Residual fertilizer and cropping sequence affects rotational nitrogen use

Tai McClellan Maaz and William L Pan
Crop and Soil Sciences, Washington State University, Pullman, WA

Problem statement

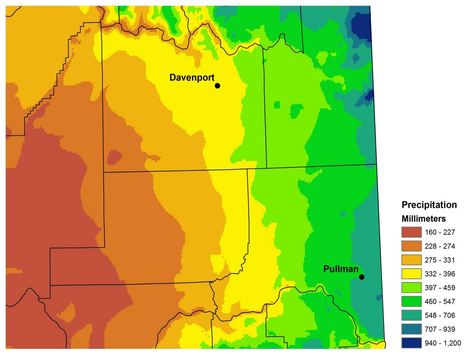
- Most research is focused on single season nitrogen (N) use, and soil N supply is often not factored into nitrogen use efficiency calculations.
- However, N cycling from one season to the next can improve the recovery of fertilizers[1].

Objective

- To develop a method for rotational N use efficiency assessments in Eastern WA
  - Must account for multiple sources of N, including inter-seasonal changes in soil N
  - Must characterize the integrated N response of sequential crops across a precipitation gradient

Materials and methods

➢ Three year cropping sequence study conducted at two site locations along a gradient of available water: Davenport and Pullman, WA



➢ No-till experiment, replicated by years
➢ Cropping sequences:
-spring canola-spring pea-winter wheat
-spring canola-spring wheat-winter wheat
➢ Fertilization:
-spring canola: 0, 89, 179 kg N ha^{-1}
-spring pea and wheat: 0 kg N ha^{-1}
-winter wheat: 0, 130 (Pullman), 84 (Davenport) kg N ha^{-1}
➢ Calculations:
-Harmsen-Mitscherlich equation to characterize N response of winter wheat following pea or spring wheat[2]
-Nitrogen use efficiency (NUE) component analysis to attribute winter wheat yield differences following pea or wheat to soil and plant processes[2]
-Adaptation of single season Harmsen-Mitscherlich equation to characterize multi-year N use:

$$Y = A * (1 - 10^{-C(X)A^{(n-1)}})$$

Where: Y – rotational sums of yield, grain C, or grain N
X – rotational N supply [sum of applied fertilizer (Nf) + initial root zone N (120 cm) + sums of apparent N mineralization] or rotational sums of plant N
A – theoretical rotational yield, grain C, or grain N maxima
C – efficiency factor (initial slope)
n – moisture dependent constant

-Assessments: (1) rotational N use efficiency (normalized on carbon basis) = grain C/N supply, (2) rotational N uptake efficiency = plant N/N supply, and (3) unaccounted for N = N supply – [plant N + final root zone N]

[1]Sebilo, M., B. Mayer, B. Nicolardot, G. Pinay, and A. Mariotti. 2013. term fate of nitrate fertilizer in agricultural soils. Proc. Natl. Acad. Sci. 110: 18185–18189.
[2]Maaz, T., W. Pan, and W. Hammac. 2016. Influence of Soil Nitrogen and Water Supply on Canola Nitrogen Use Efficiency. Agron. J. 108(5): 2099

Single season vs multi-year N response

Water availability determines spring canola N response[2]

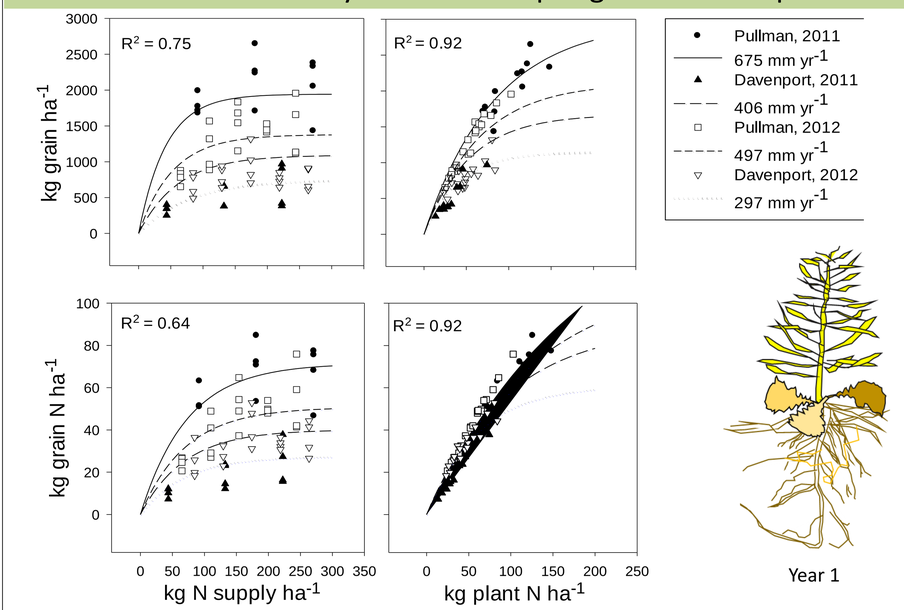


Figure 1. Spring canola yield/grain N response to increasing N supply or plant N at varying levels of available water. Soil and plant processes affecting N responses are discussed in Maaz et al., 2016.

Previous crop affects winter wheat N response

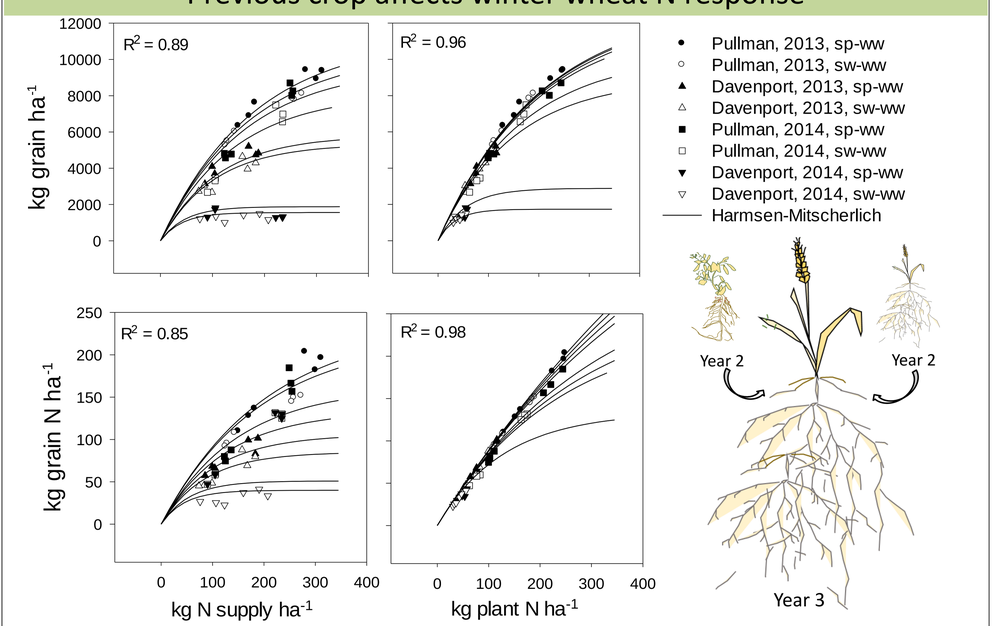


Figure 2. Winter wheat yield/grain N response to increasing N supply or plant N following spring wheat or unfertilized pea.

Residual fertilizer and cropping sequence impacts rotational N response

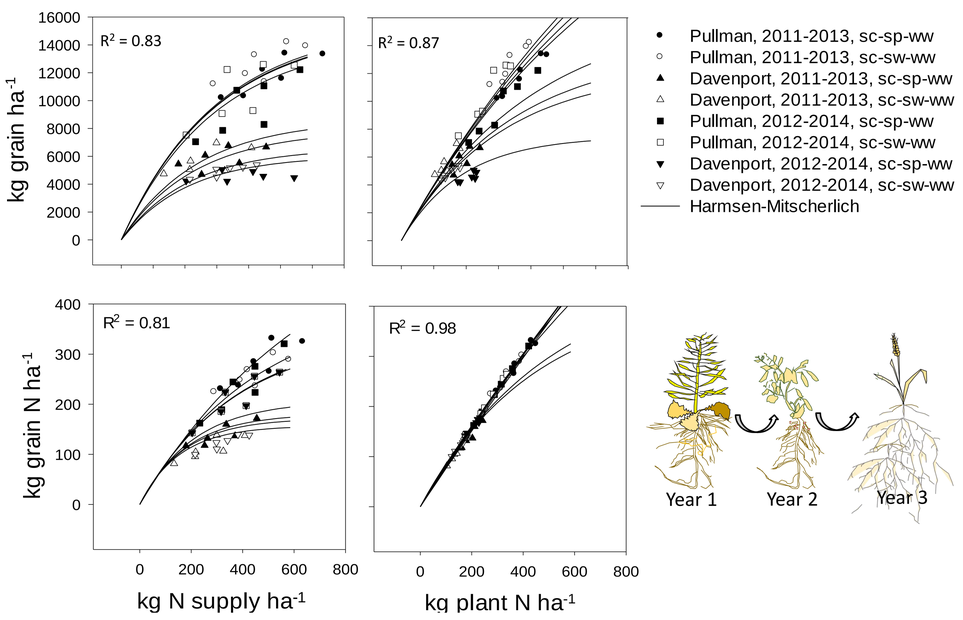


Figure 3. Cropping sequences response to rotational N supply or plant N following variable canola fertilization (year 1), spring wheat or unfertilized pea (year 2), and winter wheat (year 3).

Rotational N use efficiency assessments

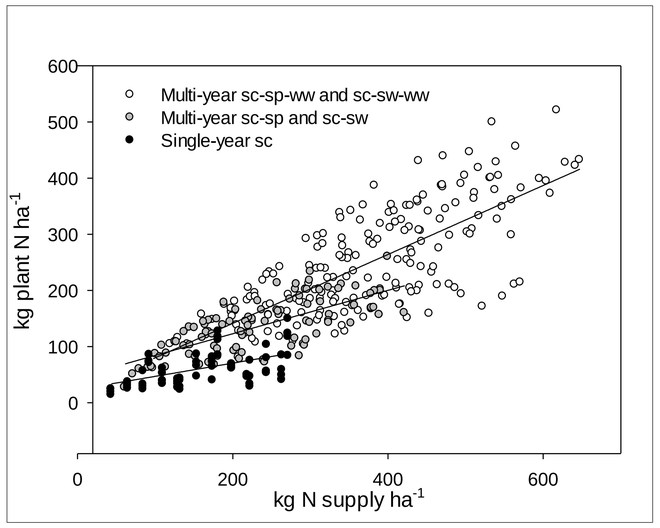


Figure 4. Cropping sequences were more efficient at taking up N for a given N supply than a single year of spring canola (sc). This provides the rationale for multi-year N use efficiency assessment. Spring pea or wheat followed spring canola (sc-sp or sc-sw) in the two year sequence. Winter wheat (ww) followed sc-sp or sc-sw in the three year sequence.

Table 1. Differences in winter wheat yields (ΔGw) following spring pea vs spring wheat (sc-sp-ww minus sc-sw-ww) were attributed to soil and plant processes, including elevated N supply (Ns) and the NUE (Gw/Ns) components of N uptake efficiency (Nt/Ns) and N utilization efficiency (Gw/Nt).

		Winter wheat grain differences (sc-sp-ww minus sc-sw-ww)				
	kg Nf ha^{-1}	ΔGw	ΔGw_{Ns}	$\Delta Gw_{Gw/Ns}$	$\Delta Gw_{Nt/Ns}$	$\Delta Gw_{Gw/Nt}$
Pullman, 2013	0	1417	853	564	522	41
	130	1329	371	959	906	53
Pullman, 2014	0	1378	692	686	599	87
	130	1562	230	1331	1101	230
Davenport, 2013	0	388	237	151	314	-163
	84	380	105	275	558	-283
Davenport, 2014	0	340	69	271	-144	415
	84	319	9	310	-95	405

- **With no added fertilizer (Nf), winter wheat yields were greater following spring pea due to a higher N supply at winter wheat planting (red circle).**
- **With fertilization, winter wheat yields were greater following spring pea due to a higher N uptake efficiency (blue box).**
- **The benefit of spring pea increased with water availability.**

Table 2. Rotational NUE (yields normalized on a carbon-basis), rotational N uptake efficiency, and unaccounted for N improved during the three-years following spring canola fertilized with 0, 89, or 179 kg N ha^{-1}.

	Rotational NUE (C basis)			Rotational N uptake efficiency			Unaccounted for N		
	kg grain C (kg N supply)$^{-1}$			kg plant N (kg N supply)$^{-1}$			kg N supply - kg available N		
	sc	sc-sp-ww	sc-sw-ww	sc	sc-sp-ww	sc-sw-ww	sc	sc-sp-ww	sc-sw-ww
Pullman 2011-2013 (1663 mm total available water)									
rNf									
0	11.5	15.1	15.5	0.78	0.91	0.94	7	4	-1
89	6.5	13.8	13.5	0.48	0.85	0.85	78	24	22
179	4.4	11.8	12.5	0.32	0.75	0.81	166	71	42
Pullman 2012-2014 (1220 mm total available water)									
rNf									
0	9.3	16.8	16.9	0.61	0.95	0.93	13	3	9
89	5.3	14.8	14.3	0.40	0.87	0.81	71	28	51
179	3.5	12.5	12.5	0.27	0.75	0.73	154	88	102
Davenport 2011-2013 (939 mm total available water)									
rNf									
0	7.9	11.9	12.1	0.49	0.72	0.74	13	56	44
89	4.5	10.5	10.4	0.35	0.66	0.69	66	88	78
179	3.0	8.6	8.6	0.24	0.57	0.61	143	152	133
Davenport 2012-2014 (759 mm total available water)									
rNf									
0	3.6	8.8	8.5	0.26	0.55	0.63	48	89	91
89	2.4	6.7	7.2	0.20	0.44	0.59	116	150	126
179	1.7	5.9	6.7	0.15	0.40	0.57	197	178	144

- **Residual canola fertilizer increased subsequent crop yields and N recycling.**
- **Less unaccounted for N was calculated after three years than in the first year.**
- **Rotational N use efficiency increased with water availability.**

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