Toward Sustainable Nitrogen Management in Vegetable Production: Balancing Yield and Nitrogen Use Efficiency

Soudeh Farzadfar[1], Jamie M. Taylor[1], J. Diane Knight[2] and Kate A. Congreves[1,*]
[1]Department of Plant Sciences, [2]Department of Soil Science, University of Saskatchewan
[*]kate.congreves@usask.ca

INTRODUCTION

One of the most pressing challenges that vegetable growers are faced with is high input costs, namely fertilizers; this is because vegetable crops tend to have high nutrient demands translating into high fertilizer requirements[1]. Research is needed to help growers better manage fertilizer costs – and one way to do this is to better manage soil nutrient cycling.

Cover crops (CC) have the potential to immobilize nutrients, especially nitrogen (N), that would otherwise be lost during post- or pre-harvest periods, leading to improved N management[2,3]. Incorporating CCs in vegetable crop rotations may benefit subsequent crops yields and/or crop nutrient use efficiencies[1-5]. However, information on how CCs influence N management for vegetable production on the prairies is scarce. The Saskatchewan vegetable industry would benefit from research and development focused on better N management, and one potential strategy to improve N management could be cover cropping.

RESEARCH OBJECTIVES

1) What are the optimum ranges of N application rate for sweet corn, carrot and broccoli based on yield, N harvest indices (NHI), and N use efficiencies (NUE)?
2) How does rye cover cropping affect subsequent crop yield, NHI and NUE?
3) What are the relationships between NUE and N application rates in these vegetable crops?

EXPERIMENTAL DESCRIPTION AND METHODOLOGY

We established a field trial for sweet corn (*Zea mays* L. var. rugosa), carrot (*Daucus carota* subsp. sativus), and broccoli (*Brassica oleracea* var. italica) in 2017 and repeated in 2018 on a Sutherland clay soil (Dark Brown Chernozem) in Saskatoon for a fully phased broccoli-sweet corn-carrot sequence.

As the main effect, each crop type received five N fertilizer treatments (ranging from 0 to 300 kg N ha^{-1}) arranged in a split-block RCBD with three replicates. In 2018, beet (*Beta vulgaris* L.) was substituted for carrot due to germination issues. After harvest, sub-plots were established with vs without a shoulder-season rye CC, and the effect followed into the subsequent growing season.

Table 1. Soil physical and chemical properties at depth of 0–15 cm prior to planting.

Sand	Silt	Clay	pH	Organic matter	CEC	NO_3–N
17.8%	41.1%	41.1%	7.6	5.3 %	29.2 meq 100 g^{-1}	89 kg ha^{-1}

Plant samples were collected at harvest for nutrient analyses. Tissues were oven dried and ground (2 mm). Total N content determined by dry combustion method using a LECO CN elemental analyzer.

ANOVA and LSD mean comparisons were performed using SAS. First, we studied the effect of N fertilizer rates on crop yield, NHI and NUE indices for the initial years of 2017 and 2018. Then, in 2018, the influence of N rate x cover crop on subsequent crop yields and NHI and NUE indices were investigated. Using PROC REG in SAS, the relationship between NUE and N application rates.

RESULTS AND DISCUSSION

Photo 1. Established fall rye cover crop where the broccoli crop was previously grown (left) and fall rye cover crop beginning to germinate where the carrot crop was previously grown (right) in 2017.

Photo 2. Sweet corn, carrot and broccoli plots at harvest (from left to right) in 2018.

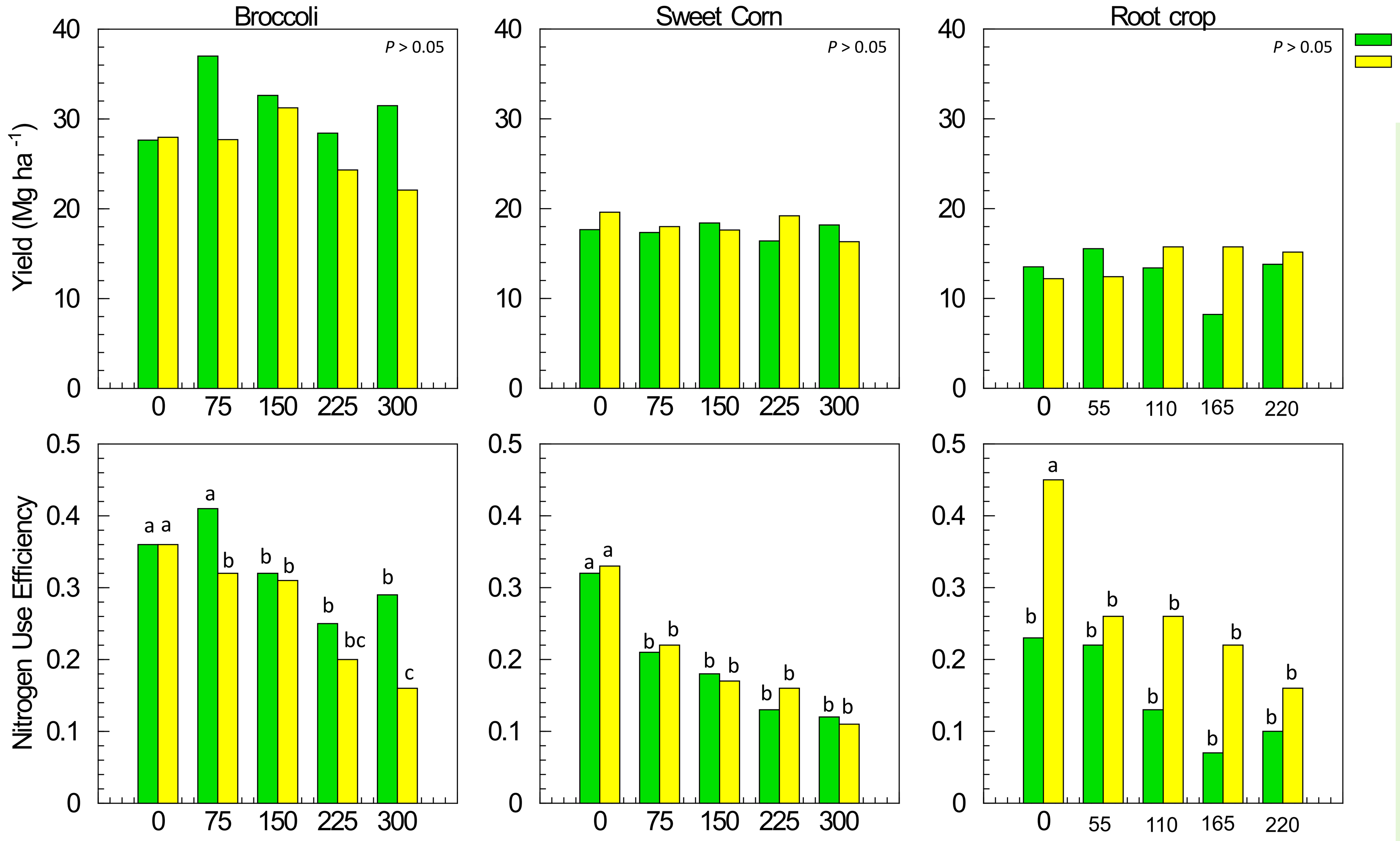

***Figure 1.** Mean yields and NUE for field-grown irrigated sweet corn, broccoli and root crop under various N rates (kg N ha^{-1}) in 2017 and 2018. The NUE index was calculated as follows: NUE = Y_n (trt)/ (P_n (ctl) + N fertilizer) x 100. Formula symbols: plant (P), yield (Y), TRT (treatment), CTL (control), nitrogen content (n) in kg N ha^{-1}.*

Compared with zero N control, N fertilizer rate did not affect vegetable crop yields in either year, demonstrating the N-rich nature of the soil at this site.

Depending on the crop, moderate to high application rates of N significantly reduced crop NUE; N rates above zero N control reduced NUE for sweet corn, rates above 75 kg N ha^{-1} reduced NUE for broccoli, all rates above 55 kg N ha^{-1} reduced NUE for the root crop in 2018.

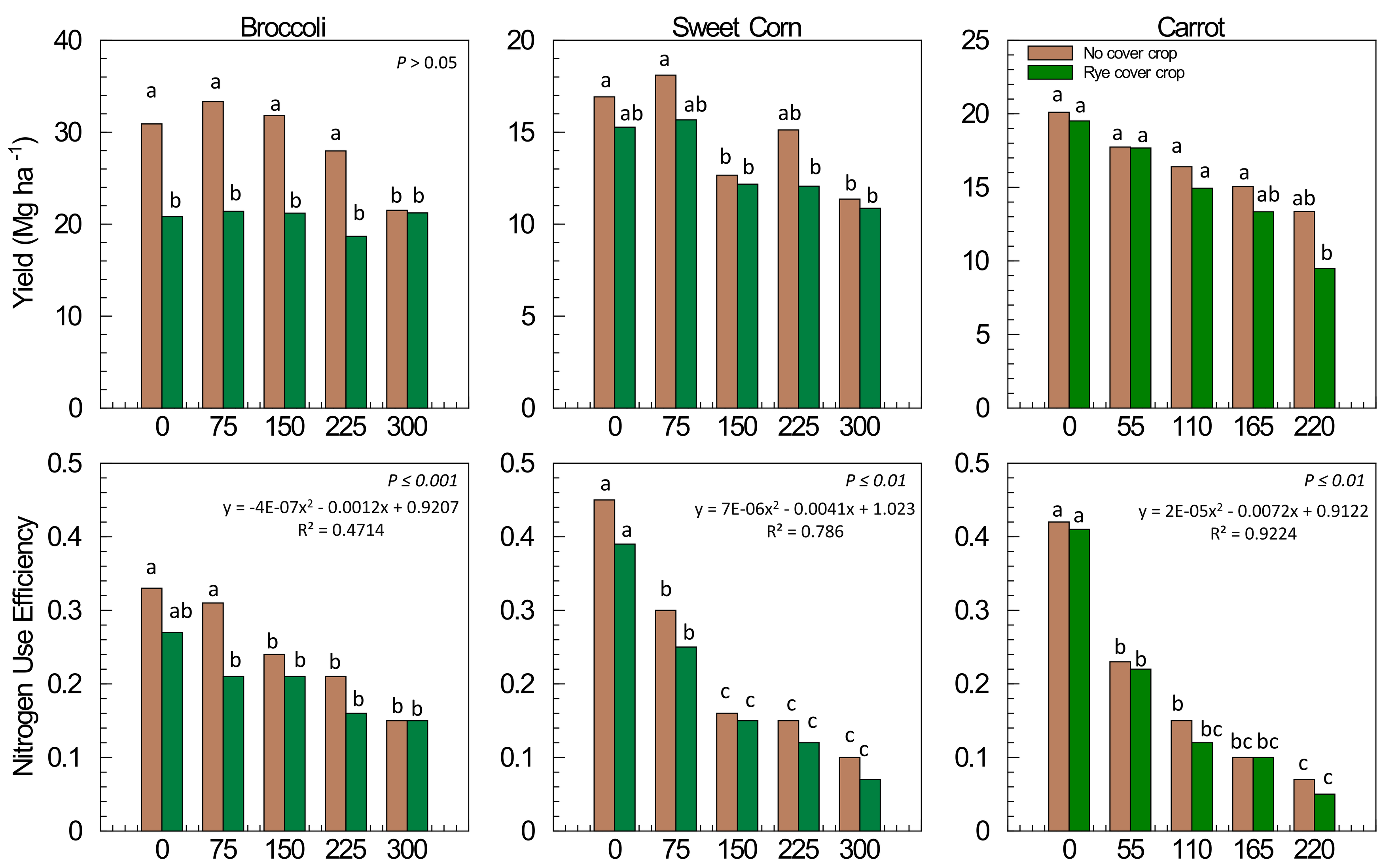

***Figure 2.** Mean yields and NUE for field-grown irrigated sweet corn, broccoli and root crop with and without rye cover crop. The NUE index was calculated as follows: NUE = Y_n (trt)/ (P_n (ctl) + N fertilizer) x 100. Formula symbols: plant (P), yield (Y), TRT (treatment), CTL (control), nitrogen content (n) in kg N ha^{-1}. Regression equations shows the relationship between the NUE and various N rates.*

Subsequent to the CC in 2018, we found no N fertilizer by CC interaction for crop yields or NUE. The rye CC had no effect on crop yield or NUE for sweet corn or carrot, but significantly reduced broccoli yield and NUE.

Regression analysis also showed a decreasing trend in NUE with increasing N rates for all three vegetables, regardless of the CC.

Table 2. Mean N Harvest Index (NHI) as influenced by N fertilizer application for field-grown irrigated vegetable crops in 2017 and 2018.

Broccoli			Sweet Corn			Root Crop		
NRs	2017	2018	NRs	2017	2018	NRs	2017 (Carrot)	2018 (Beet)
0	0.36 ± 0.03	0.31 ± 0.02	0	0.32 ± 0.06	0.42 ± 0.02	0	0.24 ± 0.08	0.42 ± 0.01 b
75	0.33 ± 0.05	0.38 ± 0.08	75	0.32 ± 0.03	0.39 ± 0.03	55	0.26 ± 0.02	0.46 ± 0.02 a
150	0.35 ± 0.01	0.27 ± 0.03	150	0.29 ± 0.03	0.33 ± 0.03	110	0.20 ± 0.03	0.41 ± 0.01 b
225	0.34 ± 0.03	0.32 ± 0.02	225	0.33 ± 0.02	0.30 ± 0.04	165	0.20 ± 0.05	0.40 ± 0.01 b
300	0.36 ± 0.01	0.29 ± 0.03	300	0.31 ± 0.02	0.32 ± 0.04	220	0.26 ± 0.10	0.40 ± 0.01 b
	p=0.32			*p=0.26*			*p<0.05*	

Means followed by different letters indicate significant differences at P<0.05. N Harvest Index (NHI) calculated and explained as follows: NHI = Yn/Pn x 100. Partitioning of plant N between harvested organ and vegetative shoots. NRs, nitrogen rates. Formula symbols: plant (P), yield (Y), nitrogen content (n).

Table 3. Mean N Harvest Index (NHI) as influenced by over cropping for field-grown irrigated vegetable crops in 2018.

Broccoli		Sweet Corn		Root Crop (Carrot)	
No-CC	CC	No-CC	CC	No-CC	CC
0.32 ± 0.04	0.31 ± 0.03	0.38 ± 0.05	0.33 ± 0.04	0.42 ± 0.06a	0.41 ± 0.02 b
p=0.28		*p=0.16*		*p<0.05*	

Means followed by different letters indicate significant differences at P<0.05. NHI calculated and explained as follows: NHI = Yn/Pn x 100. Partitioning of plant N between harvested organ and vegetative shoots. Formula symbols: plant (P), yield (Y), nitrogen content (n).

The NHI index showed that neither N fertilizer or CC influenced the partitioning of N between vegetative biomass and yield, except for carrot.

CONCLUSIONS

Ideally, the best N management practices result in high yield and quality vegetable production, but also minimize adverse impacts on soil health and ecosystem services. In this study, finding the balance may be challenging.

The site is so rich in soil N that cover cropping was not enough to improve crop NUE. Instead, fertilizer N management might be more important for improving crop NUE – the less N fertilizer applied, the better for improving crop NUE without negatively impacting yields. Repetition of this experiment is necessary to gain more robust insight into how the rye CC influences N cycling.

It is recommend that further research characterizes crop N status during rapid growth stages with diagnostic tools, test N efficient genotypes, and use crop models to assessment of different interactions between vegetable crop growth and the environment[6].

REFERENCES

[1] Congreves KA, Van Eerd L. L. 2015. Nitrogen cycling and management in intensive horticultural systems." Nutrient cycling in agroecosystems 102:299–318
[2] Van Eerd LL. 2018. Nitrogen dynamics and yields of fresh bean and sweet corn with different cover crops and planting dates. Nutrient Cycling in Agroecosystems 111:33–46
[3] Norris CE, Congreves KA. 2018. Alternative management practices improve soil health indices in intensive vegetable cropping systems: A review. Frontiers in Environmental Science 6, 50
[4] Burket JZ, Hemphill DD, Dick RP. 1997. Winter cover crops and nitrogen management in sweet corn and broccoli rotations. HortScience 32:664–668
[5] Cober JR, Macrae ML, Van Eerd LL. 2018. Nutrient release from living and terminated cover crops under variable freeze–thaw cycles. Agronomy Journal. 110:1036–1045
[6] Nkoa R, Desjardins Y, Tremblay N, Querrec L, Baana M, Nkoa B. 2003. A mathematical model for nitrogen demand quantification and a link to broccoli (*Brassica oleracea* var. italica) glutamine synthetase activity. Plant Science 165:483–496

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