Research Article

Seasonal Variation in Macronutrient Composition of Robusta Coffee (*Coffea Canephora*) Leaf as Influenced by Exclusive Organic and Integrated Nutrition Management (INM) Practices in Selected Coffee Estates of Western Ghats of India

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Abstract

In India, coffee occupies a place of pride position among the plantation crops grown. Mineral nutrients are elements acquired by the plants primarily in the form of inorganic ions from the soil. After being absorbed by the roots, the mineral elements are trans located into various parts of the plant, where they are utilized in numerous biological and metabolic functions. Macro and micro nutrients are involved in numerous plant metabolic processes; foliar analysis has proven useful in establishing fertilizer schedules that sustain yields and ensure the food quality of many crops. Consequently, the current field experiment is conducted to know the influence of organic and integrated nutrient management practices (INM), on nutrient status of leaf major nutrient composition and yield of Robusta coffee. The experimental results revealed that, the leaf major nutrients under the INM mode was found to be superior over exclusive organics. The average bean yield remained higher (1230 kg ha^{-1}) in INM mode of nutrition compared to that of exclusive organics (1101 kg ha^{-1}).

Keywords: Robusta Coffee, nutrient management, micro nutrients, yield

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Introduction

The early science of plant mineral nutrition benefited from developments in chemistry, in that it became clear that plants required several different elements in balanced proportions to maintain healthy growth [1]. Around the world, Arabica coffee (*Coffea arabica*) and Robusta coffee (*Coffea canephora*) are the most common species found and consumed. The central aim of plant ecology is to understand the mechanisms by which plants assimilate nutrients and allocate essential resources to physiological processes, growth and leaf production [2]. Nutrient assimilation is the process by which nutrients acquired by plants are incorporated into the carbon constituents necessary for growth and development. These processes often involve chemical reactions that are highly energy intensive and thus may depend directly on reductant generated through photosynthesis.

Foliar Macronutrient composition of as influenced by organic and integrated nutrition management (INM) practices

To optimize yields, farmers depend on soil and plant tissue test to determine fertilizer schedules. Foliar analysis has proven useful in establishing fertilizer schedules that sustain yields and ensure the food quality of many crops [3]. Leaf analysis method is based on the contention that the leaves are the principal seats of metabolic activity and that changes in nutrient supply are reflected in the chemical composition of leaves [4]. Levels of foliar nitrogen (N) and phosphorus (P) are broadly correlated with maximal net photosynthetic rates across thousands of plant species [5, 6] classified the seasonal patterns for the concentrations of the various leaves nutrients broadly grouped into three types. Concentrations of potassium decline throughout the season, whereas nitrogen, phosphorus, copper and zinc concentrations decline initially but reach values which remain relatively constant by mid-season. For calcium, magnesium, sulphur, boron, manganese and iron, concentrations in the leaves also decline initially but then increase for the remainder of the season. Earlier studies conducted on seasonal variations of plant nutrients coffee leaves revealed that there were distinct peak demand periods with respect to the nutrients N, P and K which stressed the importance of the timing of fertilizer application [7]. Generally, in coffee plants it was found that leaf nitrogen and potassium contents were high during May, July and November. Phosphorous was found to be high in October - November months. In case of Robusta the nitrogen content of leaves we high during May and September. Leaf phosphorous content was found to be high during May, September and November months, while potassium content was high during October and November months [8].

In India, the use of organic manures (farmyard manure, compost, green manure, etc.) is the ancient and most widely accomplished method for nutrient replenishment. Organic manures have a significant role to play in nutrient supply besides improving soil physio-chemical properties and soil health. However, generally lower plant performance observed in the case of organic compared to conventional systems, due to slow release of nutrients by organic manures in comparison with mineral fertilizers. This is because the maximum N obtainable from common organic manures is <10 %, P <2 % and K <10 % of dry matter compared with high nutrient outflows of up to 105 kg ha^{-1} of N, 13 kg ha^{-1} of P and 107 kg ha^{-1} of K to achieve yield levels of 1 t ha^{-1} per year resulting in serious negative nutrient balances [9, 10]. The undesirable nutrient balance resulted from exclusive use of organic manures is apparent in cropping coffee plants. However, integrated nutrient management is able to provide a positive nutrient balance for sustainable coffee production. Many studies have also concluded that, integrating organic and inorganic fertilizers is competitive in terms of growth and economic returns for crops [11, 16]. Irrigation water management is very critical component in coffee production system. Worldwide, coffee is predominantly cultivated as a rain fed crop. In India, coffee usually encounters 90-120 days of dry spell in a year. Under such conditions, growth and productivity could be boosted substantially by irrigation and this is very important in the case of Robusta coffee. At field conditions, rainfall pattern decides the crop production, timely irrigation is progressively becoming an imperative for coffee production to mitigate climate change such as unreliable rainfalls and frequent droughts that affect growth, yield and quality of coffee [12].

All the merits of shading in coffee plantations have been discussed by many authors showed that shade conditions in coffee plantations, although not required, are highly profitable for organic farming [13]. Coffee, like many other tropical tree crops, has a high potential for environment friendly agricultural production especially when grown in a kind of agro-forestry system [14]. Shade thus under South Indian conditions acts as-a buffer and most beneficial against vagaries of climate and their adverse effect [15]. In the coffee agro-forestry systems, shade trees contribute to the formation of litter which, after decomposition, can influence nutrient levels in soil [16]. The coffee requires much higher levels of nutrient inputs and crop management to achieve environmental sustainability, than generally assumed by the proponents of organic agriculture [17]. The nutrient cycling processes in organically and conventionally managed soils are similar, organic matter is especially important in maintaining soil quality, but additional inputs of inorganic fertilizers remain necessary for balanced plant nutrient flows and adequate yield levels [18]. In coffee plants, nitrogen (N), phosphorous (P) and potassium (K) are considered as the major nutrients and have one or more essential roles in the development of beans. Nitrogen is important for protein synthesis, hence the quality of the beans. Seasonal fluctuations in N reserves have been noted in the coffee leaves; from the early flush had a 34% reduction in N level, the drop in fruit N averaged approximately about 45 % [19]. Phosphorous (P) is the most limiting nutrient for coffee cultivation [20]. Optimum P content in leaves (0.12 to 0.16%) facilitates good growth and yield in coffee plants [21]. Phosphorus helps in fruit set, while potassium is necessary for the berry development and ripening. The phosphorus uptake is intense during the wet season at the time of fruit formation [22]. After fruit maturation during dry season, the leaf P content would be reduced. High P is required by coffee during blossom period. Right amount of phosphorous preferably rock phosphate, DAP, MAP or SSP needs to be given to plants along with N and K during the pre-monsoon period, ensuring sufficient soil moisture [23]. Potassium uptake is governed by the season, even more than that of nitrogen and phosphorous. During the rainy season, leaf potash is at maximum. Few months before the commencement of dry season, the leaf content begins to decline and reaches a maximum in the middle of the dry season. There is low leaf potash content corresponding to the period of coffee berry development and this continues to the following flower-bud initiation [24]. The objectives of this study to know the impact of exclusive organic and integrated nutrient management practices, shade and irrigation levels on major nutrient status of coffee leaf, which has direct associations on sustainable coffee production.

Materials and Methods

Study Location

This field experiment was carried out at nine selected robusta coffee estates located at Western Ghats of India, i.e., Koppa region of Chikkamagaluru District, Chikkamagaluru district is situated in the south western part of Karnataka State, between 12º 54′ and 13º 53′ north latitude and between 75º 04′ and 76º 21′ east longitudes. 2,509 m above sea level. The climate in study location is having three distinct seasons; 1) Summer season - March to early June, 2) Monsoon season – early June to September, however very less rainfall occurs during October to November due to impact North East Monsoon, 3) winter season initiates in mid-November and ends in mid-February. Among the selected 9 coffee estates, four estates practice organic mode of nutrition, while four estates follow integrated nutrition management practice and one estate where no nutrition management is practiced (absolute control). Varying shade pattern (open and thick) and irrigation (blossom, backing and winter) are the differentiation factors in the selected estates practicing exclusive organic cultivation and integrated nutrient management. The experiment was laid out in randomized block design (RBD) with 25 plants per treatment (plot size- 112 m^2) with four replications. The selected estates under organic cultivation were practicing organic farming since preceding four years. The other cultural practices were carried out as per the package of practices [25]. The treatment details are as follows

- **T1**- Control
- **T2 -** Organic nutrition*, thick shade (TS - 50 to 60% canopy) + Irrigation - I (winter)
- **T3 -** Organic nutrition*, thick shade (TS - 50 to 60% canopy) + Irrigation -II (Blossom & Backing)
- **T4 -** Organic nutrition*, optimum shade (OS - 25 to 30% canopy) + Irrigation - II (Blossom & Backing)
- **T5 -** Organic nutrition*, optimum shade (OS - 25 to 30% canopy) + Irrigation - I (winter)
- **T6** – INM#, thick shade (TS - 50 to 60% canopy) + Irrigation - I (winter)
- **T7 -** INM#, thick shade (TS - 50 to 60% canopy) + Irrigation (Blossom & Backing) - II
- **T8 -** INM#, optimum shade (OS - 25 to 30% canopy) + Irrigation – II (Blossom & Backing)
- **T9** - INM#, optimum shade (OS - 25 to 30% canopy) + Irrigation - I (winter)
- **Organic nutrition** -100% organics [Farmyard Manure and Compost -2.5 tones ha^{-1}, Rock phosphate 0.2 tones ha^{-1}],
- # **Integrated nutrition** [50% recommended dose of fertilizer (Anonymous, 2003) + 50% organic manures]
- **Winter-irrigation (I):** At least four irrigations at winter, blossoming, backing and summer (interval of twenty days), extended if dry spell continuous
- **Blossom backing irrigation (II):** Irrigations at blossoming and backing

Experimental Design and sample collection

The experiment was laid out in randomized block design (RBD) with 25 plants per treatment (plot size- 112 m^2) with four replications. The organics estates were selected where organic farming practices were practiced in the preceding 4 years. The other cultural practices were carried out as per the package of practices [26]. Representative 3rd pair of leaf from all nine Robusta coffee estates were collected during pre and post monsoon periods. The leaf samples were subjected to di-acid digestion (Hydrochloric acid + Per chloric Acid – 9:4) except nitrogen. For N analysis, sulphuric acid digestion followed by Kjeldhal procedure was employed. The data was subjected to appropriate statistical analysis as suggested by Gomez and Gomez [27] (1984) to draw valid inferences. Coffee yield was evaluated by harvesting the entire selected plants (10 plants per treatment per replication). The berries were dried until a constant weight was reached. The yield was calculated as per hectare base. The spacing between plants and between rows was the same for treatments.

Analysis of Chemical composition of leaf

Nitrogen (N) content in the leaf samples was determined by Micro-Kjeldahl's Method using Automatic Nitrogen Analyzer (Vapodest. 30), phosphorous content was analysed using Vanadomolybdo phosphoric Acid Colorimetric Method, the method Dhyan Singh [28] *et al*, (1999) and potassium content by flame photometer method [29].

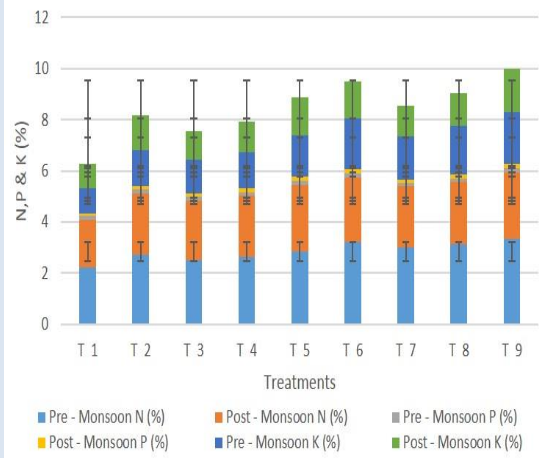
Results and Discussion

By using analytical data comparisons are made between organic and INM against the backdrop of a standard control. Attempts were made to delineate the effective allocation of nutrients in different modes of nutrition into leaf by comparison of nutrient status at pre and post monsoon seasons. As far as nitrogen is concerned, the INM mode facilitated higher (22.1%) transportation of N to various sinks compared to that of exclusive organics (9.3%). Despite higher mobilization, the leaf N status remained higher (2.5%) in INM mode compared to that of exclusive organics (2.4%). The higher accumulation of N despite larger transportation in INM mode may also be due to higher uptake of the nutrient during rainy season facilitated by the mode of nutrition. Thus, higher N retained in the INM mode would be utilized by the plants during grain filling stage besides supporting fresh vegetative sprouts meant for bearing in the subsequent season. Owing to lower contribution to the sinks as well as lesser reserves meant for maturation of the crop, the exclusive organics mode of nutrition remained inferior compared to the INM mode. Even though the P concentration in both the modes was same but the contribution from INM mode to the sinks remained higher (6.3%) compared to the exclusive organics. The INM mode facilitated higher (25.4%) transportation of K to various sinks compared to that of exclusive organics (9.2%). Despite higher mobilization, the leaf K status remained higher (1.4%)

in INM mode compared to that of exclusive organics (1.3%). Moreover, higher K required for maturity that would be replenished by INM rather exclusive organic mode of nutrition. The analytical data is presented in **Table 1**.

Table 1 Seasonal variations of foliar major nutrients of Robusta coffee as influenced by organic and integrated nutrition on nutrient practices

Seasons	**Pre - Monsoon**			**Post - Monsoon**		
Treatments	**N (%)**	**P (%)**	**K (%)**	**N (%)**	**P (%)**	**K (%)**
T 1	2.2	0.13	1	1.9	0.10	0.94
T 2	2.71	0.15	1.4	2.4	0.15	1.35
T 3	2.52	0.15	1.3	2.3	0.15	1.15
T 4	2.63	0.14	1.4	2.4	0.14	1.22
T 5	2.84	0.17	1.6	2.6	0.17	1.5
T 6	3.23	0.17	2	2.5	0.16	1.45
T 7	2.99	0.14	1.7	2.4	0.13	1.2
T 8	3.15	0.15	1.9	2.4	0.14	1.31
T 9	3.34	0.18	2.0	2.6	0.17	1.71
Sem +/-	0.17	0.01	0.12	0.02	0.002	0.04
CD at 5%	0.35	0.03	0.26	0.05	0.004	0.06



The average of 2 years yield data (clean coffee kg/ha) revealed that, highest (1875 kg ha^{-1}) yield was observed in the treatment with INM nutrition mode under open shade and winter irrigation followed by T5 (1790 kg ha^{-1}) where all the things remained constant except a shift in the nutrition pattern from INM to exclusive organics. The hierarchy of yield attributes were nutrition mode (INM better than organics), followed by irrigation schedule (winter irrigation better than blossom and backing irrigation) and shade pattern (open shade better than thick shade). The yield data is presented in Figure.1. A correct fertilization can have a positive impact on the quality of coffee. In most of the long-term experiments, combined use of mineral fertilizers and farmyard manure has usually produced the highest crop yields [30]. From an agronomic point of view, there is also considerable ground for criticism on the principles of organic farming when applied to coffee [31].

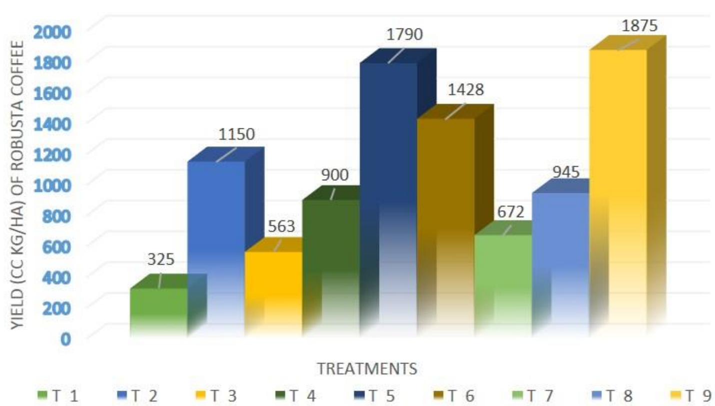


Figure 1 yield (cc kg/ha) of Robusta coffee influenced by organic and integrated nutrition with varying shade and irrigation management practices

Conclusion

The analytical data indicated that the INM mode was superior to exclusive organics in maintaining higher nutrient concentration and intern reflected in coffee yield. The open shade was found to be superior compared to that thick shade in nutrient assimilation. Similarly, the winter irrigation (irrigation at specified interval throughout the dry spell) was found to be better than the limited irrigations during blossom and backing for assimilation of nutrients. To conclude, the combination of INM nutrition mode under open shade with winter irrigation was found to be appropriate in realizing higher yields with desired bean nutrient composition. Therefore, by considering all above conclusions integrated nutrition practice (INM) is recommended for sustainable eco-friendly coffee production over the years.

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