Lab 10. Nutrient Management, Soil Temperature & Soil Ecology Part 1.

In this lab students will rotate through 3 stations. Station A. will include some experiments relating to soil temperature. Station B. will include preparation for next week's soil ecology lab part 2, including setting up soil organism extraction equipment. Station C. will include checking on your potting media treatments in the Plant Science greenhouse. For the last hour of the lab period, we will work together as a group to analyze the Cornell Nutrient Analysis Laboratory results for the soil samples we submitted from Dilmun Hill farm.

Objectives:

Station A: Soil Temperature

- To observe the factors which influence soil thermal conductivity and soil temperature

Station B: Soil Ecology Part 1

- To gain experience with techniques for extraction of soil organisms

Station C: Greenhouse experiment

- Assess soil and soil-less media for plant production in the greenhouse
- Understand the function that soil perform in promoting plant growth

Group discussion/problem solving: Nutrient Management

- To become familiar with the information provided by a soil testing lab
- To understand the meaning of reported nutrient compositions of fertilizers
- To learn the procedure for calculating fertilizer requirements from soil data

Reading:

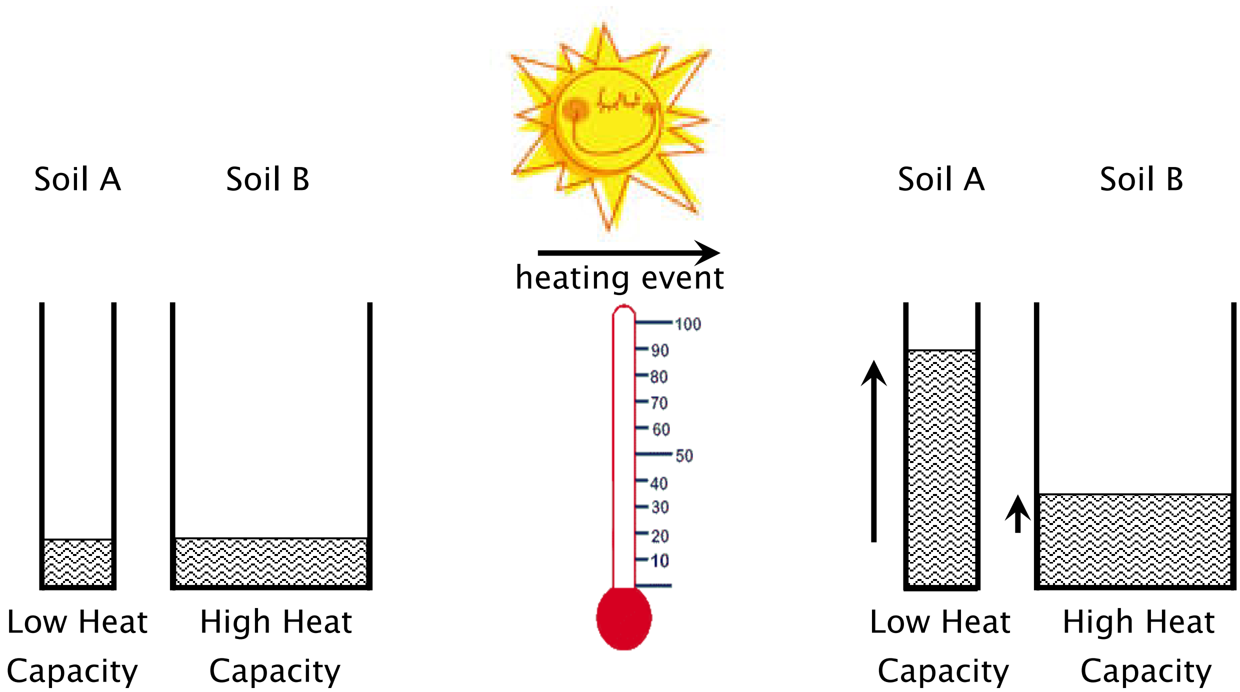
- Section A: Brady & Weil 7.8, 7.9, 7.10 & 7.11

- Section B: Brady & Weil Chapter 11 in Brady and Weil (also reading for lab 10.)
- Section C (see lab 8)
- Nutrient management: 16.7, 16.8, 16.9, 16.10 & 16.11

Station A. Soil temperature

<u>Soil Heat Capacity</u>

The soil's heat capacity is one of the most important factors controlling rates of soil warming and cooling. Heat capacity of a material is a measure of its ability to store heat. For example, mineral particles have a heat capacity of about 0.3 – 0.5 $cal/cm^3/deg$. (meaning that these solids store an additional 0.3 – 0.5 calories of heat energy per cm^3 volume for every degree (Centigrade) increase in temperature. On the other hand water has a heat capacity of 1.0 $cal/cm^3/deg$., while air has a very low capacity to store heat (0.003 $cal/cm^3/deg$.). This means that wet soils have much more heat capacity than dry soils. Soil high in organic matter tend to have low densities, and for this reason, their heat capacities, which are usually expressed on a volume basis, are lower that those of mineral soils.



Soil Thermal Conductivity

Heat flow into and out of soil occurs mostly by conduction. The thermal conductivity (K) of the soils measures the ability of a soil to conduct heat. Dry soils have low thermal conductivity and wet soils have higher conductivity. Soils with high organic matter content have lower conductivity than soils with lower organic content. The thermal conductivity, then, can greatly affect the warming and cooling processes in the soil which result from the presence or absence of solar radiation. In particular, the soil temperature at the beginning of the growing season must rise enough fro the planted seeds to germinate and grow properly. For some crops, the temperature must reach 15^{o}C or higher. Conversely, in mid-summer, high soil temperatures may be harmful to plant roots.

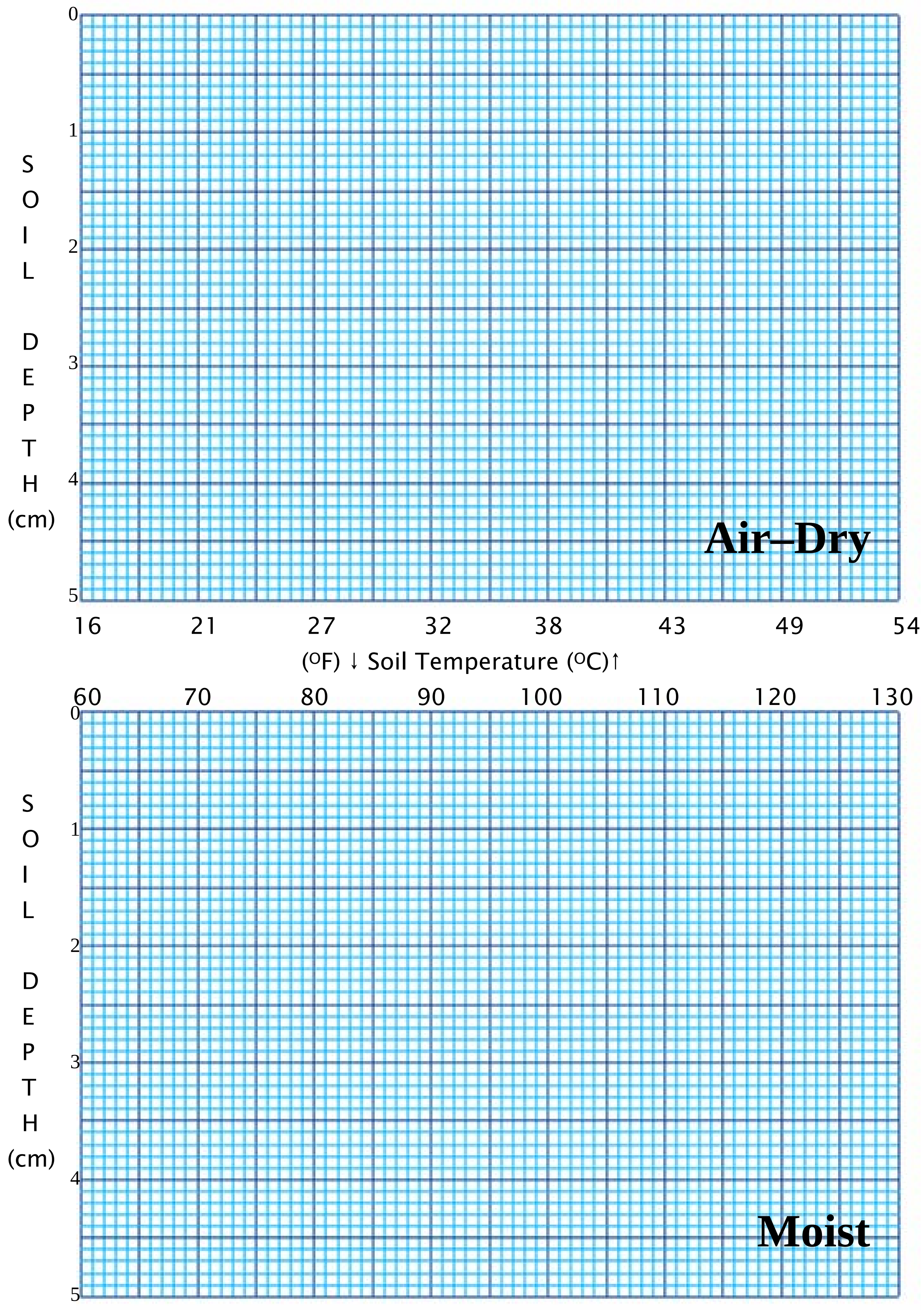
Soil temperatures can be managed in principle by controlling soil moisture levels and by using mulches, but this in not usually done on commercial scale except with high-value crops.

EXERCISE A:

1. Fill one paper cup with an organic soil (or potting mixture) and two other cups with mineral soil (Mardin). The soil should be level with the top of the cup.
2. Saturate one of the two mineral soils with water.
3. Center all three cups under a heat lamp and turn on the lamp for exactly five minutes.
4. Immediately after turning the lamp off, touch the soil surface of each cup and determine which feels warmest.
5. Now insert a dial thermometer 5 cm deep into each soil and measure the actual temperature. Explain your observations.

EXERCISE B:

1. Set up a column of air-dry soil directly beneath a heat lamp. Dial thermometers are provided which should be inserted at three depths (1cm, 3cm and 5cm) in the column. Record the initial temperature at each depth by pushing the probe into the holes at the side of the column and waiting until a stable reading can be obtained. Plot temperatures on the top graph (next page). Is there a temperature gradient?
2. Turn on the heat lamp. Measure the temperatures at the three depths again after exactly five minutes. Plot the temperatures on the graph. Is there a gradient?
3. After another 5 minutes of heating, record and plot the temperature a third time. Repeat.
4. Turn of lamp and leave the thermometer inserted in the deepest (5cm) position. Watch for any temperature change for 15 minutes. Explain the result.
5. Now remove the dry soil column and replace in EXACTLY the same position under the lamp a second column of the same soil which is field moist.
6. Insert the thermometers and record the initial temperature (as in step 1). Plot on the bottom graph (next page).
7. Turn on the heat lamp. Record and plot temperatures on the graph after 5 minutes and twice more after a 5 minute interval (as in steps 2, 3 and 4 above). Compare these results with the results for the dry soil. Explain any difference in behavior.
8. Remove this soil column and replace with an air-dry column in EXACTLY the same position. Apply surface mulch to this column. NB: YOU WILL NEED TO MONITOR THIS TREATMENT AT ALL TIMES AS THE MULCH MAY IGNITE! Repeat the heating process (steps 2, 3 and 4) and plot the temperatures on the top graph (next page). Explain the results.
9. Interpret all of the results in terms of your understanding of thermal conductivity and heat capacity.

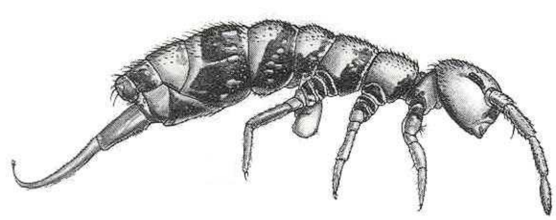

S O I L D E P T H (cm)
0
1
2
3
4
5
Air–Dry
16
21
27
32
38
43
49
54
(°F) ↓ Soil Temperature (°C)↑
60
70
80
90
100
110
120
130
S O I L D E P T H (cm)
0
1
2
3
4
5
Moist

Station B: Soil Ecology Part 1.

Introduction:

In this exercise you will be preparing soil and compost samples for microarthropod and nematode extraction. The resulting samples will be examined next week in part 2 of this exercise.

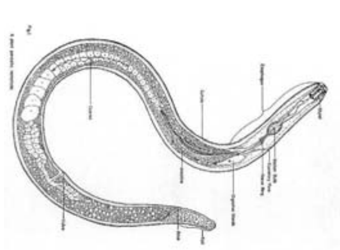
Microarthropods:



Collembola (Springtail)

Many arthropods live in soil environments. Larger arthropods include insects, Arachnids (spiders), Myriapods (Chilopods = centipedes, Diplopods = millipedes and Isopods = pill bugs or potato bugs). The smaller arthropods, or microarthropods, include Collembola (springtails), Acari (mites), and Pseudoscorpions. The most commonly used extraction methods involve using temperature or moisture gradients that force the microarthropods to migrate towards a collection vessel. The Berlese – Tullgren funnel method uses both moisture and temperature gradients. Soil samples are placed in a funnel that is positioned over a small beaker of ethanol. A 60W light is placed over the funnel and over the course of a few days the soil becomes progressively dryer forcing the microarthropods to migrate downwards and eventually fall into the beaker of ethanol where they can be counted and examined.

Nematodes:



Nematodes are microscopic animals that live in thin films of water surrounding soil particles. They occupy almost every trophic level of the soil food web. Some are plant pathogens, others feed on fungi, and still others feed on other nematodes. The most common method of nematode extraction is the Baermann funnel assembly. Soil samples are wrapped in cheesecloth, and placed in a funnel filled with water. Because of their muscular structure nematodes can only swim downwards when they are placed in large volumes of water, so over time they accumulate at the bottom of the funnel. After a few days the funnel is opened and a couple milliliters of the water is collected. The solution is examined under a microscope. Individual nematodes can be isolated and fixed on a slide for later classification.

Exercise C.

Berlese-Tüllgren funnel for microarthropod extraction:

1. Place a weigh boat onto the scale and tare it.

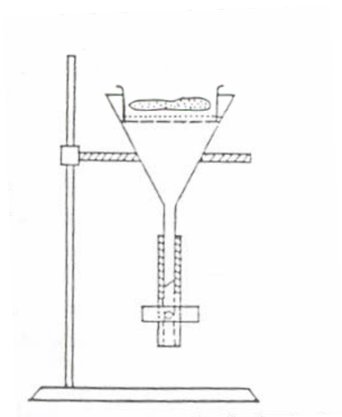
2. Weigh out 100 g of moist unfinished vermicompost, thermophilic compost, forest leaf litter or field soil.

3. Gently place the sample onto the mesh screen inside the Berlese/Tüllgren funnel assembly.

4. Pour about 50 mL of ethanol into the beaker at the base of the assembly and reassemble.

5. Place the unit where it will not be disturbed. Turn the 60W light on above the unit and incubate for 7 days.

Baermann funnel: Nematode extraction



6. Place several layers of cheesecloth onto a scale.

7. Weigh 50 g of moist compost, leaf litter or field soil onto the cheesecloth. Tie the cheesecloth closed with a length of twine. If you're using vermicompost make sure to remove the worms. There is not much worse than the smell of rotting red worms!

8. Fill the Baermann funnel assembly with water, making sure that the clamp at the bottom is closed, and suspend the cheesecloth containing the compost or soil from the top edge so that it is fully submerged.

9. Place the unit where it will not be disturbed. Turn the light on above the unit and incubate for 7 days.

Station C:
(please see lab 8 handout for instructions concerning the greenhouse lab)

Final Group Exercise:

Nutrient Management
<u>Fertilizers</u>

Fertilizers exist in many forms. Some are single compounds, such as $(NH_4)_2SO_4$ or KCl, which provide only one or two plant nutrients. Others are mixtures of several compounds and provide at least two nutrients. Many commercial fertilizers are mixtures of compounds which provide substantial amounts of nitrogen (N), phosphorus (P) and potassium (K). These three nutrients are required in the greatest quantities by plants. The analysis of these fertilizers is presented as a set of three numbers, such as 10-20-5, which indicates that this particular fertilizer contains 10% N, 20% P_2O_5, and 5% K_2O. The fact that P and K content are expressed as the oxide is a relic from the past, when elemental analyses of solids were always expressed in oxide form. In fact, P and K are **not** present in fertilizers as oxides, but rather as soluble salts.

For example, ammonium phosphate, a commonly used fertilizer, has an analysis determined as follows:

$NH_4H_2PO_4$: Formula weight = 115.0

$$\% N = \frac{\text{(atomic weight of N) x (moles of N in formula)}}{\text{formula weight}} \times 100$$

therefore,

$$\% N = \frac{14 \times 1}{115} \times 100 = 12\%$$

and,

$$\% P = \frac{\text{(atomic weight of P) x (moles of P in formula)}}{\text{formula weight}} \times 100$$

therefore,

$$\% P = \frac{31 \times 1}{115.0} \times 100 = 27\%$$

% P_2O_5 is obtained from % P by first determining the difference in weight between a given amount of phosphorus and the **same** amount of phosphorus in the oxide form.

1 mole of P_2O_5 weighs 2(31) + 5(16) = 142 g
2 moles of P weigh 2(31) = 62 g

$$\frac{142\ g}{62\ g} = 2.29$$

This means that % P_2O_5 = 2.29 x % P
In the above example of $NH_4H_2PO_4$, this means that

$$\%\ P_2O_5 = 2.29 \times 27\% = 62\%$$

This material, if pure, would then be given an analysis of 12-62-0. Commercial grades of this material are less pure, and have a typical analysis of 11-48-0.

Organic fertilizers, such as composted manure, have much lower contents than synthetic inorganic fertilizers. However, they have some real advantages such as slow nutrient release (by mineralization), tendency not to damage roots, provision of micronutrients, and improvement of soil structure. Because they rely on mineralization (organic decay) for N and P release, they maybe unable, under cool climatic conditions, to provide sufficient nutrients for the growing plants. This means that rates of N and P applications from organic fertilizers are adjusted to higher levels in order to compensate for slow release over the growing season.

Some fertilizers are much less soluble than others, and are effectively "slow-release" fertilizers. The table below shows that rock phosphate is much less soluble than the more commonly used commercial phosphates.

Compound	Solubility in H_2O (ppm)
Monocalcium phosphate, $Ca(H_2PO_4)_2$	150 000
Dicalcium phosphate, $CaHPO_4$	60
Rock phosphate (apatite), $Ca_3(PO_4)_2 \cdot Ca(OH)_2$	0.01

Soil Testing and Fertilizer Recommendations

Recommended rates of nutrient additions to soils are estimated based upon:

1. The extractable level of the nutrient in the soil (determined by a chemical soil test), which has been correlated by field experiments to nutrient availability.
2. The predicted requirements of the crop to be grown.
3. To some extent, the cropping history of the soil.

These recommendation are typically reported as **pounds** of N, P_2O_5, and K_2O per **acre** in the United States, using the assumption that 1 acre of soil six inches deep weighs about 2 million pounds.

These recommendations can be rounded to an approximate ration of N-P_2O_5-K_2O needed, say 1-2-2. Ideally, a fertilizer would be commercially available with this same ratio of nutrients. For example, a 5-10-10 fertilizer has the desired 1-2-2 ratio of nutrients. This means that there are 2 pounds of P_2O_5 and 2 pounds of K_2O in the fertilizer for every pound of N. If the recommendation indicated that 20 pounds of nitrogen were needed, this could be provided by adding 20 (pounds of N needed) / 0.05 (5% of fertilizer) = 400 lbs/acre of 5-10-10 fertilizer. NOTE: if you use an organic fertilizer you should assume that typically 50-60% of the total nutrient content is **not** available for the present crop.

EXERCISE D:

1. Derive the formula for converting from %K in fertilizer to % K_2O.

2. Use the answer to 1 (above) to obtain the fertilizer analysis of pure K_2SO_4.

3. Calculate the fertilizer analysis for pure urea ($CO(NH_2)_2$) and anhydrous liquid ammonia (NH_3).

4. What would be the fertilizer analysis of a 1:1 mixture (by weight) of diammonium phosphate $(NH_4)_2HPO_4$, and potassium nitrate, KNO_3?

5. Examine the bag of organic fertilizer in the laboratory.
   (a) what is the nutrient analysis?
   (b) estimate the C/N ratio of this material: (assume that 60% of organic matter is carbon)
   (c) suggest some anticipated problems in using this material as the only source of macronutrients.

EXERCISE E:

1. Examine the nutrient analysis sheet for the soil to be used in this exercise.

2. Find the measured extractable levels of P, K, Mg, Ca, Fe, Mn and Zn (lbs/acre). Are any of these nutrients deficient in this soil?

3. Find the measured exchangeable acidity. What are the units of exchangeable acidity?

4. Find the recommended lime and fertilizer rates for growing next year's crop on this soil. Record on worksheet.

5. Choose fertilizer materials from those provided on the back bench in the lab, and using their known nutrient contents, calculate the amounts of these fertilizers needed per acre. Record on the worksheet the analysis of each fertilizer selected and lbs/acre needed to meet the recommendations.

Example: Suppose the recommended P_2O_5 addition is 30 lbs/acre, and you decide to use a fertilizer with an analysis of 11-48-0. So,

$$\text{Fertilizer needed} = \frac{30 \text{ lbs } P_2O_5}{\text{Acre}} \times \frac{100 \text{ lbs fertilizer}}{48 \text{ lb } P_2O_5} = 62.5 \text{ lbs/acre}$$

62.5 lbs/acre of 11-48-0 fertilizer meets the recommended P_2O_5 and since 1 lb fertilizer/acre is equivalent to 0.5 mg/kg, 62.5 lbs/acre is equivalent to 62.5 x 0.5 mg/kg = 31.2 mg fertilizer/kg soil.

6. Convert from lbs/acre to mg/kg as follows:

$$\frac{\text{lbs fertilizer}}{\text{acre}} = \frac{\text{lbs}}{2 \times 10^{16} \text{ lbs soil}} = \frac{0.5 \times \text{grams}}{10^{6} \text{ grams soil}} = \frac{0.5 \times 10^{-3} \text{ grams}}{1 \text{ kg soil}}$$

So: 1 lb of fertilizer/acre = 0.5 mg fertilizer/kg soil

Worksheet

	Recommended Additions (lbs)	Fertilizer chosen and analysis (%)	Amount to be added lbs/acre	mg/kg
N (lbs/acre)	_______________	_______________	_________	________
P_2O_5 (lbs/acre)	_______________	_______________	_________	________
K_2O (lbs/acre)	_______________	_______________	_________	________
Lime (tons/acre)	_______________	_______________	_________	________

Appendix A: <u>Some Rules of Commercial Fertilizer Use</u>

1. Avoid salt injury –

If too much fertilizer is banded near the seedling roots, the roots maybe injured as evidenced by wilting leaves and scorched leaf tips and edges.

Rule: NO MORE THAN 80 LBS/ACRE OF N & K_20 SHOULD BE USED IN A FERTILIZER BAND

Example: 400 lbs/acre of 10-10-10 fertilizer would be 40 lbs of N + 40lbs of K_20 = 80 lbs/acre of N & K_20.

2. Avoid urea and diammonium phosphate injury – if too much urea and/or diammonium phosphate is banded near the seedling, injury due to NH_3 toxicity (or NO_2^- accumulation) may result. This combination produces a high pH which favors the reactions:

$$NH_4^+ \rightarrow NH_3$$

$$NH_4^+ \rightarrow NO_2^-$$

Rule: IN THE FERTILIZER BAND THERE SHOULD BE **NO MORE** THAN:

(a) 20 LBS N/ACRE AS UREA
(b) 30 LBS P_2O_5 AS DIAMMONIUM PHOSPHATE
(c) 20-30 LBS N IN UREA AND DIAMMONIUM PHOPSHATE COMBINED
(d) 30-40 LBS OF AMMONIUM N FROM **ALL** SOURCES USED WITH DIAMMONIUM PHOSPHATE

3. The injuries discussed above can be avoided by broadcasting rather than banding fertilizer.

Appendix B. Important Properties of Common Nitrogen Fertilizers

	% N	Form	Limitations in Use
Anhydrous Ammonia	82	liquid (pressurized)	1. Volatile, must be injected 2. Extremely caustic! 3. Creates high soil pH where injected
Urea	45 – 46	dry pill	1. Must be converted microbially to NH_3 2. Unless covered by soil, maybe partly lost as volatile NH_3 3. Creates high pH if banded
Ammonium Nitrate	33 – 34	dry pill	1. On high pH soils, NH_4^+ may be lost as volatile NH_3 2. Forms explosive mixture with petroleum products
Ammonium Sulfate	20	dry crystals	(similar to Ammonium Nitrate)