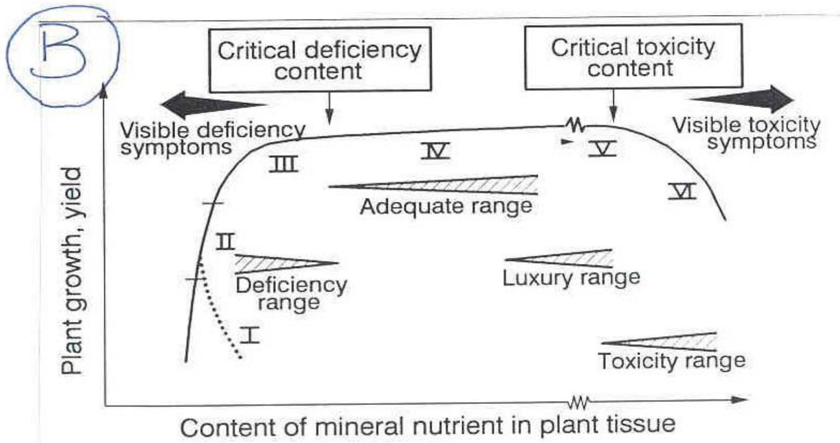
Agronomy 515 ~ Plant Mineral Nutrition

NUE Worksheet:

1) Concentrations of a nutrient in a tissue can provide important information about plant status. Below is the schematic from your book of the generalized relationship between the concentration of the nutrient in tissue and plant growth potential, net primary productivity, yield and/or health.



Range	I II deficient	II III low	IV adequate	V high	VI toxic
Element*					
P (%)	<0.16	0.16-0.25	0.26-0.50	0.51-0.80	>0.80
K (%)	<1.26	1.26-1.70	1.71-2.50	2.51-2.75	>2.75
Mn (mg kg^{-1})	< 15	15 - 20	21 -100	101 - 250	> 250

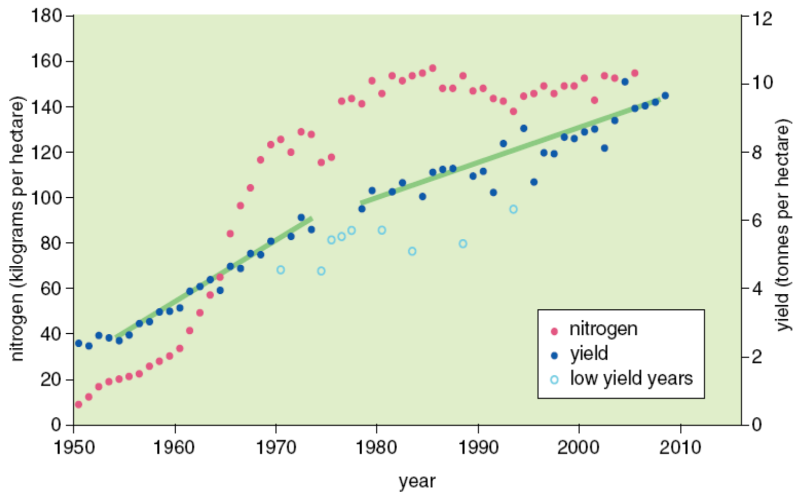
* Soybean, upper leaves (from Jones, 1967)

a) The schematic shows a very broad range of tissue concentrations over which growth is optimized but distinct boundaries or critical concentrations between adequate and deficient or toxic ranges. In the real world, are you likely to be able to identify such distinct critical values?
b) What are likely to be the biggest factors interfering with your ability to define a distinct critical level for a given tissue of a given species?
c) The data of concentration ranges for P, K, and Mn in soybean were collected in 1967. If you examined the relationship between concentration and yield in today’s commercial soybeans grown in Indiana what differences might you expect to see? Why?
d) Some have used the inverse of the concentration as indicative of relative “ecological efficiency” when comparing among crop species (e.g. see Beale and Long, 1997 where *Miscanthus g.* is compared to sorghum, maize, wheat, etc.). At a minimum, what two things do you have to know to use this information to make a valid statement about comparative ecological efficiencies?
e) 0.16 % equals how many mg P/kg tissue?

2) Nutrient use efficiency (NUE) has many definitions. Here we will explore a few of them because we did not spend much time on them in class and they are not well covered in Marschner:
a) For a plant species growing across a natural N fertility gradient, how would you measure and calculate overall P use efficiency?
b) For a crop plant growing in intensively managed soils, how would you quantify the “agronomic” use efficiency of P fertilizer?

c) Define uptake efficiency (UE) and physiological efficiency (PE) and describe how you calculate general NUE or agronomic efficiency from these 2 parameters?

You find a historical survey of fertilizer applied to US maize fields and mean regional yields and the data show that N applications have been constant since about 1985 but yields have continued to increase (Sinclair, 2009).



Your favorite commercial seed dealer assures you that this is because genetic improvements over time have increased the nitrogen use efficiency and therefore the crop can yield more with less fertilizer – she is certain this is true both when only considering the grain yield (for use as a feed or fuel source) as well as considering the entire above ground biomass of both grain and vegetative tissue. She shows you the following from Lauer et al. (2001) to support her arguments:

Era	Hybrid	Total plant N (kg N/ha)	Grain Yield (Mg/ha)	Biomass Yield (Mg/ha)
1976-1990	A554xCM105	201.9	8.0	15.2
1976-1990	W2343	159.9	4.5	11.9
1976-1990	W4363	232.1	8.5	18.6
1976-1990	A641xMO17	256.6	11.2	21.1
1976-1990	W540xB73	285.6	11.3	23.8
1976-1990	W5472	263.7	11.3	20.6
1991-1998	Mycogen 4120	248.9	10.9	20.2
1991-1998	Delkalb DK401	233.4	10.1	18.7
1991-1998	Pioneer 3905	196.8	8.2	16.4
1991-1998	Cargill 4327	226.6	10.0	19.4
1991-1998	Pioneer 3394	289.7	11.9	24.8
1991-1998	Dairyland 1407	269.9	12.5	24.1

For two time periods or eras, the data show the mean aboveground N accumulations, grain yields and total aboveground biomass accumulations for the 6 highest yielding commercial hybrids that dominated Wisconsin

d) What aspect of NUE can you evaluate with this dataset?

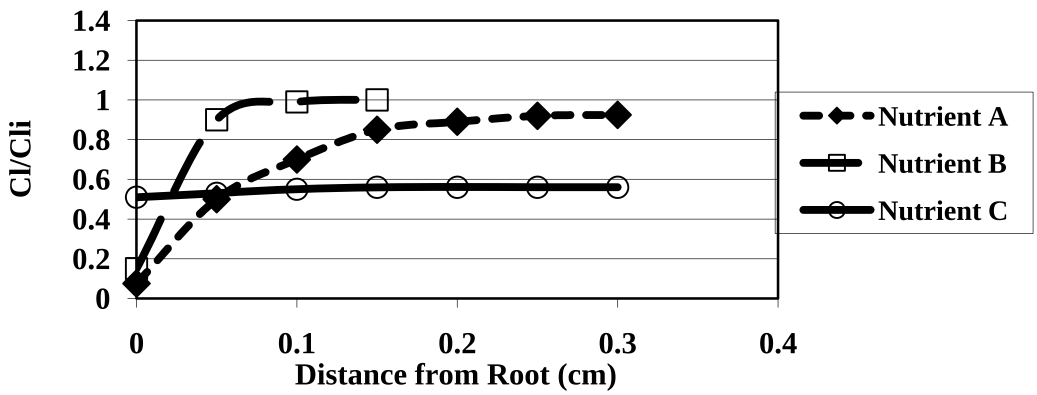
e) Is there any evidence that the best commercial hybrids from the 1990s were more N efficient than the commercial hybrids from the early era? (Hint: draw plots of yields as a function of nutrient content in the plant – preferably before you attend class with Stephanie on Thursday so that you can annotate your graphs.)

f) What data are you missing if you want to understand all aspects of plant and fertilizer efficiency?

3) For your research project you try to avoid spending way too much time in the lab and you use a model to develop a data set of the relative solution phase concentrations of K, P, and NO_3-N perpendicular to a root after 10 days of root uptake activity (Figure 1 shown below). You calculated the relative solution phase concentration as $Conc._{final}/Conc._{initial}$ or C_f/C_i and you assumed P, K, and NO_3-N were all moved to the root surface by ***diffusion***.

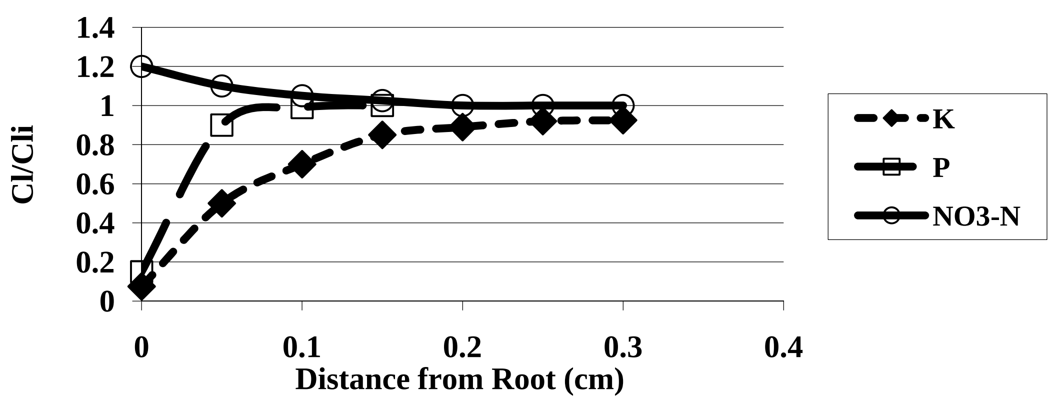
a) Which curve corresponds to NO_3-N? P? K? Explain your results.

Figure 1: Model results



b) Your major prof. doesn't think that your results are realistic and sends you to the lab to make some real measurements on a real, growing plant. Your lab results after 10 days of root uptake are shown in Figure 2. How do you explain these results to the boss? You are asked to run your experiment for and additional 20 days. How will the curves change and why?

Figure 2: Results from actual lab measurements



c) (S)he now asks you to extend your knowledge to the following situation:

Assume a crop uses 3 x 10^6 liters of water per hectare to produce a total biomass of 10,000 kg ha^{-1}. This crop is growing on soil with average soil solution concentrations of 20, 0.05, and 50 mg L^{-1} for N, P, and Ca respectively.

i) How much (total amount) N, P, and Ca would you expect to find in this biomass if tissue concentrations were in the normal range for general plant dry matter?
ii) Calculate the approximate percent contribution of mass flow and diffusion to the nutrient supply of the crop. Indicate how you calculated your results and then draw the curve of Cl/Ci as a function of distance to the root surface as you neared the end of the growth or biomass accumulation period.

4) The following potassium (K) uptake or influx rates (I) were obtained from plant species **A** as solution K concentrations increased from 0 to 0.2 mM.
   a) Plot the relationship between [K] and I. Show this plot and identify Km I_{max} and C_{min}.
   b) Use a double reciprocal plot to of these data to calculate the K_m and I_{max} for K uptake under these conditions. Show this plot and the math you used to determine these kinetic constants. (Remember to ignore the observation at I=0.)
   c) If plant species B were more efficient at acquiring K than A, how would the curves on both graphs shift? Draw the curves on the two graphs and explain your result.
   d) Calculate I for plants provided a solution K concentration of 0.033 mM. Show your work.

K conc. mM	**I, µmol/g/h**
0.005	0
0.01	2
0.02	3.5
0.04	6
0.06	7
0.08	7.5
0.1	7.8
0.125	7.9
0.15	8
0.175	8.05
0.2	8.08