Agronomy 515 ~ Plant Mineral Nutrition

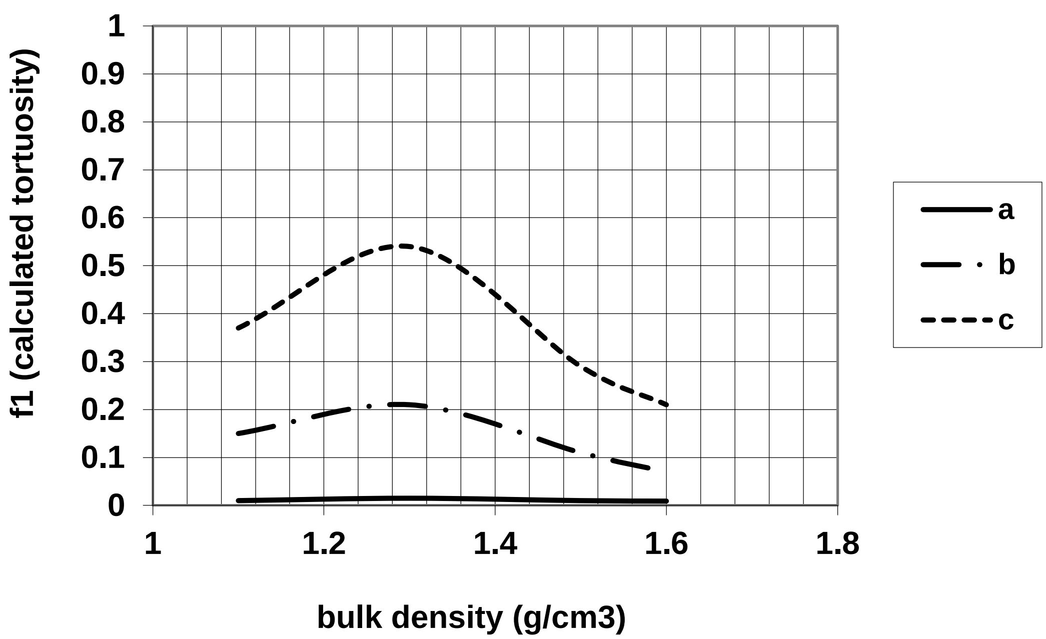
Problem Set 1, Fall 2012

Directions: Answers to this problem set may be brief and in outline format. Show all work for calculations. State ANY and ALL assumptions you use in developing your answers. These questions will serve partially as a study guide for the midterm exam.

Due Date: September 25th, 5pm, in my box in the Main Office or handed to me directly. If your answers are entirely in electronic format, you may email it to me but I must receive it before 5pm.

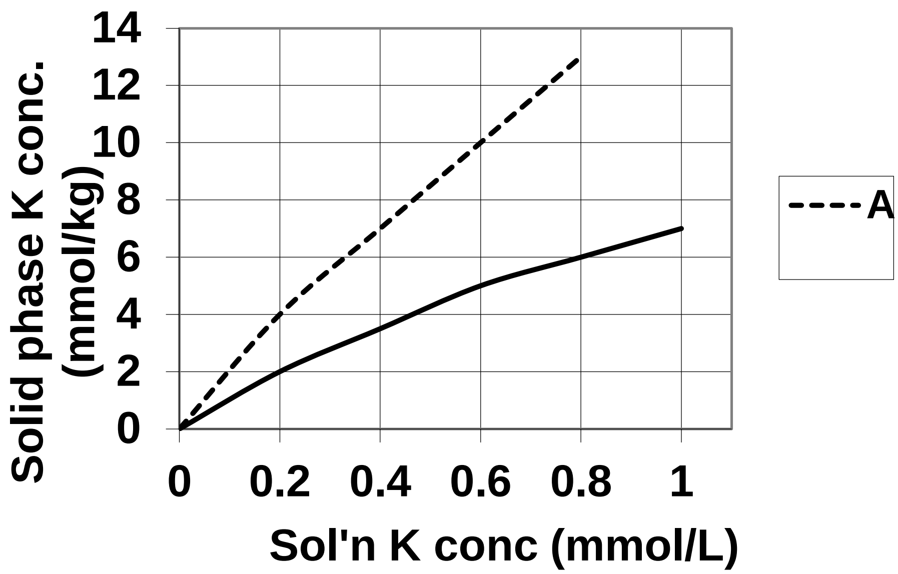
1) You are interested in the effects of soil bulk density and soil water content on the impedance or tortuosity component of nutrient diffusion in soils and on the effective diffusion coefficient (De) of K^+ and H_2PO4^-. Using a nonadsorbed ion (^{36}Cl) you observe the following relationships between calculated tortuosity (f1) and bulk density for soil A equilibrated at gravimetric (w/w) water levels of 10, 20, 30%.

Figure 1.



You then take soil A and another soil (B) and, by adding successive increments of K to the soil, you develop the following quantity / intensity curves.

Figure 2. (next page)



a) In Figure 1, identify which curve corresponds to gravimetric moisture contents of 10, 20, 30 % (w/w) and then explain your experimental results. Address both the moisture and bulk density effects. Feel free to use a drawing to help explain your answer.
b) How is De (the effective diffusion coefficient) calculated?
c) In figure 2, which soil has the higher CEC? Higher clay content? Higher organic matter content? Be sure to state a justification for your answer.
d) What will be the effective rate of diffusion (De) in soil A and B at 20% gravimetric water content when the solution phase K level is between 0.4 and 0.6 mmol/L? Which factor (SOIL TYPE, MOISTURE CONTENT, TORTUOSITY) has the greater influence on De? Briefly state the rationale for your answer.
e) When De for H_2PO4^- and K^+ are as follows:
   i) H_2PO4^- = 4.6 x 10-11 $cm^2\ s^{-1}$
   ii) $K^+ = 3.3 \times 10^{-8}\ cm^2\ s^{-1}$
   How far will each ion move in soil by diffusion in 2 days? in 60 days? Note, this requires estimating the linear distance of travel. For how to calculate the linear distance traveled see http://5e.plantphys.net/article.php?ch=3&id=26
f) For soil A and B in Figure 2, draw a graph showing the ***relative solution concentration*** profile as function of distance from the surface of a root that is actively accumulating K. Assume the same initial starting K concentration and that the plant is not transpiring. Do the two depletion zones differ and, if so, why?
g) Your friend has a new micro-electrode to measure charge across the membrane of a root cell and measures a membrane potential of -105mV at 20^{o}C. If…
   i) the concentration of K^+ external to the cell is 0.75mM and the internal cell K concentration is 63 mM, is further K uptake active or passive?
   ii) If the concentration of Mg^{2+} is 0.25 mM, what is the internal concentration of Mg^{2+} if external and internal concentrations are at equilibrium?

2) You collect the following data from a field experiment on soybean and K nutrition. The field has 3 general levels of K fertility: low, medium and high. Soybean are grown from seed to maturity and measurements at maturity are made before the crop starts to senesce (drop leaves). As plants emerge, you collect soil from 3 depth increments (0-5, 5-10, and 10-20 cm) and you measure:

- θ (gravimetric (g H20/g soil) soil moisture content)
- Solution phase K (this is the measurement of the concentration of K in the soil water)
- NH_4 acetate (NH_4OAc) extractable K (this measurement captures both the K that is easily exchangeable on the CEC of soil colloids and the K that is in the solution phase; it is the current, routine protocol for K fertility assessment but is has some know shortcomings)
- Na tetraphenylboron (TPB) extractable K (this measurement captures plant-available fixed K as well as the exchangeable and solution phases)

At maturity, you make all these same soil measurements and you collect several plants at the ground level, and measure the total tissue K content in the aboveground **dry matter**. You also measure soil bulk density and find a uniform BD of 1.48 g/cm3 across all depth increments. You assume K below 20 cm does not contribute significantly to the plant. By Christmas vacation you have the following numbers:

		Plant Emergence				Physiological Maturity				
K Treatment	Soil Depth (cm)	θ (g H_2O/g soil)	Sol'n Phase K (µg mL^{-1})	NH4-Ext. K (µg g^{-1})	TPB Ext. K (µg g^{-1})	θ (g H_2O/g soil)	Sol'n Phase K (µg mL^{-1}	NH4-Ext. K (µg g^{-1})	TPB Ext. K (µg g^{-1})	Above-ground K uptake (kg ha^{-1})
Low K	0 - 5	0.21	3.7	100	315	0.15	3.6	51	236	51.7
	5-10	0.18	3.0	47	269	0.16	6.4	32	207	
	10 - 20	0.15	2.3	42	251	0.18	6.4	31	232	
Med. K	0 - 5	0.21	7.1	185	437	0.15	6.8	99	376	125.4
	5-10	0.18	4.1	86	310	0.16	7.3	83	284	
	10 - 20	0.15	3.3	52	271	0.18	9.4	49	258	
High K	0 - 5	0.21	19.8	366	587	0.15	9.7	225	498	199.3
	5-10	0.18	10.7	229	429	0.16	8.3	171	380	
	10 - 20	0.15	4.5	93	304	0.18	6.0	107	303	

Note: for answering the question (especially a and b), you may want to report results in a table. This is fine but show me how you calculate the values in each of the columns (e.g. for one cell, write out the calculations).

a) What was the net amount of K per unit land area contributed to the plant by the solid-phase exchangeable K pool of the entire 0 – 20 cm profile for each fertility level?

b) What proportion of aboveground K came from solution, exchangeable, and fixed K pools for low, medium and high K soils? What (if any) aboveground K is unaccounted for by the soil tests of each of the three soils?

c) Your friend's research is focused on developing a better soil K test. She takes the samples you collected at plant emergence in the medium testing soil and measures the following K levels:

1. 0-5 cm = 5.72 mmol kg^{-1}
2. 5-10 cm = 2.74 mmol kg^{-1}
3. 10-20 cm = 1.48 mmol kg^{-1}

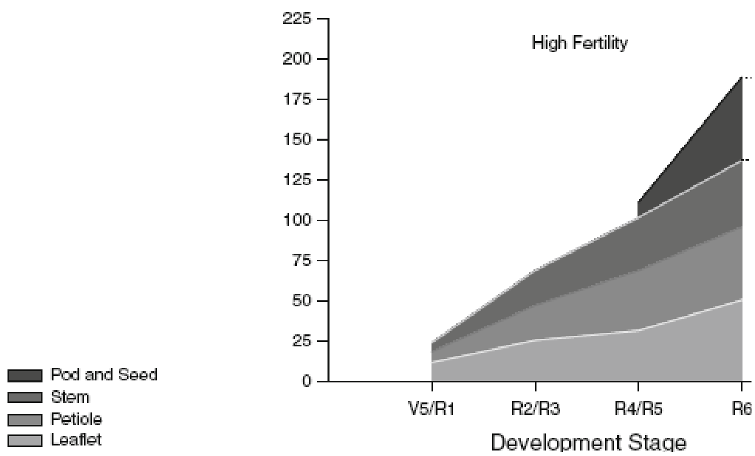
If no net aboveground plant K uptake is occurring from below 20 cm and her test really is a perfect predictor of plant K uptake, what is the K concentration at plant maturity in a 0-20 cm composite soil sample given the crop accumulates 125.4 kg K per ha.

d) If you can only do one of the three soil tests (not including your friend's new test) to predict plant K uptake, which would you choose and why?

e) Of the total above ground K, your measurements of K contents in just the seed are:

1. low = 23 kg ha^{-1}
2. medium = 50 kg ha^{-1}
3. high = 48 kg ha^{-1}

The graph below gives the partitioning of K among leaves (leaflets), petioles, stems, and pod+seed as a function of development in the reproductive phase of plant growth. Draw the expected figures for the medium and low fertility soils. Explain your rationale for your allocation among the plant tissues and whether or not (and why) you think the medium testing soil is K deficient.



3) You conduct a long-term field experiment where you measure cumulative P fertilizer added to a field (thoroughly mixed into the top 20 cm of soil). You have 4 rates of P (0, 49, 98, 196 kg P ha^{-1}) that you add at the start of the experiment and then you reapply the same rates to the same plots every 3 years for a total 4 subsequent applications. Each year at harvest, you collect a sample of grain and analyze it for P so that you can calculate P removal in your yields in each year and then, by addition, for a 3 year cycle. At the start of the experiment and right before each application (after the 3^{rd} harvest in each 3yr cycle), you carefully collect the soil from the 0 – 20cm layer and analyze it with a Mehlich 3 extraction (an accepted assay for plant available soil P). Your data are the following:

P Trt. (kg P/ha)		Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5
0	Crop P Removal (kg/ha)	37.3	45.9	43.5	42.9	41.2
	Mehlich 3 P (ppm)	5.5	4.4	4.1	5.9	5.7
49	Crop P Removal (kg/ha)	56.1	66.7	65.5	59.1	61.3
	Mehlich 3 P (ppm)	10.3	9.2	8.2	10.8	13.0
98	Crop P Removal (kg/ha)	68.4	79.3	77.4	71.5	75.6
	Mehlich 3 P (ppm)	13.8	19.3	20.5	26.4	31.1
196	Crop P Removal (kg/ha)	79.7	97.2	96.2	83.8	88.8
	Mehlich 3 P (ppm)	21.8	26.2	37.2	44.6	55.3

a) Is your field P deficient at the beginning of the experiment? Why or why not?
b) How much P does the Mehlich 3 test indicate is "plant available" in the plow layer (0 – 20 cm layer of soil) of the 0 and 196 kg P/ha treatments at the end of cycle 5 if the plow layer has a soil bulk density is 1.3 g/cm^3.
c) How much fertilizer P does it take to increase your soil P availability by 1 ppm as measured by the Mehlich 3 test? (Hint: create a plot of the Mehlich 3 values measured at the end of each cycle as a function of the cumulative fertilizer P added that is not removed in the yield for each treatment at the end of each cycle.)
d) When the cumulative field P balance is negative (less P added than is removed in the crop), does the Mehlich P value decrease to the same degree it increases when the cumulative P balance values are positive? Provide an explanation of your observations.
e) In the last year of the study you do a detailed examination of P concentration in the soil solution as a function of perpendicular distance from the root surface. Draw figures representing the solution phase P concentrations in the 0 and 196 kg P/ha treatments as a function of distance from the root surface i) just as the root begins to accumulate P from the soil solution and ii) after 10 days of active P accumulation. In general, this soil has very high concentrations of Ca. Draw figures representing Ca concentrations in the 0 and 196 kg P/ha treatment iii) just as the root becomes active in uptake and iv) after 10 days of nutrient accumulation. (Put both P curves on one graph and both Ca curves on another graph so that the differences between treatments, if any, are evident). Provide a short written explanation of what is happening.