Long-term Crop Rotation Studies Remain an Invaluable Teaching Tool

By Dick Puurveen

The photograph on the following page provides a classic example of crop response to nutrient application. Crop growth improves and deficiency symptoms lessen as nutrients become less of a limitation. In this case, the image shows spring wheat plant samples taken from the long-term Breton Plots in Central Alberta, Canada. Samples were taken on June 24, 45 days after seeding (May 10). Plants are generally at the six-leaf stage, some plants are tillering depending on the nutrient input.

The classical crop rotation of the Breton Plots was initiated in 1929 on Orthic Gray Luvisol (typic cryoboralf) soil near Breton, Alberta, Canada. Two cropping systems have been studied since its initiation: 1) a two-year wheat–fallow rotation; and 2) a five-year rotation of wheat–oats–barley (underseeded with alfalfa/brome)–hay–hay. The study has fertility treatments superimposed over each crop phase of the rotation. These treatments have varied over the entire length of the study but have remained constant since 1980. Corresponding to the image (left to right) these treatments include: 1) No fertilizer (check); 2) NKS (-P); 3) NPKS (all nutrients); 4) NPS (-K); 5) NPK (-S); 6) PKS (-N) (**Table 1**).

Table 1. Fertilizer inputs (kg/ha) at time of seeding for selected treatments at the Breton Plots.

	N	P	K	S
Check	0	0	0	0
NKS (-P)	50	0	46	20
NPKS	50	22	46	20
NPS (-K)	50	22	0	20
NPK (-S)	50	22	46	0
PKS (-N)	0	22	46	20

Wheat–fallow rotation received 90 kg N/ha and the same P, K, and S rates listed.

The picture also compares representative plants from the same fertility treatment applied to each rotation. The first wheat plant (1) is from the wheat–fallow rotation; therefore, the crop is grown after a year of fallow. The second wheat plant (2) is from the 5-year rotation; therefore, grown after the year 5 forage plowdown. Although N fertilizer is not applied during either forage phase of the rotation (PKS is applied annually to all phases), the 5-year rotation benefit from N-fixing legumes during the forage phases.

Table 2. Soil nutrient analysis (ppm) from 0 to 15 cm depth prior to 5-year rotation wheat establishment on selected treatments at the Breton Plots, 2016.

	N	P	K	S	OM, %
Check	2	7	182	3	3.1
NKS (-P)	4	6	423	15	3.8
NPKS	10	>60	490	36	4.5
NPS (-K)	7	>60	128	12	4.0
NPK (-S)	<2	>60	863	8	3.7
PKS (-N)	5	>60	364	24	3.9

N as nitrate-N (modified Kelowna extraction); S as sulfate-S (0.01M $CaCl_2$ extraction).

For the 5-year rotation, soil is sampled annually in late summer only after the year 5 forage plowdown. **Table 2** shows the soil test results of the five-year rotation prior to wheat establishment. Since the wheat–fallow rotation is sampled every fifth year, corresponding samples were not collected in 2016.

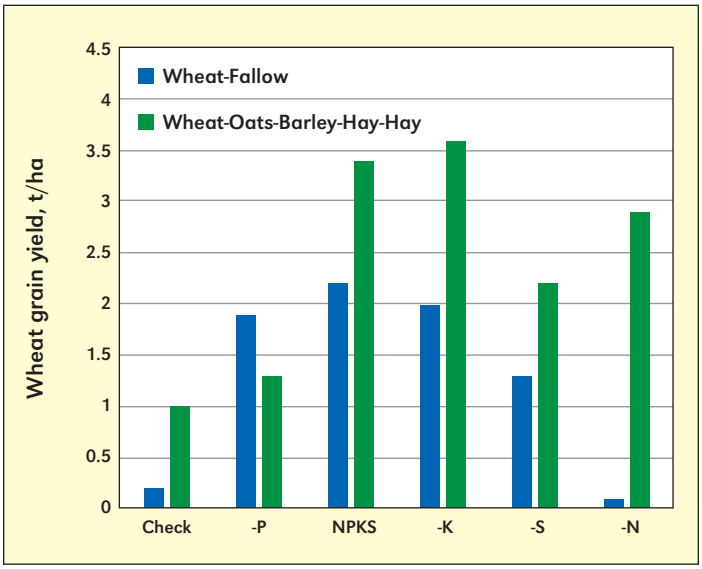

Figure 1. Wheat grain yield from selected fertilizer treatments at the Breton Plots, 2016.

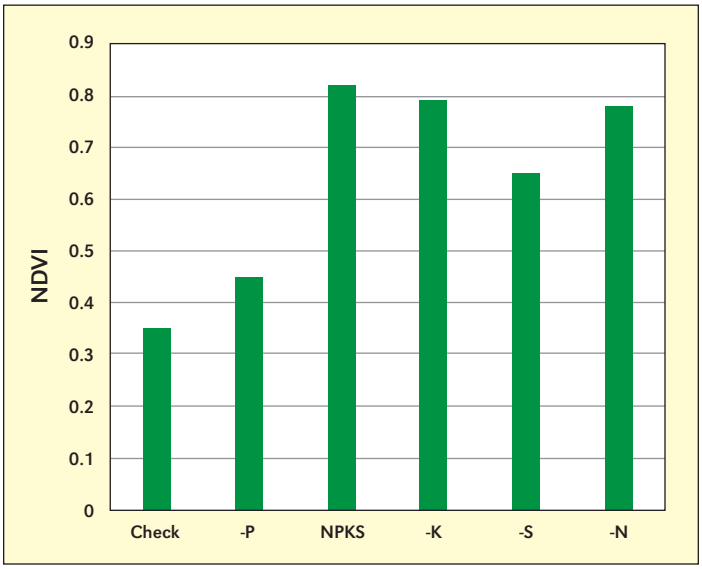

Figure 2. Average NDVI measured by Greenseeker® on the 5-year rotation wheat on July 5, 2016 (12 days after photograph was taken).

Grain yield (**Figure 1**) followed similar trends as NDVI (**Figure 2**). The benefits of legumes in rotation on yield are most notable in the -N treatment, but the -P comparison demonstrates the increased use of P with alfalfa. The NPKS treatment is generally equivalent to the -K treatment because

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; S = sulfur; NDVI = normalized difference vegetation index.

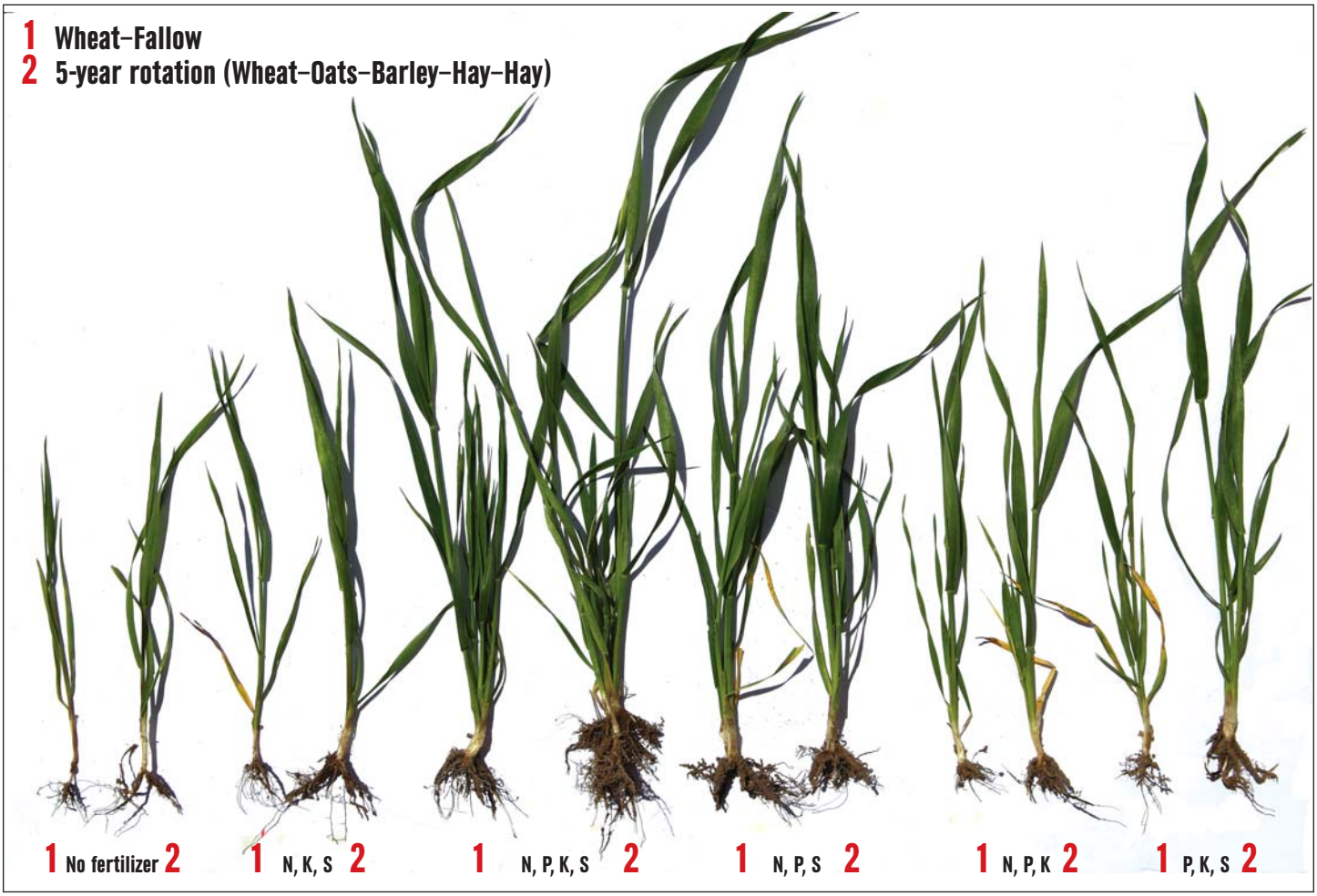

Photo by Dick Puurveen, Department of Renewable Resources, University of Alberta.

Table of notes and observations from wheat plants sampled from the Breton long-term study.

No fertilizer (Check)	Plants shows poor root development. Plants are severely stunted and spindly. No tillers. Plants are yellow throughout, with no visible necrosis. Wheat grown in rotation with legumes is less stunted.
NKS (-P)	Plants have better root development than check, especially in 5-year rotation with legumes, yet plants are still stunted. No tillers. Wheat grown in rotation with legumes has better root and shoot development. Purpling not evident. NDVI data shows -P plants to be generally equal to values for -N plants under the wheat–fallow rotation; however, for the 5-year rotation that includes legumes the NDVI values for -P plants are much lower than -N plants (**Figure 1**).
NPKS (Complete)	Best root development, particularly in the 5-year rotation. Plants have several tillers, tallest height, and dark green color.
NPS (-K)	Plants are second tallest, but still have excellent root development. Tiller development is good, but less extensive than the with all nutrients. Signs of necrosis on oldest leaves for plants taken from the wheat–fallow rotation.
NPK (-S)	Plants have poor root development compared to the complete, but better than check. Plants have no tillers. The plant from the 5-year rotation has better root and shoot development; however, it is also showing a higher degree of necrosis on the oldest leaves.
PKS (-N)	These plants show the largest contrast between the two rotations. Although both rotations do not receive any fertilizer N, a significant benefit from the inclusion of legumes is obvious for the 5-year rotation. The plowdown of forage residue, and subsequent nutrient mineralization, provides some N, and as N is mobile in the plant, this plant shows a general yellowing throughout, but little necrosis. In contrast, the wheat–fallow rotation shows classic symptoms of N deficiency, with overall yellowing and necrosis in the lower leaves.

of K-rich soil minerals, but declining K concentrations (**Table 2**) with high yields suggest that the tipping point is near. Further yield reductions occur without S, followed by P, to "bankruptcy" yield with no fertilizer. The Long-term Breton Plots continue to teach the importance of nutrient management and crop rotation. BC

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For more details on this long-term study see the article by Dyck et al., (2016) titled *Testing the Benefits of Balanced Nutrient Use and Crop Diversification on Soil Productivity and Health*, in Better Crops 100 (4):7-9.