IMPACT OF CROP SEQUENCE AND TILLAGE ON CROP YIELD AND QUALITY, SOIL NUTRIENTS, PH, TEXTURE AND MICROBIAL POPULATION – YEAR 3 REPORT.

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The increasing demand for agriculture productivity which aligns with sustainable and conservational goals has been a significant challenge for both growers and researchers (Cohen, 2002). Crop rotation and tillage practices which are considered a part of a "conservation agriculture" system (Giller et al. 2015) could significantly improve crop yield and quality (Pittelkow et al. 2015) in an environmentally friendly manner which resonates with the United Nations Sustainable Development Goals (SDGs) focuses on ensuring zero hunger, responsible production, and consumption, with positive impact on global climate. Conservation tillage (where ≥ 30% crop residue remains) and crop rotation (systematic inter-cropping over the years) can provide benefits such as reduced labor and energy use contributing to low CO2 emissions, soil conservation (Busari et al. 2015), improved soil organic matter content (Somasundaram et al. 2019) and infiltration which helps to reduced erosion losses (Govaerts et al., 2009). To tackle the earlier mentioned challenge of increasing food demand and sustainable agricultural productivity, there is a need to adopt conservational over conventional agricultural practices (Saikia et al. 2020).

To provide information that would help growers make that positive decision for the switch, an interdisciplinary study was carried out to assess the impact of crop sequence and tillage on crop yield quality, soil nutrients, pH, texture, and microbial population.

MATERIALS AND METHODS

A field trial was conducted at Prosper, ND in 2023 (Figure 1). The experimental design was a strip block with four replicates. Strip tillage and conventional tillage were conducted in both the fall of 2022 and prior to planting on 31 May 2023. Field plots comprised of six 30-feet long rows spaced 22 inches apart. Plots were planted on 1st of June with corn (Peterson Farms Seed 22T83), soybean (AG09XF0) and hard red spring wheat (Faller). Corn seeds were planted at a population of 35,000 seeds per acre, soybean seed was planted at a rate of 175,000 seeds per acre while wheat was drilled at a rate of 124 pounds per acre. Weeds in the corn and soybean plots were controlled with herbicide applications (Zidua @ 3 fl oz per acre; Roundup Powermax 3 @ 25 fl oz per acre) on June 6, (Outlook @ 12 fl oz per acre; Amsol @ 2.5%v/v; Interlock @ 4 fl oz per acre; Cornerstone 5 Plus @ 35 fl oz per acre) on June 18 and (Roundup Powermax 3 @ 30 fl oz per acre; Outlook @ 12 fl oz per acre; Amsol @ 1% v/v; Interlock @ 4 fl oz per acre) on June 30 as well as hand weeding throughout the summer.

Wheat was sprayed with Huskie Complete on June 6 to control weeds and hand weeding was done throughout the summer as needed. Urea fertilizer (46-0-0) was spread on the conventional tillage plots to be planted to corn and wheat prior to conventional tillage. Urea fertilizer (46-0-0) was spread on the strip tillage and no-tillage plots planted with corn and wheat on June 21 prior to rainfall. Wheat was harvested by plot combine on September 11, soybeans were harvested with a plot combine on October 17 and corn was harvested by a plot combine on November 2. Soybean and wheat analysis was conducted by the Plant Pathology Department at North Dakota State University. Corn analysis was conducted with Dickey John moisture and protein reader by the Plant Science Department at North Dakota State University. The data analysis was performed with the ANOVA procedure of the Agriculture Research Manager, version 2019.4 software package (Gylling Data Management Inc., Brookings, South Dakota). The least significant difference (LSD) test was used to compare treatments when the F-test for treatments was significant.

Soil samples were collected from different treatments just before planting. Representative soil samples were sent to the soil microbiology department, specifically Dr. Samiran Banerjee's lab, as well as the University of Minnesota for soil microbiome analysis. The remaining soil samples were sent to AGVISE for analysis of various soil parameters, including nutrients, organic matter, and carbon. The respective data will be analyzed after the testing is completed. In addition to the initial objectives, 27 soil temperature probes were installed to collect soil temperature data corresponding to the crop sequence and tillage type. Furthermore, soil erosion pads were installed within the planting rows to measure the impact of crop sequence and tillage type on soil erosivity. Early disease symptoms were not observed during the seedling stage in any of the treatments, and the plants are growing well, although the emergence rate differs among the different crop and tillage types. Towards the end of the season, there was no significant disease impact due to proper agronomic practices incorporated throughout the study, so there was no evaluation for disease severity.

RESULTS AND DISCUSSION

The effects of tillage methods and crop sequences respectively, were not significant on yield for soybean ($p>0.14$), corn ($p>0.20$), and wheat ($p>0.21$). This was the same for moisture content and test weight respectively in soybean ($p>0.78$, $p>0.70$), corn ($p>0.29$, $p>0.45$) and wheat ($p>0.16$, $p>0.21$). All values of LSD at $p=0.05$ were calculated and given in Table 1 a, b, and c. As can it be seen, none of the differences between any treatments was larger than the respective LSD value.

The microbiome study revealed no significant differences in observed taxa across crops or tillage methods ($p > 0.05$). However, the number of observed taxa tended to decrease with increasing depth ($p = 0.001$). Numerically, corn exhibited a higher abundance of observed microbial taxa than soybeans (Fig 2). Additionally, there was no significant interaction between tillage types and soil nutrients, pH, and carbonate. Nevertheless, a significant difference in pH across various soil depths was observed (Fig 3).

Remarkably, soil erosivity data indicated that wheat experienced significantly less soil erosion compared to corn and soybeans ($p < 0.05$). Soil erosivity across tillage types was significantly lower in the wheat crop sequence and the no-tillage type which is an indication that the type of tillage employed can significantly increase soil erosion which is a significant limitation faced in many research and commercial fields. This difference was attributed to the previous year's crop sequence, where no-till corn was planted, and existing corn residues helped prevent erosion. Across tillage types, no-till practices demonstrated significantly less soil erosion than conventional and strip tillage (Fig 4).

Analysis of beneficial and other insects' collection revealed that the highest number of insects was observed in weeks 1 and 3, with corn and wheat hosting the most insects. Insect populations decreased in weeks 4 and 5, followed by a gradual increase until week 8 (Fig 5). Similarly, earthworm collections, indicative of healthy soil, showed a uniform distribution of their numbers across both crop types and tillage methods, although the counts were generally lower (Fig 6).

Recent data from the year 2023 field experiment further supports previous research results which indicated that corn, soybean, sugar beet including wheat can be successfully grown under different tillage types in the Red River Valley. Where possible, care should be taken to reduce corn residue especially in strip tillage and moving residue with coulters in to till to facilitate planting to get a good plant population. With continuous flooding of some plots which seems to be the recurring challenges faced every year regarding this research, there are ongoing consultations as to how to prevent these limitations in future experiments.

With additional objectives added to the focus of these project, there is a more diverse insights to how crop sequences and tillage type can impact not only crop yield, quality, soil physio-chemical properties, microbial populations but also earthworm and beneficial insects' distribution as well as soil temperature and erosivity. The overall results from these objectives would significantly contribute to more environmentally friendly agronomic practices that can be adopted by growers in the Red River.

Considering the continuous progressive results obtained from this project, we aim to proceed with another field year in 2024. This will complete the initial 4-year crop rotation plan initially budgeted for this project. The 2024 plots will be planted in May with the crops being corn, soybean, and sugar beet in the 4^{th} year of the sequence (Sugar beet/Soybean/Soybean/Corn).

Table 1a. Soybean, Table of Means, Tillage

Tillage	Yield	Moisture (%)	Test weight
Conventional Tillage	41.73a	11.25a	57.20a
Strip Tillage	44.63a	11.20a	57.28a
No Till	42.55a	11.13a	57.38a
LSD at p=0.05	3.16	0.43	0.50

Table 1b. Corn, Table of Means, Tillage Type

Tillage	Yield	Moisture (%)	Test weight
Conventional Tillage	208.93a	15.53a	58.34a
Strip Tillage	208.25a	17.43a	57.53a
No Till	184.73a	15.98a	58.93a
LSD at p=0.05	23.17	1.98	1.81

Table 1c. Wheat, Table of Means, Tillage Type

Tillage	Yield	Moisture (%)	Test weight
Conventional Tillage	64.43a	12.80a	58.40a
Strip Tillage	52.15a	14.03a	57.15a
No Till	61.00a	19.80a	53.30a
LSD (p=0.05)	15.6	8.25	6.46

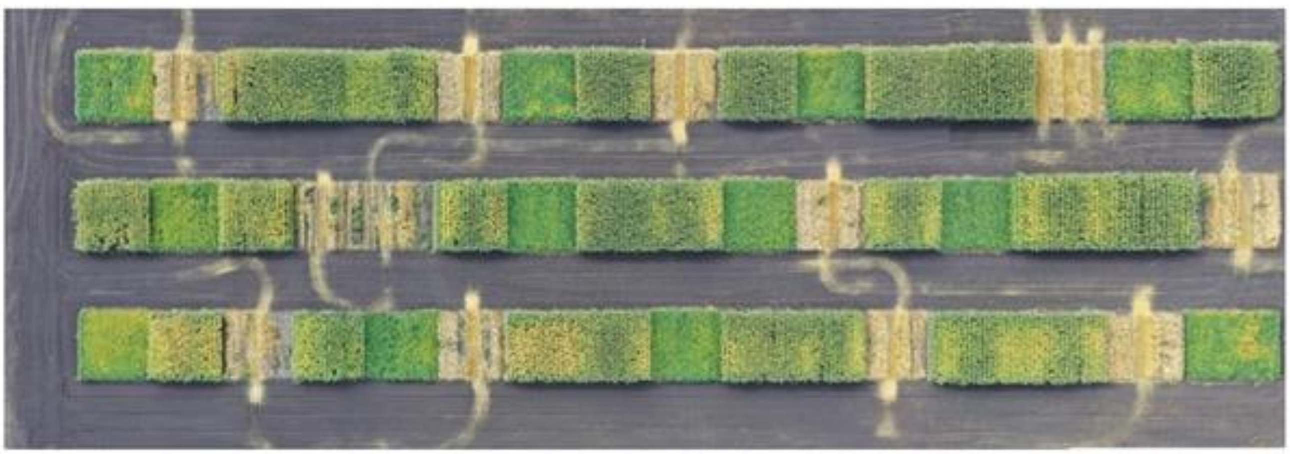


Fig 1: Crop sequence and tillage trial (wheat/corn/corn/soybean) located at Prosper, ND

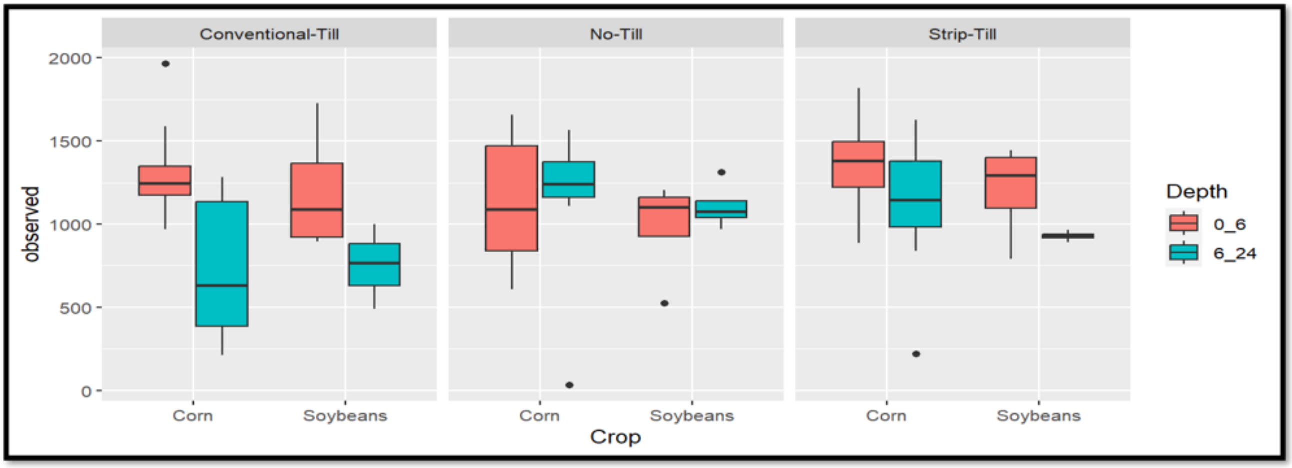


Fig 2: 2023 Data for Corn and Soybean (Beta Diversity) showing the relative abundance of the 16S gene from soil samples (0-6'' and 6-24'') under different tillage regimes

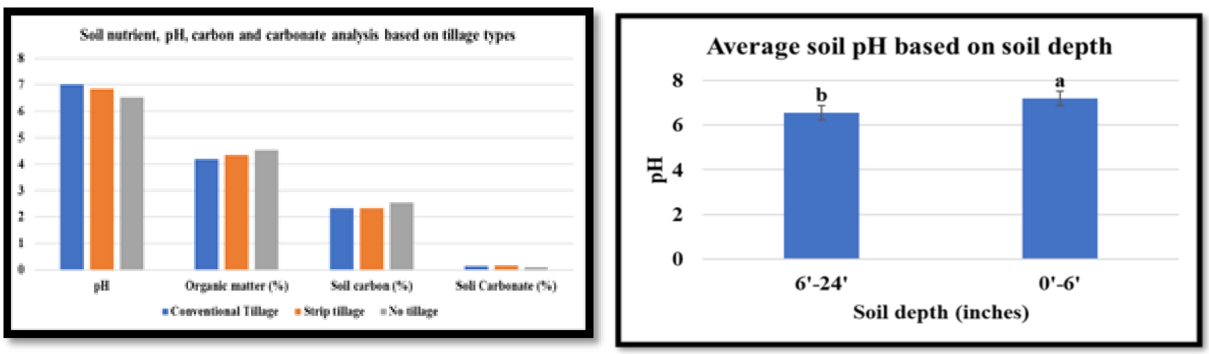


Fig 3: Soil nutrient, pH, carbon, and carbonate analysis (left) and soil pH based on soil depth (right)

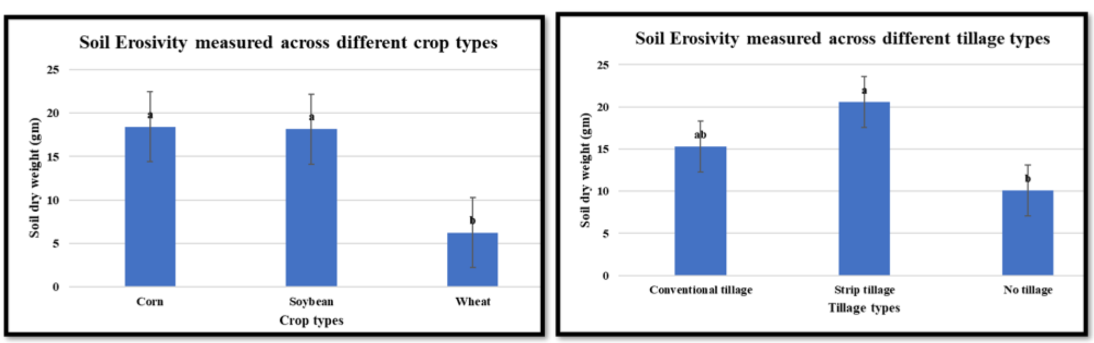


Fig 4: Soil erosivity across crop types (left) and tillage types (right)

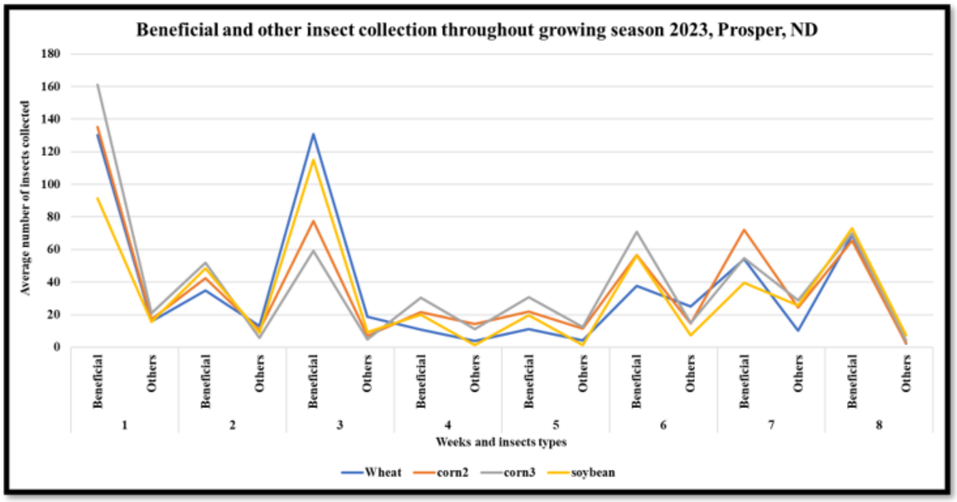
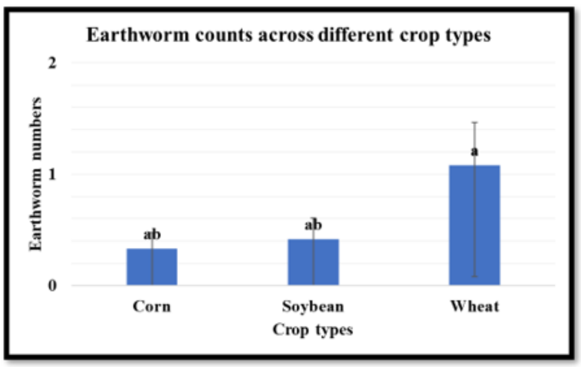


Fig 5: Survey of beneficial and other insects collected throughout growing season 2023



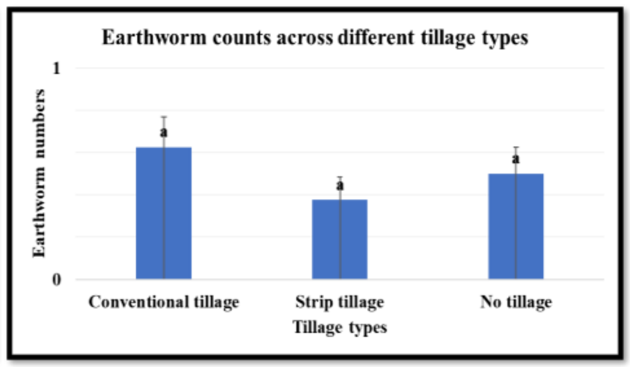


Fig 6: Earthworm distribution across different crop types (left) and tillage types (right)

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