Title: Revising the crop nutrient uptake and removal guidelines for Western Canada (ADF 20190185)
Reporting Period: December 11, 2020 to December 15, 2021
Report Date: February 15, 2022

Principal Investigators:

Fran Walley
University of Saskatchewan
Department of Soil Science
51 Campus Drive
Saskatoon, SK S7N 5A8
Ph. 306-966-6854
Email: fran.walley@usask.ca

Richard E. Farrell(co-PI)
University of Saskatchewan
Department of Soil Science
51 Campus Drive
Saskatoon, SK S7N 5A8
Ph. 306-966-2772
Email: r.farrell@usask.ca

Collaborators:

John Heard
Manitoba Agriculture
Food and Rural Initiatives
Box 1149, #65-3rd Ave. NE, Carmen
Manitoba, R0G 0J0
Ph. 204-745-8093
Email: john.heard@gov.mb.ca

Lyle Cowell, M. AAgric, PAg, CCA
NutrienAgSolutions
Manager, Agronomy Solutions, Northeast Saskatchewan
Box 1238, Tisdale, SK, S0E 1T0
Ph: 306-873-7105
Email: Lyle.Cowell@Nutrien.com

All results in this summary are PRELIMINARY and are from a single year of data collection. Importantly, we do not know how much year-to-year variation to expect, and thus none of the observations to date should be used for changing fertilizer recommendations or management plans. Until we have a second year of data collection, the existing nutrient uptake and removal guidelines remain unchanged, and provide the best information that we have to offer at this time.

Summary: The objective of this research is to develop new estimates for crop nutrient uptake and removal, based on grain and biomass samples collected from commercial fields and from existing literature. Through the collaborative efforts of NutrienAgSolutions field agronomists and Manitoba Agriculture, over one thousand grain samples were collected from across the three prairie provinces during the 2020 harvest, and analysed for macronutrient (N, P, K, S) and micronutrient (Cu, B, Zn) uptake. Results from the 2020 growing season suggest that although a limited number of existing nutrient uptake guideline estimates of nutrient removal (e.g., CFI Nutrient Uptake and Removal Guidelines for Western Canada, 2001) are aligned with removal assessed in 2020 (particularly for N), for the most part existing removal guidelines either over- or underestimate macro nutrient removal. Importantly, the existing ranges for nutrient removal do not capture the full extent of the observed variability in nutrient uptake and removal. Existing nutrient removal guidelines do not include micronutrient estimates, and thus data from 2020 represents a source of new information. Due to the extreme drought experienced in 2021 across the prairies, we limited our sample collection to approximately 20% of what we had originally planned; we will be completing all sample collection in the upcoming growing season. Importantly, in 2022 we also will be collecting biomass samples from commercial fields to determine total nutrient uptake and

we need cooperators interested in participating. Simply providing a legal location and permission for us to access your fields would be great; we'd also really appreciate help physically collecting the samples and sending them to us – it is entirely up to you as to how you might like to participate. For further information on the sampling requirements, scan the QR code at the end of this report OR contact fran.walley@usask.ca.

Introduction: Soil testing remains a valuable tool for determining the levels of available and, in some cases, potentially available nutrients in the soil; however, nutrient uptake and removal guidelines provide an additional layer of information regarding crop requirements. Knowledge of potential uptake and removal can be used to help balance the nutrients removed when the grain is harvested with nutrients replaced as fertilizer, helping to ensure consistently high yield goals and sustainable cropping systems. There is a growing interest in utilizing multiple sources of information beyond a soil test for developing nutrient management plans for subsequent crops. This interest is driven in part by the economic reality of soaring fertilizer costs, and the desire to closely match crop requirements with nutrient inputs, thereby reducing unnecessary fertilizer inputs without compromising yield goals. The desire to more closely match fertilizer inputs and crop yield goals goes hand-in-hand with environmental goals, reducing the likelihood of potential environmental losses. Indeed, nutrient uptake and removal guidelines are an integral part of 4R fertilizer management practices (i.e., right source, right rate, right time, and right place) which help farmers identify management practices that keep nutrients in the field for crop uptake, thereby aligning economic and environmental goals.

Although many on-line resources and published nutrient uptake and removal guidelines are available, these guidelines typically are not specific to western Canada. For example, IPNI Canada provides crop nutrient uptake estimates (http://www.ipni.net/article/IPNI-3296), last modified May 2014, and cautions that "*Reported nutrient uptake coefficients may vary regionally depending on growing conditions. Use locally available data whenever possible*." Importantly, the data used in their resources (including an i-OS app and web-based version) are not specific to Saskatchewan, or western Canada, with most data originating from other continents. Additionally, many of the available nutrient removal calculators are based either on the IPNI data, or on the early Western Canada Fertilizer Association guidelines, revised in 1992 (and presumably based on research conducted in the 80's), and again in 2001 by the Canadian Fertilizer Institute (CFI) (https://www.canolacouncil.org/download/2042/canola-watch/14659/20110309_fpj_aut11_beckie-et_-al_-2). The revisions at that time, however, retained the original data, reporting it as a 10% ± range for each nutrient and crop. Since then, many different nutrient uptake and removal apps have become available (e.g. NutrieneKonomics Nutrient Removal Calculator at https://nutrien-ekonomics.com/ROItools/calculators; Mosiac Crop Nutrition Nutrient Removal Calculator at https://www.cropnutrition.com/nutrient-management), with many reformatting portions of the original CFI or IPNI guidelines, but none have taken on a full revision and expansion of the original CFI nutrient uptake and removal guidelines.

Importantly, few of the existing guidelines, include micronutrient estimates for crops commonly grown in western Canada. Over the years, there have been a number of studies examining response of various crops to micronutrient application in western Canada, but a comprehensive survey of micronutrient uptake and removal by commercially grown crops currently is not available. Interest in understanding micronutrient uptake has been growing and questions regarding potential micronutrient depletion, particularly as crop yields climb (Statistics Canada 2019 https://www150.statcan.gc.ca/) with improved management, continuous cropping, and higher yielding crop varieties. It is our contention that the development of new crop varieties with enhanced yield potential and different genetics, and with the changes in farming practices, the nutrient uptake demands have changed over time, and a full revision is indeed required.

Our project aims to develop new nutrient uptake and removal guidelines for 14 annual crops based on both measured values from seed and straw samples collected across Western Canada and data in the published and grey (i.e., unpublished) literature. Additionally, the existing values for forage dry matter production (alfalfa, clover, forage grass, barley silage, corn silage) will be updated based on values published in the scientific and

grey literature. Values for root production and nutrient requirements will be estimated where data from existing literature is available. Building on the previous guidelines, the revised guidelines will include estimates for both macro (N, P_2O_5, K_2O, S) and micronutrients (Cu, Zn, B). Importantly, we are midway in our project, so there is only one year of data available to us. We know that nutrient uptake and removal can vary depending on environmental conditions, so any data collected to date is PRELIMINARY, and should not be used as a replacement for existing

Methodology – Grain samples for all 14 crops were obtained following the 2020 harvest from commercial fields. The samples were collected by NutrienAgSolutions agronomists across the three prairie provinces under the leadership of Lyle Cowell (Manager, Agronomy Solutions, Northeast Saskatchewan). Additionally, John Heard (Manitoba Agriculture) coordinated the collection of samples from across Manitoba. For each sample collected (grain and plant tissue), relevant data attributes were collected including crop, variety, legal location, year, yield, and fertilizer nutrient applied during the 2020 growing season. Fields that had received manure within the past three years were omitted.

The original goal was to collect 100 samples of each of the 14 crops, with the number of samples for each crop collected within each province adjusted to reflect relative acreage in each (based on total acreage estimates). We did not achieve our goal of 100 samples in 2020 for mustard and dry bean due to the limited acreage of these crops that season, whereas 165 canola samples were collected – again reflecting total acreage availability (Table 1). Grain samples were analysed for total nutrient uptake. Grain nutrient contents are based on grain weight adjusted to the recommended moisture content using the "straight" moisture percent (Canadian Grain Commission, August 2021).

In response to the severe drought in 2021, grain and plant tissue sample collection was reduced to 20% of what was initially planned, with the remaining 80% to be collected in 2022 (i.e., Year 2). Grain sample collection was again conducted by NutrienAgSolutions agronomists across the three prairie provinces with additional samples collected in Manitoba by John Heard (both seed and biomass samples). Additionally, plant tissue (i.e., biomass) samples were collected at Agri-Arm sites (Irrigation Crop Diversification Corporation (Outlook), Indian Head Agricultural Research Foundation (Indian Head), Southeast Research Farm (Redvers), Conservation Learning Centre(Prince Albert), and at University of Saskatchewan research plots (Saskatoon), and from a commercial farm at Central Butte. Plant tissue samples were dried, ground and are being analysed. Analyses and data processing are ongoing.

Table 1. Number of grain samples collected across the Prairies from the 2020 harvest.

Crop	Manitoba	Saskatchewan	Alberta	Total
Barley	5	45	51	101
Canola	37	87	41	165
Chickpea	0	85	15	100
Corn	94	0	6	100
Lentil	0	90	10	100
Oats	16	56	28	100
Soybean	90	9	0	99
Field pea	3	50	47	100
Flax	5	83	12	100
Mustard	10	20	10	40
Spring wheat	17	47	36	100
Durum wheat	0	98	2	100
Winter wheat	18	46	36	100
Dry beans	20	10	10	40
Total	315	726	304	1345

Results and Discussion: Unsurprisingly, existing yield estimates of most crops in 2020 are low relative to the median values observed in 2020, likely reflecting a combination of improved genetics and management practices. The greatest increases were observed for cereal grain crops with increases of greater than 70% for spring wheat (68 bu/A versus 40 bu/A) and 54% increase for corn (154 bu/A versus 100 bu/A) although modest increases also were observed for the oilseeds (e.g., 28% increase in canola yields) and the various pulse crops. The exception was lentil, and it is likely that the CFI estimates for lentil in the 1980's were based on small plot research data as lentil was still a relatively new crop in western Canada at that time.

Median values for N removal in 2020 were, in some cases, consistent with existing CFI ranges, whereas for some crops, the CFI estimates are no longer acceptable. For example, the median and range of N values for fababeanare closely aligned with the CFI estimates (Figure 1). In other instances, the median value is consistent with the existing CFI range but the range in values is not captured. For example, N removal by canola aligns closely to the median and 50% interquartile range (i.e., 25% of the data points immediately above and 25% of the data below the median), but fails to capture the true range of data observed in 2020. Other estimates of N removal are significantly under-estimated by the existing CFI guidelines. For example, N removal (per bu basis, i.e., N concentration) by lentil and winter wheat in 2020 far exceeded the CFI estimates. In all instances, there was a notable variation in N removal values, far exceeding estimated ranges provided by the CFI guidelines. Importantly, examination of the data revealed that N removal (on a per bushel basis) was largely unaffected by yield. For example, N removal by barley was highly variable, but the variation was largely unrelated to yield (Fig. 2). A possible exception may have occurred with very low yielding barley. No other crops had a statistically significant relationship between seed N removal (per bushel, i.e., N concentration) and yield (data not shown).

As observed for N, P_2O_5 removal (i.e., seed) was characterised by a high degree of variability, far exceeding the CFI range estimates (Fig. 3), which differed between crops. Importantly, CFI guidelines both over-estimated (e.g., canola, fababean) and under-estimated (e.g., corn, flax, lentil, oat, wheat) actual removal observed in 2020.

Similarly, the CFI estimates for K_2O removal in the seed both over-estimated (e.g., canola, lentil, wheat) and under-estimated (e.g., pea, fababean, corn) actual removal (Fig. 4). Additionally, K_2O removal similarly had a high degree of variability in the nutrient removal, exceeding the estimated range provided by the CFI guidelines. Importantly, the variability differed between different crops. Soybean, in particular, had high levels of potassium removal and a high degree of variability inlevels of removal relative to other crops.

Sulphur removal in the seed similarly was varied and CFI guidelines both over- (e.g., canola, flax) and under-estimate (e.g., fababean, oat) actual removal observed in 2020 (Figure 5). As with other macronutrients, the actual range in S removal far exceeded the estimated range provided by the CFI guidelines.

Micronutrient removal is also being analysed and data currently are being verified. Micronutrient data is not shown at this time.

Data from the 2020 field season underscores the need to revise the nutrient uptake and removal guidelines for western Canada. Yields achieved for most crops have increased–in some cases dramatically–and higher yield goals necessarily result in greater uptake and removal. Additionally, estimates of macronutrient removal on a 'per bu' basis similarly are no longer accurate and nutrient concentration in the seed is in some cases either overestimated or underestimated. Although the focus of this report has been the comparison with the CFI guidelines for western Canadian crops, it is important to note that other nutrient removal calculators available on-line or as downloadable apps typically use data collected from regions other than western Canada, further underscoring the need for this research.

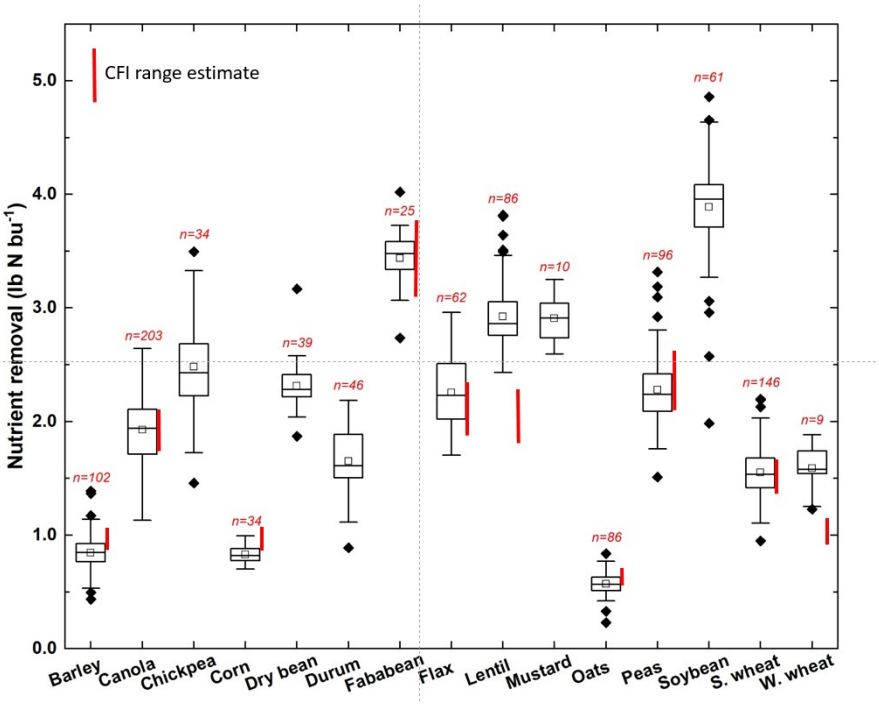

Figure 1. Nitrogen removal in the seed of the fourteen crops grown in 2020. Boxplots show the median value with 50% of the values within the box (25% above and 25% below), and the remaining 50% of the data represented by the whiskers (25% above and 25% below). Outliers are represented by the solid black diamonds. The CFI range estimates (where available) are represented by the solid red line.

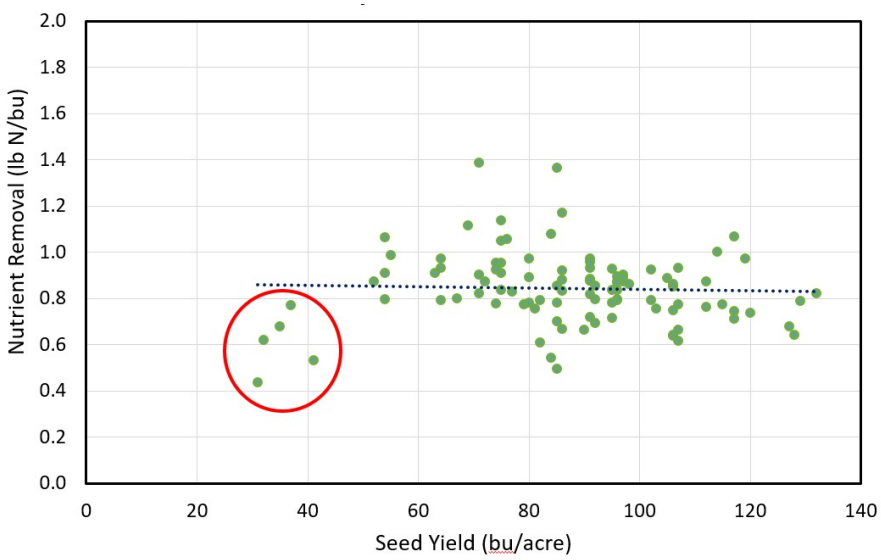

Figure 2. Relationship between N removal in the seed (lb N/bu) and seed yield. Except for values associated with very low yields (denoted by the red circle), data reveal that yield had little or no impact on N concentration in the seed.

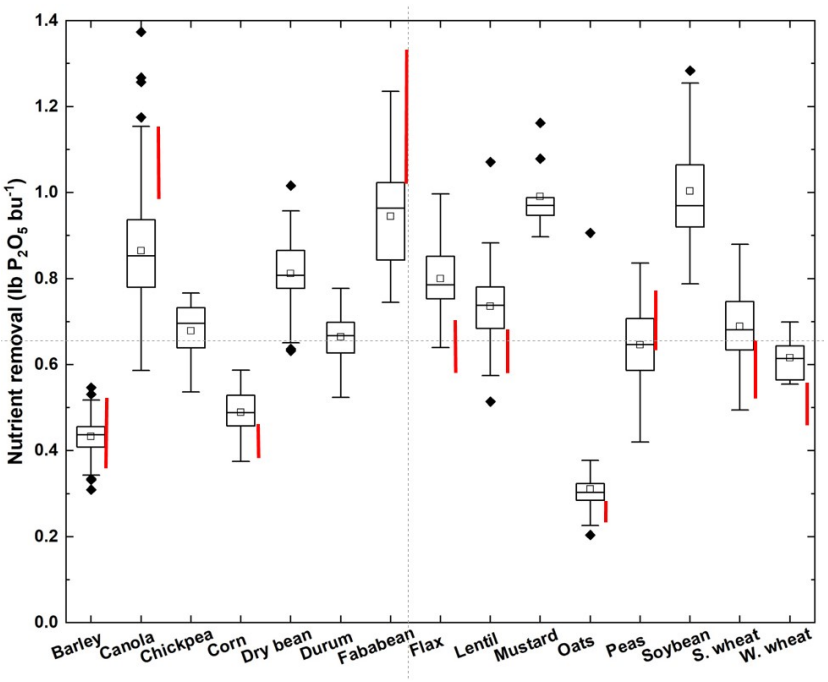

Figure 3. Phosphorus removal in the seed of the fourteen crops grown in 2020. Boxplots show the median value with 50% of the values within the box (25% above and 25% below), and the remaining 50% of the data represented by the whiskers (25% above and 25% below). Outliers are represented by the solid black diamonds. The CFI range estimates (where available) are represented by the solid red line.

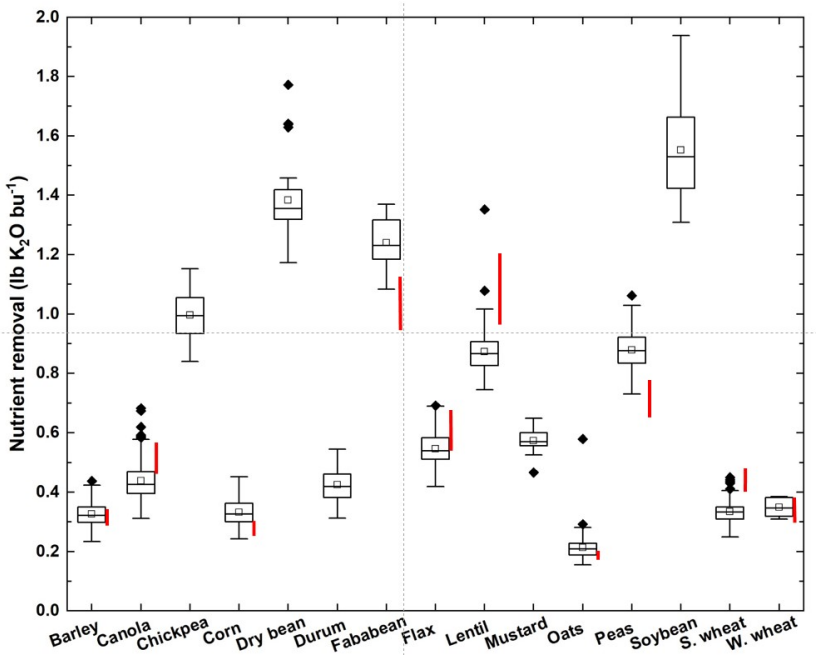

Figure 4. Potassium removal in the seed of the fourteen crops grown in 2020. Boxplots show the median value with 50% of the values within the box (25% above and 25% below), and the remaining 50% of the data represented by the whiskers (25% above and 25% below). Outliers are represented by the solid black diamonds. The CFI range estimates (where available) are represented by the solid red line.

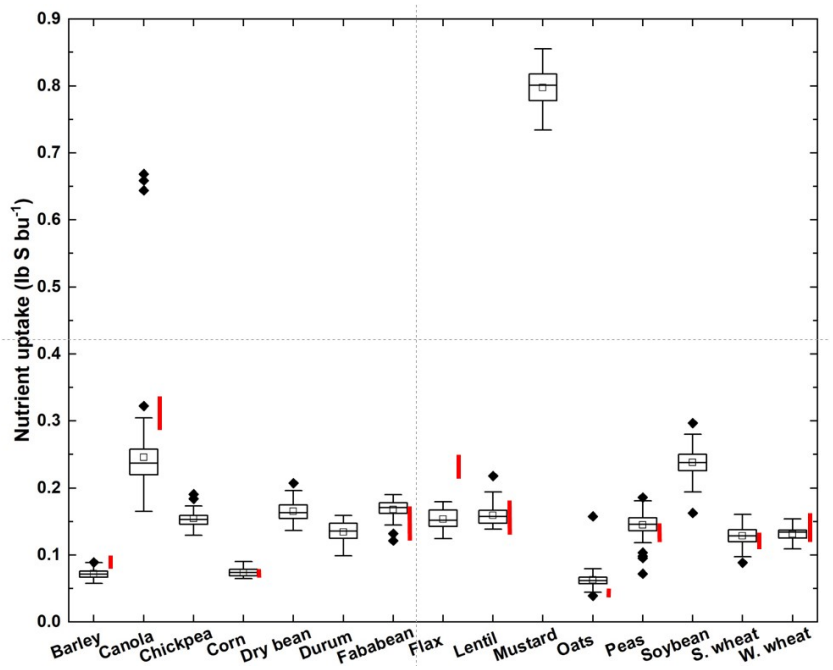

Figure 5. Sulphur removal in the seed of the fourteen crops grown in 2020. Boxplots show the median value with 50% of the values within the box (25% above and 25% below), and the remaining 50% of the data represented by the whiskers (25% above and 25% below). Outliers are represented by the solid black diamonds. The CFI range estimates (where available) are represented by the solid red line.

Acknowledgments

Funding for this project was provided by Western Grains Research Foundation, the Saskatchewan Wheat Development Commission, the Saskatchewan Canola Development Commission, the Saskatchewan Flax Development Commission, the Prairie Oat Growers Association and the Alberta Wheat Commission.