DOES NITROGEN MANAGEMENT IN WINTER WHEAT AFFECT ITS YIELD AND NITRATE-N LEACHING IN A WHEAT-SOYBEAN DOUBLE CROPPING SYSTEM?

Oluwaseun Ola[1], Osman Guzel[1], Karla L. Gage[1], Karl W.J. Williard[2], Jon E. Schoonover[2], Steffen Mueller[3], Amir Sadeghpour[1]

[1]*School of Agricultural Sciences, Crop, Soil, and Environmental Program, Southern Illinois University, Carbondale, IL, USA*

[2]*School of Agricultural Sciences, Forestry and Horticulture Program, Southern Illinois University, Carbondale, IL, USA*

[3]*Energy Resources Center, University of Illinois Chicago, Chicago, IL*

ABSTRACT

Conventional corn (*Zea mays* L.)-soybean (*Glycine max* L.) rotation contributes to nitrate-N and phosphate leaching to waterbodies causing water quality concerns. Two strategies that could minimize N and P losses include (i) incorporating winter rye (*Secale cereale* L.) (WR) as a cover crop to capture residual nutrients or (ii) intensifying the corn-soybean rotation with winter wheat (WW) (*Triticum aestivum* L.) (Double cropping). Double cropping WW at a right N management could increase farm profit and provide incentives for adoption as well. A trial was established at two sites (Carbondale, and Belleville, IL) to evaluate soybean and overall cash crop performance along with nitrate-N and phosphate losses in a single season [soybean following a no-cover crop control vs. WR as compared to three double cropping scenarios (low, medium, and high intensity N management of WW prior to soybean). The results indicated that double cropping decreased soybean yield regardless of N management intensity during the previous WW. Nitrogen addition to WW resulted in increased nitrate-N leaching during the WW phase but, at medium and high N intensity scenarios, decreased the nitrate-N leaching during the following soybean phase and overall WW-soybean growing seasons suggesting double cropping could minimize N losses and provide farm profit.

INTRODUCTION

Nitrate loss in row crop agriculture remains a global concern due to its impact on the environment. To this effect, the Illinois Nutrient Reduction Strategy has set a goal to reduce nitrate-N leaching by up to 15% by 2025 (IEPA, IDOA, and University of Illinois Extension, 2015). Planting cover crops (CCs) including cereal rye (CR; *Secale cereale* L.) has been recommended as the most effective strategy to manage nitrate-N leaching. However, growers are reluctant to plant cover crops such as cereal rye in corn (C; *Zea mays* L.)-soybean (S; *Glycine max* L.) rotation. Double cropping corn-wheat (W; *Triticum aestivum* L.)-soybean, however, is fairly common in Southern Illinois. While the economic potential of double cropping wheat and soybean is well established (Tsiboe *et al*., 2017), literature is limited on the effects of N and P loss during wheat and soybean growing seasons at different N management intensities during wheat production season. Therefore, our objective was to evaluate the effect of N management during the wheat growing season to find best N management for reducing nitrate-N and phosphate leaching in a wheat-soybean rotation as compared to a no-cover crop or a cereal rye-soybean rotation.

MATERIALS AND METHODS

Experimental Site, Design, and Treatments

The study was laid out in a Randomized Complete Block Design (RCBD) with four replicates at the Agronomy Research Center (ARC), Carbondale, and Belleville Research Center (BRC), Belleville. The eight treatments, applied at the same time were (1) corn-soybean rotation with no-CC (control), (2) corn-rye-soybean-rye rotation (maximum nitrate-N reduction control), (3) corn-wheat (medium input)-soybean-no-CC, (4) corn-wheat (low input)-soybean-no-CC, (5) corn-wheat (high input; NREC growers suggestions)-soybean-no-CC, (6) corn-wheat (medium input)-soybean-rye CC, (7) corn-wheat (low input)-soybean-rye CC, and (8) corn-wheat (high input; NREC growers suggestions)-soybean-rye CC.

Winter Wheat, Soybean, and Cereal Rye Establishment

A no-till drill was used to plant wheat (var. AgriMaxx 495) and CR (var. SoilFirst) at 2 million seeds ac^{-1} and 78 lbs ac^{-1}, respectively in October 2021. Cereal rye was terminated in May 2022 while wheat was harvested in June 2022. Soybeans (var. Asgrow 47xF0) were planted after the termination of cereal rye and harvesting of wheat in May (single season) and June 2022 (double crop). Soybean was harvested and cereal rye was planted on October 2022.

Nitrogen Management for Wheat

The low input treatments (4 and 7) were subjected to a nitrogen (N) application regimen, wherein 40 lbs of N ac^{-1} was applied in the form of Urea Ammonium Nitrate (UAN) both at the tillering stage and during the jointing stage. In contrast, the medium input treatments (3 and 6) received a total of 70 lbs of N ac^{-1} in the form of UAN, with applications taking place at the tillering and jointing stages. Conversely, the high input treatments (2 and 5) followed a distinct N application strategy. These treatments involved the application of 27 lbs of N ac^{-1} in the form of Diammonium Phosphate (DAP) during the fall season, in addition to 70 lbs of N ac^{-1} in the form of UAN, administered at both the tillering and jointing stages. Therefore, the total N applied for treatments 2,3, 5, and 6 was 167 lbs N ac^{-1}.

Data Collection

Prior to crop termination, 7.25 ft^2 per plot were harvested with grass shears at 2 inches above the ground surface. Plant heights (from the ground to the top of the canopy) were measured with a yardstick. At each site, a GreenSeeker Handheld Crop Sensor HCS 100 (Trimble Ltd., Sunnyvale, CA) was used to measure the canopy reflectance and NDVI for each crop by passing it over the two center rows for the full length of each plot. An AccuPAR (LP–80; METER Group, Pullman, USA) ceptometer was used to calculate the LAI from above and below canopy photosynthetically active radiation (PAR) measurements.

Nitrate-N and Phosphorous Leaching Measurement
Resin lysimeters were meticulously positioned within each experimental plot to facilitate the direct measurement of nitrogen (N) fluxes. These lysimeters consisted of a combination of cation and anion exchange resins interposed between Nitex R nylon cloth and sand layers, all enclosed within polyvinyl chloride tubes measuring 6 centimeters in diameter. The deployment of these lysimeters spanned the entire duration of the cash crop growing seasons and continued through the subsequent cover crop growth, thus enabling the comprehensive year-round monitoring of N losses. Each individual lysimeter was carefully situated at a depth of 20 inches within the respective plot, ensuring that it maintained undisturbed contact with the soil profile. Following the harvest of the cash crops, each resin lysimeter was collected for subsequent analysis of nitrate-N and phosphorous concentrations.

RESULTS

The wheat biomass and grain yield did not exhibit significant differences across the various treatments at both research sites (Figure 1). Similarly, the measurements of nitrate-N and phosphorous leaching in each treatment plot were comparable to those in the no-cover crop plot, with no significant differences noted (Figure 2).

The soybean grain yield from the double crop treatment significantly differed from that of the no-cover crop treatment, with the latter yielding higher results compared to both the double crop and winter rye treatments. However, there was no significant disparity in grain yield between the no-cover crop and winter rye treatments (Figure 3).

Significant distinctions emerged in the nitrate-N leaching when comparing the double crop with the single-season approach. Nitrate-N leaching levels were lower in the double crop treatment compared to the no-cover crop and winter rye treatments. However, there were no significant differences in phosphorous leaching measurements. The yield-scaled leaching potential exhibited a similar trend to nitrate-N leaching (depicted in Figure 3).

The cumulative nitrate-N and phosphorous leaching in both wheat and soybean crops did not reveal significant differences when subjected to a one-way analysis of variance (ANOVA). Nonetheless, contrast analysis indicated that the medium and high input treatments, as well as winter rye, exhibited similarity in leaching patterns, which were lower than those in the low input treatment and no-cover crop (Figure 4).

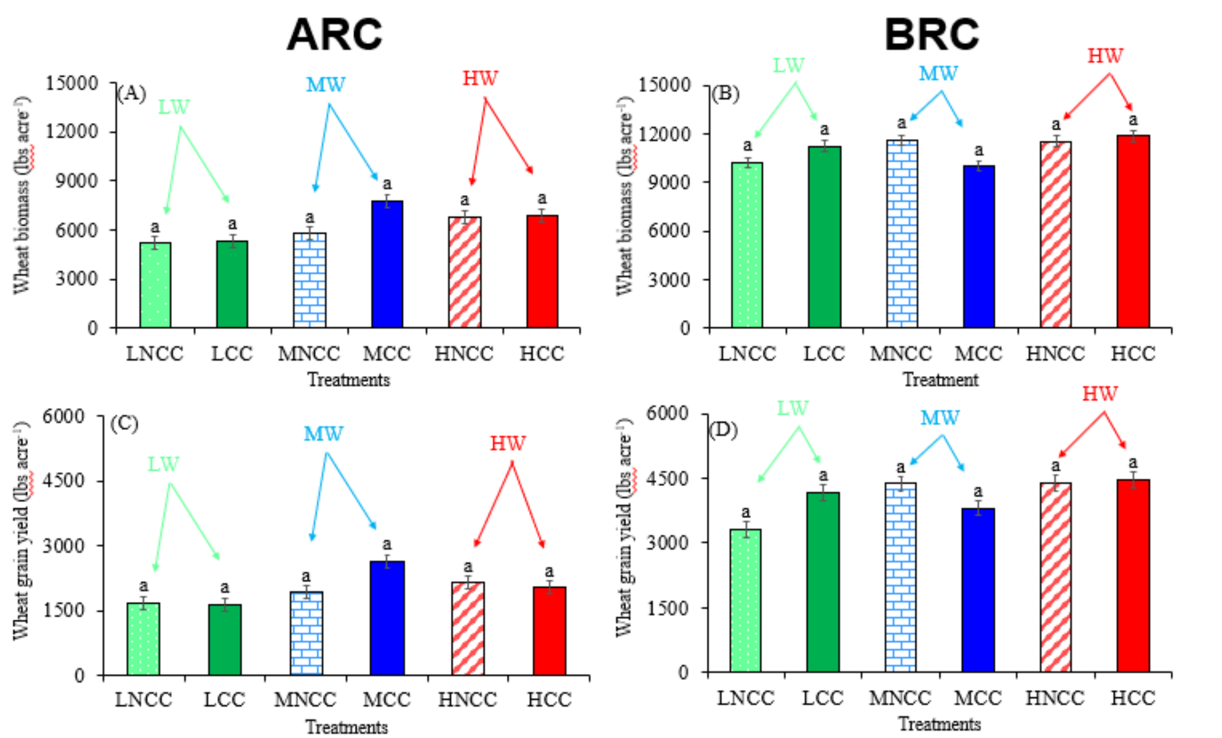

Fig. 1. Response of winter wheat biomass (A-B) and grain yield (C-D) to different N fertility management intensities and crop rotation. Error bars are standard errors. LNCC = low N rate with no cover crop; LCC = low N rate with CC; MNCC = medium N management with no cover crop; MCC = medium N management with CC = HNCC: high N management with no cover crop; HCC = High N management with CC.

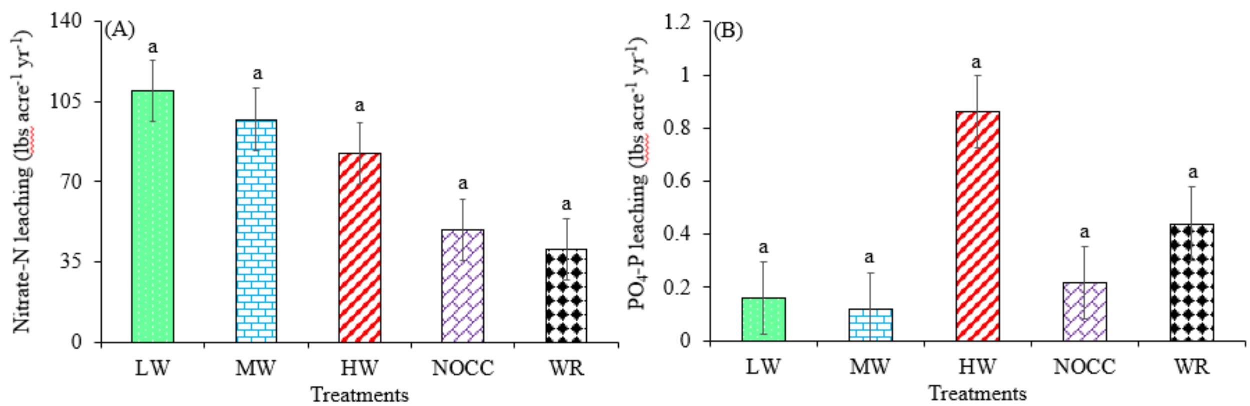

Fig. 2. Effect of treatments on nitrate-N leaching potential (A), and P-leaching potential (B) in wheat growing season at the BRC site.

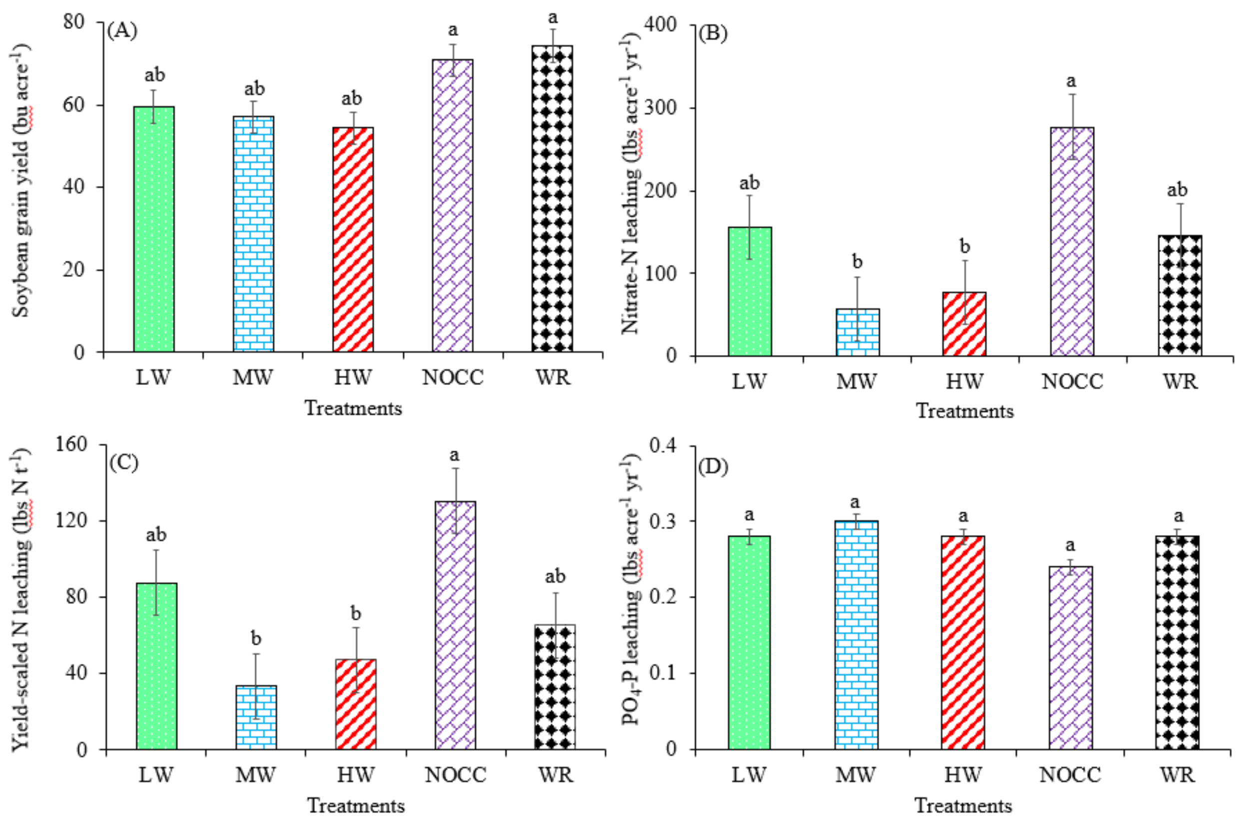

Fig. 3. Effect of treatments on yield (A), nitrate-N leaching potential (B), yield-scaled N leaching potential (C), and P-leaching potential (D) in soybean at the BRC site.

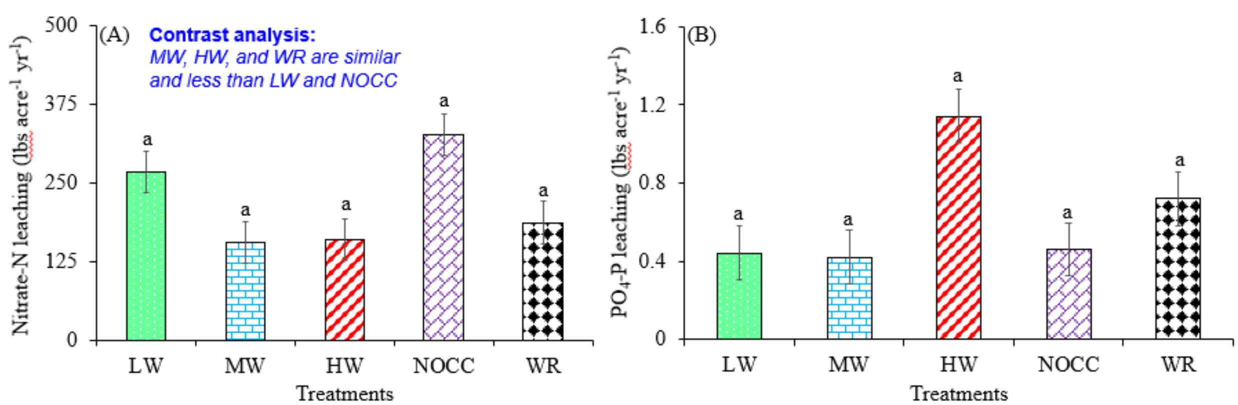

Fig. 4. Effect of treatments on cumulative nitrate-N (A) and PO_4-P (B) leaching potential in wheat and soybean at BRC site.

PRELIMINARY CONCLUSION

Low N intensity management during the wheat phase resulted in almost 30% less wheat biomass at ARC and BRC. Grain yield for wheat followed its biomass trend with medium and high intensity N management resulting in higher grain yields. Nitrate-N leaching during the soybean year was higher in the no-CC treatment indicating wheat or CR prior to soybean resulted in nitrate-N leaching reduction. Cumulative nitrate-N leaching indicated nitrate-N loss was decreased by double cropping compared to a no-cover crop control.

REFERENCES

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Tsiboe, F., Popp, J. S., and Brye, K. R., 2017. Profitability of alternative management practices in a wheat–soybean, double-crop production system in Arkansas. Agron. J. 109(5), 2149-2162.