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Nutrient Management Strategies for Sustainable Coffee Production in a Climate Change Scenario

Hareesh SB*

Division of Agricultural Chemistry, Central Coffee Research Institute, India

***Corresponding author:** Hareesh Shringeri Bhaskar, Division of Agricultural Chemistry, Central Coffee Research Institute, Chikkamagaluru District, Karnataka, India, Tel: +918762162749; Email: hareeshsb@gmail.com

Editorial

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Editorial

Coffee is cultivated in over 60 countries by approximately 25 million farmers and is of global economic, cultural, and social significance. Smallholder farmers contribute for approximately 60% of the global coffee supply. The global agricultural systems and crop performance are being pretentious by climate change, which has implications for both farmers and consumers. Similarly, prevailing climate change scenario in coffee producing regions is adversely affecting quality, yields, ultimately the livelihoods of farmers and economics of allied coffee sector. The Arabica and Robusta coffee verities are dominantly cultivated account for 99% of global coffee production. However, both will be impacted by climate change. Arabica coffee is more climate-sensitive than Robusta, despite making up 70% of coffee production and producing the highest-quality coffee. Meanwhile, Robusta coffee is commonly cultivated in unshaded/open shaded conditions due to its heat tolerance; consequently these systems are more exposed to landslips, soil erosion, extreme weather events and loss of ecosystem services [1,2]. Majority of coffee cultivation occurs in rainfed conditions; hence seasonal variations in precipitation intensity can have an impact on the growth and productivity of coffee plants. Consequently, it is imperative to enhance the endurance of coffee agroecosystems capacity to absorb climate shock by identifying soil fertility and nutrient management strategies that can create more climate resilient coffee production in the coming decades.

Introduction

The soil serves as both a source and a sink of greenhouse gasses (GHGs), and contributes an indispensable part in the exchange of energy, water and aerosols between the land surface and atmosphere. Changes in temperature and rainfall have a direct impact on a variety of soil characteristics such as soil erosion, decline organic carbon status, leaching of nutrients, and changes in soil reaction. Hence, mitigation and adaptation are two climate resilient strategies have great potential in coffee cultivation to cope with climate vagaries. Healthy development and productivity of the coffee plant be contingent on a sufficient supply of essential nutrients. Subsequently nutrition influences both bean size and quality, both of which define the value of the coffee produced. Therefore, ideal nutrition is essential for coffee cultivation during vital phases of growth and development. Since, coffee consumption in producing countries accounts for approximately one-third of the global coffee production. Majority of future growth in coffee consumption is predicted in developing countries.

Climatic Factors and Coffee Production

Generally, coffee develops naturally as an understory crop in natural forest environments. Hence, coffee is traditionally grown under shade trees. However, growing global demand for coffee and intensification of agriculture have led to a move toward monocultural coffee production marked by clearance of shade tree, high coffee crop densities and more agrochemical input. Presently, only 24% of coffee is grown worldwide under various shade systems [3]. Momentously, the effects of agroforestry on ecosystem ecology vary and usually depend on the variety of shade trees grown [4]. In India,

all coffee cultivated underneath a distinct two-tiered mixed shade canopy made up of evergreen leguminous trees. These coffee beans have an exotic full-bodied taste and a delicate aroma. Shade trees sustain a range of flora and fauna, slow down soil erosion on a sloping terrain, recycle nutrients from deeper layers into the ground, and shield coffee plants from seasonal temperature fluctuations. Meanwhile, unshaded coffee production systems are especially vulnerable to higher temperatures which may cause faster plant growth and over-ripening of the fruit, diminishing bean quality [5]. Changes to patterns and intensity of rainfall will also affect coffee crop development which is dependent on distinctive seasons for its reproductive phases [5,6]. Ultimately, climate change could contribute to a 4–25% decrease in coffee yields under agroforestry and a 20–60% decrease in full-sun systems by 2060 [7]. Similarly, areas suitable for particularly Arabica coffee cultivation are predicted to decline substantially in the coming decades [8].

Soil Health

It is ability of soil to endure functioning as an essential living system within ecosystem and land-use boundaries. Managing soil health is crucial for sustainable coffee production. Nonetheless, severe weather, nutrient leaching, and overuse of agrochemicals can all have a negative impact on soil health. Hence soil test based integrated nutrient management through optimum usage of manures, inorganic and organic fertilizers are recommended in the coffee plantations. By adopting appropriate soil conservation practices, soil erosion/landslides can be minimized. Similarly, water availability is essential for sustaining harvests of high-quality robusta coffee. As a result of climate change, there may be a rise in the number of coffee smallholders who need safe access to water in order to enhance the resilience of production systems to climate change. By increasing organic matter through external inputs, water conservation/water holding capacity can be amended in soils. Application of organic manures and mulches to soil can also reduce leaching, evaporation of nutrients from soil and also suppress weeds. Organic Manures/mulches also contain major, secondary and micronutrients; hence dependency of inorganic fertilizers can be minimized.

Coffee productivity greatly prejudiced by the soil quality characteristics. Soil organic carbon (SOC) affects a wide range of physical, chemical and biological properties. Hence it is considered as the most significant indicator of soil quality and its status will provide an indirect indication of the sustainability of the land use. Coffee agroforestry systems augment the organic carbon content of soil. Conversely, reduced organic matter input, increased erosion and increased oxidation as a result of tillage results in reduced organic carbon content in soil. Hence, in many coffee plantations regenerative agriculture is adopted to maintain or increase SOC. Mainstream of scientists are also believe that, a tiny increase in SOC could have a huge positive impact on soil health.

Nutrient Management

A critical mostly non-renewable resource, soil endures an increasing pressure. Agriculture and forestry depend on soil for supply of water, nutrients, and for root fixation. The soil performs dynamic function, which stores, filters, buffers, and exchanges gases with the environment. It must be safeguarded for sustainable crop production. Recurrently, crop output results in either excess or depletion of plant nutrients in soils. High input agriculture with only major nutrients usually results in a shortage of secondary and micronutrients. To alert such shortcomings or excesses, regular soil monitoring for its fertility status is absolutely essential. Integrated nutrient management (INM) is crucial for improving the productivity of coffee plantation. While using organic ingredients and recycling agricultural waste are vital, they cannot ensure the sustainability of coffee growing owing to non-synchronization of supply and demand of coffee plants for essential nutrients. Mineral fertilizers could provide nutrients in required quantities while environmental and budgetary problems. Soil test-based nutrient management will facilitate optimum usage of mineral, bio-fertilizers and organic manures. Through implementation of INM practice, chemical fertilizers, organic manures, biofertilizers or coffee pulp residues bridge the gap between the supply and demand of nutrients and consequences in sustainable crop production.

By means of adoption of improved nutrient management strategies in coffee, negative consequences of climate change can be reduced. Hence, sustained harvests of good quality coffee will be ensured in environmentally friendly manner. The integrated nutrient management practices on increased soil nutrient status, and yield of robusta coffee [9]. Numerous scientists have previously examined the feasibility of nutrient management practices to alleviate the effects of climate change on coffee. The green coffee bean N and P concentration remained higher in INM mode of nutrition compared to that of exclusive organics [10]. Some of the researchers compared influence of management practices and environmental factors (precipitation, light exposure, and altitude) in coffee production systems. These studies indicated that, increase in the sensory attributes of coffee was correlated with increase in the macronutrient content of soils. In the interim, nitrogen application was linked to a high-quality cup of coffee (sensory attributes) and an increase in bean biochemicals (protein, crude fat, and chlorogenic acids) under moderate irrigation conditions. Contrastingly, caffeine content and crude fiber levels were elevated as a consequence of reduced irrigation

in conjunction with the same high nitrogen application rate [11]. An additional investigation discovered that, under full sunlight conditions the quality of coffee beans was reduced when nitrogen supply was restricted. Conversely, coffee beans quality was improved after nitrogen was increased to a non-limiting quantity, regardless of the light condition [12]. Meanwhile, foliar spray of micronutrients (boron, copper, and zinc) on coffee plants led to an increase in the levels of caffeine, trigonelline, and sucrose [13]. The Sugars arabinose and mannose were also elevated as a consequence of the addition of zinc to the Boron treatment.

Regenerative Coffee Farming

Regenerative coffee cultivation is a dynamic and comprehensive method of land management that combines permaculture and organic farming to increase soil fertility and health. Globally, some farmers are using regenerative, organic coffee farming as a way to mitigate the effects of climate change. From both financial and environmental viewpoints, few coffee growers are also transforming their traditional sun farms (open cultivation) into organic shade farms via regenerative growing methods. The recycling organic residues/mulches such as shade tree leaf litter, coffee leaves and prunings, weeds and grasses, fruit skin/pulp and cherry or parchment husks through composting and returning them to the soil will augment soil fertility in coffee plantations.

Conclusion and Way Forward

Coffee quality and productivity are vulnerable to variable environmental and management conditions (water stress, temperature, light exposure, soil fertility and nutrients). For mitigating the effects of climate change on coffee quality and productivity necessitates further integrated approach towards shade management, selection of climate-resilient cultivars, tapping into wild coffee germplasm, nutrition (soil-foliar) and irrigation management, and integrated pest management. Smallholders using low-input production techniques will greatly suitable for shade-managed coffee. Since it has the ability to create ecosystem services to increase labor with minimal external agrochemical inputs. To enhance the sustainability and resilience of the coffee sector from agriculture to cup, innovations are required to mitigate the effects of climate change on coffee production systems. Climate resilience, healthy soil systems and coffee cultivation can be achieved through regenerative coffee production. Recycling organic residues/mulches through composting and returning them to the soil will reduces the requirements of fertilizes. This will also prevent pollution of streams and water sources. The integrated nutrient management is combined strategy maximizes the effectiveness of all the nutrient sources—including organic manures, mineral fertilizers, soil resources, recyclable wastes, biofertilizers.

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