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RESEARCH SUMMARY

# Complementary practices for more feed and better environmental outcomes on high-production dairy farms

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**Production Type**
- Forage

**Practice Benefit(s)**
- Improved nutrient management
- Increased yield

**Research Location**
- Agassiz, BC

## KEY TAKEAWAYS

- Injection of separated manure sludge near the corn root zone **eliminated** the need for starter nitrogen (N) and phosphorus (P) fertilizer, **cutting annual P application in half with no negative effects on yield.**
- Intercropping Italian ryegrass with silage corn as a relay crop can provide **additional high quality feed** while reducing nitrogen leaching.
- Summertime irrigation and addition of nitrification inhibitors to manure before application can **increase crop yield and N recovery** of silage corn and perennial grass substantially.

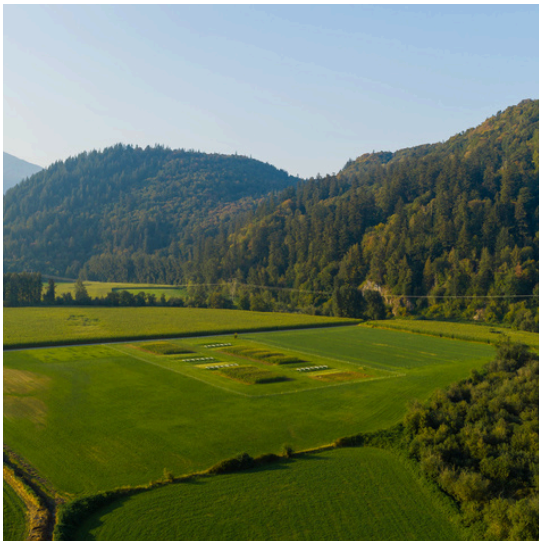

**Figure 1.** Aerial photo of the Farmlets in Agassiz, BC. Photo by Hover Collective.

***Key Terms:***
- *Relay crop: a cover crop that is planted while the main crop is still growing.*
- *Nitrogen (N) recovery: how much N the crop uses compared to how much N is applied to the field. A higher ratio or percentage means the N is being used more efficiently.*
- *Phosphorus (P) recovery: same as N recovery but for phosphorus.*
- *Nitrification inhibitor: substance that slows down the conversion of ammonium to nitrate (reduces potential leaching and greenhouse gas emissions).*

## HOW CAN THIS RESEARCH BE USED?

BC dairy farmers can increase silage corn and perennial grass productivity and reduce environmental impacts by: injecting manure sludge into corn fields, band-applying manure liquids in grass fields, intercropping corn with Italian ryegrass, irrigating in the summer, and adding nitrification inhibitors to manure. We found that these practices led to higher crop yields, better nutrient absorption, lower fertilizer use, and more efficient use of farm resources.

## WHY WAS THIS RESEARCH DONE?

As the demand for food and agricultural land grows, there's an increasing need to produce agricultural goods more intensely and sustainably. This is especially complicated in the dairy sector, where the feed must closely match the nutritional needs of dairy herds. We designed this study to explore new ways to sustainably increase dairy production in BC and reduce importing feed and nutrients onto farms.

Figure 2 shows the four different management scenarios that we tested. We called these management scenarios 'Farmlets' because they represent real and aspirational farms. Each Farmlet stacks an additional Beneficial Management Practice (BMP), where 'Farmlet 1' was conventional practices (no BMPs) and 'Farmlet 4' included three key BMPs all at the same time. The goal of our research was to boost the production of silage corn and perennial grass while also reducing the negative environmental effects of intensive crop production. We studied how these management scenarios affected crop yield and N and P recovery. We also used computer software to model and understand how much feed the cows would consume, how much milk they would produce, and the amount of nutrients they would excrete within each Farmlet. This method of research helps us understand complex farming systems and how to develop new technologies without the risk of unintended consequences.

**F1**

**Conventional**

- Broadcast whole manure slurry
- Apply starter N and P fertilizer while seeding corn
- Grass harvested 5x/year

**F2**

Conventional

**Innovative Nutrient**

- Separate whole manure into sludge and liquid fraction through natural settling
- Apply manure liquid fraction to grass through surface banding
- Apply manure sludge to corn through precision injection into the soil
- Side-dress corn at V9 stage with urea fertilizer (if indicated by soil nitrate test)

**F3**

Conventional

Innovative Nutrient

**Innovative Cropping**

- Switch corn to shorter-season variety (2 weeks earlier harvest) to increase relay crop growth in the fall
- Seed Italian ryegrass as relay crop between corn rows at 6-leaf stage
- Grass harvested 3x/year, longer growth interval

**F4**

Conventional

Innovative Nutrient

Innovative Cropping

**Advanced Techniques**

- Irrigate corn and grass weekly in the summer
- Add nitrification inhibitor (dicyandiamide (DCD) in this study) to manure before application

**Figure 2.** The four management scenarios, called Farmlets (F), tested in this study. Each subsequent Farmlet builds on the other. Photos by Derek Hunt and Shabtai Bittman.

## WHAT WAS THE OUTCOME?

Overall, we calculated that with the typical local farm ratio of 60:40 grass:corn, **Farmlet 1 had the lowest production levels per hectare (ha), while Farmlet 4 had the highest (Table 1)**. Under all Farmlets, corn yielded more dry matter, total digestible nutrients, and had higher potential milk production than grass. Grass (including the relay crop) had more crude protein and fiber than corn.

**Table 1.** Annual yield, digestible nutrients, and potential milk production of Farmlets 1 and 4.

| | Farmlet 1 | Farmlet 4 |
|---|---|---|
| **Annual yield (t dry matter (DM)/ha)** | 11.7 | 13.5 |
| **Annual digestible nutrients (t/ha)** | 9.0 | 10.2 |
| **Annual potential milk production (kg/ha)** | 21,266 | 23,886 |

***Effects of management scenario on grass and corn yield***

Annual grass yield (over the 2-year study) increased with each Farmlet management scenario, starting at 10.7 t DM/ha in Farmlet 1 and going up to 14.9 t DM/ha in Farmlet 4. The effects on corn yield were less linear: yield in Farmlets 3 and 4 were less than Farmlets 1 and 2 (Table 2) due to the earlier maturing corn variety. However, the addition of the Italian ryegrass in Farmlets 3 and 4 made up for most of the lost corn yield, so that overall yield from the field was similar between all four Farmlets (Table 2). Italian ryegrass also added high quality protein, fiber, and protected the soil from erosion.

***Effects of management scenario on N and P recovery***

Farmlet 4 had the highest grass N recovery, with 55% of N applied to the fields taken up by the grass (Table 3). In comparison, Farmlet 1 had the lowest grass N recovery, at 46%. This difference is likely a result of two factors: 1) the addition of summertime irrigation in Farmlet 4 led to increased grass growth, and 2) the use of a nitrification inhibitor in Farmlet 4 reduced the amount of N lost as ammonia gas. Farmlet 4 also had the highest grass P recovery, at 42% (Table 3).

N and P recovery in the corn fields (corn + relay crop) was highest in Farmlet 2, with 69% of N and over 100% of P applied to the fields taken up by the corn and Italian ryegrass. **The P recovery of over 100% was possible because the targeted application of manure eliminated the need for commercial starter fertilizer, which cut annual P application in half (without negatively affecting yield).** Farmlet 3 N recovery was less than Farmlet 2, even though management practices were improved, because the earlier maturing corn produced less yield, which reduced the amount of N that could be absorbed.

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**Table 2.** Average annual dry matter yield of silage corn, silage corn + relay crop (Italian ryegrass), corn grain, and perennial grass across Farmlets. Based on 2 years of data. Relay crops were only planted in Farmlets 3 and 4. Values within the same column that have different letters are statistically different.

| Farmlet | Silage corn, whole plant DM yield (t/ha) | Silage corn plus relay crop (Italian ryegrass) DM yield (t/ha) | Silage corn grain DM yield (t/ha) | Perennial grass (tall fescue) DM yield (t/ha) |
|---|---|---|---|---|
| 1 | 20.12 a | 20.12 a | 9.74 | 10.66 c |
| 2 | 20.26 a | 20.26 a | 9.82 | 11.20 c |
| 3 | 15.65 c | 18.30 a | 7.91 | 13.83 b |
| 4 | 17.60 b | 20.29 a | 8.78 | 14.94 a |

**Table 3**. Annual N and P recovery (expressed as a ratio) by silage corn, silage corn plus relay crop, and perennial grass. Average of two years. Values within the same column that have different letters are statistically different.

| Farmlet | Average annual N recovery (crop N uptake/N applied) | Average annual P recovery (crop P uptake/P applied) |
|---|---|---|
| **Silage corn** | | |
| 1 | 0.604 b | 0.463 c |
| 2 | 0.690 a | 1.027 a |
| 3 | 0.602 b | 0.905 b |
| 4 | 0.724 a | 1.107 a |
| **Silage corn + relay crop (Italian ryegrass)** | | |
| 1 | 0.604 c | 0.463 d |
| 2 | 0.691 ab | 1.027 a |
| 3 | 0.591 bc | 0.809 c |
| 4 | 0.666 a | 0.942 b |
| **Perennial grass (tall fescue)** | | |
| 1 | 0.462 c | 0.300 c |
| 2 | 0.504 b | 0.357 b |
| 3 | 0.503 b | 0.380 b |
| 4 | 0.547 a | 0.416 a |

## WHAT'S NEXT?

While the results of this study provide important information on the impact of management practices on yield and production, we did not report on the effect of Farmlets and crop ratios on cow performance and feed imports. This is reported in a paper by Karen Koenig et al. in 2023 (listed at the end of this brief). Work is ongoing to test effects of Farmlets on leaching, nitrous oxide emissions, soil nutrients, and soil organic carbon.

We are improving management methods with better hybrid choices including more resistance to a new pest (western corn root worm). We will evaluate if more aggressive manure separation is required in practice.

## HOW WAS THE RESEARCH DONE?

This study was conducted between 2016-2018 at Agriculture and Agri-Food Canada's Agassiz Research and Development Centre at Agassiz BC. The field was divided into 4 blocks, and each block was planted with 50% grass and 50% corn. The 4 Farmlet scenarios were carried out within each section of corn or grass, for a total of 4 replications.


**Figure 3.** Italian ryegrass **a)** two months after seeding; **b)** in the fall during corn harvest; **c)** in the following spring. Photos by Carson Li, Derek Hunt, and Shabtai Bittman.

For Farmlet 1, the rates of manure and fertilizer used were consistent with local practice at 297 kg N/ha for corn and 565 kg N/ha for grass. Of the 297 kg N/ha, 222 kg N/ha was applied as manure and 75 kg N/ha was applied as mineral fertilizer – 20 kg of di-ammonium phosphate was side-banded at corn planting and 55 kg of urea was side-dressed at the 9-leaf stage (V9). No mineral fertilizer was used on grass. P was applied as manure and fertilizer at 73 and 92 kg P/ha for corn and grass, respectively.

For Farmlet 2, manure was partially separated into solid and liquid components by allowing the solids to settle for several months. The thicker sludge component was injected by precision placement into furrows near the corn row, providing corn with 35 kg P/ha. The liquid fraction was banded on grass 5x annually (one dose for each growth period) using a trailing shoe applicator.

In F3, Italian ryegrass was inter-seeded between corn rows at V6. It was fertilized with manure liquid fraction in the following March, harvested in April, and lightly cultivated out before replanting corn.

Corn N and P uptake were calculated by multiplying the plant's N or P concentration by yield. Total digestible nutrients and potential milk production were calculated by inputting yield and nutrient data into MILK2006 and MILK2016 (spreadsheets that calculate production outcomes for corn and grass, respectively).

## ABOUT THIS BRIEF

**This brief is based on the following scientific journal article:**

Li, C., Hunt, D., Koenig, K., Smukler, S., & Bittman, S. (2021). Integrated farm management systems to improve nutrient management using semi-virtual Farmlets: agronomic responses. Environmental Research Communications, 3(7). https://doi.org/10.1088/2515-7620/ac13c6

**Want to learn more?**

- For any questions regarding this research, contact Derek Hunt (derek.hunt@AGR.GC.CA) or Shabtai Bittman (shabtai.bittman@AGR.GC.CA)
- Check out the related article that reports on the effect of Farmlets on cow performance and feed imports: Koenig, K. M., Li, C., Hunt, D. E., Beauchemin, K. A., & Bittman, S. (2023). Effects of sustainable agronomic intensification in a forage production system of perennial grass and silage corn on nutritive value and predicted milk production of dairy cattle. Journal of Dairy Science, 106(1). https://doi.org/10.3168/jds.2022-22110

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