Project No. RP-3

ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE

January 1, 2023- December 31, 2023

PROJECT TITLE: Rice protection from invertebrate pests.

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OBJECTIVES AND EXPERIMENTS CONDUCTED BY LOCATION:

OBJECTIVE 1. Identify effective management tactics of rice invertebrate pests while considering environmental quality

1.A Management of tadpole shrimp (TPS) with insecticides, insecticide resistance, and improving scouting/treatment timings

Tadpole shrimp (TPS) are aquatic crustaceans adapted to live in vernal pools. Conditions in rice fields, and their seasonality, make them a great habitat for this arthropod where they have been a pest. TPS have been a problem in California rice since the 1940s. Insecticides have been used to control them, although the number of materials relied upon is relatively few. Pyrethroids are heavily relied upon due to efficacy and cost. Resistance to pyrethroid insecticides has been observed in some areas. Additionally, pyrethroid use is being scrutinized by regulatory agencies due to the possibility of surface water contamination. New alternatives for control are needed as is a better understanding of how alternative materials could be used in terms of timing and rates. For materials that are more expensive, timing will be important because treatment will likely be delayed until it is clear that a population of shrimp has developed, at which point they may be on the larger side.

<u>Overview</u>

For all of the TPS field trials, the research plan and what was accomplished is presented, *but no data are presented* because of major issues that occurred with the trial. In brief, it appeared that our field used for TPS work in J7 was contaminated with a pesticide that killed off the shrimp. We fully set up rings for a trial as we normally would, treated plots, and then began checking the plots. However, it became quickly apparent that the TPS were dying off both within the rings and in the overall field. We had not even applied our later treatments when this became apparent, so would not be able to get any data for the later ones. We also do not gather that much data early on and rely primarily on “end of trial” assessments for both TPS counts and yield (taken at different times). This means that there was not even a window to salvage the trial and collect some data.

It appeared that this was likely due to drift/overspray with a thiobencarb herbicide. An insecticide application (pyrethroid/lambda-cyhalothrin) was also a possibility, but any pyrethroid applications did not appear to line up with the possible applications around the J7 field at the RES.

We did respond to this problem in the season by setting up additional rings in the bottom part of J7, which we had not yet flooded. We were going to be using this area for our seed midge trial using berm plots, so we had kept it dry. We ended up using these rings (plus additional ones) for seed midge trials because the bottom area had water leakage, preventing us from building berm plots for the seed midge trial. Moving forward, we will be addressing the drift issue by communicating with the RES staff, possibly using some combination of berms or plastic barriers to prevent contaminated water from entering our rings, or shifting our trials to a different area at the RES.

Rings – natural infestation

We again used metal rings to assess (or attempt to assess given the problems) insecticide control methods for TPS in a basin with high levels of TPS at the Rice Experiment Station (RES). Based on available space at the RES, we decided to again focus on ring plots this season rather than berm plots. This year's trial focused on a number of different materials/timings and a material not currently labelled in rice.

Methods

We placed metal rings in a basin at the RES prior to flooding. This field reliably has a high tadpole shrimp population because it is untreated for pests year after year. A total of 20 treatments were tested, including multiple active ingredients and timings, replicated six times (Table 1). Each ring was 10.7 ft^2. The field was flooded on 13 June and planted on 16 June with rice variety M-206 at a seeding rate of 150 lbs per acre. Each ring was seeded with 16.7 grams (dry weight before soaking) of M-206 seed. Seed was prepared using a standard RES protocol wherein seed was placed in a 2-hour 5% bleach soak, rinsed, soaked in clean water for 22 hours, drained, and allowed to air dry for one day prior to planting. Treatment timings consisted of pre-flood, early post-flood, and late post-flood timings. Treatments were applied using and hand held aerosol device to get good coverage in each ring, using 5 mLl aliquots per ring. The first two were applied on 12 July (pre-flood) and 14 June. The early post-flood treatments coincided with when shrimp were present and approximately 2 mm in carapace width. Shrimp can be found at this point, but are difficult to find. The late post-flood treatments were added 23 JuneLate post-flood treatments were going to be used to mimic a rescue treatment and a point when shrimp are much easier to find, although shrimp were still not large (5-6 mm carapace width). We were testing if alternative materials (at tested rates) could still be effective and could reduce damage. Our first data collection occurred on 19 June, but it turned out the shrimp populations were already crashing at this point. We stopped trying to collect data immediately after the late treatments were added when it had become abundantly clear that something was amiss across the entire field as well as in the rings. The entire field outside the rings looked worse initially, we assume because the concentration of the pesticide was reduced as it moved through the soil into the rings.

Data analysis: No data were available to analyze

Results and Discussion

None to report

Conclusions

While we had major issues with this trial, this type of work is still necessary to ensure a variety of effective tools are available for tadpole shrimp management. It does appear that alternative materials exist, but data are needed on various materials at multiple timings and rates.

Buckets inside of rings – addition of tadpole shrimp

Methods

In addition to the natural infestation trial, we were going to conduct a smaller study consisting of 8 treatments (Table 2) using the same metal rings with a nested mesh garbage can to allow water (and insecticide) flow. This method would let us expose a specific number of shrimp to each treatment. We can then accurately count the shrimp by removing the bucket, allowing the water to drain, and then counting the exposed shrimp. The timing was going to be comparable to the late post-flood treatment. This study was going to be conducted in the same field (J-7 at the RES) as the ring study, with flood up occurring on 13 June. We had placed the rings, but did not start the study at all otherwise because the shrimp in the field were already disappearing (dead) before we would be moving them over. We had planned to put 10 shrimp in each basket when shrimp were of adequate size. Rice seed was planted in each ring for weed management, but yield and stand counts were of no interest for this study.

Data analysis: No data were available to analyze

Results and Discussion

None

Conclusions

None

1.B. Management of rice seed midge(s) with insecticides

Rice seed midge damage was first recorded in California rice production in 1953 (Darby 1962, Lange and Grigarick 1970). Midges in the family Chironomidae are some of the first colonizers of freshly flooded rice fields, and in high enough numbers can cause economic damage to rice during the establishment period of rice seedlings. They often are most problematic in late-planted rice fields. In addition, rice seed midge issues are generally worse with cool springs when rice struggles to germinate and become established. This study focused on control of midge larvae with insecticides, primarily in conventional systems, to minimize their economic damage to California rice fields during the seedling establishment phase. We built off last year’s study, which was the first time we had done these trials. Last year’s data were promising in terms of identifying study methods as well as insecticide treatments that could help with seed midge management, as well as materials that appeared to not help.

Methods

We had originally planned to use 10×10 ft berm plots for this trial. We used metal rings last year and thought that we likely could get and more uniform midge infestation and better yield data using larger plots. However, we were planning to use one section of field J7 for this trial and it was flooded earlier than anticipated. We had kept the end of this field water-free, which is normally possible given the dry area between the different basins. We had to wait to build the berms until staff were available. The section flooded earlier when water overflowed at one point.

At this point, we could no longer use machinery in the field. Instead, we used the rings that we had put into this area for possible tadpole shrimp work in response to the problems with that study. We did have to add additional rings to test the number of treatments that we wanted. The one advantage to this change was we were able to test more treatments (Table 3) than we had originally planned given the smaller plot size with rings.

Rice was grown in 10.7 ft^2 metal ring plots, seeded at a rate of 150 lbs per acre, with rice variety M-206. To promote rice seed midge damage, we mimicked prior studies and commercial conditions that result in seed midge damage. Later plantings are usually exposed to higher midge populations. In brief, we planted one section of the area we use for research at the RES very late. Rings were staked into the field in a 6 x 17 grid, for 6 replications of the 17 treatments. Planting occurred June 28th, roughly 14 days after our last trial was planted in the same basin in the J-7 area and when all nearby areas had already been planted. Each ring was seeded with 16.7 grams (dry weight before soaking) of M-206 seed. Seed was prepared using RES protocol in which seed was placed in a 2-hour 5% bleach soak, rinsed, soaked in clean water for 22 hours, drained, and allowed to air dry for one day before planting. Treatments were applied the day before planting on June 27th. Each ring was sampled on July 8th (11 DAT) for midges, consisting of two shallow soil samples taken from each ring using a 0.11 ft^2 scoop. Samples were combined for each ring into a bulk sample, placed in plastic bags, with an ID tag, and frozen for processing later. We did not end up needing the TPS removal treatment (control) because there were no tadpole shrimp (this treatment would account for the fact TPS could affect midges), so that treatment was omitted from sampling and analysis

To process samples, we thawed them in their bags in warm water and then sieved them through a stack of 1 mm and 250 micron sieves to capture the midge larvae. The large debris in the 1 mm sieve was discarded, and the contents of the 250 micron sieve were washed into a large container which was then filled halfway with water. The contents were then gently swirled and decanted carefully back into the 250 micron sieve. We repeated this process four more times to extract all the midge larvae from the sample debris. The contents of the 250 micron sieve were then rinsed in to a large petri dish so any midge larvae could be counted and extracted into an ethanol-filled vial for later identification and counting. The decanting process seemed to be about 99% effective in extraction as a portion based on our periodic checks of debris remnants to ensure the accuracy of our method; our extraction rate was always within a 95% cutoff.

We counted midge samples using a dissecting microscope. Midge counts were extrapolated to the entire ring based on the area sampled and these counts. Midges from each sample vial were also identified to determine species/genus composition. We first identified midges to the sub-family level. Individuals representing each subfamily were slide mounted and identified to genus using keys in Merritt and Cummings 2019. The communities were dominated by *Paratanytarsus* species and *Chironmus* species. We therefore separated species ID’s into these genera and then all others into an “Other” category, which included *Cricotopus*, Tanypodinae, and *Ceratopogon*.

To assess the effect of the experimental treatments on yield, we harvested the plots. Harvest occurred on 23 Oct. Due to late planting and water no longer being available at the station late in the season, the rice in the ring plots was not going to reach maturity. We therefore could not take yield as normal, so we focused on number of panicles instead. We then used average panicle grain weights from the adjacent basin to predict yields in the rings. Each metal ring plot was cut by hand using a small knife and bundled. We counted all panicles from each ring to estimate grain weight. Grain weight was determined by stripping the grain from groups of 10 random panicles collected from the adjacent basin, with a total of 200 panicles collected. The average from 10 groups of panicles was then used to determine overall grain yield for all the plots. Stand counts were also determined after harvest, because this was going to be more accurate than counting emerging rice seedlings in the early season.

Data analysis: All analyses were conducted using R. For midge abundance, effects of treatments were tested with a negative binomial generalized linear model with fixed factors for treatment and block. All midge species were combined for abundance analyses. This could be influenced by non-rice seed midge species, but this is discussed in the results and is expected to have minimal results. For community composition, the communities were dominated by *Paratanytarsus* species and *Chironmus* species. For species composition, we present relative species abundance graphically. For simplicity, we analyzed percent *Paratanytarsus* for each ring since this genus was the most abundant. We only calculated and analyzed this variable when total abundance was >10 midges. Anything less, and composition could be heavily skewed one way or another. In addition, we only analyzed treatments that had four or more replicates that reached this threshold. Most of the treatments that had fewer than four replicates had only one replicate with >10 midges. Posthoc comparisons were made with a Benjamini-Hochberg correction for multiple comparisons. The level of α used was 0.05.

Plant responses (yield and stand count) were analyzed using linear models with fixed factors for treatment and block. Posthoc comparisons were made as described above. Stand count was square-root transformed to satisfy the assumptions of the analysis.

The relationship between yield and stand count and then between each of the plant responses and midge abundance were visualized using scatter plots with raw data and/or treatment means along with generalized additive model or linear model based smoothing functions.

Results and Discussion

Overall, we were able to collect useful data again using our metal ring plot method. Notably, there was a significant effect treatment on midge abundance (χ^2_{15} =, $P < 0.001$, Figure 1). The untreated had the highest number of midges, followed by the pyrethroid treatments, including Warrior II at both rates and Mustang Maxx, which were all statistically equivalent. These pyrethroid treatments were generally equivalent to the Pyganic 5.0 treatments (both rates) and the low rate of Belay, although these had numerically lower counts. Most other treatments had very few midges, which included the Aquabac XT, high rate of Belay, Dimilin, and Vantacor treatments. The high rate of Aquabac XT had the fewest midges overall.

For species composition, there were some differences among treatments. There was an overall effect of treatment on percent *Paratanytarsus* in the sample ($F_{7,31} = 4.56$, $P = 0.001$, Figure 2). The untreated, both Warrior treatments, and low rate of Pyganic 5.0 were the most dominated by *Paratanytarsus*. This was the genus that was most abundant in last year's trials as well. In the Belay 2oz and Pyganic 15.6oz treatments, the percent *Paratanytarsus* was the same as the prior treatments, but more intermediate with other treatments. Dimilin 4oz and Mustang Maxx were the most skewed towards other genera, specifically *Chironomus*. Dimilin 4oz had some "Other" genera/families. This could have skewed this treatment slightly higher than it should be for "rice seed midge" proper for abundance data, but it did not appear to be heavily influential.

For plant measures, we saw significant effects of treatments and results somewhat, but not always, lined up with midge abundance results. For yield, there was a significant effect of treatment ($F_{15,75} = 10.16$, $P < 0.001$, Figure 3). The treatments that had the highest yield were all of the Aquabac XT treatments and Vantacor treatments. The Dimilin 8oz rate was generally comparable. Many of the other treatments were comparable to the untreated, which had a somewhat intermediate, but lower yield. A number of treatments had numerically lower treatments for one or both of the rates tested (Belay, Warrior), but these were not necessarily significantly different. The one treatment that had significantly lower yield was Belay 4.5oz. We saw overall similar results for stand counts, with a significant effect on stand ($F_{15,75} = 11.50$, $P < 0.001$, Figure 4). There was a very tight linear relationship between yield and stand count (Figure 5). The Aquabac treatments had the best stands, followed by Dimilin 8oz and both Vantacor treatments. The untreated was again on the lower end of stands, although also intermediate amongst the treatments. Belay 4.5oz had the lower stands.

The relationship between midge abundance and yield is shown in Figure 6 and Figure 7 and that between midge abundance and stand count in Figure 8 and Figure 9. The graphs and relationships look very similar for the two different plant measures given the close linear relationship between these measures. These highlight the somewhat poor direct link in our trials between midge abundance and plant measures. For both, there are a large number of treatments that had fairly low midge counts, but plant measures that ranged from very low to very high.

For midge abundance, our results highlight a number of different treatments that can manage midges, along with some that do not manage midges. First, we did not find that the pyrethroids provided appreciable control of midge larvae. They were lower numerically, which was different than last year's study, where they were higher. We had previously suggested that midge management and tadpole shrimp/rice water weevil management could be in conflict if pyrethroids spiked midge populations. At the very least, it did not appear that pyrethroids can be relied upon for management of all of these arthropod pests, including rice seed midge. For materials that are otherwise typically used or possibly of utility for tadpole shrimp, we saw effects on midge abundance, especially for Vantacor (diamide) and Dimilin, and to a lesser degree Belay. For Dimilin and Belay, there was a rate response. Pyganic 5.0 surprisingly reduced midges more than at least the Warrior 1.28oz treatment. Most notably, the Bt-based product, Aquabac XT, did a very good job at managing midges. This material, along with some other Bt products, is labelled for use in rice fields for mosquito control currently. Importantly, even at reduced rates, it seemed especially promising for midge control.

The effects on plant measures were somewhat less clear. Aquabac XT clearly provided the best response, along with Vantacor. What was less clear was what was happening with many of the other treatments. A large number were simply no different than the untreated, even though they did have extremely good midge control. The relationship between plant responses and midge abundance was fairly muddled overall. It is possible that there is some sort of difference based on when larvae are affected and die. However, we did treat very early, so this does not seem like it would be the driver. However, no other driver can be suggested otherwise. It is clear that additional trial data could help elucidate these relationships.

We also applied all of our treatments at planting. This could be early relative to many cases commercially since treatments likely would not be applied until midges and possibly midge damage are apparent. It remains to be seen how these materials will behave if they are applied at a later timing.

Conclusions

Managing rice seed midge may differ from managing tadpole shrimp and rice water weevil with some materials providing good control of tadpole shrimp and rice water weevil, but slim to no control of rice seed midge. In addition, the Bt product we tested is fly-specific and thus is not anticipated to provide control of other pests. While we had different responses for midges than plant measures, we believe that this study continues our work to address rice seed midge management. It had been a fair bit of time since rice seed midge was researched in California and recent trials (2000's) do not appear to have been successful at evaluating the management of seed midge. We identified a number of materials that appear to help suppress rice seed midge and are continuing to learn how the management of rice seed midge will interact with the management of other key arthropod pests like tadpole shrimp.

OBJECTIVE 3. Remain informed of new and emerging invertebrate pests of rice in California, including those present in the other rice production areas of the U.S.

As in the past, we are still remaining aware of the brown marmorated stink bug, an invasive stink bug pest. Research by this project previously showed that the brown marmorated stink bug *can* feed on rice and cause peck. It thus far has not been an issue in rice, and there does not currently seem to be a high possibility of it spilling over from other crops into rice

During 2023, no new arthropod pests were found affecting rice in California. However, there are still a few organisms of concern in other areas of the US. The channeled apple snail remains a pest of concern that has been a problem in the southern states. This fresh-water snail has been present in California since at least 1997 (Contra Costa, Riverside, San Diego, Los Angeles, and Kern counties). If their distribution increases, they could threaten rice crops in California as they have in Asia. Currently, management is focused on preventing spread of this pest to new areas. In addition, we aim to stay apprised of any developing situations with invasive arthropod pests that could hinder California rice production.

In Texas, the rice planthopper (*Tagosodes orizicolus*) was found damaging ratoon rice in 2015 and then again in 2018. This planthopper can transmit the "hoja blanca" virus, and is therefore an insect of concern. The planthopper was found in Texas in the late 50's and early 60's, but then disappeared until 2015. This pest (and the virus) are still being studied in Texas.

CONCISE GENERAL SUMMARY OF CURRENT YEAR’S (2023) RESULTS:

Research activities outlined in the proposal for 2023 focused on tadpole shrimp and rice seed midge. The research emphases here reflects the relative significance of these pests to California rice, current management issues, and the research interests of the board.

Our work on tadpole shrimp this past year was devastated by some sort of pesticide drift, likely herbicide that can kill shrimp, at the rice experiment station. We almost fully deployed the trials, but were unable to gather useable data because shrimp were killed off very early. We had planned to evaluate a wide range of insecticides for tadpole shrimp management again using several study methodologies (open rings and trash cans+rings) and varied rates and timings for many of the materials. This research will remain important to find alternatives to pyrethroids for tadpole shrimp management and to understand the best fit and possible utility of these materials.

In the second year for our team, and for the first time in a while in California otherwise, we tested the efficacy of various insecticides against rice seed midge. We used similar methods to last year and used delayed flooding and planting to create conditions conducive to rice seed midge populations. We shifted to a ring-based trial from a berm plot trial due to some flooding issues in our field, but generated a solid dataset with this setup. We again found substantial variability among treatments in how they affected midge populations. Similar to last year, we saw that, management of tadpole shrimp and rice water weevil may not mirror management of rice seed midge. Specifically, pyrethroids do not appear to be especially effective for rice seed midge. A material that is in the registration pipeline for early season applications (chlorantraniliprole) was effective against seed midge. Furthermore, a Bt-based material was highly effective, even at low rates. Otherwise, some materials appeared to decrease midge populations but potentially not protect yields. Additional trials are needed to more fully evaluate these materials as well as effects of the treatments on the various measured variables.

We remained informed of possible new and invasive arthropod pests that could affect California rice. No new rice pests were found in California rice fields, and we hope that this trend continues into the future.

Figures and Tables

Table 1. Treatments tested or planned to be tested (later applications) in the open ring study for efficacy against tadpole shrimp. Costs given are rough estimates based on rate used and are only for material costs. Estimated cost is rounded to the nearest $0.50.

Trt#	Treatment	Rate	Units	Timing	Est. cost
1	Vantacor	1.6	fl oz/ac	Soil app preflood	$27.00
2	Vantacor	2.5	fl oz/ac	Soil app preflood	$42.50
3	Warrior II	1.28	fl oz/ac	Soil app preflood	$0.50
4	Vantacor	1.6	fl oz/ac	early, postflood	$27.00
5	Vantacor	2.5	fl oz/ac	early, postflood	$42.50
6	Warrior II	1.28	fl oz/ac	early, postflood	$0.50
7	Dimilin 2L	2	fl oz/ac	early, postflood	$8.00
8	Dimilin 2L	4	fl oz/ac	early, postflood	$16.00
9	Dimilin 2L	8	fl oz/ac	early, postflood	$32.00
10	Belay	2	fl oz/ac	early, postflood	$4.50
11	Belay	4.5	fl oz/ac	early, postflood	$10.00
12	Pyganic 5.0 EC	15.61	fl oz/ac	early, postflood	$62.00
13	Copper sulfate	217.60	oz/ac	early, postflood	$23.00
14	Dimilin 2L	4	fl oz/ac	later (~6mm carapace)	$16.00
15	Dimilin 2L	8	fl oz/ac	later (~6mm carapace)	$5.50
16	Pyganic 5.0 EC	15.61	fl oz/ac	later (~6mm carapace)	$62.00
17	Belay	2	fl oz/ac	later (~6mm carapace)	$4.50
18	Belay	4.5	fl oz/ac	later (~6mm carapace)	$10.00
19	Warrior II	2.56	fl oz/ac	later (~6mm carapace)	$1.50
20	Untreated	--	--	--	--

Table 2. Treatments planned to be tested in the trash can cage study for efficacy against tadpole shrimp

Trt#	Treatment	Active ingred.	Rate	Units	Timing
1	Warrior II		1.28	fl oz/ac	later (~5mm carapace)
2	Belay	Clothianidin	2	fl oz/ac	later (~5mm carapace)
3	Belay	Clothianidin	4.5	fl oz/ac	later (~5mm carapace)
4	Pyganic 5.0 EC	Pyrethrins	15.61	fl oz/ac	later (~5mm carapace)
5	Pyganic 5.0 EC	Pyrethrins	7.805	fl oz/ac	later (~5mm carapace)
6	Dimilin 2L	Diflubenzuron	2	fl oz/ac	later (~5mm carapace)
7	Dimilin 2L	Diflubenzuron	4	fl oz/ac	later (~5mm carapace)

Table 3. Trade name, active ingredient, mode of action (insecticide resistance management group), rates, and estimated material costs of treatments used in the rice seed midge trial**.** Estimated cost is rounded to the nearest $0.50.

Trt#	Treatment	Active ingredient	Rate	Rate	Est. cost
1	Untreated -normal	--			
2	Untreated-remove TPS	--			
3	Warrior II	lambda-cyhalothrin	1.28	fl oz/ac	$0.50
4	Warrior II	lambda-cyhalothrin	2.56	fl oz/ac	$1.50
5	Mustang Maxx	zeta-cypermethrin	4	fl oz/ac	$5.00
6	Belay	Clothianidin	2	fl oz/ac	$4.50
7	Belay	Clothianidin	4.5	fl oz/ac	$10.00
8	Pyganic 5.0 EC	Pyrethrins	7.805	fl oz/ac	$31.00
9	Pyganic 5.0 EC	Pyrethrins	15.61	fl oz/ac	$62.00
10	Vantacor	Chlorantraniliprole	1.6	fl oz/ac	$27.00
11	Vantacor	Chlorantraniliprole	2.5	fl oz/ac	$42.50
12	Dimilin 2L	Diflubenzuron	4	fl oz/ac	$16.00
13	Dimilin 2L	Diflubenzuron	8	fl oz/ac	$32.00
14	Dimilin 2L	Diflubenzuron	16	fl oz/ac	$64.00
15	Aquabac XT	Bt israelensis	32	fl oz/ac	$14.50
16	Aquabac XT	Bt israelensis	64	fl oz/ac	$29.00
17	Aquabac XT	Bt israelensis	128	fl oz/ac	$58.00

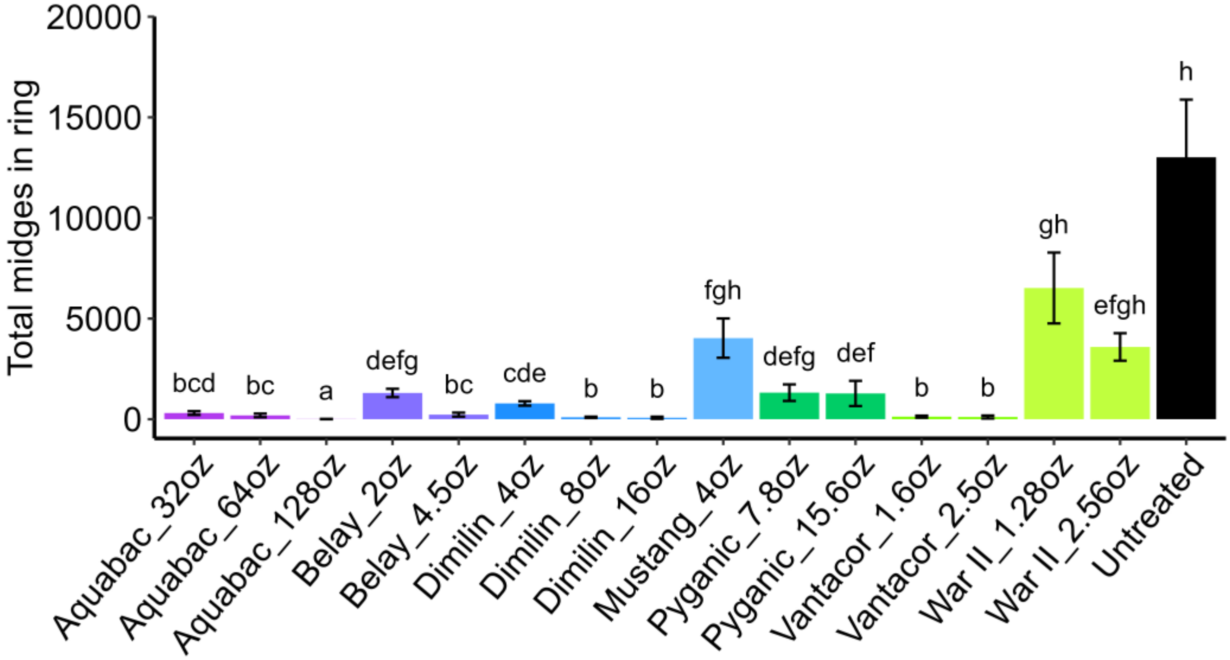

Figure 1. Rice seed midge abundance in 10.7 sq ft metal ring plots for different treatments. Values represent means across replicates. Means not sharing a level are significantly different based on posthoc comparisons and α = 0.05. Error bars are ± 1 SE.

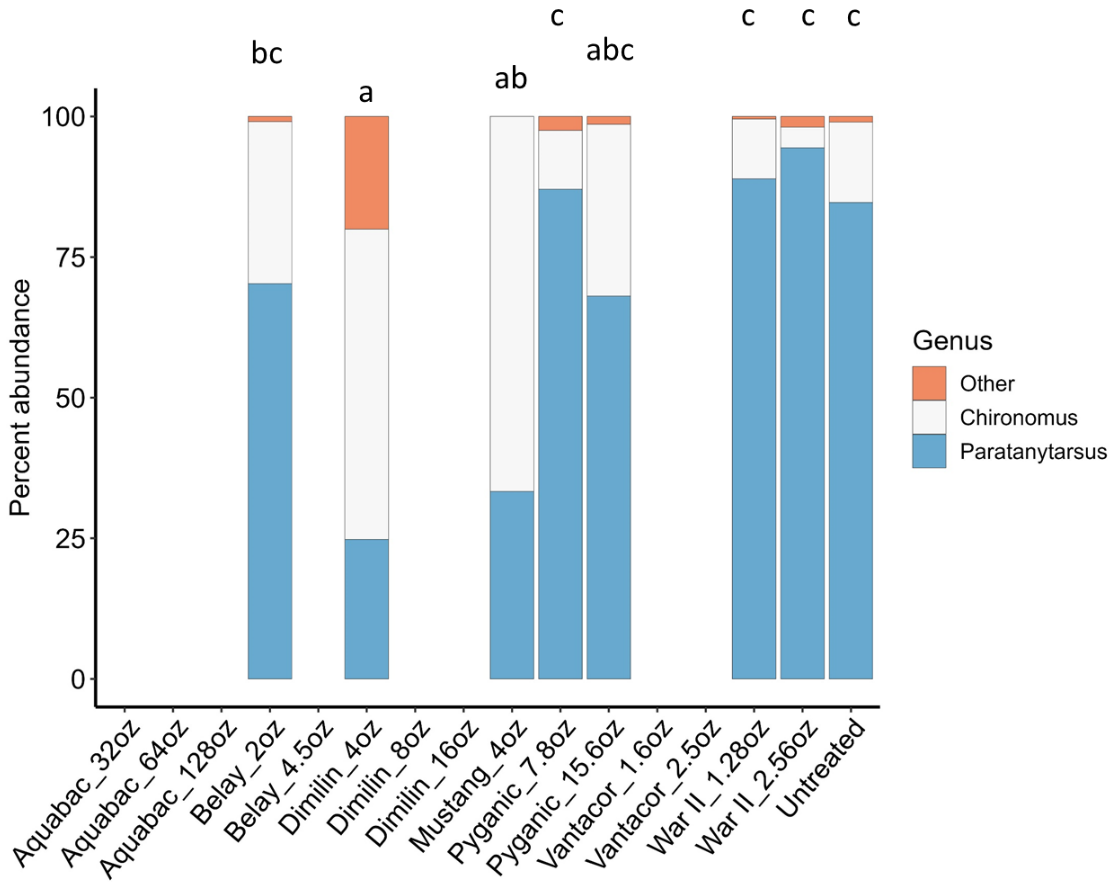

Figure 2. Percent abundance of the different midge genera among the different treatments. Treatments with no columns did not have sufficient replicates with >10 midges per sample or enough replicates to include in the anlaysis. Values represent means across replicates. Error bars are ± 1 SE.

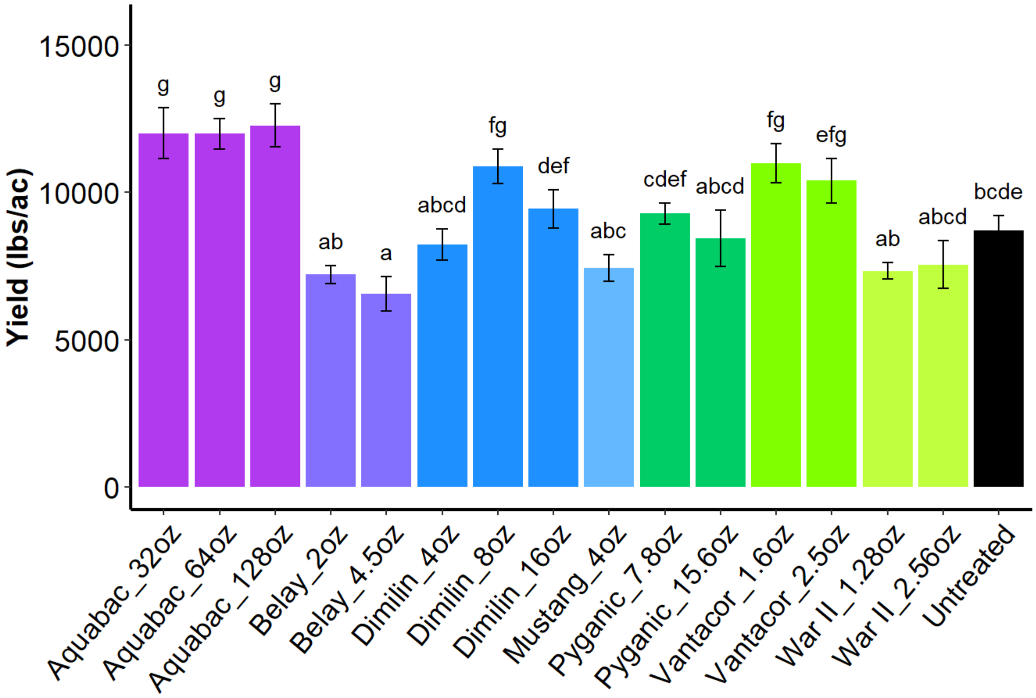

Figure 3. Yield in rings for the rice seed midge trial. There was no effect of treatment. Values represent means across replicates. Means not sharing a level are significantly different based on posthoc comparisons and α = 0.05. Error bars are ± 1 SE.

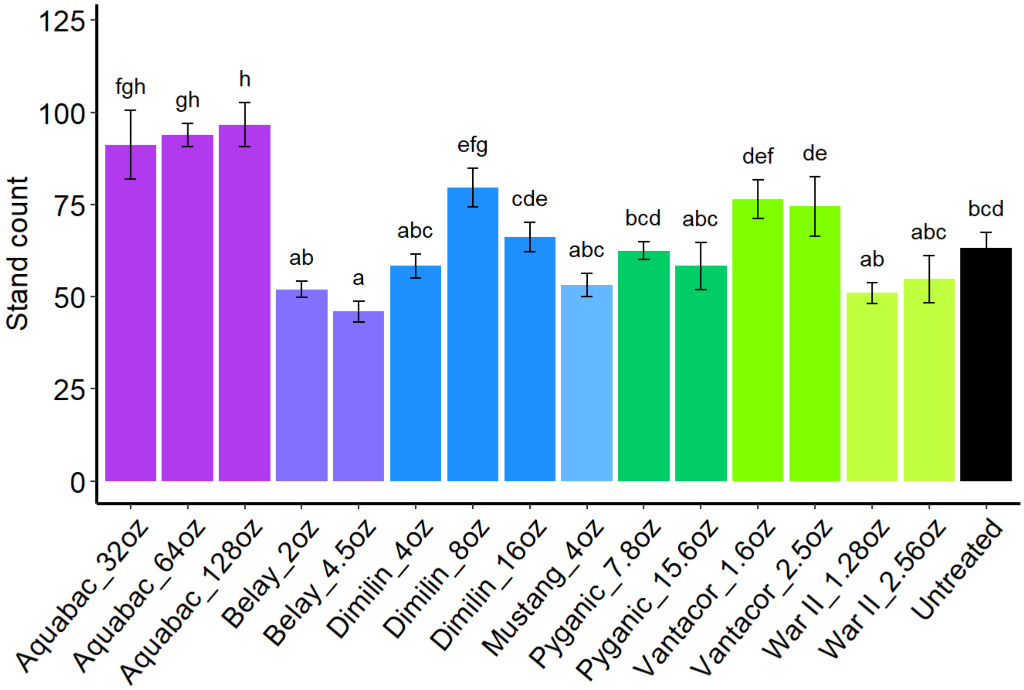

Figure 4. Stand count in rings for the rice seed midge trial. There was no effect of treatment. Values represent means across replicates. Means not sharing a level are significantly different based on posthoc comparisons and α = 0.05. Error bars are ± 1 SE.

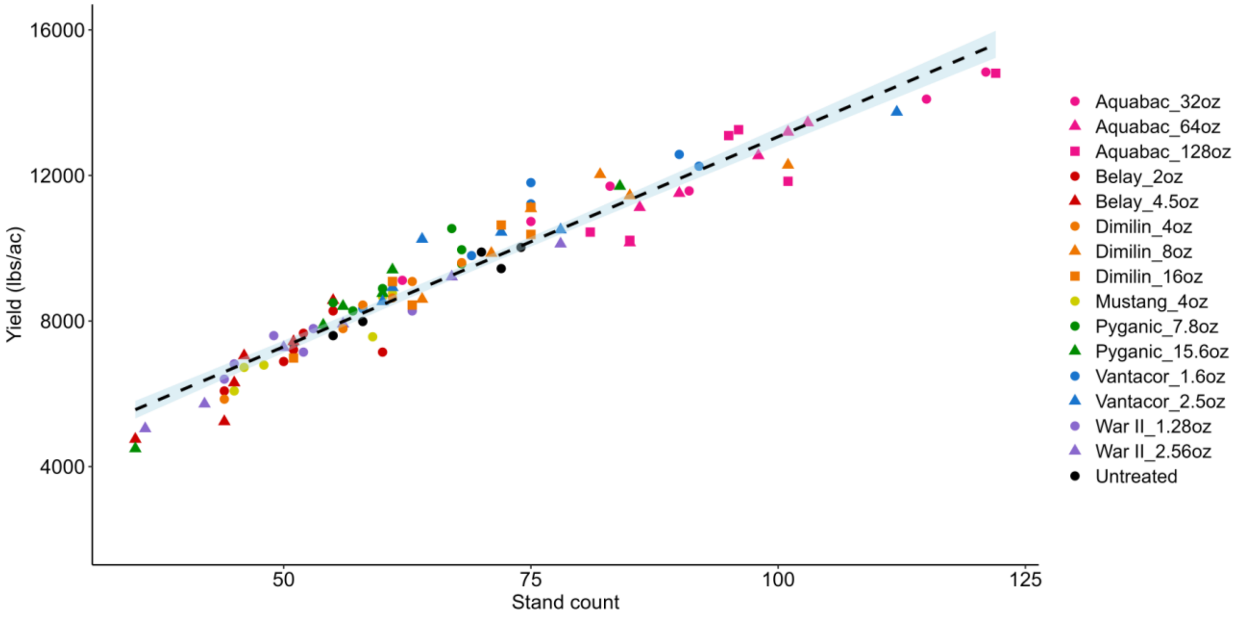

Figure 5. Relationship between stand count and yield for individual plots. Each point represents an individual plot, and treatments are denoted by points differing in color or shape. The line represents a linear smoothing function and the shaded portion is a 95% confidence interval.

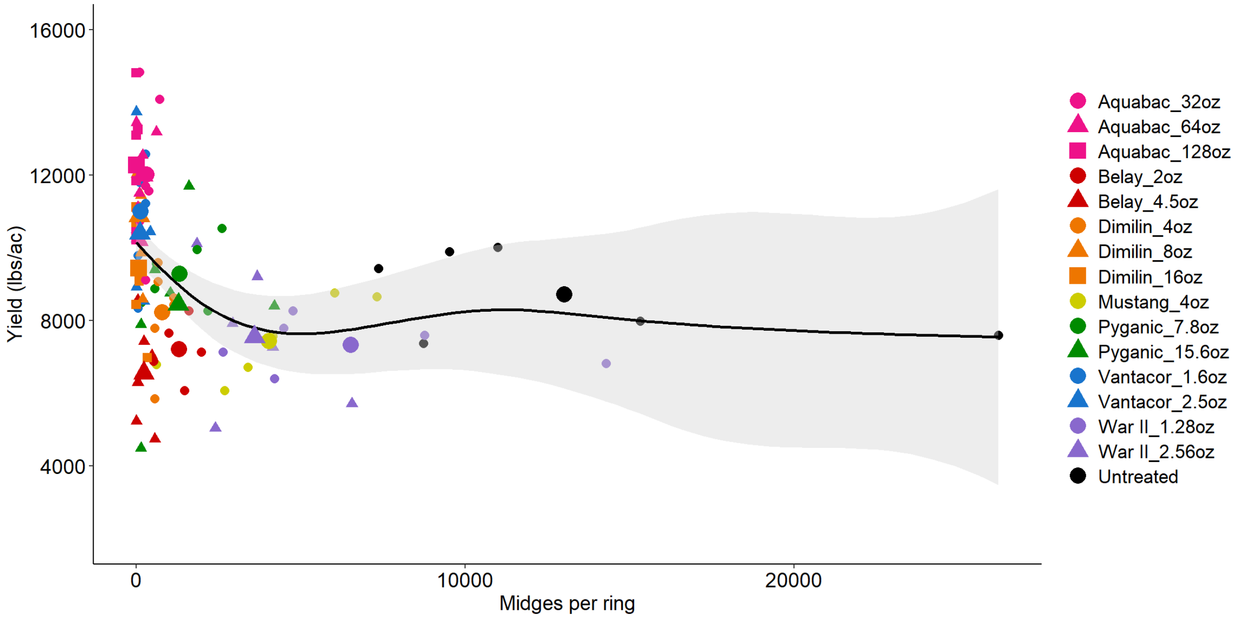

Figure 6. Relationship between midge count and yield for individual plots and across replicates for each treatment. Each small point represents an individual plot, and treatments are denoted by points differing in color or shape. The larger points represent means across plots for that treatment for both variables. The line represents a linear smoothing function based on a generalized additive model and the shaded portion is a 95% confidence interval.

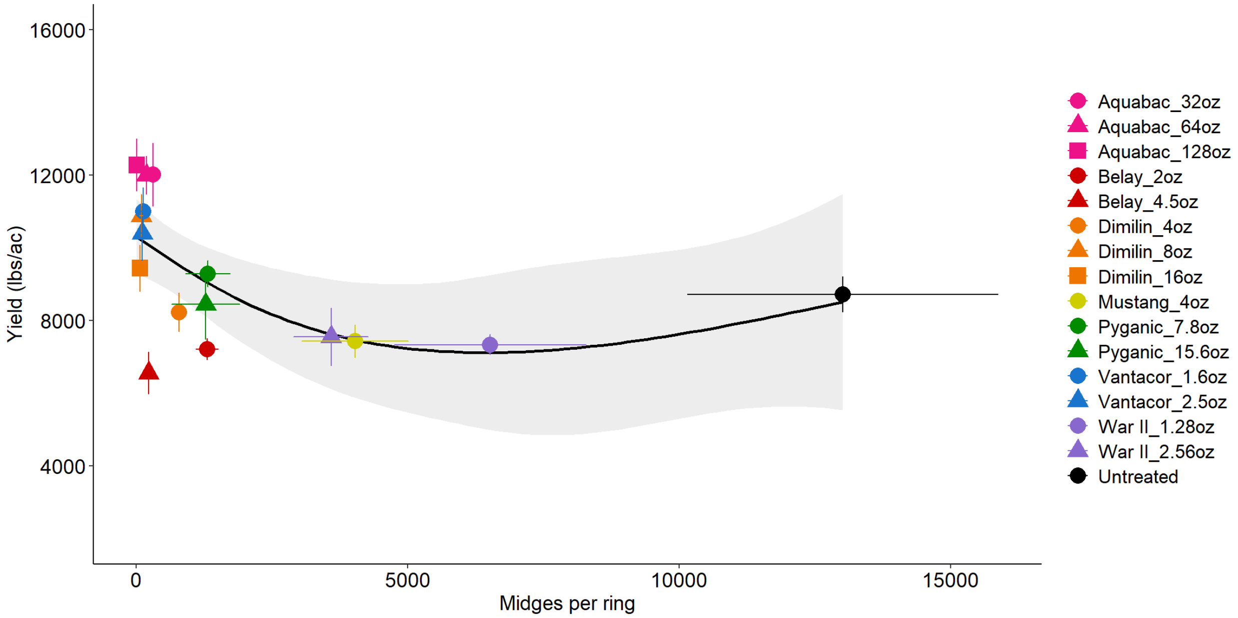

Figure 7. Relationship between midge count and yield for different experimental treatments. Treatments are denoted by points differing in color or shape. The larger points represent means across plots for that treatment for both variables. The line represents a linear smoothing function based on a generalized additive model and the shaded portion is a 95% confidence interval. Error bars are ± 1 SE for each variable.

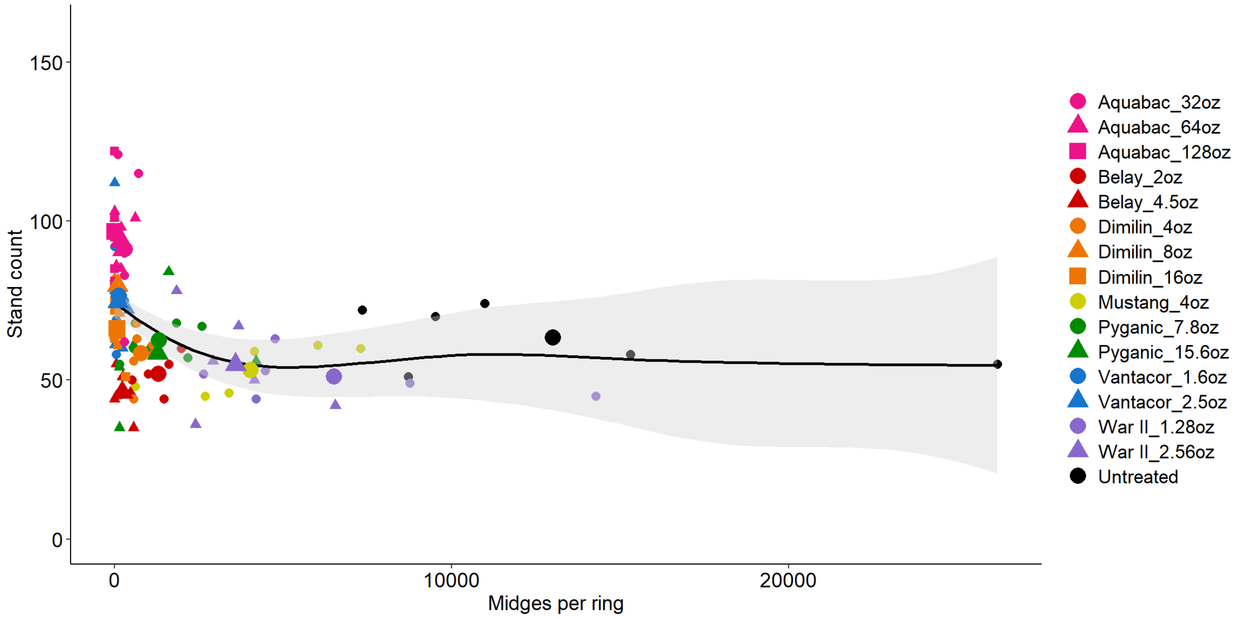

Figure 8. Relationship between midge count and stand count for individual plots and across replicates for each treatment. Each small point represents an individual plot, and treatments are denoted by points differing in color or shape. The larger points represent means across plots for that treatment for both variables. The line represents a linear smoothing function based on a generalized additive model and the shaded portion is a 95% confidence interval.

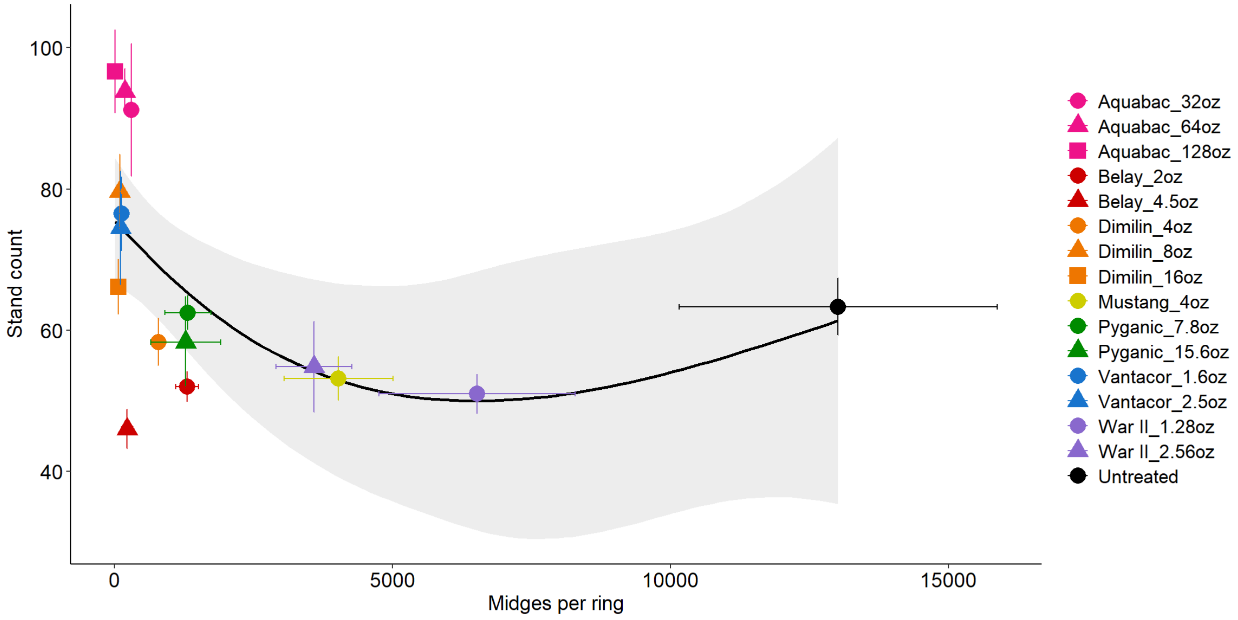

Figure 9. Relationship between midge count and stand count for different experimental treatments. Treatments are denoted by points differing in color or shape. The larger points represent means across plots for that treatment for both variables. The line represents a linear smoothing function based on a generalized additive model and the shaded portion is a 95% confidence interval. Error bars are ± 1 SE for each variable.