Progress report

The Continuous Soybean experiment was established in May 2023 in two locations: at the Agricultural Engineering and Agronomy farm in Boone, IA and at the Northwest Research Farm in Sutherland, IA. Both locations are characterized by highly productive soils, soil with low soybean cyst nematode (SCN) counts, and shallow water table. In each experiment we investigated seven cropping systems, all planted in no-till, were established in both locations in fields that were planted with soy in the 2022 season: 1) Continuous maize, 2) Maize-soybean rotation 3) Soybean-maize rotation, 4) Continuous soybean with 30 inch row spacing, 5) Continuous soybean with 15 inch row spacing, 6) Continuous soybean with winter cereal rye cover crop and 7) Continuous soybean with winter cereal rye cover crop and Fall applied manure. We established large plot sizes to allow extensive data collection by different groups (Fig. 1). Plots are 40ft X 100ft in Boone and 40ft X 80ft in Sutherland, with four replications. Soybean plots were split-plots, so that two varieties with different SCN resistance were planted. The total number of plots per experiment was 7*4*2=64 plots. In Boone, crops were planted May 5th, 2023; maize was a Dekalb hybrid 110-day, and soybean varieties were XO2963E (2.9MG, Peking SCN resistance source) and XO2832E (2.8MG, PI88788 resistance source). In Sutherland, crops were planted May 17th, 2023; maize was a Dekalb hybrid 105 RMG, and soybean varieties were P25A16E (2.5MG, Peking SCN resistance source) and P21A53E (2.1MG, PI88788 resistance source). For plots receiving treatments (6) and (7), winter cereal rye (Hazlet variety) was seeded using a high clearance cover crop seeder at a rate of 80lb/a in soybean plots at start of soybean senescence on both locations. Crops harvested October 10th in Sutherland and October 9th in Boone. For plots receiving treatment (7), chicken manure was broadcasted at a rate of 2 ton/a on November 6th in Sutherland. In Boone, manure source was beef compost, which was broadcasted at a rate of 10ton/a. All chemical control applications were carried out to reflect farmers' practices. At the Boone location, a control plot of 40ft X 220ft was planted to have a measure of the yield penalty of continuous soybean in the 2023 season. The control was planted the same day as the main experiment; with same soybean varieties XO2963E and XO2832E, but at nearby field that was cultivated with maize in the 2022 growing season.

Fig 1. Continuous Soybean experiment in Boone, IA.

Measurements were taken along the growing season to characterize crop growth and development, soil, soybean cyst nematode pressure, and field hydrology. Aboveground biomass was collected at stages V14, R2 and R6 for maize and R2, R5 and R6.5 for soybeans. Grain yield was determined by machine harvesting the center 6 rows in Sutherland and center 4 rows in Boone of each variety and plot. Soil and aboveground residue were collected before planting at 0-12 and 12-24inch depth for initial condition assessment. Each subplot was sampled for soybean cyst nematode counts both before planting, and after harvest. To better understand soil hydrology dynamics, a total of 24 sensors were installed in each location in the continuous maize and continuous soybean plots. Tubes down to 8ft were installed to allow access to TDR TRIME-PICO IPH/T3 and SOP 503 HydroProbe-Moisture Neutron Gauge to measure soil moisture at 12inch intervals. Sentek-BT sensors were installed in selected plots to measure soil moisture and temperature down to 40inch depth at 2inch intervals. Solinst 3001 Edge Leveloggers were installed to measure soil temperature and water table depth at different points of the field. Additionally, throughout the season, drone flights with RGB and NDVI cameras happened weekly to observe canopy closure. Currently, the experiment is ongoing, winter cereal rye is developing in the field ahead of the 2024 experimental year, and hydrology sensors are performing measurements aiming to get a whole year profile of soil water dynamics in two Iowa environments.

Through field data and crop modelling, the experiment established in 2023 has already allowed us to gain some insight into the continuous soybean system, and how its productivity and environmental performance compares to the other cropping systems established. In Boone, there was no yield gap associated with growing second year soybeans in 2023 (Fig. 2). In both locations, soybean varieties with different SCN resistance sources had the same performance (Fig. 3), that was expected given the low Spring SCN egg counts. Studies of the hydrology data obtained from the sensors in this study have given us important information on the importance of water tables to crop production. Regardless of a year with greater potential of water deficit in many regions of Iowa, we found the system to be resilient, as subsoil water was able to support normal yields in both locations. The observed water table dropped approximately 3ft at time of peak crop growth, agreeing with previous studies from the Archontoulis lab. Through measurements of volumetric soil water content at different depths and times of the growing season, we observed that as the season became drier, crops relied on soil water stored 4 to 6ft in the soil profile for growth (Fig. 4).

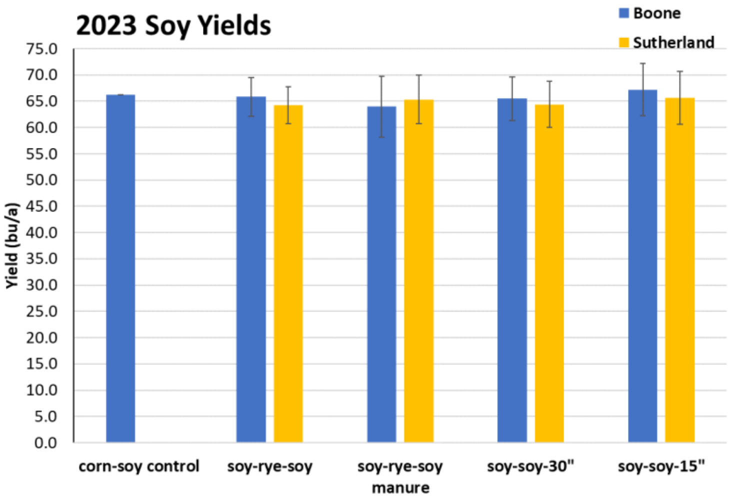

Fig. 2 Soybean yields (bu/a) for both locations, and corn-soy control established in Boone,IA.

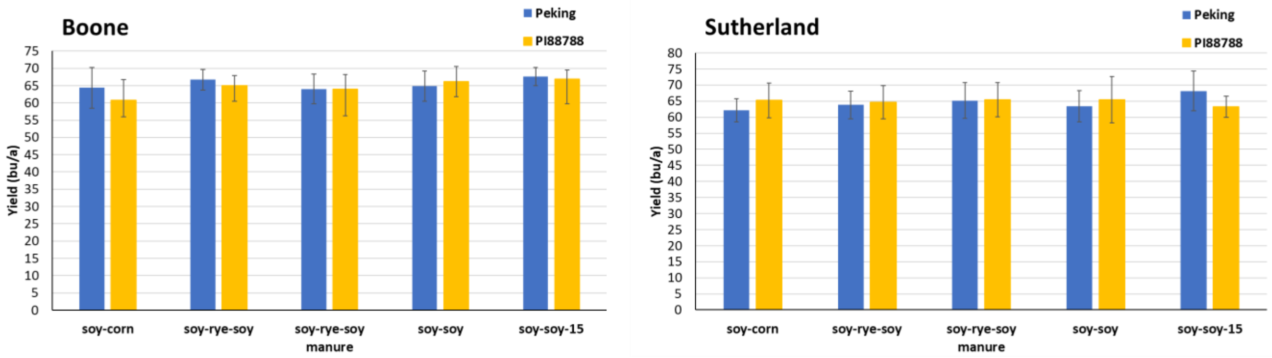

Fig. 3 2023 soybean yield (bu/A) by variety SCN resistance source for both sites.

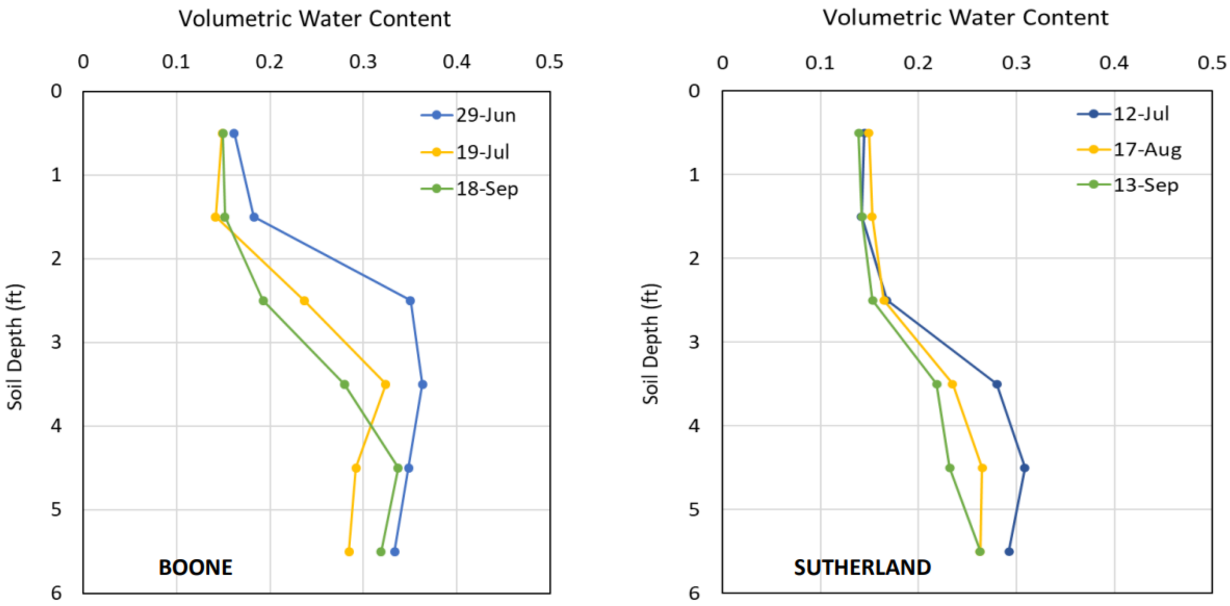

Fig. 4 Measured volumetric water content by depth at three timepoints

For doing a preliminary assessment of environmental performance of the cropping systems established in this experiment, APSIM 7.9 was used to build long-term simulations representing each treatment. Simulations were run without reset, using 30 years of local weather data for Boone. The model provided the following outputs: grain yields, biomass production, grain N uptake, soybean N-fixation, N_2O emissions, N leaching, net mineralization, soil organic carbon, plant transpiration, soil water evaporation, water table depth, runoff, and subsurface drainage. We calculated N balance as inputs (N fertilizer + N fixed) – outputs (N in grain). Cropping systems were compared based on these variables. Overall, we found that soybean-based systems had higher net N mineralization, and lower N balance compared to corn-based systems. Continuous maize had higher N-leaching and N2O emissions than all other systems. Inclusion of cereal rye cover crop was important to aid in reducing the rate of soil organic carbon loss in the topsoil when soybean is the main crop. These are all important findings on alternative ways to reduce N loss to the environment and design more sustainable systems.

Throughout the year 2023, we had opportunities to disseminate results and insights gained from the first experimental year of the continuous soybean project. On August 2nd ,2023 we received the Iowa Soybean Association (ISA) Experience Class, a group of around 35 farmers and staff, on the experiment site in Boone, IA. There was productive conversation around soil moisture measurement methods and importance, weed management in a continuous system, cover crop benefits and choice. At the 2023 Tri-Societies Meeting held in St. Louis-MO on November 1st, we presented a poster titled “Evaluating environmental and economic performance of soybean-based systems using APSIM”, where we contrasted the cropping systems’ profitability and Carbon, Nitrogen, and water balances using model outputs. Additionally, soil hydrology results from both experimental sites were presented in two sessions at the Iowa State University Integrated Crop Management conference held at Ankeny, IA on December 4th, , the talk was titled “What do deep soil moisture measurements tell us about water stress in Iowa?”. The public consisted mostly of farmers and industry professionals, with a turnout of around 100 attendees. The Continuous Soybean experiment is currently ongoing, and next steps include winter cereal rye biomass collections, Spring initial soil conditions sampling, initial soil water measurements, and similar data collection in the 2024 experimental year.

Evaluating economic and environmental performance of soybean-based systems using APSIM

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Research objective

Demands for increasing oil production in the coming years, uncertainties regarding input cost, and goals to improve sustainability call for research to enhance our options for the future. Here we explore alternative soybean-based cropping systems and compare them with current systems with regard to long-term impacts on soil carbon, nitrogen, water, and farmers' profitability via simulation modeling.

Methodology

We used the APSIM cropping systems model (version 7.9) to simulate the long-term impact of 6 cropping systems (Table 1) in a central Iowa environment. Simulations ran for 30-yr, from Jan 1990 to Dec 2020 without reset. The soil had 3% topsoil organic carbon, a 180 mm water holding capacity (0-1.5m), shallow water table depth (average of 1.5 m), and subsurface drainage (1.2 m depth, 14 m spacing). The management practices were fixed from year to year (Table 1). The APSIM model provided the following output variables: grain yields, biomass production, grain N uptake, soybean N-fixation, N_2O emissions, N leaching, net mineralization, soil organic carbon, plant transpiration, soil water evaporation, water table depth, runoff, and subsurface drainage. We calculated N balance as inputs (N fertilizer + N fixed) – outputs (N in grain). For the economic analysis, we considered the seed and the N-fertilizer cost (source: ISU Extension, Budget & Record Summaries).

Table 1: **Management practices of the cropping systems**

Cropping System	Crop	Planting Date	Plants m^{-2}	N-Fertilizer (Kg N/ha)
Corn-Corn	Corn	5-may	8	213
Corn-Soy	Corn	5-may	8	168
	Soy	15-may	32	0
Soy-Soy	Soy	15-may	32	0
Soy-Rye-Soy	Soy	15-may	32	0
	Rye	20-oct	200	0
Soy-Rye-Soy2	Soy	1-may	32	0
	Rye	7-oct	200	0

Corn and soy row spacing: 76 cm; Rye row spacing: 15 cm
Rye termination date: 28-apr
Corn hybrid: 111-day relative maturity
Soybean variety: 2.7 maturity group

Water

Fig. 1: 30-year average values of water table depth (0 cm is the soil surface), evapotranspiration (ET), subsurface drainage and runoff per cropping system.

Nitrogen

Fig. 2: 30-year average values of N_2O emissions, net N mineralization, N leaching, and N balance (N applied + N-fixation – grain N) per cropping system.

Carbon

Fig. 3: Average annual carbon inputs (crop residue; top panel) and long-term topsoil organic carbon dynamics per cropping system (bottom panel)

Economics

Fig. 4: Input cost (considering fertilizer and seed cost, top panel) and net return (bottom panel) per cropping system

Key Findings

- The soy-soy system had the highest evapotranspiration, the deepest water table, and the lowest drainage
- Soybean-based systems had higher net N mineralization and lower N balance compared to corn-based systems
- The corn-corn system had higher N-leaching and N_2O emissions compared to other systems
- The soy-rye-soybean system with early planting exhibited similar soil organic carbon dynamics after 30-yr as the corn-soy system.
- The soy-soy had much less input cost than the corn-soy while the corn-soy was the most profitable followed by the corn-corn.
- Cropping systems that rely on corn, have greater production costs and are more susceptible to fluctuations in input prices. Soybeans may provide more stability in profitability over a longer time span.

Acknowledgements

This study is funded by the Iowa Soybean Research Center (ISRC). We thank Isaiah Huber and Makis Danalatos for their help with the project.

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