APBI 200 March 13, 2020

Practice exam session #2

GROUP 1

Wood chips and grass clippings are both used as organic amendments in gardening.

Explain how wood chips (with its C/N= 400/1) and grass clippings (with its C/N=20/1) differ in terms of their capability to release plant-available forms of N in the soil.

GROUP 2

A soil has a pH 8.0 (as determined in a 0.01 *M* $CaCl_2$).

a) What can you infer about the extent to which the exchange sites of that soil are occupied by exchangeable aluminum? Explain.

b) What can you infer about the soil's base saturation of that soil? Explain.

c) Explain how base-forming cations contribute to base (or alkaline) soil pH.

[*Hint: 1st define soil pH determined in H_2O, in $CaCl_2$ and what they measure*]

GROUP 3

What soil properties enhance nitrate (NO_3^-) leaching losses from soil? Explain your answer.

GROUP 4

List and briefly describe three important roles of bacteria in the nitrogen cycle.

[Hint: consider input, transformation, and loss]

GROUP 5

(a) What is a chelate?

(b) What types of organic compounds form chelates in soils?

(c) What roles do chelates play in soils? Briefly explain importance of those roles.

GROUP 6

Recently, a soil map of the City of Vancouver (https://vancouversoils.ca/) has been developed and it includes 4 distinct soil management groups. Some of the properties of those 4 soil management groups are shown in Table 1 below.

What can you infer about capabilities of those 4 soil management groups for:

a) Nutrient supply and retention
b) Water retention
c) Drainage (i.e., movement of water through a soil profile)

Table 1. Key properties of the Ah horizons of 4 soil management groups encountered within the City of Vancouver, BC. Type of parent material on which these soil management groups have developed is also provided.

Property	Soil management group			
	Bose-Heron	**Whatcom-Scat**	**Langley-Cloverdale**	**Delta-Tsawwassen**
Textural class	Gravelly loamy sand	Silt loam	Silty clay	Silty clay loam
Soil pH	5.6–6.1	5.4–5.6	5.6–5.9	4.6–5.6
Organic matter (%)	2	7	1	1
CEC ($cmol_c$/kg)	15.3	40.1	30.4	21.5
Parent material	Ablation till & basal till	Glacio-marine	Marine	Alluvium

Answer keys

GROUP 1

Wood chips and grass clippings are both used as organic amendments in gardening. Explain how wood chips (with its C/N= 400/1) and grass clippings (with its C/N=20/1) differ in terms of their capability to release plant-available forms of N in the soil.

	Wood chips C/N=400/1	**Grass clippings C/N=20/1**
Chemical characteristics	Slow decomposition (commonly 10+ years). Full of recalcitrant (ie very stable) organic compounds (e.g. lignin, waxes, resin). Wide C/N ratio, much higher than 25/1, which guaranties adequate N supply to plants)	Narrow C/N ratio implies rapid decomposition and "excess" N available for plants Good for vegetable (annual crops) gardens as this material releases quickly nutrients such as N, S, P
Physical characteristics	Size of organic particles – large; hence, has low specific surface area, which further contributes (in addition to wide C/N ratio) to slow decomposition of this material. This material has good aeration	Size of organic particles – small; hence high specific surface area, which further contributes (in addition to narrow C/N ratio) to fast decomposition of this material
Additional comments	Not recommended to till into a garden with annual plants: wide C:N ratio → tie up soil N; best in perennial / shrub gardens	Fresh grass in thick layers will mat, produce foul odour (fermentation), reduces water infiltration, restrict gas exchange Apply as thin layers and allow to dry before application

<u>GROUP 2</u>

A soil has a pH 8.0 (as determined in a 0.01 *M* $CaCl_2$).

a) What can you infer about the extent to which the exchange sites of this soil are occupied by exchangeable aluminum? Explain.

b) What can you infer about the soil's base saturation of this soil? Explain.

c) Explain how base-forming cations contribute to base (or alkaline) soil pH.

<u>Reminder points:</u>

- Soil pH determined in H_2O measure active acidity (i.e. H^+ and Al^{3+} ions in soil solution)
- Soil pH determined in $CaCl_2$ measure active (H^+ and Al^{3+} ions in soil solution) plus exchangeable acidity (H^+ and Al^{3+} ions on exchange sites on soil colloids and easily exchanged by other cations present in soil solution)

(a) Since the soil pH determined in 0.01M $CaCl_2$ is alkaline (pH=8.0), one can infer that only limited number of exchange sites of this soil are occupied by Al^{3+} and H^+ ions

(b) Base saturation is the ratio of exchangeable Ca, Mg, K and Na (i.e. the base-forming) cations relative to total number of cations (ie CEC)

$$\%BS = \frac{\sum Ca + Mg + K + Na}{CEC} \times 100$$

NOTE - CEC: number of exchangeable cations which soil solids can adsorb (includes base-forming cations, H and Al)

Since pH of the soil in this example is alkaline, H^+ and Al^{3+} ions concentrations are low, one can infer the base saturation is high, i.e. bases make up a significant proportion of CEC

c) Salt of the base-forming cations undergo hydrolysis in soils, and as a result of that hydrolysis, OH^- ions are released, which increases soil's alkalinity; e.g.

$$Na_2CO_3 + H_2O \leftrightarrow 2Na^+ + HCO_3^- + OH^-$$

GROUP 3

What soil properties enhance nitrate (NO_3^-) leaching losses from soil? Explain your answer.

Soil properties that would enhance nitrate (ie an anion) leaching are:

- High soil water content as in humid climate or in irrigated fields
- Soils that have a significant content of nitrates. For example, soils that have received high amount of fertilizers containing NO_3^- ion, or well-aerated soils where a fresh plant residue with low C:N ratio has been recently applied (that type of fresh reside will be decomposed very quickly leading to a release of abundant quantities of NO_3^- ions)
- Coarse texture (e.g. sand) since such soil will have large, well connected pores, and consequently high hydraulic conductivity → increase leaching.

  This is particularly true if there is no aggregate formation (ie when soil is in the single grain structureless condition).
- High CEC (which also means low AEC), such as soils high in clay + high in OM at high pH
  -ve charges in soil → electrostatically repel anions from negatively charged soil particles

GROUP 4

List and briefly describe three important roles of bacteria in the nitrogen cycle.

[Hint: consider input, transformation and loss]

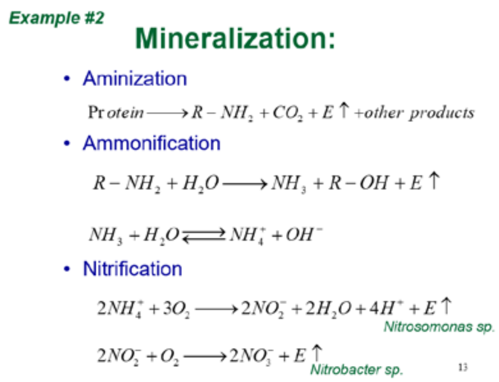
1. **Biological N fixation**

- Conversion of atmospheric N2 gas (inert) to NH3
- optional - medicated by nitrogenase enzyme, breaks N:N triple bond, allows to react with H
- significant source of N to natural ecosystems (approx. 139 million tons of N/year globally)
- e.g. Rhizobium bacteria associated with legumes (clover, lentils, vetch)

  e.g. Frankia (actinomycetes is a class of bacteria) associated with alder, birch

$$\overset{0}{N}_2 + 8H^+ + 8e^- \xrightarrow[(Fe,Mo)]{Nitrogenase} 2\overset{3-}{N}H_3 + H_2$$

2. **Mineralization**



Mineralization: conversion of organic to inorganic (plant available N)
3 step process

2a) Aminization: conversion of complex OM to amines/amino acides (-NH_2) by heterotrophic bacteria (& fungi)

2b) Ammonification: conversion of NH2 → NH3 → NH4 via hydrolysis by heterotrophic bacteria (+ fungi and actinomycetes)

2c. Nitrification
- part of mineralization (conversion from organic to inorganic or plant available N)
- conversion of NH_4^+ → NO_2^- → NO_3^-

mediated by Nitrosonomas sp. (+ archaea) and Nitrobacter sp., i.e. chemo-autotrophic bacteria (get the energy from reduced compounds e.g. NH_4, NO_2

$$2NH_4^+ + 3O_2 \longrightarrow 2NO_2^- + 2H_2O + 4H^+ + E\uparrow$$

Nitrosomonas sp.

$$2NO_2^- + O_2 \longrightarrow 2NO_3^- + E\uparrow$$

Nitrobacter sp.

Note, ok if they only do nitrification

3. Dentrification
- biological reduction of NO3- to gaseous compounds
- occurs where O2 is depleted (i.e. anaerobic conditions)

NO_3^- → NO_2^- → NO (g) → N_2O (g) → N_2 (g)

-important in climate change, NO (nitric oxide) has 298 times the global warming potential of CO_2

Combined all three components complete the N cycle

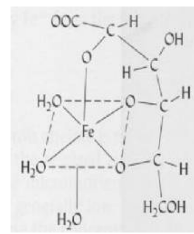
GROUP 5

a) What is a chelate?

b) What types of organic compounds form chelates in soils?

c) What roles do chelates play in soils? Briefly explain importance of those roles.

(a) **Chelates** = organo-mineral complex, metallic ion bonded to an organic molecule by multiple bonds ($\geq$2) forming a ring structure



(b) Organic compounds that form chelates with metals in soils include:

- substances synthesized by roots

- humic substances that have multiple carboxyl groups (e.g. fulvic acids)

- synthetic substances

(c) Roles of chelates in soils: impacts metal availability....

(i) Some chelates can contribute to increased mobility and availability of chelated metals relative to the same metal in ionic (ie non-chelated) form. This occurs when chelate contains either:

-Simple organic compounds (eg fulvic acids) or

-Dispersed and dissolved organic compounds create chelates that ↑ metal (micronutrient) availability

This is important in soils that have low availability of metals (ie micronutrients) such as Fe, Cu, and Zn. On such soils it has been know that both plants and microorganisms can produce organic compounds that will chelate metals and through that chelation, enhance the mobility of metal that would otherwise be immobile and not available to plants.

(ii) Some other types of chelates can also lead to reduced mobility of a metal in the chelated form relative to that metal in ionic form. This occurs when chelate contains either:

-a **complex organic compounds** (e.g. humic acids & humin) or

-flocculated organic compounds

This is important in soils that have been contaminated by heavy metals, since chelates (often added as part of soil remediation) will tie up those excessive amounts of available forms of metals in immobile & plant non-available forms.

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	Bose-Heron	Whatcom-Scat	Langley-Cloverdale	Delta-Tsawwassen
Nutrient supply & retention	Poor -coarse texture -lowest CEC -low SOM	Good (**best among these 4 groups**) -loam (ie optimum) texture -highest CEC -high SOM	Good -fine texture -moderately high CEC -low OM	Moderate -loam (ie optimum) texture -moderately high CEC -but low OM
Water retention	Poor -coarse texture -low SOM	**Good** -loam texture -high SOM	Moderate -fine texture -but low SOM	Moderate -fine texture -but low SOM
Drainage / water movement	Surface good **Subsurface poor** (compact basal till)→ waterlogging if flat topography	**Moderate** -loam texture	Poor -fine texture + Marine PM (massive structure)	Moderate -loam texture Alluvium PM