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## PLANTS IN STRESS CONCEPT-A REVIEW

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**ABSTRACT:** The current concept of stress in plants has been well developed over the past 60 years. Any unfavorable condition or substance that affects or blocks a plant's metabolism, growth, or development is regarded as stress. Vegetation stress can be induced by various natural and anthropogenic stress factors. One has to differentiate between short-term and long-term stress effects as well as between low-stress events that can be partially compensated for by acclimation, adaptation, and repair mechanisms, on the one hand, and strong stress or chronic stress events causing considerable damage that may eventually lead to cell and plant death, on the other hand. Some essential stress syndrome responses of plants are summarized in a unifying stress concept. The major abiotic, biotic, and anthropogenic stressors are listed. Some stress tolerance mechanisms are mentioned. Stress conditions and stress-induced damage in plants have so far been detected using the classical ecophysiological field methods as well as point data measurements of particular chlorophyll fluorescence parameters and of reflectance spectra. The novel laser-induced high-resolution fluorescence imaging technique, which integrates chlorophyll and blue-green fluorescence, marks a new standard in the detection of stress in plants.

**KEYWORDS:** stress, plants, abiotic, biotic, mechanisms, tolerance, anthropogenic, detection, growth

### I.INTRODUCTION

Plants are subjected to a wide range of environmental stresses which reduces and limits the productivity of agricultural crops. Two types of environmental stresses are encountered to plants which can be categorized as (1) Abiotic stress and (2) Biotic stress. The abiotic stress causes the loss of major crop plants worldwide and includes radiation, salinity, floods, drought, extremes in temperature, heavy metals, etc. On the other hand, attacks by various pathogens such as fungi, bacteria, oomycetes, nematodes and herbivores are included in biotic stresses. As plants are sessile in nature, they have no choice to escape from these environmental cues. Plants have developed various mechanisms in order to overcome these threats of biotic and abiotic stresses. They sense the external stress environment, get stimulated and then generate appropriate cellular responses. They do this by stimuli received from the sensors located on the cell surface or cytoplasm and transferred to the transcriptional machinery situated in the nucleus, with the help of various signal transduction pathways. This leads to differential transcriptional changes making the plant tolerant against the stress. The signaling pathways act as a connecting link and play an important role between sensing the stress environment and generating an appropriate biochemical and physiological response.[1,2]

Land plants are constantly subjected to multiple unfavorable or even adverse environmental conditions. Among them, abiotic stresses (such as salt, drought, heat, cold, heavy metals, ozone, UV radiation, and nutrient deficiencies) have detrimental effects on plant growth and productivity and are increasingly important considering the direct or indirect effects of climate change. Plants respond in many ways to abiotic stresses, from gene expression to physiology, from plant architecture to primary, and secondary metabolism. These complex changes allow plants to tolerate and/or adapt to adverse conditions. The complexity of plant response can be further influenced by the duration and intensity of stress, the plant genotype, the combination of different stresses, the exposed tissue and cell type, and the developmental stage at which

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plants perceive the stress. It is therefore important to understand more about how plants perceive stress conditions and how they respond and adapt (both in natural and anthropogenic environments).

Plants have to deal with many less than ideal circumstances that can push the plant to its limit in order to survive.[3,4]

### Environmental Stress

Environmental stress or more specifically abiotic environmental stress includes all the non-living environmental factors that can negatively or even harmfully affect the growth and productivity of plants. A lot of scientific research has been done on drought stress, effects of flooding or submergence, salinity stress and extreme temperatures (both high and low). But for growers well known issues as high light intensities and deficits of inorganic nutrients (for example nitrogen, phosphorus, potassium) are included. The main reason for this would be their key roles in producing yield loss of agricultural or industrial crops worldwide.

### Mechanical Stress

One of the stress types that occurs as soon as you enter your greenhouse or field is mechanical stress. Plants in general are very sensitive to mechanical stress. Experienced growers may know that if they walk through their fields or touch their plants too often, this can result in shorter plants. It can also lead to tissue injury, which is a potential entry point for diseases. Differences in air movement, vibrations or too frequent handling of plants can all cause mechanical stress. Shaking or flexing a plant for just a few minutes each day can reduce stem elongation and the weight of the plant, both fresh and dry. This has also been studied in lab conditions, where young *Arabidopsis thaliana* (Rock cress) plants were subject to stem rubbing a couple of times daily. This resulted in shorter plants compared to the control group, which were not touched. Mechanical stress cannot be prevented completely, but keep in mind when visiting your plants, either indoors or in the field, that they will be affected by your visit. So keep direct contact with your plants to a minimum.[5]

### Drought Stress

On sunny, dry days, or when the light in a greenhouse is very intense, plants may wilt because the rate of water loss through transpiration exceeds the rate at which the root system is absorbing water from the soil. In other words, there is not enough moisture in the soil, which can greatly inhibit plant growth. However, plants have control systems that enable them to cope with less extreme water deficits.

Many of a plant's responses to a lack of water help it to conserve water by reducing the rate of transpiration. A lack of water in the leaves causes guard cells to become less turgid, a simple control mechanism that slows transpiration by closing the stomata. A lack of water also stimulates synthesis and the release of abscisic acid in the leaf; this hormone helps keep stomata closed by acting on the guard cell membranes. The leaves respond to a lack of water in several other ways. Leaves of many plant species, such as grass species, roll into a tube-like shape that reduces transpiration by reducing the area of the leaf surface that is exposed to dry air and wind. Although this leaf response conserves water, it also reduces photosynthesis, which is one of the reasons why drought diminishes crop yield. Root growth also responds to a lack of water. The soil or any substrate a plant grows in typically starts to dry from the surface down. This inhibits the growth of shallow roots, partly because cells cannot maintain the turgidity required for elongation. Deeper roots, which are surrounded by moister substrate, are still able to grow. The root system proliferates in a way that maximises exposure to soil moisture, but this

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demands more of the plants' energy, which is eventually lost for potential yield. The key to drought stress (or lack of water) is to protect the plant from drying out while maintaining photosynthesis. Closing the stomata results in decreased carbon dioxide availability for the plant. And the chemical reactions of the photosynthesis system cannot be switched off on demand, unless the light source is switched off, of course. A shortage of carbon dioxide due to the closure of the stomata results in a build-up of free radicals in the chloroplasts. A complex cascade of chemical reactions, called signal transduction, is responsible for this. The plant responds to these free radicals by producing antioxidants to neutralise them. Without going into too much detail, some plant hormones and free amino acids are often involved and help to plant to build up some tolerance to the drought, which was the initial cause of stress to the plant.

A grower may experience that, as soon as the drought stress is over, wilted leaves seem to recover quickly. However, within a few days to a week the affected plants will show leaf senescence. This is actually a process in which the leaves age rapidly and become yellowish because the chlorophyll has broken down. This is partly a result of irreversible damage by the free radicals mentioned earlier.[6,7]

### **Over-Watering**

Over-watering a plant can kill it more quickly than lack of water. In waterlogged soil there is not enough oxygen for the roots. This is because oxygen diffusion through water is about 10,000 times slower than through air. Without oxygen, anaerobic respiration occurs in the roots, producing toxic compounds in the plant. The symptoms of overwatering also include wilting, yellowing of leaves, root rot and stunted growth.

The central issue in over-watering is oxygen deprivation. This triggers many plant species to produce ethylene, which causes some cells in the root to undergo apoptosis - the process of controlled cell death. The destruction of these cells creates air tubes, which can fill with air from the sections of the plant that are above ground. In this way, roots can receive the necessary oxygen even when the soil is still too wet to contain enough air.

The mechanism described above may help in crops such as corn or rice, but most commercial greenhouse crops are not able to maintain the internal oxygen levels. The roots start to rot fast and even if the grower responds quickly to water-logged substrate, the yield loss can be devastating.

### **Salt stress**

An excess of sodium chloride or other salts in the soil threatens plants for two reasons. First, by lowering the water potential of the substrate, salt can cause a water deficit in plants even though there is plenty of water in the soil. As the water potential of the substrate becomes more negative, the water potential gradient from substrate to roots is lowered, thereby reducing water uptake. Another problem with saline substrates is that sodium and certain other ions such as chloride become toxic to plants when their concentrations are so high that they overwhelm the selective permeability of the root cell membranes. In other words, the plant is unable to selectively absorb the right nutrients, and only the sodium is taken up by the plant.

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Many plant species can respond to moderate substrate salinity by producing solutes that are well tolerated at high concentrations. It has been demonstrated that strawberry is able to produce 'phenolic compounds'. These compounds are believed to restore or maintain the water potential of plant cells, as compared to the substrate, without admitting toxic quantities of salt. This is only a temporary aid, however, because production losses will occur. If the salt stress takes too long, the plant will eventually die.[8,9]

## Heat stress

Extreme heat can damage plants directly, but usually heat damage occurs through increased water loss and plant drought stress. Plants can also become sunburned when shaded foliage is exposed to sunlight during hot, dry periods. When temperatures are extremely high, plants need to bring water from the roots to the leaves and stems. This water then exits the plant through the stomata as water vapour - a process known as transpiration. Transpiration cools the leaves and other plant parts and prevents damage from heat stress. However, if there is not enough water for this process, the plant will sacrifice some of its leaf surface, allowing it to burn up.

## Cold and frost damage

Cold and frost are major causes of crop damage in tender plants, although hardy plants can also suffer if new growth is exposed to a hard frost following a period of warmer weather. Symptoms will often appear overnight, and can affect many types of plants. Leaves and stems may turn black, and buds and flowers may become discoloured. Some flowers that have been affected by frost may not produce fruit.

## Chemical damage

Any kind of chemical applied at the wrong dosage or at the wrong time is capable of damaging the plant physically. Most chemical damage comes from pesticides applied excessively, at the wrong time or during the heat of the day. Careless use of herbicides may also inadvertently damage or kill non-target plants. Spray drift is often a cause of unintentional damage to plants. Chemical damage may appear as red, yellow or brown spots on leaves, leaf tips turning brown, stunted or misshapen plants or widespread browning and death.

In this article we have tried to describe the most important plant parts and their role in some of the most obvious environmental stresses that plants may suffer from. However, the world is much more complex than this. As we have seen in this article roots, leaves (especially the stomata) and the photosynthesis used in apparatus play crucial roles in the specific response of a plant to a stress situation. These responses are often remarkably similar, such as the plant's response to drought stress or salt stress. Both situations result in a reduction in the plant's capacity for water uptake.

A lot of research is currently being carried out into exactly which processes underlie the plant's perception of stress factors and which chemicals in the plant are crucial in making the plant more tolerant to the various forms of environmental stress.[10]

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## II.DISCUSSION

### Biotic and Abiotic Stress

Situations of stress in plants can be classified into two large groups depending on the factor which causes them.

- **Biotic stress factors.** They are caused by other living organisms, animals, insects, plants, fungi, bacteria, pathogens, etc.
- **Abiotic stress factors,** such as temperature, solar radiation, drought, flooding, salinity, agronomic practices, the use of machinery or other farming tools, etc. These are physical and chemical factors.

### Types of stress in plants

Now let's get down to business. These are the most common types of stresses in plants:

#### 1.- Temperature Stress.

Most plants are sensitive to temperature stress and suffer when temperatures rise above their defined thresholds. High temperatures, for example, cause physiological and metabolic damage. With low temperatures, plants stop growing or freeze and eventually die.

#### 2.- Stress Due To A Lack Or Excess Of Light.

Light is the source of energy for photosynthesis, which is directly related to the production of carbohydrates and oxygen. Each plant has its own needs for light and sun, and the lack or excess of them also influences growth and development.

#### 3.- Stress Produced By Infections From Pathogens, Pests And Viruses.

Plants may suffer attacks from other harmful organisms that limit or affect their development, and furthermore, the application of synthetic treatments to combat them may also be stressful depending on the conditions in which they are undertaken.

#### 4.- Stress Due To Absence Or Excess Of Nutrients.

Of course, the absence of nutrients affects the growth of plants and their fruits, but an excess also produces negative effects, as is the case with nitrogen and phosphorous.

#### 5.- Salinity Stress.

This type of stress may be produced by the excess of salt in the soil or in the irrigation water. Poor irrigation control may also have an impact in these salinity problems.

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## 6.- Water Stress.

Water stress is one of the most frequent stresses and one of the primary causes of plant death. Without water, there is an imbalance between transpiration and water absorption, and plants cannot transport nutrients from the roots to the leaves, affecting crop growth and production. On the other hand, too much water in the medium may provoke a series of shocks that limit the growth of the plant because of the lack of oxygen.[11,12]

## 7.- Mechanical Stress.

This is stress caused by damage from agricultural machinery and other tools used in agricultural processes, such as pruning, transplanting, or thinning. This also includes stresses provoked by adverse weather conditions like hail, wind, etc.

### Sustainable solutions to reduce stress in plants

Reducing stress in plants is one of the main tasks to maintain crop quality and profitability. And doing so sustainably is an even more important challenge. At Symborg, we strongly believe in biotechnology as a tool to achieve this, and we've placed a large range of solutions that promote the reduction of stress in plants into the hands of farmers. The following are some examples:

The biostimulants MycoUp, Resid MG and Resid HC promote development of the roots and improve nutrient and water absorption, which leads to stronger plants. These solutions are suitable for resolving effects of abiotic stress, especially water stress and salinity problems. As a result, plants are better prepared to face droughts.

MycoUp 360 is another biostimulant. It is suitable for both abiotic and biotic stress. This solution enables production to be maximized, even in the presence of pathogens.

The biostimulant TrichoSym Bio increases plant resistance against abiotic stress such as salinity, drought, and flooding. It improves plant nutrition by solubilizing macro and micronutrients and increases the ability to develop the root system.

VitaSoil is a soil regenerator based on rhizospheric microorganisms, designed to tackle both types of stress, biotic and abiotic. It unblocks nutrients, fixes nitrogen, and solubilizes phosphorous and other trace elements that allow the plant to optimize its nutrition program in moments of maximum nutritional need.

The technology BlueN allows crops to fix nitrogen from the air during the crop's entire cycle effectively and in a controlled manner, reducing dependence on the intake of nitrogen through soil.

Balius is another of our biostimulants. Its ability to provide the plant with energy is impressive. It increases the crop's tolerance against adverse conditions such as high temperatures, freezes, droughts, waterlogging, salinity, transplanting, pruning or osmotic imbalances.

Finally, Qlimax, our new soil energizer. It is suitable for all crops and soil types, especially for eroded soils or those in risk of degradation. It allows the concentration of microbial flora in the soil to be multiplied, enables stimulation of its development, and enhances its beneficial activity in the agronomic practices of soil and crops.[13,14]

## III.RESULTS

Defense against stress and active suppression of growth are two complementary strategies by which plants respond to adverse environments. Although beneficial for plant survival, active growth inhibition is often undesirable for crop productivity. Compared with the knowledge on how plants defend against stress-caused cellular impairment, much less is



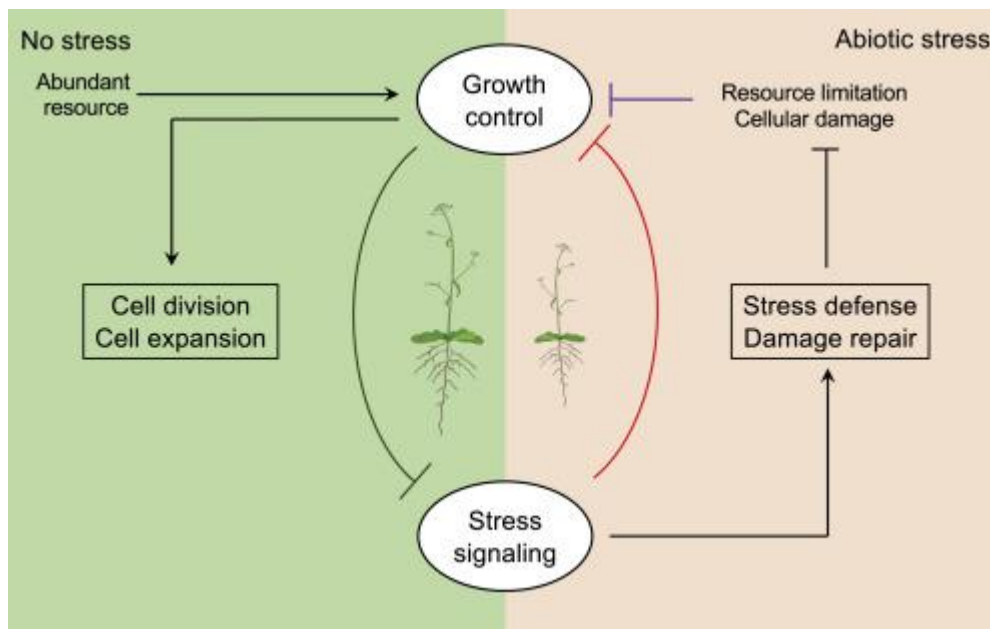
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known about how stress signaling regulates plant growth and vice versa. Plants are considered to be under stress when environmental conditions are not ideal for growth. How adverse environments affect plant growth is not only a fundamental scientific question but is also of vital importance for agriculture and food security. Adverse environments were estimated to cause an overall yield loss of ~70% in key agricultural crops, i.e., the average yield was only ~30% of the genetic yield potential. Abiotic stress caused by deficiencies or excesses in environmental factors including water, salt, light, temperature, and nutrients can substantially reduce plant growth and productivity and even survival (Figure 1). Abiotic stress reduces plant growth because, by definition, when plants are under stress, the environmental conditions are not optimal for growth processes including cell division and expansion. Drought stress, for example, inhibits plant growth because water is needed for cell turgor (the pressure on the cell wall exerted by enclosed liquid) that drives cell expansion; cold stress reduces plant growth because the activities of enzymes and other proteins are lower under cold temperatures. Slower plant growth under stress, however, is not only a passive consequence of the adverse environment. Plants under stress also actively slow their growth in order to adapt to the stress conditions (Figure 1). This “active” growth inhibition is achieved through stress-triggered cell signaling.[15]



**Figure 1. The Relationship between Stress Signaling and Plant Growth**

Researchers often measure stress resistance as the rate of plant growth or survival under stress relative to control conditions. The two measures of stress resistance (relative growth versus survival) may be inconsistent because survivability can be achieved by sacrificing growth and vice versa. In this review, we refer to “stress resistance” as the relative ability to grow, unless specified otherwise. The effect of stress on plant growth can be measured as a decrease in plant growth rate or as a decrease in biomass accumulation. For example, the leaf elongation rate of cereals responds to hyperosmotic stress within seconds and is one of the most sensitive plant responses to stress. Some plants can increase the growth of certain plant

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parts as a response to specific stresses; they can, for example, increase root growth in response to mild drought or increase stem growth in response to low light or flooding conditions. This type of stress-induced growth of a specific organ is usually achieved by sacrificing the growth of other parts of the plant. In these cases, whole plant biomass accumulation better reflects the overall effect of the stress.

Scientists have been trying to mitigate the negative effects of stress on crop productivity through genetic engineering but with limited success. Although many genes involved in plant abiotic stress signaling and response have been identified, translating the knowledge into crops with enhanced stress resistance remains challenging. Among the main crops, only one transgenic maize cultivar with a stress-resistance trait (drought resistance) has been commercialized so far. The seemingly unavoidable trade-off between growth and stress resistance is usually explained by energy and resource limitations: plants under stress must divert energy and resources away from growth and toward a stress response.[16,17] Increasing evidence indicates, however, that plants actively repress growth under stress conditions as an adaptive strategy to maximize survival. Plant species that are adapted to desert, tundra, or other harsh environments grow slowly even when they are transferred to unstressed environments where resources are not limiting, suggesting that an intrinsic process shaped by evolution controls the growth rate. In most plants, the stress-response program is sensitive to mild stresses, which prepares the plants for the possibility of more severe stress in the future. The stress signaling network actively represses cellular anabolic activities and plant growth early in the stress response even when the cellular energy status is not affected. This type of regulation becomes evident in transgenic plants overexpressing master regulators of abiotic stress responses, where the plant stress resistance in terms of survival is increased but growth is severely compromised. On the other hand, growth-promoting pathways have been found to actively repress the stress program. Understanding the reciprocal regulation between the genetic programs for stress response and growth may be the key to breaking or resetting the stress-growth trade-off and thereby for engineering hardier but high-yielding crops.

Abiotic stresses cause various physiological and molecular changes in plants. While the specific sensing mechanisms depend on the type of stresses, the resulting signal transduction processes rely on similar signaling modules. We review here major components of abiotic stress signaling and how they are connected to growth regulation pathways (Figure 2). We focus on key protein kinases such as SnRKs (SNF1/AMPK-related protein kinases) and TOR (target of rapamycin) that are instrumental in regulating cellular energy homeostasis, stress responses, and growth. The signaling of stress-related phytohormones such as abscisic acid (ABA) also involves the SnRKs and extensive crosstalk with the growth program. At the end of our review, we will discuss possible strategies that can be used to reset the balance between growth and stress resistance in order to increase crop productivity under stress conditions.[18]

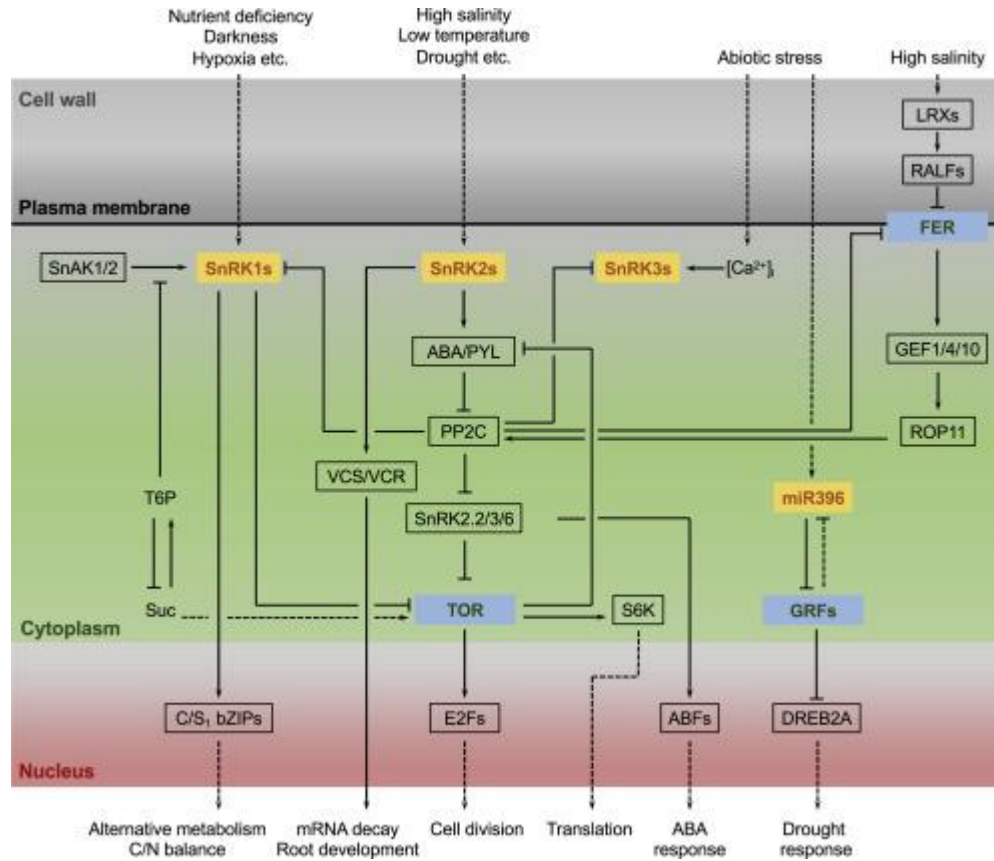


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**Figure 2. Critical Molecular Components in Stress and Growth Signaling Pathways and Their Roles in the Reciprocal Regulation of the Stress Response and Growth**

## IV. CONCLUSIONS

Plants in the wild constantly face stresses, and ideal growth conditions for any plant may only be achieved in a controlled environment. Thus, being under stress is the “normal” state, and plant growth in the wild is usually inhibited. Contrary to the presumption that the growth-stress trade-off is due to limits in energy/carbon supply, increasing evidence indicates that the trade-off mainly results from the active suppression of growth by stress signaling pathways. The regulatory networks for stress response and growth regulation crosstalk at multiple levels. Further studies will elucidate critical links and will suggest strategies for increasing stress resistance with little or no yield penalty. [19] Many traits such as stress-induced flowering and senescence increase survival but reduce crop productivity. Selection against some of these traits (e.g., selection for delayed senescence) has been effective in breeding programs. It follows that, rather than increasing crop productivity by making plants hypersensitive to stress, we should increase crop productivity by desensitizing the stress response. One caveat is that such crops may fail under very severe stresses. Regardless, our ability to achieve both stress

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resistance and high productivity is likely to increase with a better understanding of the relationships between growth and stress-response pathways.[20]

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