FINAL REPORT

TITLE: Introducing Organic Quinoa Production Systems in the Palouse

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ABSTRACT

The popularity of quinoa in the past decade has quadrupled prices at U.S. retail outlets. For all this demand, the vast majority of the quinoa consumed in the U.S. is imported from Peru, Bolivia, and Ecuador, with 65% of the quinoa sold in the U.S. being organic. This project hopes to increase organic quinoa production in the U.S. by providing growers in the Palouse region of eastern Washington – a large conventional grain-producing region – an opportunity to diversify their current cropping systems and marketing options. In March 2013, we established a long-term certified organic research project on a 1.2-ha parcel of a commercial grain farm in the Palouse region, WA, to measure the sustainability of various organic grain rotations with and without two varieties of quinoa. Our goal of this systems study was to improve the competitiveness and adoption by growers of organic quinoa in the Palouse. Supporting objectives include measuring the following sustainability indicators of 8 different organic rotation trials: crop yield and quality, weed and insect populations, soil quality, nitrogen and phosphorus budgets, and economic performance. This project also has improved understanding and management of soil quality by characterizing the interactions with arbuscular mycorrhizal fungi (AMF) in the different rotations. We have communicated this project to producers, consumers, and Extension agents through a webpage within csanr.wsu.edu, social media utilities, multiple field days at the Zakarison Farm, and will continue to present final results at producer meetings and scientific conferences. BIOAg Priority Topic Areas addressed include organic approaches to sustainable management of soil quality and farming systems; diversification to increase the resiliency and sustainability of farming; and assessment of environmental, economic, and social sustainability of agricultural systems.

PROJECT DESCRIPTION

The goal of this project is to improve the competitiveness and adoption by growers of organic quinoa and grain cropping systems in the Palouse region. The project will help fill critical knowledge gaps that exist regarding the effects of dryland organic crop rotations, including the introduction of quinoa. There is little information on the interaction of quinoa with insect pests, or with soil physical, chemical, and biological properties, and how these may carry over to affect other crops in the rotation. From what is known, including quinoa in crop rotations has the potential to mitigate some of the challenges facing organic grain production in the Palouse region. Quinoa has shown high nitrogen-utilization efficiency (Aguilar and Jacobsen, 2003; Erley et al., 2005) and is able to produce quality yields while demanding less nitrogen than small grains like spring wheat. Quinoa is not susceptible to cereal diseases and only slightly affected by some soil-borne nematodes (Jacobsen, 2003) and will therefore provide a high-value crop to break disease cycles. Furthermore, growing quinoa will diversify crop sales and marketing options, improving farmers' economic resilience, and provide more options for locally and organically grown foods to consumers in the Palouse. Successful implementation of this project will also ensure fulfillment of consumer expectations that U.S. certified organically grown quinoa and grains are produced using environmentally sound and other sustainable production practices.

This project uses a systems approach to evaluate the effects of diversifying organic crop rotations with quinoa. The specific research and extension objectives supporting this goal are the following: (1) quantify crop productivity and quality of different organic quinoa and grain production systems; (2) assess population densities and diversity of aphids and lygus bugs, and their natural enemies; (3) assess status of soil quality and soil-plant N and P balances; (4) evaluate soil microbial community changes as an index of biological soil quality; (5) Quantify colonization of AMF with quinoa and other crops; (6) measure the economic performance of the different cropping systems; and (7) Disseminate our findings to farmers, agricultural professionals, consumers, and extension agents to improve the adoption by growers of organic quinoa in the Palouse.

In March 2013, we established the primary plots for this long-term organic research project on a 1.2-ha field that had produced organic alfalfa for 5 years. The field is located on a commercial grain farm owned by Eric and Sheryl Zakarison about 11 km north of Pullman in the Palouse region of Washington State. The treatments test 3-year crop sequences as part of an 8-year crop rotation system with alfalfa. The experiment is arranged in a randomized complete block design with 4 replicate blocks. Each replicate block contains the 8 treatments in 6 m x 18 m plots. The crop sequence treatments are the following:

- Barley-quinoa-chickpea
- Chickpea-quinoa-barley
- Chickpea-barley-quinoa
- Barley-chickpea-quinoa
- Barley-spring wheat-chickpea
- Barley-chickpea-spring wheat
- Chickpea-spring wheat-barley
- Chickpea-barley-spring wheat

Each block is uniform in physical characteristics, such as slope, soil, and microclimate. The 32 plots established in 2013 are completely replicated with a second set established in 2014. This type of replication offset by one year can be helpful in accounting for differences in weather between each growing season. Each plot with quinoa is divided into subplots for two different quinoa varieties, Cherry Vanilla and KU-2. These varieties of quinoa were chosen for this study based on their success in prior trials in eastern Washington and potential for broad adaptability throughout the Northwest. Plots are managed using conservation tillage practices.

Outputs

- Overview of Work Completed and in Progress:

All of the field work for this project on the Zakarison farm has been completed. The final soil sampling was performed in April 2017. The work still in progress includes analyzing samples in the laboratory, statistical analyses of the data, and preparation of publications. Additional funding was secured in 2016 from three USDA competitive grant sources to support the ongoing analyses of this long-term project. Two grants from USDA-NIFA Western SARE ($25,000) and USDA-NIFA Predoctoral Fellowship ($93,657) are directly for PhD candidate Rachel Wieme and technical help, while the third grant from USDA-NIFA OREI ($1,999,950) is a much larger quinoa project, of which our rotations project is just a part. We would not have received these grants without seed funds of $47k from WSU-BIOAg and $40k from WSU-ERI. Presentations of final results and publications will be made available on the project's website as they are completed (http://csanr.wsu.edu/organic-quinoa-production/).

- Methods, Results, and Discussion:

Objective 1: Quantify crop productivity and quality. Crops have been planted and harvested as described in Table 1. Field preparation consisted of using an undercutter (sweep) to terminate alfalfa, and in later years light disking and rotary harrowing to prepare the seedbed for planting. Yields were calculated at the end of each growing season and are presented in Table 2.

Objective 2: Determine population densities of pests (aphids and lygus bugs) and their natural enemies. Insects were collected from all plots 2-3 times each

Table 1. Details of planting and harvesting operations.

Crop	Variety	# plots	Date Planted	Planting Implement	Date Harvested
Barley	Bob	16	10-May	Cross Slot Drill	27-Aug
Chickpea	Billy Bean	16	10-May		20-Sep
Barley	Bob	24	29-Apr	Monosem Precision Planter	18-Aug
Chickpea	Frontier	24	12-May		16-Sep
Spring Wheat	Louise	8	29-Apr		18-Aug
Quinoa	Cherry Vanilla	8 (split)	29-Apr		21-Sep
Quinoa	KU-2	8 (split)	29-Apr		21-Sep
Barley	Bob	16	24-Apr	Monosem Precision Planter	5-Aug
Chickpea	Frontier	16	16-May		28-Aug
Spring Wheat	Louise	16	24-Apr		5-Aug
Quinoa	Cherry Vanilla	16 (split)	24-Apr		28-Aug
Quinoa	KU-2	16 (split)	24-Apr		28-Aug
Barley	Bob	8	21-Apr	Monosem Precision Planter	18-Aug
Chickpea	Frontier	8	21-Apr		16-Sep
Spring Wheat	Louise	8	21-Apr		18-Aug
Quinoa	Cherry Vanilla	8 (split)	21-Apr		11-Oct
Quinoa	KU-2	8 (split)	21-Apr		11-Oct

growing season (only 2 sampling times in 2015 because of a short growing season). Insects from each collection are sorted and counted.

Objective 3: Assess status and change of soil quality and fertility. Soil samples were taken from all plots of Entry 1 in spring 2013 (10 May) and subjected to each of the analyses described in the proposal, including completing all fertility analyses, N mineralization potential, microbial biomass by fumigation (soluble C and N) and respiration methods, and particle size analysis of the top 30 cm (0-10 cm and 10-30 cm). Subsamples were subjected to DNA extraction and frozen for future analysis. Inorganic N content of the soil profile to 1.5 m was also extracted. Post-harvest samples were taken in fall 2013 and extractions performed to evaluate inorganic N levels. We also analyzed aggregate size distribution on fall soil samples. This additional analysis (not in original proposal) was added based on observations from local producers about possible soil structure change following quinoa cultivation. We will continue to evaluate aggregate size distribution of soils in each plot after each year of the crop rotation.

Surface (0-10 and 10-30 cm) soil samples taken from Entry 2 in spring of 2014 were sent to Soiltest Farm Consultants for the complete fertility analysis. Additionally, all of the fertility and biological tests described above were performed on soil samples from all plots. Post-harvest soil samples were also taken and subjected to inorganic N extraction and analysis of aggregate-size distribution.

Soil sampling was performed again in spring 2015; all plots were sampled to a depth of 1.5 m for accounting of inorganic N in the soil profile. Subsamples from the surface (0-10 and 10-30 cm) were also analyzed for P content, N mineralization potential, microbial biomass C & N, and respiration incubations, as performed each year. Post harvest samples were taken from the surface 30 cm and are being analyzed for inorganic nitrogen and aggregate size distribution.

Soil sampling in spring 2016 and subsequent analyses were completed as in previous years. Subsamples from Entry 1 were sent to Soiltest for the comprehensive soil fertility testing, as that entry set of plots completed the full 3-year sequence testing. Fall soil sampling occurred as in previous years, with soil samples being analyzed for inorganic N and aggregate size distribution.

The final soil sampling of Entry 2 plots occurred in Spring 2017. Subsamples were sent to Soiltest Farm consultants for the comprehensive fertility testing, and the remaining analyses are being currently being completed by PhD candidate Wieme.

Objective 4: Evaluate and quantify colonization of AMF. Root samples for all crops were collected from all Entry 1 plots (n = 40) in 2014 at the time of peak vegetation before crop maturity (July). Roots were processed as described in the proposal and visual counts of colonization of AMF were performed. The process was repeated for all plots in 2015 (n = 88) and 2016 (n = 40). Preliminary data from 2015 and 2016 show positive colonization of AMF in quinoa roots, but lower compared to other crops.

Objective 5: Measure the economic performance of the different farming systems. Data, such as input costs, equipment used, and time required for each field operation, were collected to create enterprise budgets that will determine the profitability of each treatment (rotation sequence) The detailed budgets are currently under construction, but estimates of economic performance (net incomes) are presented in Table 2 of this report.

Objective 6: Disseminate our findings to farmers, agricultural professionals, consumers, and research and extension agencies. Our activities towards objective 6 are described below, in the "Outreach & Education Activities" section.

Discussion: All of the results presented in this report are preliminary. There are a few more analyses to be completed before we are able to address the objectives and hypotheses from our proposal, especially those looking into overall soil quality and the nutrient budgets of the rotation treatments. As is apparent from Table 2, the quinoa yields experienced in the last two growing seasons of this project were very low. These were mostly due to unfortunate weather occurrences to which quinoa was still susceptible, including very hot weather during flowering that decreased yields (2015) and soil crusting after planting that decreased emergence (2016). As research continues to overcome these challenges with locally adapted quinoa varieties and better agronomic practices, we believe quinoa can still be a viable crop to diversify growers' operations in the Palouse region.

Table 2. Yield and estimated economic data for the crop sequence treatments.

Treatment	2013 Crop	2013 Yield (kg/ha)	2013 Net income* ($/ha)	2014 Crop	2014 Yield (kg/ha)	2014 Net income* ($/ha)	2015 Crop	2015 Yield (kg/ha)	2015 Net income* ($/ha)	2016 Crop	2016 Yield (kg/ha)	2016 income* ($/ha)	3-year Net Income* ($/ha)
1	Barley	1945	329.28	Quinoa (ChVan)	108	116.79	Chickpea	3	-482.00	N/A			-35.94
				Quinoa (KU2)	297	782.95		3	-482.00				630.22
2	Chickpea	542	68.60	Quinoa (ChVan)	108	116.79	Barley	1853	302.91				488.29
				Quinoa (KU2)	226	532.70		1625	237.61				904.20
3	Chickpea	667	178.74	Barley	2533	497.85	Quinoa (ChVan)	23	-162.46				514.13
							Quinoa (KU2)	114	158.28				834.87
4	Barley	1902	317.07	Chickpea	704	136.58	Quinoa (ChVan)	12	-201.23				252.42
							Quinoa (KU2)	22	-165.99				287.67
5	Barley	1914	320.61	Wheat	2082	513.44	Chickpea	76	-431.76				402.28
6	Barley	1991	342.43	Chickpea	889	299.60	Wheat	1721	385.83				1027.86
7	Chickpea	787	284.48	Wheat	2325	598.80	Barley	2257	418.60				1301.89
8	Chickpea	694	202.54	Barley	2572	509.09	Wheat	1547	324.50				1036.13
1	Alfalfa	7100	income not calculated for alfalfa	Barley	1842	299.76	Quinoa (ChVan)	15	-190.66	Chickpea	470	-69.62	39.48
							Quinoa (KU2)	33	-127.22		510	-34.37	102.93
2				Chickpea	697	130.41	Quinoa (ChVan)	7	-218.86	Barley	4675	1111.07	1589.21
							Quinoa (KU2)	12	-201.23		5040	1215.59	1040.24
3				Chickpea	835	252.01	Barley	2661	534.46	Quinoa (ChVan)	33	-147.56	638.91
										Quinoa (KU2)	76	4.00	790.47
4				Barley	2098	373.27	Chickpea	156	-346.30	Quinoa (ChVan)	20	-192.33	-165.36
										Quinoa (KU2)	57	-62.97	-36.00
5				Barley	2201	402.81	Wheat	2173	545.45	Chickpea	320	-201.79	746.47
6				Barley	2118	379.05	Chickpea	194	-312.82	Wheat	2945	817.25	883.47
7				Chickpea	834	251.13	Wheat	1963	471.15	Barley	4839	1158.03	1880.31
8				Chickpea	797	218.52	Barley	3295	716.20	Wheat	4462	1351.94	2286.66

* Net income equals gross returns minus operating costs.

- Publications, Handouts, Other Text & Web Products:

A webpage for the project was set up through CSANR, featuring the project description, links to the research team biographies, photos of the field site, announcements/events, and links to other relevant websites. The webpage can be found at: http://csanr.wsu.edu/organic-quinoa-production/. Public events (presentations) and links to project information will continue to be disseminated on social media platforms like Facebook and ResearchGate to increase the audience for outreach.

As data continue being collected from lab analyses, manuscripts for publication and presentations for conferences will be under preparation. These publications will be made available on the project website as they are completed.

- Outreach & Education Activities:

We utilized of a number of opportunities to communicate with farmers, agricultural professionals, and research and extension agencies about this project.

2013: Five of the seven team members attended the International Quinoa Research Symposium (August 2013) hosted at WSU, which provided the opportunity to interact with many scientists, farmers, and agricultural professionals from 24 countries, and we have maintained contact with many of them since that event.

2014: Our project was featured alongside other WSU quinoa research during Dr. Murphy's presentation at the Innovators lecture series in Seattle in April 2014. Rachel Wieme (PhD student on this project) was present at the lecture and shared ideas and discussed our project with other researchers, regional producers, and market representatives.

Multiple field tours of our research plots were given to interested parties in 2014, including Zach Wailand (Dharma Ridge Farms, Quilicine, WA), Ian Clark (Clark Family Farms, Pullman, WA), and a group of 6 company leaders from Lundberg Family Farms (Chico, CA). Drs. Murphy and Carpenter-Boggs and Ms. Wieme shared information from this project at the Eggert Family Organic Farm Field day in July 2014, which highlighted quinoa research for the region.

2015: This project was featured in two more field days during the summer 2015. Ms. Wieme presented on this project during a Tilth Producer's farm walk at the Zakarison Partnership on June 8, which included a tour of the research plots for the 33 attendees. A summary of the field day from Tilth Producers is available at: http://tilthproducers.org/2015/06/zakarison-partnership-farm-walk-june-8-2015/. Ms. Wieme also presented on this project (again, including a field tour of the plots), with additional focus on the AMF component, during a Soil Biology Workshop ("One-day University") led by Dr. Carpenter-Boggs and organized by Tilth Producers of Washington in Pullman on August 3, which boasted 28 participants. A summary of the workshop from Tilth Producers is available at: http://tilthproducers.org/2015/08/one-day-university-soil-fertility-composting-and-organic-farming-august-3rd-2015/.

2016: Dr. Reganold also discussed the project with organic producers at the annual Natural Products Expo in Anaheim, CA, on March 11-12 and with scientists as part of his seminar at the University of California at Berkeley on April 11. Ms. Wieme gave a presentation and field tour to representatives from High Mowing Organic Seeds in August. Additionally, Dr. Reganold and Ms. Wieme gave interviews and demonstrations at the field site as part of an upcoming film documentary examining various agricultural practices (organic, no-till, and conventional) in the United States. The company conducting the interviews and producing the film is IFA MEDIA from Taipei, Taiwan and Bangkok, Thailand, with the film being directed by Yen-Ming Lai (Spencer) of Public TV Service in Taipei, Taiwan.

Throughout the course of the project, we have also been collaborating with local producers that have started growing quinoa on scales from 0.2 to 4 ha. We have exchanged information regarding planting dates and densities, varietal differences, yield data, and general observations.

IMPACTS

- Short-Term: We are continually increasing the amount of information known about the challenges and benefits of growing quinoa in this region, including planting rates and dates, interactions with weeds, post-harvest processing, the effects on soil quality, and economic implications. With the help of this project, the acreage of quinoa in the region has continually expanded over the past 4 years. This project has also provided feedback to other researchers working with quinoa, both by providing insight on overcoming the agronomic challenges and also by providing many more questions for future research.
- Intermediate-Term: We expect to have a better understanding of how large-scale dryland organic farming operations can be productive and economically viable by incorporating quinoa in crop rotations. As researchers and producers work together to create locally adapted varieties of quinoa, we expect not only organic but also conventional producers in the Palouse to take advantage of the opportunity to diversify their cropping systems with quinoa and, in turn, their income base.
- Long-Term: There is good potential for a more diversified agricultural landscape in the Palouse region as more farmers become aware of the opportunities that quinoa and organic cropping systems provide. We expect to see locally grown quinoa appearing at farmers markets and in local food co-ops. Knowledge and adoption of organic quinoa and grain production will spread outside the Palouse region and throughout the Northwest as a result of this integrated research and extension project. New crops and systems will strengthen the economic and social resilience

of rural communities. Adoption of organic and conservation practices that meet environmental stewardship goals will improve environmental services of the agricultural landscape.

ADDITIONAL FUNDING APPLIED FOR / SECURED

1. USDA-NIFA Organic Transitions ($498,894)
   - Applied April 2014, project not funded but recommended for NIFA OREI program
2. USDA-NIFA Organic Agriculture Research & Extension Initiative (OREI) ($996,259)
   - Applied April 2015, not funded
3. WSARE Graduate Student Grants in Sustainable Agriculture ($25,000)
   - Applied May 2015, not funded
4. Supplemental funding from BioAg ($6,920)
   - Secured January 2016
5. USDA AFRI Pre-doctoral Fellowship ($93,657)
   - Funded August 2016
6. USDA-NIFA OREI ($1,999,950)
   - Funded 2016
7. WSARE Graduate Student Grants in Sustainable Agriculture ($25,000)
   - Funded 2016

GRADUATE STUDENTS FUNDED

- Rachel Wieme, PhD Candidate

RECOMMENDATIONS FOR FUTURE RESEARCH

The principal goal for future research would be to expand this systems research to additional farms throughout the Northwest, especially as the quinoa breeding program selects and develops more locally adapted quinoa varieties and better agronomic practices. Quinoa has the potential to be a versatile crop that could bring benefits to many different organic dryland and irrigated cropping systems throughout the Northwest, and provide economic advantages to producers. Another aspect to for research as quinoa spreads to additional farms will be economically viable ways to combat weeds. Quinoa benefits from a 16-day weed free period after emergence, and in order for it to be viable on a larger scale there needs to be an efficient way to ensure that condition. Finally, it would be prudent to continue studying the interactions that quinoa has with soil biology, as organic systems largely rely on biological processes for fertility and long-term sustainability.

Figure 1. A view of the experimental plots, July 2015. Photo by Rachel Wieme