Grant Code: AW5464
Title: Developing wheat intercropping systems in southern Idaho
Personnel: Zachary Kayler, Xi Liang
Address: Zachary Kayler, Department of Soil and Water Systems, University of Idaho, Moscow, ID, 83843, Ph: 208-885-5616, email: zkayler@uidaho.edu.

Justification/Rationale: Idaho's wheat producers need new agronomic options and revenue streams as they make decisions in uncertain markets and limited water resources. There are multiple demands placed upon Idaho's water resources and with the state's rapid growth and resource use, the pressure on water will only increase. Applying technological advances in irrigation supply is one strategy to improve water use efficiency, but it is expensive to adopt. Wheat breeding is another strategy to improve water use efficiency particularly when used with soil-building cropping systems. Intercropping water use efficient wheat with N-fixing legumes or other companion crops (e.g., canola) has the potential to increase crop yield and mitigate grain market fluctuations, while maintaining soil health and water resources compared to monocropping systems.

Despite the potential agronomic and economic benefits of intercropping, very little is known about its implementation. Currently, intercropping wheat with peas in dryland systems is a strategy used toward organic certification. However, a roadblock to the adoption of intercropping more generally is the matching of wheat varieties and intercropped species. We propose to fill this gap in our knowledge by performing field trials of candidate wheat varieties with potential companion species (pea and canola). Peas are a good candidate companion plant because of the N fixing potential. Canola is seen as a means to increase or maintain profitability since it is not tied to the grain market, furthermore, there are indications that canola in rotation can improve wheat grain quality and control soil-borne pests (e.g., nematodes). The outcomes from this research will highlight the water use efficiency of selected wheat varieties and the agronomic efficacy of intercropping in dryland systems of southern Idaho.

This proposal builds off of a currently funded USDA project on intercropping and we expect mutual benefits and efficiencies by leveraging know-how and resources for this wheat-intercropping project. The benefits to the wheat industry include minimizing investment risk through utilizing the University of Idaho's research capacity including personnel, instrumentation, and analytic capabilities. The results from this research will provide resolution to the question of whether alternative wheat cropping systems results in substantial advancement in yield, grain quality, or resource sustainability. This project will improve the citizens of Idaho livelihood by enhancing food security and educating the future agricultural work force. The results from this project will fill gaps in our scientific knowledge regarding the use of plant complementarity to mediate drought and achieve improved soil health.

Hypothesis & Objectives: The hypotheses and research objectives (RO) of this study are as follows:

Hypothesis 1: *Relative yield will be greater in wheat intercropped with pea and canola compared to wheat monocrops.*

RO 1.1 Quantify wheat crop yield when intercropped with pea and canola during each growing season.

RO 1.2 Document costs (seed, fertilizer, harvesting) and returns (bushels/acre, water and fertilizer savings) for assessing intercropping feasibility.

Hypothesis 2: *Wheat grain quality will be higher in intercropped plots compared to monocropped plots.*

RO 2.1 Quantify wheat grain quality at the end of each growing season.

Hypothesis 3: *Water use efficiency will be greater in wheat intercropped with pea and canola compared to wheat monocrops.*

RO 3.1 Quantify wheat water use efficiency during the season using leaf carbon isotopes.

RO 3.2 Quantify biomass-based water use efficiency at the end of each season.

Hypothesis 4: *Soil Health will be greater in intercropped plots compared to monocropped plots.*

RO 4.1 Quantify soil POX-C and C:N ratio.

Procedures/Plan of work: The experiment will be held over three years at the Aberdeen Research and Extension Center, University of Idaho. In each year, we will establish experimental plots with dry pea-wheat and canola-wheat intercropping plots in alternate rows with two wheat varieties 'Ryan' and 'WB 7202 CLP'. The experiment will consist of 6 cropping system treatments (monocropped Ryan, monocropped WB 7202 CLP, pea-Ryan, pea-WB 7202 CLP, canola-Ryan, and canola-WB 7202 CLP) and two water regimes (well-watered vs. dryland). We chose the wheat varieties because Ryan is the highest soft white spring wheat in planted acres in Idaho in 2020, and WB 7202 CLP is also among the highest hard white spring wheat.

The dimension of experimental plots will be 10×20 ft and consist of 14 plant rows. We are using a split-plot design where water regime treatment is the main plot. The distance between blocks is 40 ft, which is also the irrigation radius of nozzles on irrigation pipelines, thus irrigation water will not drift to other main plots. During the experiment, irrigation will be applied at 100% (well-watered) of crop evapotranspiration (ET_c), calculated by multiplying reference evapotranspiration (ET_o) by crop coefficients (K_c) of wheat. Daily ET_o will be retrieved from a meteorological station located within 1 mile of the experimental site (AgriMet Cooperative Agricultural Weather Network). For the dryland treatment, irrigation will be applied following the average precipitation distribution of Rockland where the annual precipitation is approximately 12 inches.

For each year, initial soil samples will be collected to establish a baseline. Initial soil samples will also be used for comparison to the end of the previous year's to determine nutrient credits. Water use efficiency will be quantified via leaf isotopic values over key wheat growth stages. At the end of each season, yield will be quantified, grain quality analyzed, and biomass based water use efficiency quantified. Soil sampled at the end of the year will be analyzed for POX-C (a proxy for microbial available carbon) and soil C:N ratio at three depths (0-6, 6-12, and 12-24 inches). We will summarize costs (seed, fertilizer, harvesting) and returns (bushels/acre, water and fertilizer savings) accrued over a season.

Soil fertilization tests will be analyzed at Stukenholtz Laboratory and grain yield and end-use quality will be assessed at the Wheat Quality Lab in Aberdeen. All other analyses will occur within the lab facilities of PI's Kayler and Liang. The split block design allows for mixed-model analysis of variance to test for significance of treatments on yield, land-use equivalent ratios, grain quality, water use efficiency, POX-C, and soil C:N ratio.

Duration: 3-yrs.

Cooperation/Collaboration: The proposed research will be carried out collaboratively between Dr. Kayler and Dr. Liang at the Aberdeen Research & Extension Center.

Anticipated Benefits, Expected Outcomes and Impacts, and Transfer of Information: A clear benefit to the wheat producers of Idaho is the deferred risk of establishing and carrying out a multiyear intercropping trial. Wheat prices are competitive and any deviation from expected returns represents a risk to the producer; however, in avoiding risk, new agronomic techniques and revenue streams are not explored. On large farms, intercropping can be achieved by using air seeders with 2 tanks. During harvesting, taller-statue crops are harvested first followed by the shorter ones.

Our research will bring valuable and conclusive information on intercropping and its potential to improve yield, grain quality, and soil health. The results will inform producers of viable agronomic options as they make decisions in an uncertain market and resource future. The information will be made available in different forms. We will maintain an Idaho Intercropping website that will share project aims and progress. We intend to create YouTube videos that will show the techniques we use. PI Kayler teaches a nutrient management course and PI Liang presents at field days during which the results will be shared. The results will be published in peer-reviewed extension and scientific formats.

Literature Review: Models predict up to a 32% loss in crop production for major agricultural areas under worst-case scenarios in Idaho (Xu et al. 2014). Thus, farmers need reliable agronomic tools to adapt to changes in market fluctuations and resource availability, including soil and water. *Intercropping is where two or more crops are cultivated simultaneously in one field. It increases plant species, which enhances soil C and N stocks, and has been shown to produce greater yields per unit land area compared to monocropping* (Brooker et al. 2015; Cong et al. 2015). However, the success of intercropping systems depends on the complementarity (partitioning resources, reducing competition between species) and facilitation (positive interactions between plant species responsible for supplementary services) of the plants (Duchene et al. 2017). For example, higher productivity can be achieved when different plant species are complementary in terms of spatial (e.g., different canopy and root architectures) and temporal (e.g., different timings of highest nutrient demands) resource acquisition (Cong et al. 2015).

Reports of intercropping in the region are limited. In a pilot study at the Cook Agronomy Farm in Washington, peas temporarily intercropped with wheat did not interfere with water or N resources (Ott-Borelli, 2012). Nurse crops (oats) with alfalfa have been explored and reports of double cropping wheat and peas have shown the potential for increased protein content of winter wheat (Brown et al., 1984). Pea production has also been explored in wheat intercrops previously (Murray and Swenson, 1984). In Southern Idaho, there have been local reports of the use of mustard as companion crops to improve soil health (O'Connell, 2018).

References: Brooker RW *et al.*, 2015. *Improving intercropping...* New Phytol. 206:107–117. **Brown *et al.*,** 1984. *Nitrogen fertilization ...* Idaho Archive 8586. **Cong WF *et al.*,** 2015. *Intercropping enhances soil carbon and nitrogen.* Glob Chang Biol. 21(4):1715–1726.**Duchene O *et al.*,** 2017. *Intercropping with legume...* Agric Ecosyst Environ. 240:148–161. **Murray GA and Swenson JB.** 1984 *Intercropping...* Current Information series 749. **O'Connell J,** 2018. *Capital Press.* **Ott-Borrelli, K.,** 2012. *Rotational Cropping Systems for Nitrogen Management...* WSU PhD dissertation. **Xu W et al.,** 2014. *Climate change, water rights, and water supply: The case of irrigated agriculture in Idaho.* Water Resour Res. 50:9675–9695.

FY2023
COMMODITY COMMISSION BUDGET
Principal Investigator: *(Zachary Kayler)*

Allocated by	*(Commission/Organization)*	during FY2021	$ -
Allocated by	Idaho Wheat Commision *(Commission/Organization)*	during FY2022	$ 16,039

REQUESTED SUPPORT: **Budget Categories**			***Awarded** for FY2022*	***Requested** for FY2023*
(10) Salary *(staff, post-docs, e* *NOTE: Faculty salary/fringe not allowed*			$ -	$ -
(12) Temporary Help	$	10,000	$ 8,060	$ 10,000
(11) Fringe Benefits	$	860	$ 1,979	$ 860
(20) Travel			$ 1,000	$ 1,000
(30) Other Expenses	$	6,000	$ 5,000	$ 6,000
(40) Capital Outlay >$5k			$ -	$ -
(45) Capital Outlay <$5k			$ -	$ -
(70) Graduate Student Tuition/Fees			$ -	$ -
TOTALS			$ 16,039	$ 17,860

TOTAL BUDGET REQUESTED FOR FY2023: $ 17,860

BREAKDOWN FOR MULTIPLE INDEXES: **Budget Categories**	*Kayler*	*Liang*	*(Insert Co-PI Name)*	*(Insert Co-PI Name)*
(10) Salary *(staff, post-docs, et*	$ -	$ -	$ -	$ -
(12) Temporary Help	$ 5,000	$ 5,000	$ -	$ -
(11) Fringe Benefits	$ 430	$ 430	$ -	$ -
(20) Travel	$ 1,000	$ -	$ -	$ -
(30) Other Expenses	$ 4,000	$ 2,000	$ -	$ -
(40) Capital Outlay >$5k	$ -	$ -	$ -	$ -
(45) Capital Outlay <$5k	$ -	$ -	$ -	$ -
(70) Graduate Student Tuition/Fees	$ -	$ -	$ -	$ -
TOTALS	$ 10,430	$ 7,430	$ -	$ -
			Total Sub-budgets	$ 17,860

ANNUAL REPORT

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Accomplishments: Last year we established the intercropping trial with two wheat varieties and pea and canola companion crops in four blocks. Within each block are 2 sub-blocks, one is well watered and the other is under deficit irrigation defined as 100 and 50% of evapotranspiration, respectively. Within each sub-block are plots planted with monocrops of the wheat varieties, and intercropping plots containing pea or canola intercropped with the two wheat varieties (Figure 1).

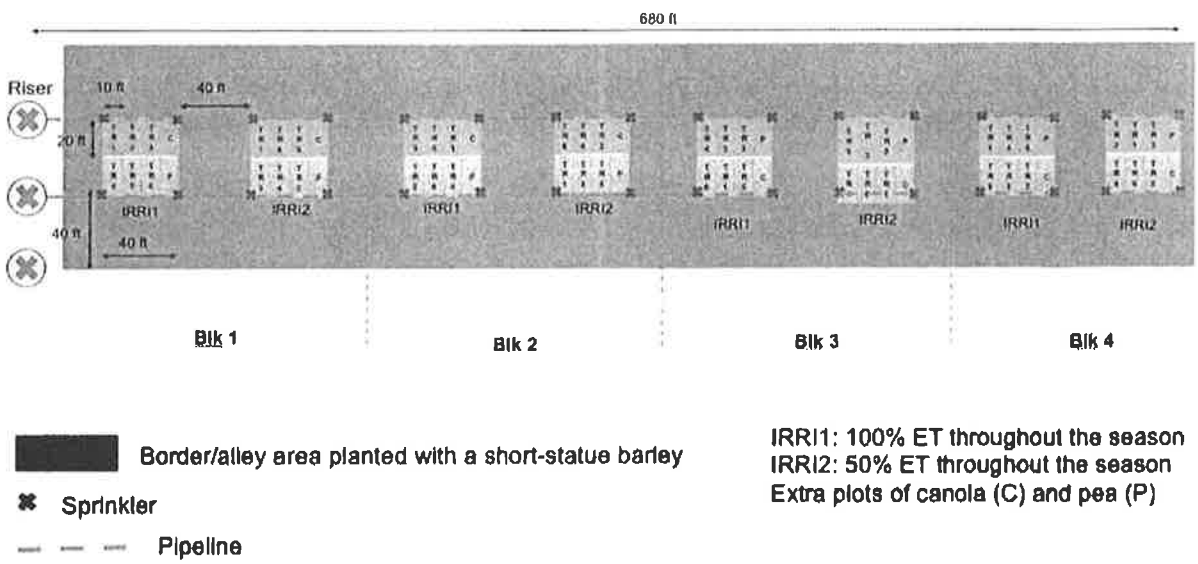

Figure 1. Field layout of the wheat intercropping experiment. We used two wheat varieties: W1 is WB6430 (soft white spring), and W2 is WB7202 CLP (hard white spring). Subplots of monocrop pea and canola are also replicated.

Soil was sampled at harvest from three depths (0-6, 6-12, and 12-24 inches). The soil is in the process of POX-C analysis to quantify labile carbon. Soil carbon and nitrogen will also be analyzed this spring and summer.

The experiment was harvested at the end of the season, and biomass samples are being processed. Leaves will be ground and analyzed for water use efficiency. We expect to see differences between the deficit irritation treatment and companion crop species. Grain samples have been sent to the Wheat Quality Lab in Aberdeen for end-use quality analyses.

Total grain yield from 2021 is shown in Figure 2. Deficit irrigation had a significant negative impact on wheat yield ($p<0.01$) across all treatments. The yield of the soft white variety when intercropped with pea was greater than the monocrop in the well-watered treatment. The hard white variety had the greatest yield when monocropped. The overall yield in wheat-canola intercrop was less than both varieties in monocrop under both water regimes, but did show an ability to compete and the capacity to add economic value to the cropping system.

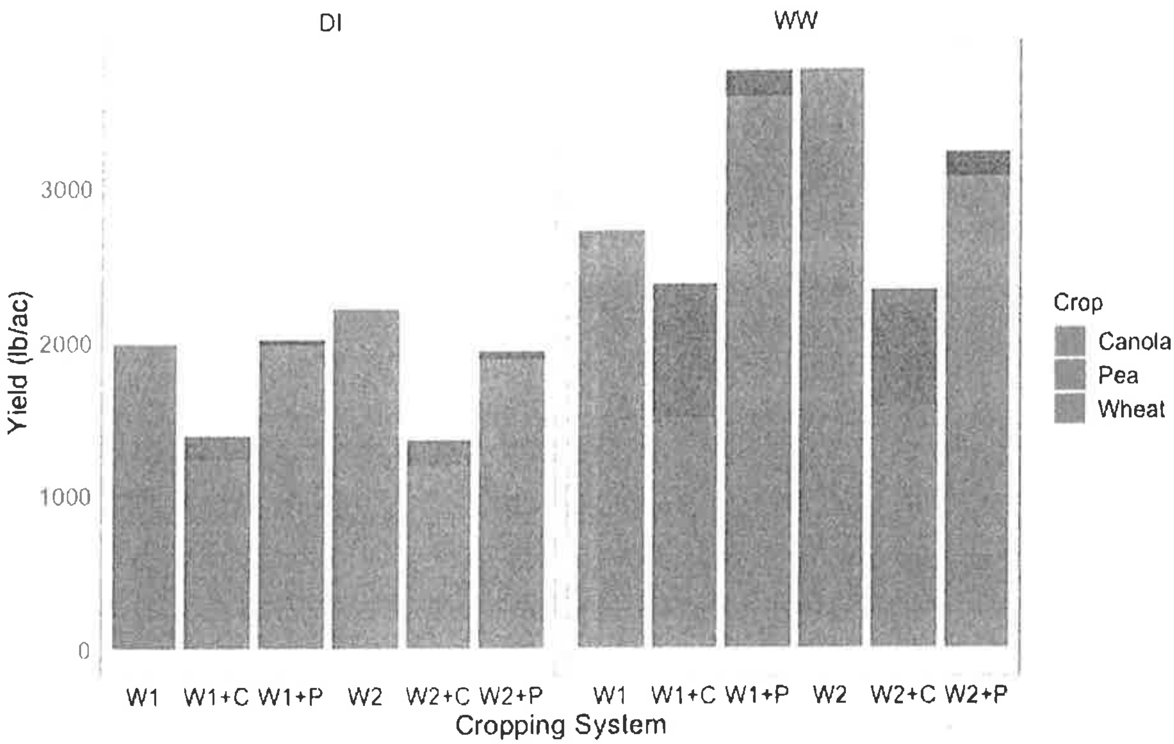

Figure 2. Grain yield from the first year of wheat intercropping with pea and canola under deficit irrigation (DI) and well-watered conditions (WW). The yield is shown with all crops present in the agronomic system. The symbols correspond to: W1-soft white wheat (WB6430), W1+C – soft white wheat intercropped with canola, W1+P – soft white wheat intercropped with pea, W2– hard white wheat (WB7202 CLP), W2+C – hard white wheat intercropped with canola, W2+P – hard white wheat intercropped with pea. The seasonal rainfall was 0.44 inch, and the irrigation for the well-watered treatment was 17.2 inch.

Within the deficit irrigation treatment, we found that wheat intercropped with canola had the worst performance (Figure 2). No significant difference was detected between the soft white wheat monocrop and soft white intercropped with pea, hard white monocrop, or hard white monocrop with pea.

Activities to complete in this period include wheat end-use quality analyses and estimating an economic breakdown.

Projections: This project has led to a USDA Organic Transitions proposal awarded to Xi Liang and Kayler.

Publications: These data will be presented at the Cereal School by Dr. Xi Liang this Spring.