Nitrogen Management Effects on Soil Water Dynamics and Wheat Evapotranspiration

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Introduction

- Understanding the interaction between crop evapotranspiration and applied nitrogen is essential for crop-water management.
- It remains challenging to quantify the effect of nitrogen on the behavior of crop transpiration and soil evaporation as well as soil water dynamics.
- The influential amount of rainfall has not been clearly determined in which range it affects the interaction between evapotranspiration and applied nitrogen rate.
- Is RZWQM2 an appropriate tool for improving the scientific understanding of the interaction between nitrogen application rate and water dynamics in the field?

Objectives

- Quantifying the effect of N application rates on the soil water dynamics and evapotranspiration behavior.
- How would crop evapotranspiration respond to N rates under different climate conditions, represented here through increased and reduced amounts of rainfall during the growing season?

Materials and Methods

- Winter wheat was grown in no-till management with corn residue 2016-2017.
- Three N fertilizer rates (UAN) were applied with four replications at the UK Research Farm, Lexington, Kentucky.
- The climate is humid subtropical. The soil is a Maury silt loam, classified as a mixed, semiactive, mesic Typic Paleudalf.

❖Nitrogen rates

1. High-N (130 kg N ha^{-1})
2. Low-N (70 kg N ha^{-1})
3. Zero-N (0 kg N ha^{-1})

❖Measured soil properties/model inputs

- Soil texture, saturated and unsaturated hydraulic conductivity, soil water retention curve, bulk density, and chemical properties (table 1).

❖Observed data

1. Soil water content
2. Soil water flux
3. Evapotranspiration
4. Crop growth

- Measured soil hydraulic property inputs were manually and iteratively calibrated within one standard error of measured values (Table 1).
- RZWQM2 was calibrated for the wheat experiment using experimental data from the N rate of 130 kg N ha^{-1} under the observed rainfall scenario which is 100% rainfall.
- The model was used for simulating the effects of different nitrogen rates on soil water dynamics, crop evapotranspiration, and crop growth under different rainfall amounts.

❖Rainfall scenarios

- 100% rainfall ➔(Actual rainfall * 1.00)
- 125% rainfall ➔(Actual rainfall * 1.25)
- 75% rainfall ➔(Actual rainfall * 0.75)
- 50% rainfall ➔(Actual rainfall * 0.50)

❖ RZWQM2 performance statistics

- Normalized Root Mean Square Error (NRMSE).
- Root Mean Square Error (RMSE).
- Mean Bias Error (MBE).

Table 1. Field measurements and model inputs of soil properties.

From field measurements								
Soil horizon	Particle fraction (%)			Bulk density	Ksat	θ at 0.10 bar	θ at 0.33 bar	θ at 15 bar
(cm)	Sand	Silt	Clay	(g/cm³)	(cm/h)	(cm³/cm³)	(cm³/cm³)	(cm³/cm³)
0-10	0.07	0.70	0.23	1.46	0.44	0.37	0.33	0.19
20-30	0.06	0.64	0.30	1.39	0.95	0.35	0.33	0.23
40-50	0.06	0.55	0.39	1.48	0.13	0.39	0.37	0.27
60-70	0.08	0.43	0.49	1.40	0.30	0.42	0.39	0.30
80-90	0.09	0.35	0.56	1.37	1.20	0.43	0.40	0.33
After the calibration								
Soil horizon	Particle fraction (%)			Bulk density	Ksat	θ at 0.10 bar	θ at 0.33 bar	θ at 15 bar
(cm)	Sand	Silt	Clay	(g/cm³)	(cm/h)	(cm³/cm³)	(cm³/cm³)	(cm³/cm³)
0-10	0.07	0.70	0.23	1.45	0.50	0.35	0.28	0.14
10-20	0.08	0.70	0.22	1.45	0.65	0.37	0.30	0.15
20-30	0.06	0.64	0.30	1.40	0.60	0.41	0.34	0.19
30-40	0.06	0.61	0.33	1.43	0.50	0.39	0.34	0.23
40-50	0.06	0.55	0.39	1.45	0.40	0.39	0.35	0.24
50-60	0.07	0.49	0.44	1.43	0.40	0.40	0.36	0.26
60-70	0.08	0.43	0.49	1.40	0.45	0.42	0.38	0.27
70-80	0.09	0.38	0.53	1.37	0.50	0.41	0.38	0.29
80-90	0.09	0.35	0.56	1.37	0.80	0.42	0.39	0.30
90-150	0.09	0.30	0.61	1.36	0.70	0.42	0.39	0.30

Table 2. Default and calibrated crop parameters for wheat.

Wheat Cultivar	Parameters	Default	Calibrated
990003 WINTER-US	**P1V** Days at optimum vernlizing temperature required to complete vernalization	40	38
	P1D Percentage reduction in development when photoperiod is 10 hours less than the threshold (P1DT=20hours) relative to that at threshold	50	98
	P5 Grain filling (excluding lag) phase duration (degree C day)	400	500
	G1 Kernel number per unit canopy weight at anthesis (#/g)	25	26
	G2 Standard kernel size under optimum conditions (mg)	30	27
	G3 Standard,non-stressed dry weight (total,including grain) of a single tiller at maturity (g)	1.5	1.5
	PHINT Interval between successive leaf tip appearances (degree days)	80	100

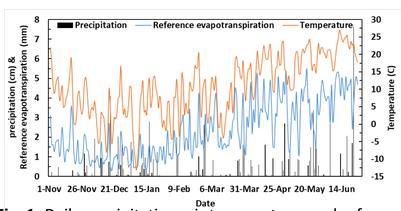

Fig. 1. Daily precipitation, air temperature, and reference evapotranspiration during wheat growing season.

Results

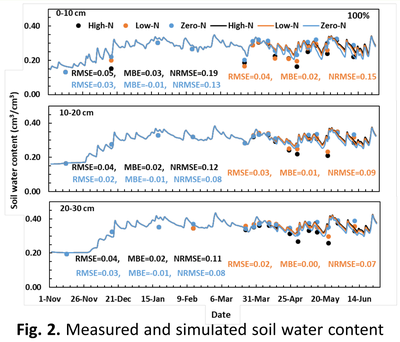

Fig. 2. Measured and simulated soil water content for different N rates under the 100% rainfall.

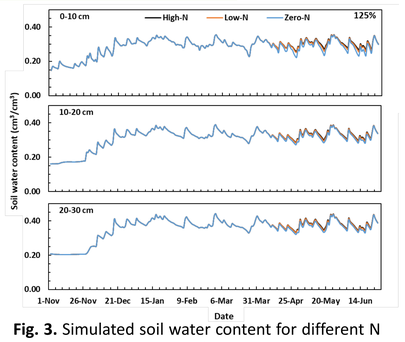

Fig. 3. Simulated soil water content for different N rates under the 125% rainfall.

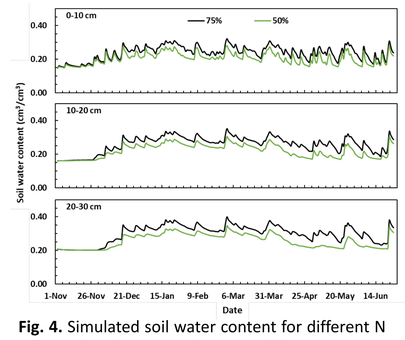

Fig. 4. Simulated soil water content for different N rates under the 75% and 50% rainfall.

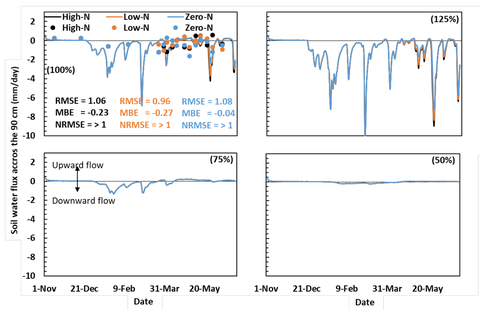

Fig. 5. Soil water flux across the 90-cm plane of the root zone for different N rates and rainfall amounts.

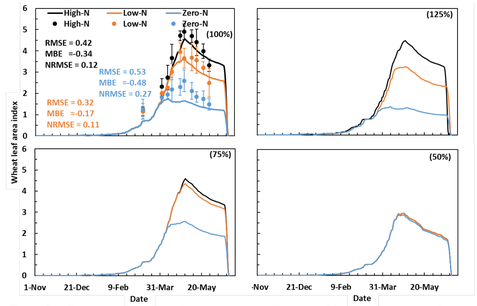

Fig. 6. Crop leaf area index for different N rates and rainfall amounts.

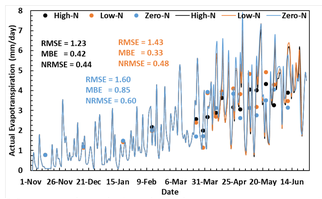

Fig. 7. Measured and simulated crop evapotranspiration for different N rates under the 100% rainfall.

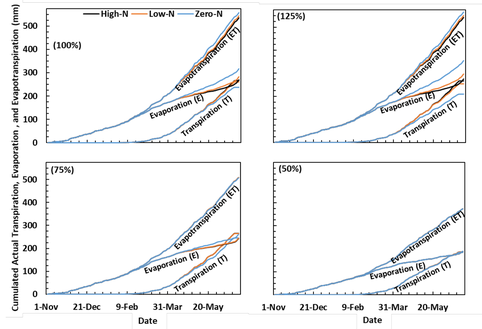

Fig. 8. Cumulated actual crop transpiration, soil evaporation, and evapotranspiration for different N rates and rainfall.

Table 3. Measured and simulated grain yield under measured rainfall (100%).

Nitrogen rate	Measured (kg/ha)	Simulated (kg/ha)
High-N	6430	6441
Low-N	5160	5433
Zero-N	3691	3650

- The model performed satisfactorily in simulating the impacts of nitrogen rate and rainfall on the daily wheat evapotranspiration, soil water dynamics, and crop growth.
- Under the effect of 100% and 125% rainfall scenarios, the High-N rate yielded higher soil water content and soil water flux than the other N rates, but its associated evapotranspiration was lower than for the other N rates; moreover, the Zero-N rate yielded the highest evapotranspiration.
- In the 75% and 50% rainfall scenarios, all N rates showed similar soil water content, soil water flux, and evapotranspiration.
- The impact of nitrogen application rates on the behavior of soil water dynamics and crop evapotranspiration components was differed depending on modeled extent of rainfall.

Conclusions

- Nitrogen application rates were appreciably manipulated the crop evapotranspiration and soil water dynamics under high rainfall amounts. However, under low rainfall amount, soil water dynamics and crop evapotranspiration were not affected by N application rate.
- The results of this study show the applicability of the RZWQM2 for improving the scientific understanding of the interaction between N rate and water dynamics in the field.

Acknowledgments

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