“Crop Nutrient Uptake and Removal: Are all Regions the Same?”

John Heard
AgVise seminars
January 2022

Manitoba

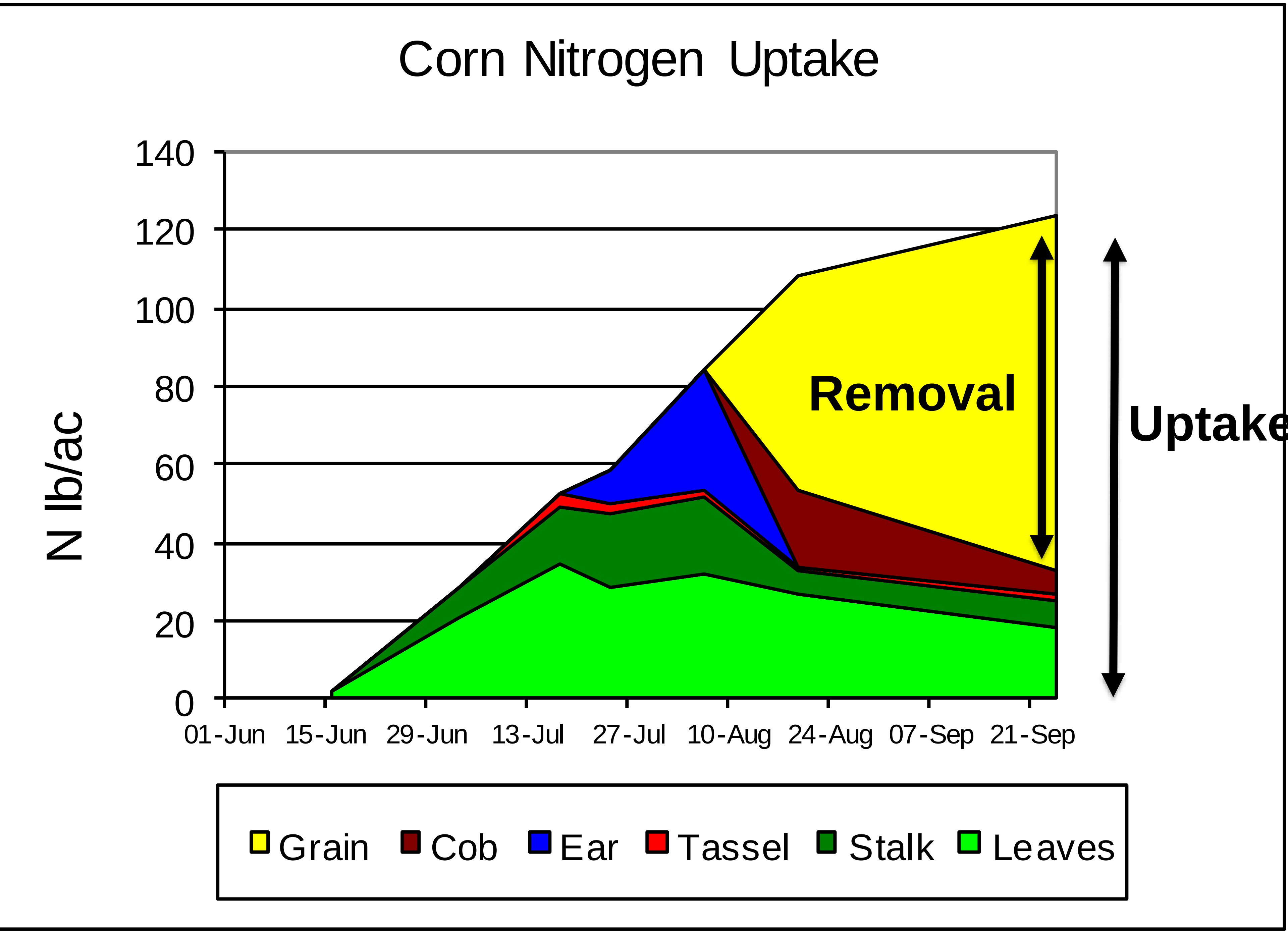
Crop uptake and removal

What do we use this information for?

Does it need to be updated?

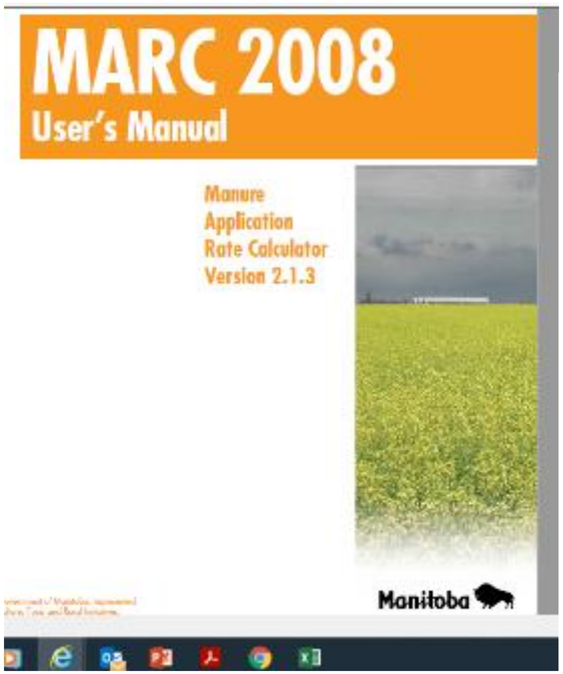
Does it change from area to area?

Can nutrient concentration be diagnostic of under fertilized crops?



Carman, 1993. 146 bu/ac corn with 125 lb N.

Manure management planning (and regulation of rates)



P205 Removal

Crop	Example Target Yield	Ave Removal N	Ave Removal P205
Wheat (Spring)	40 bu/acre	1.50 lb/bu	0.59 lb/bu
Wheat (Winter)	75 bu/acre	1.04 lb/bu	0.51 lb/bu
Barley (Grain)	80 bu/acre	0.97 lb/bu	0.42 lb/bu
Oats	100 bu/acre	0.62 lb/bu	0.26 lb/bu
Rye	55 bu/acre	1.06 lb/bu	0.45 lb/bu
Corn (Grain)	100 bu/acre	0.97 lb/bu	0.44 lb/bu
Canola	35 bu/acre	1.93 lb/bu	1.04 lb/bu
Flax	24 bu/acre	2.13 lb/bu	0.65 lb/bu
Sunflowers	22 cwt/acre	2.80 lb/cwt	1.10 lb/cwt
Alfalfa	5 tons/acre	58.0 lb/ton	13.8 lb/ton
Grass Hay	3 tons/acre	34.2 lb/ton	10.0 lb/ton
Corn (Silage)	5 dry tons/acre	31.2 lb/ton	12.7 lb/ton
Barley (Silage)	4.5 tons/acre	34.4 lb/ton	11.8 lb/ton
Soybeans	35 bu/acre	2.97 lb/bu	0.84 lb/bu

6.2.4 The Fertilizer Screen (4/8)

https://www.gov.mb.ca/agriculture/environment/nutrient-management/marc.html#Whats_in_MARC_2008_

Effectiveness of novel products

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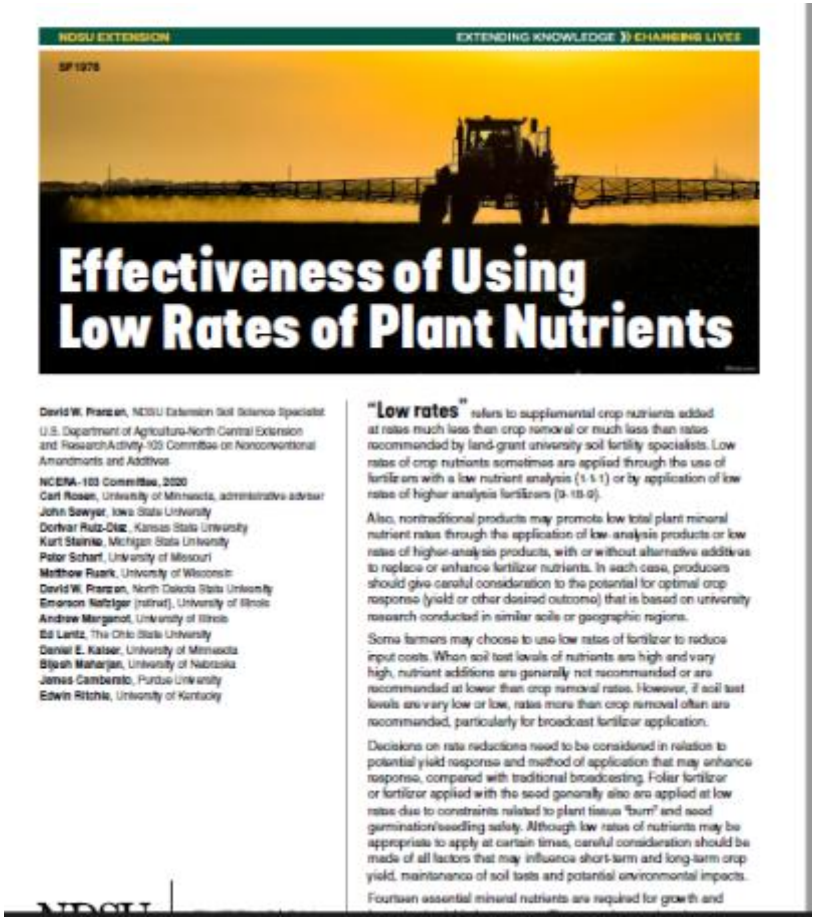
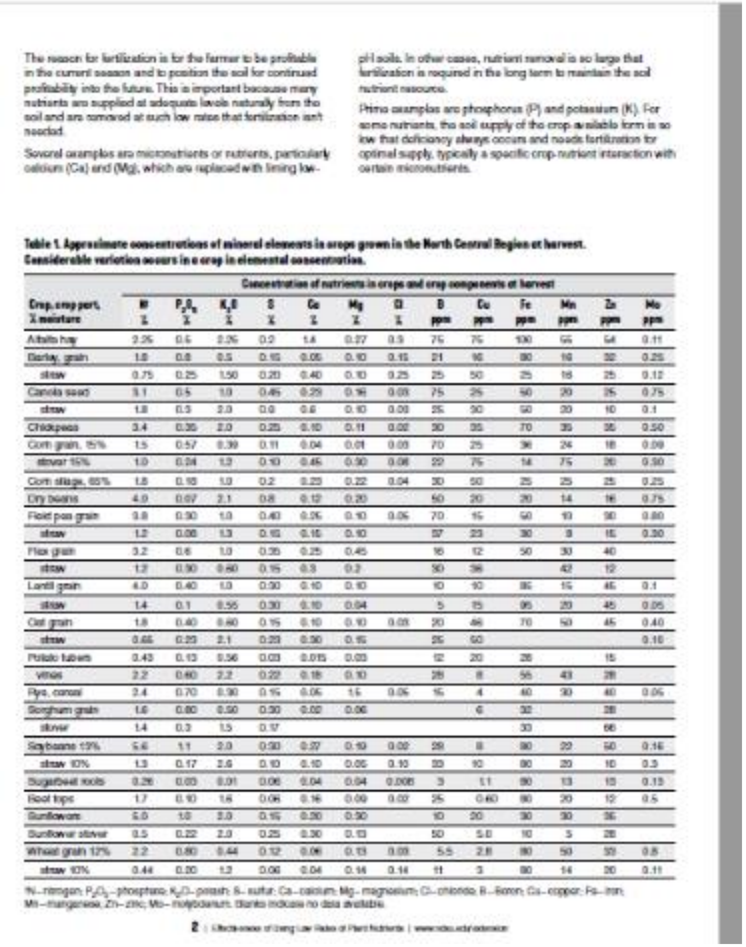




Often it is simple mathematics

https://www.ag.ndsu.edu/publications/crops/effectiveness-of-using-low-rates-of-plant-nutrients

Considering soil depletion, maintenance or building

Phosphorus Balance Calculation for a Rotation (Version 4 - October 1, 2014)

Crop	Typical Yield	Yield Units	P Applied	P Removed* per unit	P Removed* per acre	Annual Balance
			------------ (lb P_2O_5/ac) ------------			
HR Spring wheat	60	bu/ac	30	0.59	35	-5
Winter wheat	75	bu/ac	30	0.51	38	-8
Barley		bu/ac		0.42	0	0
Oats		bu/ac		0.26	0	0
Canola	40	bu/ac	20	1.04	42	-22
Soybeans	40	bu/ac	10	0.84	34	-24
Peas		bu/ac		0.69	0	0
Flax		bu/ac		0.65	0	0
Corn (grain)		bu/ac		0.44	0	0
Other**				0.00	0	0
Total for Rotation			90		149	-59

Notes: Does not account for nutrients removed when straw or chaff is removed or burned

Fill in any of the blue cells for typical rotation, yields, and P appl'n

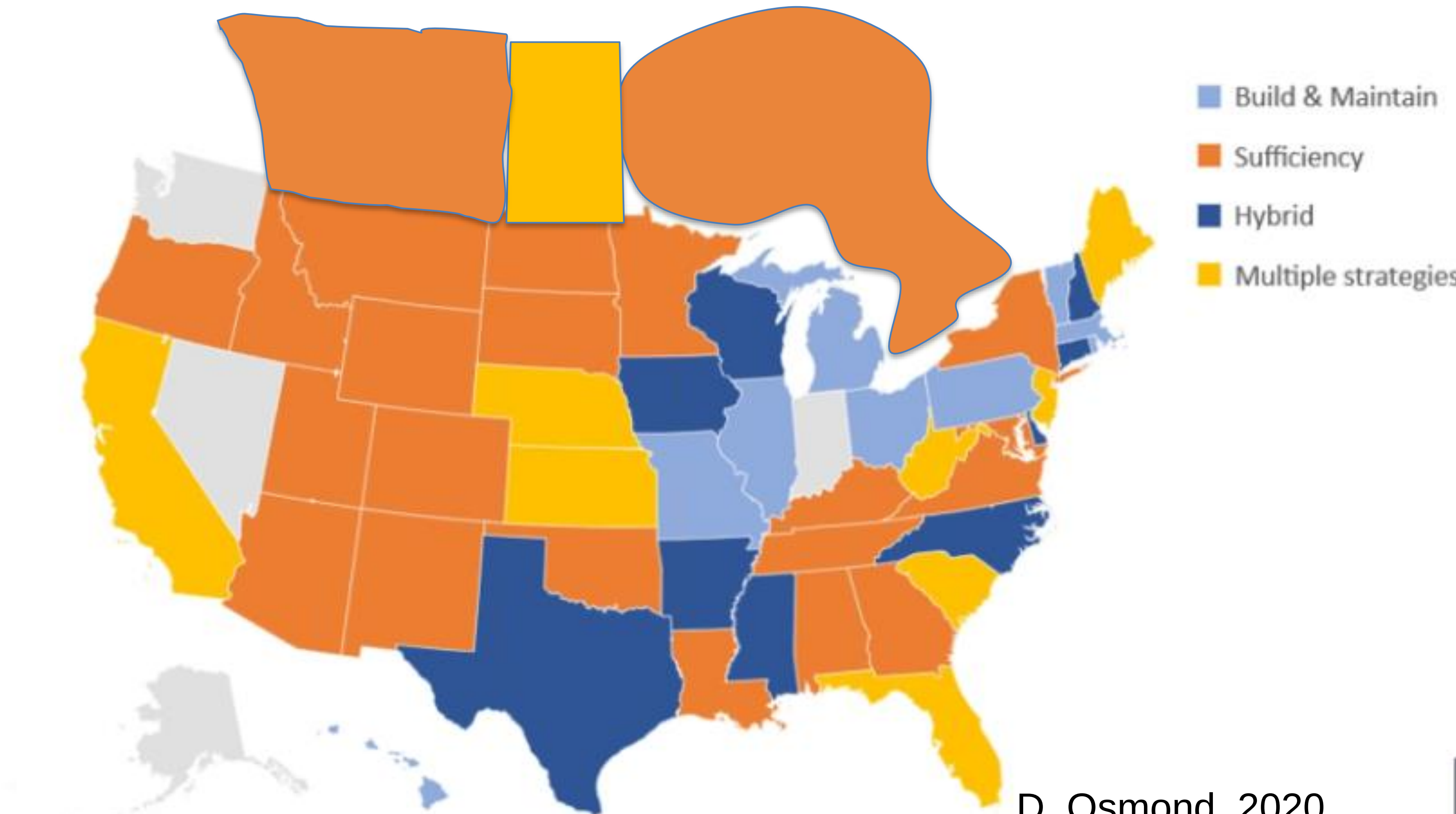
*P removal figures are estimates from the Manitoba Soil Fertility Guide.

**For nutrient removal in other crops see table in next worksheet.

Interactive P balance worksheet | Nutrient removal table

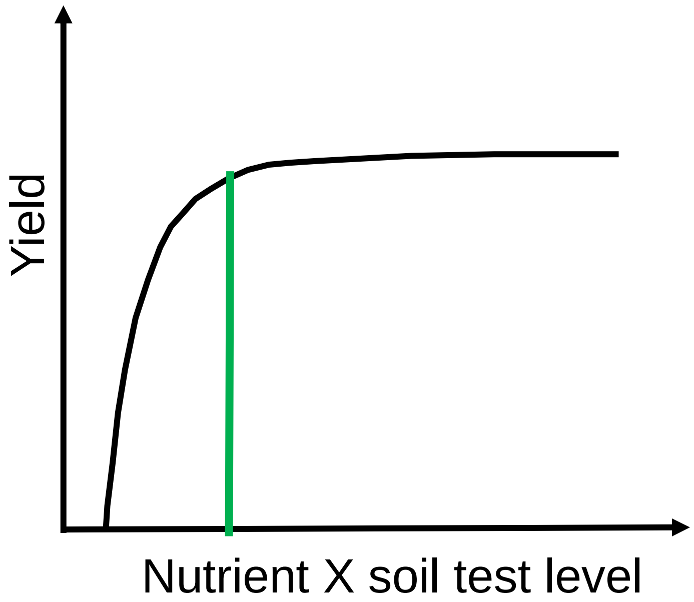
Simple spreadsheet to show impact of fertilization strategies over the rotation.
https://www.gov.mb.ca/agriculture/crops/soil-fertility/phosphorus-balance-calculator-for-a-rotation.html

2020 National Survey: Fertilizer Recommendation Philosophy for P and K



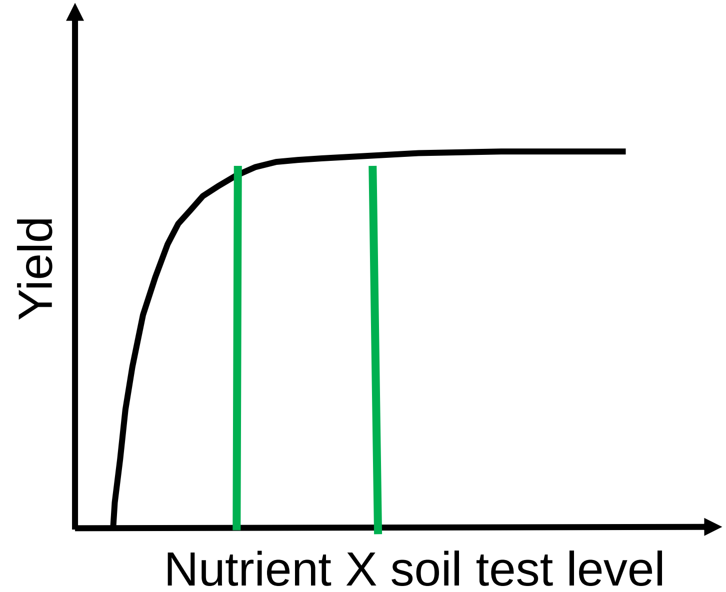
D. Osmond, 2020
Canadian images by John

Sufficiency versus Building/Maintenance



Sufficiency
- Apply only what is sufficient to meet crop demands
- Inputs match outputs
- Soil nutrient levels remain in a responsive range

Building/maintenance
- Apply more than what is needed for the immediate crop
- Build the nutrient reserve
- Soil nutrient levels remain in a medium to high range

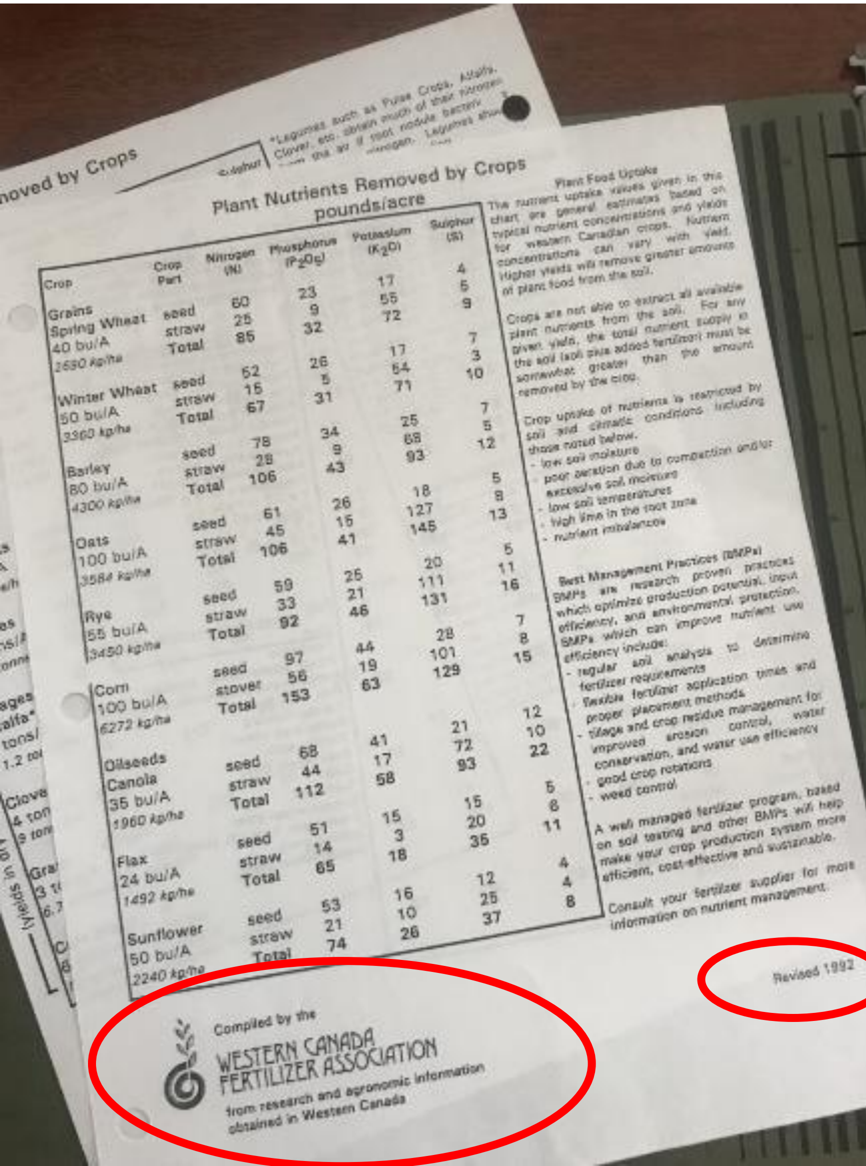


$$\frac{(\text{Target STP} - \text{Current STP}) \times \text{BC}}{\text{Years to Build}} + \textbf{CR}$$

- Example 2 for 60 bu/ac wheat, current STP = 5 ppm and 5 years to build:
- Target STP (15 ppm)
- **Crop removal (CR) = yield x P concentration**
- Typical P buffering capacity (BC) by soil characteristics (assuming 25 lb P_2O_5 /ac to increase 1 ppm STP)

$$\frac{(15-5) \times 25}{5} + 34 = \frac{(250)}{5} + 34 = 84 \text{ lb } P_2O_5 \text{ /ac}$$

1992



Plant Nutrients Removed by Crops
pounds/acre

Crop	Crop Part	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)	Sulphur (S)
Grains Spring Wheat 40 bu/A 2690 kg/ha	seed	60	23	17	4
	straw	25	9	55	5
	Total	85	32	72	9
Winter Wheat 50 bu/A 3360 kg/ha	seed	52	26	17	7
	straw	15	5	54	3
	Total	67	31	71	10
Barley 80 bu/A 4300 kg/ha	seed	78	34	25	7
	straw	28	9	68	5
	Total	106	43	93	12
Oats 100 bu/A 3584 kg/ha	seed	61	26	18	5
	straw	45	15	127	8
	Total	106	41	145	13
Rye 55 bu/A 3450 kg/ha	seed	59	25	20	5
	straw	33	21	111	11
	Total	92	46	131	16
Corn 100 bu/A 6272 kg/ha	seed	97	44	28	7
	stover	56	19	101	8
	Total	153	63	129	15
Oilseeds Canola 35 bu/A 1960 kg/ha	seed	68	41	21	12
	straw	44	17	72	10
	Total	112	58	93	22
Flax 24 bu/A 1492 kg/ha	seed	51	15	15	5
	straw	14	3	20	6
	Total	65	18	35	11
Sunflower 50 bu/A 2240 kg/ha	seed	53	16	12	4
	straw	21	10	25	4
	Total	74	26	37	8

Plant Food Uptake

The nutrient uptake values given in this chart are general estimates based on typical nutrient concentrations and yields for western Canadian crops. Nutrient concentrations can vary with yield. Higher yields will remove greater amounts of plant food from the soil.

Crops are not able to extract all available plant nutrients from the soil. For any given yield, the total nutrient supply in the soil (soil plus added fertilizer) must be somewhat greater than the amount removed by the crop.

Crop uptake of nutrients is restricted by soil and climatic conditions including those noted below.
- low soil moisture
- poor aeration due to compaction and/or excessive soil moisture
- low soil temperatures
- high lime in the root zone
- nutrient imbalances

Best Management Practices (BMPs)

BMPs are research proven practices which optimize production potential, input efficiency, and environmental protection. BMPs which can improve nutrient use efficiency include:
- regular soil analysis to determine fertilizer requirements
- flexible fertilizer application times and proper placement methods
- tillage and crop residue management for improved erosion control, water conservation, and water use efficiency
- good crop rotations
- weed control

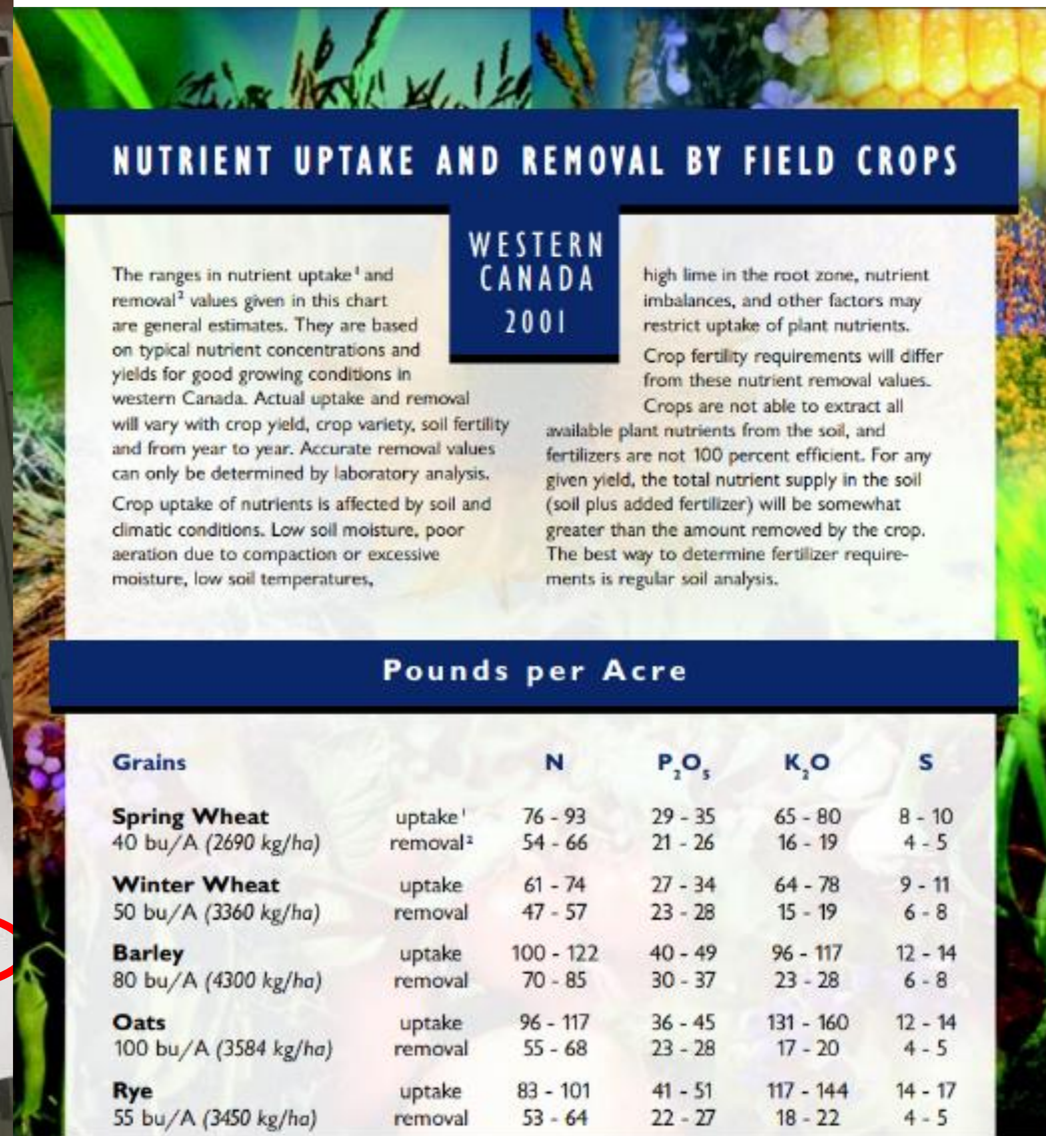
A well managed fertilizer program, based on soil testing and other BMPs will help make your crop production system more efficient, cost-effective and sustainable.

Consult your fertilizer supplier for more information on nutrient management.

Revised 1992

Compiled by the WESTERN CANADA FERTILIZER ASSOCIATION from research and agronomic information obtained in Western Canada

2001 – based on same data +/- 10%



NUTRIENT UPTAKE AND REMOVAL BY FIELD CROPS

WESTERN CANADA 2001

The ranges in nutrient uptake[1] and removal[2] values given in this chart are general estimates. They are based on typical nutrient concentrations and yields for good growing conditions in western Canada. Actual uptake and removal will vary with crop yield, crop variety, soil fertility and from year to year. Accurate removal values can only be determined by laboratory analysis.

Crop uptake of nutrients is affected by soil and climatic conditions. Low soil moisture, poor aeration due to compaction or excessive moisture, low soil temperatures, high lime in the root zone, nutrient imbalances, and other factors may restrict uptake of plant nutrients.

Crop fertility requirements will differ from these nutrient removal values.

Crops are not able to extract all available plant nutrients from the soil, and fertilizers are not 100 percent efficient. For any given yield, the total nutrient supply in the soil (soil plus added fertilizer) will be somewhat greater than the amount removed by the crop. The best way to determine fertilizer requirements is regular soil analysis.

Pounds per Acre

Grains		N	P_2O_5	K_2O	S
Spring Wheat 40 bu/A (2690 kg/ha)	uptake[1]	76 - 93	29 - 35	65 - 80	8 - 10
	removal[2]	54 - 66	21 - 26	16 - 19	4 - 5
Winter Wheat 50 bu/A (3360 kg/ha)	uptake	61 - 74	27 - 34	64 - 78	9 - 11
	removal	47 - 57	23 - 28	15 - 19	6 - 8
Barley 80 bu/A (4300 kg/ha)	uptake	100 - 122	40 - 49	96 - 117	12 - 14
	removal	70 - 85	30 - 37	23 - 28	6 - 8
Oats 100 bu/A (3584 kg/ha)	uptake	96 - 117	36 - 45	131 - 160	12 - 14
	removal	55 - 68	23 - 28	17 - 20	4 - 5
Rye 55 bu/A (3450 kg/ha)	uptake	83 - 101	41 - 51	117 - 144	14 - 17
	removal	53 - 64	22 - 27	18 - 22	4 - 5

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Western Canada

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Oats 100 bu/A *(3584 kg/ha)*	uptake removal	96 - 117 55 - 68	36 - 45 23 - 28	131 - 160 17 - 20	12 - 14 4 - 5
Rye 55 bu/A *(3450 kg/ha)*	uptake removal	83 - 101 53 - 64	41 - 51 22 - 27	117 - 144 18 - 22	14 - 17 4 - 5
Corn 100 bu/A *(6272 kg/ha)*	uptake removal	138 - 168 87 - 107	57 - 69 39 - 48	116 - 141 25 - 30	13 - 16 6 - 7

Oilseeds		N	P_2O_5	K_2O	S
Canola 35 bu/A *(1960 kg/ha)*	uptake removal	100 - 123 61 - 74	46 - 57 33 - 40	73 - 89 16 - 20	17 - 21 10 - 12
Flax 24 bu/A *(1492 kg/ha)*	uptake removal	62 - 76 46 - 56	18 - 22 14 - 17	39 - 48 13 - 16	12 - 15 5 - 6

Where did data come from?
Research plots?

Older varieties?
Open pollinated canola.
Production has changed:

- Less tillage
- More pesticide use (fungicide)
- Earlier seeding

Table 4.1 Total nutrient uptake* by selected crops (Last modified: May 2014).

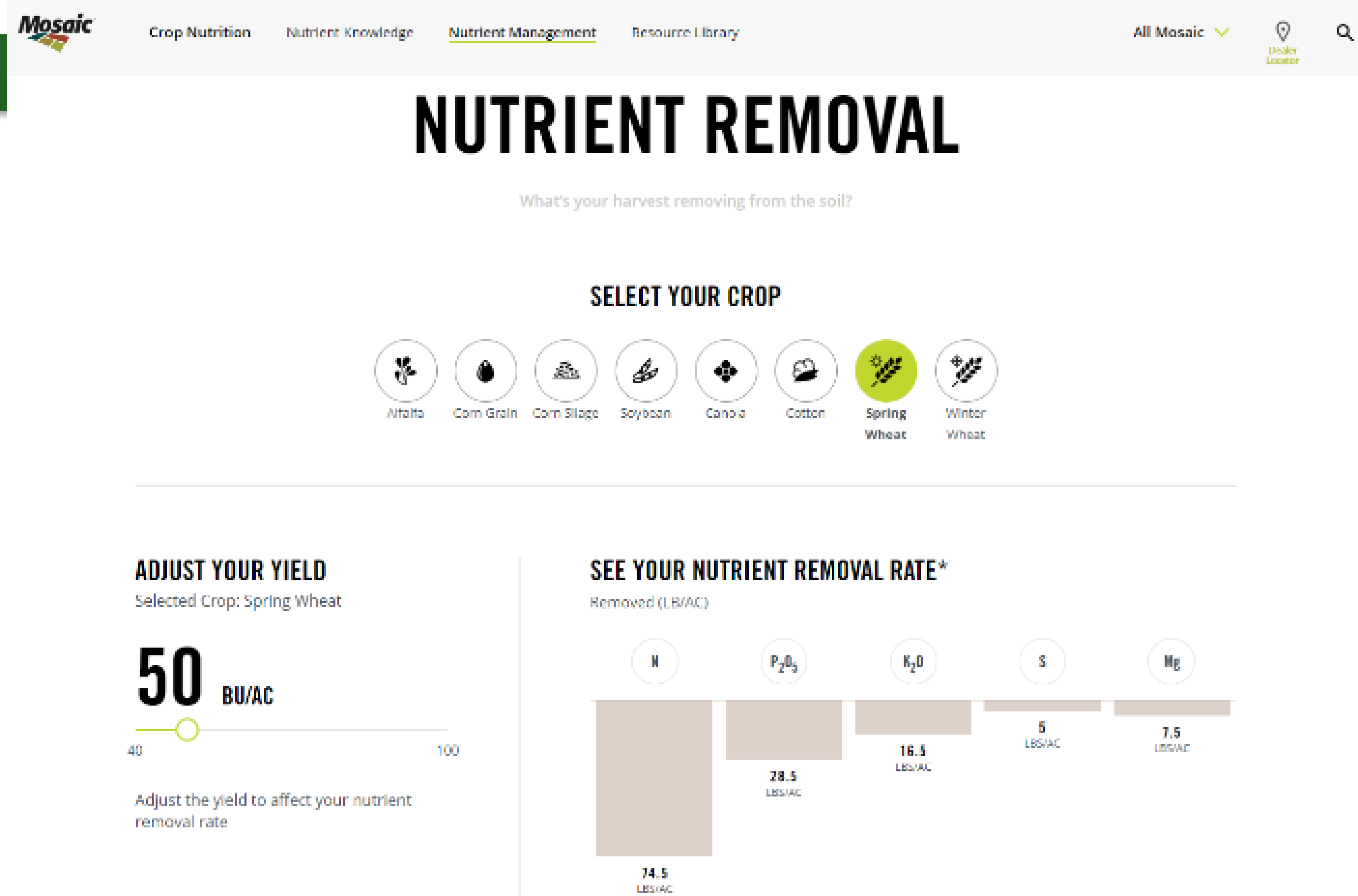
Barley	Argentina
Bermudagrass	USA
Canola	China
Chickpea	India
Corn	USA

Soybean	USA
Sugar beet	China
Sugarcane	China
Sunflower	Argentina
Tobacco	China

	S
	7.0
	0.2
	1.4
	7.8
Pea	8.6
Pota	
Rice	
Saff	1.3
Sorg	
Soyb	
Sug	
Sug	
Sun	0.50
Tob	
Tom	
Whe	
Whe	

* Total nutrient uptake refers to the quantity of nutrient accumulated in the above ground portion, and harvested portions, of the plant by the time of sampling, usually physiological maturity or when uptake is at its maximum.

IPNI Website



** N, P_2O_5, K_2O, and S removal coefficients derived from the IPNI Nutrient Removal Calculator as of Jan. 2018 (http://www.ipni.net/article/IPNI-3346). Mg removal coefficients derived from Alabama Extension: ANR-449 (1999), CFI (2001), IPNI (2008), North Carolina: AG-439-16 (1991) and other independent sources. Nutrient removal values may vary regionally depending on growing conditions. Use locally available data whenever possible. Crop nutrient removal and soil test considerations should be made for proper nutrient recommendations.*

https://www.cropnutrition.com/nutrient-management/nutrient-removal?gclid=CjwKCAjwqcKFBhAhEiwAfEr7zQlkSLtkV0eFtzA6uDy4Sn6i5jbzqhVEcSJ6iLLvqY1KBXJLAYVrJBoCJk4QAvD_BwE

ILLINOIS

Modern Corn Hybrids' Nutrient Uptake Patterns

By Ross R. Bender, Jason W. Haegele, Matias L. Ruffo, and Fred E. Below

Biotechnology, breeding, and agronomic advancements have propelled corn yields to new highs with little guidance as to how to fertilize these modern corn hybrids to achieve their maximum yield potential. Current fertilization practices, developed decades ago, may not match uptake capabilities of modern hybrids that contain transgenic insect protection now grown at population densities higher than ever before. A re-evaluation of nutrient uptake and partitioning can provide the foundation for fine-tuning our practices as we strive to achieve corn's maximum yield potential.

As summarized by Bruulsema et al. (2012), optimizing nutrient management includes using the right source at the right rate, right time, and right place—the 4R approach. Research pertaining to primary macronutrient uptake, partitioning, and timing (Sayre, 1948; Hanway, 1962; Karlen et al., 1988), though fundamentally accurate for previous hybrids and management practices, may be unrepresentative of modern hybrids in higher yielding environments. The objective of this study was to determine how modern, transgenic insect-protected corn hybrids in high-yielding systems take up and utilize nutrients.

Nutrient contents of N, P, K, S, Zn, and B were determined at six incrementally spaced growth stages: V6 (vegetative leaf stage 6), V10, V14, R2 (blister), R4 (dough), and R6 (physiological maturity) (Hanway, 1963). Field experiments were conducted at the Northern Illinois Agronomy Research Center in DeKalb, Illinois and the Department of Crop Sciences Research and Education Center in Urbana, Illinois. A total of six hybrids ranging in relative maturity from 111 to 114 days were used with genetic resistance to feeding from Western Corn Rootworm (*Diabrotica virgifera virgifera*), European Corn Borer (*Ostrinia nubilalis*), and other species in the Lepidoptera order. In all cases, hybrids were seeded to obtain a final stand of 34,000 plants/A. Representative plants were separated, analyzed, and evaluated in four tissue fractions: 1) stalk and leaf sheaths; 2) leaf blades; 3) tassel, cob, and husk leaves; and 4) corn grain, respectively referred to as stalk, leaf, reproductive, and grain tissues. Agronomic management at planting included a soil insecticide and a broadcast application of 150 lb P_2O_5/A as MicroEssentials® SZ™ along with 180 lb N/A as urea. This was followed by 60 lb N/A as Super-U (with urease

Fully-filled ears of corn—an indicator of successfully matching soil nutrient supply with crop demand.

nutrients required for production, and 2) the amount of that nutrient contained in the grain, referred to as "removed with grain" (**Table 1**). Our grain nutrient concentration values, in units of lb/bu (**Table 1**) are in agreement with those recently used by the fertilizer industry to determine replacement fertilizer rates (Bruulsema et al., 2012). In the past 50 years, however, the quantity of N, P, and K required for production and the amount of nutrients removed with the grain have nearly doubled across a variety of management systems used in the 1960s (Hanway, 1962).

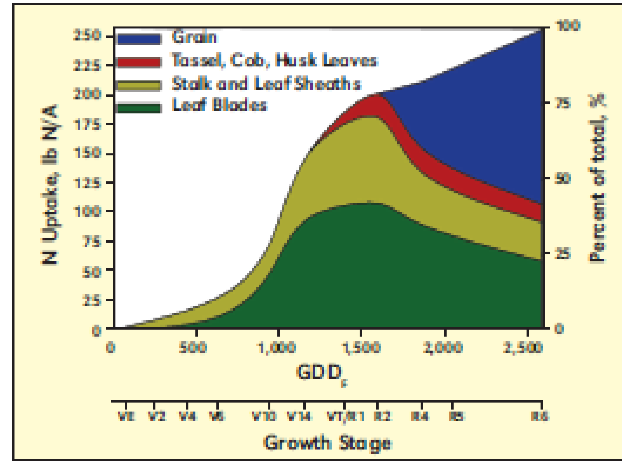


Figure 2. Total maize N uptake and partitioning across four plant stover fractions: leaf, stalk, reproductive, and grain tissues. Each value is a mean of six hybrids across two site-years at Urbana, IL (2010) and DeKalb, IL (2010). GGD$_F$ = growing degree days (Fahrenheit)

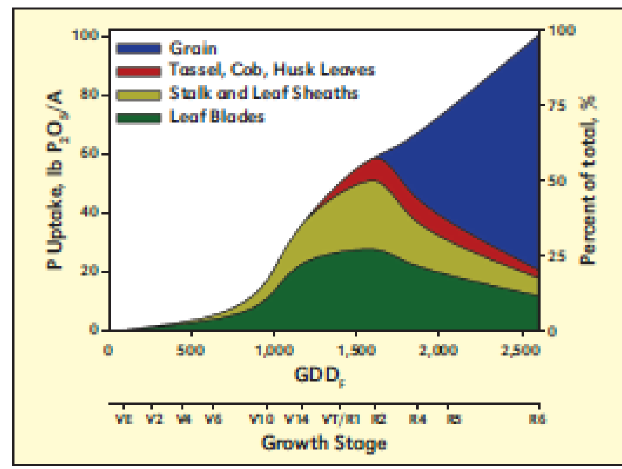
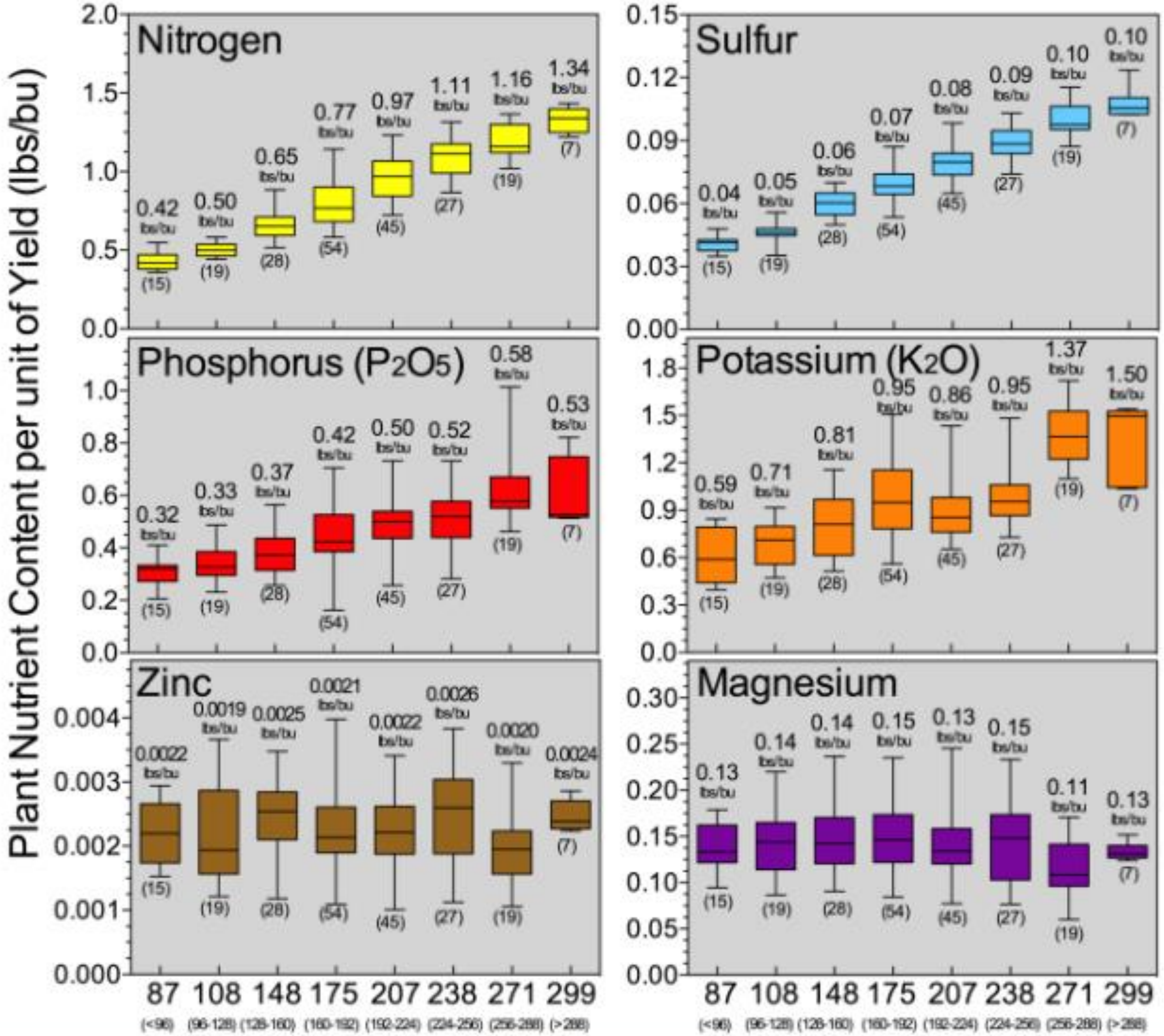


Figure 3. Total maize P uptake and partitioning across four plant stover fractions: leaf, stalk, reproductive, and grain tissues. Each value is a mean of six hybrids across two site-years at Urbana, IL (2010) and DeKalb, IL (2010). GGD$_F$ = growing degree days (Fahrenheit)

Newer, high yielding hybrids removing less nutrients per bu than "book values"

Better Crops/Vol. 97 (2013, No.1)

Uptake per bu increases with yield for N,P,K,S



But removal in grain rather constant across yield ranges

Ciampitti and Vyn, 2014.
https://ag.purdue.edu/agry/directory/Documents/CM-RS-13-0022_Final%20Version_4-11-2014.pdf

Lack of association between crop yields and nutrient concentration

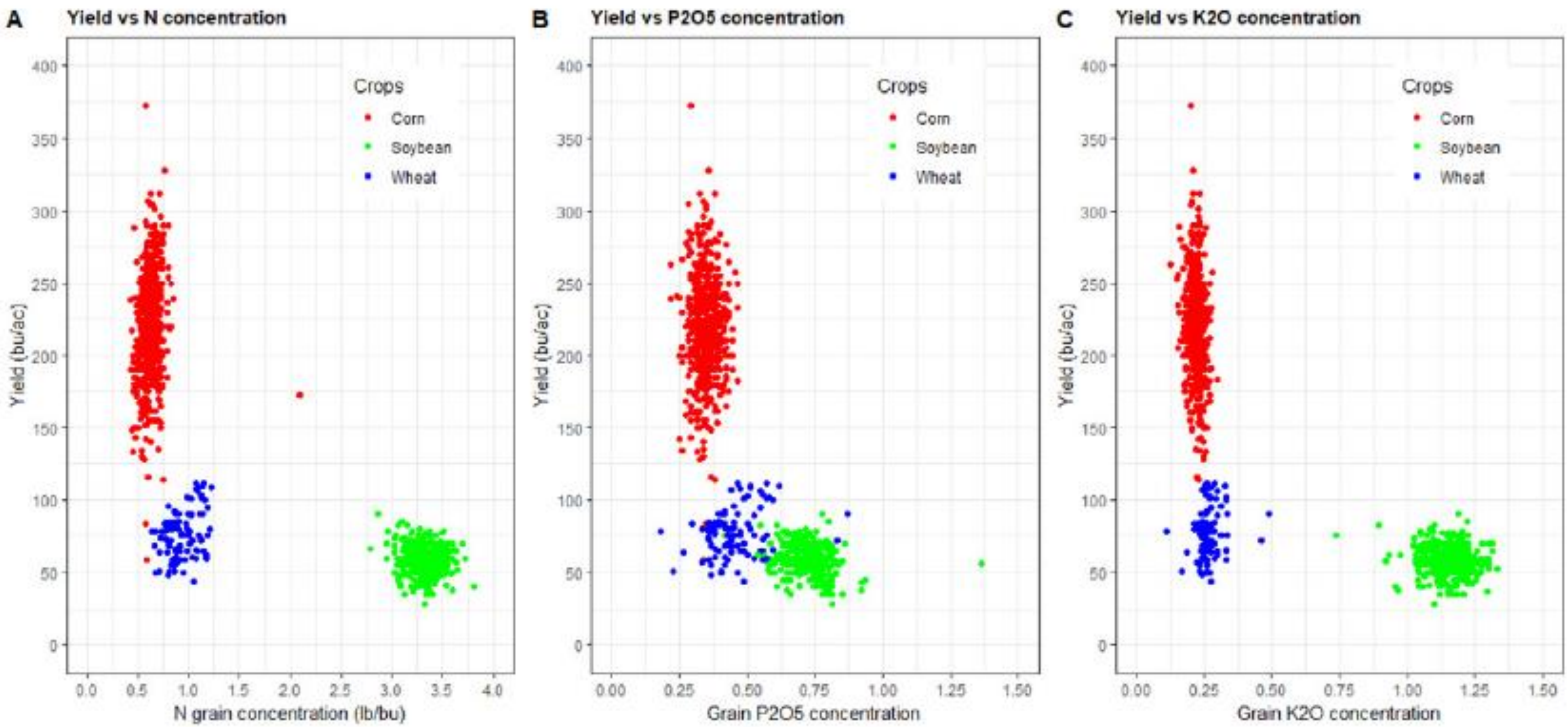


Fig.2. Scatterplots of the concentration of A), N, B) P_20_5, and C) K_20 in the grain (lbs/bu) against yield (bu/ac) of field crops of corn (*n* = 644), soybean (*n* = 390), and wheat (*n* = 101).

Illinois. Villamil et al, 2019. https://experts.illinois.edu/en/publications/new-grain-p-and-k-concentration-values-for-illinois-field-crops

Defined range of nutrients

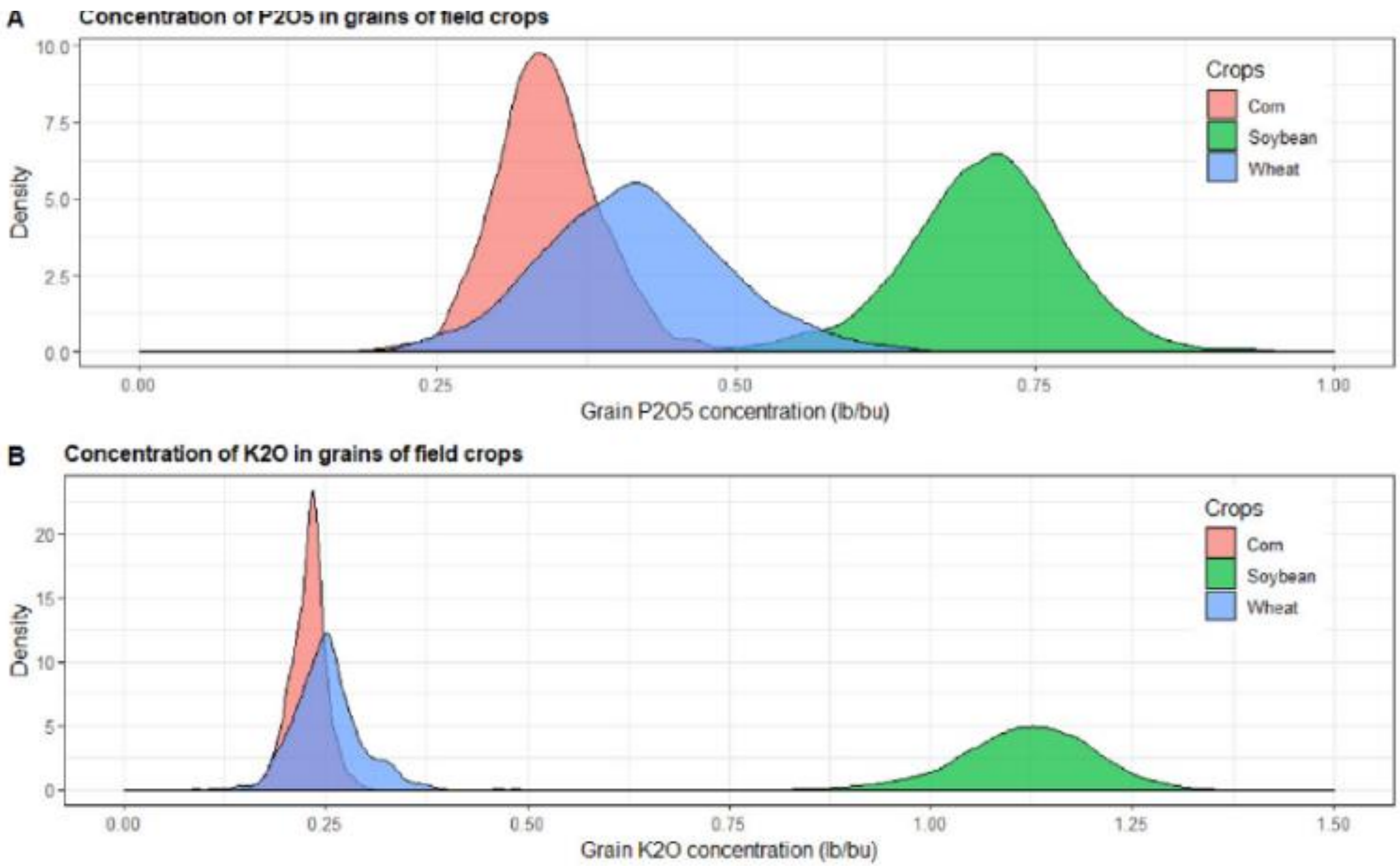


Fig. 3. Distribution of (A) P_2O_5 and (B) K_2O grain concentrations measured in 2335, 2621, and 825 samples of corn, soybean, and wheat, respectively.

Illinois. Villamil et al, 2019. https://experts.illinois.edu/en/publications/new-grain-p-and-k-concentration-values-for-illinois-field-crops

Using results for recommendations

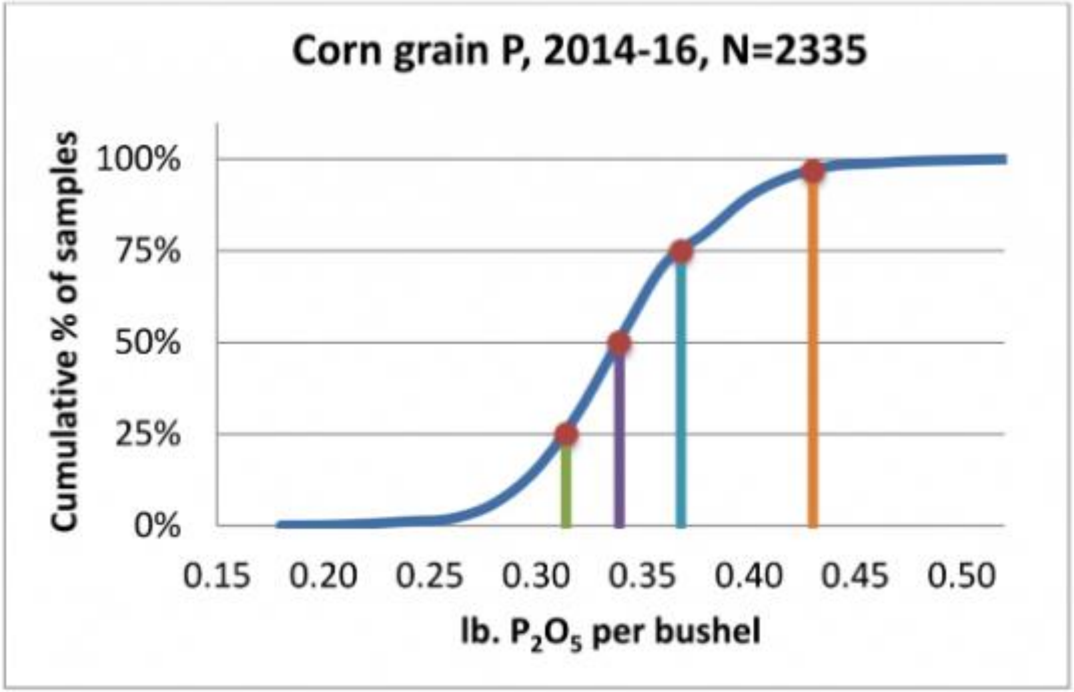
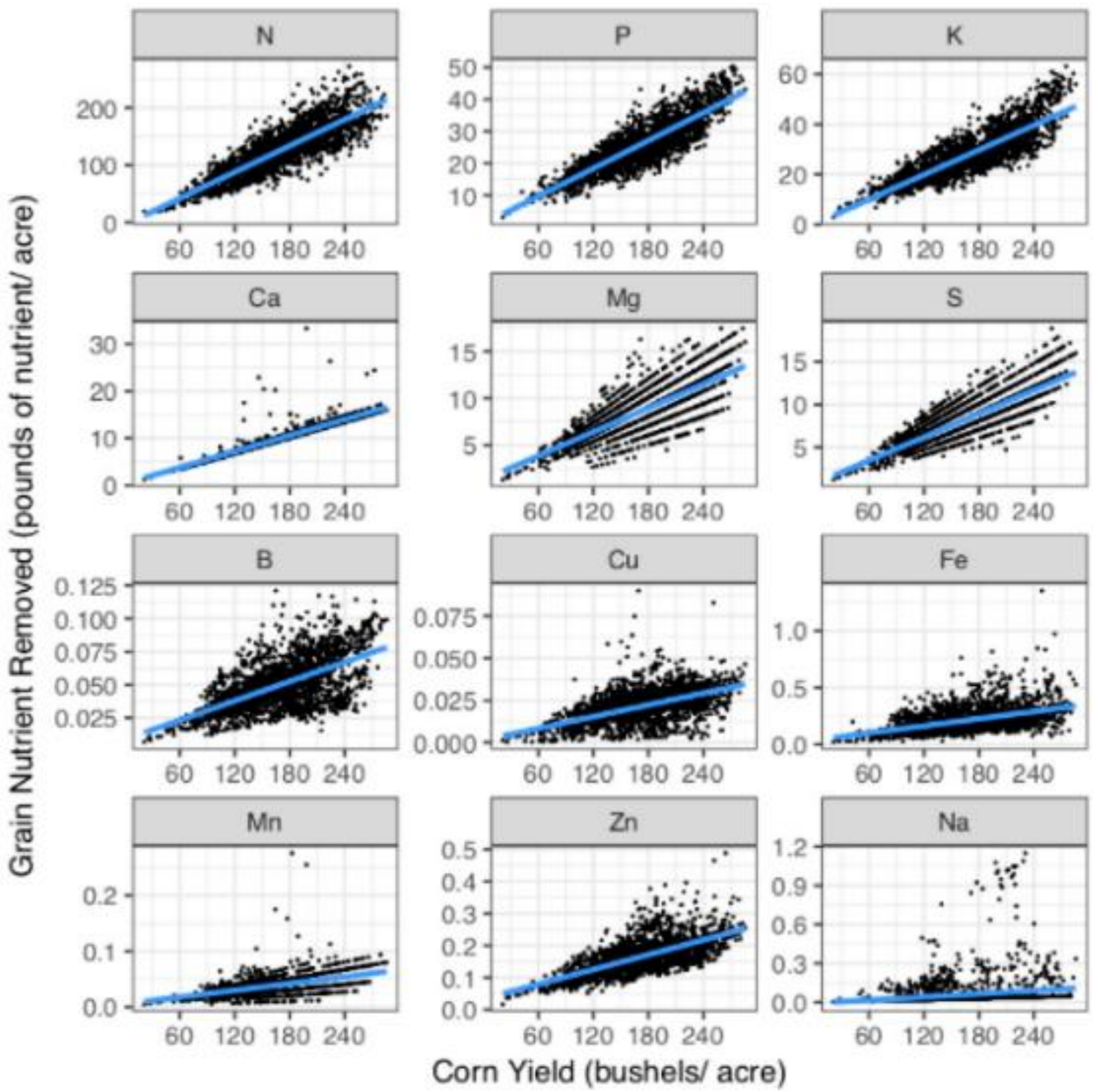


Figure 2. Cumulative distribution of corn grain P levels for 2,335 samples collected from 2014-2016 in Illinois. Vertical lines identify the 25th, 50th, and 75th percentile values, and the current "book value" (0.43 lb P2O5 per bushel, at the 97th percentile) is indicated by the vertical line on the right.

Illinois and Iowa choose to report the 75th percentile values for removals rather than the mean (or median). This was a cautious approach to avoid any risk of under fertilizing – but was still considerably less than the previous book value of 0.43

https://farmdoc.illinois.edu/field-crop-production/uncategorized/new-grain-phosphorus-and-potassium-numbers.html

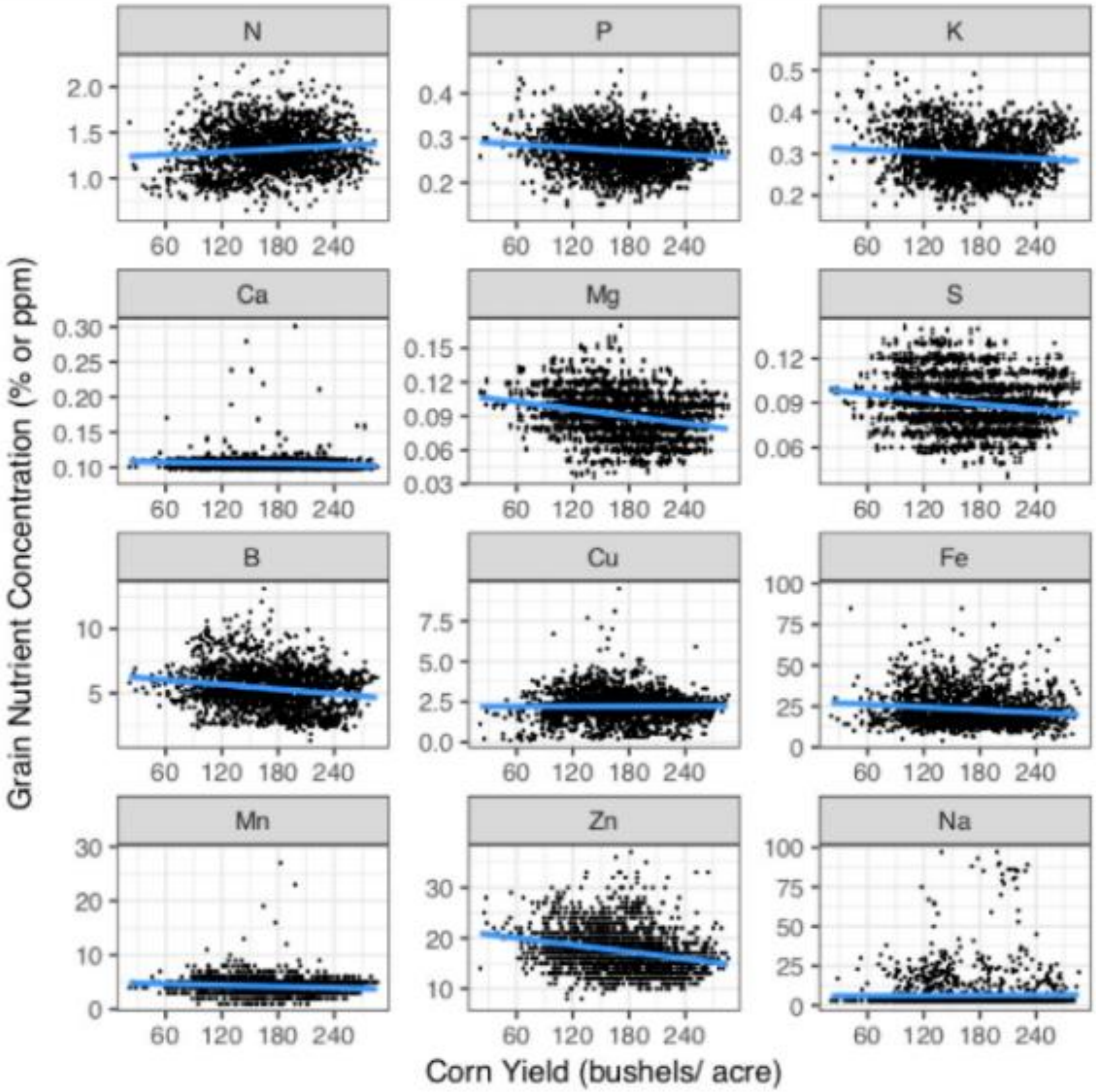
Ohio studies – a full analysis including micronutrients – corn, soybeans, wheat



Compared to 20-30 yrs ago,
K removal is:
26% less in corn,
19% less in soys,
35% less in wheat.

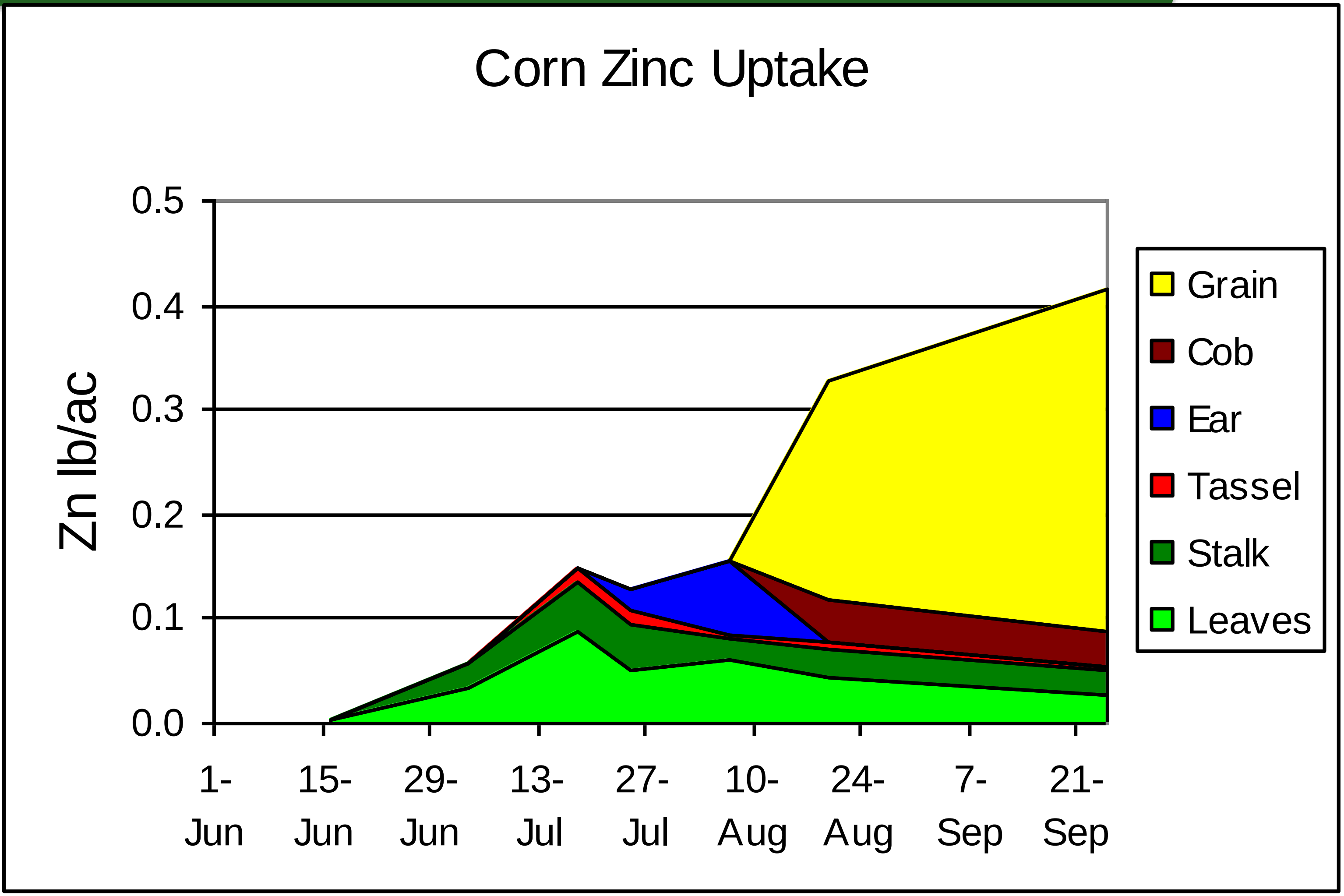
https://ohioline.osu.edu/factsheet/anr-74

Ohio studies – a full analysis including micronutrients – corn, soybeans, wheat



Nutrient concentrations are weakly related to yield.
For most, as yields increase concentrations declined slightly suggesting higher yielding grain contains more starch (or lipids) relative to nutrient.

https://ohioline.osu.edu/factsheet/anr-74



Zn was predominantly in seed of corn so crop removal is more important than other micronutrients.
Some translocation of Zn from leaves and stem to seed. Most seed accumulation is due to continued root uptake.

Manure impact on nutrient removal

		Control	Liq-N rate	Liq-P rate	Solid N Rate	Solid P rate
Canola	Lb N/bu	1.54 – 1.71	1.72-1.80	1.74-1.76	1.67-1.68	1.68-1.71
	Lb P2O5/bu	0.62-0.75	0.73-0.74	**0.53-**0.73	0.79-0.82	0.64-0.83
Barley	Lb N/bu	0.99	1.04	1.08	1.02	1.12
	Lb P2O5/bu	0.48	0.53	**0.47**	0.52	0.54

Manure marginally increased nutrient content of grain, but **occasionally P content was lower due to a dilution effect** brought about by the very high yield increase.

Flaten 2017. https://cdnsciencepub.com/doi/pdf/10.1139/cjps-2017-0160

Source	Grain P removal lb P2O5/bu			Grain K removal lb K2O/bu		
	Corn	Soybean	Wheat	Corn	Soybean	Wheat
IHA	0.43	0.85	0.90	0.28	1.30	0.30
IPNI	0.38	0.84	0.60	0.27	1.30	0.34
MI OLD NEW	~~0.37~~ 0.35	0.80	~~0.63~~ 0.5	~~0.27~~ 0.20	~~1.40~~ 1.15	~~0.37~~ 0.25
IA	0.32	0.72	0.55	0.22	1.20	0.27
IL	0.37	0.75	0.46	0.23	1.15	0.24
OH	0.35	0.79	0.49	0.20	1.14	0.24
MN	0.28 0.25-0.33	0.69 0.62-0.74		0.19 0.18-0.22	1.10 1.04-1.15	
MB	0.25 0.19-0.38	0.65 0.49-0.83	0.50 0.37-0.63	0.18 0.16-0.25	1.06	0.23 0.19-0.28

Minnesota – Removal based management of P and K, 2020

Table 12: Expected removal of phosphate and potash in harvested corn grain at 15.5% moisture

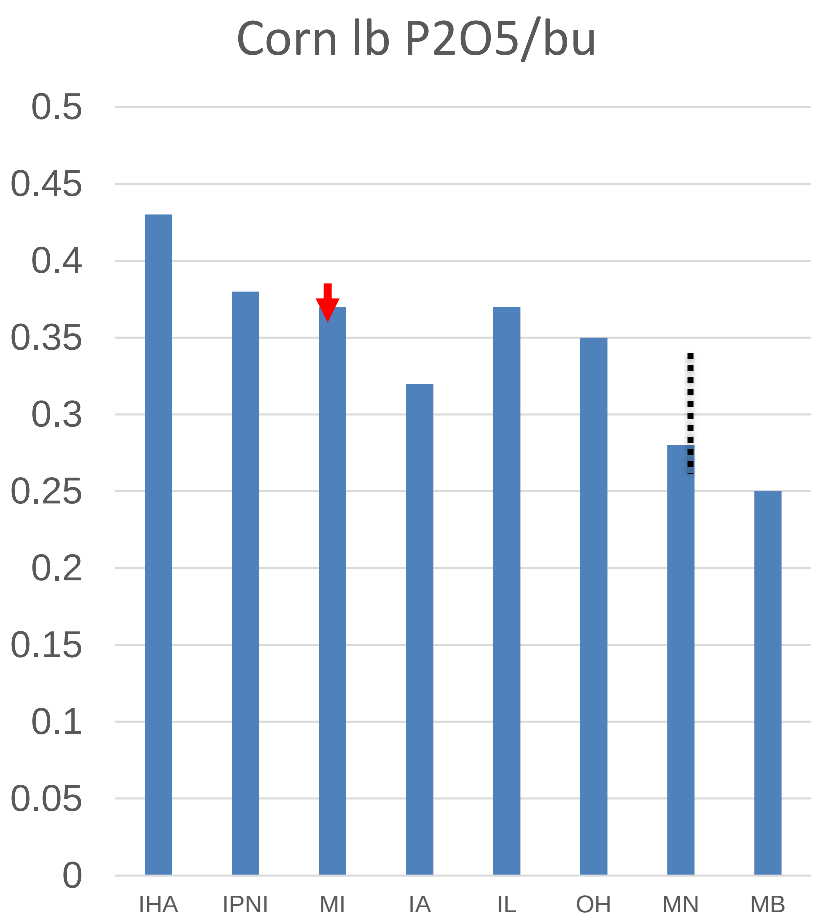
	Median	Range
Phosphate (P2O5)	0.28 (lbs/bushel)	0.25-0.33 (lbs/bushel)
Potash (K2O)	0.19	0.18-0.22

Table 6: Expected removal of phosphate and potash in harvested soybean grain at 13% moisture

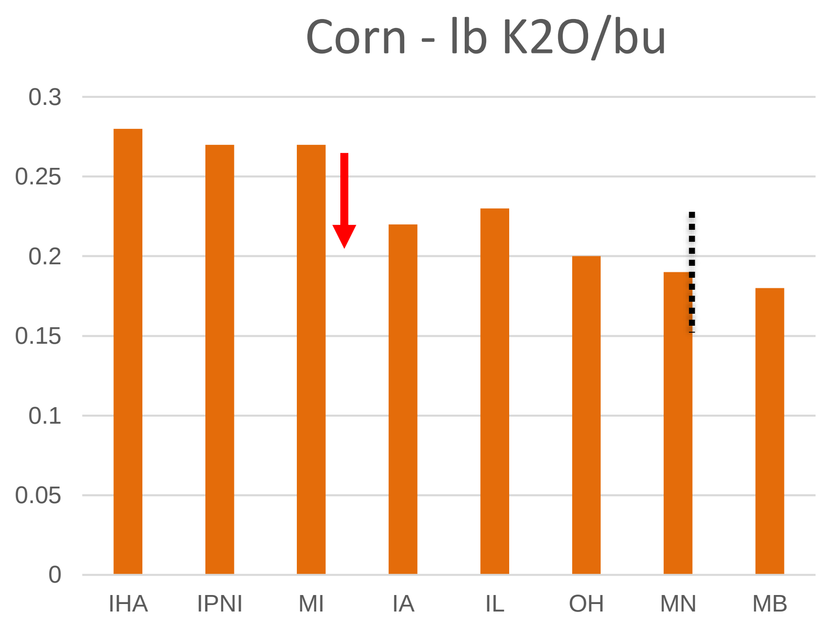
Fertilizer source	Median	Range
Phosphate (P2O5)	0.69 (lbs/bu)	0.62-0.74 (lbs/bu)
Potash (K2O)	1.1	1.04 -1.15

https://extension.umn.edu/crop-specific-needs/fertilizing-corn-minnesota#maintenance-based-p-and-k-strategies-2239912

P and K removal in Corn

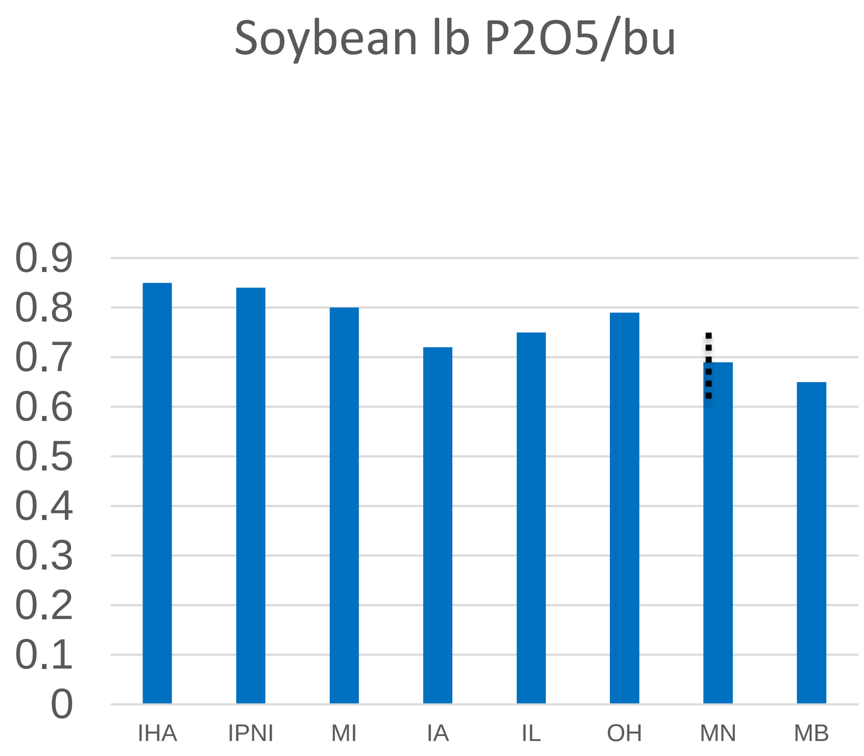


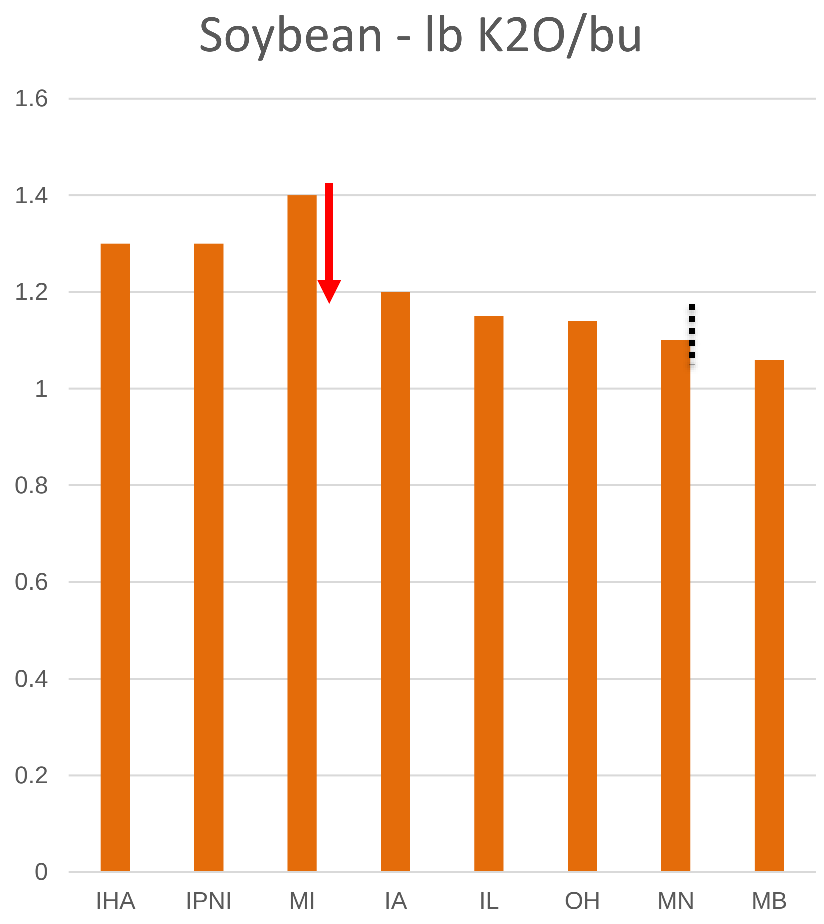
26% P
32% K



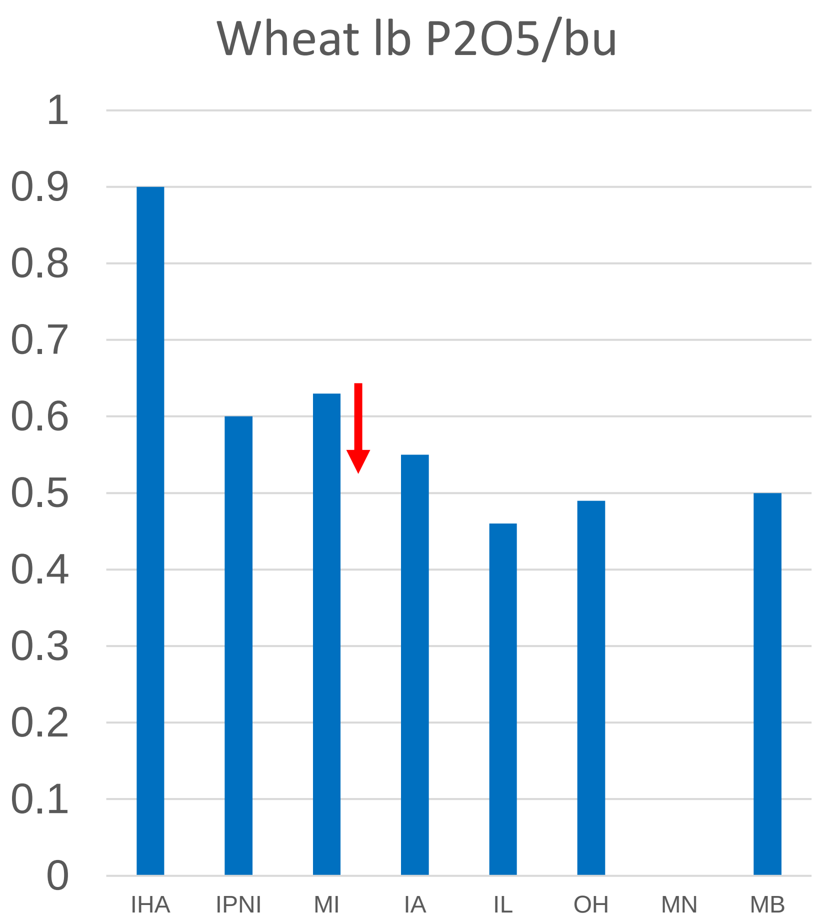
P and K Removal in Soybeans

20% P
15% K

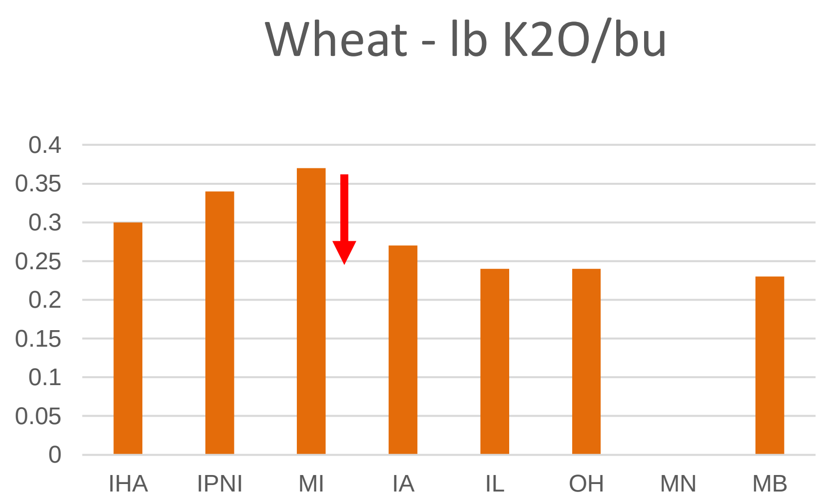


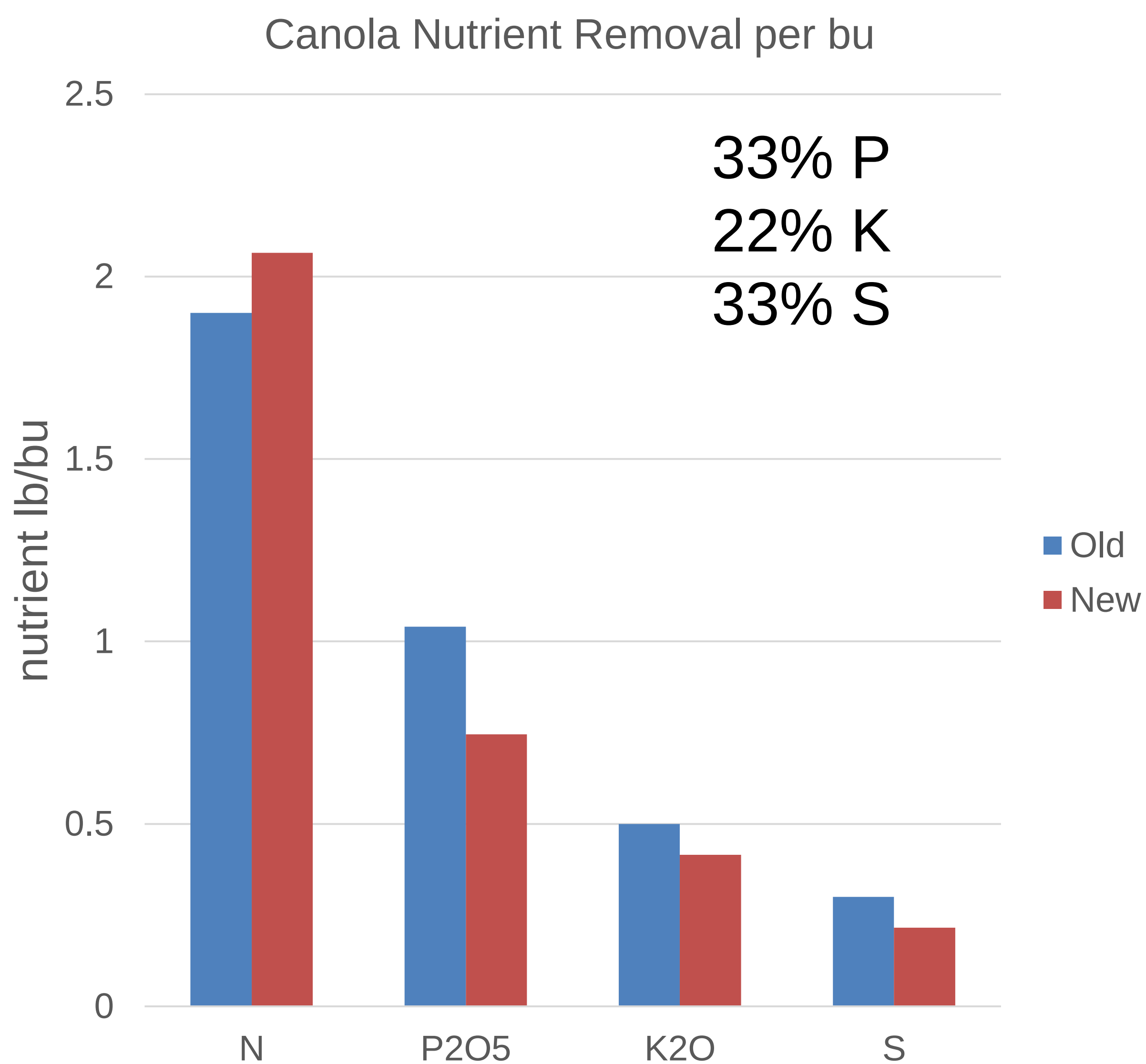


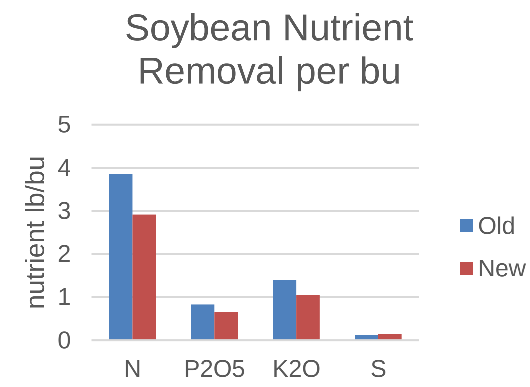
P and K removal in Wheat

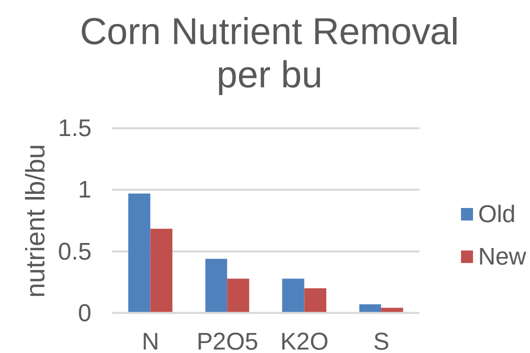


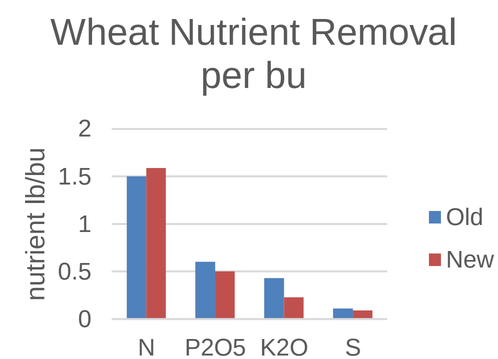
16% P
30% K











https://umanitoba.ca/faculties/afs/agronomists_conf/media/Poster_-_Heard_2.pdf

MB Evaluation – 2019 to validate historic numbers

Western Canada project led by U of SK to analyze nutrient uptake and removals of prairie grain.

	MB	SK	AB
Barley			
Canola			
Chickpea			
Corn			
Lentil			
Oats			
Soybean			
Field pea			
Flax			
Mustard			
Spring wheat			
Durum wheat			
Winter wheat			
Dry beans			

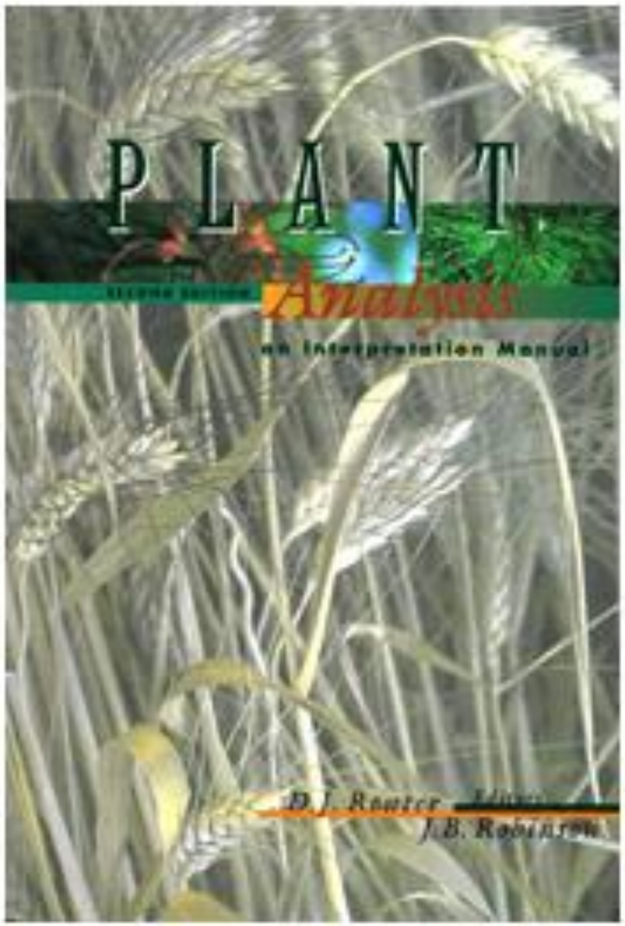
Current values are based largely on research site data, and not from farm fields, and do not represent the full geography of western Canada, or current crop varieties.

Crop yields continue to trend upwards due to changes in management (reduced till) & improved genetics.

With the development of new crop varieties with enhanced yield potential and different genetics, the nutrient uptake demands have changed over time.

Our goal is to develop new estimates for crop nutrient uptake and removal based on <u>crops grown under typical farm conditions</u>.

Is seed nutrient concentration useful as a diagnostic tool of deficiencies? Rarely.



Common benchmark uses wheat protein to indicate N sufficiency for yield
HRS = >13.2-13.5% indicates sufficient N for full yield (Racz)
HRW = >11.5% (Goos)

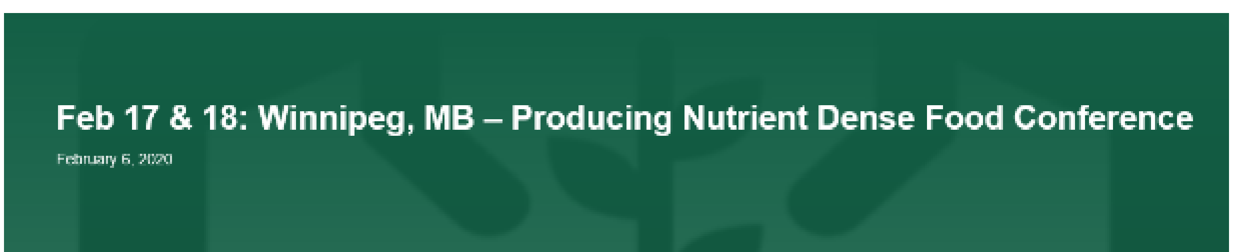
Most of the critical or deficient values listed in "Plant Analysis: An Interpretation Manual" now fall within the normal range of current crops.

Nutrient	Corn	Soys
N%	1.5%	6.14%
P%	0.28%	0.33%
K%	0.36%	1.74%
S%	0.17%	-
Mn ppm	5	13
Zn ppm	-	23

Are reductions in nutrient concentration a problem?

No – a sign of success!
Full yield expression and carbohydrate accumulation.

Despite what you might read on the internet.



If you are doing this yourself (AgVise will analyse)

- Correct for moisture
- Analysis is on dry basis, grain is at 15.5% moisture (for corn)
- Convert P x 2.28 = P_2O_5,

and K x 1.2 = K_2O

Nutrient Removal Values

Will change if we measure:

- Corn – P and K concentration/bu 26% & 32% less
- Soybeans = 20% & 15% less
- Wheat = 16% & 30% less
- Canola = 33% & 22% less
- Impact on "maintenance and build calculations"
- Important in maintaining productive fertility levels
  - yield increases are still bigger than these reductions in concentration
- Manure regulations? (P based rates, 1000 to 1500 ac)

Questions

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