Impact of waterlogging on plants

Abstract:

This review will try to illustrate some of the impacts that waterlogging has on plants, in monocotyledons & dicotyledons. The review includes, a general introduction into the impact of anaerobic/waterlogged soil condition on plants, quoting from different sources in this field. Then it focuses on five plant species of global interest or importance, Barley, Tomatoes, Soy Bean, Cotton and Rice, showing the effect of waterlogging on each, quoting journals and experiments done by fellow scientist . The topic of research into waterlogging is vast, with thousands of journals and experiments on countless plant species, so I'm focusing on just five. " Flooding and submergence are major abiotic stresses and rank alongside water shortage, salinity and extreme temperatures as major determinants of species distribution worldwide. Plants adapt to their ever-changing environment in many ways, leading to a wealth of growth forms of varying complexity" (Visser et al, 2003). " A major constraint resulting from excess water, at least for poorly adapted species, is an inadequate supply of oxygen to submerged tissues; diffusion of oxygen through water is 104-fold slower than in air" (Armstrong & Drew, 2002). " In addition to the threat of oxygen deficiency, excess water also leads to other changes in the soil that influence plants; levels of the plant hormone ethylene (Smith &Russell, 1969; Jackson, 1982), and products of anaerobic metabolism by soil micro-organisms (e. g. Mn2+, Fe2+, S2-, H2S and carboxylic acids) can accumulate (Ponnamperuma, 1984; McKee and McKevlin, 1993). It was suggested by (Zhou, Li, and Mendham, 2007), that " Waterlogging tolerance is likely to be a complex trait which is related to many morphological and physiological traits that are under strong environmental influence.

Introduction:

Waterlogging can lead to countless physiological and developmental problems as mentioned in many publications, journals and experiments. It was suggested by setter & co-workers, 1999 that, ” Stress on plants imposed by flooding of the soil and deeper submergence constitutes one of the major abiotic constraints on growth, species distribution and agricultural productivity. Waterlogging is estimated to reduce yields on average by 20 to 25%, but the loss may exceed 50% depending on the stage of plant development” (Setter et al., 1999). 50 % loss in agricultural yield can be catastrophic in the future, especially for developing countries, which is why, research into waterlogging is crucial for agricultural sustainability and food security. The general effect of waterlogging on plants ranges from physiological, developmental and metabolic effects which are mentioned in a few publications. ” Waterlogging is a major problem restricting the plant growth by leading to oxygen deficiency around roots and rhizomes, and consequently it can be fatal because aerobic respiration ceases and levels of energy-rich adenylates drop rapidly resulting in dramatic decrease in ion uptake and transport” (Huang et al, 2003; vartapetian et al, 2003) as quoted in (Changdee., et al, 2008). ” When soil is saturated with water, gas diffusion is reduced. Consequently one of the main effects of flooding is a lower pool of available O2 in submerged plant parts. This decline in O2 is heightened by aerobic processes taking place in the root zone of plants. Accordingly anoxic conditions develop, leading to reduction in ATP production and consequent decrease in root metabolism. The decline in available energy can subsequently reduce other active cellular processes such as nutrient uptake, osmotic adjustment or regulation of cytoplasmic pH” (Probert & Keating,

2000). ” Waterlogging resulted in visible yellowing and premature senescence of leaves, and greater decline in relative water content, chlorophyll content, and membrane stability” (Sairam, et al, 2009). The majority of plants respond negatively to waterlogging whilst some plants respond positively.

Discussion:

Plants throughout the years have adapted different ways to minimize damage caused by waterlogging. All plants poses survival mechanisms which are of a complex nature, and differing between some species. Plants also differ in the way they respond to anaerobic or anoxia soil conditions, some are extremely tolerant, some very sensitive and some in between. ” Even species that are susceptible to poorly aerated conditions possess metabolic and molecular responses that lengthen survival time from a few hours to several days. All plant species synthesize so-called anaerobic proteins that enable an oxygen-independent energy-generating metabolism to proceed where fermentable substrates are available” (Subbaiah & Sachs, 2003). ” Prevention of the build-up of potential phytotoxins is another mechanism that enhances plant survival under flooded conditions. A specific type of hemoglobin (phytoglobin) may play such a role by detoxifying nitric oxide formed during hypoxia of root tissues. Alternatively, phytoglobin may also regenerate NAD+, thereby serving as an alternative to fermentation as a source” (Dordas et al., 2003).

Impact of waterlogging on five plant species

Barley: In barley ” Waterlogging inhibits the uptake of N which leads to the decrease of N concentration in shoots of barley seedlings” (Drew and

Sisworo, 1977). Pang et al. (2005) found that both shoot and root growth was negatively affected by waterlogging. As waterlogging stress developed, chlorophyll content, CO2 assimilation rate, and maximal quantum efficiency of photosystem II (variable fluorescence/maximum fluorescence) decreased significantly, with cultivars showing less yellow leaf percentage having less adverse effects" (Pang et al., 2005). A decrease in nitrogen uptake, fluorescence leads to decreased leaf area index (LAI) and decreased yields. " Oxygen deficiency in the rooting zone occurs under waterlogging conditions, the lack of O2 can severely damage the root" (Drew, 1997) . Soil waterlogging usually influences barley growth in a negative way, " the inhibition of N uptake, and the consequent redistribution of N within the shoot, are important contributory factors in the early senescence of leaves and the retarded growth of shoots in flooded plants" (Drew and Sisworo, 1977). " A decrease in the N concentration in shoots of barley (Hordeum vulgare L.) seedlings can occur rapidly after the onset of flooding and precede leaf chlorosis (Drew and Sisworo, 1977; Wang et al., 1996) and consequently reduces shoot and root growth, dry matter accumulation, and final yield" (Kozlowski, 1984; Drew, 1991; Huang et al., 1994a, 1994b; Malik et al., 2002). " Roots are also injured by O2 deficiency and metabolic changes during acclimation to low concentrations of O2" (Drew, 1997).

Tomatoes: in tomatoes it was reported that; " Enhanced ethylene production and leaf epinasty are characteristic responses of tomato (Lycopersicon escukntum Mill.) to Waterlogging. It has been proposed by (Bradford &Yang, 1980) that this results from the synthesis of the immediate precursor of ethylene, 1-aminocyclopropane-I-carboxylic acid (ACC), in the waterlogged

roots, and its export in the transpiration stream to the shoot, and its rapid conversion to ethylene gas” as stated in (Kent, et al, 1982).

Soybean: It has been reported that ” cereals are generally more tolerant to flooding than legumes” (Crawford, R. M. M, 1977) as quoted by (Russel, Wong & Sachs, 1990).

Cotton: ” Waterlogging of cotton has been reported to cause a reduction in root growth and nutrient uptake (Letey et al., 1962; Huck, 1970; Hocking et al., 1987), leaf area and photosynthesis (Hodgson, 1982; Meyer et al., 1987; Sahay, 1989) and dry matter accumulation and fruiting” (Hodgson, 1982; Hocking et al., 1987).

Rice: (Oryza sativa), is one of the most interesting monocotyledonous plants in my opinion, rice is one of the few plant species that can adapt too & tolerate very low concentrations of oxygen in the soil and reacts positively to waterlogging without negative effects on plants growth and development. Rice grows better than any other plant in the same waterlogged conditions. In two experiments by Perata on rice seed germination showed interesting results.