Oat-Pea Mixed Grain Intercropping on the Canadian Prairies and U.S. Northern Plains

Contributing Authors:

South East Research Farm - Redvers, Saskatchewan, Canada
Luke Struckman, Project Lead - Oat-Pea Mixed Intercropping Study
Ishita Patel, Research Agronomist
Lana Shaw, Research Manager

General Mills Incorporated - Minneapolis, Minnesota, United States
Jim Eckberg, Research Agronomist
Tom Rabaey, Research Agronomist
Steve Eichten, Research Scientist

Agriculture and Agri-Food Canada - Swift Current, Saskatchewan, Canada
Jason Seed, Economist

Acknoweldgements:

The authors would like to thank the interview and on-farm trial participants for lending their time, expertise, and labor to the study. We would also like acknowledge the significant contributions of Paul Richter (Research Agronomist, General Mills) and Korynne Carlson (Research Specialist, General Mills) in facilitating the grain quality tests and data analysis for the on-farm field trials. Finally, we would like to recognize the support for the small plot trials and data analysis provided by Paterson Grain (Lorne Boundy, Kevin Baron, and John Waterer) and North Dakota State University (Steve Zwinger and Eric Eriksmoen).

Funding and Support:

This research was made possible thanks to the financial support and in-kind contributions of General Mills Incorporated along with significant in-kind contributions from South East Research Farm and Agriculture and Agri-Food Canada.

May 2021

SOUTH EAST RESEARCH FARM

General Mills

Agriculture and Agri-Food Canada

Photos (front and back covers): Fully developed oat-pea mixed intercrop canopies at two sites in Manitoba - July/August 2020. Robust intercrop canopy development can help to provide some degree of late season weed control.
Photos credit: Luke Struckman

Table of Contents:

Summary:

Farmers on the Canadian Prairies and U.S. Northern Plains are increasingly interested in crop diversification strategies to support improved agronomics, farm profitability, and soil health. Intercropping two or more cash crops is a widespread strategy in the region. Oats and peas are common cash crops, yet the potential benefits and challenges of intercropping these two cash crops remain unclear. Through a series of farmer interviews, farm-scale trials, and small plot trials, we provide one of the first comprehensive evaluations of intercropping oats and peas for grain production. This report describes grower perceptions, agronomics, and profitability of oat-pea intercrops.

We find numerous advantages and disadvantages to intercropping. Advantages include reduced synthetic nitogen requirements and the ability to keep lodge-prone pea varieties standing until harvest. Disadvantages include the lack of in-season herbicide options and the potential for uneven crop maturity. Seeding rates that favor peas in the stand and do not exceed 60% of standard oat monocrop seeding rates seem to be optimal. Importantly, increases to seeding rates did not lead to a linear increase in yield.

While we cannot discern a clear economic advantage to intercropping, the incredible variation ($113.00/ac loss to $128.00/ac gain) implies potential for oat-pea mixed grain intercropping to improve financial outcomes in certain contexts. Growers should carefully consider the advantages and disadvantages of oat-pea intercropping in determining the best way to implement this particular combination.

Recommendations:

1) The oat-pea combination is ideal for growing higher value, lodge-prone pea varieties since the oats will support the peas throughout the growing season until harvest.

2) Oat seeding rates in an oat-pea intercrop should not exceed 60% of standard oat monocrop rates. Otherwise oats will tend to crowd out the peas in the stand as the growing season progresses.

3) Standard pea monocrop seeding rates can be maintained or reduced slightly.

4) N fertilizer applications can be significantly reduced or eliminated.

5) Oat yields will most likely be reduced in an oat-pea intercrop as a result of lowered seeding rates and reduced synthetic N application rates. However, the higher value of the harvested peas will most likely cover the lost potential oat earnings.

6) No herbicides are labelled for simultaneous use with oats and peas. Therefore, weeds must be well-controlled during the previous growing season and/or through a pre-emergence herbicide ahead of seeding.

7) Growers must be prepared to make adjustments to seeding, production practices, harvesting, grain handling, and marketing to accommodate the specific requirements of the oat-pea mixed grain combination.

2 - Introduction

During the past decade, mixed grain intercropping has become a commercially significant practice for some farm operations on the Canadian Prairies and U.S. Northern Plains. Proven mixed grain intercrop combinations can provide significant agronomic and financial benefits. A team of researchers from South East Research Farm, General Mills, and Agriculture and Agri-Food Canada conducted a study to investigate the agronomics and commercial viability of oat-pea intercrop combinations in 2020. Due to a lack of on-farm production experience and little published research on the oat-pea mixed grain combination, it remains unclear as to which agronomic and economic parameters can make this intercrop commercially viable.

This study employs interviews with 25 farmers in Canada, U.S., and U.K. along with analyses of yield, grain quality, and costs/benefits of 12 on-farm oat-pea trials in Saskatchewan, Manitoba, and North Dakota. We also evaluate 21 combinations of oat-pea varieties and varied oat seeding rates in replicated plot trials performed in Manitoba and North Dakota to help provide specific recommendations. This is the most comprehensive evaluation of the oat-pea combination to date.

Study findings demonstrate that the oat-pea combination can provide a number of specific agronomic benefits while being more profitable than oats grown as a monocrop. However, farm operations must be willing to take on the added requirements of raising a mixed grain intercrop such as making modifications to seeding equipment and separating the oat-pea mixed grain after harvest.

Photo (top): Early stages of oat-pea canopy development - June 2020.
Photo (bottom): An oat-pea mixed grain sample
Photos credit: Paul Overby

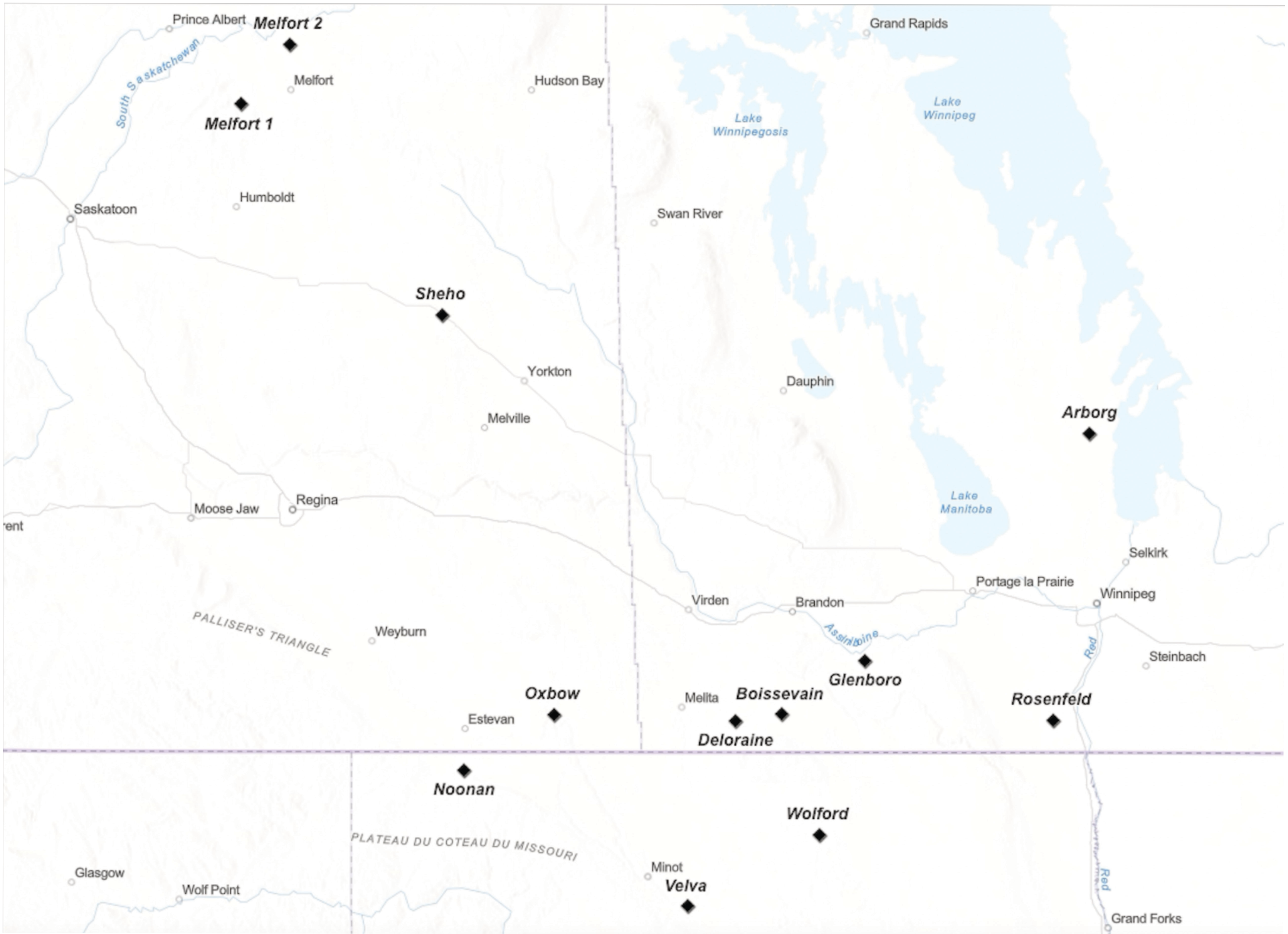

Figure 1: Locations of the 12 on-farm oat-pea trial sites in Saskatchewan, Manitoba, and North Dakota.

3 – Mixed Grain Intercropping

Intercropping is a common practice in many parts of the world thanks to specfic benefits like greater yield stability and soil health improvements. Intercropping takes a variety of forms, such as agroforestry, relay cropping, and mixed intercropping. During the past decade, there has been a resurgence of interest in different forms of intercropping amongst North American commodity cash crop farmers. Practices such as interseeding wide-row grain corn with cover crops or winter wheat and soybean relay cropping are being integrated into cash crop rotations in some regions of North America. On the Canadian Prairies and U.S. Northern Plains, mixed grain intercropping has become a commercially significant practice during the past decade. In this form of intercropping, two or more different grain, oilseed, or pulse species are seeded simultaneously and are subsequently harvested together at the end of the growing season. Typically, these cash crops are separated after harvest prior to sale.

The adoption of mixed grain intercropping should be seen as part of broader efforts on the Canadian Prairies and U.S. Northern Plains to increase the financial and environmental resiliency of production agriculture since the 1970s. This has largely been achieved through the adoption of a variety of practices and technologies such as cash crop diversification, flexible crop rotations, land use intensification, equipment designed for no-till/high-residue scenarios, precision agriculture technology, and synthetic input optimization. Such practices are compatible with conservation agriculture principles promoted by the UN FAO and regenerative methods that have gained some traction amongst North American commodity crop farmers.

Mixed grain intercropping has the potential to provide a number of specific agronomic benefits. These include improved seedling emergence for small-seeded crops, reduced fungal and insect pressure, somewhat improved in-season weed control, reduced lodging, more uniform maturity with indeterminate crop varieties, overyielding, and increased post-harvest residue, among others.

The seeding of clovers with small grains or multi-season relay cropping of spring wheat and alfalfa have been relatively common forms of intercropping on the Canadian Prairies and U.S. Northern Plains. When peas became a significant cash crop in the 1970s, mustard (and later canola) were seeded at low rates with peas in order to reduce pea lodging. By the late 1980s and early 1990s, mixed intercropping was being evaluated in small plot research trials at various sites across the region.

Although mixed grain intercropping can provide agronomic benefits, it also poses a number of practical challenges with respect to crop production, harvest, and grain handling. These challenges have been surmounted through equipment modification and adjustments, shifts in standard growing practices, and a willingness to clean and separate grain post-harvest.

From a seeding standpoint, mixed grain intercropping has become more practical in recent years as relatively low-cost aftermarket modifications to air seeders enable two or three different crop species to be planted at different seeding rates in a single pass. These modifications include two or more seeder tanks as well as double or triple shoot openers. Some drill manufacturers now offer such features as standard options. The timing and depth of seeding must be a compromise between different species' seeding requirements. It can be challenging to locate relevant information for optimal intercrop seeding rates. Despite this lack of information, seed companies, farmers who are experienced with mixed intercropping, extension materials, and peer-reviewed research can all help to inform seeding decisions.

Applied fertilizer rates must also be a compromise to meet the varying macronutrient requirements of different crop species. In-season herbicide options are narrowed or eliminated since herbicides should be labelled for all crop species used in an intercrop. With limited in-season weed control options in mixed intercrops, weeds should be well-controlled during the previous growing season leading into an intercrop and through the use of pre-emergence herbicides. At the same, using mixed intercrops as part of a cash crop diversification strategy may help to lower overall weed abundance.

The harvesting of mixed intercrops can pose some challenges due to factors like uneven crop maturity and differing seed size. Uneven maturity can be addressed either through swathing ahead of harvest or through the use of dessicants. In respect to differing seed sizes, combines available on the market have not been designed to thresh mixed intercrops. Despite the lack of attention from equipment manufacturers and little formal research in this area, intercrops can be successfully harvested with conventional combines. Typically, combine rotors are set for the largest seeded crop and then the combine fan is adjusted to suit the smaller-seeded crop(s).

Unless a ready market exists for mixed grain or it is being sold mixed as livestock feed, intercrops must be separated and cleaned post-harvest. Growers in the region who practice intercropping typically store mixed grain after harvest. The mixed grain is then separated on-farm or through a commercial grain handling facility. For on-farm separation, there are a variety of seed cleaning units available on the market which are capable of separating intercrops. A number of farm operations have even incorporated mixed grain separation capabilities into their on-farm grain handling facilities.

There are some advantages to separating and cleaning mixed grain intercrops on farm. One advantage is that dockage can be removed prior to grain being transported for sale off farm. This results in higher grain sample quality and a reduction in grain transportation costs. Another advantage is that grain screenings can be kept or sold as livestock feed. Most commercial grain handling facilities have the ability to separate mixed intercrops. Regardless of whether or not grain separation is done on-farm or through a commercial facility, additional costs associated with grain separation will have a significant impact on mixed grain intercrop profitability.

Despite the additional management and labor requirements, the potential agronomic and grain quality advantages provided by mixed grain intercropping are significant enough to make it a commercially viable practice with proven intercrop combinations. Mixed grain intercropping is being used successfully on both non-organic and organic farm operations. Some commercially proven mixed grain intercrop combinations include canola-pea, lentil-pea-canola, chickpea-flax, lentil-flax, and wheat-flax.

The oat-pea intercrop combination has a long history of being grown for hay or taken to grain as a mixed livestock feed ration. However, the oat-pea combination has not typically been used for grain oat and dry pea production. The oat-pea combination has the potential to be commercially viable due to the agronomic benefits it can provide in addition to the relatively strong market demand for both grain oats and dry peas in recent years.

4.1 - Interviews

In order to better understand current oat-pea intercropping practices, 25 interviews were conducted with farmers in four Canadian provinces, two US states, and two UK counties on their experiences growing oat-pea intercrops or monocrop oats following an intercrop. Interview questions focus on production methods, grain separation, obstacles, and profitability. The majority of interviews were with non-organic farmers. However, three organic farmers were interviewed who rely upon intercropping as a major part of their production systems. Oat-pea intercrop acreage ranged from as small as 3-acre test plots to as large as 1200 acres. In several of these large acreage scenarios, oat-pea intercrops are used to produce a farm's entire grain oat output. Farmers interviewed had between 3 and 11 different cash crops in rotation.

A) Production Methods
The vast majority of interview participants indicate that synthetic nitrogen applications can be reduced or eliminated for oat-pea intercrops. Herbicide use is significantly reduced, but several growers mentioned that this was due to a lack of available in-season herbicide options. Fungicides were shown to not be necessary in most use cases. A large majority of farmers interviewed did not find it necessary to use insecticides for any cash crops in their rotations. However, the few farmers that do use insecticides indicate that the oat-pea combination can result in at least a 50% reduction in insecticide applications.

Seeding rates are informed by the experiences of other farmers and on-farm experimentation. There were a wide range of seeding rates provided, but growers tend to favor peas and reduce oat seeding rates to 60% or less of base rates for oat monocrop. Otherwise, aggressive oat growth will dominate peas in the stand as the growing season progresses.

Several growers use specific pea varieties in the oat-pea combination. Lodge-prone varieties such as 4010 forage peas or Austrian winter peas can be incredibly difficult to grow as monocrops and oats help to keep them standing until harvest. One pea seed producer states that the only reason they are using the oat-pea combination is to grow higher value 4010 forage peas. They further state that if the market price of 4010 peas were to decrease, they would not continue with the oat-pea combination. Another grower uses Maple peas specifically in intercrops because they do not split when separated from the oats after harvest (unlike some other pea varieties).

Beyond pea varieties, oat varieties are chosen based on their grain production potential. However, two growers favor Haymaker oats (a forage variety) because of the significant amount of residue left behind after harvest. Two growers are using variable rate equipment and zone prescriptions to seed, which allows them to favor oats in wetter zones and peas in drier zones.

B) Grain Separation
Grain cleaning and separation are typically done on farm using a wide range of cleaning equipment, although rotary-style cleaners tend to be the most common. Growers cite higher quality grain samples, lower grain shipping costs, as well as significantly lower dockage as benefits to cleaning and separating oat-pea mixed grain on farm. Additionally, screenings can be kept or sold as livestock feed. Grain separation costs can be offset by higher quality grain samples in addition to reduced input costs.

For some farmers, oat-pea separation poses challenges due to the large size of both seeds. One Saskatchewan grower states that separation works well when oats make up less than 20% of the grain sample when using a rotary screener on his farm. Farmers indicate that while most commercial facilities have the capability to separate an oat-pea intercrop, the cost of commercial separation can significantly reduce profits. Therefore, it is preferable to do mixed grain separation on farm.

One Saskatchewan organic farmer mentions that economic returns on the oat-pea combination are not as significant as pea-canola or wheat-flax, making it difficult to justify growing oat-peas as a mixed intercrop. Others have found that the costs of cleaning and separation are offset by the value of higher quality grain samples. Additionally, the reduction of synthetic inputs (especially synthetic N) can help to offset separation costs. One farmer points out that they have not analyzed the financial aspects of intercropping, but the agronomic advantages it provides makes grain separation worth their time.

C) Obstacles

Although oat-pea intercropping does provide attractive benefits, there are significant obstacles to making oat-pea intercropping practical for cash crop production. Crop insurance was cited as one major obstacle to oat-pea intercropping (and mixed intercropping in general), since most insurance policies only allow for a limited acreage of novel cash crops each season.

Seeding rates, uneven maturity, and in-season weed control were common issues cited by growers. There are few clear guidelines on seeding rates. Similarly, uneven maturity was cited as an obstacle by many. Even if the chosen oat and pea varieties have similar maturity dates, a variety of environmental conditions can cause a divergence in maturity in the two crops. Additionally, the risk of bleaching in green pea varieties is cited as a concern if growers are forced to wait for oats to mature after the peas. Weed control can be another serious issue since almost no herbicides are labelled for use with both crops in-season. Relatedly, oat-pea intercrops must be planted into clean fields due to a lack of in-season weed control options.

D) Profitability

Despite significant obstacles, oat-pea intercrops have the potential be more profitable than monocrop oats. This is due to a reduction in synthetic input costs, lower grain shipping costs, higher quality grain samples, and the option of growing higher-value, lodge-prone pea varieties. At the same time, oat-pea intercrops provide benefits to farm cash crop rotations and soil health through increased amounts of crop biomass, increased cash crop diversity, and helping to mitigate adverse weather conditions through combining two different cash crops that thrive in varying soil moisture conditions.

One Alberta organic grower indicates that a significant advantage to the oat-pea combination is its resilience to hail. While peas do not recover well from hail damage, oats can typically withstand hail damage and still produce acceptable yields even with the loss of peas. Along the same lines, several growers state that the oat-pea intercrop provides flexibility when weed pressure during the growing season becomes too great, since peas can be terminated with a broadleaf herbicide. Similarily, one Saskatchewan grower sees a reduction of synthetic inputs as a way to add resiliency to a cash crop system. If a cash crop is lost due to adverse weather conditions, they have less invested in the ruined cash crop.

Photo: Oat-pea intercrop in combine concaves. Combining poses one of the most significant obstacles to raising a profitable oat-pea intercrop.

Photo credit: Paul Overby

Beyond the particular monetary advantages of the oat-pea combination, the majority of farmers state that mixed grain intercropping contributes to the overall profitability of their farms, but such benefits are difficult to quantify. Two growers stress the value of mixed grain intercropping in their soil health improvement strategies. They point out that while no-till is an important part of improving soil health, no-till cannot provide enough of an improvement to soil health on its own. Their climates are too cool for cover crops outside of the growing season and their farms are too large to graze livestock across all of their acres on a regular basis. Thus, they see mixed intercropping as one additional way to improve soil health on their farms thanks to increased cash crop diversity.

Four growers indicate that after using the oat-pea combination for two or three years, they would not be continuing with the practice in the future. This was due to challenges related to harvest, separation, and marketing. One Saskatchewan organic farmer states that he is making preparations to shift from small grain-pulse mixed grain intercrops (like oat-pea) to small grain-warm season clover intercrop mixes. The small-grain warm season clover mixes provide the agronomic benefits of an intercrop without the typical mixed grain intercrop concerns of crop insurance, harvest, grain storage, separation, and marketing. Additionally, the warm-season clovers winter kill, resulting in a significant amount of nitrogen being carried over into the subsequent year's cash crop.

These 25 interviews demonstrate that the oat-pea intercrop combination has been used successfully at production scales in a range of climates and farm economy contexts. At the same time, significant practical considerations from production to marketing must be taken into account for those considering the adoption of the oat-pea combination.

4.2 - On-Farm Field Trials

Twelve on-farm oat-pea trial sites were located in Saskatchewan, Manitoba, and North Dakota during the 2020 growing season (see Figure 1). Sites were chosen based on their proximity to current General Mills oat-sourcing areas and participating farmers' willingness to host a trial. The trials placed 10-acre oat-pea plots adjacent to 10-acre monocrop oat plots, allowing for side-by-side comparisons of oat-pea intercrop production with monocrop oat production at each site. Participating farmers chose oat and pea varieties, seeding rates, fertility treatments, and herbicide treatments based on their experiences and opinions of best management practices. Trial participants provided input and yield data along with grain samples.

The lack of replication and treatment comparisons at each trial site combined with the single year duration of these trials limits the ability to determine agronomic recommendations for the oat-pea intercrop combination. Additionally, appreciable variation exists across soil types and precipitation levels in the broad geographic area covered by the trial sites. However, some key findings on yield, grain quality, and costs/benefits can provide starting points for farm operations interested in oat-pea mixed intercropping for grain oat and dry pea production.

A) Yield
Compared to oat monocrop, yield was higher on average in oat-pea intercrop in both Black and Gray soil zones and during dry and normal rainfall conditions (Figure 2A, B). However, this result is driven primarily by three sites: Arborg, MB, Oxbow, SK, and Melfort, SK - 2. Higher monocrop oat yield was a more frequent outcome (Figure 2C). Across the 12 sites, the oat-pea intercrop trials show a mean average yield of 3561 lb/ac while the oat monocrop trials show a mean average yield of 3907 lb/ac (Table 1). Median yield in oat monocrop was 4077 lb/ac and in oat-pea intercrop median yield was 3403 lb/ac (Table 1). Despite yields being higher in oat monocrop compared to oat-pea intercrop, the highest overall yield of 6277 lb/ac was observed in oat-pea intercrop at the Melfort, SK - 2 site.

Importantly, increased seeding rates did not lead to a linear increase in yield (Figure 3). For oat monocrop, the highest yield of 5100 lb/ac (Arborg, MB site) was achieved with the oat seeding rate of 140 lb/ac. The highest oat-pea intercrop yield of 6277 lb/ac (Melfort, SK - 2 site) was achieved with the seeding rate of pea at 163 lb/ac and seeding rate of oat at 74 lb/ac.

One factor resulting in the high oat-pea yield at the Melfort, SK - 2 site could be a attributed to the site's location in Saskatchewan's Black/Gray soil zone. Another factor could be the use of variable rate seeding at this site. Seeding was done using zone presriptions based partially on soil and topographical characterisitcs of the plot. Drier zones in the plot used seeding rates which favored peas in the stand, while wetter zones used seeding rates which favored oats in the stand.

Yield was also not consistently positively influenced by fertilizer input in either oat monocrop or oat-pea intercrop. Adding large amounts of N, P, K, or S was generally done at low-yielding sites, making the addition of large amounts soil nutrients of questionable value. Adding 60 lb/ac N, 40 lb/ac P, 10 lb/ac K, and 15 lb/ac S led to highest yield in oat monocrop. The following quantities of nutrients led to highest yield in oat-pea intercrop: 108.2 lb/ac N, 27.5 lb/ac P, 14.5 lb/ac K, and 10 lb/ac S.

B) Grain Quality
General Mills conducted a grain quality analysis for all 12 trial sites. Grain size is one of the most important quality measurements for grain oats. End products such as rolled oats or oat flour are of higher quality when larger grain sizes are used. Thus, processors seek out oats with higher proportions of large grains. This analysis focuses on the largest sized oat grains in the samples and uses the following parameters to measure grain size: **% plump**, **plump 6** and **plump groat** (see Box 1). Some other grain quality parameters used in this analysis provide measurements for grain oat nutritional content and include measurements for **proteins**, **beta-glucans**, and **fat** (see Table 1).

Overall, the effect of treatment of oat monocrop versus oat-pea intercrop did not significantly influence yield, oat test weight, plumpness, groats, protein content, beta-glucan content, or fat content. The effect of soil zone or precipitation was also not significant, implying that the relationship between oats and peas was not influenced by either of these factors.

Importantly, increasing seeding rate or adding more N, P, K, or S fertilizer did not lead to increased yield in either the oat-pea intercrop treatment or oat monocrop treatment. The effect of site was significant for all quality parameters except oat test weight and % plump groat, indicating that other factors specific to different sites may be contributing to the results.

Due to the lack of treatments and replications at each site, we cannot discern the effects of agronomics from environmental differences needed to make agronomic recommendations. Instead, this portion of the study reflects realistic, farm-scale outputs expected from current agriculture practices to grow intercrops. Even with the lack of replication at each site, these results suggest that oat-pea intercropping does not have a significantly negative impact on oat quality or yield, irrespective of precipitation received during the growing season.

Box 1: Common Grain Oat Size Measurements

% plump: The amount of a 100g sample which does not fall through a 5.5/64 slotted screen. A general test for plump groats.

plump 6: The amount of a 100g sample which does not fall through a 6.0/64 slotted screen. A test for the most plump groats

plump groat: The calculated percent of total groat plump weight divided by groats recovered weight (those held by a 5.0/64 slotted screen)

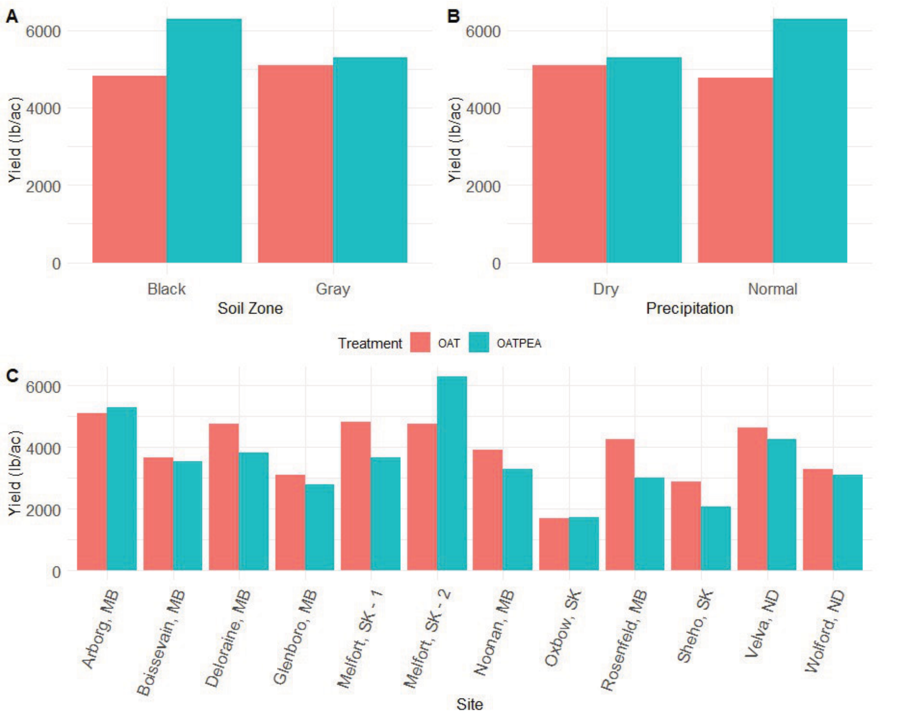

Figure 2: Total yield in oat monocrop and oat-pea intercrop in (A) different soil zones in Canada, (B) differing levels of precipitation, and (C) various trial sites across Manitoba, Saskatchewan, and North Dakota.

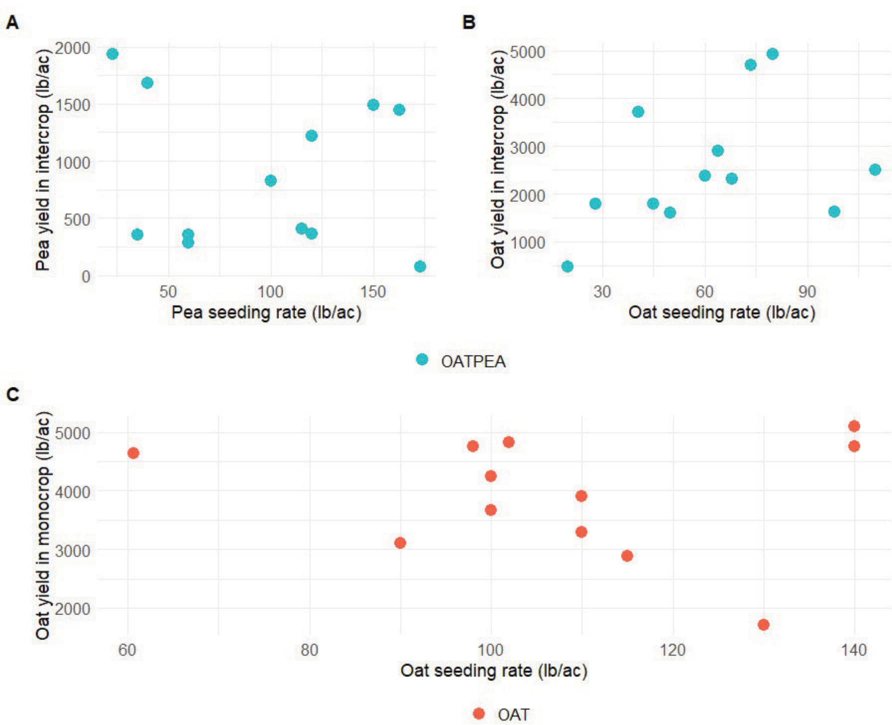

Figure 3: Yield versus seeding rate in oat-pea intercrop (A, B) and oat monocrop (C).

	Mean		Median	
Parameter	**OAT**	**OATPEA**	**OAT**	**OATPEA**
prct_PROTEIN	14.45	14.65	14.73	14.34
TEST_WT_lb_bu	37.79	37.83	36.70	37.55
Plump_6	53.80	53.04	54.74	52.92
prct_PLUMP	84.67	84.33	87.97	83.34
prct_GROATS	0.72	0.72	0.71	0.73
PERCENT_PLUMP_GROAT	0.86	0.87	0.88	0.89
NIR_B_GLUCAN	4.47	4.46	4.38	4.36
NIR_FAT	5.70	5.63	5.70	5.80
Yield_lb_per_ac	3907.40	3561.71	4077.00	3403.05
YieldProportion_peas_in_intercrop_lb_per_ac	-	869.04	-	614.60
YieldProportion_oats_in_intercrop_lb_per_ac	-	2557.90	-	2344.83
SeedingRate_Pea_Intercrop_lb_per_ac	-	96.55	-	107.50
SeedingRate_Oat_Intercrop_lb_per_ac	-	61.43	-	62.00
SeedingRate_Oat_Monocrop_lb_per_ac	107.97	-	106.00	-
Total_N_lb_per_ac	95.48	47.40	80.00	43.30
Total_P_lb_per_ac	23.78	22.18	29.60	24.95
Total_K_lb_per_ac	4.00	3.96	0.00	0.00
Total_S_lb_per_ac	4.50	5.46	2.00	5.25

Table 1: Mean and median values for OAT and OATPEA treatments for all 12 trial sites.

C) Cost/Benefit Analysis

This section summarizes a cost/benefit analysis which uses a Modified Net Income (MNI) value of the 12 oat-pea trial sites discussed in the previous section. MNI is the difference between crop revenues and the cost for inputs (including certain variable costs). The idea behind excluding portions of full production costs leaves room for farm operations to add their own expenses related to capital and general administration. Calculating costs in this manner accurately highlights differences between treatments. It also remedies the typical problem in agriculture production economics of each farm operation holding vastly different mixes of capital inputs and debt/equity levels - which can potentially lead to average costs for such amounts to be extremely unreliable.

In order to maintain comparability, some costs must be added back into calculations, such as spraying rates, to account for the difference in the number of synthetic input applications among the treatments. In this analysis, an amount of $6.00/ac was used to represent each application cost.

Trial participants provided crop seeding rates along with fertilizer and other synthetic input application rates. Input costs were derived from the Manitoba Production Economics Report (2021) and a farm input company representative (Table 2). Revenues were calculated using yield values provided by oat-pea trial participants along with inflation-adjusted 20-year average prices of both grain oats and common yellow peas. For the oat-pea intercrop, cleaning and separation were included with other crop production costs at $15.00/ac.

Results based on these calculations in Table 3 demonstrate that on average, an oat-pea intercrop has the potential to earn slightly greater returns than an oat monocrop ($3.36/ac). Results also show that fertilizer costs are reduced by almost 30% in the intercrop, while seed costs are increased by almost 65% (Table 3). This leads both revenues and total costs to be remarkably close to each other when averaged across all 12 trial sites.

In Table 4, all 12 oat-pea intercrop plots and all 12 oat monocrop plots are ranked based on net income, regardless of production method. When examining the 12 trials site by site (Table 5), three sites demonstrate a clear financial advantage in the oat-pea intercrop plots:

1) Melfort, SK - 2 ($128.10/ac MNI)
2) Boissevain, MB ($97.76/ac MNI)
3) Deloraine, MB ($44.39/ac MNI)

At Sheho, SK, Noonan, ND, and Arbourg, MB the oat-pea intercrop plots had only a marginal financial advantage in comparison to the oat moncrop plots. At the six remaining sites, the oat-pea intercrop plots were at a significant financial disadvantage in comparison to the oat monocrop plots.

This portion of the study demonstrates wide variation in the net income improvement provided by an intercrop. While we cannot conclude there is any reliable economic advantage to intercropping at this time, the incredible variation ($113.00/ac loss to $128.00/ac gain) implies potential for intercropping to improve financial returns in certain contexts.

Input	cost/lb.
Oat Seed	0.23
Pea Seed	0.28
Urea (46-0-0)	0.23
MAP (11-52-0)	0.32
Potash (0-0-60)	0.22
Sulphur (20.5-0-0-24)	0.19

Table 2: Input costs used to calculate Modified Net Income (MNI) for each site. Costs are derived from the Manitoba Production Economics Report and information provided by a farm input company representative.

Plot	Pea Revenue	Oat Revenue	Total Revenue	Seed Cost	Fertilizer Cost	Other Crop Production Costs	Total Cost	Net Income
OATPEA	113.08	201.96	**315.04**	41.08	39.27	22.30	**117.65**	**197.39**
OAT	-	308.50	**308.50**	24.61	62.45	27.38	**114.44**	**194.06**

Table 3: Net income calculations across the trial sites comparing net income in the 12 oat-pea plots to the 12 oat monocrop plots.

Site and Plot	Pea Revenue	Oat Revenue	Total Revenue	Seed Cost	Fertilizer Cost	Other Crop Production Costs	Total Cost	Net Income	Overall Rank (1-24)
Melfort, SK - 2									
OATPEA	187.86	370.72	558.57	62.43	76.42	42.38	196.23	362.34	1
OAT	-	375.83	375.83	31.91	67.12	42.55	141.58	234.24	11
Deloraine, MB									
OATPEA	251.84	141.91	393.75	16.71	-	8.00	39.71	354.04	2
OAT	-	375.59	375.59	22.34	35.60	8.00	65.94	309.65	3
Boissevain, MB									
OATPEA	218.75	140.95	359.69	17.60	10.48	22.67	65.75	293.94	4
OAT	-	290.08	290.08	22.79	48.44	22.67	93.90	196.18	13
Sheho, SK									
OATPEA	193.8	37.64	231.44	46.63	30.95	16.13	108.71	122.73	19
OAT	-	228.18	228.18	26.21	68.41	33.69	128.31	99.87	21
Noonan, ND									
OATPEA	47.45	228.25	275.7	48.25	39.46	12.37	115.07	160.62	14
OAT	-	308.24	308.24	25.07	109.07	22.95	157.09	151.15	17
Arbourg, MB									
OATPEA	36.61	389.1	425.71	35.07	58.68	36.39	145.13	280.58	5
OAT	-	402.67	402.67	31.91	58.68	39.96	130.55	272.12	7
Velva, ND									
OATPEA	45.85	292.93	338.78	19.02	38.78	15.36	88.15	250.62	10
OAT	-	365.48	365.48	13.83	58.50	30.43	102.76	262.72	8
Oxbow, SK									
OATPEA	9.88	127.61	137.49	70.86	61.05	15.36	162.27	-24.79	24
OAT	-	134.22	134.22	29.63	61.05	42.54	133.22	1.00	23
Glenboro, MB									
OATPEA	46.15	187.92	234.06	30.51	15.35	42.1	102.95	131.11	18
OAT	-	244.44	244.44	20.51	23.45	42.1	86.07	158.38	16
Wolford, ND									
OATPEA	52.54	197.17	249.71	57.33	78.2	27.24	177.77	71.94	22
OAT	-	260.47	260.47	25.07	107.9	16.58	149.56	110.92	20
Melfort, SK - 1									
OATPEA	158.82	182.36	341.18	49.16	42.11	29.55	135.82	205.35	12
OAT	-	381.2	381.2	23.25	71.69	27.12	122.06	259.14	9
Rosenfeld, MB									
OATPEA	107.4	126.96	234.36	39.45	19.73	-	74.17	160.19	15
OAT	-	335.56	335.56	22.79	39.46	-	62.25	273.31	6
Average	**56.54**	**255.23**	**311.77**	**32.85**	**50.86**	**24.84**	**116.04**	**195.72**	**-**

Table 4: All 12 oat oat-pea intercrop plots and all 12 oat monocrop plots are ranked based on net income, regardless of production method.

Site	Soil Type and Area	Precipitation	Oat-Pea MNI($/ac) Over Oat Monocrop	Oat-Pea MNI Ranking Over Oat Monocrop	Pea Seeding Rate (lbs/ac)	Average of Oat Seeding Rate (lbs/ac)	Oat Seeding Rate as % of Mono
Melfort, SK - 2	Black, NE Melfort	Normal	**128.10**	**1**	163	140	53%
Boissevain, MB	Black, SW MB/ SE SK	Dry	**97.76**	**2**	40	100	28%
Deloraine, MB	Black, SW MB/SE SK	Dry	**44.39**	**3**	23	98	46%
Sheho, SK	Black, SW MB/ SE SK	Dry	**22.86**	**4**	150	115	17%
Noonan, ND	Not Available	Dry	**9.48**	**5**	120	110	58%
Arbourg, MB	Gray/Black, Central MB	Dry	**8.46**	**6**	60	140	57%
Velva, ND	Not Available	Dry	**-12.10**	**7**	35	61	67%
Oxbow, SK	Black, SW MB/ SE SK	Dry	**-25.79**	**8**	173	130	75%
Glenboro, MB	Black, SW MB/ SE SK	Dry	**-27.27**	**9**	60	90	67%
Wolford, ND	Not Available	Dry	**-38.98**	**10**	115	110	100%
Melfort, SK - 1	Black, NE Melfort	Dry	**-53.78**	**11**	120	102	67%
Rosenfeld, MB	Gray/Black, Central MB	Normal	**-113.12**	**12**	100	100	50%

Table 5: Modified Net Income value (MNI) of oat-pea over oat monocrop. Sites ranked by MNI values.

4.3 - Seed Variety and Rate Trials

Replicated small plot trials were performed in 2020 at three research farm sites in the region:

1) North Dakota State University - Carrington, ND
2) Paterson Grain Research Farm - Lilyfield, MB
3) NDSU Minot Research Farm - Minot, ND

These trials evaluate the effects of oat variety, pea variety, and oat seeding rate.

For all three sites, a comparison can be made of the raw oat and pea yields from each plot and condition (Figure 4). Each site has drastically different yields for both crops and are subsequently examined separately due to environmental and management differences. Overall, there is a visible tradeoff between pure pea and pure oat yield. We evaluated the combined yield of intercropped oats and peas as well as the relationship between oat and pea yields. Assuming a linear relationship (1:1), we can imagine a theoretical break-even point by which additional oat yield leads to a fixed decrease in pea yield. Any intercropping results which are to the right of the gray, downard sloping trend lines in Figure 4 would indicate overyielding. The Carrington and Minot sites show the most individual intercropped plots which outperform this relationship, yet produced far lower overall yields compared to the Lilyfield site. Given these strong environmental variations, there is no consistent evidence of overyielding or underyielding within this set of intercrop small plot trials.

Yields for oat and pea can also be viewed individually and divided by experimental treatments. For oats, location was the primary factor driving oat yield. The magnitude of the differences among oat variety and seeding rate were agronomically minor compared to location (Figure 5). Seeding a lower oat rate led to a lower oat yield at Lilyfield and Carrington with little differences observed at Minot. Oat varieties differed in performance with Camden leading yield at Minot and Carrington, but with minimal varietal differences observed at Lilyfield. Intercropping oats with peas reduced oat yield. Yet selection of pea variety generally had little effect on oat yield reduction (Table 6).

Similar to oats, location was the primary factor driving pea yield with Lilyfield, MB providing the highest overall yields regardless of cropping technique. Intercropping with oats lead to a decrease in pea yield for all varieties (Figure 6). Pea varieties displayed differences in yield at Carrington and Lilyfield, which highlights varietal difference present at the three sites (Table 6).

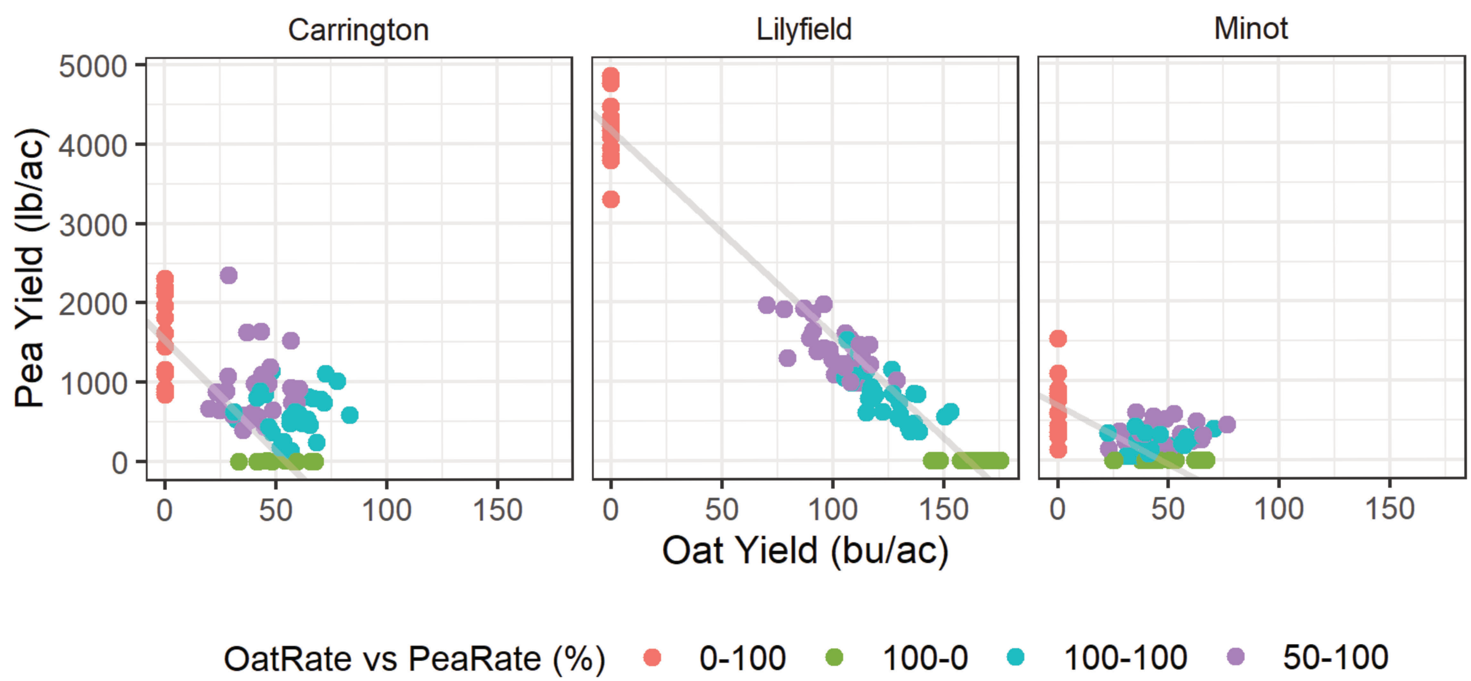

Figure 4: Small plot comparisons of oat and pea yield by locations and seeding rate. The grey line indicates the linear relationship between mean monocrop yields. Intercropped values below the line indicate decreased productivity.

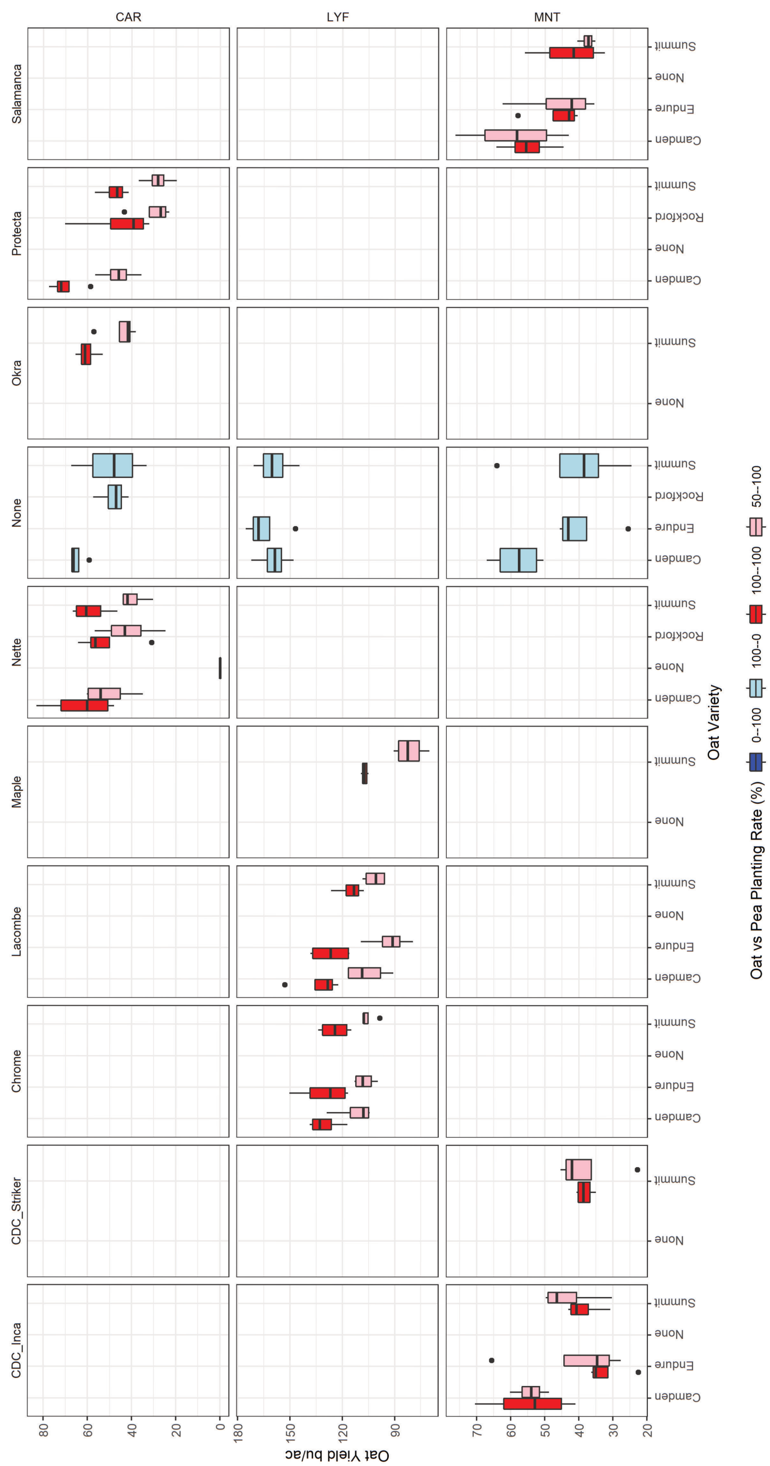

Figure 5: Summary of oat yields in small plot trials by oat variety (x axis), pea variety (plot columns), planting rate (color), and location (rows). 'None' descriptor indicates a monocrop state.

Oat Yield - Lilyfield	SumSq	Df	F value	Pr(>F)	
REP	102.4	1	0.9796	0.328094	
OAT_ID	657.5	2	3.1445	0.053639	.
PEA_ID	1995.2	2	9.5414	0.000396	***
planting_lvl	7343.8	1	70.2398	1.999E-10	***
OAT_ID:PEA_ID	107.1	2	0.5124	0.602852	
OAT_ID:planting_lvl	296.4	2	1.4175	0.25394	
PEA_ID:planting_lvl	195	2	0.9323	0.401818	
OAT_ID:PEA_ID:planting_lvl	152.5	2	0.7292	0.488447	
Residuals	4286.7	41			
Oat Yield - Carrington	**SumSq**	**Df**	**F value**	**Pr(>F)**	
REP	213.6	1	1.8715	0.1787586	
OAT_ID	2268	2	9.9346	0.0003033	***
PEA_ID	917.9	2	4.0207	0.0254408	*
planting_lvl	3819.9	1	33.4648	0.000000875	***
OAT_ID:PEA_ID	351.8	2	1.5408	0.2263472	
OAT_ID:planting_lvl	99.3	2	0.4349	0.6503117	
PEA_ID:planting_lvl	122	2	0.5346	0.5899288	
OAT_ID:PEA_ID:planting_lvl	65.6	2	0.2872	0.7518645	
Residuals	4680	41			
Oat Yield - Minot	**SumSq**	**Df**	**F value**	**Pr(>F)**	
REP	739.8	1	9.1183	0.004341	**
OAT_ID	2313.3	2	14.2566	0.00001994	***
PEA_ID	206.5	2	1.2724	0.290984	
planting_lvl	34.1	1	0.4202	0.52045	
OAT_ID:PEA_ID	214.3	2	1.3206	0.278098	
OAT_ID:planting_lvl	39	2	0.2402	0.787589	
PEA_ID:planting_lvl	71.1	2	0.4383	0.648147	
OAT_ID:PEA_ID:planting_lvl	120.3	2	0.7411	0.482867	
Residuals	3326.3	41			
Pea Yield - Lilyfield	**SumSq**	**Df**	**F value**	**Pr(>F)**	
REP	58955	1	1.8061	0.186371	
OAT_ID	453015	2	6.939	0.002538	**
PEA_ID	1506490	2	23.0754	1.93422E-07	***
planting_lvl	5173928	1	158.5016	1.131E-15	***
OAT_ID:PEA_ID	213522	2	3.2706	0.048099	*
OAT_ID:planting_lvl	7239	2	0.1109	0.895316	
PEA_ID:planting_lvl	69098	2	1.0584	0.356302	
OAT_ID:PEA_ID:planting_lvl	56996	2	0.873	0.425302	
Residuals	1338353	41			
Pea Yield - Carrington	**SumSq**	**Df**	**F value**	**Pr(>F)**	
REP	41360	1	0.3851	0.5383083	
OAT_ID	352372	2	1.6406	0.2063392	
PEA_ID	1812891	2	8.4405	0.0008513	***
planting_lvl	1390859	1	12.9511	0.0008533	***
OAT_ID:PEA_ID	54348	2	0.253	0.7776441	
OAT_ID:planting_lvl	136662	2	0.6363	0.5344067	
PEA_ID:planting_lvl	104831	2	0.4881	0.6173299	
OAT_ID:PEA_ID:planting_lvl	221856	2	1.0329	0.3650441	
Residuals	4403110	41			
Pea Yield - Minot	**SumSq**	**Df**	**F value**	**Pr(>F)**	
REP	434390	1	37.2851	3.056E-07	***
OAT_ID	2827	2	0.1213	0.8860608	
PEA_ID	9449	2	0.4055	0.6692621	
planting_lvl	191591	1	16.4449	0.0002185	***
OAT_ID:PEA_ID	7363	2	0.316	0.7308146	
OAT_ID:planting_lvl	7426	2	0.3187	0.7288729	
PEA_ID:planting_lvl	9192	2	0.3945	0.6765554	
OAT_ID:PEA_ID:planting_lvl	6854	2	0.2941	0.7467381	
Residuals	477670	41			

Table 6: ANOVA (Type II) tables for oat and pea yields.

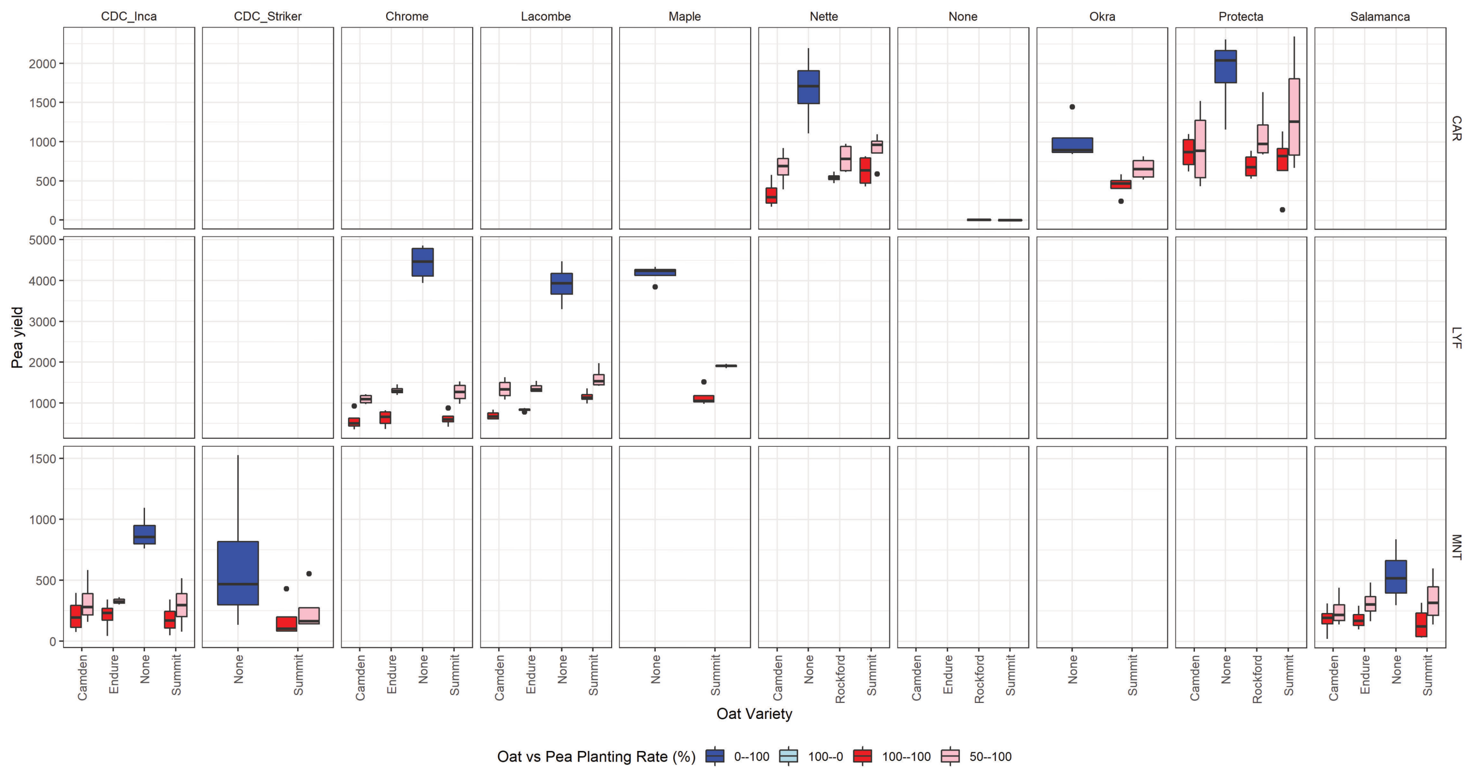

Figure 6: Summary of pea yields in small plot trials by oat variety (x axis), pea variety (plot columns), planting rate (color), and location (rows). 'None' descriptor indicates a monocrop state.

5 - Conclusion

As the interviews highlight, the oat-pea combination, while not suitable for all scenarios, has been used successfully on both non-organic and organic farms for grain oat and dry pea production since at least 2017. The on-farm field trials demonstrate that oat-pea mixed grain intercropping does not significantly impact oat quality or yield. The cost/benefit analysis shows that the oat-pea combination has the potential to improve cash crop profitability in certain contexts. The small plot trials findings align with the on-farm trials, reinforcing that the oat-pea intercrop combination does not lead to overyielding of oats and peas.

The oat-pea combination can be a viable means for improving farm profitability, increasing cash crop diversity, and building soil health for farm operations on the Canadian Prairies and U.S. Northern Plains. At the same time, appropriate seeding rates, the lack of in-season herbicide options, post-harvest storage and separation, marketing, along with other considerations, need to be given serious thought. Growers interested in adopting the oat-pea combination should consult with experienced mixed intercropping farmers and experiment at small scales on-farm before adopting this combination for cash crop production.

6 – Selected References

Cross, B. 2020. Banner Year for Canadian Oat Exports. https://www.producer.com/news/banner-year-for-canadian-oat-exports/

Corre-Hellou, G., A. Dibet, H. Hauggaard-Nielsen, Y. Crozat, M. Gooding, P. Ambus, C. Dahlmann, P. von Fragstein, A. Pristeri, M. Monti, and E.S. Jensen. 2011. The Competitive Ability of Pea-Barley Intercrops Against Weeds and the Interactions with Crop Productivity and Soil N Availability. Field Crops Research. 122(3): 264-272. https://www.sciencedirect.com/science/article/abs/pii/S037842901100116X

DIVERSify Project. 2020. Designing innovative plant teams for ecosystem resilience and agricultural sustainability. https://www.agricology.co.uk/diversify-designing-innovative-plant-teams-ecosystem-resilience-and-agricultural-sustainability

Domitruk, D. 2020. Multicrop Intercrop Trial (Pea-Oats-Wheat-Flax-Mustard). https://mbdiversificationcentres.ca/wp-content/uploads/2021/03/2020-PCDF-MultiCrop-Pea-Intercrop.pdf

Entz, M. 2004. Agronomic Benefits of Intercropping Annual Crops in Manitoba. https://www.umanitoba.ca/outreach/naturalagriculture/articles/intercrop.html

FCC. 2020. 2020 Outlook: Grains, Oilseeds, and Pulses Sector. https://www.fcc-fac.ca/en/knowledge/economics/2020-outlook-canadas-grains-oilseeds-and-pulses-sectors.html

Frick, B. and J. MacKenzie. 2016. Intercropping: Increasing Crop Diversity. https://www.pivotandgrow.com/wp-content/uploads/2019/08/PIVOT_POGI_Factsheet_Intercropping_102816.pdf

Food and Agriculture Organization of the United Nations. 2016. Save and Grow: Maize-Rice-Wheat. Rome: UNFAO. http://www.fao.org/3/i4009e/i4009e.pdf

Food and Agriculture Organization of the United Nations. 2017. Conservation Agriculture. http://www.fao.org/3/i7480e/i7480e.pdf

Green, M. 2007. Single and Double Shooting Fertilizer with Direct Seeding. https://reducedtillage.ca/article93.html

Holland, J. and E. Brummer. 1999. Cultivar Effects on Oat-Berseem Clover Intercrops. Agronomy Journal. 91: 321-329. https://www.ars.usda.gov/ARSUserFiles/60701500/Publications/Holland/HollandBrummerAgronJ99.pdf

Langat, P. 1992. Effect of Intercropping Pea with Canola or Yellow Mustard. https://mspace.lib.umanitoba.ca/xmlui/handle/1993/7227

Manitoba, Government of. 2021. Guidelines For Estimating: Crop Production Costs 2021. https://www.gov.mb.ca/agriculture/farm-management/production-economics/pubs/cop-crop-production.pdf

Martens, J.T., M. Entz, and M. Wonneck. 2013. Ecological Farming Systems on the Canadian Prairies: A Path to Profitability, Sustainability, and Resilience. Calgary: Agriculture and Agri-Food Canada. https://umanitoba.ca/outreach/naturalagriculture/articles/ecological-farm-systems_dec2013.pdf

McGuire, A. 2018. Regenerative Agriculture: Solid Principles, Extraordinary Claims. https://csanr.wsu.edu/regen-ag-solid-principles-extraordinary-claims/

Meyer, D.W. 1993. Alfalfa Management in North Dakota. https://library.ndsu.edu/ir/bitstream/handle/10365/4446/farm_36_1_5.pdf?sequence=1&isAllowed=y

Moomaw, R., G. Lesoing, and C. Francis 1991. Two Crops in One Year: Relay Intercropping. https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1723&context=extensionhist

Owens, V. and Carr, P. 2004. Pea/Oat Mixtures for Forage. http://www.midwestforage.org/pdf/72.pdf.pdf

Saskatchewan, Government of. 2021. AGR Market Trends. https://applications.saskatchewan.ca/agrmarkettrends

Sarunaite, L., A. Arlauskiene, I. Deveikyte Stanislava Maiketeniene, and Z. Kadziuliene. 2012. Intercropping of Pea and Spring Cereals for Weed Control in an Organic Farming System. In Weed Control. ed. A. Price. London: InTech. https://www.intechopen.com/books/weed-control/intercropping-of-pea-and-spring-cereals-for-weed-control-in-an-organic-farming-system

Scherber, S. 2020. Key Mechanisms Promoting Performance of Plant Teams. https://f30a38c1-5f0f-4263-a519-2e142581b93f.filesusr.com/ugd/d3d1da_082da219caa540e696d35015f28cd154.pdf

Tippin, L. 2019. Report on Practical Restrictions for Plant Teams. https://f30a38c1-5f0f-4263-a519-2e142581b93f.filesusr.com/ugd/d3d1da_f9d6ca9e440347368704a8a18e86f5cc.pdf

Wick, A. 2015. Fitting Cover Crops Into Rotation. https://www.ndsu.edu/soilhealth/wp-content/uploads/2015/12/Interseeding-Corn_7-7-16.pdf

SOUTH EAST RESEARCH FARM

General Mills

Agriculture and Agri-Food Canada