A REVIEW ON THE IMPACT OF CLIMATE CHANGE ON SUGARCANE CROP

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ABSTRACT

Sugarcane, scientifically known as *Saccharum officinarum* L., is a large perennial grass belonging to the Gramineae (Poaceae) family and is a monocotyledon. This C_4 agro-industrial crop is cultivated widely in tropical and sub-tropical regions around the world. The crop requires a long duration of 10-15 months, and in some cases up to 18 months, to mature, which depends on the geographical location. There are various factors that affect the growth and development of sugarcane, with climate change being a major factor that can either positively or negatively impact the crop. Among the many climatic factors, rainfall and temperature are the most crucial weather parameters for sugarcane productivity. However, with the increase in temperature and CO_2, global warming is leading to a deficit in rainfall, resulting in a decline in crop production. Therefore, it is crucial to assess the effects of climate change on crop growth to maximize the potential yield of all sugarcane varieties in the future.
Keywords: Climatic transformation, Control, Sugarcane, Pakistan

INTRODUCTION

Sugarcane, also known as *Saccharum officinarum* L., is a C_4 crop that holds a crucial position in the Pakistan economy. It is a significant cash crop of the country, cultivated over an area of approximately 1260 thousand hectares, including both tropical and sub-tropical regions. Sugarcane is a tall perennial plant that grows upright up to 5-6 meters and produces multiple stems, also known as canes. The crop undergoes four distinct growth phases: Germination phase (up to 45 days after planting-DAP), Tillering phase (45-120 DAP), Grand growth phase (120-270 DAP), Maturity and Ripening phase (270-360 DAP), with each phase having specific climatic requirements (Moore and Frederik, 2014). Sugarcane thrives in regions with a tropical or sub-tropical climate, with a mean temperature range of 28-32°C being best suited for its growth. Temperatures exceeding 45°C reduce tillering and growth, while temperatures below 20°C may slow down growth. Areas with a minimum temperature below 5°C are not suitable for sugarcane cultivation. A relative humidity of 70-85% during growth and 55-75% during the ripening phase is ideal. Relative humidity below 50% during the growing season is unsuitable for sugarcane cultivation.

Brazil is the largest cane growing country, followed by India, China, Australia and Pakistan with nations accounting for more than 70 % of the global cane acreage in 2021-22. Among Punjab states, Muzafargarh, contributes around 44% of the total sugarcane production (133.40 million tonnes), making it the largest sugarcane growing state in the country. Climatic factors play a crucial role in the productivity of a variety and the crop. Climate change could impact agriculture in various ways, such as affecting productivity, growth rates, photosynthesis, transpiration rates, and ultimately, the quality and quantity of the product. Climate change is expected to directly affect food production worldwide. An increase in the mean seasonal temperature could reduce the duration of many crops and result in a decline in their yield.

The warming temperatures, which are already nearing the upper limit for crops, will have an immediate impact on crop yields. Sugarcane is particularly vulnerable to changes in temperature and rainfall, with even slight deviations from normal weather patterns during different growth stages leading

to significant losses in yield and sugar production (Glasziou et al. 1965; Mali et al. 2014; Zhao and Li, 2015). Climate change, caused by various factors such as population growth, industrialization, and deforestation, has been leading to a steady increase in mean minimum temperature across all climatic regions in Pakistan, as reported by the Pakistan Meteorological Department (IMD) (Rathore et al. 2013). Such changes in temperature and rainfall patterns may have a negative impact on dry matter and sugar accumulation in the future, necessitating a shift in planting, harvesting, and crushing schedules. Water availability and temperature regimes are crucial in determining the yield and quality of sugarcane crops worldwide (Zhao and Li, 2015). The concentration of greenhouse gases has also surpassed the highest levels recorded over the past 800,000 years, leading to increased rainfall, irregular distribution of rainfall, hot extremes, floods, droughts, cyclones, and glacial retreats. For any agricultural commodity, variation in yield is closely tied to growing-season weather, which can impact pests, diseases, and weeds, ultimately affecting production and productivity.

Climatic requirement of the growth of Sugarcane

The growth of sugarcane crop is influenced by various climatic requirements. The crop requires a yearly rainfall of 1500-2000 mm to produce 100 ton millable cane. For plant crop, the average water requirement is 88kg water/kg of cane and 884kg water/kg of sugar. In Punjab districts, the average water requirement per hectare for the entire sugar season is 57 lakh liters. During different growth phases, the water requirement for subtropical zones is 17% at the germination phase, 24% at the tillering phase, 37% at the grand growth phase, and 22% at the maturity phase. Whereas, in tropical weather, the water requirement is 12% at the germination phase, 22% at the tillering phase, 40% at the grand growth phase, and 26% at the maturity phase (Bhardwaj, 2013). The crop needs adequate rainfall during the vegetative growth phase to form thick and tall cane, whereas less rain is required during the ripening time to produce good quality juice. The optimal rainfall range for higher cane yield is between 1100-1500mm/yr, but it can also be grown successfully at lower levels, even down to 600mm of annual rainfall.

Temperature

Different stages of crop require different optimum temperature ranges. The ideal temperature for the germination of cane sett is between 28º-32 ºC, and a temperature above 38 ºC impedes germination and reduces photosynthetic rates, whereas below 32 ºC, it affects germination, resulting in a poor plant population. During the tillering phase between March and June, atmospheric temperatures ranging from 30º to 32 ºC are preferred. The ripening period requires low temperatures in the range of 12º-14 ºC, which reduces the vegetative growth rate and enriches sucrose in the cane. Temperatures below 5ºC and above 35ºC are unfavorable for young leaves and buds. High temperatures can increase abiotic diseases and convert sucrose content into fructose and glucose, reducing sugar accumulation. Sucrose accumulation is facilitated by temperatures below 19 ºC, and the optimum temperature lies between 12º and 14 ºC, while sucrose accumulation has been reported to decline above 26.6 ºC (Clements, 1980; Binbol et al. 2006; Gawander, 2007; Fageria et al. 2010).

Sunlight

The growth stage of sugarcane, especially the formative stage, is heavily reliant on the intensity of sunlight, which promotes photosynthesis and stabilization ranges. During the cloudy and short days season, tillering is hindered, while 7-9 hours of bright sunshine on average is optimal for tillering, stalk formation, and good crop growth; Fageria et al. 2010). To ensure proper sunlight exposure and maximize yield, adequate spacing between rows and plants is necessary. In sugarcane, the upper six leaves' canopy intercepts 70% of the sunlight radiation, which leads to reduced photosynthesis rates in lower leaves due to mutual shading. In areas with short growing periods, closer spacing is beneficial to intercept more solar radiation and achieve higher yields, whereas wider spacing is recommended for long growing seasons to avoid mutual shading and tiller shoot mortality (Srivastava and Rai, 2012).

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Relative Humidity and Wind

Humidity and wind may have a comparatively smaller impact on sugarcane cultivation, but they can still affect the crop significantly under extreme conditions. Warm weather with 80-85% humidity is favorable for rapid cane growth, while a moderate humidity level with limited water supply is ideal for the ripening phase (SC, 2012). Wind does not harm the plant until it reaches a velocity that can cause cane breakage or leaf damage. However, high velocity wind can be harmful in the initial growth stage and can cause moisture loss if it persists for a long duration.

Generally, two sets of climatic parameters are required in the sugarcane plant's life cycle. The grand growth phase, spanning from July to September and coinciding with the monsoon season, requires long durations of bright sunshine, warm temperatures (28-32 ºC), optimum rainfall, and high humidity for rapid growth of both the plant and cane length, leading to a good yield. However, during the ripening season, which is a phase of sugar storage, clear skies without precipitation, warm days, and dry weather conditions with a relative humidity of about 51% are needed to achieve 12% cane weight and 15% cane height (Srivastava and Rai, 2012). The evapotranspiration demand risk is very high during the grand growth phase because of the active growth and high water demand, necessitating frequent irrigation using surface water and groundwater resources.

Cane growth slows down after October, and ripening begins when the temperature drops below 19.4 ºC, and relative humidity remains moderate (60-65%). The rapid build-up of sucrose and its accumulation begins in October and continues until December. The final sugar output is influenced by the climate during the maturity phase, which is favored under cold and dry weather conditions with a large diurnal temperature variation and adequate soil moisture (Moore and Frederik, 2014).

Global change in temperature

According to the latest scientific assessment on the earth's climate system, changes have been observed on both global and regional scales since the pre-industrial era. The evidence suggests that human activities are the primary cause of most of the warming (0.1 ºC per decade) observed over the last 50 years (Gautam et al. 2013). The Intergovernmental Panel on Climate Change has projected that the global mean temperature may increase between 1.4 and 5.8 ºC by 2100 (Gautam et al. 2013), which could have severe impacts on the global hydrological system, ecosystems, sea level, crop production, animal husbandry, and related processes. The impacts are expected to be particularly severe in tropical areas, which are mainly comprised of developing countries such as Pakistan. Climate change has been observed at both global and local scales.

Effect of Green Houses

Greenhouse gases, such as carbon dioxide, methane, nitrous oxide, and halocarbons, have increased significantly since the pre-industrial era, along with a decrease in stratospheric ozone and an increase in tropospheric ozone, leading to direct effects on weather conditions. Additionally, various factors such as sulfate and nitrate aerosols, black carbon and organic matter from fossil fuel burning, biomass burning, mineral dust, land use changes, clouds, solar variability, and stratospheric and tropospheric water vapor

contribute to the increase of greenhouse gases. The impact of extreme weather events on Pakistan agriculture raises questions about the role of human activities in climate change. In recent years, many such events have been linked to the rising levels of greenhouse gases, including the prolonged drought in Australia, the scorching European summer of 2003, the intense hurricane seasons in the North Atlantic in 2004 and 2005, the heavy rainfall in different districts of Pakistan, in July 2005, and others. The concentration of greenhouse gases, particularly carbon dioxide, methane, and nitrous oxide, has increased due to fossil fuel combustion and land use changes. Agriculture contributes significantly to the emission of methane and nitrous oxide (Cerri et al. 2007). The impact of global warming, caused by the greenhouse effect, will lead to changes in temperature, rainfall, solar radiation patterns, and will have both positive and negative effects on sugarcane production (Srivastava and Rai, 2012). Gradual recession of glaciers, floods, droughts, cyclones, frequent hot extremes, and increased rainfall are some of the effects of global warming due to the greenhouse effect.

Effect of Increase in CO_2

It is anticipated that climate change will cause weeds to migrate northward. While most cash crops are negatively affected by increasing CO_2, C3 “invasive” weeds tend to respond positively. Recent research suggests that glyphosate, the primary herbicide used in the Pakistan and other countries, loses its effectiveness on weeds grown in elevated CO_2 environments expected in the future. This migration and proliferation of weeds will adversely affect crop productivity as many weeds, pests, and fungi thrive in warmer temperatures, wetter climates, and higher CO_2 levels. Climate change is likely to increase the range and distribution of weeds and pests. Although rising CO_2 can stimulate plant growth, it also reduces the nutritional value of most food crops by decreasing the concentration of protein and essential minerals in many plant species (Ziska et al. 2014).

Extreme weather effects on Farmers

From 1900 to 2020, Pakistan experienced numerous severe droughts which affected a large part of its population, making it the most significant natural disaster. Since agriculture in Pakistan heavily relies on the monsoon season from June to September for about 75% of its annual precipitation, the variability of monsoon rainfall has a direct impact on food grain production. Extreme weather events like droughts, floods, and hailstorms have a significant impact on agriculture and food security, which is the primary source of income for many rural populations. Such events also damage agricultural infrastructure, soil conditions, water resources, and natural ecosystems, causing significant losses to the economy, with Pakistan annually losing around 2% of its GDP and 12% of central government revenues to natural disasters. The form, frequency, and increasing intensity of extreme events are largely attributed to changes in the earth’s climate. Venkateswarlu and Shanker (2012) reported that rainfed agriculture would be more negatively impacted by climate change due to rainfall variability and reduced rainy days. This would have greater implications for farmers' choice of crops, varieties, and cropping patterns/systems than irrigated agriculture. Additionally, studies have shown that for every 1 ºC increase in temperature, water requirements will increase by 10%, which will severely affect productivity and water use efficiency in several crops.

Effect of climate on disease development

Concerns have been raised over the quality degradation and yield reduction of sugarcane. One of the major threats to sugarcane in this region is Pokkah Boeng disease caused by Fusarium moniliformae, which has shown an increasing trend of disease incidence and made most commercial cultivars susceptible. According to Vishwakarma et al. (2013), the severity of airborne disease Pokkah Boeng increases manifold under cloudy weather and high humidity up to 70-80% with favorable temperatures during the rainy season (June, July, August, and September). Unseasonal rain, changes in relative humidity, and heavy dew influence the crop's microclimate and can lead to unpredicted insect and disease

incidences (Sharma et al. 2013). This is the most active growth period where about 80% of cane weight is attained. A shift to a higher thermal regime due to lack of rain during the elongation phase also affects the dynamics of disease and pest attacks, which ultimately influences the cane and sugar yield (Bhardwaj et al. 198).

CONCLUSION

Assessing the impact of climate change on sugarcane growth is crucial for maximizing future yields, as different phases of sugarcane have varying temperature, rainfall, evaporation, sunshine, and humidity requirements. Rainfall and temperature are particularly crucial for sugarcane productivity, and recent observations have shown a decline in rainfall and an increase in temperature during certain growth phases, as well as a rainfall deficit during critical growth stages. Breeding stress-tolerant and low-input varieties, improving soil fertility, and addressing disease and pest scenarios are important future research priorities under changing climate conditions. Climate change is expected to affect sugarcane production directly or indirectly, including through changes in extreme weather events such as droughts. Greenhouse gas emissions may also negatively impact sugarcane production. Although sugarcane is a hardy crop, even slight temperature increases may have negative effects when combined with irregular rainfall patterns. The formative and elongation phases of sugarcane growth are particularly vulnerable to water scarcity, which can greatly reduce yields and productivity. For these reasons, addressing the impacts of climate change on sugarcane growth is of utmost importance for maximizing yields and maintaining productivity in the future.

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