The Effects of Climate Change on Soybeans

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With our changing climate as a result of fossil fuels, deforestation, livestock farming, and fertilizer production we are seeing changes to our planet occur faster than ever before. Our planet is being negatively impacted and the evidence of such impact is seen in our crops. Soybeans are an extremely important crop in the United States, with an annual production value of 46.1 billion in 2020, and a consumption of 10.1 million metric tons. (Shahbandeh, 2021) Soybeans are used for products like soymilk and tofu but the primary use of soybeans lies in the livestock industry, with just over 70% of harvested soybeans being used as animal feed. (USDA, 2015) Soybeans impact ecosystem services like hydrologic cycling, soil nitrogen production, and water quality. (Ruiz-Vera, et al., 2013) From 1951-2017 the maladaptation of soybeans caused a reduction in yield by 87%, respectively. (Yu, et al., 2021) Increasing carbon dioxide levels and changing temperatures among other detrimental environmental issues stemming from climate change are affecting the agricultural industry by changing the physiology of soybeans and in turn, decreasing soybean yield. The ability for soybeans to survive in our changing climate is looking unfeasible, as yield, growth, and overall quality of soybeans will continue to suffer under these new climatic conditions.

With increasing global temperatures, changes in the physiology of beans will slowly start to unveil by decreasing yield at a global scale. High temperatures lead to less seed germination in soybeans, which in turn lead to pathogenic infections and a decline in yield. Additionally, the efficiency of photosynthesis and transpiration are also harmed by high temperatures. (Sabagh, Hossain, et al 2020) High temperatures have the ability to also affect germination and early seedling development, as they are extremely sensitive to temperature changes. If high temperatures are present, there is a significant reduction of the rate of imbibition, the ability of

embryo tissues to expand, and mitochondrial respiration in the early germination step of soybeans. (Sabagh, et al., 2020) Not only is the germination cycle of the soybeans negatively hurt by increased temperatures, but the growth stage has also shown to be adversely affected.

During the seedling and sprouting stage of soybeans, increased temperatures have shown to reduce crop growth and development, the disturbance induced by high temperatures reduces the physiological growth qualities. (Sabagh, et al., 2020) High temperatures create stressful environmental conditions for soybeans and oftentimes lead to a reduction in chlorophyll a and b, with a reduction in chlorophyll, soybeans are unable to absorb light energy. The decrease in photosynthetic cells in soybeans under high temperatures is seen through structural and anatomical changes in the cell and cell organelles, specifically the chloroplast and mitochondria. (Sabagh, et al., 2020) Additionally, it has also been shown that elevated temperatures had reduced protein content of rubisco, leading to decreased plant growth and photosynthesis. (Vu, et al., 2001) During reproductive development, high temperatures affect pod abscission and leads to abortive flowers and blocked pod development, which in turn results in decreased number of seeds per plant. The stress of high temperatures also ultimately decreased biomass accumulation and decreased the amount of sterile pollen grains leading to a decrease in overall grain formation. (Sabagh, et al., 2020)

High temperatures not only negatively impact the seeds and development of soybeans, but the root as well. High temperatures affect the bacterial infection and nitrogen fixation in legumes. Studies have shown that temperature changes impact the root hairs, bacteroid differentiation, nodule structure and the overall function of the root nodule in soybeans. (Sabagh, et al., 2020) Rhizobium have been proven by many different studies to have a positive effect on legumes as a symbiotic infection process. Under stressful

conditions like increased temperatures, rhizobium have the ability to use nitrogen oxide as a terminal electron acceptor which helps in their survival and growth during anoxia periods. An increase in soil temperature can prevent the development of the symbiotic relationship between the roots of soybeans and rhizobia. This would occur due to high temperatures inducing an inhibiting effect on the bacterial attachment to root hairs, nodule structure, and on the function of the legume root nodule. (Sabagh, et al., 2020) Additionally, high soil temperatures would lead to a delay in nodulation of soybeans, decreasing the quantity of nitrogen available to the plant. (Sabagh, et al., 2020)

Climate change brings many changes among crops, including water availability, rate of evaporation, and relative humidity. Since climate change provides more energy, higher rates of evaporation are seen and as a result reduces the share of transpiration among plants. (Bhatt, et al., 2018) Increasing air temperature causes an increase in the saturation deficit leading to higher evaporative rates and high evapotranspiration rates. Relative humidity acts in concurrence with temperature, and with high evaporative demand the lower the relative humidity. (Bhatt, et al., 2018) Low relative humidity would lead to a decrease in growth, and cause leaf drop to the lower leaves. What does this all mean for soybean production? With an ever changing climate leading to high rates of evaporation, food production will decrease while earth's population continues to increase. This drastic change of high evaporation rates is expected in arid and semi-arid areas across the world. Unable to control our ever-changing climate, we must take the right approach and research exactly what must be done to keep feeding the planet and accommodate changing temperatures and carbon dioxide levels.

We must ask ourselves why agricultural research in the era of climate change is important. With no end in sight in regard to changing temperatures and elevated carbon dioxide

levels, research in this field is needed more than ever, we must recognize the fatal effects our changing climate is having on the agricultural industry. Carbon dioxide emissions are predicted to rise to a rate 5% higher than what we see now over the next several years. Our current temperature trajectory predictions show that if we continue to burn fossil fuels at the same rate we are now, we will face possible temperature increases of around 3.6°F by the year 2100. (Irfan, Barclay, et al 2019) With our growing population predicted to increase by two billion people worldwide, feeding such a population leaves the agricultural industry with questions. Research is focusing on how we can possibly achieve feeding an additional two billion people while doing it sustainably and minimizing the negative impacts to our planet.

Copious research is being conducted on the genetic improvement of plants in order to mitigate rising temperatures and heat stress to crops. These genotypes are known as delayed senescence or Stay-Green. (Sabagh, et al., 2020) These genotypes are of great interest in the agricultural world as their photosynthetic capacity is maintained for a much longer time after anthesis, or the transition from a vegetative to a flowering state in plants. The crops of these genotypes are also tolerant to many biotic and abiotic stresses, leading to improved yield production. (Sabagh, et al., 2020) The use of Stay-Green genotypes in breeding programs is a result of genetic progress in order to achieve high yield and have crops tolerate heat stress. Water stress is another highly researched area, researchers have shared that soils with high water holding capacity and cultivars that are tolerant to effects of drought, as well as improved management practices will better ensure food security for our growing population.

The predicted future of our climate is said to change all of agriculture; future research and increased funding is needed in order to ensure food security and keep grains healthy and viable for our growing population. Further studies are needed in order to determine exactly how

changing atmospheric levels like temperature and carbon dioxide will ultimately affect soybeans among other crops. The research currently being conducted is telling of what we are currently experiencing in regard to climate change and the irreversible damages to our environment, conditions will only continue to change and appropriate research and data collection is needed in all science communities in order to ensure we have soybeans and other legumes to feed our livestock and our growing population.

Citations

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