Integrating Organic Apple and Pork Production to Benefit Pest Management and Grower Profitability

Project Directors

Entomologist
Matt Grieshop

Animal Scientist
Dale Rozeboom

Plant Pathologist
George Sundin

Entomologist
David Epstein

Graduate Student
Krista Buehrer

PROJECT OVERVIEW

We are an interdisciplinary team from Michigan State University developing a farming system integrating rotational grazing of swine into organic tree fruit farms to provide ecologically based insect, disease, weed, and nutrient management while adding a new farm product: high value organic pork. Our long-term goal is to help growers optimize benefits to pest and soil nutrient management, while ensuring adequate swine health and development. Two approaches to integration were taken: 1) total integration of apple and pork production within an organic farm and 2) a partnership between an organic apple and a swine operation where hogs were rented for grazing periods timed to key management needs.

PROJECT RATIONALE

In modern agriculture, crop and animal production systems operate in isolation of one another and petrochemical based inputs are relied upon to correct deficiencies in farm health. Organic farmers cannot rely on petrochemicals to the extent their conventional counterparts do, and as such need alternatives to maintain farm health. Crop-livestock integration presents organic farmers with the opportunity to maintain farm health through management of pests and diseases that reduces the use of off-farm inputs. Rotational hog grazing in tree fruit systems provides an ecological management approach to reducing pest populations and pest damage to fruit over time. Every farm is different and the capacity to integrate hogs will vary, hence two levels of integration were explored. Producing hogs on farm allows for diversification of farm output by adding a high-value product to the farm. While partnering with local swine producers creates a rental market linking crop and animal production that adds value to hogs and provides valuable ecological management services to tree fruit systems.

PROJECT OBJECTIVES

1) Determine the potential insect pest, disease, weed, and nutrient management services provided by hogs grazing and rooting within orchard tree rows.
2) Determine the growth performance and parasite infection of grazing pigs.
3) Determine economic costs and benefits of orchard grazing systems.

Executive Summary

Methods overview: *We conducted a three year study on the feasibility, costs and benefits of integrating hogs and organic apple production. We measured hog grazing impacts on pests, weeds, diseases, soil, beneficials, the health of hogs in the system, and the economics of the system at two organic apple farms in MI. At the first farm we looked at a farrow to finish hog production model while at the second farm we explored the potential of "rental hogs" that came from a cooperating hog farmer and were returned following a grazing period.*

Hog Pest/Disease Management: *Codling Moth, Oriental Fruit Moth, and Plum Curculio populations were extremely low and nearly undetectable for most years due to a lack of fruit crops in 2010 and 2012. No differences were seen for pest abundances or fruit damage between grazed and control plots in any year. The incidence of apple scab was also extremely low during the project, with less than 1% of leaves having lesions in 2010 and 2012. Hogs did reduce the amount of leaf litter and the amount of leaves with scab lesions suggesting that grazing can potentially contribute to apple scab management. Hogs consistently decreased grass and forbs ground cover, while they increased bare ground. Hog ground disturbance effectively contributes to weed management.*

Hog Impacts on Soil: *Grazing hogs for short periods of time does not impact soil nutrient levels.*

Hog Health: *Parasite load was very low and never necessitated treatment. Preventing infection is key. Hogs should be sourced from non-infected stock and exposure to other animals and feces should be minimized. Due to hogs being active and burning more calories while in orchards, the rental hogs did not gain weight at the standard rate. Rental hogs had to be fed extra once removed from orchard plots to catch up to cohorts not grazed in the orchards.*

Hog Impacts on Non-targets: *Our data indicates hog grazing does not impact the abundance of flying or ground surface non-target insects or earthworms in organic apple orchards, thus ecosystem services provided by natural enemies are unlikely to be deleteriously impacted.*

Hog Stocking Rate: *Throughout the project, growers used a stocking density of 12 hogs per acre. Hogs usually ranged in size from 40 to 80 lbs. Hogs were never grazed in plots larger than 2 acres, and such a high stocking rate is likely not feasible beyond a 3 acre plot size. In year 3 of the project, we determined the stocking rate of 12 hogs per acre is sufficient to achieve a moderate level of ground disturbance in the absence of apples in a time period of 7 days when hogs have no experience and 4 days when hogs have previous experience. Hogs begin rooting at the ends of plots and work their way in towards the center of plots. For hogs to achieve uniform moderate ground disturbance, plots should most likely be square in shape and 1 acre or less in size. In 1 acre plots, hogs should be rotated every 4 to 5 days.*

Economics: *Hog grazing reduced mowings and cultivations at both farms, as well as kaolin spray applications at Country Mill. Such reductions make the rental model economically beneficial to a small degree, while the farrow-to-finish model was not economically beneficial. Hogs reductions of insect damage to fruit (as seen in other experiments) creates more tangible economic benefits.*

Future research: *Future research topics identified by this project include: the feasibility of additional livestock in orchards, whether and how rotational or flashed grazed animals might impact the consumer safety of fruit produced, the feasibility of whole carcass hog sales to local consumers, and the development of improved hog forages that can be underplanted in orchards.*

Methods

Farms and Hogs: Hogs were rotationally grazed at two organic apple orchards: Jim and Karen Koan's AlMar Orchards in Flushing, MI (AlMar) and Steve Tennes's Country Mill Orchards in Charlotte, MI (Country Mill). Jim Koan breeds and farrows Berkshire hogs (**Fig. 1**) on farm, while Steve Tennes rents Duroc mix hogs (**Fig. 2**) from MI organic pork producer Aaron Keilen.

Fig. 1: Berkshire Hogs

Fig. 2: Duroc mix Hog

Three ungrazed and three grazed 2 acre experimental plots were established at AlMar (**Fig. 3)** for all three years. Three ungrazed and three grazed plots were established at Country Mill in 2010, four of each in 2011, and six 1 acre grazed plots in 2012. . Plots were two acres at AlMar and one acre at Country Mill. Every other tree row was strip-tilled on a monthly basis at AlMar for 2010 and all tree rows were strip-tilled in 2011 and 2012. Tree rows at Country Mill were not strip-tilled. At AlMar, a single group of 24 hogs was rotationally grazed in all 3 years. At Country Mill, 16 hogs were grazed per plot in 2010 and 2011 and 12 hogs per plot n 2012.

Fig. 3: Almar plots. Orange-grazed; blue-control. Red markers are gates to hog pen area with shelter.

Hogs were grazed at each farm during 'June drop' to consume dropped apples. Hogs were also grazed in April 2010 prior to bloom and November 2011 after leaf fall at AlMar to disturb and/or consume old leaf matter and disrupt apple scab inoculum. Hogs could not be grazed during spring of 2011 or 2012 because of unfavorably wet soil conditions.

At AlMar during 'June drop', the hogs were rotationally grazed once through plots for two weeks per plot in 2010, once through plots for one and half weeks in 2011, and twice through plots for one and half weeks per plot in 2012. At Country Mill during 'June drop', hogs were rotationally grazed once through plots for one week per plot in 2010 and once through plots for two weeks per plot in 2011 and 2012.

Insect Monitoring: Insect monitoring traps were set up in each plot in all project years. At AlMar, one Codling Moth (CM) (**Fig. 4**) and one Oriental Fruit Moth (OFM) pheromone trap (**Fig. 5**) were placed near the center of each plot. Two screen traps (**Fig. 6**) and two pyramid traps (**Fig. 7**) with plum essence lures were placed near the edges of each plot to track Plum Curculio (PC) (**Fig. 8**). At Country Mill, two CM and two OFM delta pheromone traps were placed a third of the way into each plot from either end in 2010 and one of each near the center in 2011. Four PC screen traps

Fig. 4: Codling Moth

Fig. 8: Plum Curculio

Fig. 5: Delta Trap

with plum essence were placed near the edges of each plot in 2010, and two screen traps along with two pyramid traps were used in 2011.

Fig. 6: Screen Trap

Fig. 7: Pyramid Trap

June Drop Apples and Insect Damage: In 2010 and 2012 there was a near total crop failure at both sites making it impossible to accurately assess insect damage or 'June Drop'. In 2010, two plots at AlMar had a patch of trees with apples, so insect damage and June drop measurements were taken with the knowledge they were not totally representative. Insect damage was measured by counting PC stings (**Fig. 9**), CM stings and CM/OFM entry wounds (**Fig. 10**) per apple on, 400 and 600 fruit per plot at the Country Mill and AlMar, respectively. In 2010 we were only able to collect 100 fruit from the two AlMar plots with fruit. To evaluate 'June Drop' we counted all dropped apples beneath 20 trees in each plot. 'June Drop' apples were collected, and kept on vermiculite to assess PC emergence.

Fig. 9: PC Ovipositional Sting

Fig. 10: CM/OFM Larval Entry

Disease Monitoring: We measured Apple scab at AlMar by sampling 20 leaf terminals per tree on 25 random trees per plot. Leaves were rated as either infected or not infected. Sampling took place on June 3, 2010, June 15, 2011, and May 11, 2012. Three 10 meter transects were established in each plot at AlMar to measure the percentage of leaf ground cover in order to assess possible hog impact on apple scab. Readings were taken at every meter using a Daubenmire frame (20 cm x 50 cm) prior to and after hog grazing in the spring and fall of years grazed. Leaves within each frame were collected dried and weighed to determine biomass.

Weed Monitoring: Three 30 m transects were established in each plot to monitor ground cover at AlMar for all three years and Country Mill for 2010 and 2011. In 2012 at Country Mill, three 90 m transects were established in each plot. Readings were taken every meter along a transect using a Daubenmire frame (**Fig. 11)** for 30 m transects and every 3 meters for 90 m transects. The percentage ground cover of grass, forbs, bare ground, and hog feces was monitored over the course of each growing season for 30 m transects 4-8 times per year. Ground cover was monitored every day for the 90 m transects during the time the hogs were in the plots. At the end of each growing season we collected all the above ground biomass from every 3rd quadrat and then dried and weighed it.

Fig. 11: Daubenmire PVC Frame and Tape Measure along a transect.

Soil and Leaf Nutrients: Composite soil samples consisting of 15 cores per plot were collected to a depth of 8 in. Samples consisting of 50 leaves were collected annually in late July.

Hog Health: Blood, tongue, heart and diaphragm samples were collected from 7 to 8 hogs from both farms. Sera were tested for *Toxoplasma gondii* antibodies. *Trichinella spiralis* was analyzed by tissue digestion, larval counting in-chamber, and examination.

Non-target Impacts: Impacts of hogs on non-target insects and annelids were measured at AlMar in 2012. Flying insects were sampled by placing 12 non-baited yellow sticky cards (**Fig. 12**) 6 ft off the ground in the tree canopy in each plot. Soil surface insects were sampled by placing 12 pitfall traps (**Fig. 13**) within each plot. Sticky cards and pitfall traps were evenly distributed within each plot, and they were placed in plots for one week prior to and after hog grazing.

Fig. 12: Sticky Card

Fig. 13: Pitfall Trap

Earthworms were sampled for by taking 12 soil cores in each plot (**Fig. 14**). Each soil core was 40 x 40 x 25 cm (h x w x d). Soil cores were hand sorted for earthworms. While hand sorting, 2 L of a hot mustard solution was poured into the soil core hole and allowed to soak in for 20 min to force deeper dwelling species to the surface. We sampled for earthworms once prior to hog grazing and once after hog grazing.

Fig. 14: Earthworm sampling

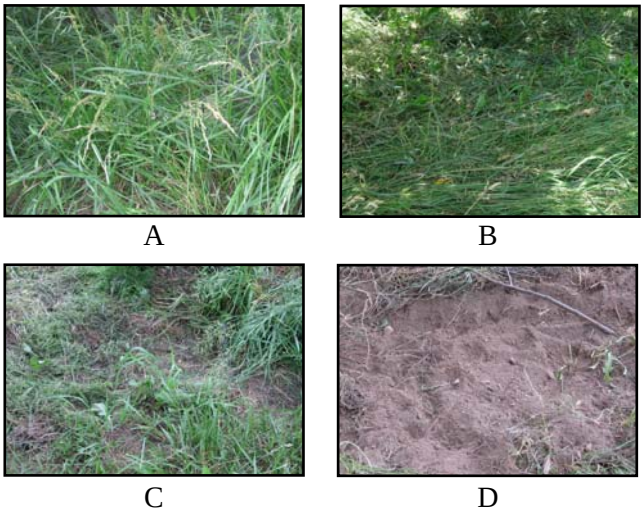
Ground Disturbance: In 2012 we performed an experiment to determine the impact of hogs on orchard floors. Ground disturbance was measured in two runs of three, 1 acre experimental plots at the Country Mill. Plots were subdivided into a grid, so that each tree and adjacent drive row area were in a 8' wide and 10' long box and 7' wide and 10' long box, respectively. We assesed ground cover disturbance daily in each grid over a 14 day period beginning one day prior to grazing.

Ground disturbance was quantified using a two factor categorical scale. The first factor was coverage type: 1 = Undisturbed, 2 = Grass, 3 = Intermediate, and 4 = Bare (**Fig. 15**). The second factor was a four point percentage area covered by each respective coverage type: 0=0%, 1=25%, 2=50%, 3=75%, and 4=100%.

We created a composite disturbance severity metric to visualize disturbence.

$$D = \frac{\Sigma(C \times R)}{12}$$

Where D is the composite disturbance value, C is the category value, and R is the percentage rating for each category.



A B C D

Fig. 15: A-Undisturbed; B-Grazed Grass; C-Intermediate; D-Bare Ground

Results

Pest and Disease Management

Insect Pest Management: In 2010 at AlMar, PC populations were undetectable. CM populations averaged averaged <5 on sampling dates in both grazed and control plots (with the exception of one day in grazed plots) (**Fig. 16**). There were no significant differences for any pest populations between treatments at AlMar in 2010.

In 2010 at Country Mill, CM populations averaged < 8 on sampling dates in both grazed and control plots **(Fig. 17**). OFM populations were undetectable. PC populations were nearly undetectable, with trap catches only occurring on 3 days

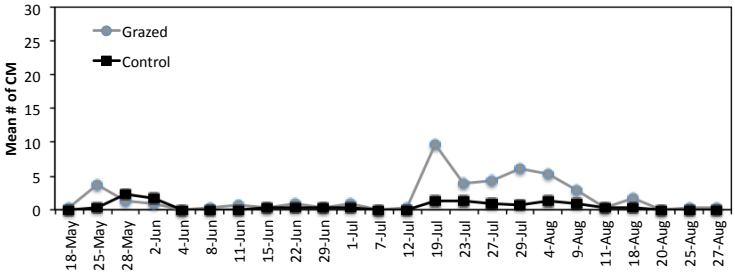


Fig. 16: 2010 AlMar Trap Data- mean number of Codling Moth caught in grazed and control plots.

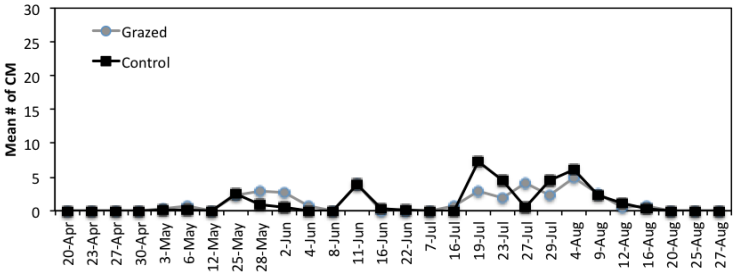


Fig. 17: 2010 Country Mill Trap Data- mean number of Codling Moth caught in grazed and control plots.

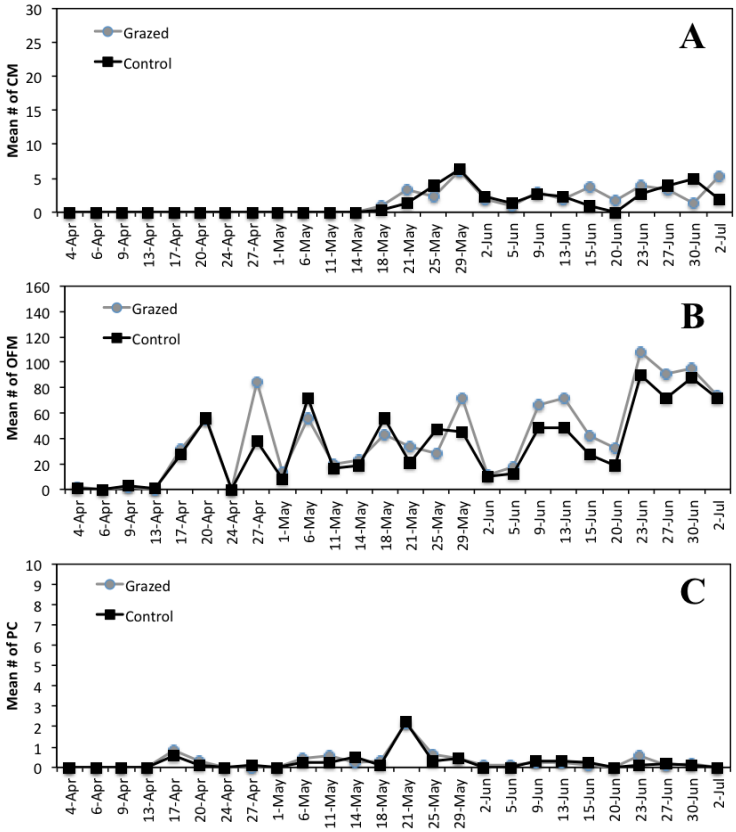


Fig. 18: 2012 AlMar Trap Data -**A**) mean number of Codling Moth caught; **B**) mean number of Oriental Fruit Moth caught; **C**) mean number of Plum Curculio caught.

*Note the different scale on each graph

throughout the growing season with an average of < 1 for both grazed and control plots. There were no significant differences for any pest populations between treatments at Country Mill in 2010.

In 2011 at AlMar, CM populations were extremely low with populations averaged < 2 for most sampling dates (except on 7-June where trap catch averaged < 7) in both grazed and control plots. OFM populations peaked 7-June with trap catches averaging between 25 and 65 in both grazed and control plots. There were no significant differences for any pest populations between treatments at AlMar in 2011.

In 2011 at Country Mill, CM and OFM populations were nearly undetectable with trap catches occurring on only 4 days with an average of < 1 for both grazed and control plots. PC populations were very low with averages < 1 throughout the season in both grazed and control plots. There were no significant differences for any pest

populations between treatments at Country Mill in 2010.

In 2012 at AlMar, CM populations averaged < 7 on sampling dates in both grazed and control plots **(Fig. 18-A**). OFM populations fluctuated greatly throughout all sampling dates with averages between 0 and 108 in grazed plots and averages between 0 and 90 in control plots **(Fig. 18-B**). PC populations were nearly undetectable with trap catches occurring only on 3 days with averages < 3 in both grazed and control plots **(Fig. 18-C**). There were no significant differences for any pest populations between treatments at AlMar in 2012.

'June drop' Apples and Insect Fruit Damage: In 2010 at AlMar, the initial damage evaluation was only feasible in one block with 206 out of 400 apples exhibiting PC stings. 'June drop' sampling was feasible in two blocks with 913 and 259 fruit collected over the course of 4 weeks in a grazed and control plot respectively. A total of 163 and 28 PC emerged from apples from the grazed and control plot respectively. A total of 83 and 43 OFM larvae emerged from apples from grazed and control plots respectively. At Country Mill, fruit damage evaluation and dropped fruit collection was not possible due to lack of fruit.

In 2011 at AlMar, an average of 3.2% (±0.2 SEM) and 5.1% (±0.9 SEM) apples had CM/OFM larval entry woulds in grazed and control plots respectively in July from the first generation of adults (**Fig. 19-A**). In August, an average of 5% (±2.2 SEM) and 4.3% (±3.1 SEM) of apples had CM/OFM larval entry wounds in grazed and control plots respectively from the second generation (**Fig. 19-A**). An average of 20.8% (±6.8 SEM) and 17.5% (±6.8 SEM) of apples had PC ovipositional stings in grazed and control plots respectively in June (**Fig. 19-B**). An average of 4.6% (±2.0 SEM) and 4.6% (±1.7 SEM) of apples had PC ovipositional stings in grazed and control plots respectively in August (**Fig. 19-B**). There were no significant differences between treatments at either sampling date for insect fruit damage. The number of 'June drop apples' from beneath 40 trees was 1451 from the first week, 390 from the

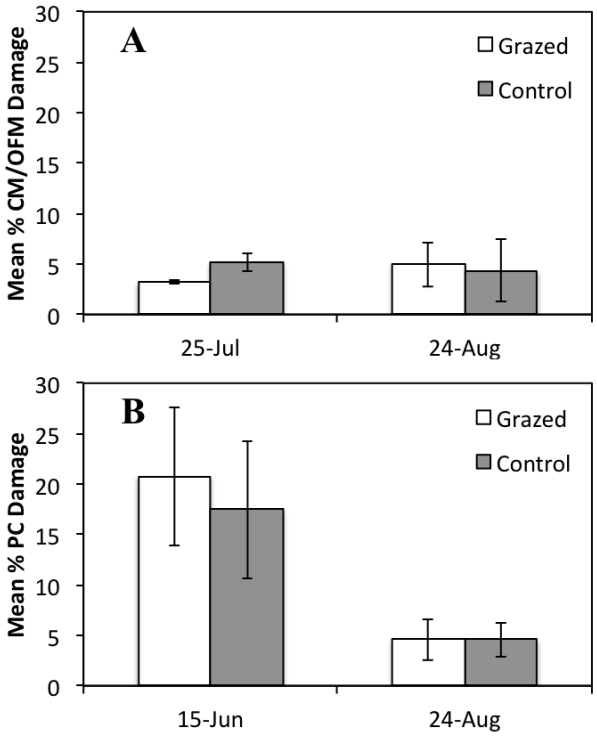


Fig. 19: 2011 AlMar - **A**) percentage of fruit with CM/OFM larval entry wounds; **B**) percentage of fruit with PC ovipositional stings.

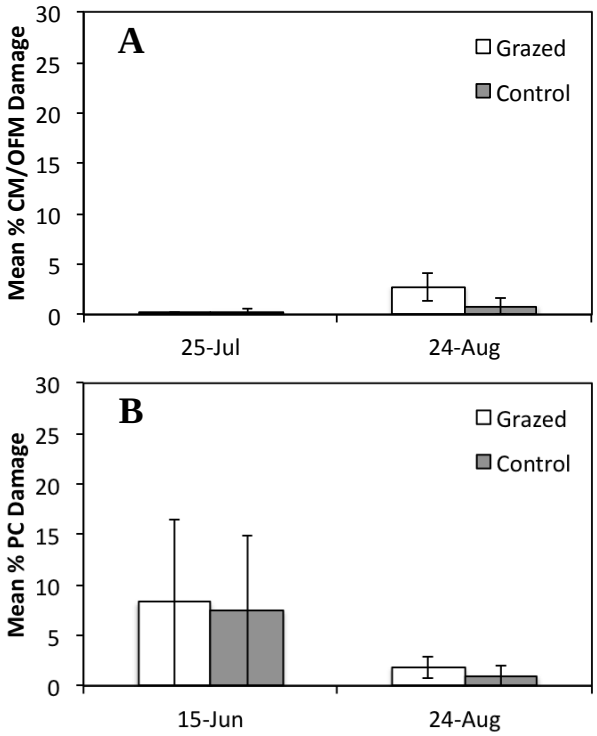


Fig. 20: 2011 Country Mill - **A**) percentage of fruit with CM/OFM larval entry wounds; **B**) percentage of fruit with PC ovipositional stings.

second week, and 12 from the third week. A total of 61 PC larvae emerged from the collected apples, 57 of which emerged from the apples collected in the first week.

In 2011 at Country Mill, an average of 0.2% (±0.1 SEM) and 0.3% (±0.3 SEM) apples had CM/OFM larval entry woulds in grazed and control plots respectively in July from the first generation of adults (**Fig. 20-A**). In August, an average of 2.8% (±1.4 SEM) and 0.8% (±0.8 SEM) of apples had CM/OFM larval entry wounds in grazed and control plots respectively(**Fig. 20-A**). An average of 8.3% (±8.3 SEM) and 7.4% (±7.4 SEM) of apples had PC ovipositional stings in grazed and control plots respectively in June (**Fig. 20-B**). An average of 1.8% (±1.1 SEM) and 1% (±1.0 SEM) of apples had PC ovipositional stings in grazed and control plots respectively in August (**Fig. 20-B**). The number of 'June drop' apples from beneath 40 trees was 755 from the first week, 558 from the second week, and 205 from the third week. A total of 196 PC larvae emerged from the collected apples, 101 of which emerged from the apples collected in the first week.

In 2012, fruit damage evaluation and dropped fruit collection was not possible due to lack fruit at either farm.

Disease Management: In 2010 at AlMar, prior to grazing the mean (±SEM) percentage of leaf ground cover in grazed plots was 42.3% (±2.13) in grazed plots and 48% (±1.58) in control plots (**Fig. 21-A**). After hogs were grazed, the mean (±SEM) percentage of leaf ground cover in grazed plots was 5.56% (±0.77) and 12.28% (±0.86) in control plots (**Fig. 21-A**). There was no significant difference between leaf ground cover prior to hogs grazing (t=1.11, d.f.=4, p=0.328). The hogs had a negative impact on leaf ground cover, which was marginally significant (t=2.39, d.f.=4, p=0.075). The mean (±SEM) biomass of leaf matter before hogs in grazed plots was 16.20g (±1.02) and 16.72g (±0.77) in control plots (**Fig. 21-B**). The mean (±SEM) biomass of leaf matter after hogs in grazed plots was 1.68g (±0.28) and 4.55g (±0.40) in control plots (**Fig. 21-B**). No significant difference was detected between treatments for biomass prior to the grazing (t=0.81, d.f.=4, p=0.464) but the hogs lowered the biomass of leaf matter at a marginally significant level after grazing (t=2.52, d.f.=4, p=0.065). The overall occurrence of apple scab at AlMar in the experimental plots was very low. Only 0.28% of leaves sampled in grazed plots and 0.44% of leaves in control plots were infected with apple scab. While this represents an 36% reduction in infected leaves it was not found to be significantly different (t=1.31, d.f. =4, p=0.259).

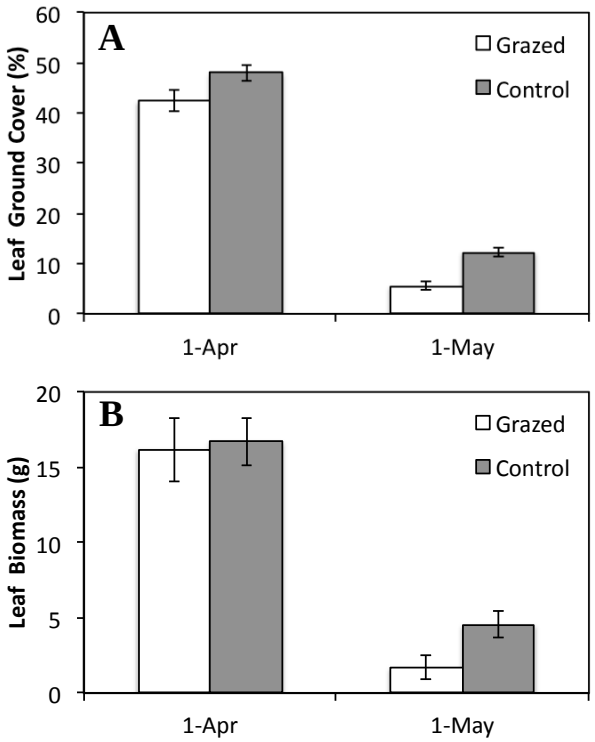


Fig. 21: 2010 AlMar Apple Scab Data - **A**) percentage of leaf ground cover; **B**) leaf biomass in grazed and control plots.

In 2011, apple scab was not detected. In 2012, apple scab was detected at extremely low levels similar to 2010. Only 0.32% of leaves sampled in grazed plots and 0.80% of leaves in control plots were infected with apple scab. While this represents an 60% reduction in infected leaves it was not found to be significantly different (t=1.78, d.f. =4, p=0.149).

Weed Management: In 2010 at AlMar, the mean (±SEM) percentage grass cover ranged from 27.77%(±1.07) to 4.27%(±0.57) in tilled rows (**Fig. 22-A**) and from 40.54%(±1.64) to 8.17% (±0.80) in untilled rows (**Fig. 22-B**). Hogs significantly decreased percentage grass ground cover in untilled rows ($p<0.001$), whereas they did not have a significant impact in tilled rows ($p=0.26$). The mean (±SEM) bare ground cover ranged from 27.03%(±1.26) to 92.03%(±0.74) in tilled rows (**Fig. 22-C**) and from 22.38%(±1.81) to 85.17%(±1.23) in untilled rows (**Fig. 22-D**). Hogs significantly increased bare ground in untilled rows ($p<0.001$), whereas they did not have a significant impact in tilled rows ($p=0.78$). Analysis of weed biomass at AlMar is forthcoming.

In 2010 at Country Mill, The mean (±SEM) percentage grass cover ranged from 42.15%(±1.33) to 77.78%(±0.88) in grazed and control plots. Although there was slightly less grass in grazed plots, hogs did not have a significant impact on grass ground cover ($t=2.11$, $d.f.=4$, $p=0.10$). The mean (±SEM) percentage bare ground cover ranged from 3.30%(±0.36) to 10.11%(±1.23) in grazed and control plots. Hogs did not have a significant impact on bare ground cover ($t=1.64$, $d.f.=4$, $p=0.17$), and percentage bare ground remained consistent over time in both treatments (Fig. 8). The mean (±SEM) biomass in grazed plots was 21.73g (±1.01) and 22.57g (±0.90) in control plots, and we did not detect a significant difference between the two ($t=1.00$, $d.f.=4$, $p=0.37$).

In 2011 at AlMar, the mean grass ground cover ranged from 38.4% to 16.0% in the plots throughout the season. The mean forbs ground cover ranged from 52.6% to 21.5% in the plots throughout the season. The mean grass and forbs ground cover was higher in grazed plots as compared to control plots. The mean bare ground ranged from 40.6% to 8.9% in the plots throughout

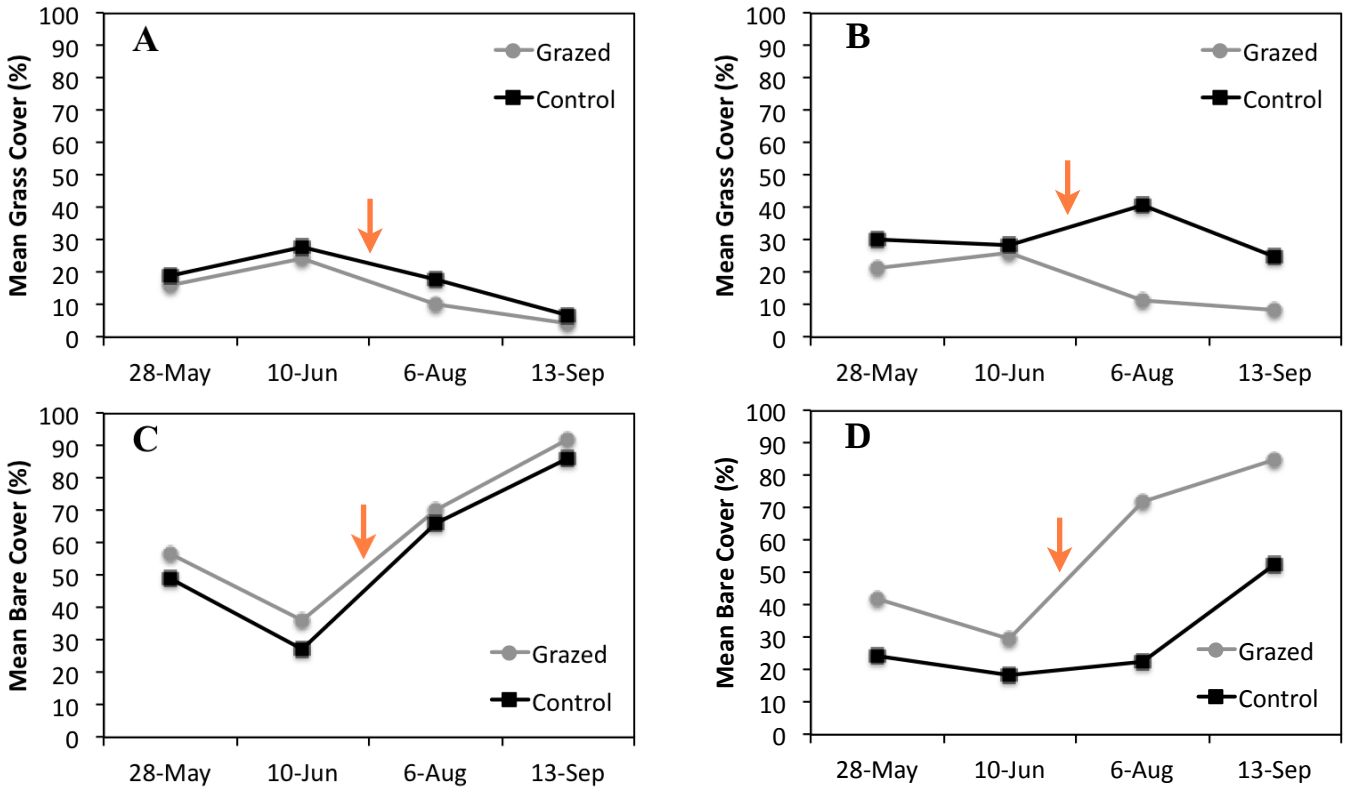


Fig. 22: 2010 AlMar Tilled and Untilled Weed Transect Data in -**A**) mean percentage grass ground cover in tilled rows; **B**) mean percentage grass ground cover in untilled rows; **C**) mean percentage of bare ground in tilled rows; **D**) mean percentage of bare ground in untilled rows. The arrow indicates when hogs were released.

the season. Bare ground was higher in control plots than grazed plots.

In 2011 at Country Mill, the mean grass ground cover ranged from 77.3% to 53.6% in the plots throughout the season (**Fig. 23-A**). The mean grass ground cover was higher in grazed plots as compared to control plots (**Fig. 23-A**). The mean forbs ground cover ranged from 14.4% to 46.1% in the plots throughout the season (**Fig. 23-B**). The mean forbs ground cover decreased slightly in grazed plots as compared to control plots (**Fig. 23-B**). The mean bare ground ranged from 0.04% to 8.2% in the plots throughout the season (**Fig. 23-C**). Hogs increased the mean bare ground increased in grazed plots as compared to control plots.

In 2012 at AlMar, hogs decreased grass and forbs ground cover while increasing the amount of bare ground (**Fig. 24-A,B,C**). The mean grass ground cover ranged from 29.7% to 54.5% in

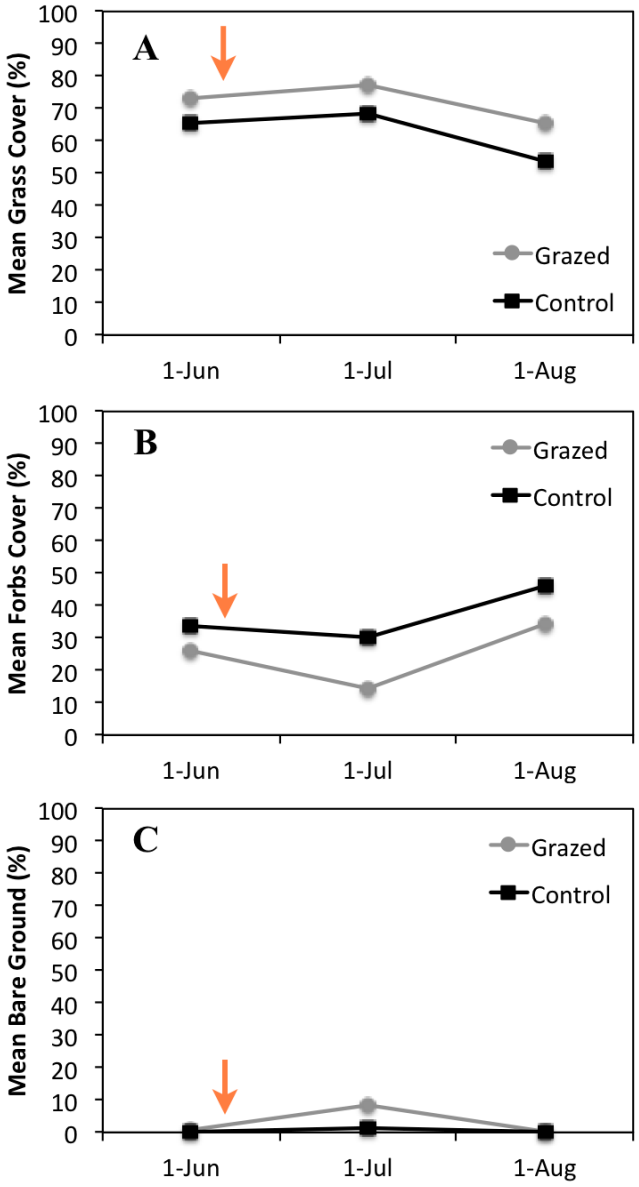


Fig. 23: 2011 Country Mill Weed Transect Data -**A**) mean percentage grass ground cover; **B**) mean percentage forbs ground cover; **C**) mean percentage bare ground. The arrow indicates when hogs were released.

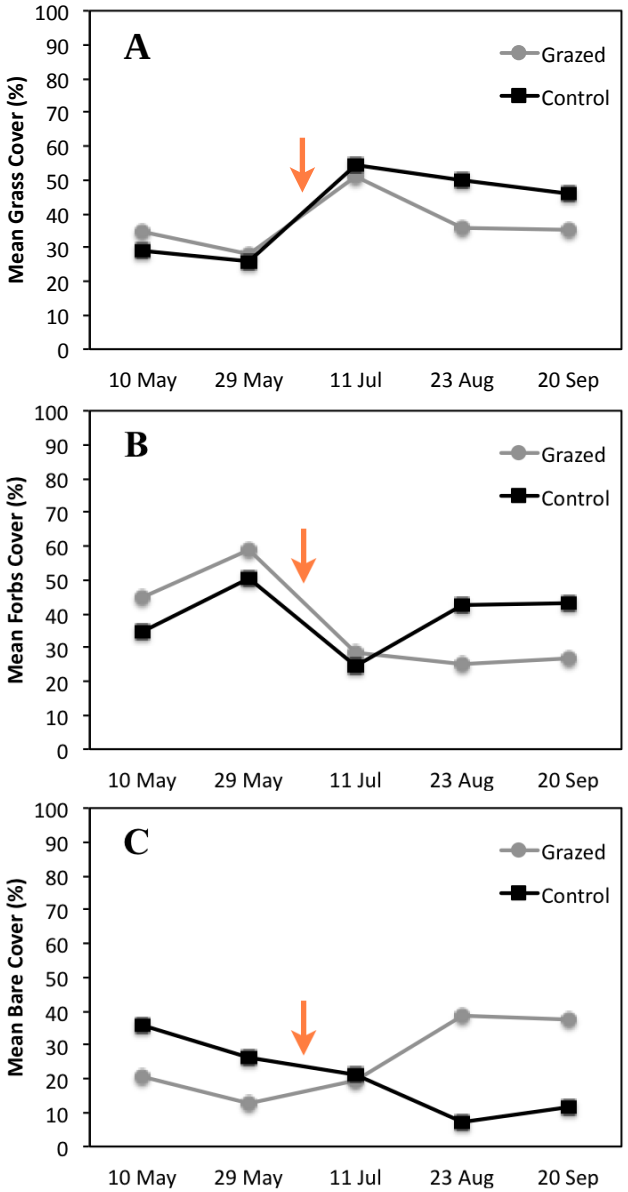


Fig. 24: 2012 AlMar Weed Transect Data -**A**) mean percentage grass ground cover; **B**) mean percentage forbs ground cover; **C**) mean percentage bare ground. The arrow indicates when hogs were released.

control plots and 28.1% to 51.7% in grazed plots during the season (**Fig. 24-A**). The mean forbs ground cover ranged from 24.3% to 50.7% in control plots and 25% to 58.9% in grazed plots during the season (**Fig. 24-B**). The mean bare ground ranged from 7.2% to 36% in control plots and 12.6% to 38.8% in grazed plots (**Fig. 24-C**).

Impacts on Soil Nutrients

The soil type at both AlMar and Country Mill is mineral. Hogs did not appear to impact soil content (**Table 1**). **Table 1** shows the mean values of soil contents for 2012. The results from 2010 and 2011 were similar.

	Before Hogs		After Hogs	
	Grazed	Control	Grazed	Control
pH	6.8	6.6	6.8	6.6
Phosphorus (ppm)	27	25.67	40	25.67
Potassium (ppm)	72	80	124.33	107.67
Magnesium (ppm)	239.93	224.33	221.67	232.67
Calcium (ppm)	1096.67	1049.33	1277.33	1215
Nitrate-N (ppm)	1.0	0.8	2.5	3.5
Ammonium-N (ppm)	1.77	2.13	1.9	2.83
Organic Matter (%)	3.47	3.07	3.4	3

Table 1: 2012 Soil Data - mean values of soil contents and characteristics before and after grazing.

Hog Health

All samples tested were negative for *T. gondii* and *T. spiralis*. Only a "few" *Balantidium coli* eggs and Coccidial oocysts were found in 12.5% of the samples, suggesting a very low prevalence of these two parasites in outdoor swine when fields are consistently rotated and the density of swine on a given field is moderate to low. There were no indications of infection by any other parasites.

In 2010, two rental hogs at Country Mill died of pneumonia. No hog deaths occurred at AlMar during the course of experiments. Hog weight remained at healthy levels during grazing periods. However, hogs did not gain as much weight compared to cohorts not grazed in apple orchards, and had to be fed a higher amount to "catch up" to non-grazed cohorts once they were finished grazing in apple orchards.

Impacts on Non-targets

Flying Non-targets: The following beneficial insects were found on sticky cards: hymenopteran parasitoids (**Fig. 25**), dolichopodid flies, syrphid flies, tachinid flies, lady beetles, and lacewings (**Fig. 26**). Parasitoids and dolichopodid flies had the greatest abundances (**Fig. 27**). Syrphid flies, tachinid flies, lady beetles, and lacewings all had means of less than two. The following pest insects were found: thrips, aphids, leafhoppers, and apple maggot flies. Thrips and leafhoppers had the greatest abundances (**Fig. 28**). Aphids and apple maggot flies had means of less than one. No significant differences were found for any of the beneficial or pest insects between treatments either before or after hog grazing (ANOVA ∝=0.05) (**Fig. 29,30**).

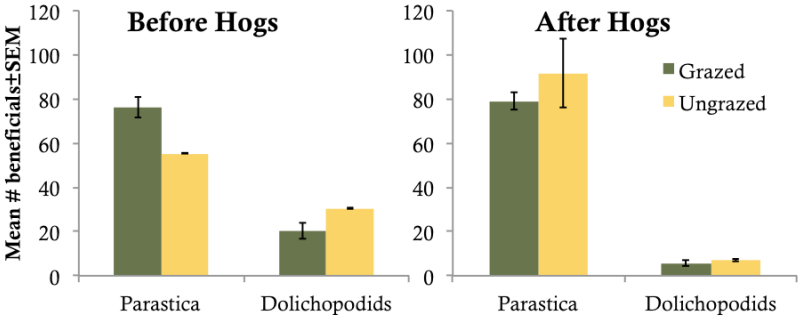


Fig. 27: Mean Number of Beneficial Flying Non-targets

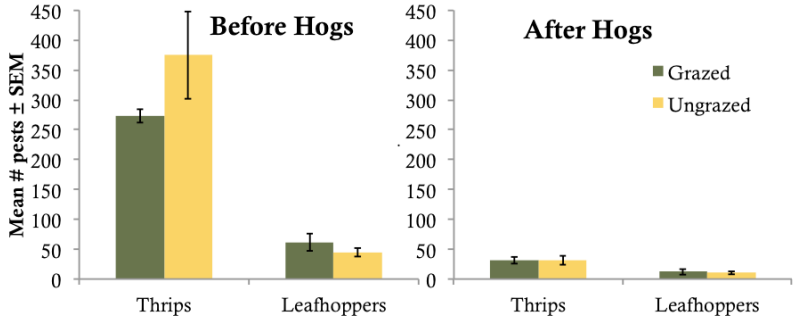


Fig. 28: Mean Number of Pest Flying Non-targets

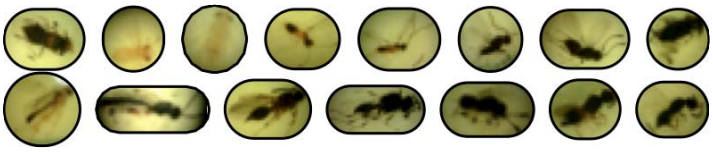


Fig. 25: Hymenopteran Parasitoids

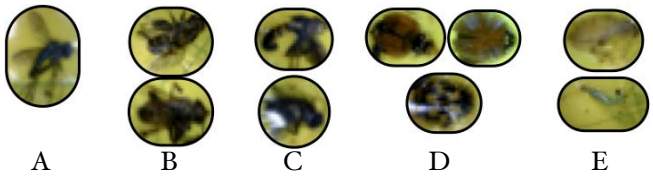


Fig. 26: A-Dolichopodid; B-Syrphids; C-Tachinids; D-Lady Beetles; E-Lacewings.

Soil Surface Non-targets: Ground beetles, rove beetles, ants, spiders, and slugs were found in pitfall traps (**Fig. 29**). Trap catches for ground beetles, ants, and slugs were extremely variable (**Fig. 29**). No significant differences were found for any of the soil surface organisms between treatments either before or after hog grazing (ANOVA ∝=0.05) (**Fig. 29**).

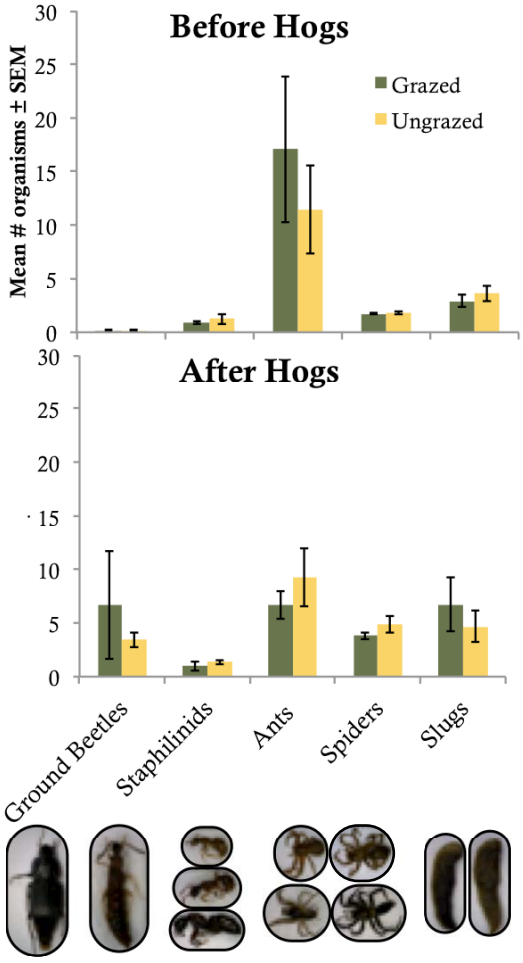


Fig. 29: Mean Number of Soil Surface Non-targets

Stocking Rate and Ground Disturbance

In 2012, at Country Mill, the weed transect data showed hogs took hogs 8 days to reach ~20% bare ground in the first set of plots, whereas it only took them 3 days in the second set of plots (**Fig. 30-A,B**). The transect data also showed hogs decreased grass and forbs while increasing bare ground in both sets of plots (**Fig. 30-A,B**), as seen in previous experiments. The same learning pattern was seen in the severity rating data where hogs took 7 days to achieve some level of disturbance in nearly all quadrants of a plot for the first period in the first set of plots (**Fig. 31**). During the second period in the second set of plots, hogs only took 4 days to achieve some level of disturbance in nearly all quadrants of a plot (**Fig. 31**). The most severe rooting was also concentrated at the ends of plots (**Fig. 31**). By day 13 in both sets of plots, the amount of bare ground was becoming extensive (**Fig. 31**).

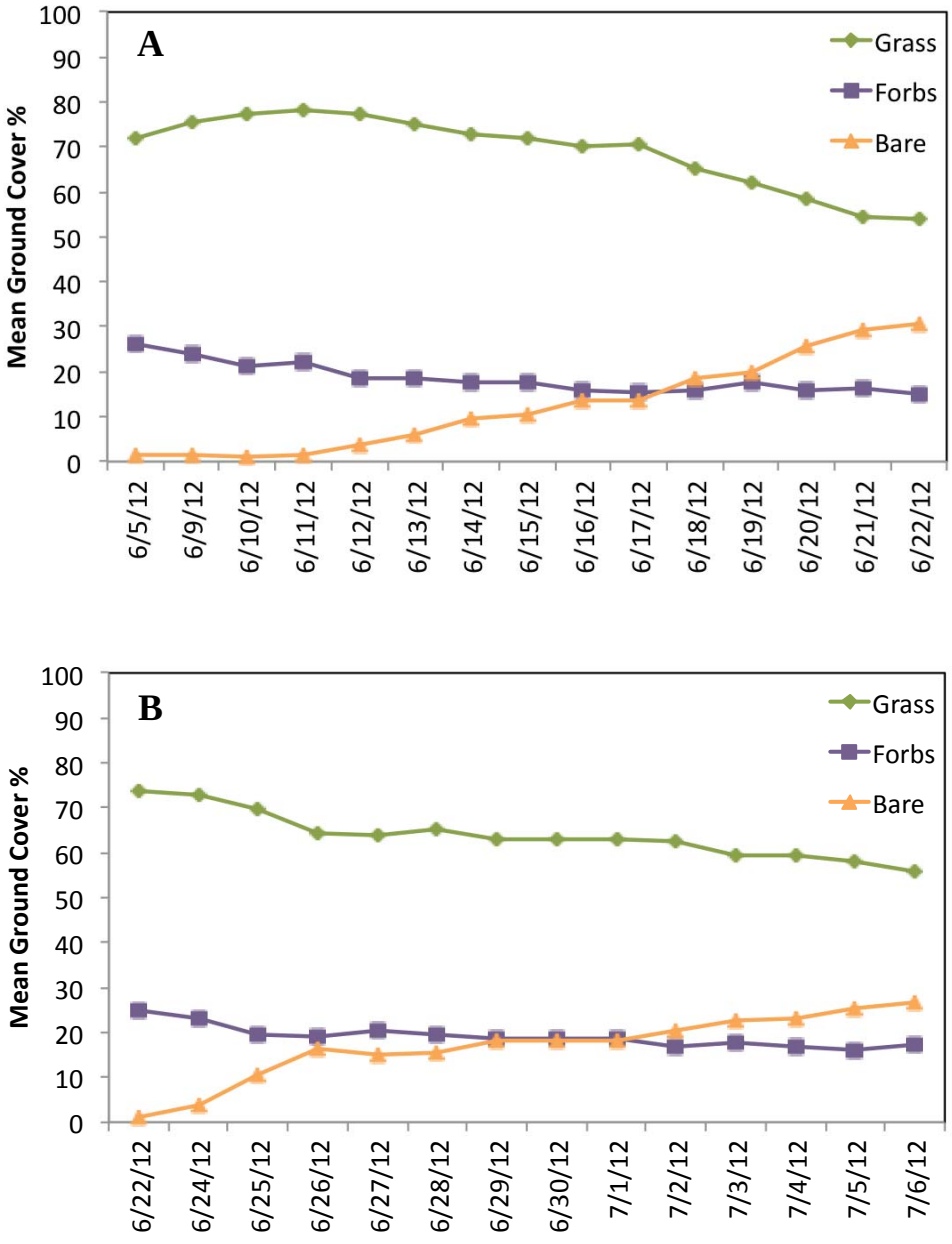


Fig. 30: 2012 Country Mill Weed Transect Data - **A**) mean ground cover of grass, forbs, and bare ground in plots A,C,E from the first two weeks at the farm; **B**) mean ground cover of grass, forbs, and bare ground in plots B,D,F from the second two weeks at the farm.

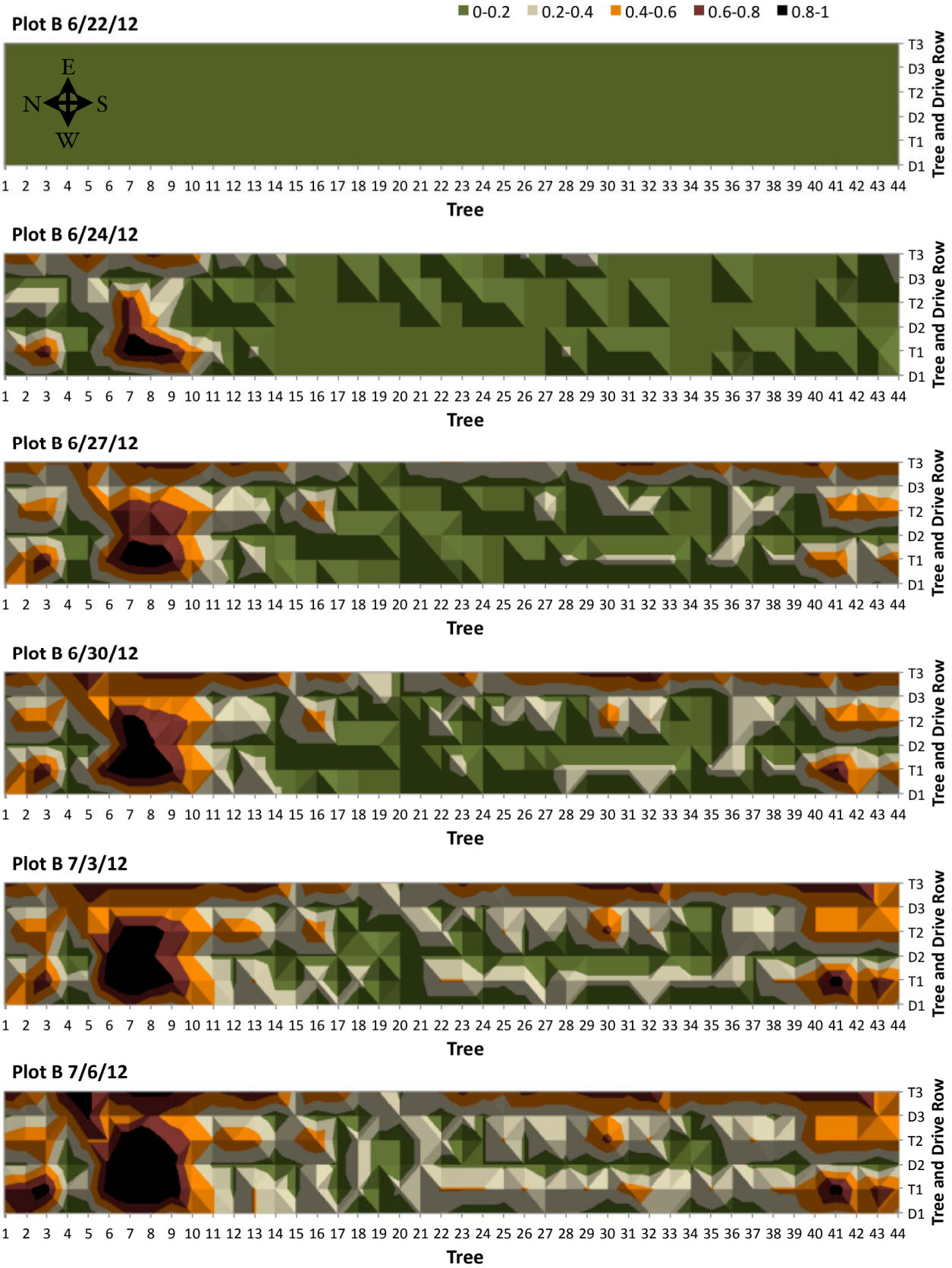


Fig. 31: 2012 Hog Ground Cover Disturbance - Day 0, 1, 4, 7, 10, and 13 for Hog Group 1 in Plot B (their second plot and representative of all groups and plots). The progression from green to dark brown shows the change from undisturbed vegetation to bare ground.

Economics

We continue to collect economic data and two patterns have emerged —one for hogs destined for the certified organic market and produced on farm and another for "rental" hogs destined for the conventional market. Hogs produced at AlMar cost approximately $3.00/lb hanging weight to produce. Assuming a 100% markup this yields a direct sale price of $6.00/lb. Unfortunately, few consumers purchase whole hogs and the few local certified organic processing plants charge a hefty markup for processing —adding $2.00 to $2.50 per pound of "wrapped weight"— bringing the production total to $5.00 to $5.50/lb, yielding a typical retail price of $10.00 to $11.00/lb. This price is too high for AlMar's local market so they have been selling the hogs at slightly above cost ($6.00/lb) at $7.00/lb of packaged meat. Identification of a whole carcass market would allow AlMar to greatly increase their margins on meat sales. The costs of producing hogs on farm can be seen in **Table 2**. The major economic issue with "rental hogs" is increased feed usage. Hogs taken from CAFO or semi confined operations required 300-400 lbs additional feed for finishing due to the active lifestyle they experience in the orchard. This translates to between $45-$60 in additional cost per head. Thus, unless the hog farmer can recover additional feed costs from marketing hogs as "pasture grazed", the use of conventionally produced hogs from off the farm is unlikely to be economically sustainable. The costs associated with renting hogs can be seen in **Table 3**.

At AlMar, grazing hogs in the orchards requires an extra hour a day in the summer, resulting in an additional 154 h of labor time a year costing $1,540. With crop failures in two of the three years, we were

Farrow-to-Finish Operation					
		Unit		Cost	
		Per Pig	Total	Per Pig	Total
Labor		10 h	1,000 h	$100	$10,000
Feed		1,050 lb	105,000 lb	$75	$7,500
Water		-	-	$0	$0
Equipment	Skid-steer	-	-	$10	$1,000
	Food Grinder	-	-	$5	$500
Overhead		-	-	$10	$1,000
Livestock Delivery		-	-	$5	$500
Kill Fee		-	-	$35	$350
Processing Fee		-	-	$400 - $450	$40,000 - $45,000
Market and Harvest	Live Weight	~250 lb	~25,000 lb	-	-
	Hanging Weight	150 lb - 175 lb	15,000 lb - 17,500 lb	~$1,050	$105,000
Net Profit		-	-	**$300**	**$30,000**

Table 2: AlMar Hog Operation Economics - calculated for an operation of 10 sows producing 10 piglets each per year; time from birth to market is 1 year; feed calculated at $8 per bushel; market price calculated at $7 per lb of packaged meat.

Hog Rental Operation					
		Unit		Cost	
			Total	Per Pig	Total
Rental Fee		36 pigs	4 weeks	$5	$720
Delivery Fee		$100/trip	2 trips	$2.77	$200
Labor		1 h/day	28 h	$7	$252
Feed		1.5 bushel/day	42 bushels	$9.33	$336
Water		70/week	280 gal	-	$2.80
Equipment	Skid-steer	-	4.5 h	$6.25	$225
Electricity (for fencing)		-	-	$2.77	$100

Table 3: Country Mill Hog Operation Economics - calculated for an operation of 36 hogs rented for a total of 4 weeks; feed calculated at $8 per bushel; cost of labor calculated at a wage of $9/hr.

not able to determine what economic benefit can be achieved if hog grazing leads to an increase of yield through reduction of insect fruit damage. For the one year with a fruit crop, the grower anecdotally noted a larger percentage of crop from the hog orchard was categorized as high quality fruit pack than from non-hog orchards. Hogs did reduce the number of times the grower mowed and tilled by two for each in the hog orchard (**Table 4**), which saved $52.50 per mowing/tilling for a total savings of $210 per year. Hogs never incurred any damage to trees or drive rows to warrant remediation. Grazing hogs resulted in reducing the net profit from the hog operation (without any yield increase).

At Country Mill, hogs reduced the number of mowings by one and tillings by two (**Table 5**), which saved $50 per mowing/tilling for a total savings of $150 per year. The grower also applied 4 fewer kaolin sprays in the hog orchard for a yearly savings of $1200 (at $200 per acre for the 6 acres of hog orchard) for the kaolin and $200 for running the tractor. Hogs never incurred any damage to semi-dwarf trees or drive rows to warrant remediation. However, hogs did damage one dwarf tree (at 6 leaf) and a new tree had to be planted in 2011. The grower anecdotally noted higher quality yield as a result of less insect damage.

	Hog Orchard			Non-hog Orchard		
	2010	2011	2012	2010	2011	2012
# of Mowings	1	1	1	3	3	3
# of Tillings	3	3	1	5	5	1

Table 4: AlMar- Hog Impacts on Orchard Management

	Hog Orchard			Non-hog Orchard		
	2010	2011	2012	2010	2011	2012
# of Mowings	2	2	2	3	3	3
# of Tillings	2	2	2	4	4	4

Table 5: Country Mill- Hog Impacts on Orchard Management

Conclusions

Pest and Disease Management

Hog impacts on pest management:

- The low population levels seen in all 3 years due to a lack of fruit crops in 2010 and 2012, along with the migratory ability of adult moths and beetles, do not allow for any conclusions to be drawn.
- In work done prior to this grant, hogs were found to decrease CM populations (Epstein et al. unpublished results). In work conducted for a graduate student CERES Trust funded grant, hogs were found to decrease both CM/OFM and PC damage to fruit when grazed post harvest in cherry, pear, and apple orchards (Buehrer and Grieshop unpublished results).
- Given the right circumstances, hogs will decrease CM, OFM, and PC abundances and fruit damage.

Hog impacts on apple scab:

- Weather conditions were not favorable for apple scab development and the extremely small crop of apples prevented us from assessing scab damage.
- However, we did record 36% reduction of primary scab infection on leaves. Furthermore, hogs reduced spring leaf litter biomass (the source of scab inoculum) by 63%.
- Thus, while our preliminary results are not conclusive they suggest that hogs may have a tangible impact on scab inoculum.

Hog impacts on weed management:

- Hogs consistently decreased grass and forbs ground cover, while they increased bare ground.
- Hog ground disturbance effectively contributes to weed management.

Soil Impacts

- Grazing hogs for short periods of time does not impact soil nutrient levels.

Hog Health

- Parasite load was very low, those found were not pathogenic, and never necessitated treatment.
- Transmission is fecal-oral and parasites can survive in the environment for several months on dust, dried feces, flies, and contaminated surfaces.
- No effective medicines exist for two of the parasites found, so preventing infection is key. Hogs should be sourced from non-infected stock and exposure to other animals and feces should be minimized.
- Hog weight gain was not at typical production levels, which was likely due to hogs being more active and burning more calories than they would in more confined areas. Growers should be aware that hogs may require more feed after grazing to reach desired weights. It is important to not overfeed hogs during grazing in order to maintain their motivation to forage for dropped fruit.

Non-Target Impacts

- The preliminary data indicates hog grazing does not impact the abundance of flying or ground surface non-target organisms in organic apple orchards, thus ecosystem services are not being lost.

Stocking Rate

- The stocking density of 12 hogs per acre was used throughout the project in plots no larger than 2 acres, with hogs ranging in size from 40 - 80 lbs.

- In year 3, we determined the stocking rate of 12 hogs per acre is sufficient to achieve a moderate level of ground disturbance in the absence of apples in a time period of 7 days when hogs have no experience and 4 days when hogs have previous experience.
- The consistent pattern of hogs working from the ends of plots in towards the middle of long thin rectangular shaped plots, suggests plot shape may play a role in the distribution of hog ground disturbance. Shaping plots as squares or reducing the size of plots may achieve a more even distribution of ground disturbance.

Economics

- Hog grazing resulted in fewer mowings and cultivations at both farms, as well as fewer kaolin spray applications at Country Mill. Such reductions make the rental model economically beneficial to a small degree, while the farrow-to-finish model was not economically beneficial.
- If hogs reduce insect damage to fruit (as seen in other experiments) and increase yield, the economic benefit would increase for the rental model and possibly become economically beneficial in the farrow-to-finish model.

Extension and Outreach Activities

Oral and poster presentations highlighting project activities were presented at scientific and grower meetings, and on-farm field days (**Fig. 32** and **Table 6**). Some of the talks, posters and handouts can be downloaded at www.opm.msu.edu. Further questions or requests for presentations should be emailed to grieshop@msu.edu.

Fig. 32: Farm Field Day at AlMar 2011

Presentation Venue	Location	Date
Midwest Organic and Sustainable Education Service Annual Organic Farming Conference	La Crosse, WI La Crosse, WI La Crosse, WI	25-Feb-2011 24-Feb-2012 22-Feb-2013
Annual Michigan Organic Conference	East Lansing, MI East Lansing, MI	5-Mar-2010 2-Mar-2012
Organic Tree Fruit Association Field Day	Berrien Center, MI Flushing, MI Northport, MI	19-Jun-2010 6-Aug-2011 18-Aug-2012
EPA Farm Field Day	Northport, MI	20-Jul-2011
Entomological Society of America Annual Meeting	Reno, NV Knoxville, TN	6-Dec-2011 12-Nov-2012
Great Lakes Fruit, Vegetable, and Farm Market Expo	Grand Rapids, MI Grand Rapids, MI Grand Rapids, MI	9-Dec-2010 5-Dec-2011 4-Dec-2012

Table 6: Extension presentations made over the course of the project.

Next Steps

Where do we go from here?

Integration of Additional Livestock Species: *Integration of sheep, goats, and poultry may all have merit as alternatives to hogs in orchard systems. Combinations of species may be especially interesting and provide the possibility of year round pasturing of different species in the orchard.*

Pork Market Development: *We identified the scarcity of small scale organically certified processors as a major impediment to organic hog/apple integration. The development of a whole carcass market is likely the best solution for this problem.*

Improved Orchard Pastures: *Our research focused on using "natural" ground cover as pasture for hogs. Integration of forage crops into orchard floor systems might improve the economics of running hogs in orchards.*

GAP and Organic Manure Standards: *Present Good Agricultural Practice (GAP) and NOP manure standards have become a major impediment to integrating livestock into plant agriculture. More research is needed to determine whether and how risks to consumer safety exist from these practices.*

Acknowledgements

This project was funded by the CERES Trust. Preliminary project funding was provided by MSU project GREEEN and the USDA OREI program. We would like to provide a special thank you to growers Jim Koan, Steve Tennes, and Aaron Keilen for their participation, hard work, and contributions to this project. We would like to thank Emily Pochubay, Philip Kouvariaris, Kristy Morell, Steve Licavoli, Paul Owen-Smith, Michelle Brosius, Michael Kehlleher, Bradley Baughman, Joseph Riddle, and Kristin Deroshia for their assistance with fieldwork and data collection.

Jim Koan of AlMar Orchards

Steve Tennes and Family of the Country Mill

MICHIGAN STATE UNIVERSITY

THE CERES TRUST

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The Country Mill

MICHIGAN STATE UNIVERSITY

THE CERES TRUST

Organic Pest Management Lab
578 Wilson Rd. Rm 205 CIPS
East Lansing, MI 48824

John/Jane Doe
4321 First Street
Anytown, State ZIP