Fish Extracts for Integrated Disease, Insect, and Fertility Management in Organic Blueberries in the Southeastern U.S.

Final Report (2009-2010)

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PROJECT SUMMARY

The overall aim of this project has been the development of an integrated system for disease, insect, and nutrient management in organic blueberries centered around foliar applications of fish-derived products. Three on-farm trials (two in 2009 and one in 2010) were conducted on rabbiteye and southern highbush blueberries in collaboration with grower cooperators in south Georgia's blueberry belt. Four to six foliar spray applications of four fish product formulations (Omega Grow, Organic Gem, Organocide, and SeaCide) were made during summer and early fall at each site and compared with an untreated check, an organic standard fungicide (Serenade Max), and one or two additional biofungicides. Two different foliar diseases, Septoria leaf spot and leaf rust, were suppressed successfully with fish products across the three trials. There was no clear "winner" among the four formulations, with Omega Grow, Organocide, and SeaCide being most effective in different trials. Effects on leaf beetle damage were inconsistent across trials, with one trial showing damage reduction by SeaCide and another showing no such effects. This inconsistency could be due to the higher amount of leaf damage already present at the onset of the latter trial. The effects of fish products on plant vigor and leaf retention also were variable, with Organocide and SeaCide improving both parameters at a low-vigor site (rabbiteye trial in 2009) but not a higher-vigor site (southern highbush trial in 2010). Thus, improvements in plant growth seem to be limited to conditions with weaker growth potential. Regardless, none of the treatments translated into a higher flower bud set for the next growing season. Consistently across the three trials, application of Organic Gem resulted in considerably higher Na concentrations in leaf tissue of treated plants. Although these high Na levels did not appear to

impact plant growth negatively, it would be advisable to apply this product only in rotations to preclude potential negative effects. In two of the three trials, increased concentrations of P were observed following application of some fish products, providing a potential nutritional benefit of these products. Overall, although fish products are no "silver bullets" for managing blueberries organically, they do contribute consistently to leaf disease suppression and foliar nutrition and can have added, more incidental benefits on leaf beetle suppression.

INTRODUCTION

Blueberry is the most important fruit crop in Georgia (Boatright & McKissick 2010), and the organic blueberry acreage is expanding rapidly in the state and in neighboring Florida (Scherm & Krewer 2008). However, pest management options for organic blueberries are currently limited. For example, sustainability of production is threatened by several leaf diseases, which cause premature defoliation in the summer, reduced flower bud set during the fall, and lower return yields the following year (Ojiambo *et al*. 2007, Scherm *et al*. 2007). Prior to the beginning of the current study, a field trial conducted in 2007 with several organic fungicides (Scherm *et al*. 2008; see Fig. 1) showed that two OMRI-listed fish byproducts provided substantial control of Septoria leaf spot, the most important foliar disease on blueberry in Georgia. Based on these preliminary results, our primary objective was to compare and demonstrate the efficacy of several such products against the leaf disease complex on organic blueberries.

Insect and nutrient management are major challenges in organic blueberries. The blueberry leaf beetle (*Colaspis pseudofavosa*) can destroy the tender new vegetative growth produced after berry harvest during the summer. Fields containing natural weed growth in the aisles, such as most organic blueberry farms, can have a serious problem with this pest, and several months of young growth can be destroyed in a short period when beetles are numerous. Furthermore, nutrient supply is often inadequate in the sandy, highly acidic blueberry soils, leading to reduced shoot growth and flower bud formation, thereby providing a poor foundation for next year's yield. Previous studies on other perennial crops have shown that fish product applications can have powerful repellent, antifeedant, and/or insecticidal activity against a range of insects and mites (Beattie *et al*. 1999, Sams and Deyton 2002), and most of these products are also marketed as fertilizers to supplement both macro- and micronutrients. In a systems context, therefore, the added value of fish extracts as foliar fertilizers and/or insecticides or insect repellents would provide a powerful incentive for their use as summer sprays in organic blueberries. Thus, additional objectives were to evaluate leaf beetle suppression, foliar nutrient status, and plant growth in organic blueberries treated with fish extracts.

OBJECTIVES

The overall aim of this project has been the development of an integrated system for improved disease, insect, and nutrient management in organic blueberries during the summer and fall centered around foliar applications of fish-derived products. Specific objectives were to:

- compare and demonstrate the efficacy of several fish products against foliar diseases of blueberry in a certified organic planting,
- evaluate blueberry leaf beetle suppression in fish extract-treated plots, and
- determine the nutritional benefits of fish extract applications by measuring foliar nutrient status, plant growth, and flower bud formation in treated plots.

MATERIALS AND METHODS

2009 trials

Two on-farm trials were conducted during summer and fall 2009 in close collaboration with grower cooperators in south Georgia's blueberry belt. Site 1 was a certified organic farm near Baxley (Appling County), where several cultivars of rabbiteye blueberry (*Vaccinium virgatum*) were grown. The trial was conducted in mature bushes (>10 years old) of Brightwell, a commonly grown cultivar in both conventional and organic production systems. Site 2 was a higher-fertility farm near Alma (Bacon County), where the trial was carried out in mature bushes of Bluecrisp southern highbush blueberry (*Vaccinium corymbosum* interspecific hybrid). The latter planting was not certified organic, but remained untreated with fungicides and insecticides during the experimental period. Southern highbush cultivars are generally more susceptible to disease and insect pest damage than rabbiteye cultivars (Scherm & Krewer 2008, Scherm *et al*. 2007), but both species can be grown organically in the southeastern U.S.

Six foliar spray applications of the following products were made between late July and early October (site 1) or mid-July and late September (site 2):

Treatment	Rate	Supplier	Comment
Omega Grow	2%	Omega Protein, Houston, TX	Fish product
Organic Gem	2%	Advanced Marine Technologies, New Bedford, MA	Fish product
SeaCide	1%	Omega Protein, Houston, TX	Fish product
Organocide	2%	Organic Laboratories, Stuart, FL	Fish + sesame oils
Sporan	2.5 pt/A	EcoSMART Technologies, Franklin, TN	Rosemary + wintergreen oils
Serenade MAX	1.5 lb/A	AgraQuest, Davis, CA	Organic standard
Untreated	---	---	Untreated check

All products are OMRI-listed. Applications were made with backpack sprayers at a rate equivalent to 60-75 gal/A. At both sites, treatment plots were arranged in a randomized complete block design with four replicates. Individual plots were four (site 1) or between two and four (site 2) bushes long and separated by untreated buffers.

Periodic disease, leaf beetle damage, and plant growth assessments were made during the experimental period. Severity of Septoria leaf spot (Fig. 2), caused by *Septoria albopunctata*, was determined in late August and late October by counting the number of spots on a sample of ~40 leaves per plot. In early December, severity of leaf rust (Fig. 2), caused by *Thekopsora minima*, was estimated as the percentage of leaf area covered with rust pustules on a sample of ~25 leaves per plot.

Leaf beetle damage (Fig. 2) assessments were made in early and late October using a rating scale from 0 (no damage) to 4 (severe damage).

A plant vigor rating (considering leaf coloration, leaf retention, and overall shoot growth) was conducted for each plot in late October using a scale from 1 (poor) to 5 (excellent). At the same time, a random sample of spring leaves from each plot was submitted for tissue nutrient analysis (both macro- and micronutrients) to the Soil, Plant, and Water Laboratory at the University of Georgia. In early December defoliation and flower bud set were determined by counting the leaves missing and the flower buds present on a sample of ten spring shoots per plot.

Data were subjected to analysis of variance followed by means separation (Fisher's protected LSD test) where appropriate.

2010 trial:
An on-farm trial was conducted during summer and fall 2010 in a certified organic planting of mature Star southern highbush blueberry in Clinch County, GA. Four foliar spray applications of the following products were made between late August and early October:

Treatment	**Rate**	**Supplier**	**Comment**
Omega Grow	2%	Omega Protein, Houston, TX	Fish product
Organic Gem	2%	Advanced Marine Technologies, New Bedford, MA	Fish product
SeaCide	1%	Omega Protein, Houston, TX	Fish product
Organocide	2%	Organic Laboratories, Stuart, FL	Fish + sesame oils
Sporan	2.5 pt/A	EcoSMART Technologies, Franklin, TN	Rosemary + wintergreen oils
KeyPlex 350 OR	0.5%	KeyPlex, Winter Park, FL	Micronutrient-based host resistance inducer
Serenade MAX	1.5 lb/A	AgraQuest, Davis, CA	Organic standard
Untreated	---	---	Untreated check

Applications were made with backpack sprayers calibrated to deliver the equivalent of 75 gal/A. Treatment plots were arranged in a randomized complete block design with four replicates. Individual plots were five bushes long with the outer two bushes serving as buffers.

Periodic disease, leaf beetle damage, and plant growth assessments were made during the experimental period. Septoria leaf spot was again the dominant foliar disease. Disease severity was evaluated by visually estimating percent leaf area covered with spots on a sample of 40 leaves per plot. The assessor had been trained with DiseasePro (Nutter 1997), a computerized disease assessment training program, prior to making the assessments. Leaf beetle damage assessments were made using the 0 to 4 scale described above. In addition, detailed counts of the number of leaf beetles per bush were made 1 and 7 days after the third spray application in late September. Plant vigor and defoliation were assessed as described above in mid-October, and leaf samples were collected similarly and submitted for foliar nutrient analysis. In early February of the following year (2011), flower bud set was determined on 20 shoots per plot to assess treatment effects on return yield potential. Data were subjected to analysis of variance followed by means separation (Fisher's protected LSD test) where appropriate.

PROJECT RESULTS

Leaf disease suppression, plant vigor, and defoliation

At site 1 (Brightwell rabbiteye blueberry) in 2009, Septoria leaf spot was the dominant foliar disease. Disease severity remained low during the early fall, with an average of only 2.4 spots per leaf counted in the untreated check during the late-August assessment; because of the low leaf spot levels, no biofungicide effects on disease severity were apparent for this assessment date. During the subsequent 2 months, Septoria leaf spot increased to moderate levels, reaching an average of ~10 spots per leaf in the untreated plots during the late-October assessment (Fig. 3A). Biofungicide treatments differed at a significance level of $P = 0.0647$ (slightly more liberal than the customary $P = 0.05$ level), with all fish products (Omega Grow, Organic Gem, Organocide, SeaCide) as well as Sporan having less severe disease than the untreated check (Fig. 3A). Leaf spot severity was lowest for Omega Grow (less than one-third of untreated).

When plant vigor was assessed in late October, biofungicide treatment effects were highly significant ($P = 0.0011$). Vigor was increased by all treatments relative to untreated, except by Organic Gem (Fig. 3B). Ratings were highest for Serenade Max, Organocide, and SeaCide. The latter two fish products also increased leaf retention (assessed separately in early December) significantly compared with the untreated plots (Fig. 3C). For example, the SeaCide-treated plants retained three times more leaves than their untreated counterparts. Flower bud set (also assessed in early December) was very low overall and was not significantly affected by treatment (Fig. 3D).

Septoria leaf spot was all but absent at site 2 (Bluecrisp southern highbush blueberry) in 2009, with <0.2 spots per leaf in the untreated plots during the late-October assessment. However, late-season leaf rust developed at this site, as evident in the early-December assessment (Fig. 4A). Due to high variation among replicates, no significant treatment effects on rust severity were observed; however, Omega Grow and SeaCide-treated plots consistently had very low rust severities (Fig. 4A). No vigor or leaf retention assessments were made at this site due to confounding effects of infections with bacterial leaf scorch, a novel systemic disease of blueberry.

In the 2010 trial on Star southern highbush blueberry, Septoria leaf spot was already present in the planting at moderate levels when the treatments commenced in late August, attaining very high levels by the end of the trial (Table 1). At a *P*-level of 0.0689, Organocide (15.6% severity) reduced disease compared with the untreated check (23.1% severity). None of the other treatments resulted in disease reductions compared with untreated.

There was no treatment effect on plant vigor in the 2010 trial ($P = 0.3748$; Table 2), most likely because overall plant growth was relatively vigorous at this site (mean score = 3.00). In contrast, in our 2009 trial at site 1, in which untreated check plants were consistently less vigorous (mean score = 2.13), showed significant increases in vigor for all treatments. Thus, it appears that the ability of the treatments to increase plant vigor is dependent on overall plant growth potential, with greater increases likely in conditions with weaker growth potential.

The mean defoliation level in the untreated check in mid-October was 59.2% (Table 2). Although several of the treatments (Sporan, Omega Grow, Serenade Max, and KeyPlex) had defoliation levels below 40%, these reductions were not statistically significant (P = 0.1280) due to experimental variability among plots. Treatment effects on flower bud numbers in late winter were similarly not significant (P = 0.1077; Table 2).

Leaf beetle suppression

No leaf beetle populations built up at site 1, hence only results from site 2 are shown for 2009. On average, about 20% of the leaves inspected during the late-October assessment showed symptoms of leaf beetle damage. Beetle damage differed among biofungicide treatments at a level of P = 0.0641, with SeaCide, Serenade Max, and Sporan having lower damage scores than the untreated plots (Fig. 4B).

In the 2010 trial, high levels of beetle-induced leaf damage developed in the experimental plots by early October, with the untreated check averaging 3.92 on a 0 (no damage) to 4 (severe damage) scale (Table 1). None of the treatments reduced leaf damage significantly (P = 0.2369), presumably because a large part of the damage had already been done by the time the treatments commenced in late August. When detailed counts of leaf beetles per bush were made after the third spray application in late September, none of the treatments affected the number of live or dead beetles 1 day after application (Table 3); however, beetle numbers were reduced significantly (P < 0.0001) and by more than 50% in all treated plots 7 days after application, indicating that the insects avoided the treated plots.

Plant nutritional effects

In 2009, a highly significant (P < 0.0001) increase in leaf Na concentrations following application of Omega Grow and, to a lesser degree, Serenade Max was observed at site 1 (Fig. 5A). A less pronounced (P = 0.0643) increase in leaf Na concentrations following the application of Omega Grow was also observed at site 2 in 2009 (Fig. 5B). At the latter site, applications of Organic Gem and Organocide had the beneficial effect of increasing leaf P levels compared with the untreated check (P = 0.0510, Fig. 5C).

In the 2010 trial (Table 4), OmegaGrow again increased Na concentrations significantly (by almost 3-fold). In addition, KeyPlex, which was not tested in the previous year, resulted in >5-fold and >4-fold increases in Fe and Zn levels, respectively. Less pronounced but significant were the increases in Mn following KeyPlex application and in P following application of Organic Gem and Omega Grow. All treatments reduced foliar Ca and Mg levels compared with the untreated check.

CONCLUSIONS AND DISCUSSION

Although cultivars, cultural practices, and disease and pest pressures differed among the three trials, several conclusions can be drawn from this 2-year project:

- Two different foliar diseases, Septoria leaf spot and leaf rust, were suppressed successfully with fish products across the three trials. There was no clear "winner" among the four tested formulations, with Omega Grow, Organocide, and SeaCide being most effective in different trials.

- Effects on leaf beetle damage were inconsistent, with one trial showing damage reduction by SeaCide applications and another trial showing no such effects. This inconsistency could be due to the higher amount of leaf damage already present at the onset of the latter trial. Regardless, it appears that any leaf beetle suppression associated with fish products is mostly incidental, with the greater impact being on leaf disease management.
- The effects of fish products on plant vigor and leaf retention also were variable, with Organocide and SeaCide improving both parameters at a low-vigor site (rabbiteye in 2009) but not a higher-vigor site (southern highbush in 2010). Thus, improvements in vegetative plant growth seem to be limited to conditions with weaker growth potential. Regardless, none of the treatments translated into a higher flower bud set for the next growing season.
- Consistently across the three trials, application of the fish product Organic Gem resulted in considerably higher Na concentrations in leaf tissue of treated plants. Although these high Na levels did not appear to impact plant growth negatively, it would be advisable to apply this product only in rotations to preclude potential negative effects. In two of the three trials, significantly increased concentrations of P were observed following application of some fish products, providing a potential nutritional benefit of these products. The organic host resistance inducer KeyPlex, which was tested only in one of the trials, markedly increased Fe, Zn, and Mn levels in treated plants, providing a potential benefit in terms of micronutrient supply.
- Overall, although fish products are no "silver bullets" for managing blueberries organically, they do contribute consistently to leaf disease suppression and foliar nutrition and can have added, more incidental benefits on leaf beetle suppression.

OUTREACH

Our most important outreach activity was the close collaboration and interaction with the respective grower collaborators and their county extension agents while the three trials were conducted in 2009 and 2010. They were active participants in the trials, received regular updates, and provided much needed feedback. In terms of reaching a large audience of organic growers and those interested in converting to organic production, our most important activity has been the participation in the organic blueberry educational sessions at the Southeast Fruit and Vegetable Conference and Trade Show in Savannah, GA, in January 2010 and 2011, where more than 100 growers specifically attended our sessions each year. A major venue for outreach to extension personnel was a presentation at the North American Blueberry Research and Extension Workers Conference (NABREW) in Kalamazoo, MI, in July 2010; this biannual conference has been a key educational forum for blueberry researchers, Extension educators and industry leaders since the 1960s.

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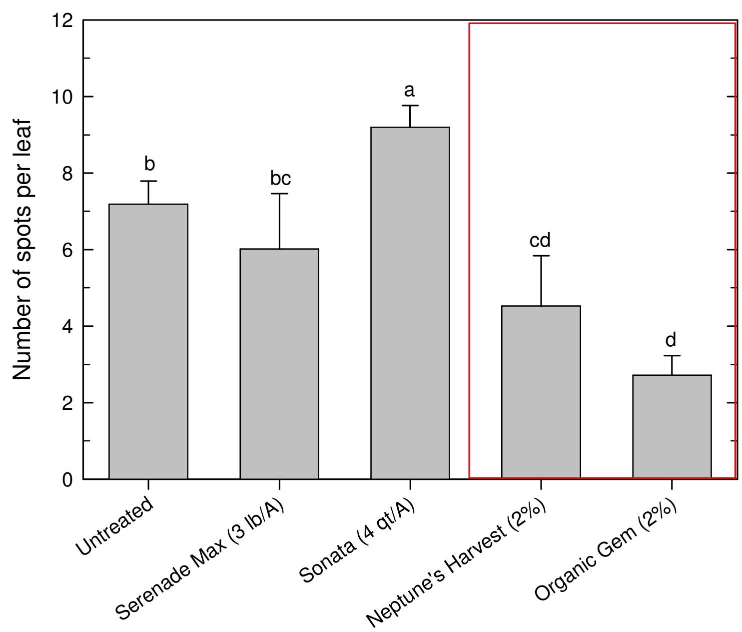

Fig. 1. Effect of two fish products (in red box) and two other biofungicides on Septoria leaf spot severity on Brightwell rabbiteye blueberry in an on-farm trial conducted in 2007, prior to the beginning of the OFRF project. Four foliar applications of each product were made between late August and early October. Means with the same letters are not significantly different from each other according to Fisher's protected LSD test ($P = 0.05$).

Fig. 2. Septoria leaf spot (top), leaf rust (middle), and feeding damage by the blueberry leaf beetle (bottom) on blueberry.

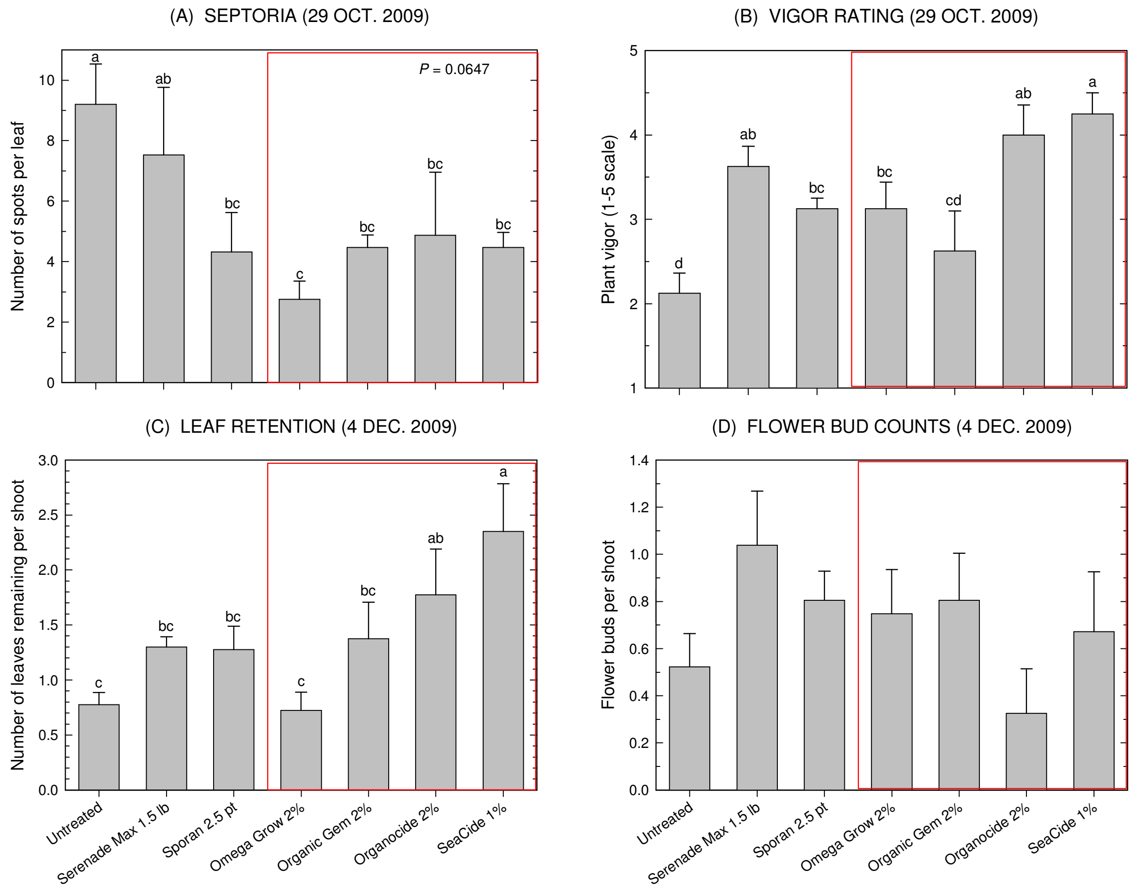

Fig. 3. Effect of four fish products (in red box) and two other biofungicides on Septoria leaf spot severity (A), plant vigor (B), late-fall leaf retention (C), and flower bud set (D) at site 1 in 2009 (Brightwell rabbiteye blueberry). Six foliar applications of each product were made between late July and early October. Means with the same letters are not significantly different from each other according to Fisher's protected LSD test (at $P = 0.05$ or the P-value indicated).

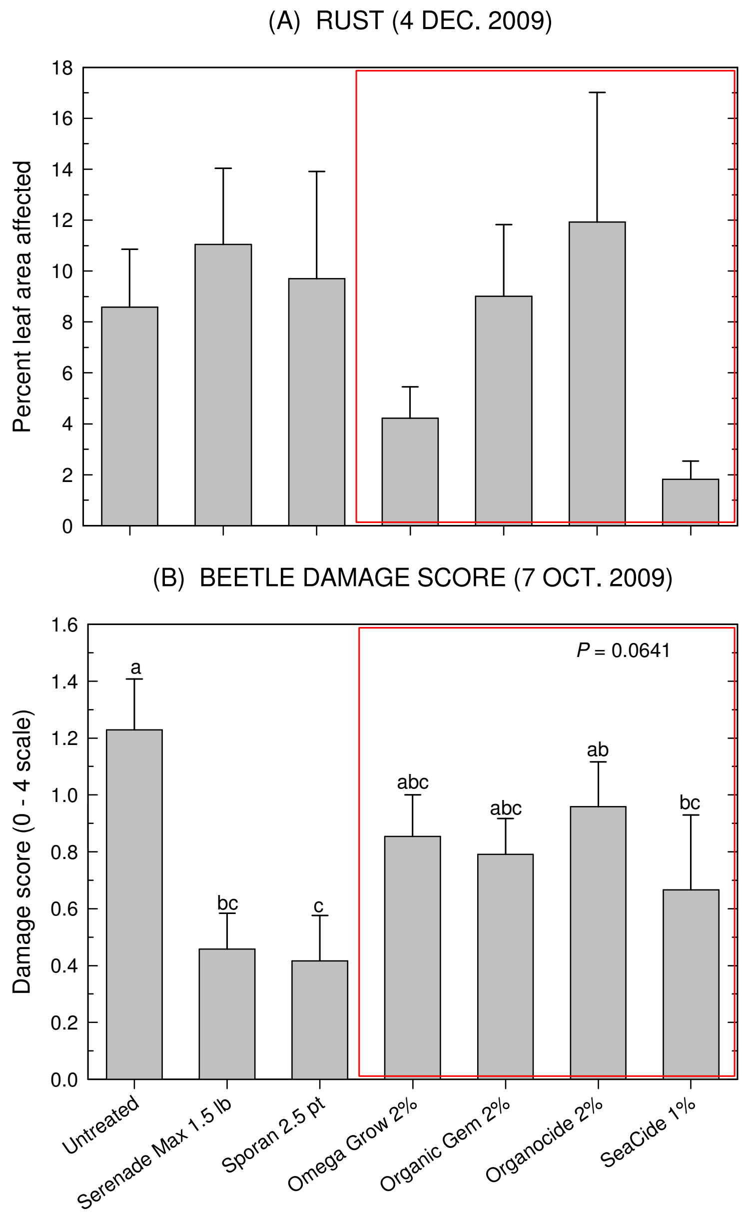

Fig. 4. Effect of four fish products (in red box) and two other biofungicides on leaf rust severity (A) and leaf beetle damage (B) at site 2 in 2009 (Bluecrisp southern highbush blueberry). Six foliar applications of each product were made between mid-July and late September. Means with the same letters are not significantly different from each other according to Fisher's protected LSD test ($P = 0.0641$).

Table 1. Effect of fish products and three other biofungicides on Septoria leaf spot severity and leaf beetle damage on 'Star' southern highbush blueberry in Clinch County, GA, Oct. 2010

Treatment[a]	Disease severity (%)	Beetle damage[b]
Untreated	23.1 a	3.92
Serenade	20.0 ab	3.58
Sporan	24.9 a	3.33
Keyplex	22.0 a	3.42
OmegaGrow	19.8 ab	3.58
Organic Gem	21.7 a	3.42
Organocide	15.6 b	3.58
SeaCide	19.5 ab	3.50
LSD (α = 0.05)	5.44	0.435
P-value	0.0689	0.2369

[a]Four applications between late August and early October. Fish products are underlined. Letters within each column indicate means separation results by Fisher's protected LSD test.
[b]Assessed visually on a scale from 0 (no damage) to 4 (severe damage).

Table 2. Effect of fish products and three other biofungicides on plant vigor and defoliation (Oct. 2010) and flower bud set (Feb. 2011) on 'Star' southern highbush blueberry in Clinch County, GA

Treatment[a]	Vigor[b] (0-5 scale)	Defoliation (%)	Buds per shoot
Untreated	3.00	59.2	1.65
Serenade	3.06	33.0	2.44
Sporan	2.63	38.2	1.96
KeyPlex	3.00	30.5	1.61
Omega Grow	3.19	35.8	1.70
Organic Gem	2.25	49.2	1.81
Organocide	2.69	47.5	1.56
SeaCide	2.38	44.2	1.08
LSD (α = 0.05)	0.941	20.7	0.8062
P-value	0.3748	0.1280	0.1077

[a]Four applications between late August and early October. Fish products are underlined.
[b]Assessed visually on a scale from 1 (poor) to 5 (excellent).

Table 3. Effect of fish products and three other biofungicides on the number of blueberry leaf beetles per bush on 'Star' southern highbush blueberry in Clinch County, GA, at different time periods after application in the 2010 trial[a]

Treatment[b]	Live 24 h	Dead 24 h	Live 7 days
Untreated	2.92	0.167	1.583a
Serenade	0.75	0.667	0.083c
Sporan	1.25	0.167	0.167c
Keyplex	1.25	0.333	0.083c
Omega Grow	2.50	0.167	0.167c
Organic Gem	1.33	0.417	0.083c
Organocide	1.00	0.500	0.167c
SeaCide	1.33	0.583	0.667b
LSD (α = 0.05)	1.82	0.463	0.451
P-value	0.2242	0.1901	<0.0001

[a]Number of insects per bush counted 1 and 7 days after the third application on Sept. 23, 2010.
[b]Fish products are underlined. Letters within the last column indicate means separation results by Fisher's protected LSD test.

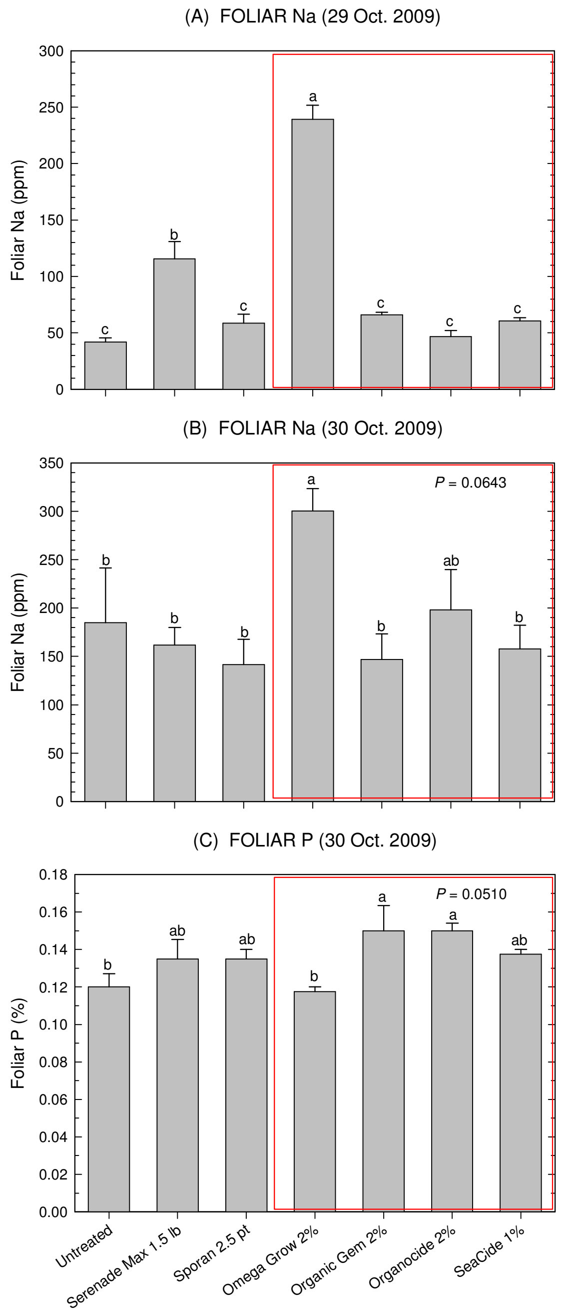

Fig. 5. Effect of four fish products (in red box) and two other biofungicides on foliar sodium (A and B) and phosphorus (C) concentrations at sites 1 (A) and 2 (B and C) in 2009. Six foliar applications of each product were made at each site. Means with the same letters are not significantly different from each other according to Fisher's protected LSD test (at $P = 0.05$ or the P-value indicated).

Table 4. Effect of fish products and three other biofungicides on the concentrations of select foliar nutrients on 'Star' southern highbush blueberry in Clinch County, GA, Oct. 2010.

Treatment[a]	Ca (%)	Mg (%)	P (%)	Fe (ppm)	Mn (ppm)	Na (ppm)	Zn (ppm)
Untreated	0.913a	0.305a	0.080c	44.7b	54.4b	97.9b	7.87d
Serenade	0.678b	0.258b	0.090abc	46.0b	43.1bc	150.4b	10.32bc
Sporan	0.730b	0.268b	0.085bc	50.6b	44.8bc	103.4b	9.81bcd
KeyPlex	0.620b	0.238b	0.095ab	261.8a	72.4a	173.1b	36.76a
Omega Grow	0.720b	0.260b	0.095ab	50.4b	47.1bc	264.6a	9.12bcd
Organic Gem	0.660b	0.260b	0.098a	43.1b	40.7c	168.9b	9.04bcd
Organocide	0.688b	0.248b	0.090abc	58.9b	38.9c	133.6b	11.46b
SeaCide	0.695b	0.248b	0.090abc	46.0b	44.2bc	107.0b	8.59bcd
LSD (α = 0.05)	0.164	0.037	0.010	24.5	13.6	77.5	2.29
P-value	0.0515	0.0407	0.0321	<0.0001	0.0011	0.0042	<0.0001

[a]Four applications between late August and early October. Fish products are underlined. Letters within each column indicate means separation results by Fisher's protected LSD test.