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Review Article

Production of Climate Smart Coffee (Coffea Arabica)

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Abstract: Coffee is an important crop in many countries and one of the world's most popular beverages. The world's most important tropical export is coffee. However, according to current research, Arabica coffee will be greatly affected by climate change. The world is alarmed by climate change as it affects agriculture and the products it produces. Coffee production depends on the need for safety. Climate change is the world's biggest problem and will be catastrophic unless it is changed and mitigated. Safe coffee is an important step towards solving the problem of climate change. The aim of this review is to examine the impact of climate change on coffee (Arabica) production and adaptation and mitigation strategies for these issues. It has been determined that the biggest impact of climate change on coffee production areas is high risk and more efforts are needed to prepare for the future of coffee. Climate change can be addressed using a variety of adaptation and mitigation strategies, including renewable energy, crop production, coffee-banana intercropping, and other conservation methods. Full implementation of these measures can help reduce the impact of climate change. There are some differences in establishing an Arabica coffee shade tree variety, determining appropriate shade, identifying drought-tolerant seeds, and affecting coffee.

Keywords: Adaptation, Climate Change Impact, Climate Smart Coffee, Mitigation

1. Introduction

The biggest problem currently facing the world is climate change, which will continue into the 21st century and beyond. The increasing use of fossil fuels and changes in land use are key factors in climate change as they continue to release more greenhouse gases into the atmosphere. As greenhouse gases such as carbon dioxide (CO_2), methane (CH_4) and nitrogen dioxide (N2O) continue to enter the atmosphere, more solar heat is retained in the Earth's atmosphere as the return to space increases [34]. Not only does climate change require a strong response to greener, more efficient business models, but unless humans change the way they live, the future of all living things will be destroyed. Many areas of human life and the natural environment are affected by changing rainfall patterns, temperature and other changes. Ecosystems are changing due to climate change at an exceptional rate and magnitude. The primary effects of climate change include an increase in the average global temperature (global warming), modifications to cloud cover and precipitation, particularly over land, melting of ice caps and glaciers, reduced snow cover and an increase in ocean temperatures and ocean acidity as a result of seawater absorbing heat and carbon dioxide from the atmosphere [16]. Since more people depend on agriculture for their livelihood than any other economic activity, and since the majority are self-employed subsistence farmers who live in the tropics, it is not surprising that 75% of agriculture has attracted a lot of attention in recent years as climate change action has risen to the top of the international political agenda. According to [34, 16] study, South Asia and sub-Saharan Africa will experience less of the negative effects of climate change on agriculture than the tropics and subtropics. This indicates that areas that produce the most coffee are at the greatest risk and must put out the most effort to get ready for the future.

In the case of the coffee crop, increasing temperature should have a negative impact leading to changes in the crop. These changes can have many effects, such as increased susceptibility to certain diseases, tougher competition and post-harvest handling [20]. The reduction of arable land caused by coffee insect pests poses the greatest threat to coffee production and quality management due to climate change.

The effects of coffee berry borer and the safety of prediction have been shown to be important. The mountainous regions of East Africa are one of the main growing areas of Arabica coffee, and recent data shows that climate change is having a major impact on the areas suitable for cultivation [14].

In addition to impacting biodiversity and ecosystem services, this could lead to coffee growing in new and potentially conflicting areas with other land uses, such as natural forests [25]. The occurrence and spread of coffee leaf rust is another important effect of climate change. Thousands of small farmers and harvesters suffer directly from reduced coffee yields and quality. Coffee is often a source of income for these people, especially in Central America, who use coffee to pay for the food and materials needed to grow their food. Coffee rust is common and therefore has serious consequences for food safety [2]. Studies show that areas suitable for coffee cultivation will decrease by 50% by 2050 [22, 11]. Approximately 56% of the world's Arabica coffee plantations are covered with trees. Regionally, the Andes and Southeast Asia are the regions with the highest risk of deforestation associated with Arabica cultivation, while Brazil and East Africa are the regions with the lowest risk of expansion. Temperatures above 23°C can affect the quality of your coffee. As the temperature increases, the coffee ripens faster, thus its quality decreases [22].

Although climate change has a significant impact on coffee production worldwide, there are still ways to adapt to climate change and maintain sustainable coffee (Arabica) production. The production of climate-friendly coffee is part of the daily business of 75% of the world's Arabica coffee producers, processed through a variety of methods. Following good agricultural practices, or GAPs, similar to coffee production, can help reduce the effects of climate change. Good agriculture always helps to protect soil and water, making it easier to adapt to global warming and reducing its effects. Planting and planting shade trees are additional tools in combating climate change. Reforestation, planting trees at borders and stopping deforestation will save huge amounts of carbon. Reforestation of degraded lands using forests or coffee agroforestry systems can also improve other ecosystem services, such as soil and water conservation, and reduce soil degradation. Border cultivation is another form of renewable energy that can store a lot of carbon [31, 9]. In fact, efforts are being made to prevent and/or reduce the impact of climate change on Arabica coffee production through mitigation and adaptation. Climate agriculture includes conservation agriculture (tillage, cover crops, and crop rotation) as well as irrigation, agroforestry, and soil conservation. This review/topic was created to evaluate climate-friendly coffee (Arabica) production.

2. Coffee Production and Climate Change

According to [18], climate in the narrow sense can be defined as “the average climate, or more precisely, a description of the average and practical results varying over time, from months to hundreds or centuries.” "The term 'climate change' may refer to climate change that can be described as average and/or long-term (usually decades (years or longer) [18] changes since the 1900s. The increase in global mean temperature is driven primarily by internal natural processes, external forcings or due to the effects of human emissions of greenhouse gases such as carbon dioxide (CO_2) and methane (CH_4), as well as persistent changes in climate or land use. Approximately 6.5 billion tons of carbon dioxide are released into the atmosphere every year, mostly due to the burning of fossil fuels. The total of net CO_2 emissions will increase to 1-2 billion tons per year due to land change. Since the industrial revolution, the concentration of greenhouse gases in the atmosphere has increased, and the global climate has been changed by keeping more energy in the lower atmosphere [5, 13]. Climate events that will be used in the future and will affect agriculture include the following physical changes: increase in air and soil temperature, change in climate carbon dioxide concentrations, sea level rise, changes in the hydrological cycle and water quality and availability, climate change. Droughts and floods, changes in dew point altitude, etc. Intensification and increase in frequency of such events. Some of these changes are unidirectional and gradual, meaning they can occur over time at an unclear but known rate. In this case, climate change will increase the pressure on the natural conditions that support the development of agriculture, which, although not beneficial, will have an economic and social impact [35].

3. The Effect of Climate Change on the Production of Coffee (Coffea Arabica)

There is no doubt that Arabica and Robusta growers, especially small farmers without modern development, will be affected by climate change. In this context, the coffee crop has many disadvantages, from being more susceptible to some diseases to different production lines. Global coffee production (produced mostly by small farmers who produce most of the world's coffee) will be affected by many factors, including climate change [22]. Additionally, coffee plants have an effect on microclimate changes. It is known that high pressure affects the metabolism of plants. Coffee grown outdoors is exposed to high radiation, absorbs more energy than required for photosynthesis, causing energy overload and scorching of the leaves [13]. Below 18°C, growth is inhibited, and above 23°C, fruit growth and ripening are rapid, resulting in a decrease in quality. Additionally, the photosynthetic rate of Arabica coffee trees in light shade is three times higher than that of coffee leaves in full sun [10]. The best temperature for Arabica coffee is 18 to 21°C, and shade helps keep the coffee cool during the day and warm at night. Temperatures above 24°C affect cherry growth and ripening, with net photosynthesis of coffee dropping to zero at 34°C. If this is followed, it will cause the leaves to turn yellow and fall off [24, 15]. An annual average temperature below 18°C greatly inhibits growth. Even inconsistent frosts will reduce the economic success of crops [7]. Warm soil accelerates the decomposition and evaporation of organic matter. This will

make the soil poor and vulnerable to erosion [23]. The main climatic limitation for coffee production is total drought and unfavorable temperature, but the ideal rainfall should be between 1500 mm and 2000 mm per year [26]. As the global climate changes, these constraints are expected to become more important in many coffee growing areas [10]. The availability of water as precipitation can affect many important aspects of crops. The formation of flower buds first requires prolonged drying. Then, in response to drought, the buds open suddenly and are opened for pollination within 48 hours. Additionally, fruit pressure control, maximum photosynthetic rate, and fruit size were found to be affected by water availability. Therefore, both the number and duration of rainfall events affect coffee phenology [24]. Heavy rains prevent the coffee tree from blooming, causing floods and causing the branches to die. The change of the rainy season will cause serious problems in drying and processing, reducing the quality of coffee and therefore affecting its business. Random flowering, flowers and fruits at different stages of development on the same main branch, flower abscission and biennial fruiting are the effects of sporadic rainfall [23]. Insufficient rainfall can also cause coffee to bloom at different times of the year, forcing farmers to harvest more coffee. Increased sun exposure and drying may cause premature ripening of coffee beans, resulting in decreased yield and quality. The physiological activity of Arabica plants is also affected by drought, which slows down photosynthesis [15]. Diseases, pests and pest severity are currently the biggest impacts of climate change on coffee production. The two most important coffee pests, which have become more common and destructive with climate change, are the coffee weevil (Hypohenemus hampei) and leaf rust (Hemileia badatrix) [8]. Higher temperatures make coffee leaf rust, a disease that affects coffee at lower altitudes, more common [23]. Over the years, the area affected by the coffee berry borer has gradually expanded. Ten years ago, Arabica coffee plantations 1,500 meters above sea level were not reported. Based on four safety measures, it is estimated that coffee disease can spread, affecting 93.02 ± 1.3% of Robusta plants and 77.8 ± 1.7% of Arabica farms [25]. The temperature-related pest occurs at higher altitudes in the highlands of Ethiopia, where coffee is produced. Small-scale coffee farmers can be severely affected as they depend on natural resources for survival and do not have the money to carry out expensive adaptation measures and/or pest and disease control. However, pests and diseases will spread faster than before [13]. Rains and low temperatures also contribute to the development of CBD, which is now stronger than ever. Changes in temperature can alter pests, for example small insects such as thrips can become a serious problem [23]. Over the past 50 years, nighttime minimum temperatures have increased by 1°C, cloud cover has increased and pest pressure has increased. Infections and infestations can reduce crop quality and yield. The physical activity of Arabica plants is also affected by water stress, causing photosynthesis to decrease [15]. Another problem caused by climate change is the loss of Arabica coffee planting areas. Production must be relocated and other crops identified, [19] as increasing temperatures make some areas unsuitable, even unsuitable, for growing coffee crops. By 2050, Arabica varieties will lose 56% (7%) of the area currently suitable for cultivation (mainly Brazil, East Africa and Madagascar), while only 9% (1%) of the more suitable area will need to be increased [25]. A 3°C temperature increase this century would be equivalent to a 10–20-foot increase in coffee in less than a year [5]. The weakening of the landless and the poor, the change of climate and agricultural areas towards higher altitudes, [23] change in production and production patterns, change in temperature and change in precipitation patterns. Currently, 57% of Arabica coffee production and 50% of Robusta coffee cultivation are affected. Only one of the four climate models predicts 1.2 million hectares of forest loss for Arabica coffee under an 8% impact rate [25]. One consequence is that the requirement has changed, and the other is that the pest has spread to areas where coffee is grown at high altitudes and has not been determined to pose any risk in the past. Due to the problems arising from climate change mentioned above, coffee production will decrease by 34% in 2020 and the profit will drop from 200 USD per acre to less than 20 USD. Since Arabica coffee is a plateau plant and does not adapt to the climate, the decrease in yield due to high temperatures in tropical regions is almost negligible [5].

4. Potentially Using Climate Smart Practices in Coffee Production

The authors reported various measures that can be used in coffee production and quality control to protect against climate change. The steps to be taken in this regard are briefly discussed below. Adaptation: Coffee farmers often use this to reduce the negative effects of climate change and take advantage of the new opportunities it creates. It can be improved by providing farmers with more tools and information and by helping people and organizations adapt to the dangers posed by the wind of climate change [13]. In contrast, this strategy views stakeholders as victims of climate change and will therefore be more hopeful and easier to engage with them. It does this by discussing ways to make people more relevant. There are many strategies to cope with change in coffee production, which can be divided into short-term and long-term. Improving agricultural practices, estimating and reducing the carbon footprint of agriculture, and assessing carbon emissions are some of the short-term reforms [22]. Long-term strategies include capacity building, mapping climate data, improving soil fertility, working on variety design, developing/growing drought and disease resistant varieties, developing adjustment mechanisms to adapt to future climate risks, and utilizing financial mechanisms. Manufacturers, especially small business owners, are connecting to the carbon market to benefit from their carbon footprint [22, 12]. Activities that reduce climate change by reducing, preventing or eliminating greenhouse gas emissions. These measures also include reducing the impact

of coffee production on carbon emissions, mainly from coffee's carbon footprint, and carbon sequestration by shade trees in forest areas or coffee farms and protecting existing ones [8]. Creating the ability to reduce the impact of climate change is one of the short-term technologies [22]. Durability: Like "sustainability," the word "resilience" is now widely used. According to [13], the definition of resilience includes the ability to change, the ability to assimilate changes (ability to tolerate climate change), and the ability of coffee growers to understand what needs to change and how. use these changes.

4.1. Utilization of Shade and Reforestation

Although coffee tree shading technology reduces coffee yield, it is generally considered to be ecologically and economically beneficial [29]. In addition to biennial fruiting, overproduction, and mortality, shade trees can absorb carbon dioxide from the air and store it in plants, control moisture, prevent soil erosion, and limit plant growth [29, 23]. It would be good to reduce the temperature and rainfall in the shade and control fruit yield. Additionally, shade trees can limit sunlight, cover the ground with fallen leaves, keep soil lower, reduce light, and increase air humidity. For coffee receiving fertilization or supplemental water, the optimal hue will be less than 50% [36]. Although overall yield is reported to be lower and CBD concentration higher, shade-grown coffee produces larger beans and greater coffee quality than sun-grown coffee. Plants in shaded areas show higher rates of photosynthesis than plants in full sun [4]. Any shade will result in lower foliage compared to coffee grown in full sun [33]. Agroforestry cultivation for coffee will be important for the management of biodiversity in the forest area. In this way, beneficial insects and animals use the shade as shelter. Planting coffee using agroforestry technology can create additional benefits that are more important in terms of local health needs, such as generating income from coffee production and improving capital nature to increase coffee production capacity and climate change [31]. Coffee shade trees will create the most reduction potential in degraded areas. Compared to sun-grown coffee trees, shade-grown coffee trees are subject to environmental stress from climate change, have a greater potential for biochemical and physiological sequestration, and produce larger, heavier, better-tasting coffee beans [4]. They are also exposed to less environmental stress due to climate change.

4.2. Genetic Advancement

The development of environmentally friendly, dependable and drought resistant coffee varieties is a fundamental effort to meet the difficulties of climate change, even though integrated techniques may be more appropriate given the complexity of the trait [28]. Although the molecular processes underlying the adaptation of coffee plants to drought are mostly understood [32], coffee demonstrates a diversity of acclimation mechanisms and/or resistance genes to avoid and sustain drought and heat shocks. Evaluation and selection of characteristics that are employed for drought resistance are necessary for a harmonizing approach that aids in developing plant performance for drought prone areas. Water extraction efficiency, water use efficiency (WUE), hydraulic conductance, osmotic and elastic adaptations, and regulation of leaf area are a few significant characteristics that show resilience to drought. The regulation and molecular basis of the majority of these features are poorly known and they are complicated [28]. The reaction was unrelated to morphological characteristics like leaf area or the ratio of root mass to leaf area. Instead, the drought tolerant clones' considerably deeper root systems allowed them to have greater access to water near the bottom of the pots and, as a result, to maintain a better internal water status for a longer period of time than the drought sensitive clones. Drought adapted plants frequently have deep, robust root systems because root growth and features play a critical role in preserving the plant's water supply [7]. The spectrum of how different coffee kinds react to drought is complicated, but in some areas, research on creating drought tolerant coffee varietals has begun. Basic research is being conducted in Kenya and Uganda, where coffee genotypes are being treated to heat stress and drought by not providing them with enough water in a greenhouse [7]. Compare the effects of two commercial Arabica species grown in controlled fields (water) by using RNA extracted from shoot tips to perform shoot sequencing and analyze the expression of 38 candidate genes and genes induced by dry weather. Conditions in coffee. The expression patterns of 25 genes were altered under drought conditions. Breeding and use of genetic changes that have been shown to be effective in breeding are practiced. Genotypes of mutants were used to assess disease, demonstrate genetic diversity and produce best crops, including Caturra (contract of variation). Bourbon, Maragogipe, Typica (including large bean), San Ramon, dwarf Typica and Purpurasens with purple leaves [32].

4.3. Intercropping of Banana and Coffee

Intercropping of coffee and bananas can help combat climate change by developing the ideal environment for growing coffee. Bananas have two advantages: they provide shade, keep the mouth covered during times of water stress, and reduce turnover, allowing them to retain plenty of water in a stressful environment. Compared to some shade trees, planting bananas is good because it reduces water competition between bananas and coffee trees [14]. In addition to the health benefits of hybridizing banana and coffee, there are many biophysical interactions where ground cover continues to control less soil erosion and stabilize or enhance coffee effectively and efficiently [21]. Intercropping is a good way to prevent reduced soil availability and provide cover to reduce plant growth and increase soil moisture [1]. The air temperature in the coffee shop is below 2°C due to the shade of banana trees. Therefore, the finished product tastes better and manufacturers can charge higher prices [14]. Coffee grown in the shade of banana trees will generally be heavier, larger cherries because it can reduce many fluctuations in coffee yields and act as a buffer against biennial fluctuations.

4.4. Additional Conservation Techniques

Mulching with a variety of grass seeds and crop residues will help retain moisture, provide nutrients and reduce evaporation. Similar covering techniques also increase soil moisture, increase soil nutrients, and act as a shade tree [29]. The main strategy for coping with water scarcity (dry season) and water use is rainwater harvesting. Before you open your coffee shop, get rid of all the rain by forking, digging and mulching your patio. This also helps to stop soil erosion, removing unneeded branches, blooms and berries that are a waste of water and nutrients [23]. Important defenses against the adverse effects of climate change include terracing and contouring, proper irrigation, growing hedges and contour planting to reduce wind and water deficit [22]. Constructing biogas to eliminate methane, the most potent greenhouse gas, which is created by fermentation in cows' stomachs. Making coffee growers aware of the effects of climate change and providing them with daily weather reports can assist them in preparing for and responding to the changing environment [31, 6].

5. Conclusion

Climate change is defined as changes in climate that can be seen through changes in mean and/or variability over a long period of time (usually a decade or longer) [18]. Emissions of greenhouse gases such as carbon dioxide (CO_2), nitrogen dioxide (N_2O) and methane (CH_4) into the atmosphere damage the ozone layer and are a major global problem. Land expansion through deforestation is another factor of climate change. Due to global warming, coffee (Arabica) production and fertile agricultural lands have been greatly affected. Coffee exposes leaves to high radiation, absorbing more energy than needed for photosynthesis, causing energy overload and leaf heating. It is known that high pressure affects the metabolism of plants. The many negative impacts of climate change on coffee production include flooding, soil erosion, drought, disease outbreaks and declines. Producers can combat climate change if adaptation and mitigation technologies are implemented. These include developing drought-tolerant and ecologically compatible varieties, mulching, intercropping of coffee and bananas, irrigation and rainwater harvesting, and planting shade trees. Conservation methods not only help coffee trees grow better in the changing environment, but also improve the fertility and structure of the soil. Planting shade trees not only reduces strong radiation, strong wind and heavy rain, but also improves the quality and size of your coffee cup. Take advantage of all technological innovations to ensure quality products, good coffee environment and healthy ecology.

6. Future Possibilities

The most important part of growing coffee (Arabica) is to keep it in the shade to get good results and grow well. In response to the severity of rust on coffee leaves and increasing levels of carbon dioxide in the atmosphere, world coffee (Arabic) production is turning to shade cultivation. On the other hand, it is stated that the results are lower than those of sun-grown coffee. Therefore, it is important to determine the appropriate shade and install a tree that provides good shade. Although the molecular mechanism of coffee plant adaptation to drought is not well known due to the complexity of drought tolerance genes [32], the creation of drought-tolerant, high-yielding and disease-resistant varieties is an important responsible for the change of coffee plants to drought. This. Sustainable and good coffee (Arabica) production. To obtain a good and profitable coffee crop, a lot of work needs to go into the development of the vaccine. More research on crop cultivation such as intercropping of other crops with coffee and bananas is crucial. Since bananas and plantains are members of the same family, it is necessary to understand how the crops grow, the interaction between them, and their economic benefits.

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Conflicts of Interest

The authors declare no conflict of interest.

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