1. Project details

Project File number: AGR-17173, Western Grains Research Foundation, Prairie Oat Growers Association
Project title: Continuing studies on intercropping for increasing yield and quality of grain and forage crops, and improving soil quality, by Fernandez et al.
Reporting period: April 1st, 2021-March 31st, 2022
Approved Project Date: Amended CRDA signed by all parties in May 2020
Report prepared by: H. Brackenridge and M.R. Fernandez

2. Specify project activities undertaken during this reporting period

a.) Methodology:

In 2021, field trials were initiated on organically managed land at the Swift Current Research and Development Centre (SCRDC) of Agriculture and Agri-Food Canada. Intercrop and living mulch treatments were separated into two trials, herein referred to as “intercrop trial” and “living mulch trial”. Phase 1 of both trials was conducted in 2021, which included the intercrop and living mulch treatments initially proposed for the first study year. In addition to a new Phase 1 in 2022, Phase 2of the 2021 trials is planned for 2022, which includes a durum wheat crop planted on the same trial areas. Due to on-going restrictions to prevent the spread of COVID-19, the SCRDC milestones were delayed by one year.

A green manure cocktail mix was seeded on the trial areas in 2020. The cocktail mix consisted of a legume, a cereal and a brassica.It was plowed down at flowering/headingat the end of July. In the spring of 2021, soil samples were taken from trial areas to measure soil moisture, N, P, Kand pHbefore seeding. Following soil sampling, intercrops and living mulches were seeded in 4 m x 8 m plots. Intercrop combinations included field pea/oat and lentil/barley in either mixed rows or alternate rows, and mustard/chickling vetch. Living mulch combinations included common wheat or oat with crimson or subterranean clover. Each combination of intercrops and living mulches were sown at various ratesas a proportion of their typical monocrop seeding ratefor organic production. Intercrop treatments were compared to monocrops of each crop species, with the exception of chickling vetch. Living mulch treatments were compared tomonocropped wheat and oat. There were 19 treatments in the intercrop trial and 10 treatments in the living mulch trial, each replicated 4 timesin a RCBD.

The following measurements were taken from both trials in 2021:number of seedlings emerged (separated by crop), plant height (separated by crop), photosynthetically active radiationto calculate leaf area index, plant growth throughout the summer (separated by crop), incidence and severity of above-ground crop diseases (separated by crop), weed identification/density and weed biomass, crop biomass (separated by crop), grain yield (separated by crop), grain protein concentration (separated by crop), 1000-kernel weight (separated by crop). The NPK concentration in the crop biomass will be determined in the next few months (see issues related to the grinding of tissue below). Based on these data, Harvest Index, Land Equivalency Ratio for crop biomass and grain yield, and Competitive Ratio were calculated for each treatment.Additionally, samples of roots of each crop were collected for further root rot evaluation and fungal identification, as well as soil and plant tissue of each cropfour timesthroughout the growing season for three intercrop treatments to model plant growth and nutrient dynamics. These analyses are still underway.

In 2022, a second iteration of each trial will be conducted on a different organicland. In preparation,this land was sown in 2021 to a similar green manure cocktail and plowed down at flowering/heading, as for Trial 1.

b.) List and explain any deviations from the approved objectives:

With restrictions in place at AAFCto stop the spread of COVID-19, milestones were delayed one year. In 2021, neither field days nor workshops were authorized, however, in 2022, outdoor events are in the process of being approved, and therefore organization of a field day with collaboratorsto present this research is currently underway.

Repeated soil and plant tissue sampling from seeding to harvest was initially proposed for all treatments in both trials at least 8 times. These data were to be used to model plant growth and nutrient dynamics. In 2021, it was discovered that this method of sampling was too destructive to the plots to be completed 8 times, therefore, it was reduced to 4 sampling events. Additionally, labor shortages in 2021 prevented such intensive sampling of all treatments in both trials, therefore, 3 intercrop treatments were chosen for sampling. In 2022 and onward, repeated soil and plant tissue sampling will again be completed 4 times from seeding to harvest.

Progress towards all other objectives and milestones has been made and there are no other deviations to report.

c.) Research results in the reporting period

Objectives	**Progress**
To determine if intercrops with crops or a living mulch can reduce weeds compared to sole crops, and in the following crop	Dominant weed species in both trials included redroot pigweed (*Amaranthusretroflexus*), prostrate pigweed (*Amaranthusblitoides*), common lambsquarters (*Chenopodium album*), and wild buckwheat (*Polygonum convolvulus*). In addition, green foxtail (*Setariaviridis*) and stinkweed (*Thlaspiarvense*) were dominant in the intercrop trial, while purslane (*Portulacaoleracea*) was additionally dominant in the living mulch trial. The living mulch trial contained exclusively broad-leaved annuals, but the intercrop trial contained a variety of annual and perennial broadleaf and grass species. Weed densities did not differ between sole crops and intercrops with crops or a living mulch. Weed biomass in intercropped lentils and barley planted in alternate rows decreased compared to monocropped lentils but were not different than monocropped barley. Weed biomass was lower in intercropped pea and oat thanmonocropped pea. Weed biomass of pea-oat treatments planted in alternate rows did not differ from monocropped oat, whereas mixed rows were higher. There were no differences in weed biomass between intercropped mustard-chickling vetch and monocropped mustard.Seemost of these data in the attached slides in Appendix A. Wheat sown at 100% rate with a crimson clover living mulch at 100% rate decreased weed biomass compared to moncropped wheat. All other living mulch treatments were not statistically different. The effect on the following crop is not yet determined.

To determine the N benefit from legumes in intercrops or living mulch to the following crop compared to sole legume crops	Not yet determined.
To determine if intercrops have less disease than monocrops, and their effect on diseases in the following crop	Due to drought conditions, no above-ground diseases were observed in any of the crops. The severity of root rot in non-legumes, measured by percent discolouration of the subcrown internodes, tended to be higher in the mixedintercrop treatments than their monocrop counterparts. None of the cereals seeded in alternate rows had higher root rot levels than their respective monocrops.Root rot in the legumes is still being assessed on all collected samples.Isolation and identification of fungi from affected subcrown internodes and roots has not yet been completed. The effect on the following crop is not yet determined.
To determine biomass and grain yield/quality of crops in intercrops at various ratios compared to monocrops and of following crop	Compared to predicted values based on seeding rate, cropbiomass and grain yield of barley and oat increased when intercropped with lentil and fieldpea, respectively. Comparatively, cropbiomass and grain yield of lentil and fieldpea decreased when intercropped with barley and oat, respectively. The effect of the intercropson grain quality and the following crop are not yet determined.
To determine optimal seeding ratio of intercrops with crops or living mulch for achieving greatest agronomic/economic benefit	Not yet determined.
To develop growth and nutrient uptake models and determine optimum ratio(s) for intercrops compared to the respective monocrops	Not yet determined.
To determine inter and intra-specific competition for nutrients and soil moisture in intercrops under various seeding ratios	Not yet determined.

d.) Discussion:

The ongoing drought conditions experienced in southern Saskatchewan in 2021 impacted the results of this study. As in the previous dry years, the legumes did not tolerate dry conditions well, either as sole crops or intercrops. As such, treatments will remain unchanged for the upcoming 2022 field season in hopes of evaluatingthese cropping systems under better weatherconditions.

Potential benefits to alternate row planting of intercrop species were observed, however, field peas experienced increased lodging with oats compared to mixed rows and monocrops. These treatments will continue to be evaluated in 2022 to assess the positive and negative effects of field peas and oats in alternate rows, however, the lentil-barley alternate row combination showed more promise.

As such, an additional treatment of 60% lentil + 25% barley planted in alternate rows will be sown in 2022 to provide greater insight into an optimal seeding ratio for this system.

Processing of crop biomass samples: The ventilation system for the dust collector (essential for the grinding of crop biomass samples) has not functioned since the fall of 2021, thus we have not yet been able to grind the crop samples collected in the summer of 2021. Due to chip shortages (attributed to the ongoing supply chain issues as a consequence of the pandemic), the Delco controller that operates the dust collection system and safety interlocks will not be on site until mid-June 2022. The dust collector cannot be run without the controller. This issue has significantly delayed the processing of our crop samples, and thus the NPK analysis by the Analytical Lab. We have looked at other options to no avail.

Ongoing COVID issues: throughout 2021-22, all members of our research group ended up being diagnosed with COVID. This meant the on and off closure of our operations due to quarantine. It also meant some delays in our 2021 field and lab operations. This was compounded by the shortage of labour due to AAFC's COVID protocols which prevented us from hiring more than one summer student. However, these setbacks did not result in any significant impact on the deliverables of this project.

e.) List summary of findings, implications, and briefly discuss any conclusions

- Non-legume crops were more competitive in intercrops than legumes, and can compensate for lower seeding rates. This was reflected in the higher than expected crop biomass and grain yield of the non-legumes, compared to thelower than expected valuesin thelegumes.
- Alternate rows provided improved weed control and did not experience increased root rot severity compared to some of the mixed row treatments. However, field pea intercropped with oat in alternate rows had lower yields which may have been due to increased lodging, compared to mixed rows. In the latter, oat provided support for the field pea plants.More study years are required to confirm this result. If lodging is repeatedly observed in alternate rows, it would be recommended that alternate rows be avoided unless implemented with the sole intention of reducing weeds. Mixed rows have been used since the start of our intercropping research in 2016 to allow for more interaction, and likely increased N transfer, between the N-fixing plants and the non-legumes.
- Under the drought conditions observed in 2021, intercrops experienced enhanced vegetative growth but not grain yield. Lower seeding rates would enhance grain yield under drought conditions, however, high seeding rates are required under organic and low-input management to provide more competition against weeds. More study years are required to verify, but it appears that the full benefits of intercropping may not be fully realized under drought conditions. However, under such conditions, various benefits in both Phases 1 and 2 (following sole crop) were observed in our previous intercropping project.

3. List any technology transfer activities undertaken in relation to this project:

We appeared to be the only research program at AAFC that had planned an in-person field day in the summer of 2021. However, due to the ongoing COVID situation in SK and the rest of the Prairies, and upon further discussions with AAFC management, a joint decision was made not to go ahead with any in-person event in 2021. This decision was notified in an e-mail sent out to our mailing list (>400 contacts) on July 20, 2021.

Thus, due to COVID restrictions, in 2021-22 dissemination of our research was not possible through any in-person events, as in previous years before the pandemic. All of it occurred through virtual events, e-mails and phone calls. Information from our intercropping research continues being disseminated mostly by phone and e-mail toorganic and conventional producers interested in intercropping, and to other researchers and agronomists throughout western Canada.

Some of the entries below are from before April 1, 2021 and so are mostly from our previous intercropping project. However, they are relevant to this New Intercropping/Living Mulch project which was based on our previous research:

- Fernandez, M.R., P. Lokuruge, L. Abdellatif, M.P. Schellenberg. Ongoing and newly-funded organic projects for 2021.New projects presented and discussed included:(1) Intercropping and (2) Living Mulch. Annual General Meeting of the Advisory Committee on Organic Research at SCRDC-AAFC. 25/02/2021 Teams.
- A virtual Open Organic Meeting was heldin conjunction with the Annual General Meeting of the Advisory Committee on Organic Research at SCRDC-AAFC. 25/02/2021. Attended by committee members and invited guests. Presentations related to this intercropping project were: Update on our Organic Research Program, Progress on organic intercropping studies, Progress on crop diseases in organic intercrops, and Progress on the biocontrol of important crop pathogens in intercrops.
- Fernandez, M.R. (1) Report on the 2021 New Intercropping and Living Mulch projects, (2) Plans for 2022: Presentation and discussion of ongoing New Intercropping and Mulch projects. Meeting of Advisory Committee on Organic Research at SCRDC-AAFC. Members of the committee and invited guests.20/12/2021.Teams.
- Fernandez, M.R. An hour virtual seminar was given to staff and students (40-50) at the University of Fraser Valley, BC. Invited by Dr. Dieter Geesing. “Organic Agriculture, and Organic Research Program at SCRDC-AAFC” (focused on intercropping and cover cropping). November 15, 2021.
- Organic Research Workshop, organized by Fernandez et al. and TCO Chapter 8.December 15, 2021, 9 to 12:30 p.m. Teams. Presentations at this workshop included “New findings from our intercropping research, and 2021 field trials”, by M.R. Fernandez and Organic Research Program at SCRDC. Attended by 38invited guests.
- Fernandez et al. An hour seminar on Intercropping Research at SCRDC-AAFC, with emphasis on the 2021 New Intercropping trial, was given at avirtual Intercropping Webinar, organized by SK Ag. March 22, 2022. Attended by 250-300 people.
- Fernandez was interviewed by Donna Fleury, Top Crop Manager, in March 2021 for an article on diseases in intercrops grown under organic management.
- DISEASE PRESSURE IN INTERCROPS GROWN UNDER ORGANIC MANAGEMENT - Impact depends on the intercrops used and associated underground fungal communities, by Donna Fleury, published in Top Crop Manager, June 2021 Digital Edition.
- Designing intercrops for multipurpose benefits in organic systems - Intercrop combinations for improving crop yield, quality and disease control extends to the subsequent crop. Top Crop Manager – Interview by Donna Fleury in January 2022. To be published in summer of 2022.
- In early 2021, Fernandez was interviewed by Kasia Kaluzny, AAFC Communications, for an upcoming Weekly Science Story on Intercropping under organic management.
  AAFC Weekly Science Story“Better Grown Together” on intercropping research, was published and distributed to all AAFC staff on June 16, 2021 to commemorate National Indigenous Peoples Day on June 21, 2021.
- Fernandez was interviewed by Pam Yule in February 2021 for an article on the New Intercropping/Living mulch project. Published in the Prairie Oat Growers’ Association Newsletter (‘Producers Are Interested in More Research on Intercropping’). June 2021.
- A new service contract (#3000736921, November 29, 2021 to March 31, 2022 - M.R. Fernandez as project authority for AAFC) was established with Dr. FrancisZmovuya, Professor and Head of

theSoil Science Department at theU. of Manitoba, for the final statistical analysis of data collected from Phase 2 of the Intercropping project held from 2016 to 2021.

- Report on: "Impact of intercrops on soil N the following spring, and growth and health of the following sole durum wheat crop – Phase 2" (2018, 2019), by Dr. Francis Zvomuya. 12 pages.

Results from our Intercropping research were also used for other initiatives:

- **Food System Vision Prize from the Rockefeller Foundation:** In 2019, M.R. Fernandez was invited to participate in a proposal to be submitted to the Rockefeller Foundation for the Food System Vision Prize. In August of 2020, it was officially announced that this proposal was the only recipient from Canada. The Prairie Food System Vision is a long-term vision to transform the agriculture system across rural and urban settings on the Prairies. https://www.rockefellerfoundation.org/meet-the-top-visionaries-food-system-vision-prize/kwayeskastasowin-wahkohtowin/Some of the findings from our organic projects at SCRDC, including all intercropping trials, were shared throughout the development of this proposal with the co-participants, and continue being shared with the steering committee. Organic sustainable agriculture practices such as intercropping are at the core of the Prairie Food System Vision, based on Treaty 4 land which is where SCRDC is located.
- **AAFC Climate Change Roadmap - Science-based assessment of GHG mitigation and C-sequestration options:** (led by Dr. J. Gracia-Garza, Special Advisor, Agriculture and Climate Change, AAFC): In 2020, M.R. Fernandez was invited to be part of this Government of Canada initiative. Its objective was to provide the best science-based advice to AAFC on what the agriculture sector should focus its collective efforts in order to realize meaningful contributions to the 2030 and eventually 2050 GHG reduction objectives.Fernandez co-wrote documents under "Farming Systems: Potential for alternative production systems to mitigate emissions (conservation, organic, regenerative, agroecology)". Some of the findings from most of our organic research, including our intercropping trials, were included in the documents on alternative production systems to mitigate GHG emissions. In particular, our results served to demonstrate the unique characteristics and constraints of these practices in the environment prevailing in the western Prairies versus other regions of Canada.

4. List any changes expected to industry contributions, in-kind support, collaborations or other resources

No major changes are expected in 2022-23.

5. Appendices:

Attached in Appendix 1 is a portion of a virtual presentation on intercropping given at an Intercropping Webinar, organized by SK Ag on March 22, 2022 (see above). These slides address the 2021 New Intercropping trial, although the conclusions also include results from our previous intercropping project.

In all events, presentations, articles, and media interviews, funders for this project were properly acknowledged. Logos from the funders were also displayed on the large field signs we ordered made for this project, plus smaller signs with the logos provided by each funder. Field signs were prominently displayed all summer.