LAB 5 - PLANT NUTRITION

I. General Introduction

All living organisms require certain elements for their survival. Plants are known to require carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), calcium (Ca), sulfur (S), potassium (S), and magnesium (Mg), which are called **Macronutrients**, because they are needed in larger amounts. Plants also need large amounts of carbon (C), hydrogen (H), and oxygen (O) for growth and development. Plants absorb these elements through air and water, they are not usually applied as fertilizers.

Micronutrients which are needed in very minute quantities are: iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (B), molybdenum (Mo), and chlorine (Cl). There is no "most important element" since all are required for life, growth and reproduction. They are therefore called essential elements.

Plant tissues also contain other elements (Na, Se, Co, Si, Rb, Sr, F, I) which are not needed for the normal growth and development.

Chemical Element	symbol	Atomic weight	Ionic forms Absorbed by plants	Approximate dry tissue concentration
		Macronutrients		
Nitrogen	N	14.01	NO_3^-, NH_4^+	4.0 %
Phosphorus	P	30.98	PO_4^{3-}, HPO_4^{2-}, $H_2PO_4^-$	0.5 %
Potassium	K	39.10	K^+	4.0 %
Magnesium	Mg	24.32	Mg^{2+}	0.5 %
Sulfur	S	32.07	SO_4^{2-}	0.5 %
Calcium	Ca	40.08	Ca^{2+}	1.0 %
		Micronutrients		
Iron	Fe	55.85	Fe^{2+}, Fe^{3+}	200 ppm
Manganese	Mn	54.94	Mn^{2+}	200 ppm
Zinc	Zn	65.38	Zn^{2+}	30 ppm
Copper	Cu	63.54	Cu^{2+}	10 ppm
Boron	B	10.82	BO_3^{2-}, $B_4O_7^{2-}$	60 ppm
Molybdenum	Mo	95.95	MoO_4^{2-}	2 ppm
Chlorine	Cl	35.46	Cl^-	3000 ppm
		Essential But Not Applied		
Carbon	C	12.01	CO_2	40 %
Hydrogen	H	1.01	H_2O	6 %
Oxygen	O	16.00	O_2, H_2O	40 %

Under most agricultural and horticultural conditions, only **nitrogen, phosphorus,** and **potassium** are depleted from the soil to the extent that growth and development are interrupted. These are the fertilizer elements. Modern agriculture depends on the addition of these elements to the soil to ensure optimum yields of food crops. Soil tests are used to determine the levels of the elements available to the crop and the quantities that must be added as fertilizer to get profitable yields.

Deficiencies of other elements such as sulfur, zinc and copper may occur in some soils. These deficiencies can be corrected by the addition of small amounts of these elements to the soil or as sprays to the plant. Under some conditions the soil may contain adequate supplies of the element, but because of soil pH (acidity or alkalinity) the element is unavailable to the plant. This occurs with iron in high pH (alkaline) soils. Many plants growing in these soils will have yellow (chlorotic) leaves. All species of plants do not react the same under these conditions. Some will show the deficiency symptom, while others are apparently able to extract the iron from the soil.

II. Fertilizer Concentrations Calculations

A. Units Used

ppm = parts per million
mM = milli molar
meq/l = milliequivalent per liter

B. Conversion Factors (metric vs. British system)

1 ounce = 28.35 g
1 pound = .45 kg
1 gallon = 3.78 liters
1 g = .035 ounce
1 kg = 2.205 pounds
1 acre = 43,560 ft^2

C. Fertilizer Concentrations

a. ***Parts per million*** (ppm)

The term, parts per million, is an expression of concentration used often to describe very dilute solutions. The term states how many parts of solute there are in a million parts of the whole solution. Parts per million almost always expresses concentrations on a mass basis. For example, a 10 ppm solution is one in which every million grams of solution contains 10 grams of solute. The ppm designation is most often applied to dilute solutions in water. For example,1 kilogram (1000 gram) of water contains 1 million milligrams of water; thus

$$1 \text{ kg} = 1 \text{ kg} \times 1000 \text{ g/kg} \times 1000 \text{ mg/g} = 1{,}000{,}000 \text{ mg}$$

At normal temperatures, 1 liter of a dilute water solution has a mass of approximately 1 kilogram. So if we have 10 milligrams of solute in 1 liter of solution, we have a concentration of 10 ppm.

$$\frac{10 \text{ mg solute}}{1 \text{ liter solution}} = \frac{10 \text{ mg solute}}{1{,}000{,}000 \text{ mg solution}} = 10 \text{ ppm}$$

Thus when we say that the concentration of nitrogen in water is 200 ppm, we mean that 1 liter of the solution contains 200 milligrams of nitrogen. The important thing to remember is:

1 kg = 1,000,000 mg
1 liter water = 1 kg
therefore, 1 liter water = 1,000,000 mg

b. ***Milli-molar*** (mM)

One millimolar (mM) concentration refers to a solution containing one-thousandth of molecular weight (g) of the solute per liter of water. One molar (M) concentration equals 1000 millimolar (mM)concentration.

Chemical	Molecular or atomic weight
N	14.01
K^+	39.10
NH_4NO_3	80.05
NH_4^+	18.01
NO_3^-	62.01
Ca^{++}	40.08
Mg^{++}	24.32
S	32.07
SO_4^{-2}	96.07
$MgSO_47H_2O$	246.50

1 mM NH_4NO_3 = 80.05 mg per liter (mg/l)
1 mM NO_3^- = 62.01 mg/l
1 mM SO_4^{-2} = 96.07 mg/l
1 mM $MgSO_47H_2O$ = 246.5 mg/l

c. *Milliequivalent per liter (meq/l)*

Milliequivalent per liter (meq/l) concentrations are often used to show the strength of fertilizer ions (anion or cation) in a solution. Since one equivalent weight is the molecular weight divided by valence, one meq/l refers to the ionic concentration of a solution that contains one millimole/valence per liter of water.

NH_4NO_3 ------< NH_4^+ + NO_3^- (Monovalent ions)
(80) (18) (62)

$MgSO_47H_2O$ ------< Mg^{++} + SO_4^{-2} (Divalent ions)
(246.5) (24.3) (96.1)

1 meq/l NH_4NO_3 = 80 mg/l
1 meq/l NH_4^+ = 18 mg/l
1 meq/l NO_3^- = 62 mg/l

1 meq/l $MgSO_47H_2O$ =(246.5 mg/2)/l = 123.3 mg/l
1 meq/l Mg^{++} =(23.3 mg/2)/l =11.6 mg/l
1 meq/l SO_4^{-2} = (96.1 mg/2)/l = 48.0 mg/l

D. Fertilizer Analysis

a. *Commercial Analysis*

Commercial analysis is given by the percentages of nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O) in that order. For example, Peters 20-16-20 fertilizer contains 20% N, 16% P_2O_5, and 20% K_2O by weight.

b. *Elemental Analysis*

Elemental analysis is used for more technical and scientific purposes. It is expressed as percent weights of elemental nitrogen (N), phosphorus (P), and potassium (K) in that order.

c. *Conversion of Commercial Analysis to Elemental Analysis*

By using the ratios of elemental to oxides for phosphorus and potassium, the commercial analysis can be converted to elemental analysis.

Nitrogen - always expressed as elemental N
Phosphorus - $P/P_2O_5 = 0.44$, or $P_2O_5/P = 2.99$
Potassium - $K/K_2O = 0.83$, or $K_2O/K = 1.20$

Thus, Peters 20-16-20 commercial analysis fertilizer can be labeled as a 20-7.4-16.6 elemental analysis fertilizer.

$$20\%\ N - 16\%\ P_2O_5 - 20\%\ K_2O = 20\%\ N - 7.4\%\ P - 16.6\%\ K$$

For example, if you want to apply 200 ppm nitrogen to your plants and were going to mix up 1 liter of solution you then would have to put 1000 mg or 1 gram of fertilizer into the liter of water.

1 liter water = 1,000,000 mg therefore, 200 mg of N are needed. However, the fertilizer is only 20% N. So:

$$\frac{200}{.20} = \frac{x}{1.00} \qquad x = 1000 \text{ mg} = 1 \text{ g.}$$

III. Problems

1) You wish to prepare 5 gallons of a 100 ppm nitrogen (N) fertilizer. How much 15-10-05 commercial analysis fertilizer will you need to add to 5 gallons of water to get the desired concentration?

2) You are mixing 5 gallon of concentrate fertilizer to apply with a hose-on (1:15 proportion), and you want the final concentration to be 200 ppm nitrogen (N). What amount of fertilizer, if you are using 20- 20-20 commercial analysis fertilizer, do you need to add to 5 gallon of water?

3) What would be the concentrations of phosphorus and potassium in the fertilizer solution above (#2)?

Nitrogen	=	200 ppm N			
Phosphorus	=	____________ ppm P_2O_5	=	______________	ppm P
Potassium	=	____________ ppm K_2O	=	_____________	ppm K

4) The fertilizer bag says add 2 oz. to ten gallons of water. What ppm N, P, K will this solution be assuming the fertilizer is at 100%?

LAB 5 - DEMONSTRATION OF NUTRIENT DEFICIENCIES

A. Objective

Plants require large quantities of macronutrients (N, P, K, Ca, Mg, S). Of these macronutrients, deficiency symptoms of nitrogen, phosphorus, and potassium can be visually detected on plants grown under an artificially controlled culture system. The objective of this study is to artificially induce and characterize deficiency symptoms of nitrogen, phosphorus, and potassium on selected plants. During the course of this study, students will observe and characterize abnormal symptoms of plants lacking nitrogen, phosphorus, or potassium.

B. Materials and Method

<u>Plant Materials</u>

Three species of plants (corn, bean, leaf lettuce) will be used. Corn and bean will be grown in perlite, whereas leaf lettuce will be grown hydroponically.

<u>Nutrient Solutions</u>

Five different solutions containing the complete combinations of macronutrients lacking one of the three macronutrients N, P, and K. All solutions will contain the standard concentrations of micronutrients (a modification of Hoagland Solution):

Treatment 1 --- Complete fertilizer
Treatment 2 --- Lacking nitrogen (N)
Treatment 3 --- Lacking phosphorus (P)
Treatment 4 --- Lacking potassium (K)
Treatment 5 --- Lacking all macronutrients

C. Procedures

Germinate seeds of the three species on an inert medium (rockwool, perlite, sand, etc.) using deionized water. When the seedlings start developing true leaves, plant them in 6-inch plastic pots containing perlite (corn and bean). For lettuce, place the seedlings on the a styrofoam board which will float on top of a hydroponic solution contained in a plastic tub. Observe plant growth and development of deficiency symptoms for 8 weeks.

D. Results

Observe the growth of plants with each of the four treatments. Characterize the growth and development of nutrient deficiency symptoms for nitrogen, phosphorus, and potassium in 8 weeks of observation. Based on your observation, complete the lab report.

LAB 5 - WORKSHEET

Name ______________________________

1. Describe the functions of macronutrients nitrogen (N), phosphorus (P), and potassium (K) in plants.

2. Write the chemical forms (ions) of nitrogen (N), phosphorus (P), and potassium (K) that are actually absorbed by plants.

3. Why is an inert growing medium used to grow plants for detecting nutrient deficiencies?

4. Describe macronutrient deficiency symptoms that you have observed in each species, and provide comments on your findings.

   Symptoms:

   Nitrogen (N) deficiency

   Phosphorus (P) deficiency

   Potassium (K) deficiency

   Conclusion: