during application. CoRoN ™ at 6lbsN/acre was applied to the entire 3 ft x 50 ft plots on June 12, 2004 of the prune year and to half the 3 ft x 50 ft plot on June 24, about two weeks later. Both Cu and Fe Keylate (Stoller Enterprises, Inc.) were added to CoRoN ™ treatments at 0.5 lbs/acre to see if they enhance N uptake. Ammonium Sulfate was added to the Cu/Fe solution at 0.7%, as suggested by the manufacturer. CoRoN ™ plus Cu and Fe without the Ammonium Sulfate was also tested. A control plot received no fertilization. These 9 treatments (Table 1) were replicated 6 times in a randomized complete block design.

Table 1
Treatment Summary

Treatment 1	**Control**
Treatment 2	**CoRoN pH 5 using buffer**
Treatment 3	**CoRoN pH 6 using buffer**
Treatment 4	**CoRoN pH 7 using buffer**
Treatment 5	**CoRoN pH 8 using distilled H2O**
Treatment 6	**CoRoN pH 8, Cu, Fe, and Ammonium Sulfate (.7%)**
Treatment 7	**CoRoN pH 8 and Ammonium Sulfate (.7%)**
Treatment 8	**CoRoN pH 8, Cu, And Fe**
Treatment 9	**Ammonium Sulfate at 3lbs N/acre**

Composite leaf tissue samples were taken July 13, 2004. Soil samples were taken from control plots July 13, 2004. Stem samples were taken October 20 & 21, 2004 for growth and potential yield measurements. Yield will be taken in August 2005.

RESULTS:

2004 Leaf Tissue Concentrations

Treatments had no meaningful effect on P, K, Ca, Mg, Al, B, Mn,or Zn. Leaf N concentrations were raised by all CoRoN ™ treatments compared to the control, except that which was buffered at pH 5 (Fig. 1). Adding Cu/Fe, Cu/Fe plus ammonium sulfate, or ammonium sulfate did not improve the effectiveness of CoRoN ™ in raising leaf N concentrations. The leaf N concentrations in plots receiving ammonium sulfate at 3 lbs N/acre was not different from the controls. When the control and the four buffered sources were analyzed alone, there was a significant linear trend of increasing leaf N concentration with increasing pH (Fig. 2). The CoRoN ™ solution buffered at pH 7 appeared to be the best for raising leaf N concentration. Two applications of CoRoN ™ are slightly better than a single early application (Fig. 3). While adding Cu/Fe with or without ammonium sulfate did not enhance N penetration, the leaf Cu concentrations were raised to above the 7 ppm standard concentration (Fig. 4). Leaf Cu concentrations were also raised higher with two, compared to one application (Fig. 5). Leaf Fe concentrations were also raised by the CoRoN ™ and Cu/Fe solutions with or without the ammonium sulfate (Fig. 6). Two sprays were more effective than one (Fig. 7). The addition of ammonium sulfate to these solutions increased both the leaf Cu and leaf Fe concentrations.

2004 Soil Data- Soil pH of samples taken from controls on July 13, 2004 ranged from 4.3 to 4.5.

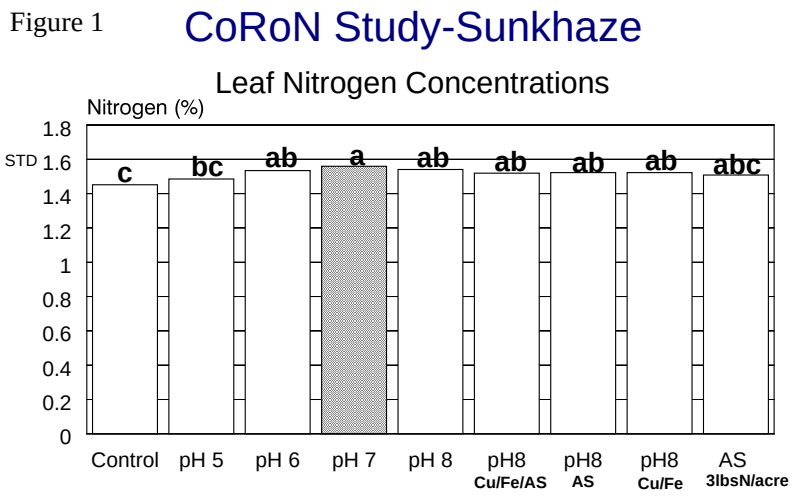
2005 Yield Data

Blueberry yield was not influenced by any of the treatments (Fig. 7). This is not surprising since the CoRoN ™ treatments did not raise the leaf N concentrations to the standard (1.6%) at the rate used. Two applications, while more effective in raising N concentrations compared to only one, did not significantly raise yield. This may be because the N concentration was still below the 1.6% standard and that the P concentration in leaf tissue (.114%) was also below the standard (.125%)

CONCLUSIONS: CoRoN ™ was effective in raising leaf N concentrations compared to the control; but the concentration was not raised to above the sufficiency level. Adding Cu/Fe with or without ammonium sulfate did not improve the penetration of N from CoRoN ™. Lowering the CoRoN ™ solution pH did not improve efficacy. Two applications appear to be better than a single early application.

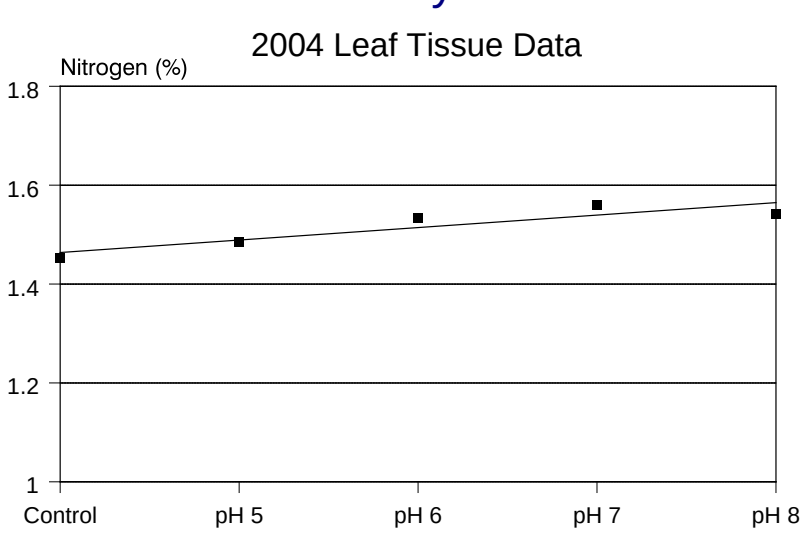
RECOMMENDATIONS: More work needs to be done on the most efficient rate of CoRoN ™ and the best time to apply CoRoN ™. Multiple applications should be further explored.

Figure 1



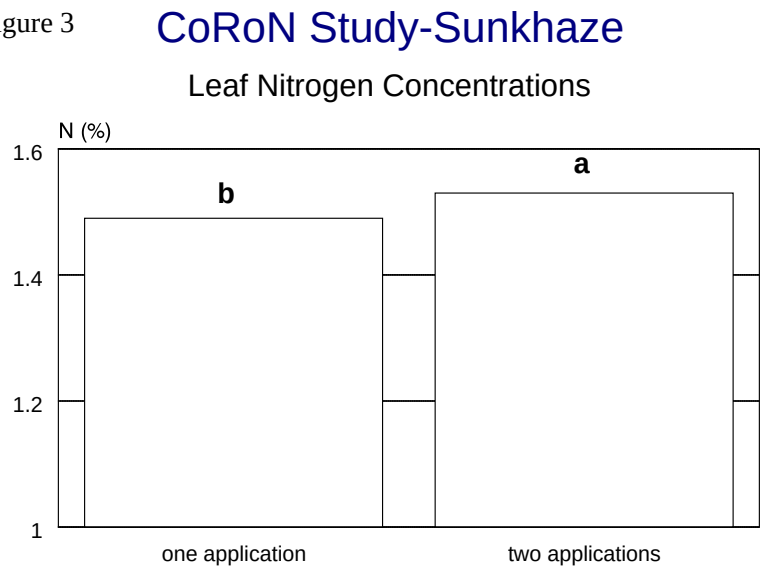
CoRoN applied at a rate of 6lbsN/acre,Copper and Iron each applied at 0.5 lbs/acre, Ammonium sulfate with Cu/Fe at 0.7% and alone at 3lbs N/acre. Mean Separation by Duncan's Multiple range test, 5% level.

Figure 2



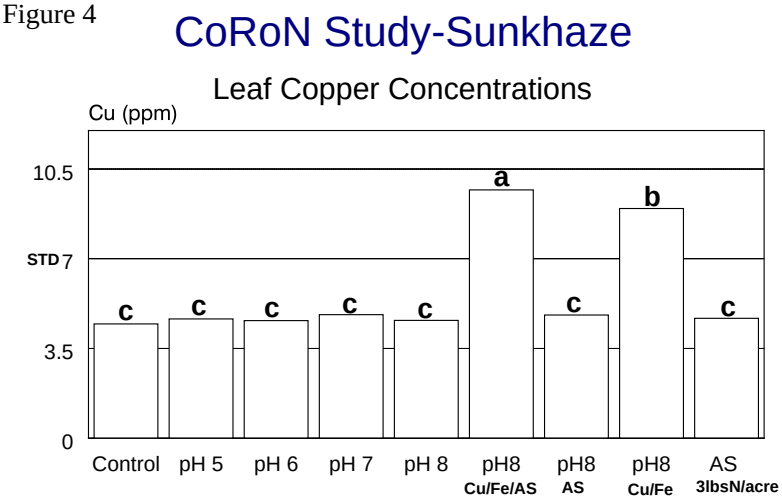
CoRoN applied at a rate of 6lbsN/acre.

Figure 3



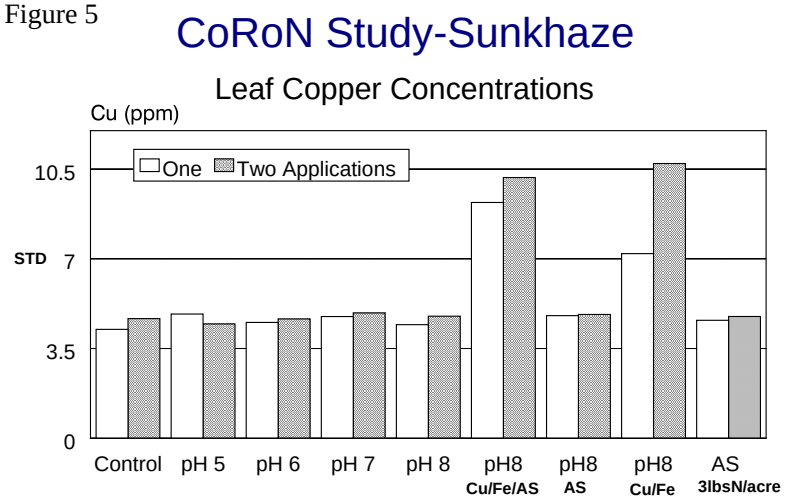
Means are average N concentrations across all treatments. Mean Separation by Duncan's Multiple range test, 7% level.

Figure 4



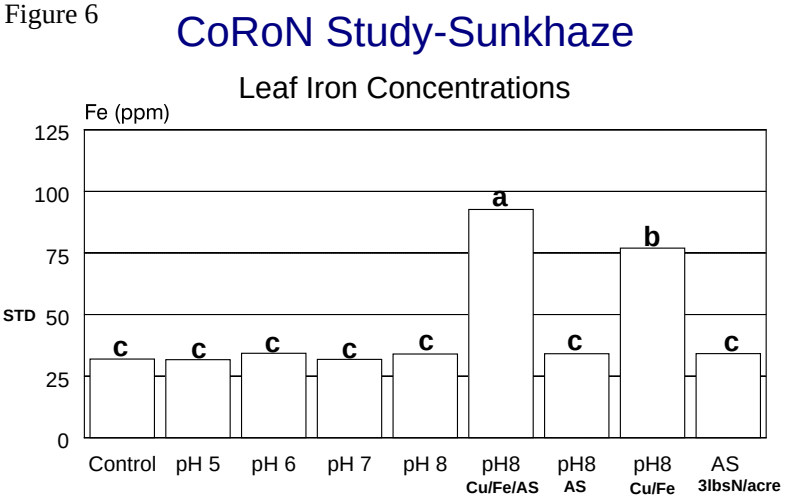
CoRoN applied at a rate of 6lbsN/acre,Copper and Iron each applied at 0.5 lbs/acre, Ammonium sulfatewith Cu/Fe at 0.7% and alone at 3lbs N/acre. Mean Separation by Duncan's Multiple range test, 0.01% level.

Figure 5



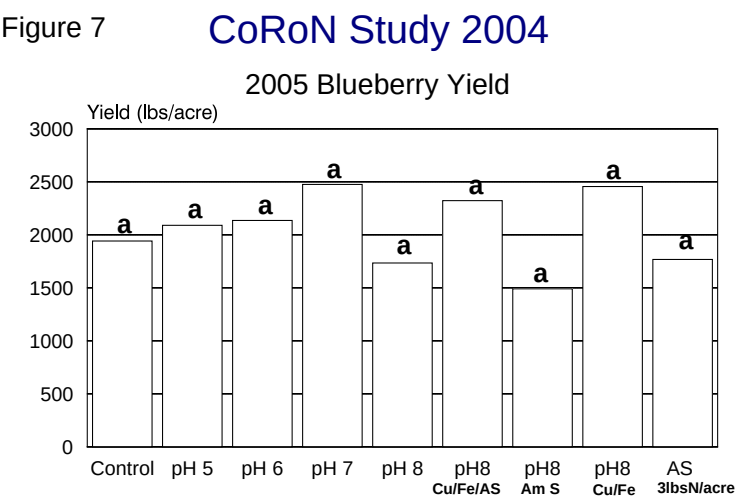
CoRoN applied at a rate of 6lbsN/acre,Copper and Iron each applied at 0.5 lbs/acre, Ammonium sulfate with Cu/Fe at 0.7% and alone at 3lbs N/acre. Mean Separation by Duncan's Multiple range test, 0.01% level.

Figure 6



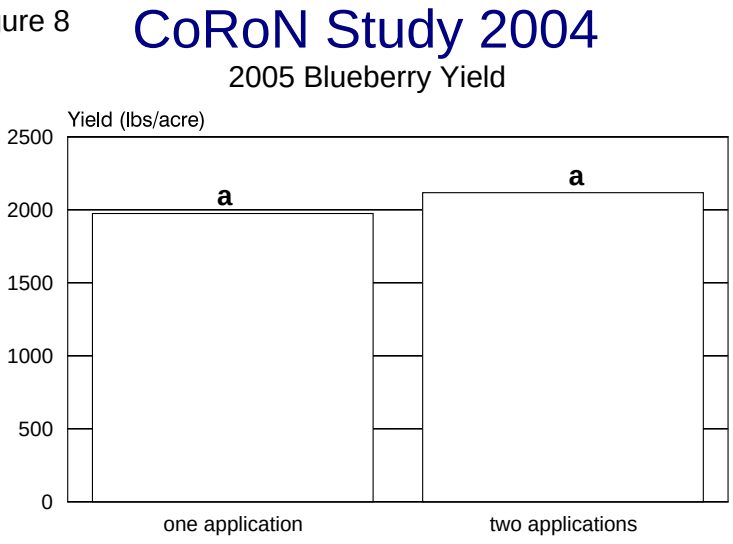
CoRoN applied at a rate of 6lbsN/acre,Copper and Iron each applied at 0.5 lbs/acre, Ammonium sulfate with Cu/Fe at 0.7% and alone at 3lbs N/acre. Mean Separation by Duncan's Multiple range test, 0.01% level.

Figure 7



CoRoN applied at a rate of 6lbsN/acre,Copper and Iron 1gal/acre, Ammonium sulfate 0.7% and alone at 3lbs N/acre. Means separation by Duncan's Multiple range test, 5% level.

Figure 8



CoRoN applied at a rate of 6lbsN/acre,Copper and Iron 1gal/acre, Ammonium sulfate 0.7% and alone at 3lbs N/acre. Means separation by Duncan's Multiple range test, 5% level. Mean Separation by Duncan's Multiple range test, 5% level.

PLANT NUTRITION AND FERTILITY

INVESTIGATORS: John M. Smagula, Professor of Horticulture
Loretta Kreider, Scientific Technician

14. TITLE: Effects of Summer Foliar Fertilization to Increase Branch Length and Flower Bud Formation in the Prune Year.

OBJECTIVES: Determine the effect of raising foliar nitrogen (N) after initial tip dieback on growth and yield of wild blueberries.

IMPACT OF RESEARCH: At the time of tip dieback in early July, the lateral buds on emerging shoots can either develop into a flower bud or remain a vegetative bud. The vegetative buds can break and elongate to form lateral branches. We have found in recent studies that preemergent application of DAP in the prune year increases the number of these branches. These branches are usually short and produce only one or two flower buds. If they could be encouraged to grow longer, would more flower buds form? A positive correlation between stem length and number of flower buds of unbranched stems has been found in a number of studies. Nitrogen may be a limiting factor affecting the length of lateral branches. Would applying fertilizer after branching has started, through foliar sprays, overcome a nitrogen deficiency and increase the length of these branches and in turn result in more flower buds? Is N the only nutrient that is needed? What would be the optimum time for this foliar application? This study will answer these questions.

METHODOLOGY: A commercial blueberry field from which previous analysis of leaf samples indicated nitrogen deficiency was used to determine the most effective time to apply CoRoN™ in order to influence the branch length and flower bud formation. CoRoN™, containing 28% N, was used in a foliar spray volume of 67gal/acre. The highest rate of CoRoN™ without leaf burning (12 lbs N/acre) was determined in a greenhouse study using blueberry sods of two clones. In the field study, an application of foliar N following a soil application of DAP was evaluated to see how it affects growth and development of branches and flower buds. A foliar fertilizer containing P and K (12 lbs P/acre) was also tested, with or without the application of CoRoN™ at 12 lbs N/acre. The most beneficial time for the application of N, PK, or N + PK foliar sprays was studied by applying these treatments to plots at three-week intervals, beginning two weeks before tip dieback. Treatment plots measuring 6 ft x 50 ft treatment plots received the following prune-year treatments:

1. Control (no treatment)
2. DAP
3. DAP + CoRoN™ June 9
4. DAP + CoRoN™ + PK June 9
5. DAP + PK June 9
6. DAP + CoRoN™ June 28
7. DAP + CoRoN™ + PK June 28
8. DAP + PK June 28
9. DAP + CoRoN™ July 19
10. DAP + CoRoN™ + PK July 19
11. DAP + PK July 19

12. DAP + CoRoN™ August 8
13. DAP + CoRoN™ + PK August 8
14. DAP + PK August 8
15. DAP + CoRoN™ September 2
16. DAP + CoRoN™ + PK September 2
17. DAP + PK September 2
18. DAP + CoRoN™ September 22
19. DAP + CoRoN™ + PK September 22
20. DAP + PK September 22

Treatments were randomly assigned to treatment plots in a randomized complete block design with 10 blocks. Sixteen stems in each treatment plot were tagged to evaluate the effect of the early foliar sprays (prior to normal tip dieback) on time of branching. Two weeks after each treatment spray, stems were sampled from those plots as well as the controls to determine leaf nutrient concentrations. Branching was evaluated weekly for 5 weeks, between 7/21 and 8/12 on the tagged stems in plots receiving foliar sprays before 8/12. In the spring 2006, the tagged stems will be used to evaluate the effect of treatments on fruit set, the percentage of blossoms on a stem that develop into fruit. To determine the effect of treatments on stem density, stem length, branching and branch length, stem samples from 4 randomly placed 1/4 ft^2 quadrats will be collected in November 2005. The number of flower buds on each stem will also be measured. Stems will be ground and analyzed for nutrient concentrations. Yield will be determined in August 2006.

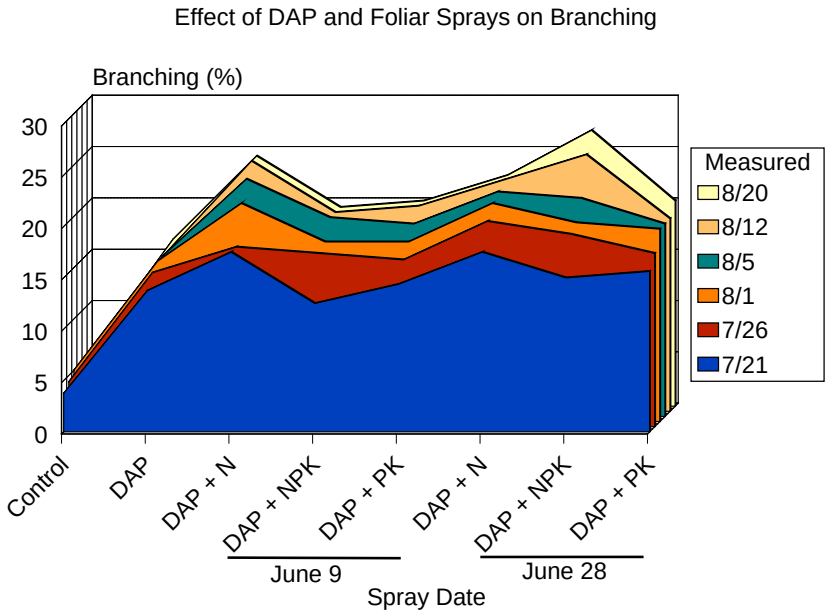
RESULTS:
Branching was increased by DAP and DAP plus foliar sprays of N and NPK compared to the controls (Fig.1). DAP plus PK foliar spray had less of an effect than one which included N.
Leaf tissue samples have not been analyzed at this date.

CONCLUSIONS: No conclusions can be made at this time.

RECOMMENDATIONS: No recommendations can be made at this time.

Figure 1

Summer Foliar Fertilization Study



WEED MANAGEMENT

INVESTIGATORS: David E. Yarborough, Professor of Horticulture
Kerry F. L. Guiseppe, Research Assistant

15. TITLE: Assessment of Hexazinone Alternatives for Weed Control in Wild Blueberries and Field Cover Program Base.

METHODOLOGY: A split block design was established on six wild blueberry fields to obtain a diversity of soil types and weed species. A block was established in the Maine towns of Lamoine, Northport, Union, North Penobscot, T-19, and at Blueberry Hill Farm in Jonesboro. Each 120' x 72' block was comprised of 24' X 36' treatment plots including an untreated control, a pre and post-emergence application of Mesotrione at 6 oz/a and a pre and post-emergence application of Flumioxazin at 12 oz/a. At a right angle a 36' X 120' plot of an untreated control and a hexazinone treatment at 64 oz/a was applied to give a total of ten combinations. Pre-emergence treatments, including the hexazinone treatment were applied May 11 – June 7 and post-emergence treatments were applied June 14-June 22. The unusually persistent rain during May resulted in a delay of pre-emergence applications. A soil sample was taken from the plot at each site and soil texture, OM and pH were determined by the Maine Soil Testing Laboratory at the University of Maine (Table 1). Treatment effects were assessed for blueberry, broadleaf, fern and grass weed cover and wild blueberry phytotoxicity on 27 June and 26 August 2005 from four 1 M^2 subplots within each treatment. A weed species list was made for each site (Table 2).

RESULTS: Blueberry cover was significantly affected by treatment type, which was influenced by the high phytotoxicity found on the postemergence treatments (Figures 1, 2 and 3). All flumioxazin treatments had considerable phytotoxicity, mostly from the postemergence treatments (Photo 1, 2) which also reduced the blueberry cover. In general, post-emergence applications had a much higher phytotoxicity than pre-emergence applications. Grass cover was higher in the untreated control than all treatments at the June evaluation but not the August evaluation. In June, all of the applications reduced grass cover but significant additional suppression was obtained with the addition of hexazinone to the flumioxazin and mesotrione treatments, with the best suppression obtained with the post-emergence application of flumioxazin (Figure 4). The use of hexazinone also significantly reduced the amount of grass and broadleaf weed cover at the June evaluation (Figure 5). Although broadleaf weed cover was initially reduced after pre and postemergence applications in June, except for the preemergence mesotrione application, the cover of postemergence mesotrione was higher than the control at the August evaluation. The addition of hexazinone to both herbicide treatments further reduced the broadleaf cover, though not significantly (Figure 6). Neither flumioxazin nor mesotrione reduced fern cover without hexazinone but the addition of hexazinone to either herbicide treatment reduced fern cover with the exception of the postemergence mesotrione treatment for the August evaluation. The post-emergence flumioxazin application had the lowest fern cover (Figure 7) (Photo 3).

CONCLUSIONS: It is evident that the postemergence applications, although providing some of the best weed suppression had too much phytotoxicity to consider this use, this was especially true for the flumioxazin. These herbicides were evaluated at Blueberry

Hill Farm in Jonesboro last year and no phytotoxicity was seen on blueberry plants with their postemergence treatments. I also noted a delay in the emergence of the blueberry plants at all sites with the preemergence application of flumioxazin but the plants recovered and no effect was seen on the August evaluation. The cold wet weather may have increased the susceptibility of the blueberries to the herbicides. This shows the value of multi-year and multi-site experiments to determine the effects of new herbicides. It also appears that neither flumioxazin nor mesotrione was sufficient to suppress weeds as well as if hexazinone was also added to the application.

RECOMMENDATIONS:

Do a final weed rating and harvest plots to determine if the treatments resulted in improving productivity. Since the value of these herbicides are in increasing the weed suppression when applied with hexazinone I recommend that we establish six new plots at six locations in 2006 with an untreated plot and a preemergence application of flumioxazin at 0.45 and 9 kg/ha, and mesotrione at 222 and 444 ml/ha with hexazinone at 0, 0.5 and 1.0 kg/ha applied at right angles to the flumioxazin and mesotrione treatments to give a combination of fifteen treatments. The 24' X 36' plot size for each treatment was sufficient for an evaluation of weed cover.

Table 1. Soil Texture, OM and pH at the six test sites

Site	**pH**	**Organic Matter (%)**	**Texture**
Union	4.9	9.2	Loam
Northport	5.1	6.2	Loam
Cherryfield	4.9	5.9	Sandy Loam
Blueberry Hill Farm	5.1	5.6	Sandy Loam
Lamoine	4.8	11.6	Loam
Penobscot	4.9	11.8	Loam/Sandy Loam

Table 2. Plant Species List for Pre and Post-Emergence Herbicide Plots, 2005

First Evaluation 27 June
Control
dogbane, wild oat grass, yellow loosestrife, common rush, bluets, bunchberry, honeysuckle, rose bush, vetch, goldenrod, sheep sorrel, yellow cinquefoil
Hexazinone Only
Sedge, vetch, braken fern, goldenrod
Pre-emergence Flumioxazin
Braken fern, wild lettuce, bunchberry, dogbane, vetch, pointed broom sedge, rush, hawkweed, wild oat grass
Hexazinone Velpar Pre-emergence Flumioxazin
Dogbane, honeysuckle, braken fern, vetch, wild oat grass
Post emergence Flumioxazin
Wild oat grass, sedge, sheep sorrel, rose bush, dogbane
Hexazinone Velpar Post-emergence Flumioxazin
Dogbane, sedge, vetch
Pre-emergence Mesotrione
Wild oat grass, yellow loosestrife, yellow hawkweed, dogbane, cherry tree, bluets, vetch, wiregrass rush, rose bush
Hexazinone Velpar Pre-emergence Mesotrione
Dogbane, braken fern, vetch, rose bush, blackberry, yellow loosestrife,
Post-emergence Mesotrione
Dogbane, bunchberry, grass, dying fern, bluets, sheep sorrel, wild oat grass, common rush
Hexazinone Velpar Post-emergence Mesotrione
Dying dogbane, dying fern, dying grass

Second Evaluation 26 August
Control
Queen Anne's lace, wild oat grass, goldenrod, dogbane, bunchberry, quack grass, ragweed, birch, wild lettuce, vetch
Hexazinone Only
Cherry, vetch, dogbane, goldenrod, rose bush, cherry, ragweed
Pre-emergence Flumioxazin
Dogbane, goldenrod, sedge, bunchberry, wild oat grass, quack grass, aster, bracken fern, wild lettuce, birch, meadowsweet, blackberry, ragweed
Hexazinone Pre-emergence Flumioxazin
Ragweed, bracken fern, vetch goldenrod
Post emergence Flumioxazin
Cherry, bunchberry, quack grass, dogbane, vetch, sheep sorrel, rose bush, ragweed
Hexazinone Post-emergence Flumioxazin
Cherry, sheep sorrel, sedge, bunchberry, dogbane, rose bush, raspberry, ragweed, goldenrod
Pre-emergence Mesotrione
Birch, bunchberry, wild oat grass, dogbane, rose bush, vetch, ragweed
Hexazinone Pre-emergence Mesotrione
Asparagus, wild oat grass, cherry, dogbane, vetch, goldenrod, ragweed, raspberry
Post-emergence Mesotrione
Sedge, cherry, ragweed, wild oat grass, dogbane, bunchberry, bracken fern, blackberry
Hexazinone Post-emergence Mesotrione
Cherry, wild oat grass, dogbane, honeysuckle, rush

Figure 1. Blueberry Cover following Pre and Post-Emergence Herbicide Applications

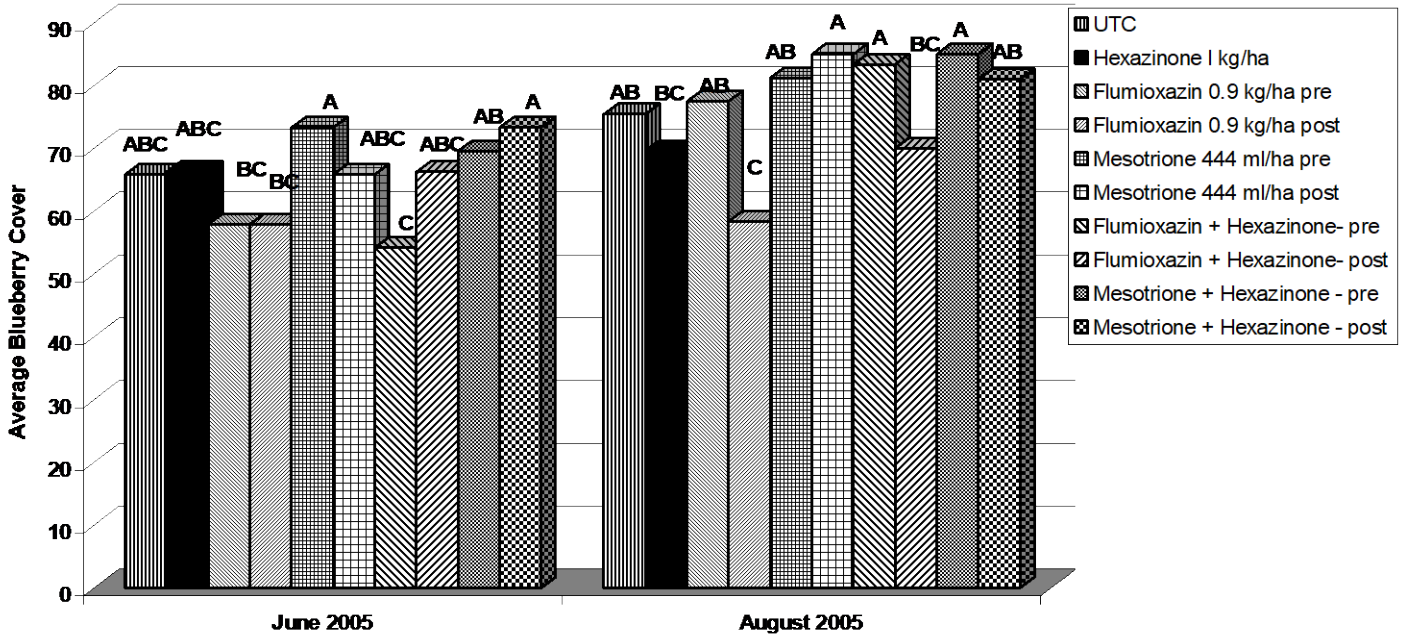


Figure 2. Blueberry Phytotoxicity following Pre and Post-Emergence Herbicide Applications

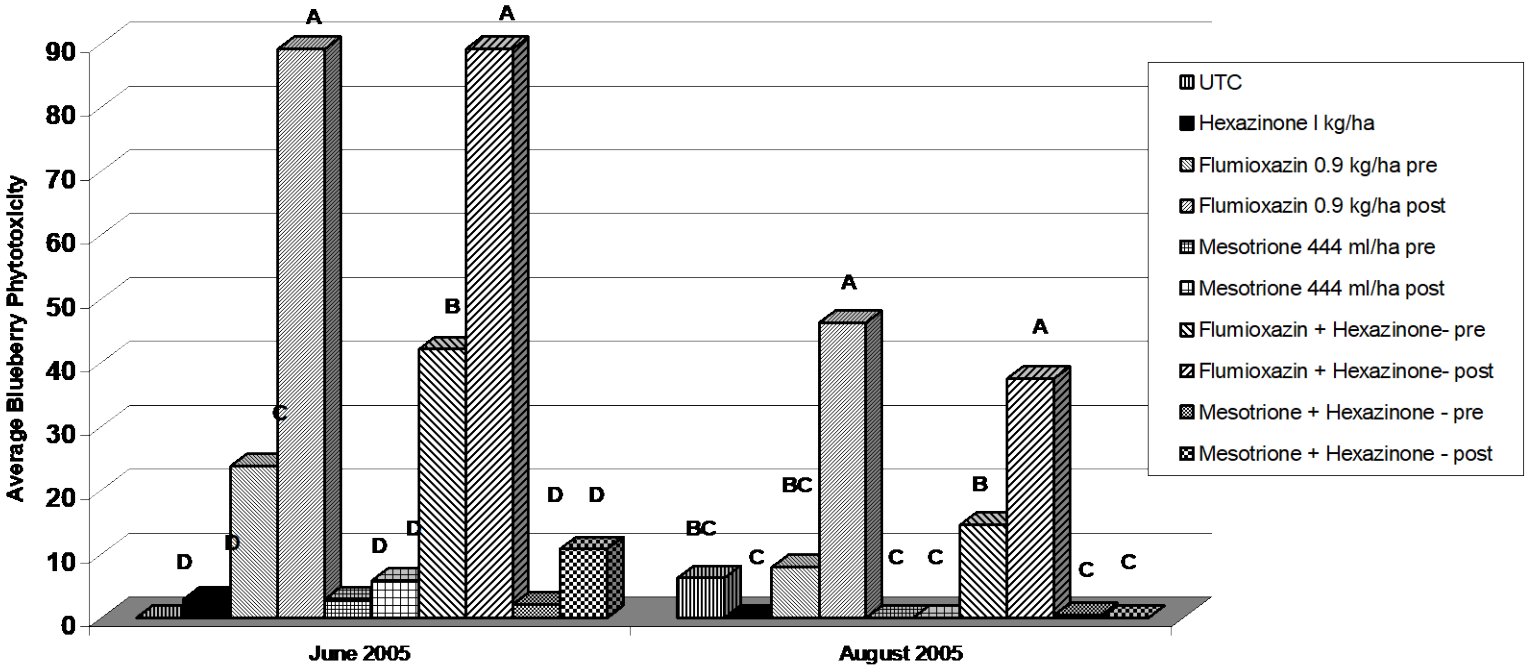


Figure 3. The Effect of Herbicide Type on Blueberry Cover

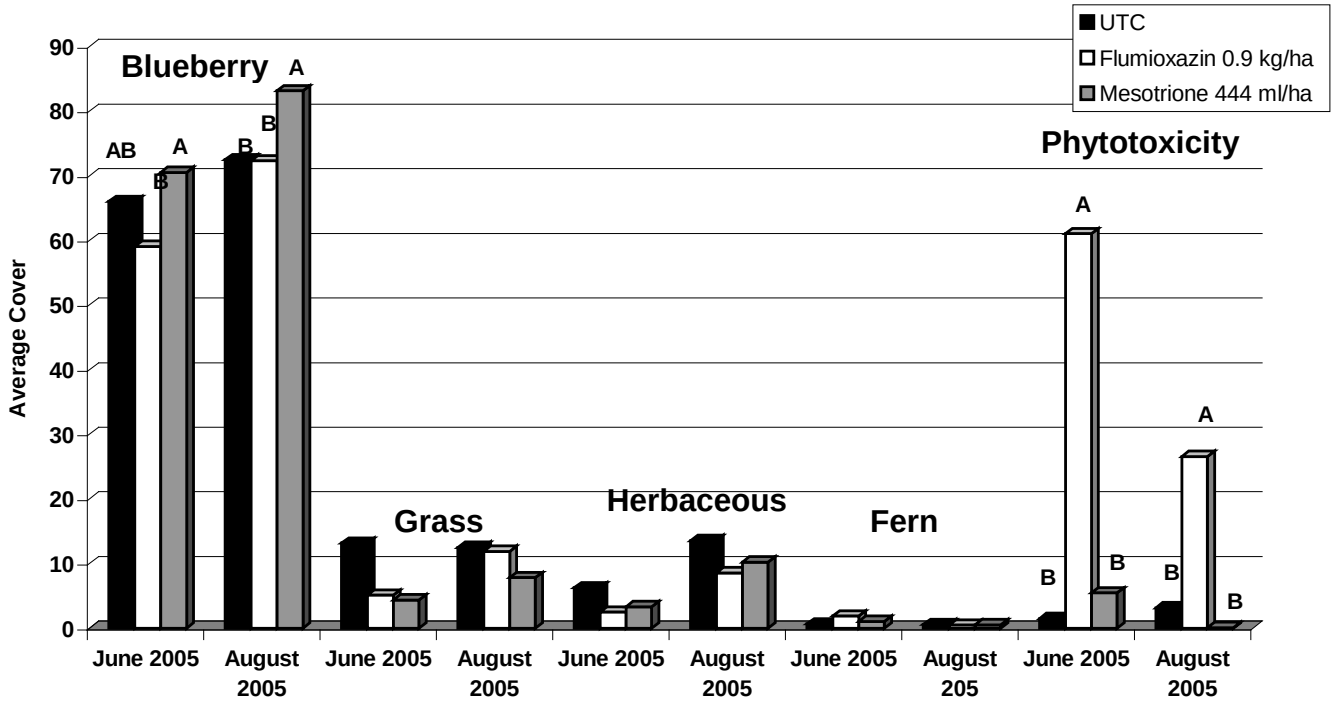


Figure 4. Grass Cover following Pre and Post-emergence Herbicide Applications

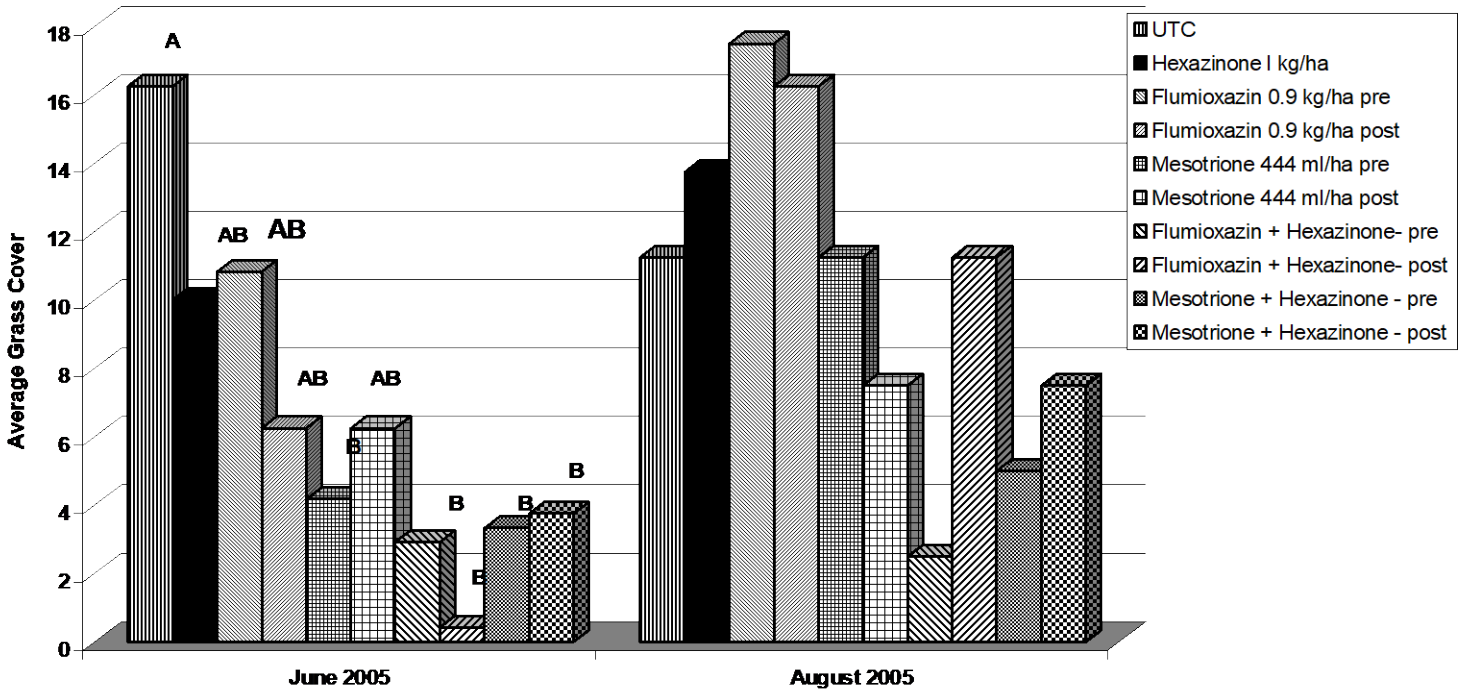


Figure 5. The Effect of Hexazinone on Weed Cover

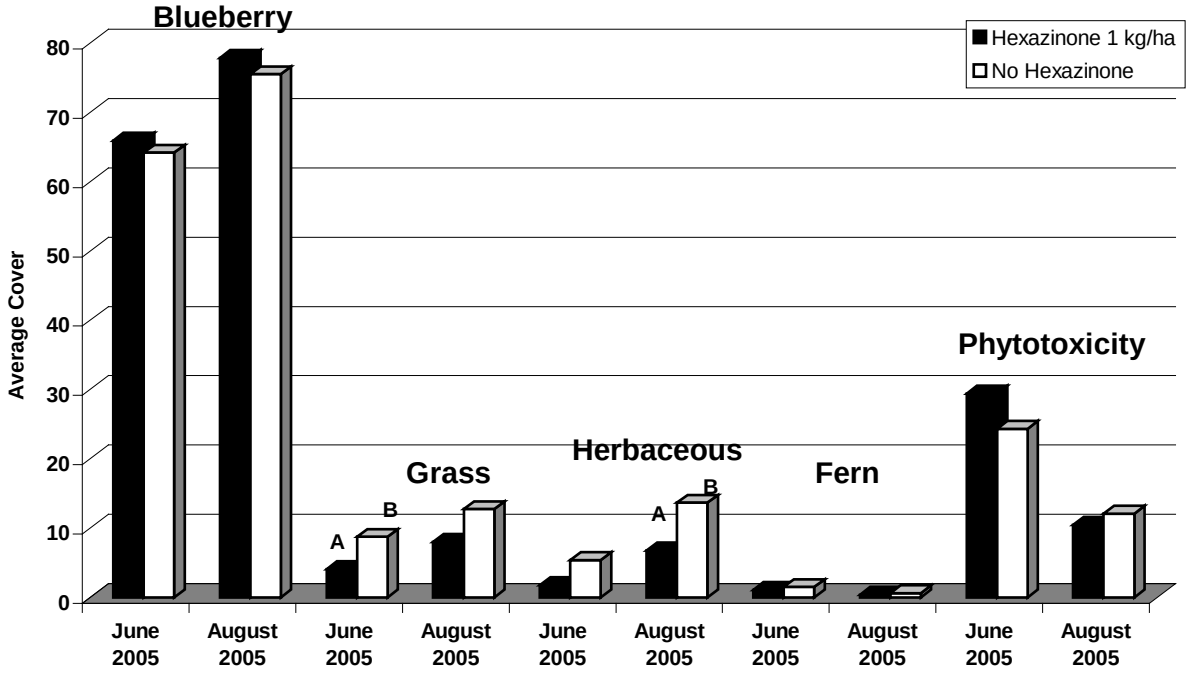


Figure 6. Broadleaf Weed Cover following Pre and Post-emergence Herbicide Applications

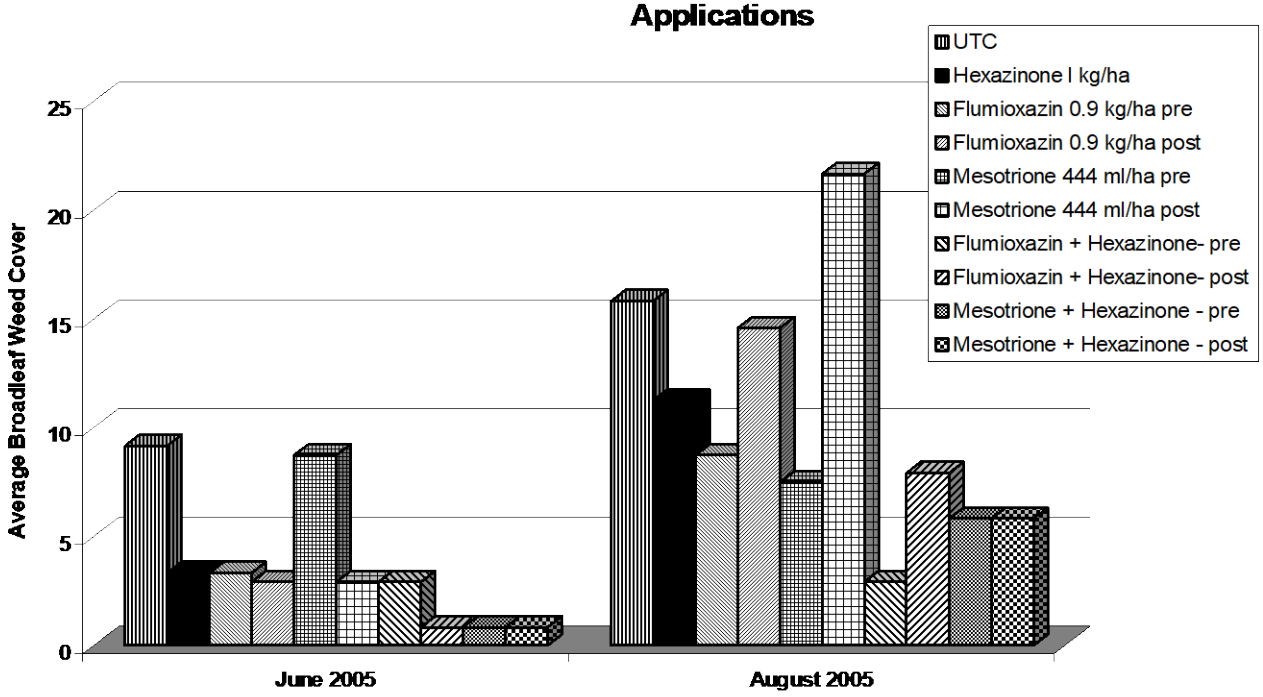


Figure 7. Fern Cover following Pre and Post-emergence Herbicide Applications

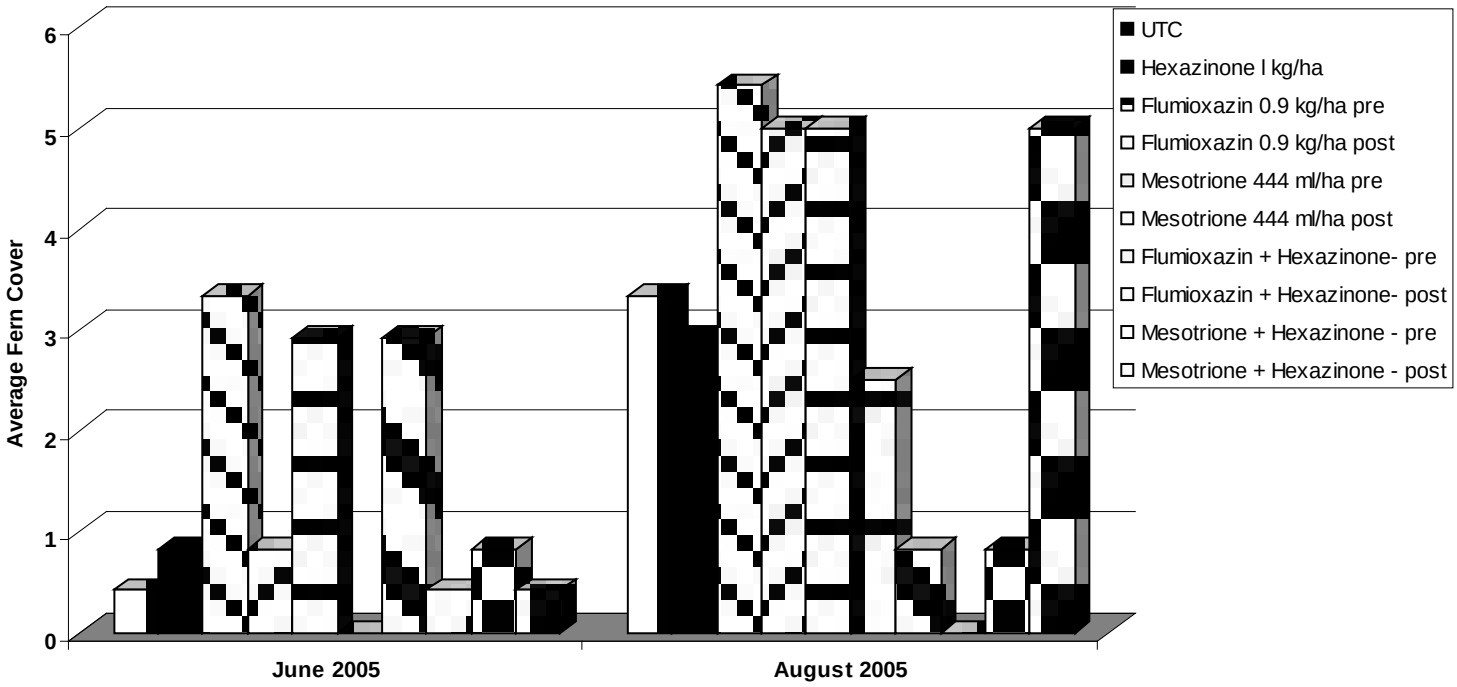


Photo 1. Phytotoxicity on blueberry on Northport site from postemergence application of Flumioxazin.

Photo 2. Phytotoxicity on blueberry and weeds on Union site from postemergence application of Mesotrione.

Photo 3. Lamoine site in August, Check, Hexazinone only, Hexazinone with Pre-emergence Flumioxazin and Hexazinone with Post-emergence Mesotrione (clockwise).

WEED MANAGEMENT

INVESTIGATOR: David E. Yarborough, Professor of Horticulture
Kerry F. L. Guiseppe, Research Assistant

16. TITLE: Evaluation of Fall Applications of Tribenuron Methyl for Bunchberry Control in Wild Blueberries.

METHODOLOGY: In 2004 tribenuron methyl was applied at 0.43 oz ai/a and 0.86 oz ai/a to a non-cropping field on 1 m^2 plots with untreated control plots replicated 10 times at Blueberry Hill Farm. Ten plots of each rate were applied on each of 30 August, 13 September, and 6 October to test the timing of application. Bunchberry, wild blueberry cover, and phytotoxicity of blueberry plants were rated before treatment on 26 August 2004 and post-treatment on 29 June 2005. Phytotoxicity was rated based on necrosis.

RESULTS: There were no significant differences among the treatment plots pre-treatment for bunchberry or blueberry cover. Bunchberry cover was significantly higher in the untreated control than all of the treated plots (Figure 1). In general, treatment plots with higher rate of tribenuron-methyl had lower bunchberry cover than those with the lower rate, though it was only significant for the September-lower rate treatment. Blueberry cover was significantly greater in the October-lower rate treatment than any of the three higher rate treatments (Figure 2). The September-higher rate had the lowest blueberry cover. The phytotoxicity of blueberries was highest in the September-high treatment (Figure 3). The October-low treatment and control had the lowest amount of phytotoxic damage. Damage caused little re-growth or leafing of plants treated in 2004 by the evaluation date in 2005.

CONCLUSIONS: The October-low treatment had best overall effect when taking into consideration the bunchberry, blueberry and phytotoxicity cover. This is likely to do the increasingly dormant state of the blueberry plants, which could decrease the damage form tribenuron methyl to the blueberry plants.

RECOMMENDATIONS:
Continue the experiment another year to validate the treatment effects. Harvest fruit yields to determine any effect on productivity.

Figure 1. Bunchberry Cover after Tribenuron-Methyl Treatments, 2005

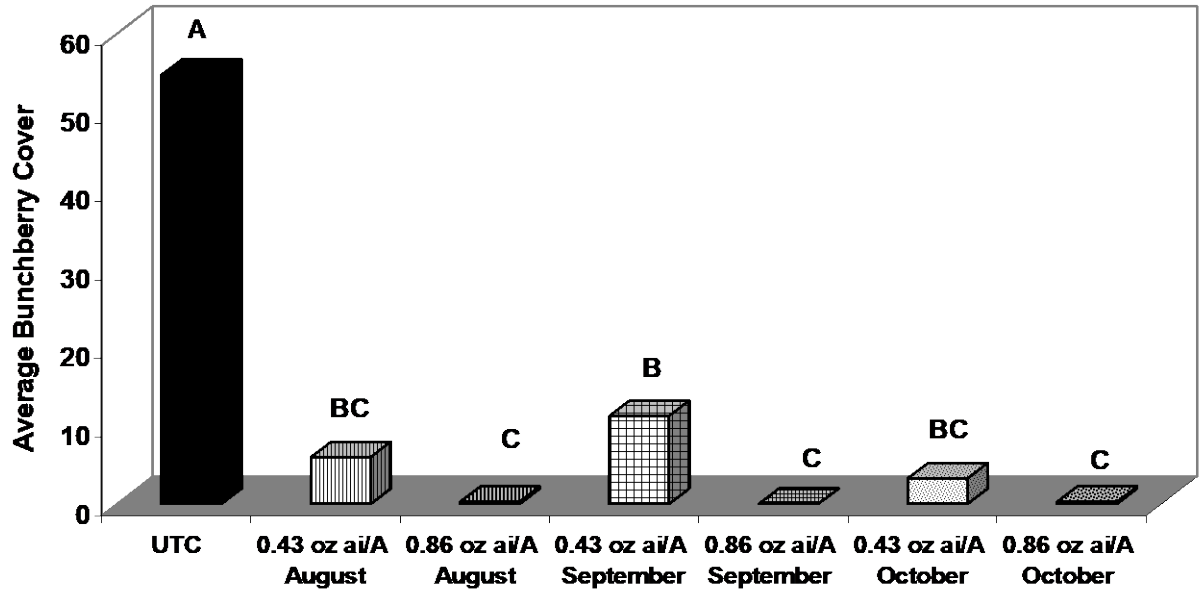


Figure 2. Blueberry Cover after Tribenuron-Methyl Treatments, 2005

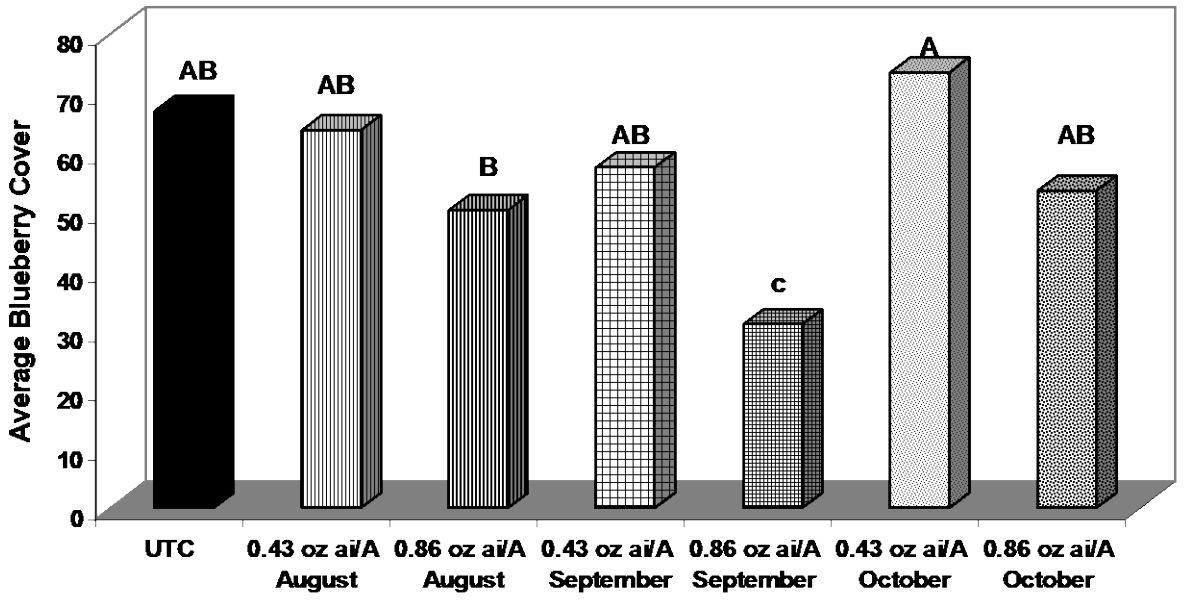
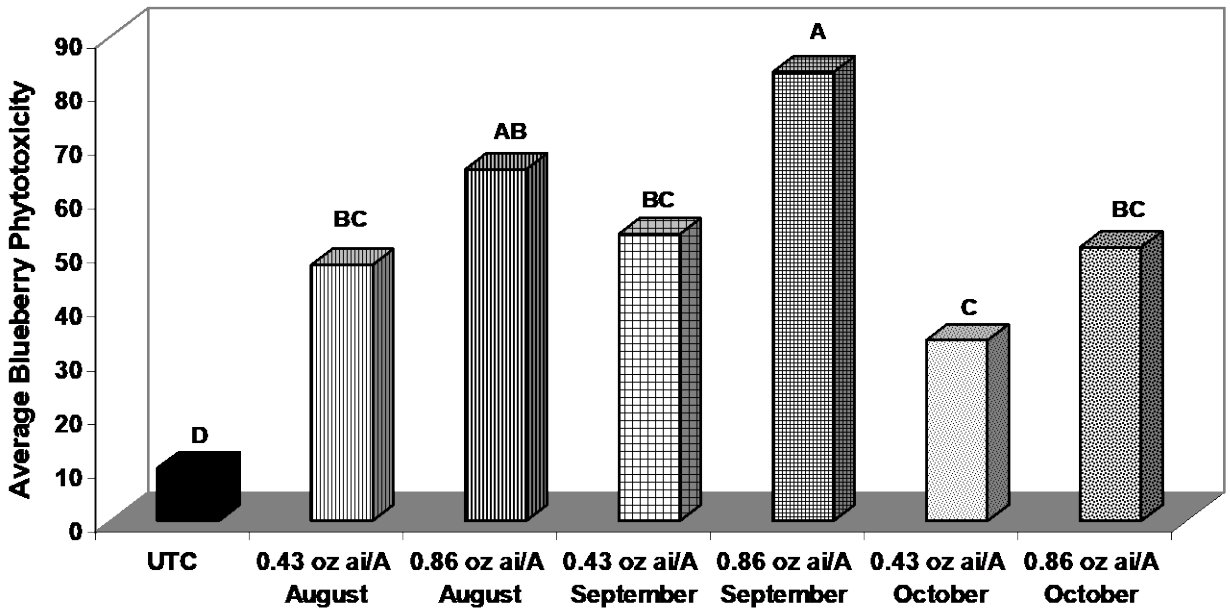


Figure 3. Phytotoxicity of Blueberries after Tribenuron-Methyl Treatments, 2005



WEED MANAGEMENT AND FIELD COVER

INVESTIGATOR: David E. Yarborough, Professor of Horticulture
Kerry F. L. Guiseppe, Research Assistant

17. TITLE: Evaluation of spot treatments of Tribenuron Methyl for weed control in Wild Blueberries.

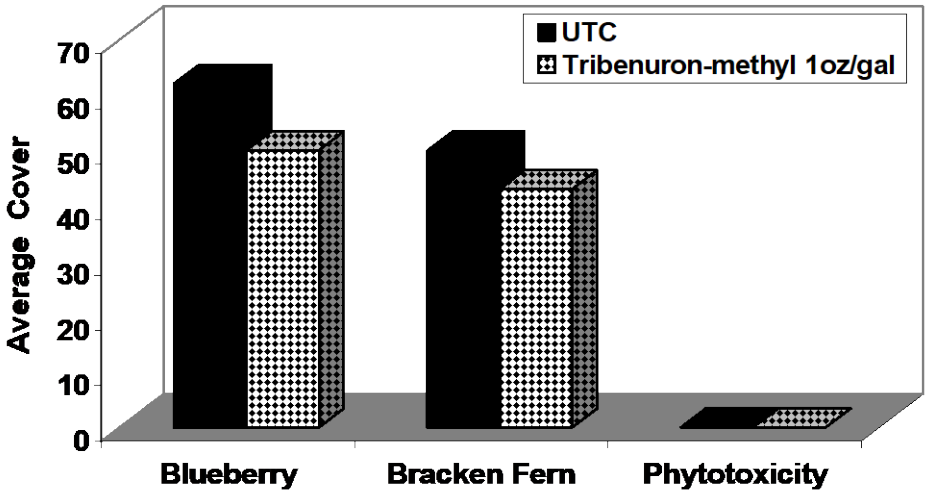
METHODOLOGY: Tribenuron methyl at 1 oz/gal with a surfactant was applied on 18 July 2005 to spot treat 10, 1-meter square plots for bracken fern, yellow loosestrife or purple vetch, on non-cropping fields. An equal number of untreated plots were laid out at each site. A spray bottle was used to apply the herbicide directly to the weed. Bracken fern and purple vetch plots were located at Blueberry Hill Farm and yellow loosestrife plots were treated in Columbia Falls. In Cooper, Ten each of untreated and treated 1-meter square plots, were used to evaluate the efficacy of a rimsulfuron and nicosulfuron mix as Ultim at 2 oz/acre applied on ???? to control bulrush. Efficacy of bulrush control and phytotoxicity to wild blueberries were rated on 7 September 2005.

RESULTS: Though bracken fern cover was reduced after treatment, it was not significantly reduced (Figure 1), nor was there any signs of phytotoxicity observed even though blueberry cover was reduced in the treated plots. Yellow Loosestrife was significantly reduced following treatment with tribenuron methyl (Figure 2, Photo1-2). There were no blueberry plants within the treatment plots because of the thickness of the loosestrife, so there was no phytotoxicity. Purple vetch was significantly reduced following treatment, but like the bracken fern, there were no signs of phytotoxicity even though the blueberry cover slightly declined (Figure 3). Finally, bulrush was reduced following treatment and no phytotoxicity to blueberries was observed because no blueberry plants were present in the plots (Figure 4, Photo 3-4).

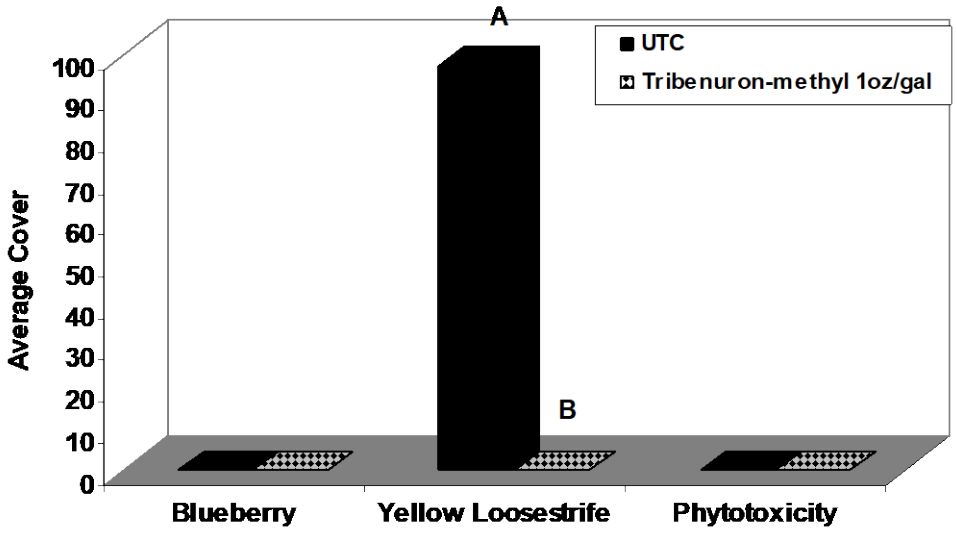
CONCLUSIONS: Spot treatments of tribenuron-methyl have the potential to suppress yellow loosestrife and purple vetch with out injury to blueberries.

RECOMMENDATIONS: Repeat tribenuron methyl experiment this year to obtain data on more sites to confirm results. Discontinue the Ultim bulrush treatments.

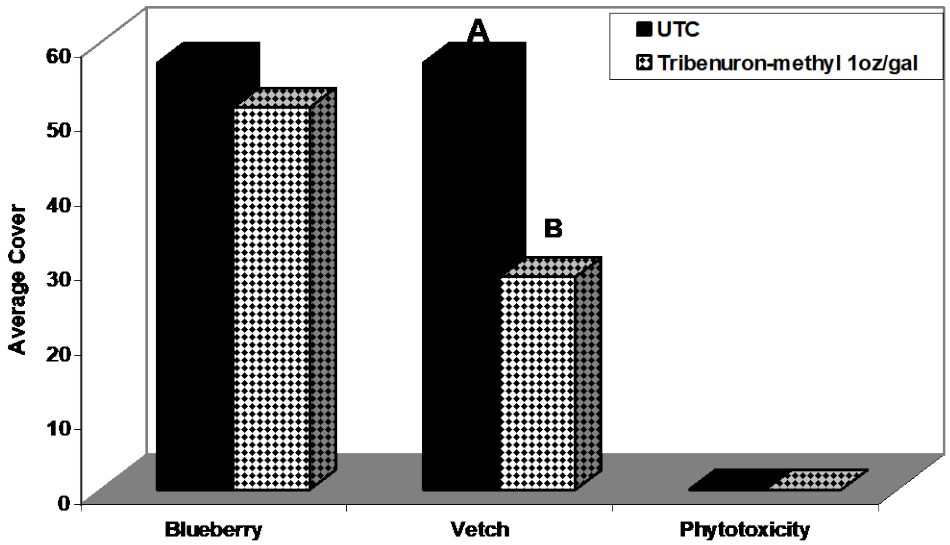
Fern Cover following Spot-Treatment with Tribenuron-methyl, 2005



Yellow Loosestrife Cover following Spot-Treatment with Tribenuron-methyl, 2005



Purple Vetch Cover following Spot-Treatment with Tribenuron-methyl, 2005



Bullrush Cover after Spot-Treatment with rimsulfuron, 2005

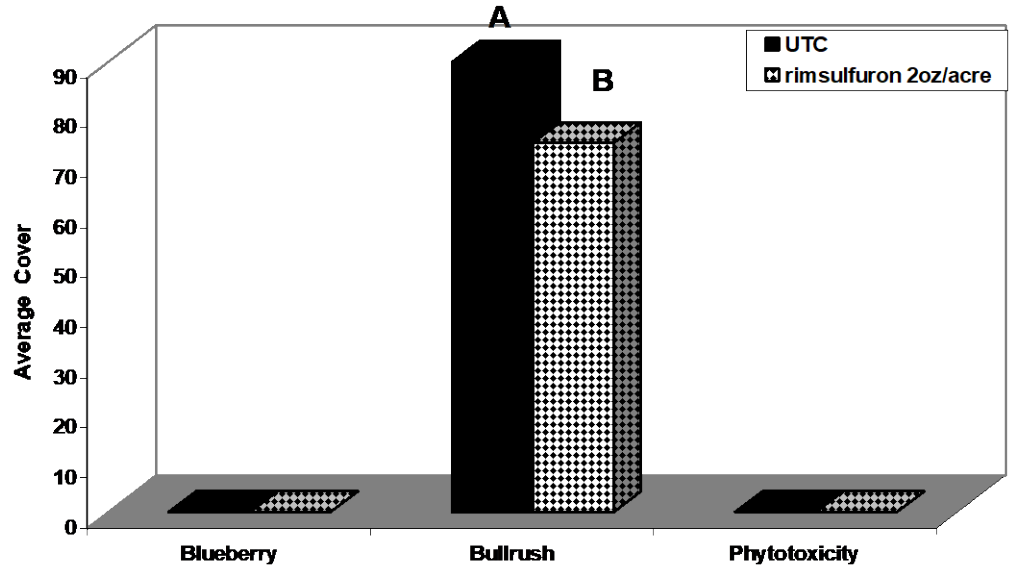


Photo 1. Untreated Yellow Loosestrife

Photo 2. Yellow Loosestrife treated with Tribenuron-methyl

Photo 3. Untreated Bulrush

Photo 4. Bulrush treated with rimsulfuron

WEED MANAGEMENT AND FIELD COVER

INVESTIGATOR: David E. Yarborough, Professor of Horticulture

18. TITLE: Evaluation and Demonstration of Techniques for Filling in Bare Spots in Wild Blueberry Fields.

METHODS: Tissue culture wild blueberry plants were planted at a 1 foot spacing and mulched with three inches of bark. In 2000, in Aroostook County, one 40' x 40' plot was planted in an old potato field in Caribou and 2 lb/a Velpar and 1000 lb/a sulfur was added because the pH was 5.5. Another Aroostook site was established in Hamlin, in a field owned by Rene LeVasseur that had wild blueberry plants coming in naturally and so provided a good demonstration site. Soil analysis of the Hamlin site showed a pH of 4.7 and a sandy loam texture, both of which are suitable for blueberry growth. A 40' x 120' area in the field was mowed, Velpar applied at 2 lb/a and bark mulch spread at a depth of 3" in an 80' x 40' area. Blueberry plants were put in at 1' spacing over a 40' x 40' area. This site will serve as a demonstration on the feasibility of growing blueberry plants in Aroostook. For comparison purposes, plants were inter-planted in bare spots among the established clones at Blueberry Hill Farm, and at Guptill Farm by their wild blueberry freezer building in Wesley. In Wesley a 30'x30' plot with plants at a 1'x1' spacing was established by the freezer. In 2002 the Hamlin and Jonesboro locations were treated with 1 lb/a Velpar and the Wesley location received 10 lb/a Pronone. In 2003 the Hamlin location was treated with 1 lb/a Velpar and the Wesley location was weeded by hand in the 1'x1' area of the blueberry plant.

Wild blueberry plant survival and spread from 10, 1-foot square subplots in each area were measured using cover scale ratings taken each year in the summer of 2001 through 2005. The rating represents the mean cover plants spread in a one-foot square plot.

RESULTS:

All sites increased in cover in 2005 but Jonesboro was the only site that increased substantially (Figure 1). The Pronone application from 2002 continued to kill blueberries in Wesley so the mortality was at 60% compared to 30% in Hamlin and 20% in Jonesboro. Mortality in Wesley was 50%, but was only 10% in Hamlin and 20% in Jonesboro. Weed pressure was excessive in Wesley because of the lack of herbicide (Figure 2) but spread was good on plants that survived (Figure 3). Hamlin increased in spread with the Velpar + Sinbar application applied in the spring or 2005 (Figure 4). Although it was slow to start Jonesboro it now has best growth and spread of plants because it had the least weed pressure and most sandy soil; there was less spread in Hamlin because of previous weed pressure and a heavier soil (Figure 5).

CONCLUSION: Effective weed control at Hamlin and Wesley are needed to continue the increases in blueberry cover. Although the Jonesboro site had a slow start it has the least mortality and best spread in year four and five.

RECOMMENDATIONS: Continue with the project for one more year, maintaining weed control for next year, and continue the final evaluation of cover. I use these sites to demonstrate feasibility of inter-planting tissue culture wild blueberry plants.

Figure 1.

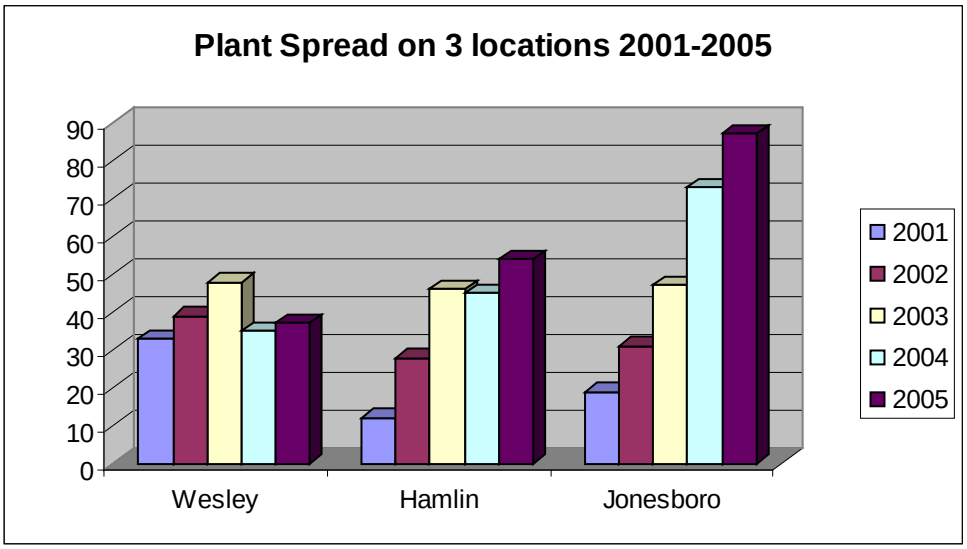


Figure 2. Excessive weed growth without herbicide application on heavier soils in Wesley.

Figure 3. Wesley high mortality at 60% from application of Pronone herbicide in 2003 but good growth on surviving plants.

Figure 4. Weed control at Hamlin site.

Figure 5. Jonesboro and Hamlin plant spread.

WEED MANAGEMENT AND FIELD COVER

INVESTIGATOR: David E. Yarborough, Professor of Horticulture
Kerry F. L. Guiseppe, Research Assistant

TITLE: Assessment of Evitol and Kerb for Sedge Control in Wild Blueberries.

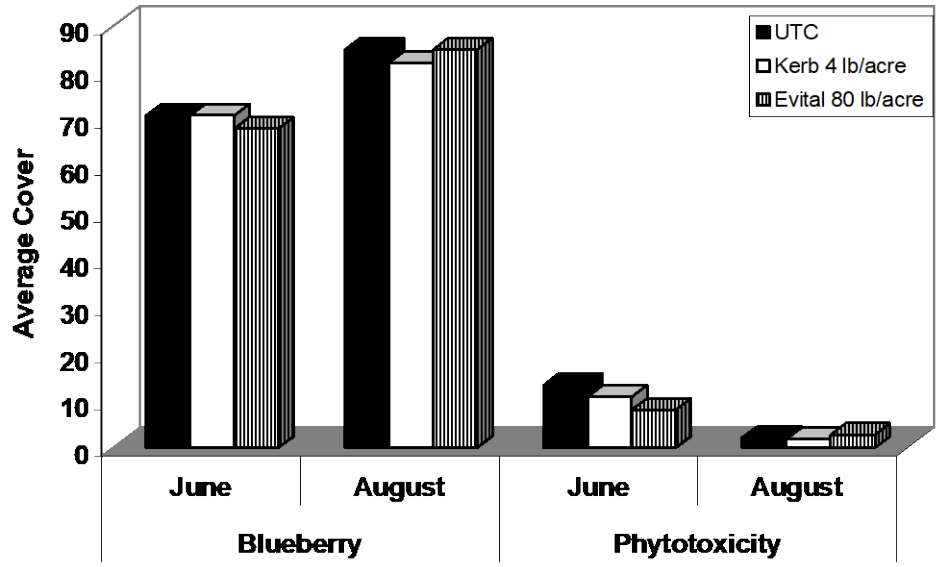
METHODOLOGY: A completely randomized block design was used to assess the effectiveness of Evitol and Kerb in grass and sedge control. Treatments included an untreated control, Evitol 80lb/a, and Kerb 4 lb/a. Plot sized varied between Evitol and Kerb treatments because a Gandy spreader was used to apply Evitol in plots 3.5' x 30' and Kerb was applied using a CO_2 propelled boom sprayer on 6' x 30' plots. The Evitol was applied on 1 November 2004 and the Kerb treatment was applied 4 November 2004. Treatments were not applied in the Spring 2004 as originally intended because of concerns of blueberry damage. Blueberry, grass and sedge cover as well as phytotoxicity was evaluated on 29 June and 2 August 2005. Phytotoxicity was rated as any apparent lack of re-growth from mowing the previous year or stunting.

RESULTS: Blueberry cover was not significantly affected by any of the treatments, nor was there much phytotoxicity (Figure 1). The observed phytotoxicity in the control treatments may be a result of winter damage or delay in re-growth from mowing in Fall 2004. The evital treatment had similar grass and sedge weed cover as the untreated control, but the kerb treatment had a higher cover rate, which could be a result of a release of sedge from competition with other weeds (Figure 2).

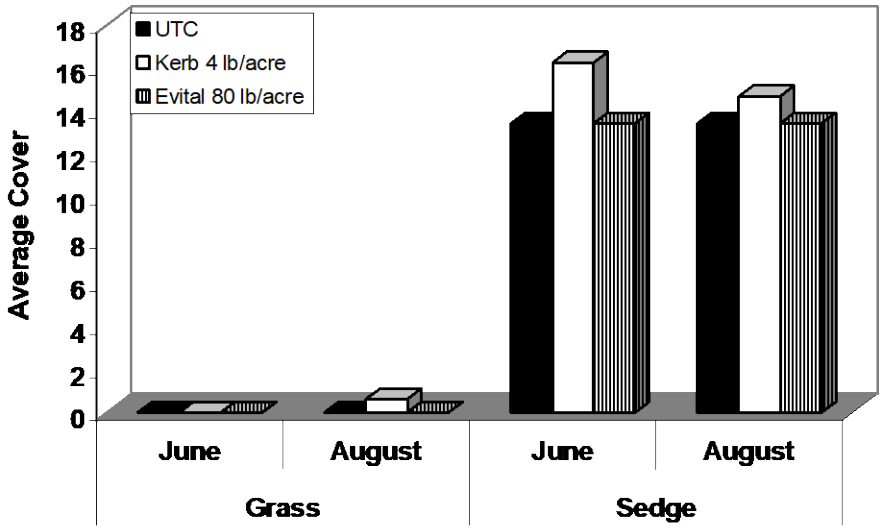
CONCLUSIONS: Evitol and Kerb were ineffective in suppressing the sedge growth.

RECOMMENDATIONS: Discontinue evaluation of these herbicides.

Blueberry Cover and Phytotoxicity after Fall Herbicide Treatment 2004-2005



Grass and Sedge Cover after Fall Herbicide Treatment, 2004-2005



EXTENSION
INVESTIGATOR: David E. Yarborough, Extension blueberry Specialist

20. TITLE: Wild Blueberry Extension Education Program in 2005

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 blueberry newsletters, fact sheets in the wild blueberry grower's guide both in print form and on the web at www.wildblueberries.maine.edu , telephone and correspondence, and conduct field visits as appropriate. Cooperate with County Educators and provide support for blueberry initiatives requested by the County office. Cooperate with the Blueberry Research Advisory Committee, 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, Board of Pesticides Control) and federal agencies (USDA, IR-4) on blueberry related matters. Needs are determined from Blueberry Advisory Committee long-range plan, Wild Blueberry Newsletter survey, 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 the need for blueberry quality and groundwater concerns.

RESULTS:

Educational Activities:
This year the Blueberry Integrated Crop Management program consisted of field demonstration sessions conducted three times in three counties. Program requirements have been better defined over the past years, new fact sheets have been developed and better examples have been provided, such as weed mapping and explanation of decision making for blight control and perimeter spraying of insecticides for blueberry maggot fly control.

Professional Improvement Activities:
Delivered the following talks at Professional Meetings:

Yarborough D.E. and K. Lough. 2005. Evaluation of pre and postemergence herbicides for Wild Blueberries in Maine. Northeastern Weed Science Society 59th Annual Meeting, Washington, DC. January 3-6, 2005.

Weed Management Principles and Bare Spots in Wild Blueberry fields and Wild Blueberry Pollination at Wild Blueberry Short Course in Truro, NS on February 1-3, 2005.

Wild Blueberry Technical Assistance Curriculum. 2005 National Extension Risk Management Education Conference. Kansas City, MO, April 5-7, 2005.

Lowbush Blueberry Production Costs and Returns and Lowbush Blueberry Production Trends. Great Lakes EXPO – Mapping Your Route to the Future, Grand Rapids MI, December 9, 2004.

Grower meetings:

Wild Blueberry Spring Grower Meetings: Waldoboro, March 16; Ellsworth, March 17;

Machias, March 19, 2005.

Blueberry Hill Farm Annual Field Day on July 20, 2005.

Lowbush Blueberry Production Costs and Returns. Great Lakes EXPO – Mapping Your Route to the Future, Grand Rapids Michigan, December 9, 2004.

Lowbush Blueberry Production Trends. Great Lakes EXPO – Mapping Your Route to the Future, Grand Rapids Michigan, December 9, 2004.

ICM sessions:

2005 Wild Blueberry Pest Management. Augusta Trade Show, Augusta, ME. January 13, 2005.

Wild Blueberry Pesticide Applicator Training. University of Maine, Machias, ME, March 19, 2005.

ICM field training sessions: *Knox/Lincoln Counties:* May 3, May 31 and June 28;

Washington County: May 5, June 1 and June 29; *Hancock County:* May 4, June 2 and

June 30, 2005.

Extension Presentations:

Taming the Wild Blueberry and Upland Cranberry Production for LCH110 Horticultural Science class at UMaine, March 18, 2005.

Stinger herbicide for weed control in cranberries, Cranberry Growers meeting, Cherryfield, April 12, 2005.

2005 Wild Blueberry Crop, Bar Harbor Health Summit, August 12, 2005.
Wild Blueberry Production Trends and Taming the Wild Blueberry at Machias Blueberry Festival, August 18-21, 2005.

Explained Maine wild blueberry production to hundreds of attendants of the Big E Agricultural Fair in Springfield, MA on September 30- October 1 & 2, 2005.

Publications:

Strik, B.C. and D.E. Yarborough. 2005. Blueberry Production Trends in North America-1992 to 2003 & Predictions for Growth. HortTechnology 15(2) 391-398.

Yarborough D.E. and K. Lough. 2005. Evaluation of pre and postemergence herbicides for Wild Blueberries in Maine. Proceedings of the Northeastern Weed Science Society 59:63-64.

Yarborough, D. 2005. Blueberry Pruning and Pollination in The Blueberry, N.F. Childers, Ed. Dr. Norman F. Childers Publications, Gainsville, FL (in press).

Smagula, J and Yarborough, D. 2005. The Lowbush Blueberry in The Blueberry, N.F. Childers, Ed. Dr. Norman F. Childers Publications, Gainsville, FL (in press).

Perkins, B. L., D. Yarborough, K. Guthrie, and R. Bushway. 2006. Detection of Hexazinone in Maine's Groundwater- A Nine Year Study. Acta Horticulturae (in press), MAFES 2708.

Starr, G. C. and D. E. Yarborough. 2006. Influence of Vapor Deposition on Wild Blueberry Water Requirements in a Humid Coastal Climate. Acta Horticulturae (in press), MAFES 2706.

Yarborough, D. E. 2006. Innovations in Weed Management in Wild Blueberry Fields in Maine. Acta Horticulturae (in press), MAFES 2701.

Web Publications:
Yarborough, D.E. 2005. Wild Blueberry Technical Assistance Curriculum Program. National Extension Risk Management Education Library.
http://www.agrisk.umn.edu/Conf05/uploads/DYarborough02.ppt

Yarborough, D.E. 2004. Lowbush Blueberry Production Costs and Returns. Great Lakes EXPO – Mapping Your Route to the Future. Blueberries – Maintaining a competitive advantage I. http://www.glexpo.com/abstracts/2004abstracts/blueberryI.pdf

Yarborough, D.E. 2004.Lowbush Blueberry Production Trends. Great Lakes EXPO – Mapping Your Route to the Future. Blueberries – Maintaining a competitive advantage II. http://www.glexpo.com/abstracts/2004abstracts/blueberryII.pdf

Television/radio/newspaper Interviews 2005:

The number of sources and multiple contacts are to illustrate that I am regarded as a reliable source in the media and that this interaction gives exposure and credibility to the University of Maine as a good, unbiased source of information.

Bangor Daily: September 19, October 4, January 26
Bangor Daily: December 1
Boston Globe: June 10, November 21, 24

CBC Radio: August 26
Ellsworth American: November 24, January 14, 22, March 22
Fortune Small Business Magazine: March 5
Maine Public Radio: July 24
NewsinMaine.com: December 20
New York Times: January 13
Portland Press Herald: July 17, August 27
Quoddy Times: July 30, November 10, 25, December 10
Successful Farming Agriculture Online: May 24
Time -Warner: August 23
Village Soup: November 20

Public testimony

Public testimony Maine Board of Pesticides Control, Augusta, ME: April 15, 2005 and December 17, 2004.

Other program activities:

I am the principle investigator for USDA/CSREES *Wild Blueberry Production and Processing Technologies*, which provides funds for all aspects of wild blueberry production. I am responsible for obtaining, compiling and producing the proposals and reports both on paper and providing summaries for the Current Research Information System database on line.

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 projects. 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.

Since 1997, I have petitioned the Board of Pesticides Control each year to request a Section 18 for the use of the fungicide Orbit for the control of mummy berry disease in wild blueberry fields in Maine. I developed the original petition and continue to update it each year.

I report on the wild blueberry crop to the New England Agricultural Statistics Service (NAAS) on a weekly basis during the wild blueberry-growing season. NAAS uses the information to provide updates on the web for the wild blueberry crop for all that are interested.

I serve on the peer review committee for Cooperative Extension, the Department of Plant Soil and Environmental Sciences and the joint peer review committees of Renae Moran & Mark Hutton. These review activicties take four weeks a year.

I served as the chair of the committee to hire the Blueberry Hill Farm Manager Jeffery Brann in 2004-2005.

I serve on the graduate committees of:

Qian Wang MS Student Major Advisor J. Smagula 2004 – present
Theresa Thornton MS Student Major Advisor L. Osher 2004 – present
Kirsten McGovern MS student Major Advisor S. Annis 2005 - present

Wild Blueberry Fact Sheets - 2005

Revised
Fact Sheet #209 (UMCE #2001) 2005 Insect Control Guide for Wild Blueberries
Fact Sheet #239 (UMCE #2025) 2005 Weed Control Guide for Wild Blueberries
Fact Sheet #219 (UMCE #2000) 2005 Disease Control Guide for Wild Blueberries
Fact Sheet #227 (UMCE #2253) Sources of Lowbush Blueberry Plants

Added on web site
2005 Agrichemical and Fertilizer Suppliers in Maine
Sources of Rakes and Harvesters
Source for Phercon AM Baited Trap

CONCLUSION: Growers are participating in IPM programs in the four primary 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 in calibration, reducing the rate of hexazinone used, being able to control blight, identifying and controlling weeds, being able to detect and control insects and the blueberry maggot fly and that they used soil and leaf samples to determine fertilizer rates. Adoption of these management practices will enable growers to improve the efficiency of blueberry culture by reducing unnecessary pesticides and fertilizers.

The hexazinone groundwater survey I have conducted from 1992 through 2004 provides information on the movement of this herbicide into the groundwater that is used at ICM meetings. This information has been used by the Department of Agriculture in both developing and in updating Best Management Practices and by the Board of Pesticides control in deciding to continue use of hexazinone in Maine. The most recent survey conducted form the newsletter mailing list indicates that grower's 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.

RECOMMENDATIONS: Continue to support Extension educational program.

EXTENSION INVESTIGATOR: David E. Yarborough, Extension Blueberry Specialist
Kerry F. L. Guiseppe, Research Assistant

21. TITLE: Cultural Weed Management Using pH.

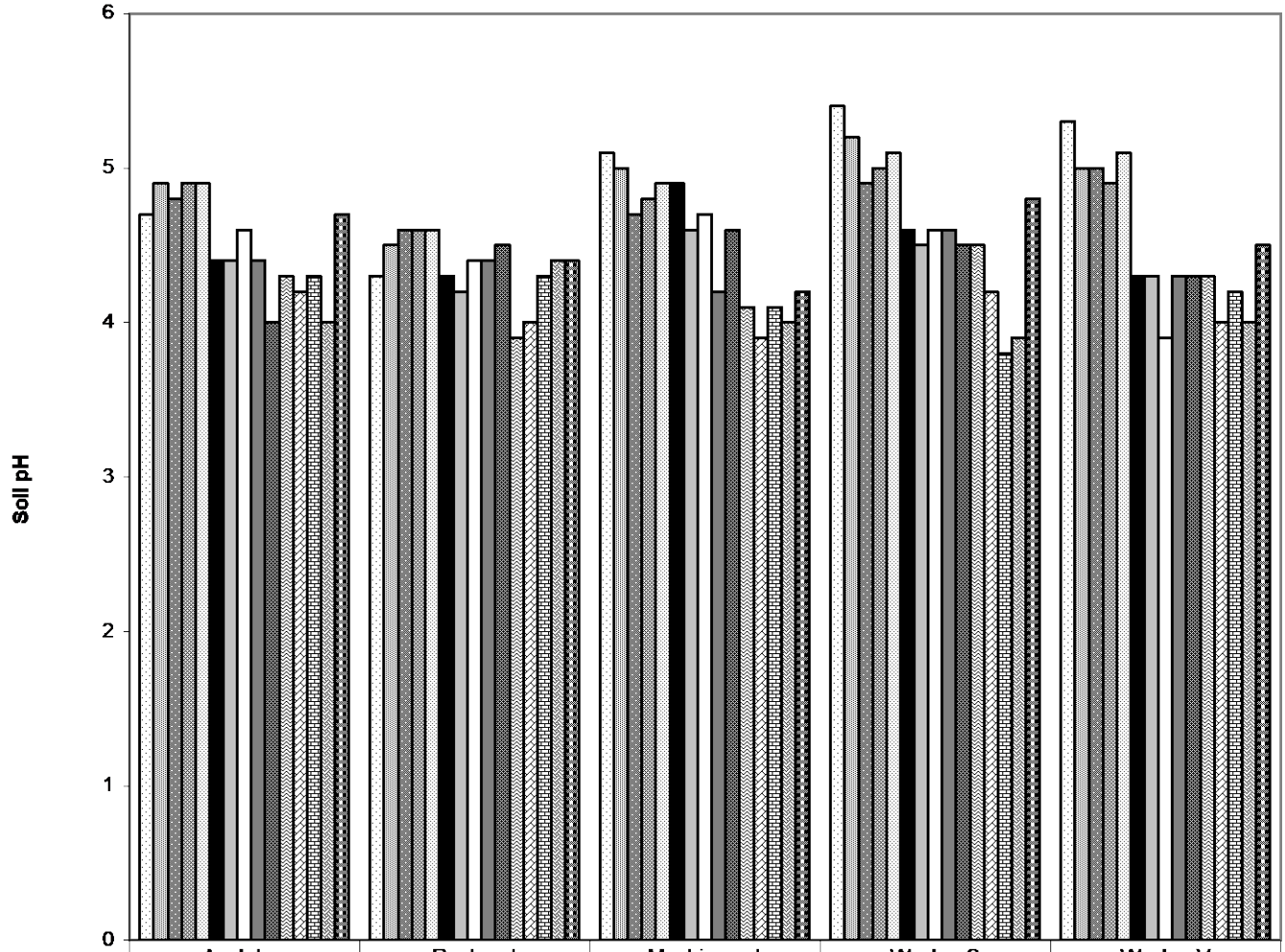
METHODOLOGY: Six sites were established in 2000 in Appleton, W. Rockport, Machiasport, Whiting and Wesley (2), four sites were established in 2001 in Union, Jonesboro and Wesley (2) and treated with either 0, 0.5, 1 or 2 lb ai/a Velpar® (except for Sinbar® on two sites) and with sulfur at 0, 500 or 1,000 lbs/a. Three more sites were established in 2003 at Eastbrook, Franklin and Blue Hill and were half treated with 0, 0.5, 1 or 2 lb ai/a Velpar® and half treated with 0, 0.5, 1, or 2 lb ai/a Sinbar®. The Eastbrook site was not treated with herbicide because the owner was carrying it over from the year before. The Blue Hill site was treated by the owner with 1 lb/a Velpar over all of the plots.

Sites established in 2001 and 2003 were treated with 0, 0.5, 1 or 2 lbs Velpar® or Sinbar®. These sites were evaluated in 28-29 July for weed cover density. Soil samples were taken in each sulfur plot to determine the extent of pH change. The Whiting site was discontinued in 2002.

RESULTS: Soil pH varied by site and year treated. There were some small increases of pH at several sites, ranging from 0.1 to 0.9, but overall the increases were very small, around 0.1. For plots treated in 2000 (Figure 1), pH levels ranged from 4.6 – 5.1 for 0lbs/acre of sulfur, 4 – 4.6 for 500 lbs/acre, and 4.2 – 4.8 for 1000 lbs/acre. For plots treated in 2001 (Figure 2), pH levels ranged from 4.7 – 5 for 0 lbs/acre, 4.2 – 4.7 for 500 lbs/acre and 2.6 – 4.6 for 1000 lbs/acre. For plots treated in 2003 (Figure 4), pH levels ranged from 4.4 – 5.1 for 0 lbs/acre, 3.9 – 4.7 for 500 lbs/acre, and 4.1-4.4 for 1000 lbs/acre. Herbicide type and rate did not have any significant effects on blueberry, grass, fern, broadleaf or woody weed cover. Sulfur rate did significantly affect grass and fern cover (figure 4).

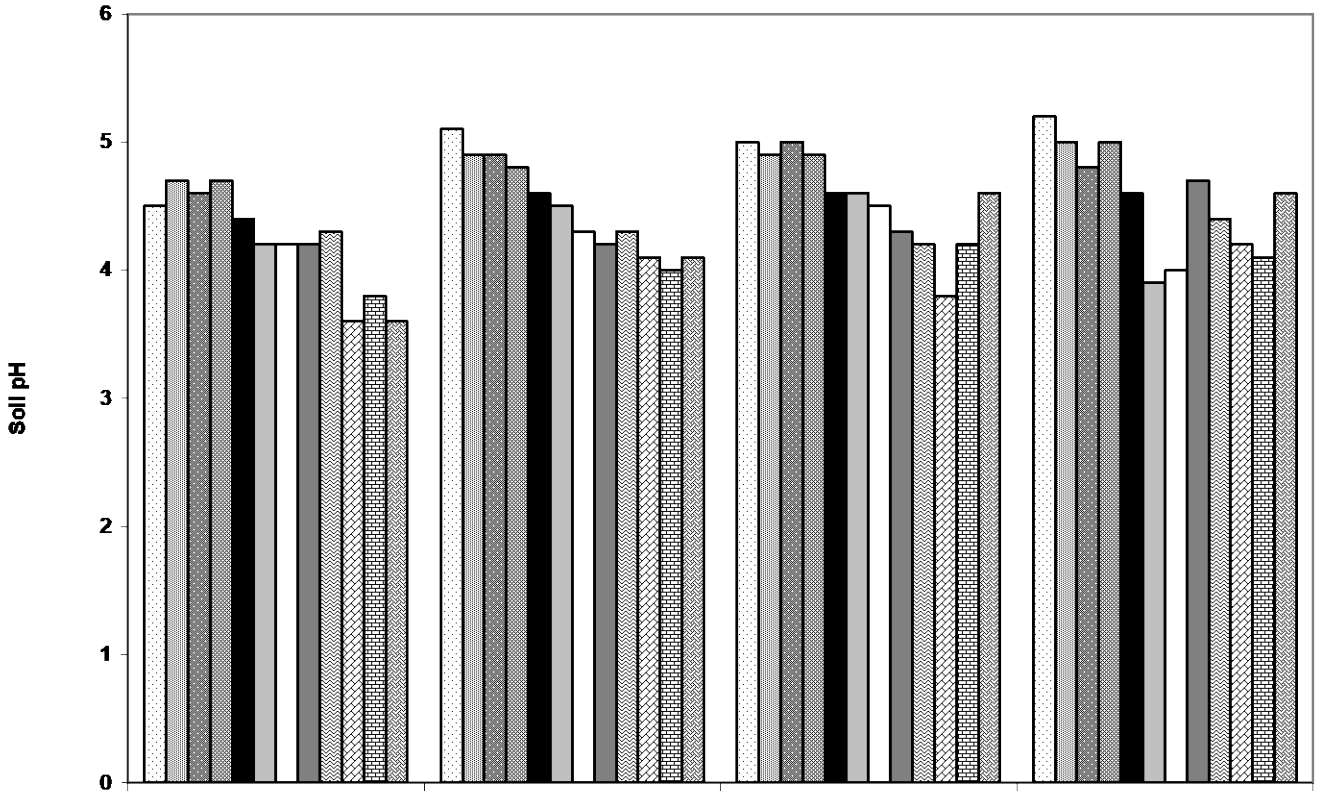
CONCLUSIONS : Continue project through Summer 2006.

Figure 1. Effect of Sulfur Treatments on pH in Blueberry Fields. Treated 2000.



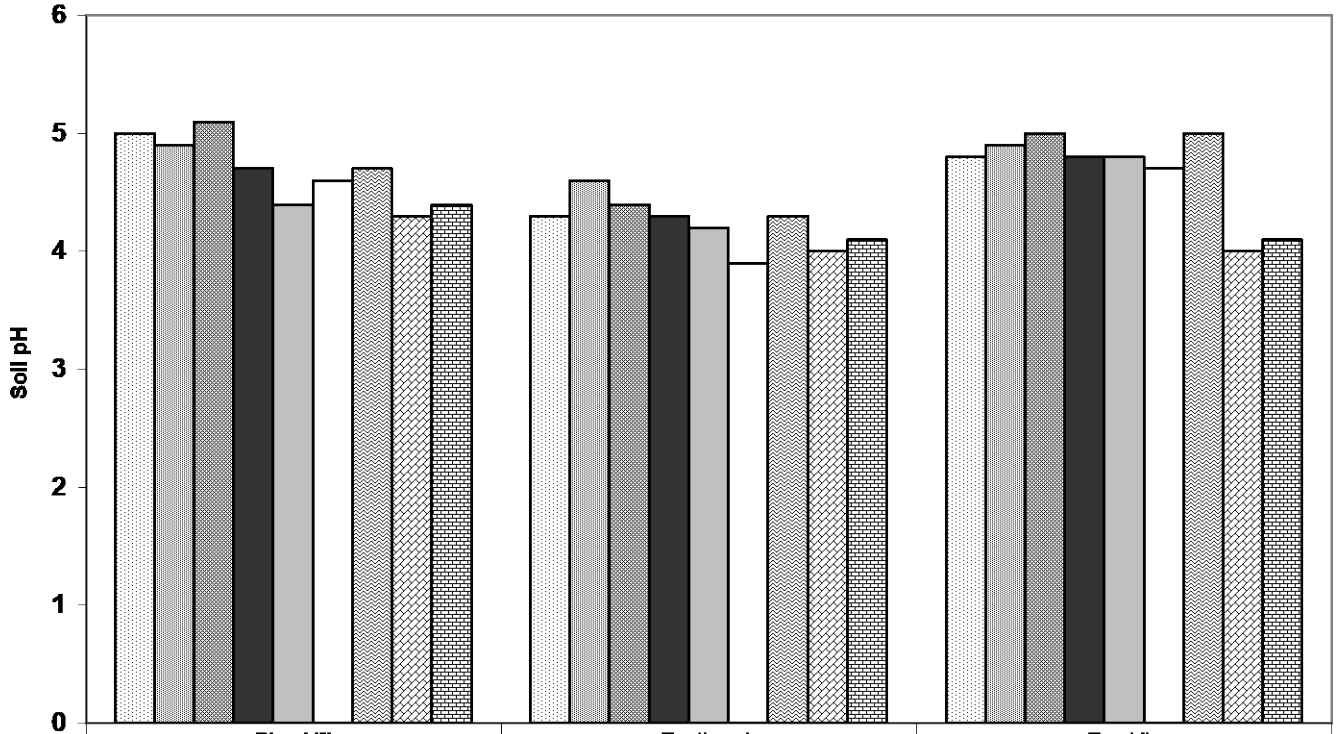
	Appleton	Rockport	Machiasport	Wesley-S	Wesley-V
0S-01	4.7	4.3	5.1	5.4	5.3
0S-02	4.9	4.5	5	5.2	5
0S-03	4.8	4.6	4.7	4.9	5
0S-04	4.9	4.6	4.8	5	4.9
0S-05	4.9	4.6	4.9	5.1	5.1
500S-01	4.4	4.3	4.9	4.6	4.3
500S-02	4.4	4.2	4.6	4.5	4.3
500S-03	4.6	4.4	4.7	4.6	3.9
500S-04	4.4	4.4	4.2	4.6	4.3
500S-05	4	4.5	4.6	4.5	4.3
1000S-01	4.3	3.9	4.1	4.5	4.3
1000S-02	4.2	4	3.9	4.2	4
1000S-03	4.3	4.3	4.1	3.8	4.2
1000S-04	4	4.4	4	3.9	4
1000S-05	4.7	4.4	4.2	4.8	4.5

Figure 2. Effect of Sulfur Treatments on pH in Blueberry Fields. Treated 2001.



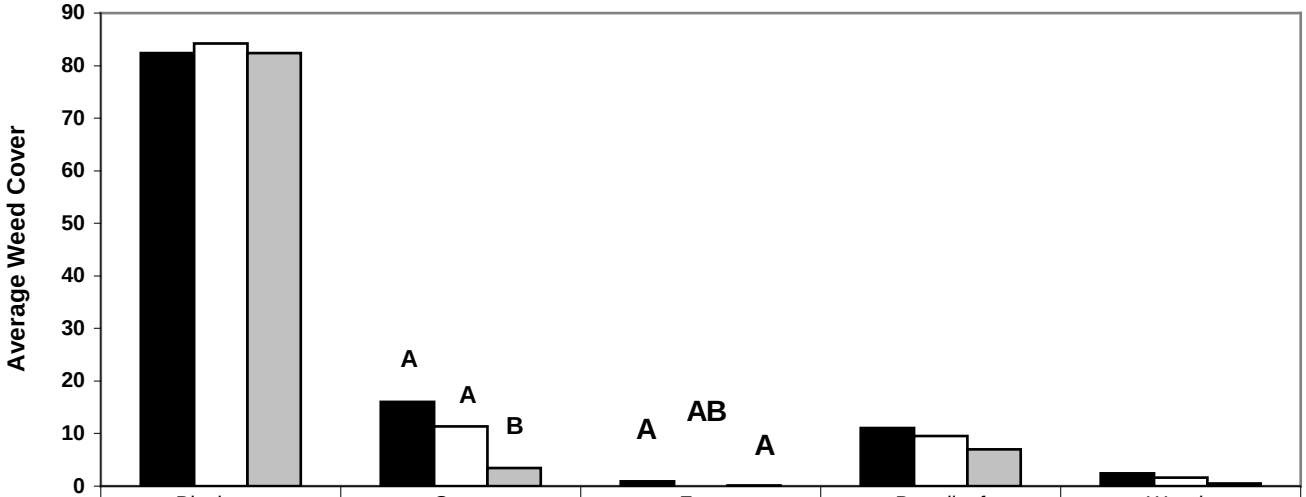
	BBHF	Union	Wesley-S	Wesley-V
0S-02	4.5	5.1	5	5.2
0S-03	4.7	4.9	4.9	5
0S-04	4.6	4.9	5	4.8
0S-05	4.7	4.8	4.9	5
500S-02	4.4	4.6	4.6	4.6
500S-03	4.2	4.5	4.6	3.9
500S-04	4.2	4.3	4.5	4
500S-05	4.2	4.2	4.3	4.7
1000S-02	4.3	4.3	4.2	4.4
1000S-03	3.6	4.1	3.8	4.2
1000S-04	3.8	4	4.2	4.1
1000S-05	3.6	4.1	4.6	4.6

Figure 3. Effect of Sulfur Treatments on pH in Blueberry Fields. Treated 2003.



	Blue Hill	Eastbrook	Franklin
0S-03	5	4.3	4.8
0S-04	4.9	4.6	4.9
0S-05	5.1	4.4	5
500S-03	4.7	4.3	4.8
500S-04	4.4	4.2	4.8
500S-05	4.6	3.9	4.7
1000S-03	4.7	4.3	5
1000S-04	4.3	4	4
1000S-05	4.4	4.1	4.1

Figure 4. 2005 Weed Cover Evaluation for Seven Sulfur Treated Plots



	Blueberry	Grass	Fern	Broadleaf	Woody
Sulfur 0 lb/a	82.424	16.061	0.9	11.061	2.424
Sulfur 500 lb/a	84.167	11.364	0	9.545	1.591
Sulfur 1000 lb/a	82.348	3.485	0.07	7.045	0.53

EXTENSION
INVESTIGATORS: F. A. Drummond, Professor of Insect Ecology/Entomology
J. A. Collins, Assistant Scientist of Insect Pest Management

22. TITLE: Evaluation and Demonstration of Backpack and ATV Mist sprayers

METHODS:

Three mist sprayers were purchased during the spring of 2005. Two of the sprayers were backpack models (Solo® 450 and Maruyama®) and a third was an ATV-mounted mist sprayer (Big John®). Comparative data were collected for the three sprayers, including but not limited to: estimated retail price, weight, chemical tank capacity, fuel tank capacity, maximum discharge volume, maximum effective swath width (droplet size and density), ease of start, and comfort.

The sprayers were each calibrated to deliver 1 gallon in 200 ft at a slow walking pace. Pace was maintained using a metronome. Swath width varied according to the sprayer and was estimated using water sensitive cards. Cards were laid out at 10 ft intervals for 50 ft. There were three replications. Ideal spray droplet distribution is 20-30 droplets/cm (3.39 inches).

RESULTS:

Comparative data and observations for the three sprayers are shown in Table 1 and Fig. 1.

Fig. 1. Spray droplet distribution.

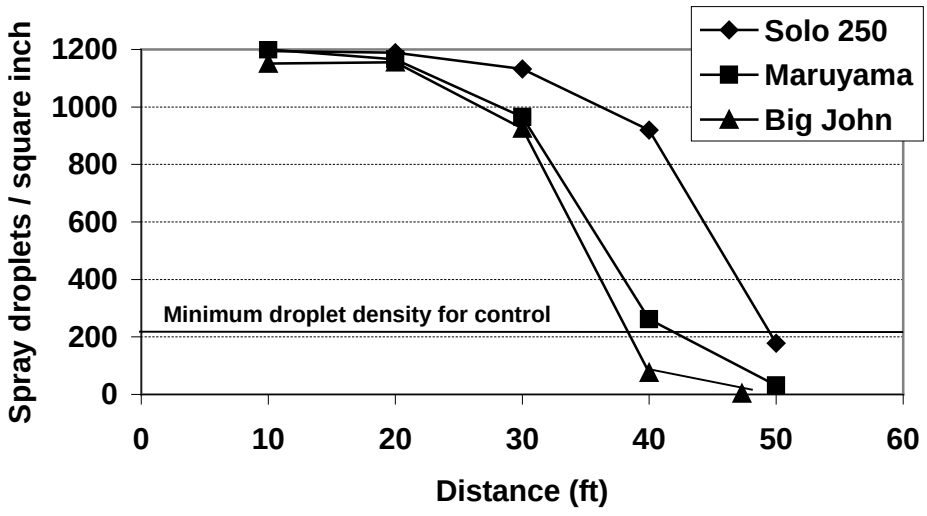


Table 1. Sprayer specifications and comparison of features.

	Solo 450	Maruyama	Big John	Comments
Estimated retail cost	$625	$700	$1250	
Weight	23.7 lbs	24.3 lbs	NA	Similar for both back-pack models.
Fuel tank capacity	0.5 gal	0.5 gal	0.5 gal	Same specifications for all models.
Chemical tank capacity	3.4 gal	3.4 gal	24 gal	The larger tank capacity of the Big John allows a longer operating time between refills.
Max. discharge volume	0.88 gal/min	0.92 gal/min	0.88 gal/min	Similar for all models.
Max. effective swath	40 ft	30 ft	30 ft	Larger effective coverage area for Solo.
Duster attachment	No	Yes	No	Duster attachment of Maruyama offers increased versatility.
Carburetor	Shielded	Not-shielded	Shielded	Safety concerns with unshielded carburetor.
Position of on/off switch	On sprayer arm	On backpack	On sprayer arm	Position on back-pack is inconvenient and is a safety concern due to proximity to the unshielded carburetor.
Chemical tank fill opening	Small	Larger	Small	Larger tank fill opening allows for less spillage during mixing.
Starter	Hard pull	Easy pull	Hard pull	Maruyama is generally easiest to start.
Straps	Easy adjusting	Harder to adjust	NA	The straps on the Solo are easier to adjust and more comfortable to wear for extended periods. Plastic straps of Maruyama tend to cut into neck and shoulders of the operator.

Additional comments:

Chemical tank design of the Big John does not allow for complete discharge of tank mix and can lead to changes in pressure as unit is driven over rough terrain. It also makes the unit very difficult to calibrate.

The spray arm of the Big John is not mounted on the unit and must be aimed manually by the operator.

Both back-pack models tend to be top-heavy when chemical tank is full.

CONCLUSIONS/RECOMMENDATIONS:

This project was aimed at the smaller grower; although, it does not exclude large grower participation. The goal of this project was to increase awareness of growers to pest management options. It is anticipated that this project will allow growers to make informed choices regarding mist sprayers before a potential purchase. An extension fact sheet will be produced for the growers during winter of 2005 that will outline the use of mist blowers, features important when considering a purchase, and a list of potential manufacturers. In addition, the mist sprayers will be stored and maintained at Blueberry Hill Farm Experiment Station. We recommend that any growers interested in this technology come to the experiment station to test and examine the different models.

EXTENSION
INVESTIGATORS: F. A. Drummond, Professor of Insect Ecology/Entomology
J. A. Collins, Assistant Scientist of Insect Pest Management

23. TITLE: Demonstration of Spot Treatment for Control of Blueberry Maggot Fly Using Mist Sprayer and Grid Trapping, 2005

METHODS:

Baited, yellow Pherocon® AM traps were deployed in a grid pattern with 20 ft between traps in two fields at Blueberry Hill Farm. In Field A, 12 traps were placed in four rows of three traps each. Field B had two rows of 9 traps each. The traps were monitored at 3 to 5 day intervals and any BMF counted and removed. Insecticide applications were made when any trap exceeded currently recommended thresholds of 6 BMF on any single visit or 10+ over a series of visits. Materials, rates, and application dates are given in Table 1. The materials were applied in a 20-ft swath around each trap where fly numbers exceeded threshold levels, in 7.25 gallons of water-mixture per acre using a SOLO® 450 mist sprayer (Fig. 1).

Table 1. Application information.

Site	Date	Material	Rate (oz/A)	Traps treated
Field A	12 July	SpinTor 2 SC	6.0	1 of 12 Traps
Field B	12 July	SpinTor 2 SC	6.0	2 of 18 Traps
Field A	19 July	Asana XL	9.6	5 of 12 Traps
Field B	19 July	Asana XL	9.6	10 of 18 Traps

RESULTS:

Table 2 is an estimate of the cost of spot-treatments compared with full-field applications in the same fields. Cost per acre ($20, CE Fact Sheet #260 “Enterprise Budget for Blueberries”) is the estimated cost of a commercial application. Total estimated costs were derived from this figure, the size of the area treated, and the amount of pesticide applied. In Field A, a spot-treatment of Asana XL saved an estimated 3.2%% over the cost of a full-field treatment; a spot-treatment with SpinTor 2 SC saved 17.7%. Similar savings were observed in Field B where the spot-treatment of Asana saved 7.8% and SpinTor 64.8%.

CONCLUSIONS:

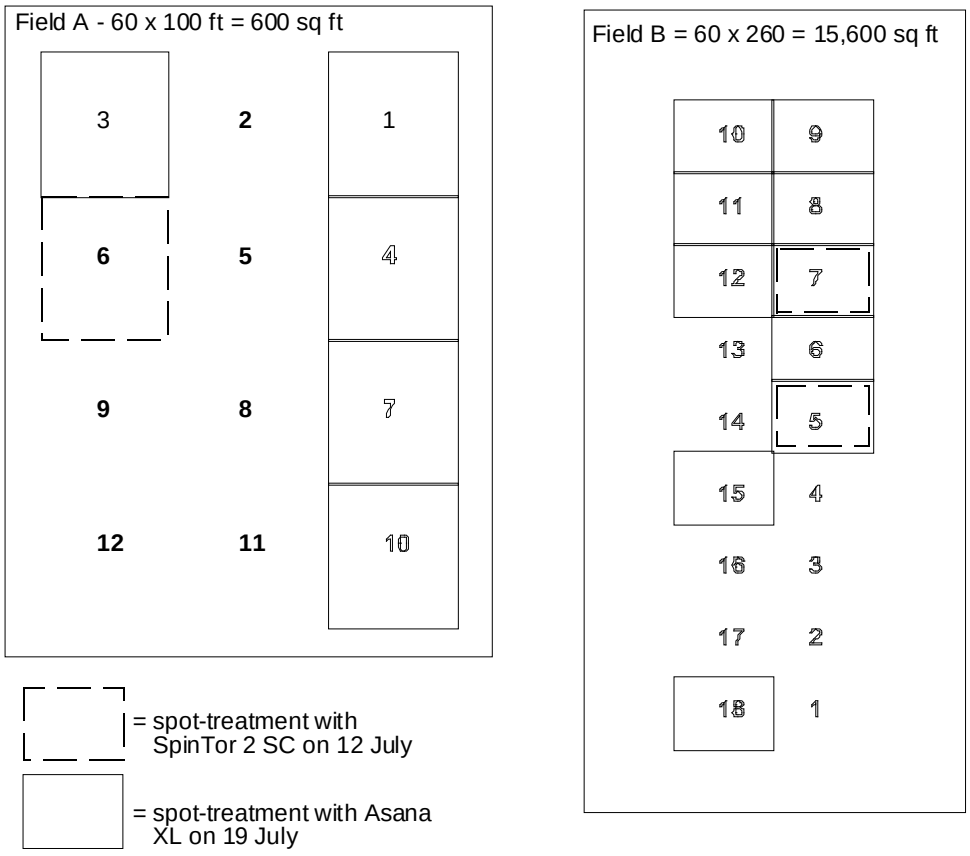
The ability to control insects with an inexpensive alternative to aerial spraying or contract ground tractor application has definite advantages for the small grower. Use of spot spraying is a very effective method for controlling the blueberry maggot fly on small acreages.

Table 2. Comparison of the estimated costs associated two types of application.

Cost of application (labor and equipment)	*$ 20.00/acre*	
Field A		
Full-Field Application:		
Size of area treated	6000 sq ft	
Cost of pesticide (1 application)		
Asana XL ($97 per gal)(1.3 oz applied)	$ 1.00	
SpinTor 2 SC ($720 per gal)(0.83 oz applied)	$ 4.67	
Total estimated cost (Labor + Insecticide)		
1 Application of Asana XL	$ 21.00	
1 Application of SpinTor 2 SC	$ 24.67	
Spot-Treatment Application:		
Size of area treated with Asana XL	2000 sq ft	
Size of area treated with SpinTor 2 SC	400 sq ft	
Cost of pesticide (1 application)		
Asana XL ($97 per gal)(0.44 oz applied)	$ 0.33	
SpinTor 2 SC ($720 per gal)(0.05 oz applied)	$ 0.31	
Total estimated cost (Labor + Insecticide)		
1 Application of Asana XL	$ 20.33	
1 Application of SpinTor 2 SC	$ 20.31	
Estimated savings with spot-treatment of Asana XL	$ 0.67	***3.2 %***
Estimated savings with spot-treatment of SpinTor 2 SC	$ 4.36	***17.7 %***
Field B		
Full-Field Application:		
Size of area treated	15,600 sq ft	
Cost of pesticide (1 application)		
Asana XL ($97 per gal)(3.4 oz applied)	$ 2.42	
SpinTor 2 SC ($720 per gal)(2.1 oz applied)	$ 11.81	
Total estimated cost (Labor + Insecticide)		
1 Application of Asana XL	$ 22.42	
1 Application of SpinTor 2 SC	$ 31.81	
Spot-Treatment Application:		
Size of area treated with Asana XL	4000 sq ft	
Size of area treated with SpinTor 2 SC	800 sq ft	
Cost of pesticide (1 application)		
Asana XL ($97 per gal)(0.88 oz applied)	$ 0.67	
SpinTor 2 SC ($720 per gal)(0.11 oz applied)	$ 0.62	
Total estimated cost (Labor + Insecticide)		
1 Application of Asana XL	$ 20.67	
1 Application of SpinTor 2 SC	$ 20.62	

Estimated savings with spot-treatment of Asana XL	$ 1.75	***7.8 %***
Estimated savings with spot-treatment of SpinTor 2 SC	$ 11.19	***64.8 %***

Fig. 1. Design of spot-treatment demonstration.



Note: treatment area treated around each trap = 20 x 20 = 400 fsq ft

Not drawn to scale

RECOMMENDATIONS:

We suggest that growers wishing to manage insect pests and limit the amount of insecticide applied to blueberry fields attempt to intensively monitor blueberry maggot fly in their fields and spot treat those areas that have high numbers of fly captures.