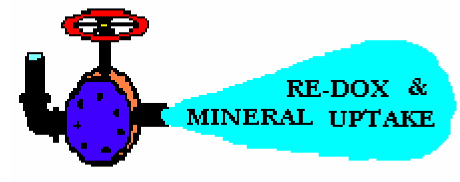
CCS PIPELINE



NUTRIENT UPTAKE BY PLANT ROOTS AND RE-DOX POTENTIAL

The state of soil (RE-DOX POTENTIAL) and the soils aerobic (oxygen rich) and anaerobic (oxygen poor) zones is essential for; normal root growth, nutrient uptake and is fundamental to profitable crop production. Injection of oxygen into flooded or reduced soils will help elevate the RE-DOX POTENTIAL (RDP). Circumstances or conditions leading to reduced oxygen supplies in the soil should be identified and dealt with prior to crop damage.

Cultural practices should be adopted to prevent RE-DOX problems; insure water drainage ditches or devises are clear, do not over irrigate, monitor soil moisture content and utilize mechanical (aerification) equipment prior to or at the onset of conditions that lead to reduced air (oxygen) supply to the soil. Prevention is easier than curing existing RE-DOX problems.

For more information on this subject contact Creech Crop Services, LLC at this email address: CCS creechcrop@aol.com

MINERAL UPTAKE BY PLANT ROOTS

Minerals required by plants are mainly absorbed by roots from the soil solution. In addition to taking minerals by adsorption from soil solution plants also may have an association with soil organisms. An example is (Ecto or Endo) Mycorrhizal Fungi whereby the fungus invades the plant and exchanges mineral ions for amino acids and/or sugars from the plant. Another example is an association of legumes with nitrogen fixing bacteria (Rhizobium sp.).

Mineral ions are passively carried along with the adsorbed soil water via Xylem transport (the path of their movement through the plant is similar to that of water). The dissolved soil minerals pass through the endodermal layer of the root, through the plasma membrane and into the endodermal protoplasts.

The plasma membrane screens the passage of minerals into and out of the vascular system between the Soil and main plant body. The plasma membranes of most cells, including those of root cells, contain active transport (energy requiring transport mechanisms) systems that discriminate between various ions. Some ions may accumulate to high concentrations inside the protoplasts (ie: K+). Others may be pushed back into the wall space (ie: Na+). These active transport systems may raise the concentration of a given ion within the protoplasts as much as 1000 times above the concentration in the soil solution. This may be a great aid to the plant in acquiring rare elemts. The energy cost of this system is ATP (adenosine tri-phosphate) which must be produced by respiration with a consequent demand for Oxygen and Glucose. Other high energy compounds are involved ($NADPH_2$, ETC.)

ORGANIC TRANSPORT SYSTEM

The Phloem sieve cells move organic materials rapidly throughout the plant. The phloem is the major path for food transport in plants. Active transport of sugars, amino acids, organic acids and other organic molecules into the mass flow of the phloem sieve elements facilitates the movement of nutrients to sinks. This movement is growth and storage sink driven.

OXYGEN DIFFUSION RATE (ODR)

The oxygen diffusion rate is the rate at which oxygen diffuses into the soil. The rate is measured in grams per square centimeter per minute (g/cm^2 min.). The below chart gives oxygen diffusion rates in various soil textures and depths where plant root growth is good.

ODR CHART

Soil Texture	ODR 10 cm	20 cm	30 cm	Remarks
Loam	50	30	38	Very Good Growth
Silt Loam	49	26	32	Good Growth
Sandy Loam	36	32	34	Chlorotic Plants
Sandy Loam	64	45	39	Rapid Root Growth
Clay Loam	7	9	-	Chlorotic Plants
All Soils	< 20	< 20		Root Growth Ceases

ODR 20×10^{-8} g/cm^2 min. = minimum growth

$30 - 40 \times 10^{-8}$ g/cm^2 min. = good (satisfactory growth)

60×10^{-8} g/cm^2 min. = excellent growth.

(20×10^{-8} g/cm^2 min. = 16.186 g/acre min. = 23307.84 g/acre day = 51.33 lb O_2/acre day)

Conversion Table

20	=	51.33 lb O_2 per acre per day
30	=	77.00 lb O_2 per acre per day
40	=	102.66 lb O_2 per acre per day
60	=	154.00 lb O_2 per acre per day

A cubic yard of soil under ideal conditions would contain 25 % air pore space, and since air is approximately 21 % O_2 a cubic yard of air at sea level contains approximately 250 g O_2.

This translates to an equation of 0.25 x 250 g = 62.5 g O_2 in the air space of a cubic yard of ideal soil.

In farming or turf terms this translates (dealing with the top 6" of soil) 807 cubic yards of soil per acre. Therefore, if we multiply 807 x 62.5 = 50437.5 g O_2 per acre (111 lb O_2 per acre). Under ideal conditions we can expect 111 lb O2 per acre per day in soil that is maintaining a strong root system. These calculated numbers agree with the tested numbers above from ODR 40 - 60.

OXIDATION AND REDUCTION

Oxidation - A chemical reaction that increases the oxygen content of a compound. A chemical reaction in which a compound or radical loses electrons and the valence in increased. The compound, molecule or radical becomes more positive. The valence is increased. Valence = oxidation number.

Reduction - A chemical reaction of hydrogen with another substance. Chemical reaction where an element gains electrons. The compound, molecule or radical becomes more negative. The valence is decreased.

Oxidizing Agent - The substance reduced in an oxidation-reduction reaction. The compound that gives up oxygen easily removes hydrogen from another compound or attracts negative electrons.

Reducing Agent - The substance oxidized in an oxidation-reduction reaction. A material that adds hydrogen to an element or compound. A material that adds an electron to an element or compound, that is, decreases the positive ness of its valence.

Oxidation Potential - The difference in potential between an atom or ion and the state in which an electron has been removed to an infinite distance from the atom or ions.

Reduction Potential - The potential drop involved in the reduction of a positively charged ion to a neutral form or to less highly charged ions.

Redox Potential - The voltage difference at an inert electrode immersed in a reversible oxidation-reduction system, measurement of the state of oxidation of the system. Also known as the Oxidation-Reduction Potential.

EXAMPLE: $Zn_{(m)} + 2\,H^{+}_{(aq)}$ >>>>>> $Zn^{+2}_{(aq)} + H_{2}(g)$

Zn = Reducing agent - loses electrons to H
H = Oxidizing agent - gains electrons from Zn
Zn is oxidized to Zn^{+2}
$2H^{+}$ is reduced to H_2

Soil Redox - A characteristic related to soil aeration. It is the reduction and oxidation states of the chemical elements in the soil. In a well-aerated soil, the oxidized states of: Fe (Fe^{+3}), Mn (Mn^{+4}), Nitrate (NO_3^-) and Sulfate ($SO4^{-2)}$ dominate. In poorly drained soils or poorly aerated soils with compaction and aggregation problems the reduced form of these nutrients exist: Fe^{+2}, Mn^{+2}, NH_4^+ and S^{-2}. In the reduced form nutrients are not in a form ideal for plant uptake. Remember - plants take up ions and charge makes a difference.

Redox Potential - E h - Provides a measure of the tendency of a soil system to reduce or oxidize chemicals and is usually measured in volts or mVolts (v/1000). If E h is large >0.3 V then oxidizing conditions exist. If E h is small < 0.2 V, then reducing conditions exist.

In well drained soils E h is in the range of 0.4 - 0.7 volts . As O_2 is depleted E h declines to a level of less than 0.3 V. At this level O_2 is depleted from soil air pores. Microbes use combined oxygen for metabolism at E h levels lower than 0.3 V, and in this situation the oxygen containing elements are reduced.

E h Chart for Some Molecules

Oxidized Form	Reduced Form	E h Level below which Reduction occurs
O_2	H_2O	0.38 - 0.32
NO_3^-	N_2	0.28 - 0.22
Mn^{+4}	Mn^{+2}	0.28 - 0.22
Fe^{+3}	Fe^{+2}	0.18 - 0.15
SO_4^{-2}	S^{-2}	- 0.12 - - 0.18
CO_2	CH_4	- 0.20 - - 0.28

Soil aeration helps to determine the species present in the soil and also what form the soil elements are in.

If soil is wet (saturated to field capacity or flooded) this relationship exists between time and ODR with respect to Redox E h. The time period is days…this period is over 14 days (2 weeks).

	T0	T2	T4	T6	T8	T10	T12
O2 % in soil air…………	6	8	9	11	12	13	15
E h…………………………	0.3	0.38	0.46	0.50	0.54	0.58	0.60

If a wet soil remains wet for extended periods it may become fallow. Microbial diversity and numbers will diminish, aggregation properties will deteriorate, compaction will occur and the ODR recovery time will be greatly extended. This will lead to serious problems for crops and turf.

The Redox potential of soil is one of the most dynamic characteristics. It is an indirect measure of potential biological activity and soil tilth.

SYMPTOMS OF REDOX PROBLEMS

1. **Black Layer Formation - Definite black line indicative of Metal Sulfide formation.**
2. **Rotten Egg Smell - H_2S (hydrogen sulfide smell)**
3. **Root deterioration - Roots are short, stumpy and dark colored with tips necrotic.**
4. **Compaction problems - Water will not penetrate. Soil is wet for long periods.**
5. **Poor plant vigor - Roots, stolons, crowns and leaves are slow growing.**
6. **Thin plant stands - Grass blades have a lot of opening between them.**
7. **Pale colored plants - Plants can not take up K^+ or Nitrogen.**
8. **Plants slow to recover - There is no substitution for Oxygen.**

HOW TO RESPOND TO OXYGEN PROBLEMS IN THE SOIL

1. **AERIFY THE SOIL - CULTIVATE, PUNCH HOLES, SLICE**
2. **BALANCE NUTRIENTS WITH AERIFICATION**
3. **REDUCE IRRIGATION IF THE SOIL IS TOO WET**
4. **REDUCE TRAFFIC**
5. **USE NITRATE NITROGEN**
6. **CONSIDER FOLIAR FERTILIZATION**
7. **INSURE pH IS NOT TOO HIGH OR TOO LOW**
8. **REMOVE ALGAE & TREAT FUNGAL PROBLEMS**