TITLE: Interrow cultivation and intercropping for organic transition in dryland crop production systems

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Abstract

Organic farming in the dryland agriculture region of eastern Washington is rare, and little information exists for growers to make a successful transition from conventional to organic production. Fertility and weed control pose the biggest challenges during the three-year transition period, as nitrogen fixation by green manure legumes is limited by low rainfall, and in-season tillage is difficult in small grain cropping. The costs associated with the transition period often prove prohibitive to growers. To address these challenges, an organic transition study was designed that examines wheat and triticale intercropped with peas, which are mowed down mid-season to serve as a green manure. This system enables growers to begin the soil-quality-building process essential to organic production without sacrificing a full year of crop production in exchange for growing a green manure. After the first year, the study showed that while yields were lower in intercropped systems, they were not insubstantial. Intercropped systems also demonstrated superior suppressive ability towards weeds, compared to mono-cropped systems. As research continues, intercropping's impact on soil inorganic nitrogen, soil quality, and grain yield will be further assessed.

Project Description

Due to the prohibited use of synthetic nitrogen sources, organic cropping systems must rely on other inputs to satisfy nutrient requirements. In large-scale systems, nitrogen (N) is most commonly obtained from animal manure or leguminous cover crops (green manure). Eastern Washington is an area characterized by large-scale small grain cash cropping systems with few livestock producers, making manure as a cost-effective fertilizer difficult to find.

Green manure is an important source of nitrogen for organic growers, who use it as a cover crop or as part of a cropping rotation to diversify the system and supplement nitrogen stocks in the soil. Lack of moisture in eastern Washington restricts the use of cover crops, which means that producers wishing to grow a green manure crop must sacrifice a year of crop production to do so. For growers transitioning to organic production this can prove a particular burden, as the transition period from conventional to organic is often associated with increased costs and decreased revenues. However, intercropping a green manure crop with a small grain crop can provide growers with moderate income, while at the same time contributing to soil N stocks and soil improvement.

To study the benefits of intercropping, seven treatments were compared to assess yield, grain quality, weed competition, and soil N. The study was seeded in the spring in 10-inch rows with a Monosem planter in a randomized complete split-block design at a site just outside of Pullman, WA. Treatments 1 and 3 consisted of mono-cropped spring wheat and a grain variety of triticale, respectively. Treatment 2 was a green manure control, where only spring peas were planted, and treatment 4 was a mono-cropped forage variety of triticale. The remaining three treatments consisted of intercropped spring wheat + spring peas, forage triticale + spring peas, and grain triticale + spring peas (treatments 5, 6, and 7, respectively). All peas planted in the study were Aragorn field peas, and were cut down at pod set using sweeps placed on the pea rows in treatments 5 and 7. The green manure control was mowed down with a brush hog mower. Pea biomass was left on the surface in all treatments.

One of the two subplots in each block was fertilized with quail manure at a rate of 1975 kg ha^{-1}, in order to compare soil nitrogen with animal manure as a supplemental fertilizer versus only green manure as an N source. A weeding operation was performed on half of the plots in early June using a field cultivator, with the shanks positioned between rows. The forage triticale treatments (mono- and inter-cropped) were swathed when triticale reached the head emergence stage, and baled for hay. The peas were baled along with the triticale. Spring wheat and spring triticale grain was harvested in early September.

Outputs

Results

Intercropped treatments had significantly lower mean yields than mono-cropped treatments in both the grain and hay treatments. While spring triticale often yields higher than spring wheat in the region, the intercropped and the mono-cropped wheat and triticale yields were similar. Similarly, hay yield for mono-cropped triticale was significantly higher than the intercropped triticale + pea forage. Mean yields of spring wheat and triticale were 4647 kg ha^{-1} and 4516 kg ha^{-1}, respectively, relative to the 2012 Whitman county average spring wheat yield of 3777 kg ha^{-1} (2013 data not yet released). The quail manure fertilizer had no significant effect on grain or hay yields (p-value = 0.7018); however, this is likely due to slow mineralization during the summer season where low moisture limits soil microbial activity. Fertility effects on yield are expected to be observable in 2014 after mineralization of nitrogen occurs during the winter, after which soil nitrogen levels can be compared between green manure-only treatments and those receiving both green and animal manures.

The weeding operation performed by the inter-row cultivator had no effect on end-of-season weed biomass, and had a negative impact on yield. This was likely due to the difficulty of keeping the shanks positioned between the 10-inch rows, and deviations from the area between rows resulted in crop takeout. Improvements in GPS or driving technologies are necessary for this type of mechanical weeding to be successful, and will be explored in later years of the study.

Intercropping spring wheat and triticale did not significantly decrease the harvest index, indicating that the presence of the peas did not affect resource allocation in the crop. Unsurprisingly the harvest index for mono-cropped spring wheat was significantly higher than both the mono-cropped and intercropped triticale, as triticale produces much more straw than does wheat. Again, fertilizer effects on harvest index were not significant.

Soil moisture change from planting to pea mow-down was significantly different at an alpha level of 0.10 between treatments (p-value = 0.0932). The intercropped wheat and grain triticale had less soil moisture loss than the mono-cropped treatments. Small grains have a stronger competitive ability for moisture compared to pea (Willey, 1979; Hauggaard-Nielsen, 2001), so intraspecific competition for soil moisture in mono-cropped treatments was likely greater than the interspecific competition in intercropped treatments, resulting in more total moisture uptake in mono-cropped wheat and triticale. Analysis of post-harvest soil moisture will determine whether intercropping had any effect on soil moisture throughout the season. If so, incorporating an intercropping phase into a rotation could result in yield gains in crops planted later in the rotation due to higher soil moisture levels. This could compensate for reduced yields and profitability in the intercropped year, and provide benefits beyond the transition period.

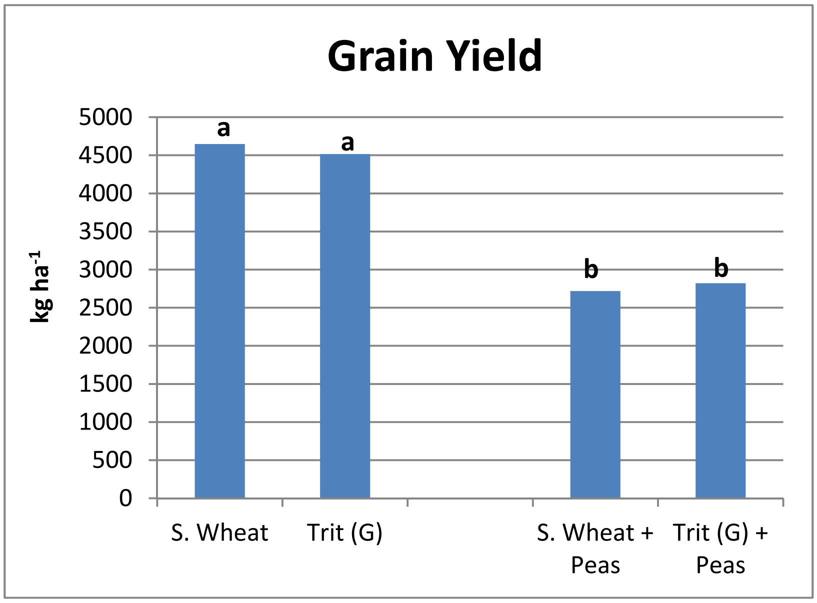

Figure 1. 2013 grain yield LSmeans. Means with the same letter are not significantly different at the 5% level. G = grain triticale variety

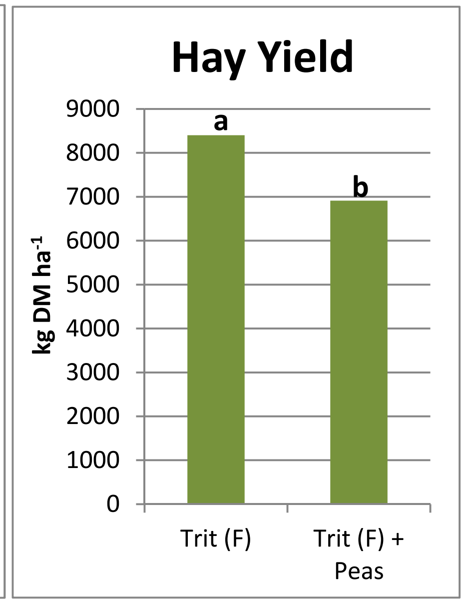

Figure 2. 2013 hay yield LSmeans. Means with the same letter are not significantly different at the 5% level. F = forage triticale variety

Aboveground pea biomass was significantly different at an alpha level of 0.10 between treatments (p-value = 0.0786). Pea biomass was much greater in the spring wheat + pea treatment than the other intercropped treatments and the green manure control. This was likely due to excessive crop takeout as a result of the cultivator weeding operation that occurred in the other treatments, though there may be some synergy between spring wheat and field peas that results in greater pea biomass accumulation. Results of next year's intercropping rotation may help to further explain the relationship between intercropping and pea biomass.

Treatment	Pea Aboveground Biomass (kg ha^{-1})
S. Wheat + Peas	1316.4
Peas (green manure control)	894.1
Grain Triticale + Peas	887.1
Forage Triticale + Peas	832.5

Table 1. LSMeans of pea biomass harvested at time of green manure mow down.

Quality, specifically N content, can also play a role in the peas' ability to improve soil fertility. Results indicate that intercropping may have negative effects on the quality of the green manure, as the presence of the crop can increase competition for soil-N, and N newly fixed by the peas. The green manure control treatment had significantly higher N biomass content than the spring wheat, forage triticale, and grain triticale intercropped treatments, likely due to increased competition for soil N from the grain crops. However, as the difference was not large, the effect of reduced green manure N content in intercropped treatments may have little effect on green manure contributions to soil-N in the long-term. Differences in yields in later crops in the rotation will be examined to elucidate green manure quality effects, and whether intensifying the green manure phase of the rotation results in losses in the future. The addition of the quail manure had no effect on pea tissue quality.

Treatment	% N
Peas (green manure control)	3.24*
Forage Triticale + Peas	2.94
Grain Triticale + Peas	2.73
S. Wheat + Peas	2.66

Table 2. LSMeans of nitrogen content as a percent of total biomass.
* significant at the α = 0.05 level

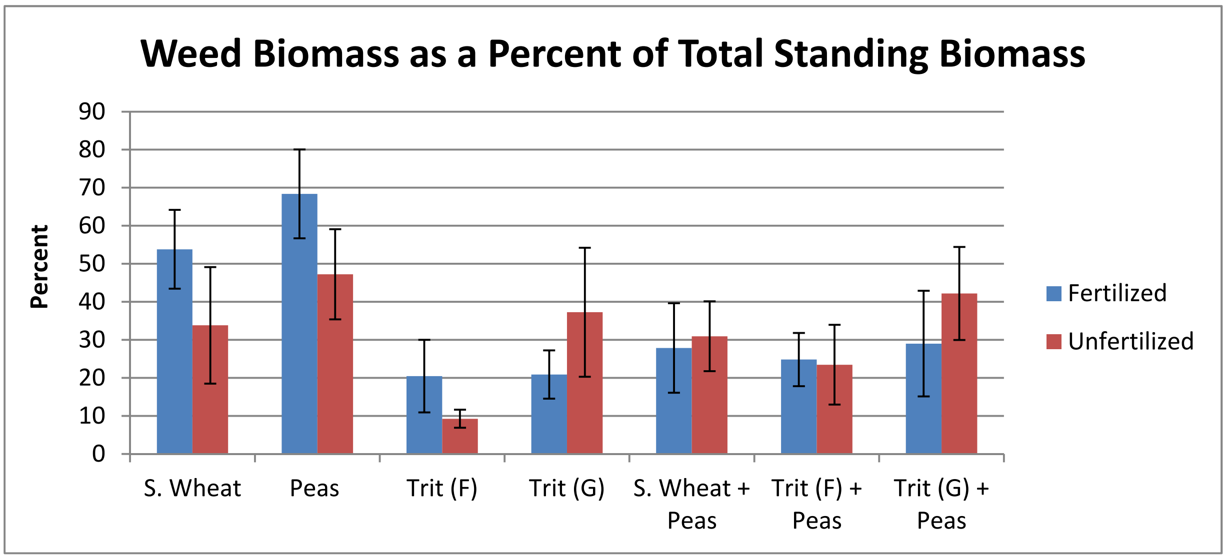

Figure 3. Weed biomass depicted as a percent of total standing biomass, at time of pea (green manure) mow down.

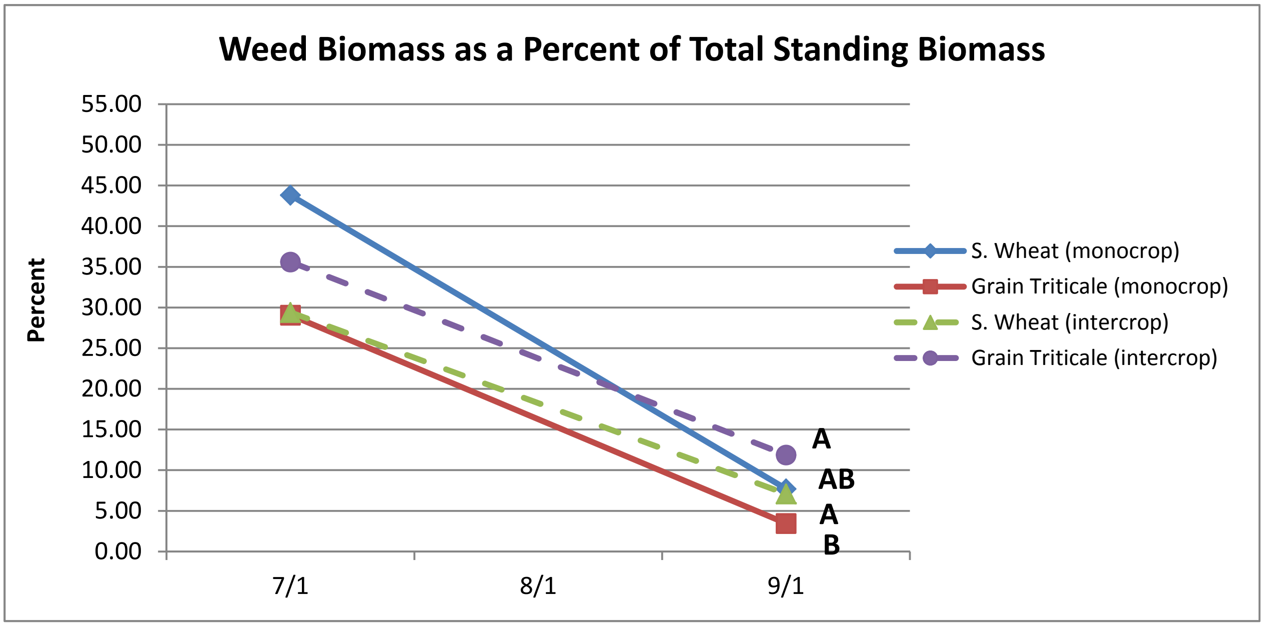

Figure 4. Trends in weed biomass as a percent of total standing biomass in grain treatments throughout the growing season. Final sampling was performed just prior to grain harvest.

Organic grain growers must often rely on a crop's innate competitive abilities to keep weeds in check. As the inter-row cultivator weeding operation had no impact on weed biomass, the type of crop largely determined the weed pressure present in each treatment.

At the time of pea mow down, the pea green manure control treatment had a significantly higher percent weed biomass than mono-cropped forage and grain triticale, and intercropped spring wheat and forage triticale (see Figure 3). Mono-cropped forage triticale was the most competitive with weeds during the period of pea growth, which likely contributed to its yielding higher than the intercropped forage triticale. Weed pressure was relatively high overall, as is characteristic of organic systems, though plots that did not experience high levels of crop takeout as a result of the weeding operation competed well with weeds, with some winter wheat plots yielding over 110 kg/ha. The quail manure had no effect on weed biomass. At harvest after dry-down, weed biomass is similar in most treatments. Mono-cropped grain triticale weed biomass was significantly lower than that of intercropped wheat and triticale, demonstrating the competitive value of triticale as a grain crop. This trait makes triticale an important potential crop to include in organic small grain rotations.
As this research is in its first year, no publications have yet been produced. The findings of the first year of the study will appear on the "Dryland Organic Production" website (http://smallgrains.cahnrs.wsu.edu/dryland-organic-production/), which is available to growers and the public. We will post additional reports as research continues.

Impacts

Short-term, modifications to equipment have impacted the possibility of intercropping being viable on a field scale. Though the inter-row weeding cultivation needs improvement, pea mow down using sweeps between the grain rows was very effective. Organic and conventional growers alike could benefit from the viability of this practice. A few organic small grains growers have already adopted inter-row weeding operations similar to this system and achieved good results. Intermediate and long-term impacts include advances in soil improvement and nitrogen delivery to organic systems. Outreach could result in increasing grower income through organic grains by providing information on an organic transition system that has a lower financial burden for the producer while providing the fertility for a productive system following the transition.

Additional Funding

We are in the process of applying for a 2014 BIOAg grant to fund the next year of the project, which will involve another year of the intercropping phase of the transition system.

Graduate Students Funded

Nicole Tautges

Recommendations for Future Research

To properly assess the impact of intercropping a green manure crop with small grains, the rotation should be continued another year. The fertility effects of the green and quail manure occur over time as nitrogen is mineralized, and their respective effects on grain yield, quality, weed competition, and soil health can be measured in future years of the rotation. More agricultural engineering work should be done to improve technology enabling inter-row operations, specifically for weeding in narrow-row crops. Current GPS, RTK, and other precision agriculture technologies have the potential to be adopted for large-scale organic grain production. Further research and market development should be conducted to improve the viability of triticale as an organic and conventional grain crop in the Pacific Northwest, as its inherent competitive abilities could improve productivity and reduce the need for herbicide applications in conventional production systems.

Works Cited

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