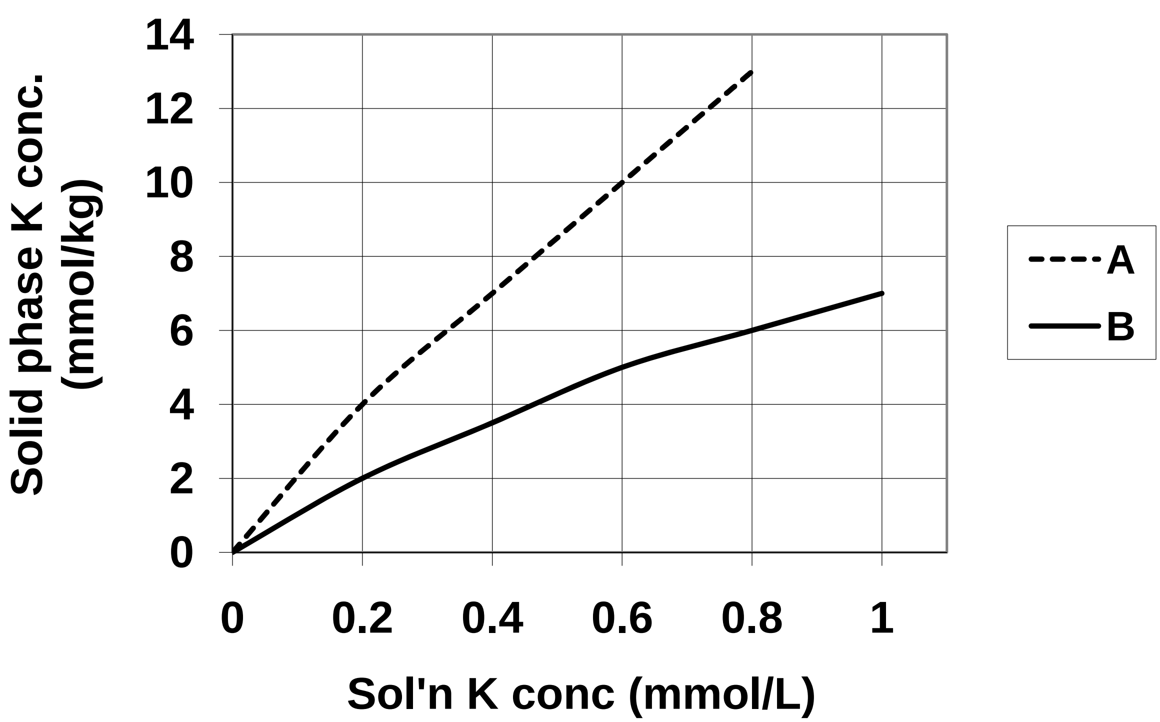
Agronomy 515 ~ Plant Mineral Nutrition

Problem Set 1, Fall 2010

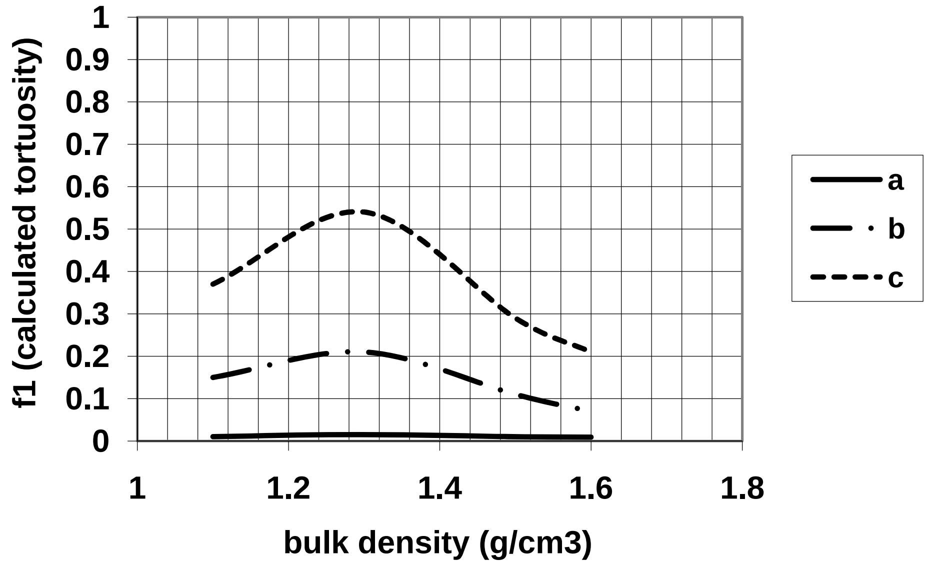
Directions: Answers to this problem set should be brief and may be in outline format. Show all work for calculations. State ANY and ALL assumptions you use in developing your answers. These questions will serve partially as a study guide for the midterm exam.

Due Date: September 29th, 5pm, in my box in the Main Office or handed to me directly. Note, this is a **Wednesday not a Tuesday as given in the calendar**. I have given an extra day so that you have a couple of days when I am back in the country to ask questions. You may also leave it with Cindy Boone in Rm 3-460.

1) Use the K desorption figure below to answer the following questions.
    a. Which curve reflects the soil with the higher CEC? Clay content? Organic matter content and why?
    b. For soil B, what is the total amount of plant available K per unit of soil volume when the soil solution K concentration is 0.6 mmol L^{-1}? For your answer, assume a soil bulk density of 1.30 g cm^{-3}. What would the solution K^+ concentration be in soil A if it were supplying the same total amount of plant available K per unit of soil?
    c. Draw a graph showing the relative solution concentration profile as a function of distance from the surface of a root actively accumulating K. Assume the same initial starting solution K concentration and that the plant is not transpiring. Do the 2 depletion zone profiles differ and, if so, why?
    d. Describe a situation where these soils would have approximately the same buffer (b) value. Which soil would be more "fertile" and why?



2) 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 and bulk density for a soil equilibrated at gravimetric (w/w) water levels of 10, 20, 30%.



a) 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?

3) You conduct an experiment to examine the interactive effects of temperature and fertilizer on the effect on K movement in soil maintained at a volumetric soil moisture content of 30%. Your data are the following:

K added (mg/kg)	De at 15°C cm^2/s	De at 29°C $cm^{2/}s$
0	0.15×10^{-7}	0.39×10^{-7}
50	0.50×10^{-7}	0.94×10^{-7}
100	0.69×10^{-7}	2.7×10^{-7}
300	2.7×10^{-7}	5.0×10^{-7}
500	5.0×10^{-7}	7.5×10^{-7}
700	5.0×10^{-7}	7.5×10^{-7}
900	X	Y

a) What are likely De values at each temperature following additions of 900 mg/kg?
b) How far can one ion travel in one direction in one day (eg. mm/day toward a root) at each temperature level without any fertilizer added? How far can an ion travel in one direction in one day at each temperature level when 500 mg/kg has been added to the soil? (Hint: check out http://4e.plantphys.net/article.php?ch=3&id=26 if you missed the lecture where planar diffusion versus diffusion in one direction was discussed.)
c) If a plant root system requires linear movement rates of at least 1 cm/week to meet its uptake demand, approximately how much K should be added if the soil is maintained at 15oC? 29oC?

d) How do you expect the solution concentrations (C_{li}) and buffer values (b) to change with fertility? With temperature at a given fertility level?
e) You are asked to make a fertilizer recommendation for a farmer who has spring tomato fields in northwestern Nebraska, west of Chicago and in southern Indiana. If the initial soil test level is similar and soils are relatively similar in mineralogy, where should the farmer apply high, intermediate and low rates of K fertilizer and why? (Hint: you need to consider 2 aspects of the prevailing weather regime.)

4) In a greenhouse "pot" experiment, you grow a plant from a seed for 30 days. Your pot contains 6.3 kg of soil packed to a bulk density of 1.48 g cm^{-3}. You add water daily to maintain volumetric water content of 0.25 mL cm^{-3}. At the beginning and end of the growth period you measure the following soil and plant variables.

At planting:

- Solution phase K = 2.03 µg mL^{-1} (This is the actual concentration of K in the soil water)
- NH_4Cl-Extractable K = 52.05 µg g^{-1} (This measurement includes the "solid-phase" K held on the soil exchange complex and the solution-phase K.)

At harvest of the experiment:

- Solution phase K =1.07 µg mL^{-1}
- NH_4Cl-Extractable K = 49.97 µg g^{-1}
- Shoot dry weight of the plant = 2.34 g pot^{-1}
- K concentration in the plant shoot = 353 mmol kg^{-1} dry weight
- Root fresh weight = 4.68g
- K concentration in the plant root system = 56 mmol kg^{-1} wet weight

a) What was the amount of K contributed to the plant by the solid-phase exchangeable soil K pool?
b) What percent of total plant K came from the exchangeable plus solution phase pools (the atomic mass of K=39.1)?
c) How do the measured soil solution and tissue K concentration values compare to the "typical" values given in the class handout (1^{st} week of class)?
d) You have developed a new soil test that is a perfect measure of bioavailable K. If your soil test level at planting is 213 µg g^{-1}, what should the soil test level be at harvest?

5) 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 3rd 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.