PART III. Selected Management Practices for Rice Diseases

Section 5. Abiotic stresses in rice

T.W. Mew

1. Introduction

The manifestation of biotic stresses of rice that we call diseases—caused by either bacterial, fungal, nematodal, or viral pathogens—depends on three components: host (the rice plant), the pathogen, and the environment. The interaction of this triangular relationship is always related to human activities on crop production and farm operations. A stressed caused by an abiotic factor (such as drought, flooding, or nutrient deficiency) is not a "disease" in the general sense of the term, even though it is also caused by a deviation in normal physiology and growth. These disorders are caused by either the deficiency or excess of something that supports the plant's life or by the presence of some external agent that interferes with the plant's survival.

Abiotic stress is not a dynamic or continuous process. It is an injury or more commonly referred to as a metabolic dysfunction. Thus, the stress is more appropriately called a "physiological disorder." One thing in common, however, is that both biotic and abiotic stresses result in a syndrome that causes "symptoms." The distinction between a biotic and an abiotic stress is that in the latter, the cause can be removed or neutralized, which will prevent the syndrome from subsequent development. And most abiotic stresses are reversible once they have occurred if an adequate amount of a deficient nutrient such as nitrogen is added to the soil through fertilization. the plant can recover from the stress. This is not likely with a biotic stress unless the causal agent is killed or removed, if possible. Both types of stresses cause symptoms and, in some cases, a biotic stress symptom might be confused with that of an abiotic stress. Rice tungro, for instance, was initially thought to be a physiological disorder but it was eventually identified to be a disease caused by a virus. So, proper diagnosis is needed. Experimentally, the causal relationship of particular stress to the plant can be established and distinguished. This is the general concept between biotic and abiotic stresses presented in this online resource.

Abiotic stresses are also known as physiological diseases (Baba et al 1965). All physiological disorders or abnormalities of rice plants may be the effect of nonparasitic (abiotic) agents. These include physico-chemical properties of the soil such as deficiency or excess of mineral nutrients; pH; toxic substances such as H_2S and organic acids that affect the availability and uptake of nutrients; improper use of pesticides; environmental conditions such as drought, flooding, extremely high and low temperatures, reduced light; and atmospheric and water pollutants. The type and severity of abiotic stress depends on the growth stage and often specific parts of the rice plant.

The description of physiological disorders provided here is restricted to the stresses induced by mineral nutrients documented in Ou (1985) and Fairhurst et al (2007).

There is more information on abiotic stresses of rice plants in relation to low temperature than on other unfavorable climatic conditions. Temperature beyond the normal range of rice growth, i.e. 15-32°C, often causes sterility due to the failure of anthers to dehisce and flowers to open or in part due to failure of fertilization.

2. Nutritional disorders

Nutritional disorders are common in rice plants and may occur across the rice-growing world. A brief description of the symptoms caused both by deficiency or excessive quantity (toxicity) is presented here. Management practices involve avoiding the circumstances described by, for example, increasing or decreasing specific nutrient levels in applied fertilizers, using appropriate field irrigation, and keeping some rice straw on the field after harvest.

2.1. Nitrogen

2.1.1. Deficiency. Nitrogen deficiency is the most commonly occurring disorder in rice usually noticed during the tillering and panicle initiation stages when the demand for nitrogen is greater. Plants across the entire field may appear pale and yellowish. The entire plant may turn light green with chlorotic spots at their tips or, at times, only the young leaves remain green. Leaves are short and erect and the plants are stunted with the number of tillers reduced.

The cause of N deficiency may be due to low levels of N in the soil and/or insufficient application of N fertilizer.

2.2. Phosphorus

2.2.1. Deficiency. Plants are stunted and usually appear dark green with thin and twisted stems. The young leaves may appear normal but older leaves are erect, narrow, and have a dirty green appearance; the leaves eventually turn brown and die. Rice varieties with high anthocyanin content may develop red to purple foliage. The root systems of affected plants are poorly developed. The number of leaves, panicles, and grain per panicle are greatly reduced.

The cause may be due to excessive use of N fertilizer with inadequate application of phosphatic fertiliser and low in indigenous soil coupled with hampered phosphate supplying power due to high phosphate fixation in soil,..

2.3. Potassium

2.3.1. Deficiency. Plants are usually dark green but the tips of the lower leaves become yellowish brown. The numbers of tillers may be slightly reduced. The leaves may exhibit yellowish brown margins along with dark brown necrotic spots that initially appear on the tips of older leaves.The leaves are droopy and often exhibit yellow stripes. With severe deficiency, the leaf yellowing appears on younger leaves, which is often confused with tungro.

The cause may be related to excessive use of N or N+P fertilizer with insufficient K application. In direct-sown rice during early growth stages, the problem can be exacerbated when the plant population is large and the roots are shallow. In hybrid rice because of a greater K demand. K-deficiency often occurs on rice plants grown in soils already low in K. The K deficiency symptom is often confused with bacterial blight.

2.4 Sulfur

2.4.1 Deficiency. Sulfur deficiency affects chlorophyll developmet, protein synthesis, plant function, and structure. The symptoms are somewhat similar to those of N-deficiency. The main difference is that sulfur deficiency may cause leaf yellowing beginning in the younger leaves, whereas with N deficiency leaf discolouration starts in the older leaves and then spreads to the whole plant. S deficiency is less common in irrigated rice. In the nursery, the seedlings appear pale yellow with high mortality after transplanting. The whole plant may be pale yellow with a conspicuous yellowing and chlorotic appearance of young leaves along with browning of the tips due to necrosis. Necrotic brown spotting between the veins is also common. Older leaves do not exhibit these symptoms. However, the overall plant growth may be retarded with reduced tillering, shorter panicles and fewer spikelets per panicle.

The cause may be related to low S availability in soil due to intensive cropping or use of S-free fertilizer such as urea, which has nearly replaced the use of ammonium sulfate.

Sandy soil or soil low in organic matter is prone to be deficient in S.

2.4.2.Toxicity. Sulfur is reduced to a sulfide form under anoxic (depleted oxygen) conditions in submerged paddy soils that can result in the generation of a high concentration of H_2S in the soil solution. Excessive application of sulfate in fertilizers or urban or industrial sewage on poorly drained, strongly reducing soils can also result in similar situations. Free H_2S in paddy soils with low content of free iron oxide and high sulfate content inhibits plant root growth. Sulfur toxicity reduces nutrient uptake by plants resulting in severe nutrient imbalances.

The morphological symptoms include interveinal chlorosis of emerging leaves. Freshly uprooted rice hills possess poorly developed coarse root systems with many black roots due to stasis of iron sulfide unlike healthy roots that are smooth and orange-brown in color due to coating of Fe3+ oxides and hydroxides. In severe cases, crown rotting can be seen and the dark roots emit a bad odor.

2.5. Calcium

2.5.1. Deficiency. Bleaching of young leaves from the tip downward along the margins gives a whitish appearance and the leaves are curled. Sometimes, necrotic spots develop on the bleached tissue. Root elongation is retarded. In extreme cases, plants are stunted and may die.

The cause may be due to high soil pH and reduced Ca uptake because of a wide exchangeable Na:Ca ratio. Calcium deficiency is usually associated with excessive use of nitrogenous, potassium, and phosphoric fertilizers coupled with water shortages that slow down calcium transport to growing tissues. It is not common in irrigated and in lowland rice soils.

2.6. Magnesium

2.6.1. Deficiency. Magnesium deficiency affects CO_2 assimilation and protein synthesis besides the cellular pH and cation-anion balance activation in plants. The symptoms include orange-to-yellow interveinal chlorosis leading to necrosis, on older leaves initially. Then these symptoms are expressed on younger leaves. The green coloring appears as a string of beeds with green and yellow stripes running parallel to the leaves.

It is more commonly found in lowland and upland crops and is rarely seen in irrigated rice. It is not frequently observed in the field but may occur in fields where available Mg is low.

2.7. Iron

2.7.1. Deficiency. Symptoms initiate as interveinal chlorosis in the emerging leaves and then extend to whole leaves turning them chlorotic resulting in a pale appearance. In severe cases, the whole plant becomes chlorotic leading to death. As a result, dry matter production is greatly reduced.

The cause may be due to high pH of alkaline or calcareous soil following submergence. It is more common in upland soils where the concentration of soluble Fe is low, in lowland soils low in organic matter, or in medium land irrigated with alkaline water.

2.7.2. Toxicity. Iron toxicity occurs in a wide range of soils, but is most commonly observed in fields with stagnate water. It can appear at all stages of plant growth. It causes enhanced phenol oxidation in plants leading to leaf bronzing as a result of tiny brown spots more conspicuously seen in the lower surface of the leaves starting from the leaf tips and spread downward to the leaf base. The spots coalesce with each other and the entire leaf may become orange-yellow to brown eventually leading to its death. In severe cases, leaves appear purple-brown with the plants being stunted with reduced tillers. A sparsely developed root system is coarse in texture and appears to have a brown-to-black coating of dead roots.

The cause is due to a Fe^{2+} concentration in the soil solution because of a low pH or strong reducing soil conditions.

2.8. Zinc

2.8.1. Deficiency. Zinc deficiency is more common in modern rice varieties under intensive cultivation. The symptoms appear around 2 to 4 weeks after transplanting in the form of dusty brown spots on the upper leaves with chlorotic midribs near the base and stunted plant growth.

Rice varieties differ in their sensitivity to Zn deficiency. When sensitive varieties are cultivated in fields where large amounts of N, P, and K fertilizers have been applied in the previous crop, the cause is related to a low amount of available Zn in soil, high pH under anaerobic conditions due to continuous flooding, and immobilization of Zn due to fixation with organic matter.

2.9. Boron

2.9.1. Deficiency. Although not very common, this malady occurs in rice grown in sandy or acid soils and also in soils with high organic matter. B deficiency affects cell growth and panicle development.

The symptoms initially appear on young leaves in which the tips turn white and are rolled twisted (resembling calcium deficiency). In full grown plants, growth is retarded with thinner and weak stems and reduced tiller numbers. When B deficiency coincides with the panicle initiation stage, it hampers panicle development resulting in the production of seeds which may not be viable. In severe cases, B deficiency prevents panicle production.

The cause is related to low B content in soil aggravated by B adsorption on organic matter and clay minerals, and reduction in B mobility due to drought.

2.9.2. Toxicity. Toxicity symptoms appear in the leaf tips of older leaves turning them necrotic with dark brown elliptical spots. This can easily be confused with brown spot caused by *Bipolaris oryzae* (see **Part I, Section 1, Chapter 2**) especially during the panicle initiation stage.

B toxicity is normally encountered in crops grown in coastal saline and volcanic soils. The cause is related to high B concentration in the soil solution due to use of B-rich groundwater and accompanying high temperatures. B toxicity interferes with starch formation and structural carbohydrates in the plant.

2.10. Copper

2.10.1. Deficiency. Copper is a component of many proteins. Cu deficiency causes the emerging leaf tips not to unfurl properly while the lower portion of the leaves exhibiting brown necrotic lesions. Chlorotic streaks can be seen on either side of the midrib and, sometimes, the leaves appear to be bluish green. In severe cases, tillering and pollen viability are affected leading to the production of unfilled or sterile grains. Rice plants deficient in Cu tend to lodge easily because of a lack of lignin production.

Rice crops grown in soils high in organic matter (humid and volcanic ash soils), or peat soil tend to suffer more Cu deficiency. Low Cu content is also due to application of large amount of N-P-K fertilizer, resulting in rapid crop growth which exhausts the Cu supply in the soil.

Naturally occurring Cu toxicity is rare except in areas were Cu is being mined commercially.

2.11. Silicon

2.11.1. Deficiency. Although Si is not recognised as an essential element, it can have a profound effect on rice plant growth and development. Its deficiency weakens the physical strength of the leaves, stems, and roots exposing them to infection by pathogens and infestation by insect pests. Consequently, the leaves and culms become soft and droopy, making the plant more vulnerable to lodging with a reduction in photosynthetic activity, grain filling, and grain yield.

The cause is related to a low Si supplying power of the soil. It may also be aggravated by the removal of rice straw over long periods of intensive cropping.

2.12. Manganese

2.12.1. Deficiency. Mn deficiency affects photosynthesis and protein synthesis. The damage occurs throughout all rice plant growth stages. Symptoms include interveinal chlorosis starting at tips of younger leaves and spreading towards the leaf base. Over time, necrotic spots develop and the leaf becomes dark brown. Emerging leaves are short, narrow, and light green. Although the plants are stunted with fewer leaves and smaller root systems, tillering is not affected.

Mn-deficient plants are often also deficient in phosphorus and contain more iron in the tissues. As a result, the leaves turn bronze. In addition, affected plants are more susceptible to brown spot caused by *Bipolaris oryzae* (see **Part I, Section 1, Chapter 2**).

The cause may be due to little or no available Mn in the soil. It occurs frequently in upland rice, but is uncommon in paddy fields.

2.12.2. Toxicity. Mn toxicity affects the normal metabolic processes in the plant through interference in enzyme activities and synthesis of proteins and organic compounds.

The toxicity is expressed in the form of chlorosis on young leaves, occurrence of yellowish brown spots in the interveinal area of the leaves, brown spots on the veins of lower leaves and leaf blades, leaf tip browning, stunted plant growth with reduction in tillering, and reduced yield due to sterility of the spikelets.

The cause is mainly due to a large concentration of Mn^{2+} in the soil solution due to low soil pH resulting in an unbalanced nutrient status in the soil. Manganese toxicity occurs in acid upland soils, but is not common in lowland rice. Mn toxicity often occurs along with Al toxicity (see below).

2.13. Aluminum

2.13.1. Toxicity. The symptoms of Al toxicity include orange-yellow interveinal chlorosis on leaves and, in severe cases, yellow-to-white mottling of interveinal regions followed by drying of the leaf tips and scorching of leaf margins leading to death of the leaves. Poor root growth results in plant stunting.

The cause is due to excess Al^{3+} in the soil solution because of low pH. It is uncommon in lowland rice. It commonly occurs in upland soils and also in acid sulfate soils before flooding. Mn toxicity often occurs along with Al toxicity.

2.14. Salinity injury

The leaf tips are white in the beginning and the symptom develops as tip burning (under salinity due to soluble chlorides and sulfates), while leaf browning leading to death, poor root development, stunted plant growth, low tillering, and spikelet sterility are common under sodicity conditions, which entails high concentrations of free carbonate and bicarbonate with a presence of excess of sodium. Its occurrence is patchy in the field.

The cause of salinity injury is due to plants grown on soil having high levels of soluble salts (NaCl) causing ion toxicity and imbalance and impaired water uptake.

References

Baba, I., Inada, K., Tajima, K. 1965. Mineral nutrition and the occurrence of physiological diseases. Pp.183-195 in: Proc. of Sympoiun on the Mineral Nutrition of Rice Plant, International Rice Research Institute, Los Baños, Laguna, and Johns Hopkins Press, Baltimore, Maryland, USA.

Fairhurst, T., Witt, C., Buresh, R., Dobermann, A. 2007. Rice: A practical guide to nutrient management (2nd ed.). International Rice Research Institute and International Potash Institute.

Ou, S. H. 1985. Rice Diseases. (2nd ed.) Commonwealth Mycol. Inst. Kew, Surrey, UK.