BRITISH COLUMBIA | Ministry of Agriculture

Intro to Agricultural Soils

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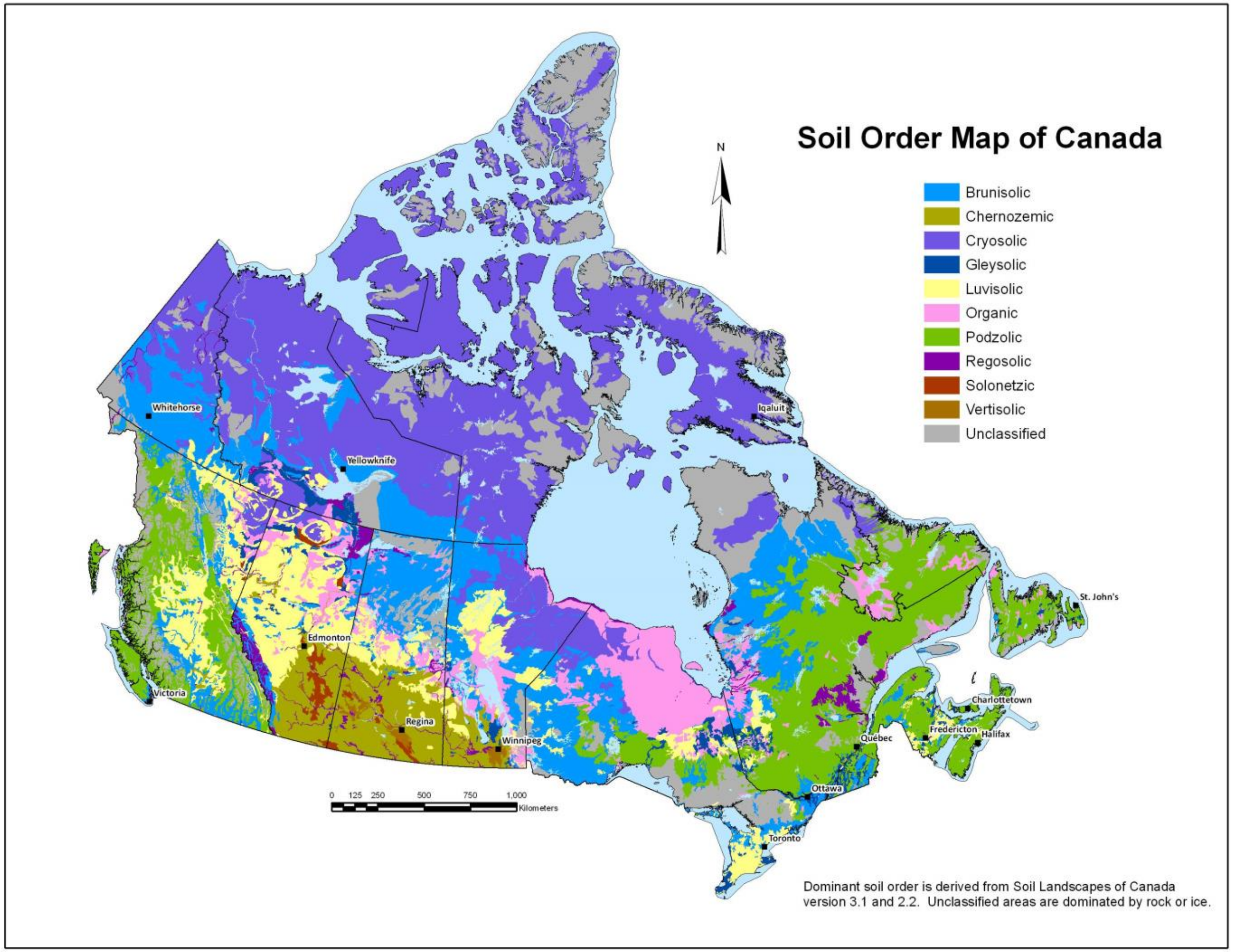
BC Ministry of Agriculture

Introduction

- Soil is the mineral layer between the surface and bedrock
- Formed through many different processes:
  - Climate
  - Parent material
  - Topography
  - Relief
  - Organisms

SOIL



soilsofcanada.ca

Introduction

- More than just a zone and a classification
  - Focal point of human activities - we are highly dependent on processes in soils
  - If left alone, many soils would be unproductive
- Soil is managed to improve agricultural production
  - Greater yields
  - Improved nutrient use efficiency
  - Better fruit/fiber quality
- Important to know about soil and soil processes
  - Helps to inform management decisions to improve agricultural production and maintain/improve soil viability

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Outline

1. Soil texture
2. Soil bulk density
3. Soil water
4. Cation exchange capacity
5. pH
6. Nitrogen
7. Phosphorus
8. Organic matter
9. Soil testing

All influenced by the physical, chemical, and biological processes in soils - not exclusively one process

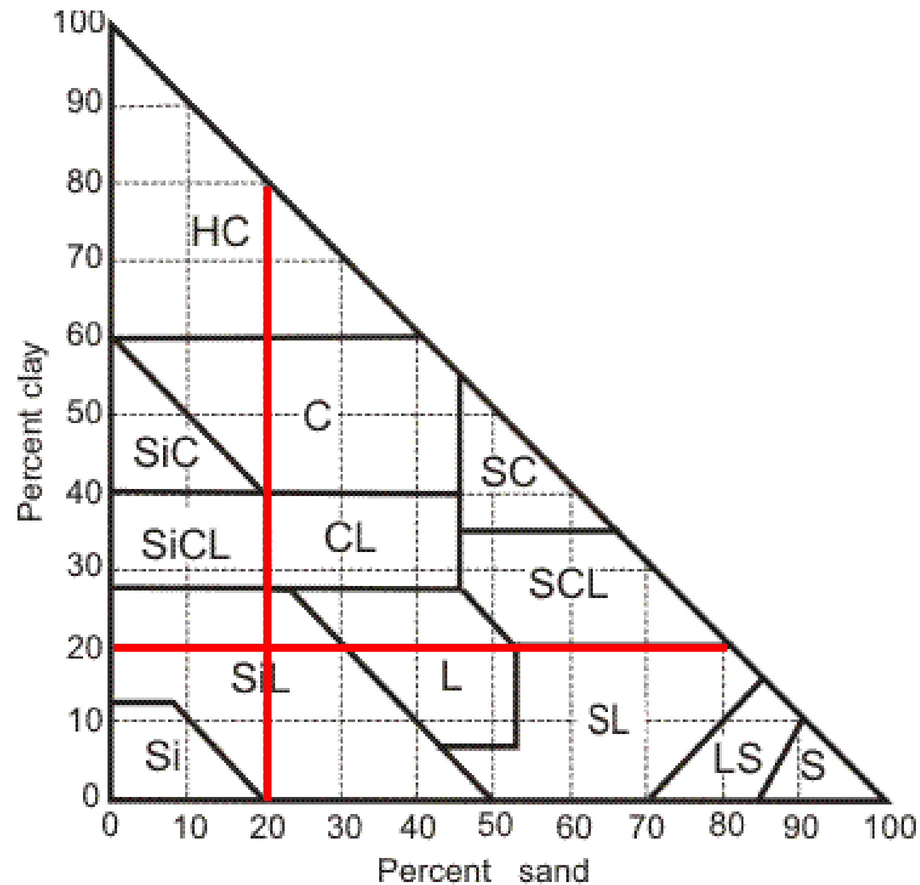
All influence one another

Soil texture

- Soil texture is the distribution of soil particles based on size
- One of the most important factors affecting soils because it also affects other soil properties, such as:
  - Soil structure
  - Water holding capacity
  - Plant available water
  - Soil bulk density
  - Cation exchange capacity

Soil physical properties

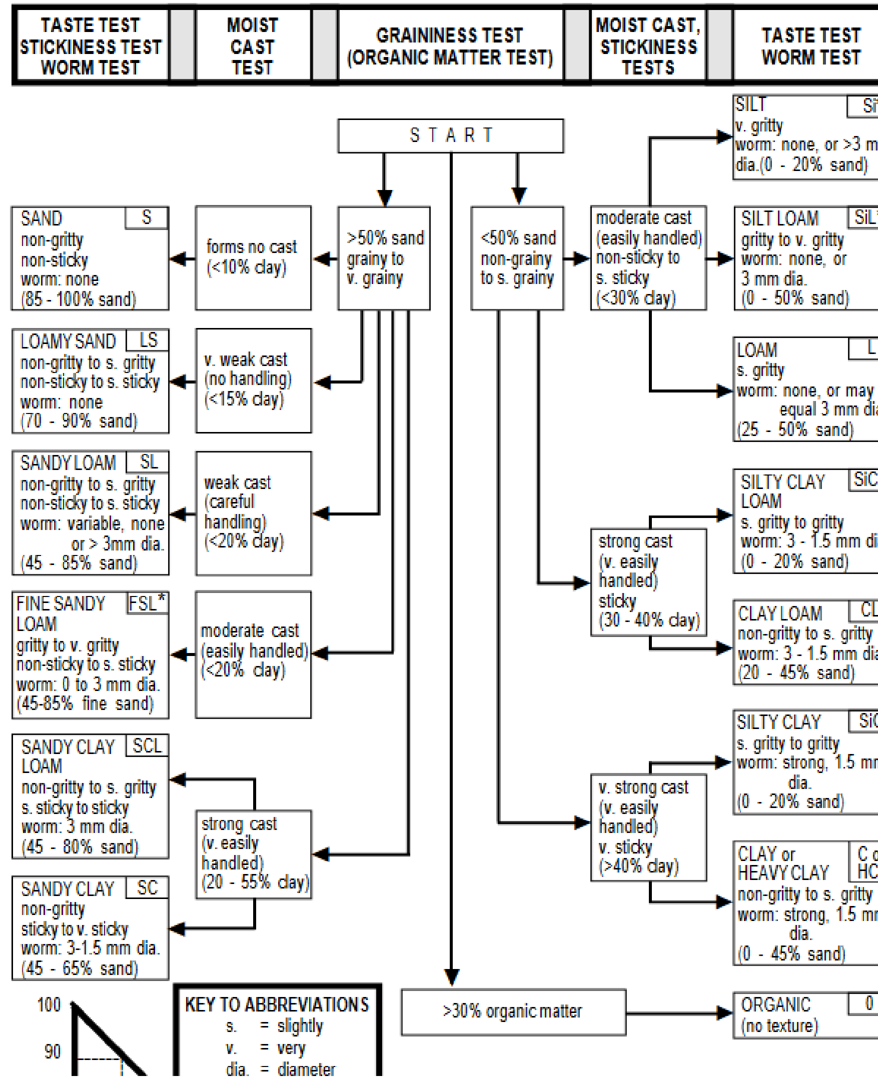
- Soil textural triangle
  - Based on the size of soil particles
  - Classification is based on the proportions of sand, silt, and clay
- Determining soil texture
  - *Pipette* and *hydrometer* methods in the lab
  - Field methods
    - Not exact, but usually pretty close
    - “If you have four soil scientists, you’ll end up with five opinions”



ESTIMATING SOIL TEXTURE IN THE FIELD

https://www.for.gov.bc.ca/isb/forms/lib/fs238.pdf

- The field determination of soil texture is subjective and can only be done consistently with training and experience. The field tests, outlined below, are used in sequence with the accompanying flow chart to assist in the field determination of soil texture:
  1) **Graininess Test:** Rub the soil between your fingers. If sand is present, it will feel "grainy". Determine whether sand comprises more or less than 50% of the sample.
  2) **Moist Cast Test:** Compress some moist soil by clenching it in your hand. If the soil holds together (i.e., forms a "cast"), then test the durability of the cast by tossing it from hand to hand. The more durable it is, the more clay is present.
  3) **Stickiness Test:** Wet the soil thoroughly and compress between thumb and forefinger. Degree of stickiness is determined by noting how strongly the soil adheres to the thumb and forefinger upon the release of pressure, and how much it stretches. Stickiness increases with clay content.
  4) **Worm Test:** Roll some moist soil between the palms of your hands to form the longest, thinnest worm possible. The more clay there is in the soil, the longer, thinner and more durable the worm will be.
  5) **Taste Test:** Work a small amount of soil between your front teeth. Silt particles are distinguished as fine "grittiness", unlike sand which is distinguished as individual grains (i.e., graininess). Clay has no grittiness at all.

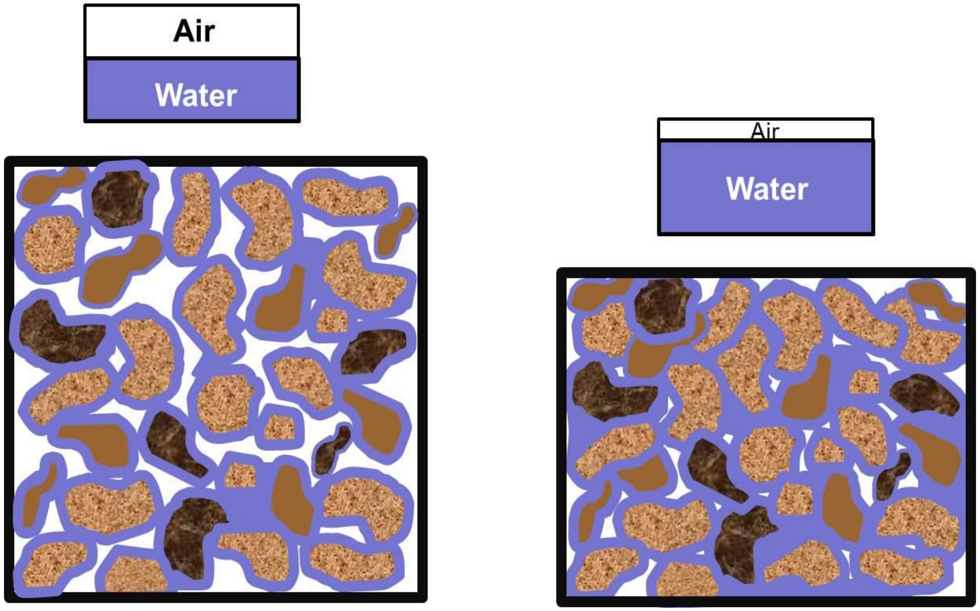


Soil bulk density

- The amount of soil in a given area
  - Generally given in units of kg/m^3 or g/cm^3
  - Clays generally have the lowest bulk densities
- Bulk density is inversely related to porosity
  - If soil is packed tightly, there is less space for air and water
  - However, if soil is loose then there is more pore space
- High bulk densities can be a sign of compacted soil
  - Difficult for plant roots to grow

Soil bulk density

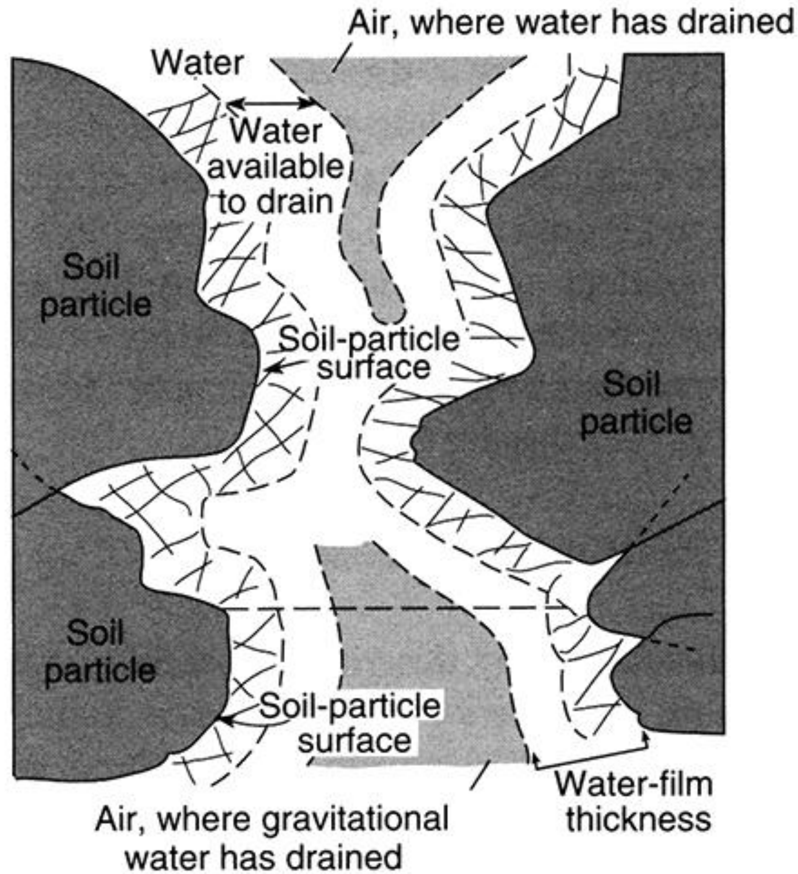
- Managing soil bulk density and compaction
  - Tillage can temporarily reduce bulk density near the soil surface
    - Beware tillage pans!
  - Maintaining a healthy crop or cover crop for long term reductions in compaction
    - Root growth, soil organisms
  - Improving soil organic matter reduces bulk density in the long-term



University of Minnesota Extension

Soil water

- The amount of water that soil can hold is mainly dependent on soil texture
  - Clay soils hold the greatest amount of water, sandy soils hold the least
  - Soil water coats the surface of soil particles, so those with the greatest surface area can hold the most water



Kansas Geological Survey Bulletin 239

Soil water

- *Plant available water* is a better tool for agricultural producers
  - The amount of soil water that is available for plant uptake
- Which soil texture has the greatest amount of plant available water?
  - Sands don’t hold much water when wet, need more frequent additions of irrigation
  - Clays hold water more tightly than plants can access when the soil is dry
  - Loams actually have the most PAW

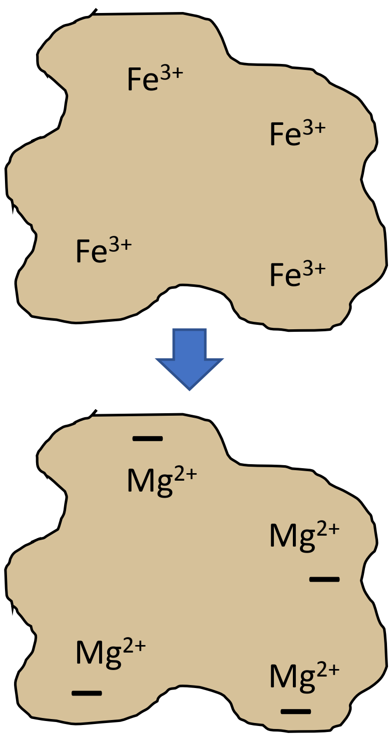
Soil water

- Increasing plant available water
    - Avoid compaction
        - Keep soil surface covered
        - Keep heavy equipment off of soil
        - Don’t work in the soil if it is too wet
    - Reduce compaction
        - SOM additions
        - Tillage

Department of Agriculture and Food Western Australia

Cation exchange capacity (CEC)

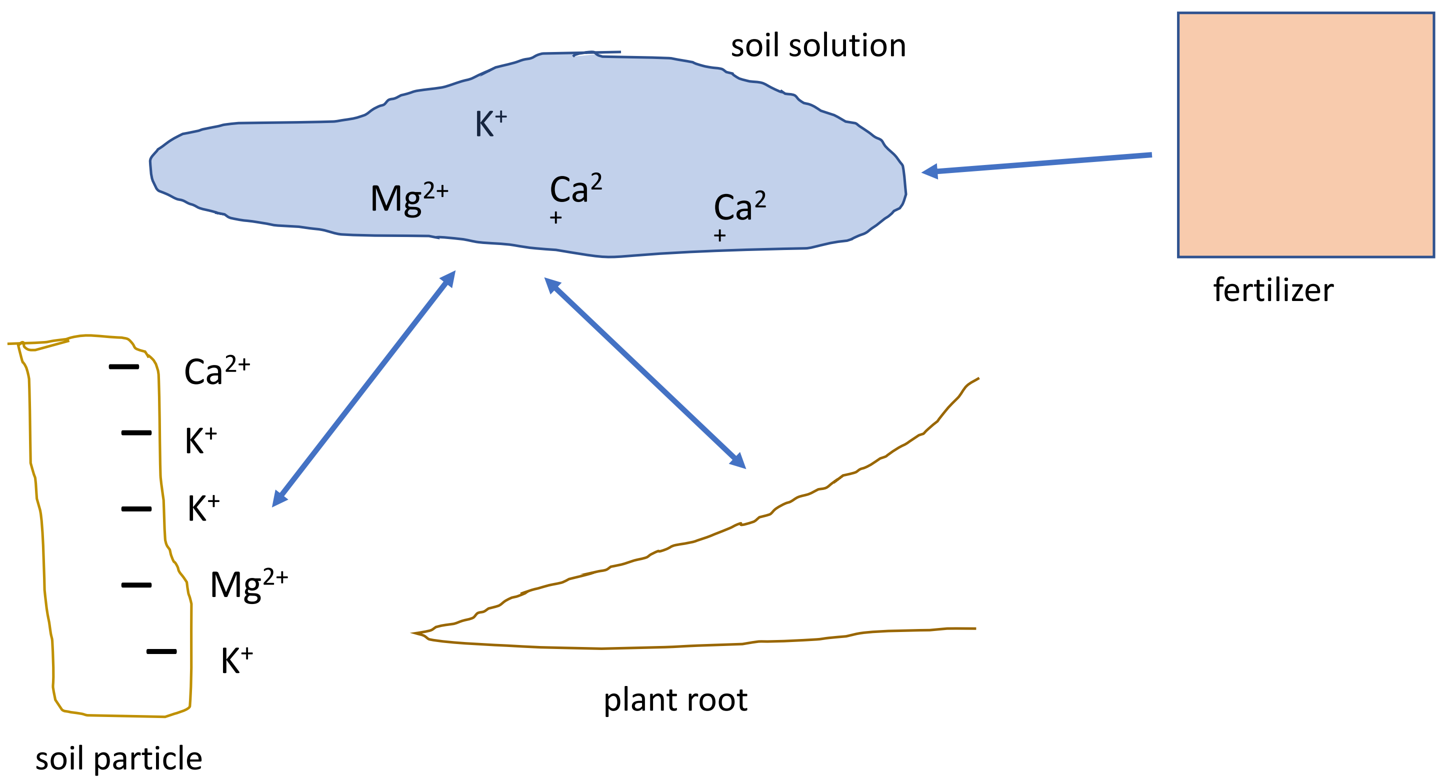
- Soils have a permanent negative charge
    - Due to a process called *isomorphic substitution*
    - When positively charged ions (cations) that make up soil particles are replaced by other ions that have a lesser positive charge
    - For example, iron (3+ charge) is replaced by magnesium (2+) charge



Cation exchange capacity (CEC)

- The surface areas of the soil particles where a negative charge exists is called a *cation exchange site*
- CEC: The ability of a soil to exchange cations, generally measured in meq/100 g soil or cmol/kg soil
  - How many negative charges in soil particle
- Cations: positively charged nutrients and ions
  - Cations essential for plant growth:
    - K^{+}
    - Ca^{2+}
    - Mg^{2+}
    - NH^{4+}

Cation exchange capacity (CEC)



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Cation Exchange Capacity (CEC)

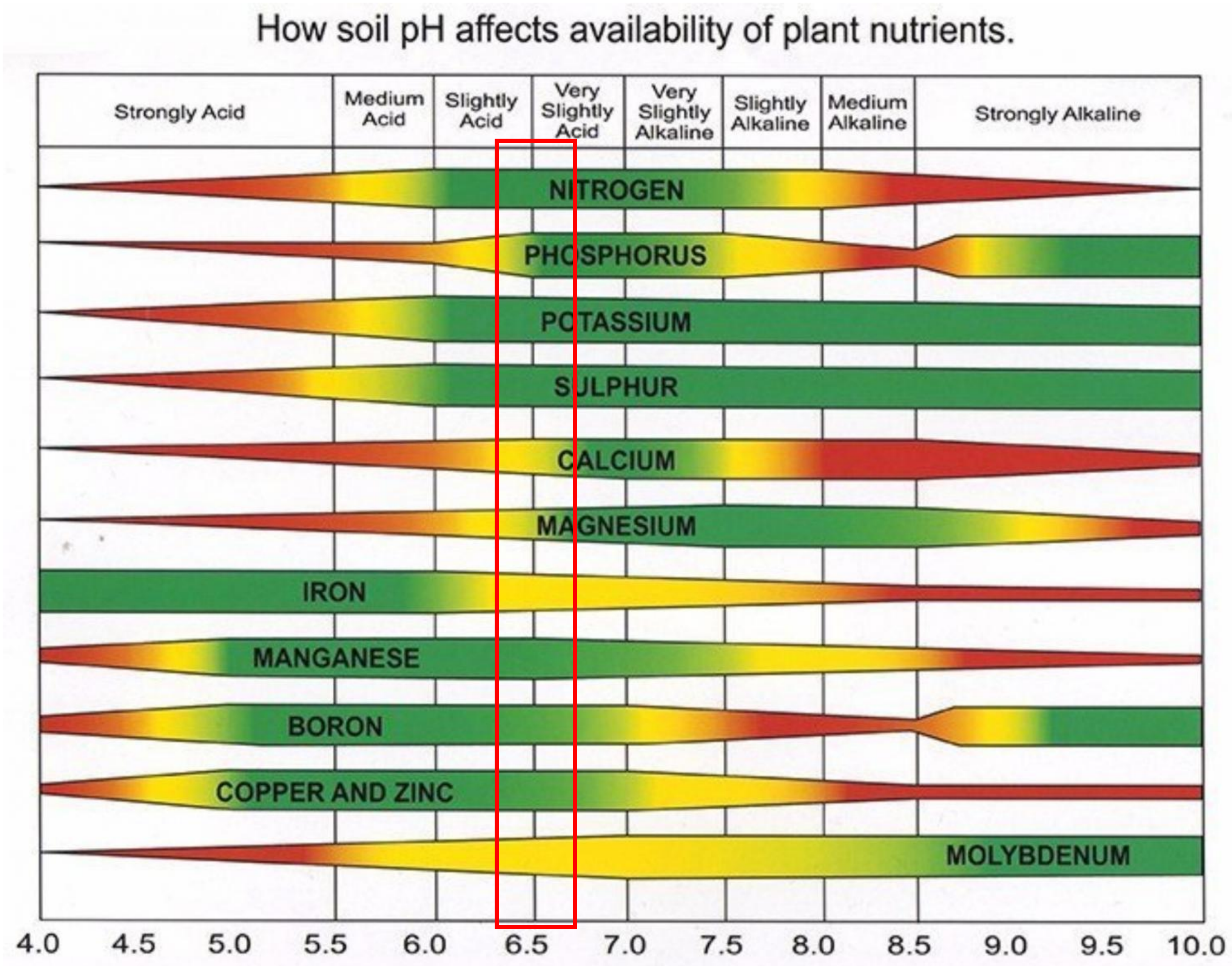
- Generally, clay soils have the greatest CEC due to greatest amount of surface area
  - Lowest in sandy soils
- Also depends on the type of clay mineral in a soil
  - Depends on parent material and weathering
    - Tropic soils vs. recent glacial till
  - Very weathered clays can lose their negative charge and become unproductive

Cation exchange capacity (CEC)

- Managing cation exchange capacity
  - Generally a function of soil texture and type of clay mineral
  - However, adding soil organic matter through organic matter additions can increase CEC
    - Soil organic matter (SOM) is the same size of clay particles and have a greater CEC
    - Organic matter has other soil benefits - more on that later!

Soil pH

- pH is the acidity or basicity of a soil
  - Measured as the negative log of the H+ ion concentration
  - 0 - 6.5: acidic, 6.5 - 7.5: neural, 7.5 - 14: basic
  - Most agricultural soils range from 4.5 to 6.5
  - Can be basic depending on additions and soil parent material
- Affects the availability of soil nutrients
  - Solubility, adsorption



SOURCE: https://www.emporiumhydroponics.com/what-is-ph-1-to-14

Soil pH

- Why are most agricultural soils acidic?
  - Rainfall is mildly acidic due to dissolved CO_2 in water droplets
  - Process of nitrification
    - Conversion of ammonium to nitrate
    - Releases H^+ ions
    - Manures, urea fertilizers, ammonium fertilizers will all eventually lead to a net acidification of soil

Soil pH

- Managing pH
  - Lime is used to raise soil pH
    - Calcitic lime - calcium carbonate
    - Dolomitic lime - calcium and magnesium carbonate
  - Lime has low solubility
    - Should be applied in fall to be ready for spring
    - Should be incorporated in soils that are cultivated

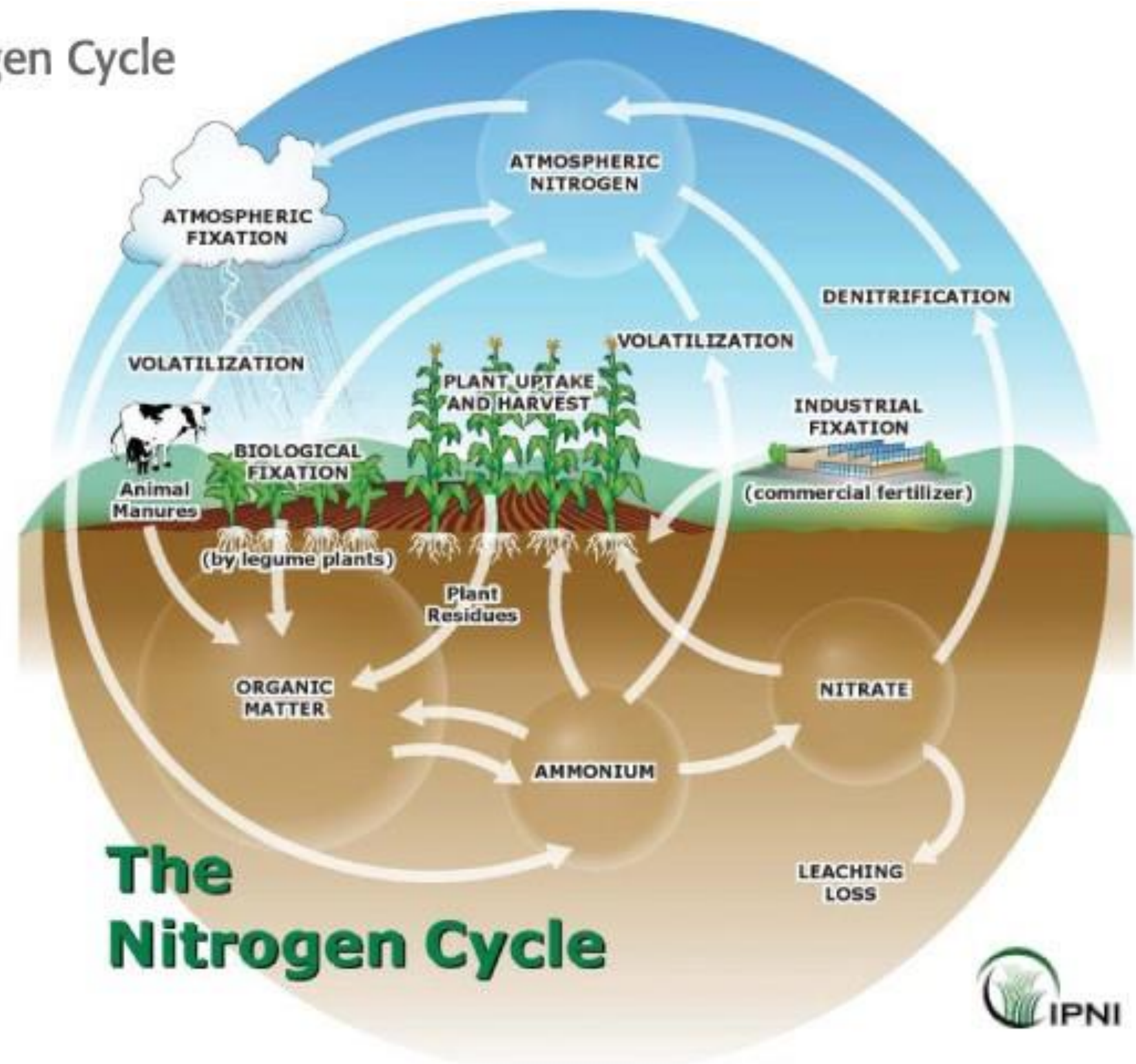
Soil pH

- Managing pH
  - How much lime to apply?
    - Soil tests generally report the Lime Buffer Capacity (LBC) - can be requested
    - Amount of lime necessary to change the pH by 1 unit, such as from pH 5.0 to 6.0
    - Based on the buffering capacity of the soil
      - Higher in clays, lower in sands
    - Generally between 1 and 4 tons of lime per acre

Soil pH

- Managing pH
  - Lowering pH
    - Rarely has to be done in agricultural soils
    - Generally in soils whose parent material is limestone - calcium carbonate
    - Addition of elemental sulphur or aluminum
      - Sulphur - biological process
      - Aluminum - chemical process

Nitrogen Cycle



Soil nitrogen

- Nitrogen (N) is cycled through biological processes
  - Agricultural soils - bacteria
  - Forest soils - fungi and bacteria
- Needed in the greatest concentrations in the plant of all supplemental nutrients (not C, H, O - found in air and water)
- N forms
  - Organic N: R-NH_3
  - Mineral/Plant available: Ammonium (NH_4^+) and Nitrate: NO_3^-

Soil nitrogen

- Mineralisation
  - Conversion of organic N into ammonium
    - From a plant-unavailable form to an available form
  - Also called ammonification
  - Conversion depends on the C:N ratio of the substance
    - Less than 30:1 - mineralisation
      - Urea, manure
    - Greater than 30:1 - immobilisation
      - Pine bark, wood chips
  - Raises soil pH

Soil nitrogen

- Nitrification
    - Conversion of ammonium to nitrate by soil bacteria
    - Very acidifying process
        - Greater effect than other N processes in soil
    - Since nitrate is negatively charged, it can leach through soil with water
        - Important to not apply N excessively
        - Nitrate in water causes health problems - interferes with oxygen carrying capacity of the blood

Soil nitrogen

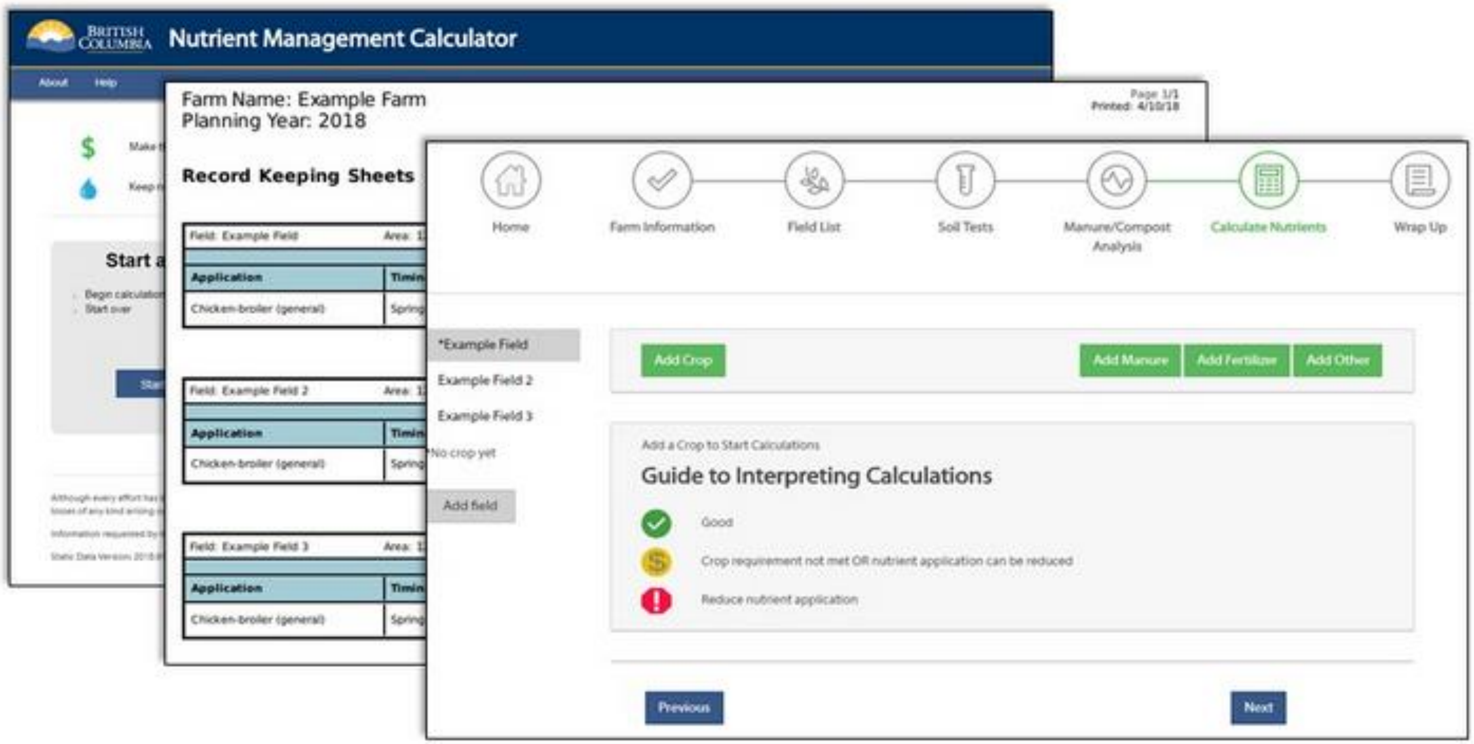
- Managing mineralisation and nitrification
  - Two factors influence the mineralisation rate of materials the most: temperature and moisture
  - Increases with increasing moisture up to field capacity
    - Above field capacity, soil bacteria don't have enough access to oxygen
  - Increases with increasing temperature
    - Highest at 25-35C
    - Decreases at higher temperature

Soil nitrogen

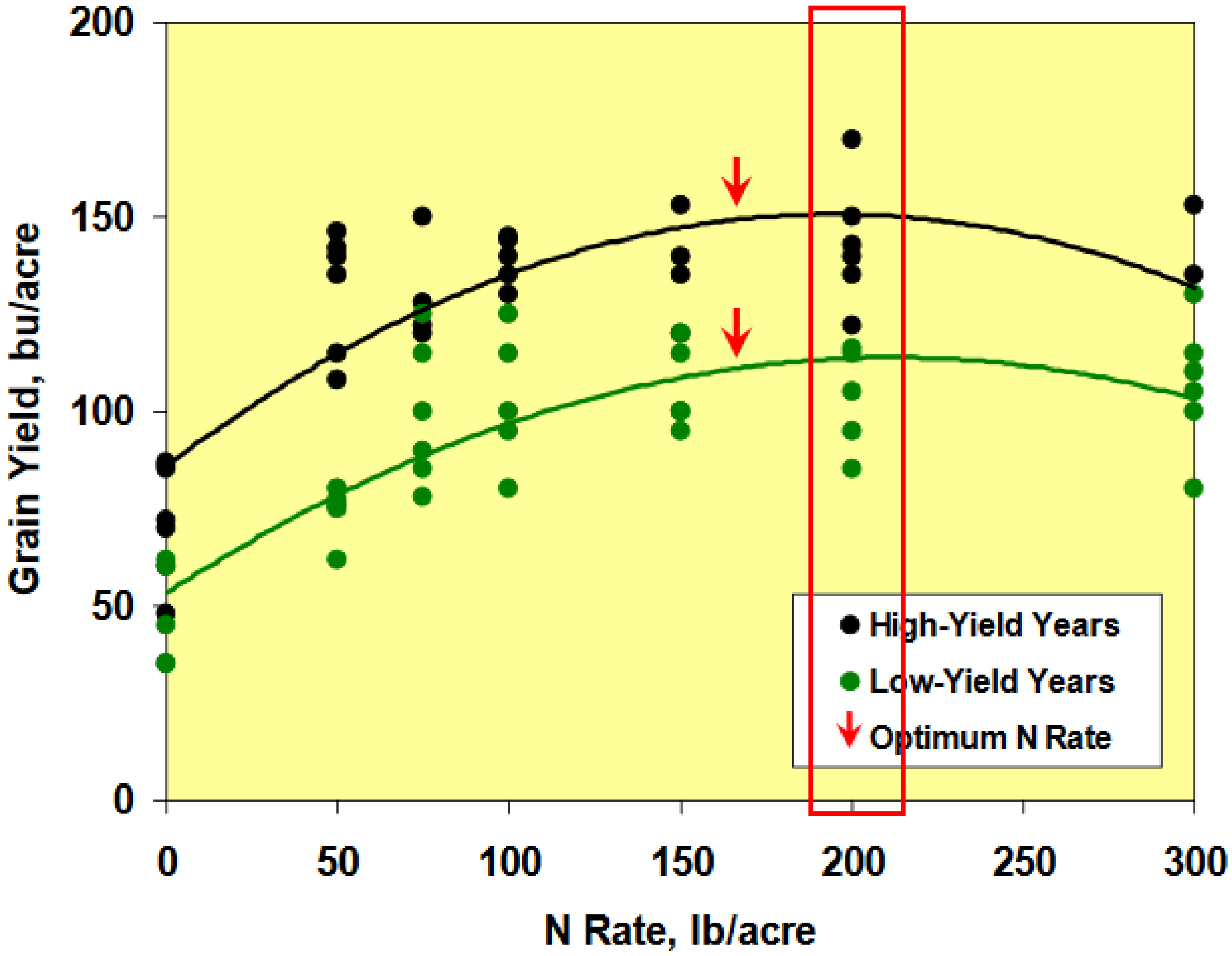
- Immobilisation
  - Uptake of mineral N (ammonium and nitrate) by bacteria to break down a substance with a high C:N ratio (> 30:1)
  - Less N available for plant uptake
    - Best not to apply certain materials during early plant growth when N demand by the plant is high
  - Materials
    - Sawdust
    - Bark
    - Wood chips

Soil nitrogen

- N budgeting - Nutrient Management Calculator

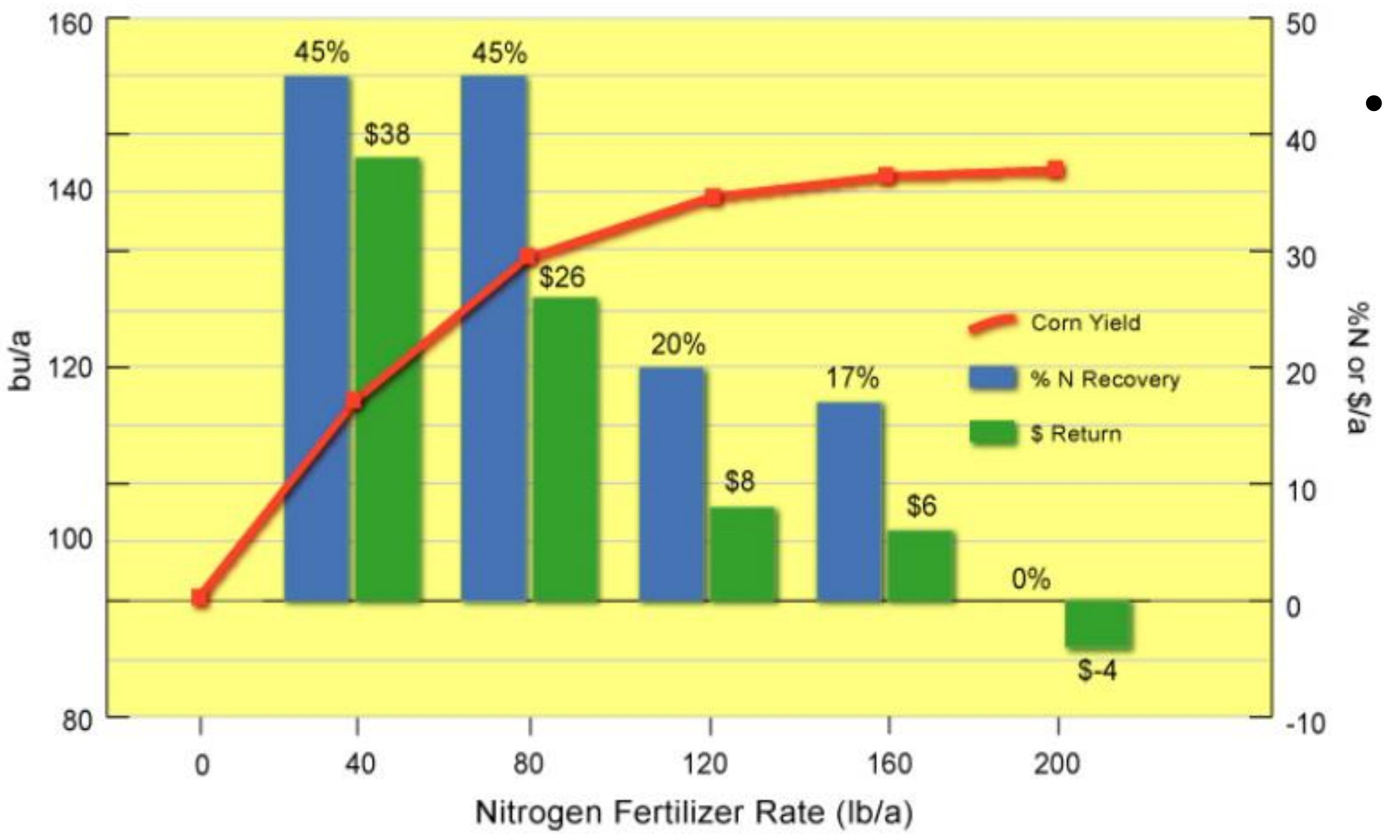


Soil nitrogen - managing N applications



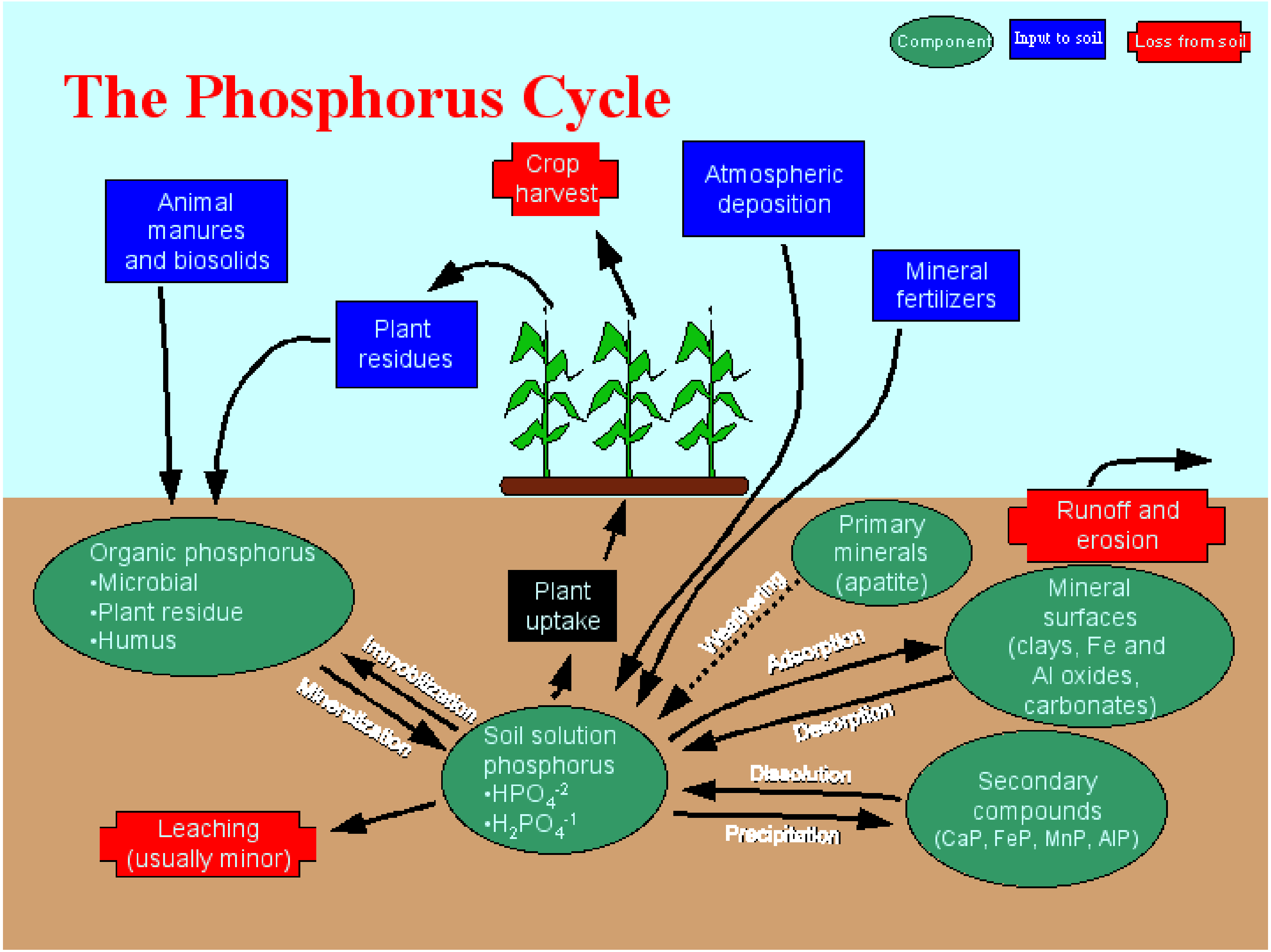
University of Wisconsin Extension

Soil nitrogen - managing N applications



University of Wisconsin Extension

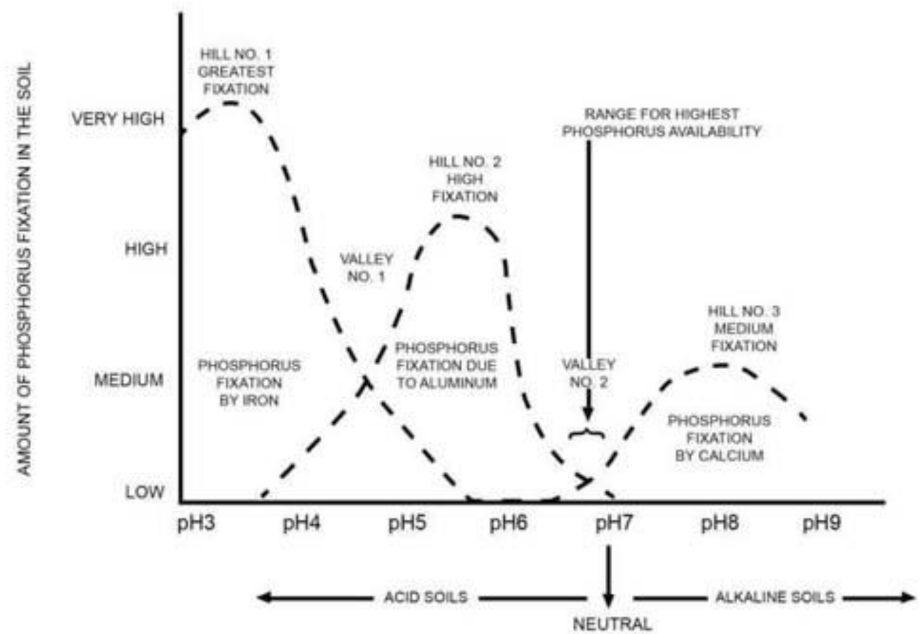
- Apply N until the return ($) on the increase in yield is less than the cost of increased fertilization



Mississippi State University Extension

Soil phosphorus

- Not needed in large concentrations in plant compared to N and K
  - Usually < 1%
- Availability is a limiting factor to plant P uptake
  - Fixation and adsorption processes
  - Most available around pH 6.5



Michigan State University

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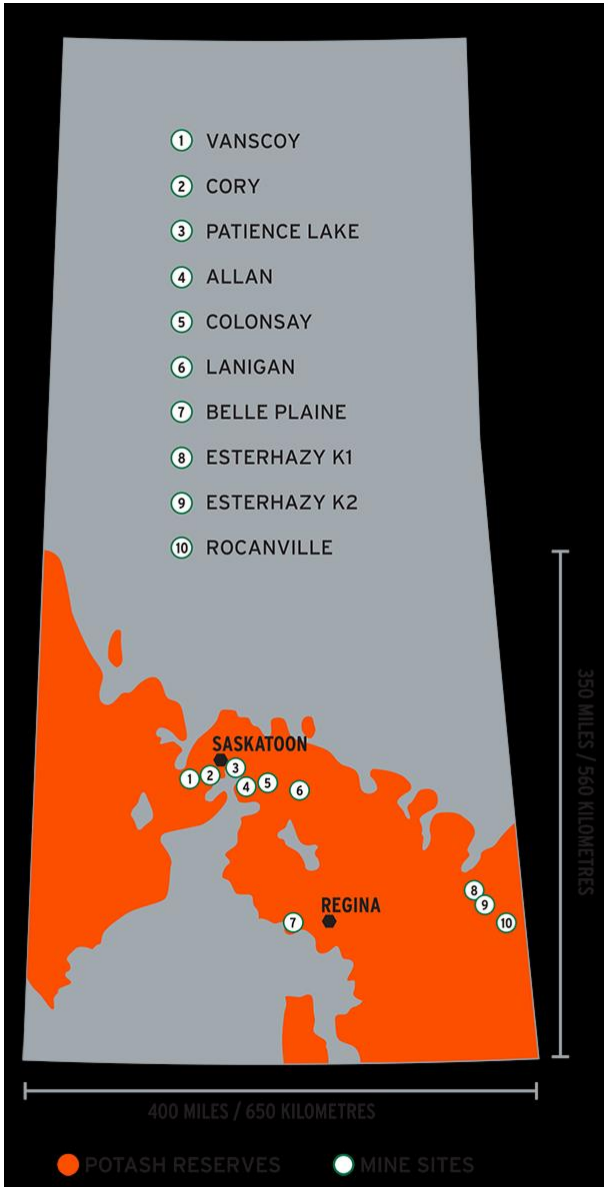
Soil phosphorus

- Most P fertilizers come from rock phosphate
  - Primary mineral, mined
    - World’s largest reserves - Saskatchewan
- Organic P
  - Mineralisation at C:P ratio of < 200:1
  - Immobilisation at C:P ratio of > 300:1



Canpotex

Soil phosphorus

- Soil test P
  - Soil P is tested using a soil extractant - chemical used to mimic root exudates by plants to uptake nutrients
    - Used for many plant nutrients: P, K, Ca, Mg, S, Zn, etc.
  - Most P in soil is unavailable
    - Purpose of extractant is to extract the P that is available to the plant
      - Not total P
  - Many different types
    - Kelowna, Mehlich III, Bray, Olsen, etc.

N and P environmental impacts

- N
  - Main issue - leaching of nitrate into groundwater
- P
  - Loss of P into surface water causes algal bloom that removes oxygen from water and kills aquatic wildlife
    - P lost as soil erosion
    - P lost in manure as runoff
      - Bacterial issues
    - If using manure, P requirement should be met with manure and supplemented with N fertilizer

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Soil organic matter

- What is soil organic matter (SOM)?
    - Highly decomposed particles of organic matter in a soil
    - High in carbon
        - Source of food for soil organisms, causes SOM to be broken down
    - Very small particle size - similar to clay soil particles
    - Organic matter additions will build SOM
    - Many soil benefits

Soil organic matter

- Benefits of soil organic matter
  - Increased water holding capacity
  - Increased CEC
  - Improved soil structure
  - Decreased soil bulk density
  - Source of N - up to 40 lb/ac/yr
  - Improved soil microbial activity

IMPROVED CROP GROWTH AND YIELD

Soil organic matter

- Building SOM
    - Organic matter additions
        - Be mindful of C:N ratio, not during peak crop growth when nutrient requirements are high
    - Reduced tillage
        - Aerification of soil increases microbial breakdown of SOM
    - Alternatively, incorporation of organic materials into soil

Oregon State University

Soil organic matter

- Common organic amendments:
  - Garden compost
  - Leaves from deciduous trees
  - Crop residues
  - Manure and composted manure
- Request a laboratory analysis if purchasing or accepting composted materials
  - OSU - Improving Garden Soils with Organic Matter

Table 1. Estimating the volume of organic amendment needed.

Depth of amendment desired (inches)	Area of garden (square feet)*			
	200	500	1,000	2,000
	Organic material to add (cubic yards)			
1	0.6	1.5	3.1	6.2
2	1.2	3.1	6.2	12.3
3	1.9	4.6	9.3	18.5
4	2.5	6.2	12.3	24.7

*To estimate square footage of a garden, multiply the length by the width (in feet).

Oregon State University

Soil testing

- Samples taken from 0-15 cm (6”) depth from sites throughout the field
  - If fertilizer is broadcast applied, take 15-20 samples from random locations
  - If fertilizer is banded, take 30-40 samples from random locations
- Sampled areas should have the same crop, management (fertilizer rates, tillage, etc.), and soils
  - If not, take different samples
- Mixed thoroughly in a plastic bucket and send to the lab
  - Nutrient Testing Laboratories

Soil testing

Report Number: C16307-10001
Account Number: 05219

A & L Canada Laboratories Inc.

2136 Jetstream Road, London, Ontario, N5V 3P5
Telephone: (519) 457-2575 Fax: (519) 457-2664

C16307-10001

Reported Date:2016-11-07 Printed Date:Nov 8, 2016

SOIL TEST REPORT

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Sample Number	Legal Land Descpt:	Depth	Lab Number	Organic Matter	Phosphorus - P ppm Bicarb	Phosphorus - P ppm Bray-P1	Potassium K ppm	Magnesium Mg ppm	Calcium Ca ppm	pH	Buffer pH	CEC meq/100g	% K	% Mg	% Ca	% H	% Na
T311A		6	47733	3.9	52 G	154 H	276 VH	305 H	1800 M	7.2		13.1	5.4	19.4	68.8	4.5	1.8
T311B		12	47734	2.0	34 M	78 M	132 M	250 H	1400 M	7.2		10.2	3.3	20.5	68.9	4.5	2.8
T311C		24	47735	1.2	28 M	54 M	81 M	255 M	2380 H	7.8		14.6	1.4	14.6	81.7		2.4
T311D		36	47736	1.0	31 G	48 M	66 L	315 L	4680 VH	8.0		26.6	0.6	9.9	88.0		1.6

Sample Number	Sulfur S ppm		Sulfur S lbs/ac	Nitrate Nitrogen NO3-N ppm		Nitrate Nitrogen NO3-N lbs/ac	Zinc Zn ppm	Manganese Mn ppm	Iron Fe ppm	Copper Cu ppm	Boron B ppm	Soluble Salts mmhos/cm	Saturation %P	Aluminum Al ppm	Saturation %Al	K/Mg Ratio	ENR	Chloride Cl ppm	Sodium Na ppm
T311A	23	VL	41	36	H	65					0.5 L		32 H	624	0.1 G	0.28	51		54 H
T311B	24	L	43	26	H	47							15 H	674	0.1 G	0.16	32		66 VH
T311C	31	L	112	25	H	90							4 L	552	0.0 G	0.10	24		81 VH
T311D	87	VH	313	16	M	58							4 M	239	0.0 G	0.06	22		99 H

W VL = VERY LOW, L = LOW, M = MEDIUM, H = HIGH, VH = VERY HIGH, G = GOOD, MA = MARGINAL, MT = MODERATE PHYTO-TOXIC, T = PHYTO-TOXIC, ST = SEVERE PHYTO-TOXIC

SOIL FERTILITY GUIDELINES (lbs/ac)

- Look at pH
    - Do I need to raise or lower pH? Best done in fall

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SOIL FERTILITY GUIDELINES (lbs/ac)

- CEC and Base Saturation?
    - Not particularly helpful unless you have a sodic soil - high in sodium

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(% K, % Mg, % Ca, % H, % Na: Percent Base Saturations)

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SOIL FERTILITY GUIDELINES (lbs/ac)

- Nitrate-Nitrogen
  - Available to plant
  - Lab assumes soil bulk density to calculate lbs N/ac
    - Fine unless you have a compacted soil or soil with high soil organic matter

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Sample Number	Legal Land Descpt:	Depth	Lab Number	Organic Matter	Phosphorus - P ppm Bicarb	Phosphorus - P ppm Bray-P1	Potassium K ppm	Magnesium Mg ppm	Calcium Ca ppm	pH	pH Buffer	CEC meq/100g	Percent Base Saturations % K	% Mg	% Ca	% H	% Na
T311A		6	47733	3.9	52 G	154 H	276 VH	305 H	1800 M	7.2		13.1	5.4	19.4	68.8	4.5	1.8
T311B		12	47734	2.0	34 M	78 M	132 M	250 H	1400 M	7.2		10.2	3.3	20.5	68.9	4.5	2.8
T311C		24	47735	1.2	28 M	54 M	81 M	255 M	2380 H	7.8		14.6	1.4	14.6	81.7		2.4
T311D		36	47736	1.0	31 G	48 M	66 L	315 L	4680 VH	8.0		26.6	0.6	9.9	88.0		1.6

Sample Number	Sulfur S ppm		Sulfur S lbs/ac	Nitrate Nitrogen NO3-N ppm		Nitrate Nitrogen NO3-N lbs/ac	Zinc Zn ppm	Manganese Mn ppm	Iron Fe ppm	Copper Cu ppm	Boron B ppm	Soluble Salts mmhos/cm	Saturation %P	Aluminum Al ppm	Saturation %Al	K/Mg Ratio	ENR	Chloride Cl ppm	Sodium Na ppm
T311A	23	VL	41	36	H	65					0.5 L		32 H	624	0.1 G	0.28	51		54 H
T311B	24	L	43	26	H	47							15 H	674	0.1 G	0.16	32		66 VH
T311C	31	L	112	25	H	90							4 L	552	0.0 G	0.10	24		81 VH
T311D	87	VH	313	16	M	58							4 M	239	0.0 G	0.06	22		99 H

W VL = VERY LOW, L = LOW, M = MEDIUM, H = HIGH, VH = VERY HIGH, G = GOOD, MA = MARGINAL, MT = MODERATE PHYTO-TOXIC, T = PHYTO-TOXIC, ST = SEVERE PHYTO-TOXIC

SOIL FERTILITY GUIDELINES (lbs/ac)

- Look at extractants - P: Olsen (Bicarbonate) and Bray; K, Mg, Ca: Ammonium acetate - not listed, must research
  - Most recommendations in BC are using the Kelowna extractant
  - Also given in ppm?

Soil testing

Table 1. Relationships between soil test P extractants and the Kelowna extractant for British Columbia soils.

Kelowna-P = **0.74** * Bray-1 P	pH < 7.2	$r^2 = 0.96$
Kelowna-P = **1.00** * Bray-1 P	pH ≥ 7.2	$r^2 = 0.85$
Kelowna-P = **0.99** * Bicarbonate (Olsen) P	pH < 7.2	$r^2 = 0.99$
Kelowna-P = **1.21** * Bicarbonate (Olsen) P	pH ≥ 7.2	$r^2 = 0.96$
Kelowna-P = **0.72** * Mehlich-3 P	all pH values	$r^2 = 0.98$
Kelowna-P = **1.24** * Modified Kelowna-95 P[7]	all pH values	$r^2 = 0.96$

Table 2. Relationships between soil test K extractants and the Kelowna extractant for British Columbia soils.

Kelowna-K = **0.80** * Ammonium Acetate K	all pH values	$r^2 = 0.98$
Kelowna-K = **0.75** * Mehlich-3 K	all pH values	$r^2 = 0.99$
Kelowna-P = **0.76** * Modified Kelowna-95 K[7]	all pH values	$r^2 = 0.97$

- Convert to concentration using the Kelowna extractant
- BC Factsheet

Soil testing

- Look up fertility recommendations for your crop - [BC Factsheet]

Table 3. Recommended potassium (K_2O) applications based on soil test potassium (K) values for the Okanagan, Kootenays, Kamloops, Williams Lake and Quesnel

ppm*	Rating	K_2O recommended							
		kg/ha	lb/ac	kg/ha	lb/ac	kg/ha	lb/ac	kg/ha	lb/ac
0-25	VL	150	134	200	178	200	178	250	223
26-35	L-	100	89	150	134	200	178	250	223
36-50	L	80	71	100	89	200	178	250	223
51-65	L	60	54	80	71	150	134	250	223
66-80	L+	40	36	60	54	100	89	200	178
81-100	M-	30	27	40	36	80	71	150	134
101-125	M-	30	27	40	36	60	54	100	89
126-150	M	20	18	20	18	60	54	80	71
151-160	M+	20	18	20	18	40	36	60	54
161-175	M+	20	18	20	18	40	36	40	36
176-190	H-	0	0	0	0	40	36	40	36
191-220	H	0	0	0	0	0	0	40	36

Soil testing

- Last step - apply nutrients!
- 4Rs
  - Right time
  - Right place
  - Right source
  - Right rate

Questions?

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