# Agronomic and economic performance of organic forage, quinoa, and grain cropping systems in the Palouse Region of the Pacific Northwest

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## Introduction

Volatile commodity crop prices and concern for long-term agroecosystem health have farmers looking for alternative practices to increase revenue diversity and protect soil quality.

Organic management is a rapidly growing alternative, and quinoa is a potential new cash crop for organic systems in the Pacific Northwest. Price premiums remain strong for organic grains and forage in the region, but there are very few certified organic operations in large part due to the challenges of maintaining soil fertility and combating weeds. Furthermore, there are many knowledge gaps regarding the agronomic attributes of quinoa in dryland crop rotations with common crops for this region.

The study presented here tested the agronomic and economic effects of diversifying crop rotations with quinoa as part of an organic cropping system with alfalfa to help address these challenges.

## Methods

Eight 3-year grain treatment sequences (Table 1) were tested in a randomized complete block design. One set of treatments with 4 replicate blocks was initiated in 2013 (Entry 1); a second complete set began in 2014 (Entry II) to account for potential differences in weather across growing seasons.

The study field, located near Pullman, WA, was organically managed alfalfa for 5 years prior to the establishment of this project. Alfalfa was terminated with an undercutter; grain crops were planted each year following a light disking and rotary harrow. No fertilizer inputs were used; weeds were managed by mechanical methods when possible, otherwise by hand.

| Treatment | Position after alfalfa: One | | Two | | Three |
|---|---|---|---|---|---|
| **BCQ** | Barley | - | Chickpea | - | Quinoa |
| **BCW** | Barley | - | Chickpea | - | Wheat |
| **BQC** | Barley | - | Quinoa | - | Chickpea |
| **BWC** | Barley | - | Wheat | - | Chickpea |
| **CBQ** | Chickpea | - | Barley | - | Quinoa |
| **CBW** | Chickpea | - | Barley | - | Wheat |
| **CQB** | Chickpea | - | Quinoa | - | Chickpea |
| **CWB** | Chickpea | - | Wheat | - | Chickpea |

Table 1. Three-year organic crop sequence treatments following alfalfa.

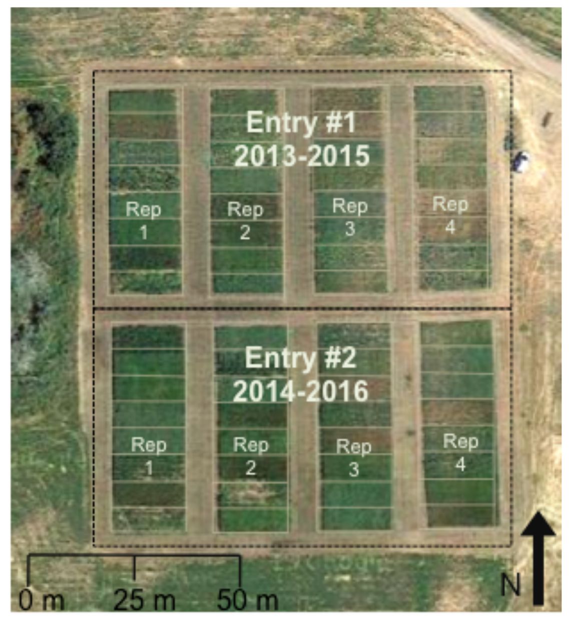


Figure 1. Experimental field layout. Satellite image from Google Maps, June 2015

Crop yields were determined by harvesting a center strip with a plot combine. Crop quality parameters were also tested using appropriate methods for each crop type and parameter.

Annual enterprise budgets were constructed for each treatment, consisting of the components listed in Table 2.

Seed and crop prices are shown in Table 4. Regional organic prices were used when available; if not available, national organic prices were used or a 30% premium for local conventional prices, as with alfalfa.

Linear mixed effects models were used to determine statistical differences and treatment effects.

| Variable Costs | Fixed Costs | Revenue |
|---|---|---|
| Annual Inputs (seed, inoculant, fertilizer) | Machinery ownership (including depreciation and interest) | Yield x Harvest Prices |
| Machinery use (fuel, labor, repairs) | Cost of Land (Crop-Share) | |

Table 2. Components of the enterprise budgets

| Growing Season | Precipitation (mm) |
|---|---|
| 2013 | 581 |
| 2014 | 353 |
| 2015 | 451 |
| 2016 | 528 |

Table 3. Precipitation amounts for the growing seasons. 2015 also had record high temperatures in June

## Results

| Year | Crop | Seed Cost $ kg$^{-1}$ | Harvest Price $ Mg$^{-1}$ |
|---|---|---|---|
| 2008 | Alfalfa | 7.18 | - |
| 2009 | Alfalfa | 8.62 | 220.51 |
| 2010 | Alfalfa | - | 226.02 |
| 2011 | Alfalfa | - | 314.22 |
| 2012 | Alfalfa | - | 325.25 |
| 2013 | Barley | 1.26 | 440.93 |
| | Chickpea | 1.04 | 562.17 |
| 2014 | Barley | 1.26 | 468.48 |
| | Chickpea | 1.13 | 476.19 |
| | Quinoa | 13.26 | 837.10 |
| | Wheat | 0.60 | 477.68 |
| 2015 | Barley | 1.26 | 440.93 |
| | Chickpea | 1.33 | 476.19 |
| | Quinoa | 13.26 | 705.88 |
| | Wheat | 0.60 | 440.93 |
| 2016 | Barley | 1.26 | 413.37 |
| | Chickpea | 2.21 | 593.03 |
| | Quinoa | 4.42 | 542.99 |
| | Wheat | 0.60 | 293.96 |

Table 4. Seed cost and harvest prices for each crop used in the enterprise budgets.

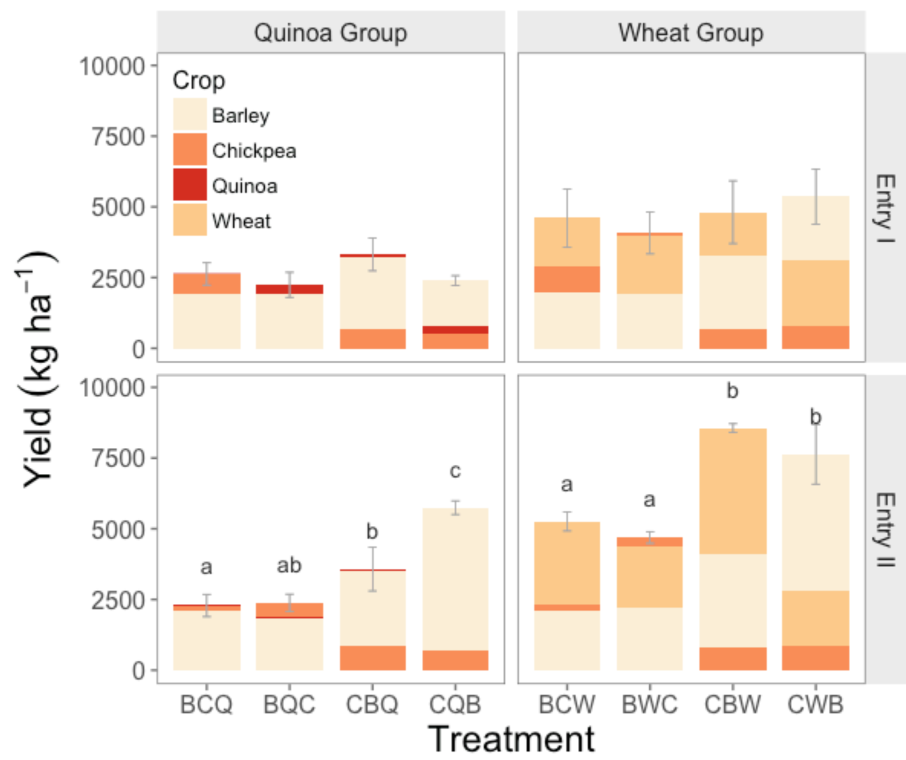


Figure 3. Total sequence yields (divided by crop) of quinoa group treatments (left) and wheat group treatments (right) for both entries. Letters indicate significant differences between treatments in Entry II determined by post hoc Tukey pairwise comparisons at P ≤ 0.05.

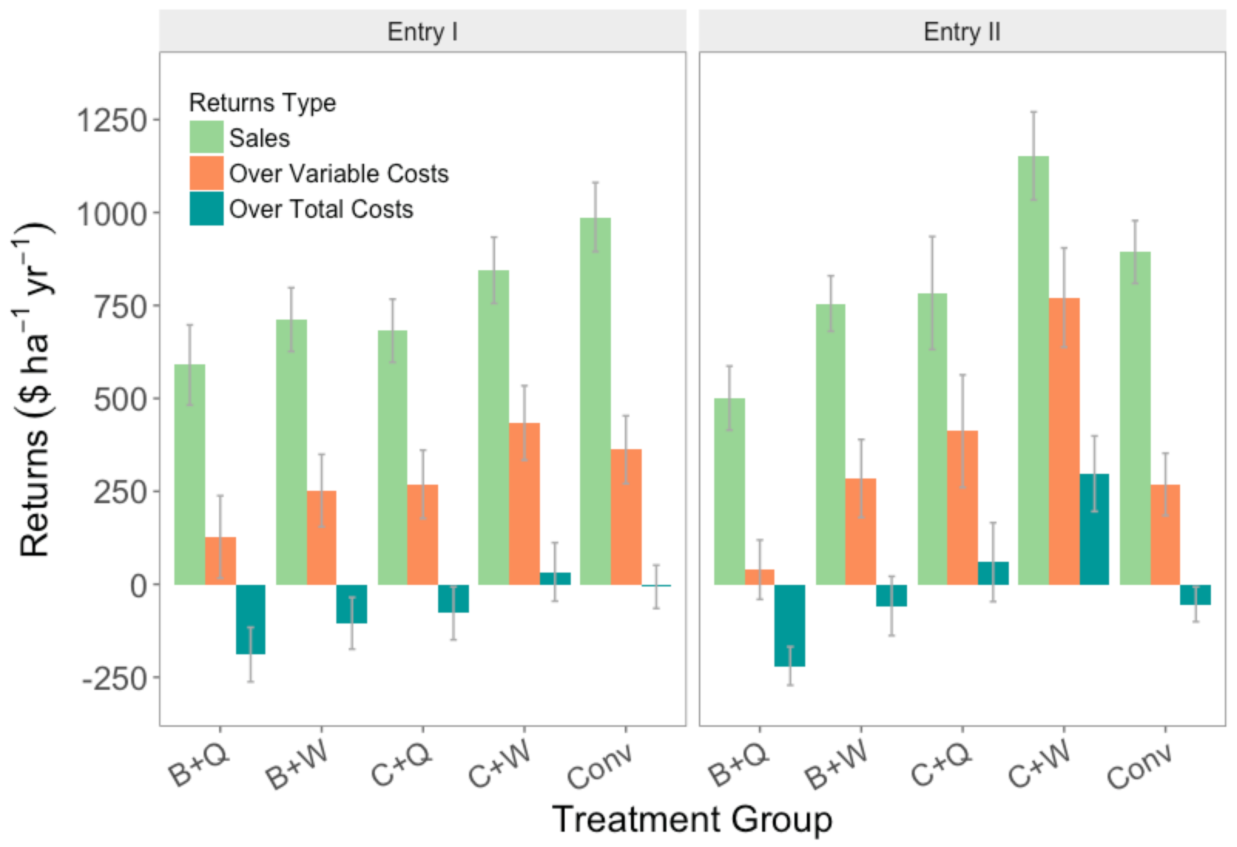


Figure 4. Revenue and net returns for the 3-year grain sequences, averaged in groups by beginning sequence crop (after alfalfa) and quinoa vs. wheat groups, for each entry. Experimental treatments are also compared to an enterprise budget of a simulated conventional crop rotation (**Conv**) of Winter wheat–Spring Wheat–Chickpea using county average yields from the same 3-year periods (2013-2015 for Entry I & 2014-2016 for Entry II)

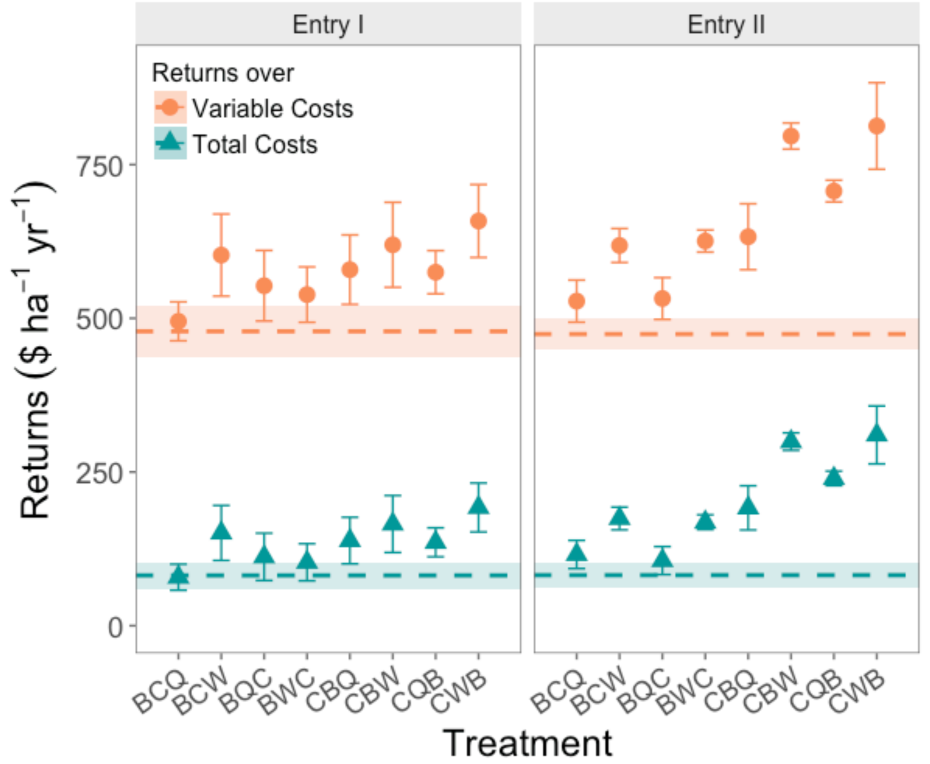


Figure 5. Figure 5. Average (± SE) returns over variable costs and total costs (green) for the entire 8-year crop rotation (including alfalfa). Dotted lines represent the average returns (± SE, shaded area) for the standard conventional crop rotation described in Figure 4 for the same 8-year periods.

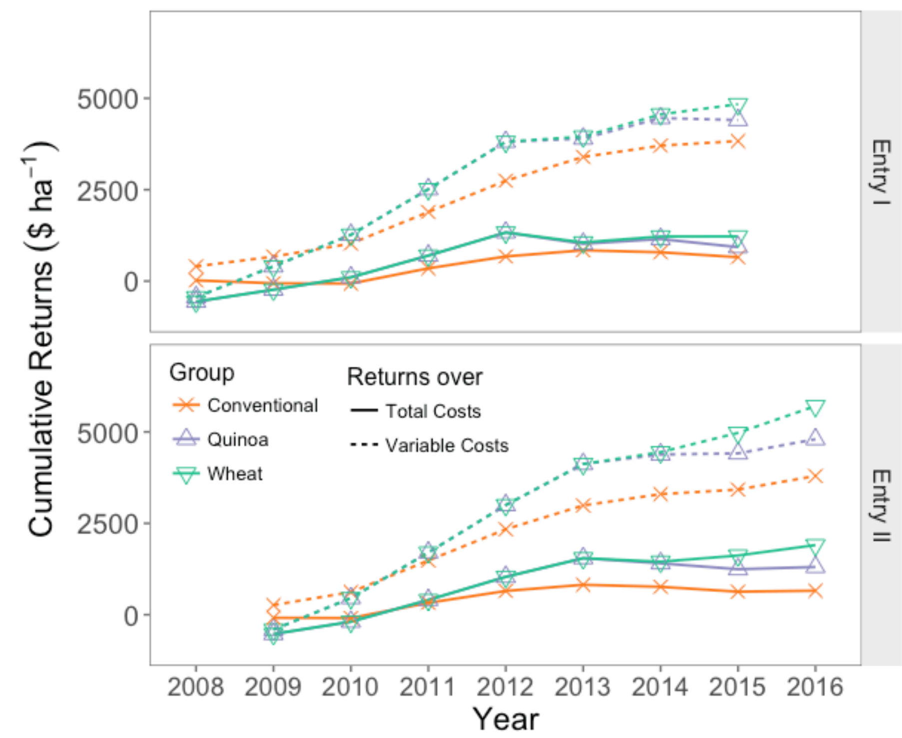


Figure 6. Cumulative net returns for the 8-year crop rotations tested in this study compared with the cumulative net returns for the standard conventional crop rotation described in Figure 4. "Quinoa" and "Wheat" groups are averages of all four treatments containing those crops.

## Results

- Crop yields varied greatly with weather differences across years (Figure 3; Table 3).
- Barley and spring wheat yields averaged 2552 and 2402 kg ha$^{-1}$, respectively (68% and 71% of the county averages of conventional yields for that period).
- Chickpea yields were very low most years, averaging 544 kg ha$^{-1}$ (35% of county conventional yields), and average quinoa yields (104 kg ha$^{-1}$ ) were also much lower than the reported conventional yield potential for the region.
- Quality parameters were also driven mostly by weather differences; However, barley protein was higher after quinoa compared to after wheat and quinoa protein was higher after chickpea than after barley.
- Overall sequence yields were greater in treatments that started with chickpea.
- High input cost for chickpea seed drove differences in variable costs (Table 4).
- Returns over variable costs for the 3-year sequences averaged $324 ha$^{-1}$ yr$^{-1}$
- Net returns were significantly higher in the wheat group treatments than the quinoa group. Net returns were also higher in treatments that started with chickpea compared to those that started with barley.
- During the 3-year sequences, profits were made 21 out of 48 crop years (43.8%). Negative returns occurred during many chickpea years and some quinoa years.
- The revenue from the alfalfa phase greatly improved the economic performance of the 8-year organic rotations (averaged $617 ha$^{-1}$ yr$^{-1}$ over variable costs and $135 ha$^{-1}$ yr$^{-1}$ over total costs). Alfalfa establishment for the years in this study averaged $554 ha$^{-1}$ loss, but it was regained after 2 years of alfalfa harvest.
- Alfalfa phase also increases the profitable years to 75% for the organic rotations tested here.

## Conclusions

Cropping sequence choice had a significant effect on the overall yields and economic returns for the cropping systems tested. Weather stresses on crops can be diminished or magnified depending on the position crop sequence. For example, cereals performed better when they followed a non cereal in a dry year, and weed pressure was more detrimental later in the sequence.

Organic cropping systems (8-year) performed equally or better than the standard conventional rotation in this region; organic premiums help make up for lower yields of organic crops. The organic cropping systems tested had greater variability in yields and economic returns compared to the standard conventional crop rotation for the region.

Longer-term alfalfa (greater than 3 years) provided a significant economic boost, in addition to being critical for weed and soil management for these organic dryland rotations.

### Acknowledgements

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