Advancing sustainable cropping systems for dairy in the Northeast

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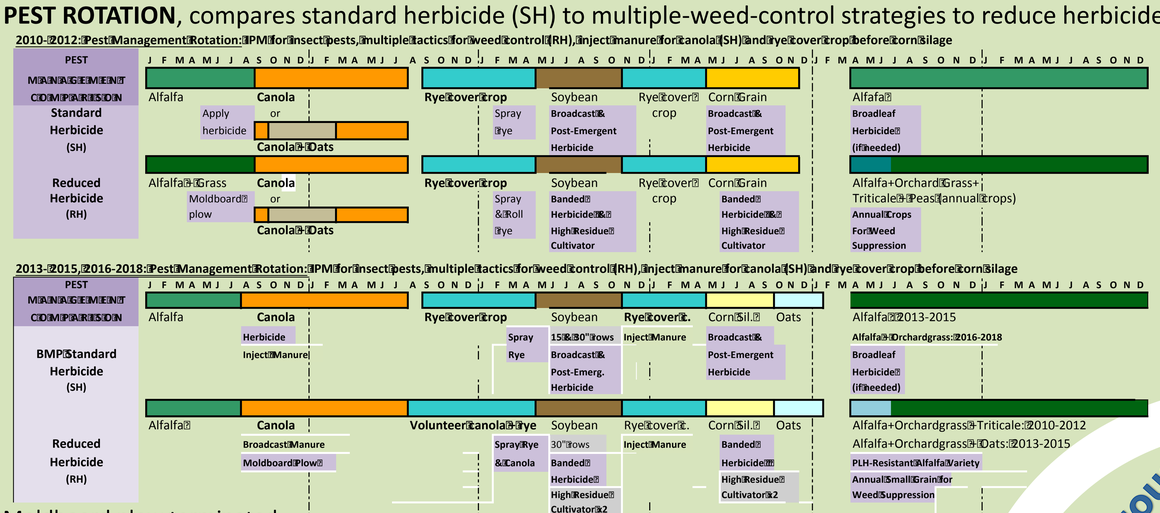
Our interdisciplinary team designed two diverse 6-year no-till crop rotations managed with IPM in consultation with an Advisory panel of farmers, experienced cropping systems researchers, and NRCS personnel with the **Objectives** to:

- minimize off-farm inputs and provide all forage and feed for a dairy herd, and canola fuel for a SVO tractor
- minimize environmental impacts, sustain soil health, and maximize profitability.

Methods Crop production experiment simulates a typical PA dairy farm (240 acres with 65 cows) at 1/20th the scale, using farm-scale equipment at the Penn State Univ. Agronomy Research farm. Beginning in 2010, all 6 years of our rotations were planted each year, replicated four times. Nested split plots compare innovative conservation strategies. Informed by what we learned, each 3 years we have modified the rotations to improve their performance. Silage making was simulated in lab; crop yield and quality data are used by the Dairy Scientist to develop rations and simulate milk and manure production of a virtual dairy herd with dairy nutrition models.

PEST ROTATION, compares standard herbicide (SH) to multiple-weed-control strategies to reduce herbicide (RH)

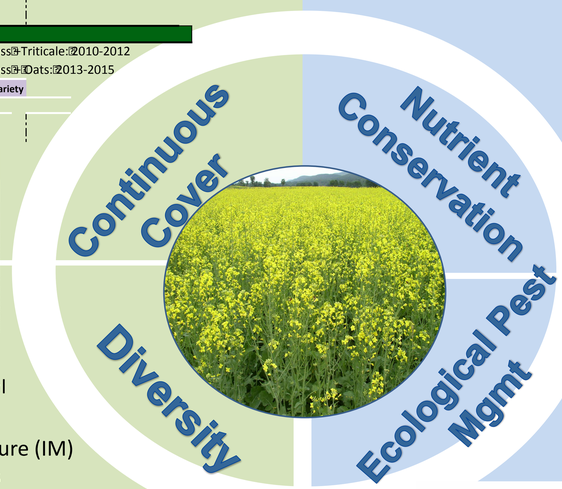


Moldboard plow terminated alfalfa +orchardgrass

Canola for SVO tractor farm operations & feed

Banding herbicide over the crop row (left), using high residue cultivation post (right).

Annual crops left grown to suppress weeds in perennial establishment year.



MANURE ROTATION: compares same rate of broadcast manure (no-till practice in NE) vs. injected manure (IM) to reduce ammonia N loss & reduce P run-off, and green manures or silage and green manure crops

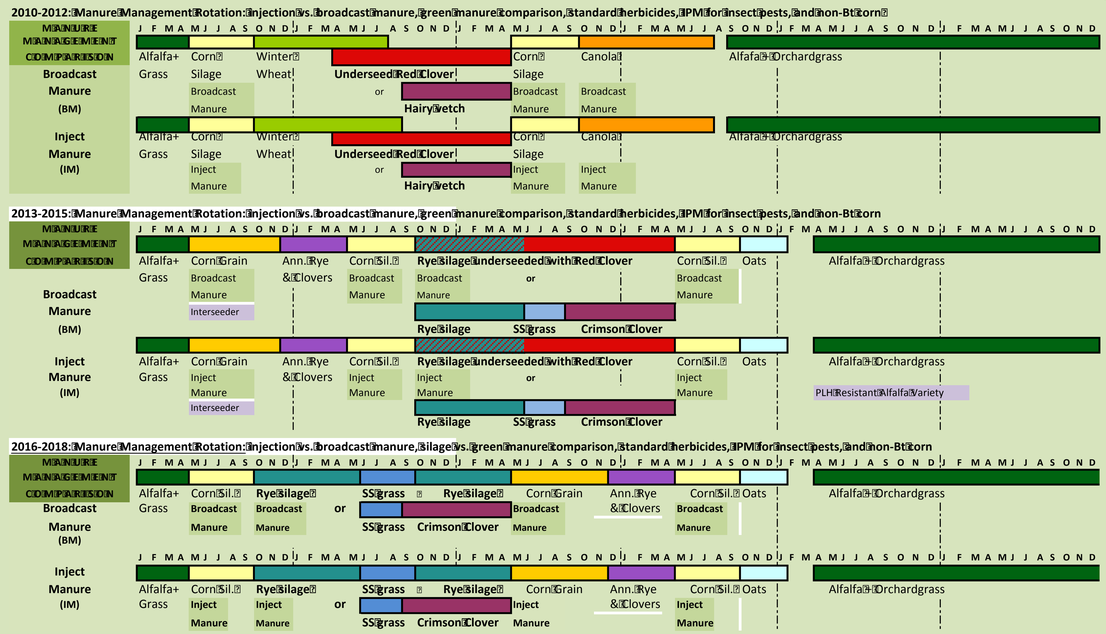


Fig. 1. Cropping systems schematic for Pest (top) and Manure (bottom) rotations and modification over the years since the study initiated in 2010.. Each rotation was under two main management practices. Standard and reduced herbicide managements for pest rotation and boradcast and injected manure managements for manure rotation.

Broadcasting manure

Injecting manure.

Red clover underseeded into A small grain crop.

Hairy vetch.

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Results: We monitored weather, all crop inputs (fertilizer, manure, herbicide, insecticide) crop yield and quality, soil fertility, soil quality, milk production, and farm profitability.

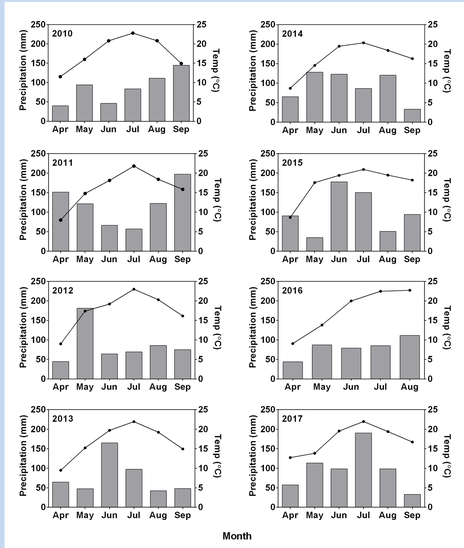

Fig. 2. Weather varied over 8 years (2010-2017), impacted yields & crop rotation modification decisions.

Rationale for rotation changes:

- **Pest rotation 2013:** No-till farmers said they would not use high residue cultivation, post-emergent herbicide split-plot treatment added. Cultivated RH soybean require 30 inch rows; potential SH 15 inch row yield gain tested by addition of 30 inch SH soybeans for comparison of row spacing (Fig. 1, top figure).
- **Manure rotation:** Dry weather in early years revealed need for another corn entry. Wet falls delayed fall manure & canola planting after corn silage. Slugs damaged canola planted in late fall. So, corn silage, rye silage, & sorghum sudangrass replaced wheat & canola. Sorghum-sudangrass and rye silage provide lower CP feed needed for heifer & dry cows (Fig. 1, bottom figure).

Pest Rotation Yields: Corn RH and SH yields were similar (Fig. 3). In a few years, slugs reduced stands in SH canola and both soy. Higher yields in 15 inch SH soy and when only soy SH was replanted in 2012. Alfalfa Yr3 was terminated in August to plant canola. SH alfalfa monoculture yielded more than RH alfalfa and orchardgrass, likely due to cool season orchardgrass in June, July, August harvests.

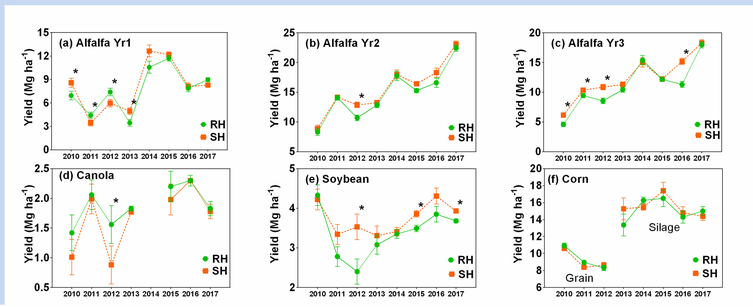

Fig. 3. Summary of crop yields of pest rotation (dry matter) each year for the RH and SH managements. Asterisk indicated significant difference at $P \leq 0.05$.

Herbicide Use: Pest Rotation: Average herbicide use was reduced by 27% in corn, 19% in soybean, and 40% in alfalfa establishment year, 100% when alfalfa was terminated.

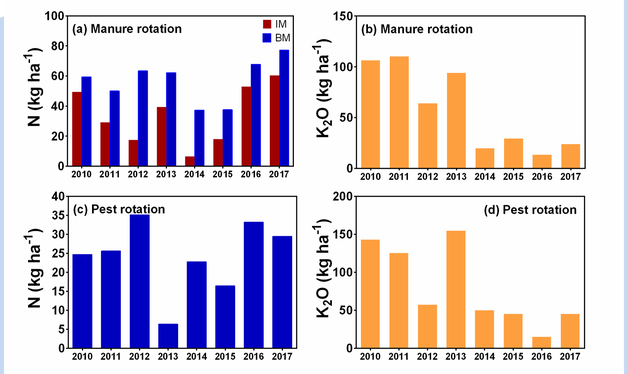

Fig. 4. Summary of fertilizer N and K_2O application for the manure and pest rotations.

Fertilizer Use: The same rates of manure was applied in BM and IM. Inorganic N fertilizer (starter + side-dress based on PSNT) was reduced in IM by average 42% over the 8 years. Fertilizer P was applied only as starter. Fertilizer K_2O need in general declined over time in both rotations (Fig. 4).

Manure Rotation Yields: Crop yields did not differ except in 1 yr. Alfalfa Yr 2 when BM was higher than IM (Fig. 5).

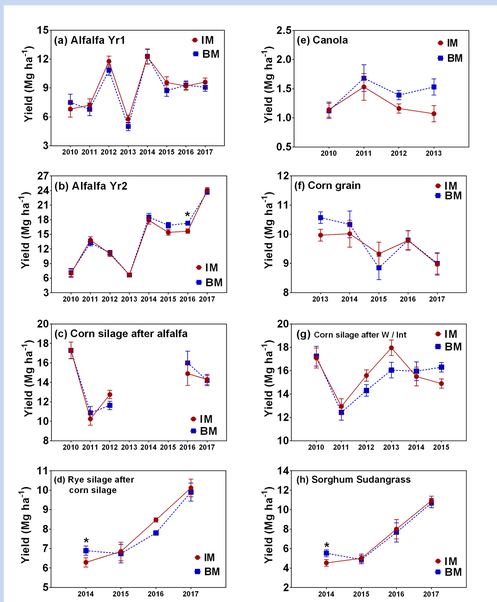

Fig. 5. Summary of crop yields (dry matter) in the manure rotation for IM and BM managements. An Asterisk indicates significant differences at $P < 0.05$>

Insecticide Use was reduced with IPM (ex. insect scouting & population monitoring).

- European corn borer did not reach economic thresholds in non-Bt corn, which had the same or higher yields as sister Bt corn varieties in a control Corn Soy rotation (data not shown).
- In only two of eight years, in two of four corn rotation entries synthetic pheromone was sprayed for armyworm (after rye or orchardgrass) and black cutworm.
- Alfalfa fields were sprayed once per year or twice one year with insecticide rather than multiple times as is more typical.

- Modified rotations have grown all forage, most grain for the dairy and some fuel
- Reduced fertilizer use by average 30% with injected manure
- Reduced pesticide by conserving natural enemies, diverse rotations & IPM