Report Type: Final

Title: Water, Land, and Nutrient Use Efficiency for Intercropping Systems in the Dryland Pacific Northwest

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Abstract:

Agricultural systems are currently experiencing pressure to become more efficient in the utilization scarce resources such as space and N and P fertilizers. One practice which might greatly increase the efficiency of agricultural systems is that of intercropping. Intercropping is an ancient cropping practice which has been reduced since the advent of mechanized agriculture with large scale synthetic chemical and fertilizer inputs. Intercropping continues to be practiced in small scale and subsistence agricultural systems around the world. However, intercropping is rarely practiced in large-scale agricultural systems. Recent efforts have focused on adapting intercropping to large-scale mechanized agriculture. A prominent intercrop to include in some such systems is the intercropping of peas and canola sometimes referred to as peaola. However, peaola has not been formally attempted in the inland Pacific Northwest (iPNW). In this project we sought to assess the feasibility and potential efficiency gains of winter peaola intercropping in the iPNW. The land equivalence ratio (LER) was used to asses the possible increases in land use efficiency with the incorporation of peaola intercropping while increasing the N and P rates were used to assess the efficiency of N and P in peaola cropping system. Peaola was shown to have significantly higher LER than either of the monocultures. No response in either pea or canola seed yield was detected with increasing N and P fertilizer rates. Additionally, LER was not shown to be affected by the N or P rate. In conclusion winter peaola systems in the inland Pacific Northwest appear to offer large potential increases in land and fertilizer efficiency for iPNW. Future research should focus on removing the technical barriers to adoption and quantifying the ecosystem service provided by intercropping.

Project Description:

Conventional agriculture lacks the requisite resource use efficiencies to sustainably produce adequate food, fiber, and feed to support a growing global population. Improved resource efficiency may be achieved through increased crop diversity and intensity. In many regions the integration of cover crops serves to increase crop diversity and intensity. However, due to regional rainfall patterns, cover cropping has met with limited success in the inland Pacific Northwest (iPNW). An alternative method for increased diversity and intensity is through intercropping. Intercropping of peas and canola (peaola) is of special interest in the iPNW. Research in both Australia and Canada have previously demonstrated the agronomic feasibility of legume-oilseed intercropping. Additionally, these practices have been adopted by a few largescale conventional farming operations in Canada. In order to assess the feasibility of these practices in the iPNW a two-year plot study was planned at two locations in Washington. The two locations (Ralston, WA and Davenport, WA) were chosen to represent the low (A) were chosen to represent the low (<12”) and intermediate (12-18”) precipitation zones of dryland crop production in the region.

The plot studies were designed to compare canola and pea monocrops with full nitrogen (N) and phosphorous (P) inputs to peaola under full and reduced N and P inputs. The plot studies at Ralston, WA and Davenport, WA had six identical treatments. The treatments were canola 100% N and 100% P, peas 0% N and 100% P, and peaola at four different levels of N and P inputs. The peaola intercrop treatments were three N fertilizer rates of 0%, 50%, 100% of the recommended canola N rate at 100% P, and one 0% P treatment at 100%. The treatments were designed to assess the response of N and P to peaola in the iPNW. Of the six treatments, only the two monocrop treatments and the peaola at 0% and 100% N will be utilized for constructing nitrogen balances and calculating N and P use efficiencies (Table 1). Each treatment was replicated four times in a randomized complete block design.

Crop	*N rate*	*P rate*	*N and P Efficiencies Analyzed*
Pea	0%	100%	Yes
Canola	100%	100%	Yes
Peaola	0%	100%	Yes
Peaola	50%	100%	No
Peaola	100%	100%	Yes
Peaola	100%	0%	No

Table 1: Experimental Treatments for Plot Studies

Outputs

Two successful years of small plot winter peaola were completed at Davenport verifying the increased LER and fertilizer use efficiency over the two years. Two attempts were made to establish peaola in Ralston Washington. However, in both 2020 and 2021 the canola failed to establish, and the plots were terminated the following spring. The plots established at Davenport were taken to harvest and the yield data was used to analyzed to assess the effects of N and P fertilizers on the yield of peas and canola in the peaola intercropping. The monoculture yields were used to calculate the relative yields for the intercropped canola and peas as well as the land equivalence ratio (LER). The relative yields and LERs were analyzed, and the LER of the canola was found to be significantly greater than the LER of the monocultures.

Methods:

Treatments: The control will be monoculture winter peas and canola fertilized at the recommended rates for all nutrients including N and P. The winter peaola intercrop treatments will be three N fertilizer rates of 0, 50%, 100% of the recommended N rates and one 0 P treatment. Resulting in a total of six treatments, of these six treatments only the two controls and peaola at 0% and 100% N will be utilized for constructing nitrogen balances and calculating NUE and PUE as nutrient analysis on all treatments would be cost prohibitive.

Planting methods: Plots (6 foot x 40 foot) will be planted using a Fabro seed drill with two tandem ‘gangs’ of double disk openers allowing for two depth settings (3” for peas) and (1.5” for canola).

Fertilizer methods: In furrow micronutrient and phosphorous applications will be made. However, N applications will be applied as late fall and early spring split application as Urea Ammonium Nitrate following the current WSU recommendations for winter canola.

Harvest methods: Plots will be harvested using a Wintersteiger combine previously set and utilized for canola harvest. Additionally meter row hand samples will be harvested in order to calculate the harvest index of the peaola and the monoculture treatments. The combined samples of pea and canola seed will then be separated and weighed as estimate of commercial harvest in order to calculate the NUE, PUE, WUE, and LER. Sub samples of the harvested canola and peas will be analyzed for N and P concentrations to calculate the effects of intercropping treatments on partitioning N and P.

Results:

The average yield of monoculture peas in 2020 and 2021 growing seasons was 2455 lbs/acre and 76 lbs/acre respectively. The average yield of the monoculture canola in the 2020 and 2021 growing seasons was 1960 lbs/acre and 832 lbs/acre respectively. The average yield of canola in the peaola in 2020 was 1530 lbs/acre in and 710 lbs/acre in 2021. The pea yield in the peaola plots was 1740 lbs/acre in 2020 and 73/lbs/acre in 2021. During both 2020 and 2021 there was no significant effect of the N fertilizer rates on pea, canola, or LER due to the N and P fertilizer rates. In both 2020 and 2021 the LER of the peaola (1.64) was significantly greater than the LER of the monocultures.

Discussion:

At the Davenport location the small plot experiments were successfully established in both 2020 and 2021. However, at the Ralston location the peas established in both 2020 and 2021, but the canola failed to emerge. In both 2020 and 2021 yield data was collected from the Davenport location resulting in two site years of yield data. The 2020 and 2021 growing seasons were dramatically different from each other with the 2020 growing season having above average precipitation across the region, and 2021 being a severe drought with record-breaking heat in late June. The heat wave in late June along with the cumulative effect of the drought reduced the yield of the winter peas to a crop failure 76 lbs/acre in the control plots. The failed establishment of canola in at Ralston for the 2020 and 2021 cropping seasons demonstrates the need for research focused on developing the planting guidelines for peaola. Specifically, such research should establish guidelines for planting depth, seed ratios, and seeding time.

Another important consideration when developing management guidelines for peaola production is the roll of fertilizers in peaola production. In both the 2020 and 2021 cropping years the yield of the peas, canola, and peaola were not increased or decreased with the rate of N and P fertilizers. These results indicate that the fertilizer use efficiency as far as N and P are concerned is at least as efficient as the monoculture canola. Nutrient response experiments in both N and P on monoculture winter canola in the inland Pacific Northwest have had difficulty in obtaining significant results or responses to fertilizers. It is therefore impossible from our research to determine whether the canola is receiving N from the peas or if the exceptional N scavenging ability of canola is resulting in no response to the additional N. In either case the peaola production could likely be carried out in the inland Pacific Northwest with negligible fertilizer inputs. The lack of response to both N and P fertilizer inputs indicates that the NUE and PUE of the intercropped systems exceeds that of the monocultures. However, since there was no 0 fertilizer check in the monoculture peas or canola, further inferences on the relative efficiencies of the intercropped system cannot be made from this data set. Future research on the rotational nutrient use efficiencies of peaola vs. the monocultures on the subsequent wheat crop.

The LER which is a measure of efficiency on a land basis showed peaola was significantly greater than the monocultures in both 2020 and 2021. From the perspective of efficient land use these results demonstrate that once successfully established the peaola intercropping system outperforms the monoculture alternatives. While the primary objective of this study was to assess the resource use efficiency of peaola intercropping, resilience in the face of changing climates is equally important to sustainable agriculture. The average LER of the peaola increased from 1.49 in 2020 to 1.81 in 2021 indicating that the land use efficiency of peaola is likely resilient and perhaps even antifragile under certain extreme weather conditions. These results should be incorporated into models used to estimate the resilience of agriculture to adverse climate conditions.

In conclusion, the preliminary data collected in this project highlights the potential of peaola intercropping to increase the efficiency and resilience of the current monoculture systems in the inland Pacific Northwest. Future research should focus on the understanding the ecological effects of the peaola systems as well as further developing the management practices which will allow peaola to succeed at a large scale. Success of peaola across the region has the potential to greatly improve the productivity and sustainability of agricultural systems across the region and future research should continue to focus on this production method.

Publications, Handouts, Other Text & Web Products:

Journal Article:

Madsen, I.J., Friesen, M., Parks, J., and Clark, R. Increasing Biodiversity and Land Use Efficiency Through Pea-Canola Intercropping (Peaola). Frontiers in Soil Science (Submitted)

Field Day Abstracts:

Clark, R., Madsen, I. J., (2021) Peaola Intercropping as a Pest and Beneficial Insect Management Tactic. 2021 Field Day Abstracts: Highlights of Research Progress (pp. 63). Pullman, WA: Washington State University. https://css.wsu.edu/extension/field-day-abstracts/

Madsen, I. J., Ford. J. (2021) Peaola Yield and Land Equivalence Ratio Experiments. 2021 Field Day Abstracts: Highlights of Research Progress (pp. 66-67). Pullman, WA: Washington State University. https://css.wsu.edu/extension/field-day-abstracts/

Podcast:

Lyon, D. and Madsen, I., (2021) Intercropping with Isaac Madsen. The WSU Wheat Beat Podcast Episode-82 https://smallgrains.wsu.edu/wsu-wheat-beat-episode-82/

Outreach & Education Activities:

Madsen, I.J. Peaola for the PNW. Spokane Farm to Food. Nov. 5th, 2021 (>100 participants)

Canola Field Day near Davenport. May. 26th, 2021 (~10 participants)

Impacts

- Short-Term: In the short term this project has been used to develop the preliminary datasets necessary for understanding the potential of peaola intercropping systems in the inland Pacific Northwest. Additionally, this project provides preliminary data on the best management practices for fertilizer in peaola intercropping.
- Intermediate-Term: In the midterm this project has been used to increase awareness of the inefficiencies in existing systems and the potential for increased efficiencies with intercropping systems. Additionally, this project has been used to encourage growers to attempt strips of peaola in existing production fields with two strip trials being conducted by growers in the during the 2021-2022 growing season.
- Long-Term: In the long term, the results of this project should serve as a starting point for the introduction and adoption of peaola intercropping in the inland Pacific Northwest. Increased intercropping should lead to a long-term increase in resilience and efficiency in mechanized agricultural systems in the inland Pacific Northwest.

Additional funding applied for/secured:

Understanding the impact of the peaola microbiome on soil fertility, crop yield, and plant nitrogen content. WSARE – graduate student grant ($29,929) PI: Maren Friesen, Graduate Student: Janice Parks, Researcher: Isaac Madsen

Graduate students funded:

None

Recommendations for future research:

This funding leveraged additional resources which were able to analyze the soil microbiome as well as conduct preliminary data on the arthropod diversity and populations in the peaola and monoculture settings. Additional research should focus on assessing ecological diversity which can be introduced through the integration of intercropping systems into the monoculture dominated landscapes. Additional research is needed to further develop best management practices for the peaola production system. Specifically, seeding depth, rate, and time guidelines should be established.