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Exogenic Agents Influencing the Sugarcane Production

Syed Shehzad Hassan*
Wuhan University China
***Corresponding** sshn.mesp@gmail.com

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Sugarcane is a crucial crop for producing bioenergy and sugar, and it helps Pakistan's GDP. Extreme weather events are becoming more intense and frequent as a result of global warming and rising greenhouse gas emissions. A significant environmental stressor that restricts sugarcane growth, production, and metabolism globally is temperature. The development of plants involves a variety of biochemical processes, many of which are extremely sensitive to temperature stress. The production of sugarcane is currently greatly affected by temperature stress, and methods for achieving high sugarcane yields under temperature stress are key agricultural objectives. The sugarcane plant has developed a variety of acclimation and avoidance strategies to combat various environmental stresses. The capacity to produce and convey signals, as well as biochemical and physiological changes, are necessary for plant survival under various conditions. Because sugarcane has a high vulnerability to natural hazards, a relatively limited adaptive capacity, and a weak forecasting system, climate change will have a significant impact on sugarcane production globally in the future. In this paper, we briefly discuss the effects of climate change on sugarcane, the production of sugar in many nations, particularly Pakistan, and future challenges for sugar production under a changing climate scenario, and we suggest mitigation techniques for the adverse consequences of climate change.

Keywords: Sugarcane, Climatic Variability, Production.

Introduction

Global climate change and variability in the twenty-first century are the outcomes of both natural and manmade processes. Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report [1] predicts a temperature increase of 1.8–4 °C between 2090 and 2099 compared to 1980–1999. This increase is expected to be accompanied by an increase in the frequency of extreme events like floods and drought. Since the middle of the eighteenth century, [2] atmospheric CO2 concentration has increased by 30% due to the burning of fossil fuels, industrial processes, and deforestation, and projections show that CO2 concentration would be doubled in a high emission scenario by the end of this century. Certain plants thrive in environments with higher levels of carbon dioxide in the air and higher average temperatures [3]. In the future, we might expect abiotic pressures, such as a shift in the distribution of precipitation, an increase in the frequency of extreme low and high temperatures, and even more extreme weather events like floods and droughts [1].

Most sugarcane insects, pathogens, and weeds have their population dynamics, life cycle durations, and overall occurrences influenced by varying environmental conditions. Climate change will have an impact on agricultural pests such as weeds, pathogens, and insects. The competitiveness of pathogens, insects, and weeds in the wheat crop will shift when temperatures, precipitation, and CO2 levels change. Compared to C4 cultivars, C3 plants thrive in high CO2 environments. Temporary weather fluctuations, as well as monthly, yearly, and long-term climatic variations, can have a significant impact on the agricultural industry. There is a strong correlation between agronomic practices, soil, seed, pests, diseases, and ultimately, crop output. Limiting factors include climate change and environmental concerns that humans have caused. Sugarcane, a C4 crop that thrives in the tropics and subtropics, is a major international contributor to the production of both bioenergy and sugar. Sugarcane is a perennial crop grown on 20 million hectares in the subtropical and tropical regions [4], with an annual yield of around 1 325 million tonnes of stalks used to make sugar, energy, rum, and chemicals [5]. Cane sugar from sugarcane accounts for around 75% of the world's total sugar production for human use [6]. In Pakistan, sugarcane is a major source of income and accounts for 0.6% of the country's GDP. The sugarcane crop in 2015–2016 was grown on 1132 thousand hectares, down from 1141 thousand hectares the year before, yielding 65,475 metric tonnes [7]. The decline in sugarcane cultivation is the result of land being reallocated to produce other crops. Figure 1 shows the total area of sugarcane farms and the amount of sugarcane harvested in Pakistan. Cuts or complete stalks of sugarcane are typically planted in rows to grow new plants. Ratoons grow primarily from stubble after each harvest, and 20 successful ratoon crops can be harvested from a single plantation [8]. However, environmental factors such as pathogen infection, low winter temperature, weed competition, stalk borer injury, and water deficit conditions reduce production from season to season. The global production of sugarcane is highly dependent on climatic and meteorological factors [9].

Related Studies.

Sugarcane is a C4 species, meaning that rises in temperature between 8 to 34 degrees Celsius boost carbon dioxide assimilation and cane growth in the winter, while decreases in temperature slow photosynthesis and leaf growth. Sugarcane production was hindered by temperatures below 15°C, although sugarcane yields were boosted by a shift in climate during the low-temperature period. While frost is known to cause poor quality in sugarcane [10], high temperatures during the winter months are expected to diminish both its occurrence and severity. Nevertheless, sugarcane is negatively affected by high temperatures, resulting in a reduced plant population and delayed germination [11].

Temperatures above 32 degrees Celsius cause a rise in the number of nodes, a decrease in the length of the internodes, an increase in the amount of fiber in the stalk, and a decrease in the amount of sucrose [12]. Sugarcane's internode and leaf growth slows or stops entirely when nighttime temperatures are excessive, limiting the crop's potential sugar and cane output [13]. With an increase in temperature and associated changes in daily evaporation due to shifting climatic conditions, water stress may result, necessitating more frequent irrigation cycles to keep up with water loss and crop needs. Over-irrigation, which leads to waterlogging and salinity issues, can lower sugarcane yield [14]. Sugarcane ripening is also affected by changes in temperature. When it comes to natural ripening, low temperatures in the winter are crucial. Sugarcane's ripening and quality are negatively impacted by rising temperatures brought on by climate change.

The degree, length, and kind of plant's reaction to temperature stress. High temperatures can cause cells to die or get damaged, which can result in the catastrophic breakdown of cellular order [15]. The stability of different proteins, the structure of the cytoskeleton, and the efficiency of enzymatic activities are all negatively impacted by heat stress [16]. When plants are subjected to extreme heat, they respond in some ways. They range from long-term, phonological, and morphological changes to the more immediate, avoidance mechanisms including increased transpiration and reduced photosynthesis a shift in the leaves' position. Plants respond to stress by closing their stomata, increasing their stomatal densities, and changing the composition of the lipids in their membranes. Leaf rolling intensity is modified by high-temperature stress [17].

Even more so in tropical and subtropical locations, low temperatures have an impact on crop distribution and planting windows due to the stress they place on plant life [18]. To prevent oxidative and osmotic stress, low temperatures stifle a plant's metabolic activity, stunting its growth and development [19]. Temperature-responsive plant tactics include cellular remodeling, changes in gene expression, and reprogramming of metabolic pathways [20]. This system, known as ICE-CBF-COR, is activated in response to low-temperature stress by binding C-repeat binding factors to dehydration-sensitive elements in gene promoters [21][22]. Both cold-tolerant and cold-sensitive sugarcane varieties showed up-regulation of miR139 and down-regulation of its target (ref. Other miRNAs involved in cold response have been discovered, including miR156K and miR394 [23].

Results

The rate at which many plants grow increases when atmospheric CO2 levels rise, as this gas has a direct effect on photosynthesis and stomatal physiology. Increasing temperatures combined with higher concentrations will impact plant growth, leading to changes in weed distribution and competitiveness over the world [24]. C4 plants' CO2 transport is more efficient, their photosynthesis is greater, and their photorespiration is lessened due to a different arrangement of internal mesophyll cells than in C3 plants. In the future, when CO2 levels rise, C4 crops may face more severe competition from C3 weeds. Both C3 and C4 plants' stomatal aperture and transpiration loss may be reduced by 30–40% if the CO2 concentration was doubled. Both C3 and C4 plants may have their stomatal aperture and transpiration loss reduced by 30–40% and 25–40%, respectively if the CO2 content in the air is doubled. Long-term field studies showed that under high CO2 conditions, LAI (Leaf Area Index) did not grow in any species. According to Brown [25], as CO2 concentrations rise, starch concentrations fall. Likewise, a rise in body mass results in a lower total protein level. Plants' photosynthesis is affected and their growth and root-shoot ratio are both accelerated by high CO2 levels [4]. Under increased CO2, plants have less nitrogen available to them [26]. With rising CO2, the carbon-to-nitrogen ratio in leaves rose. Environmental stress inhibits crop productivity and plant growth, with drought being the primary abiotic stress that affects crop productivity [27]. When there is a shortage of water, sugarcane crops can lose as much as 60 percent of their productivity [19]. Sugarcane is a vital catalyst for the advancement of biotechnological methods in water-deficient regions [28]. Plants respond to drought by employing some drought-tolerant strategies, including slowing their rate of growth, altering their life cycle, evolving their sensitivity to stress to express stress tolerance quickly, and allocating resources more equitably to facilitate stress adaptation and growth [29]. Molecular breeding and other biotechnological methods can be used to increase agricultural yields even in water-scarce environments [30].

Sugarcane's physiological and morphological response to drought stress varies with its length, severity, damaged tissues, and the plant's genotype [31]. Common water responses in sugarcane include stomatal closure, restriction of the stalk and leaf growth, leaf rolling, reduced leaf area [32], and interruption of cell elongation and division [33]. Most severely impacted is the lengthening of stems and leaves [34]. Similarly, root growth affects [51] under water-deficient situations. Under water stress, the transpiration rate, stomatal conductance, and photosynthesis rate all drop in sugarcane crops, even though they use the C4 photosynthetic pathway [35].

During periods of water deficit, photosynthesis slows down because of a decrease in phosphoenol pyruvate carboxylase and Rubisco activity. The accumulation of sugar in leaves also affects the rate of photosynthesis, and a high sugar content moderates carbon fixati]. Cell membrane damage is mitigated by an uptick in trehalose sugar under water-deficient conditions [36]. Increased starch hydrolysis under conditions of low CO2 fixation maintained carbon availability, allowing for speedier post-stress growth recovery.

Increasing temperatures, fluctuating precipitation patterns, higher CO2 concentrations, and the increased likelihood of extreme weather events like floods and droughts are just some of the ways that climate change can impact agricultural production. Further droughts are on the horizon, as anticipated by Held et al. [37], with only minor variations in precipitation expected. Sucrose yield is affected by both extremes in rainfall and regular drought since sugarcane needs more water to grow. In addition to affecting stomatal conductance, photosynthesis, and respiration are all impacted by water stress. Farmers may irrigate more to lessen the effects of the drought, but this will just exacerbate the salt problem and raise the water table. Weaker rainfall during the harvesting period is associated with better crop yields. Sugarcane productivity is severely constrained by nitrogen. Extreme nitrogen fertilizer use is common among farmers in wetter years because of the risk of nitrogen leaching during floods. Roots may have less oxygen to use, which can prevent them from taking up nutrients if the soil is constantly soggy from too much water. Cane quality declines as a result of increased precipitation due to a shorter "dry off" period. Weeds, illnesses, and insect pests all increase or decrease in frequency as precipitation patterns shift. Insect pests like termites and nematodes thrive in hot, dry climates. A drop in the number of weeds, such as Cyperus spp., may occur in areas that experience frequent drought. How drought affects sugarcane harvest is conditional on the plant's growth stage and how long the stress lasts. Sucrose yield is mostly affected by drought during the early to mid-growth stages. During the final stages of development, moderate dryness raises the amount of sucrose in stalks. Chinese agriculture faces the greatest threat from drought [38].

When crops are under environmental stress, they are less able to compete with weeds and are more susceptible to insect and disease attacks. Alterations in weather patterns also affected the regularity and severity of rainstorms. Herbicides lose some of their effectiveness when it rains after they've been applied. Weeds have a competitive edge over crops because moisture is necessary for weed seed germination. Herbicides applied to the soil will be taken up less effectively in the presence of more rain and a change in the intensity of that rain.

Sethoxydim's efficacy was reduced in goosegrass and Urochloaplantaginea (signal grass) was not effectively controlled by ACCase-inhibiting herbicides when applied later in the growth cycle. When dryness, leaf pubescence, and thickness increase, which prevents herbicides from penetrating the plant [39]. Reduced plant growth and reduced herbicide effectiveness are both effects of water stress. Fewer efforts have been made to determine how climate change will affect weeds, in contrast to the many studies that have focused on the effects of climate change on crop output. Production losses can be attributed in part to how environmental stress modifies the effectiveness of herbicides. Understanding how environmental variables affect the efficacy of herbicides is essential under these varying climatic settings.

The agricultural sector is affected in multiple ways by climate change, both directly due to shifts in temperature and/or precipitation and indirectly due to shifts in pest pressure and the availability of pollination services. Sugarcane is vulnerable to attack from herbivores due to some abiotic and biotic stressors, including weed competition, low soil nitrogen levels, and a lack of water. Input costs for managing disease pathogens and overwintering pests have risen as a result of the prevalence of these problems brought on by extreme weather. There are a couple of pests that threaten sugarcane crops in Florida, and they're called sugarcane leaf and orange rust. The decline in crop and pasture growth and the resulting reduction in canopy covers make ideal conditions for weed invasion as a result of less precipitation. Eoreumaloftini is a serious problem for sugarcane, and the abundance of dry leaf tissue during a drought correlates positively with the number of E. lofting eggs. There were 82.8%-90.2 % fewer E. lofting eggs on sugarcane plants when water was plentiful, as opposed to when water was scarce. Cyclones in the moist tropics can spread weed seeds by wind and water. Even moderate drought can boost the population of many herbivorous arthropods, leading to crop damage and making host plants more appealing to arthropod herbivores.

There are a few weeds that may survive the summer's high temperatures only to return in the dead of winter. Pest insects include the aphid-like Heteronychuslicas and the stink bugs (Margarodes spp. No protection from rising or falling temperatures. According to research [41], rising temperatures make it easier for new pests and illnesses to invade sugarcane fields. Temperature changes brought on by global warming will have an impact on infectious illnesses, noxious weeds, and insect pests. A temperature rise is associated with an increase in the incidence of smut illnesses, as discussed. Increased temperatures during pollination caused sterility, led to premature pollen shed and shortened the time it took for grains to fill. Heat stress inhibits herbicide uptake by increasing the conductance and permeability of stomata. The above discussion will aid in determining potential measures for weed control in the face of altering climatic conditions. As a result, assessing how climate change may affect weed flora and the effectiveness of herbicides is essential for developing effective adaptation and mitigation plans.

Temperature and precipitation patterns are dynamic systems that are constantly shifting in response to both human and natural influences. Human-caused emissions of greenhouse gases accumulate in the Earth's atmosphere and cause its concentration to rise over time.

The CO2 concentration has already reached 387 mol mol1 as of 2007 and is projected to reach 600 mol mol1 by 2050. The employment of modern agricultural technology is a primary factor in the 30% increase in GHG emissions. The spread of weeds can harm crops and people's health. The Sugarcane ecosystem is affected in several ways by weed species in the wild. A 24% decrease in sugarcane stalk density, a 19% decrease in biomass, and a 15% decrease in commercial sugar production [41] are the results of annual summer weeds that are not controlled. The C3 weeds outperformed the c4 weeds in terms of leaf area and biomass growth when exposed to greater CO2 concentrations. Weeds like Parthenium (Parthenium hysterophorus), which is a C3 plant, will fare significantly better in a higher-CO2 setting. Weed density and species both play a role in how much of a toll they take on crop yields. When weeds emerge in large numbers, competition is fierce. Changes in crop-weed competition due to climate and CO2 levels have been observed.

At more northern latitudes, the temperature is the most important element in determining where weeds grow. Several species might thrive in conditions made possible by an increase in precipitation and warmth. The consequences of water stress were mitigated by CO2 enrichment, which also boosted the development of water-stressed C3 and C4 plants. Increases in water use efficiency (WUE) of 55% in sunflower, 54% in maize, 48% in soybeans, and 76% in redroot were seen when concentrations of CO2 were raised from 300 to 600 ppm. This stimulation of WUE was greater in weeds than in crops, giving them a competitive edge. It will be important in the future to optimize herbicide application for more effective weed management as rising CO2 concentrations diminish the effectiveness of many herbicides and plant development.

Weed population and phenology are both affected by climate change. Most weed species are known to invade new regions, and scientists worry that invasive species will become a problem as the climate changes because of the weeds' strong reactivity to high CO2. C3 plants respond more favorably to elevated CO2 levels, increasing their photosynthetic rates, than do C4 plants. According to the research by Alberto, who discusses the relationship between temperature and carbon dioxide, higher CO2 levels promote the development of barnyard grass at a temperature of 37/29 degrees Celsius. For effective chemical management, knowing how chemicals interact with plants and the environment is crucial. This includes knowing what factors diminish the effectiveness of pesticides and herbicides. The ability of a plant to take in a herbicide depends heavily on how that herbicide reacts with its surrounding environment.

Conclusions

The sugarcane plant's growth, development, and productivity are severely hampered by the environmental hazards it must contend with. Temperature increases, shifts in precipitation patterns, and environmental fragility are all thought to be the result of the current rate of greenhouse gas emissions, which is driving global warming. Sugarcane farmers need a deeper understanding of how plants react to and adapt to environmental challenges including fluctuating temperatures and the presence of invasive species like weeds, insects, and pathogens. In recent years, researchers have examined sugarcane yield in response to shifting climates, but a full comprehension of sugarcane production in the face of climate change remains elusive. Sugarcane plants respond to various stresses by activating a wide range of metabolic pathways and amassing a wide range of metabolites, including antioxidants, osmoprotectants, and heat shock proteins.

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