Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.8, No.21, 2018
www.iiste.org

Inorganic Fertilizers Requirement of Coffee (Coffea arabica L)-- Review

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Abstract
Arabica coffee (coffea Arabica L), is indigenous still grows wild in the forests of south-western Ethiopia, which remains an important source of genetic resources for the world coffee industry. It is one of the stimulating crops widely drunk in the world next to tea , contributes to more than 50-60% of the Ethiopia's foreign earning and with 44% of all production consumed domestically. In Ethiopia, most soils are exposed to nutrient leaching over a long period resulting in low organic matter content and require careful management to support good crop yields. However, 85% of Ethiopian farmers don't use organic fertilizers while the rest add it at levels significantly below the recommended rate. The bulk of coffee soils in the south western region are classified at nitosoils, which are highly weathered and originate from volcanic rock. These soils are deep and well drained having a PH of 5-6, and have medium to high contents of most of the essential elements except nitrogen and phosphorous. The importance of proper coffee nutrition cannot be over emphasized because nutrition affects bean size and bean quality, both of which determine the value of the coffee produced. It is worth remembering that for optimum growth and productivity, the coffee plant requires adequate nutrients. Nutrients are applied to replenish those that are lost through tissue formation, yields, leaching and those that form compounds where they cannot be easily extracted by roots. This calls for application of fertilizers so as to apply the necessary nutrients in the required .amounts. When fertilizing coffee trees, two distinct aspects should be considered: The compensation of the actual deficiencies, the necessary inputs to replace depletion caused by the coffee trees themselves and by lixiviation. Fertilization should also provide for the needs of the various microorganisms which play an active part in the quality of the topsoil. Replacing mineral depletion in the topsoil and neutralizing the effects of toxic elements are basic prerequisites to ensure production & Coffee quality in the coffee plantation. Therefore the objective of this paper is to review various investigations of coffee inorganic nutrient requirement & its influence on growth, yield and quality. A balanced fertilization of all major and minor nutrients will result in two important functions, namely production of good crops and also production of fresh cropping wood frame work for the succeeding year. Coffee plants have high N and K requirements Coffee has a very high demand for nutrients and takes up huge quantities from the soil. It has been estimated that a hectare of fast- growing highly-yielding coffee takes up an annual total of about 135kg N, 34kg P_2O_5, and 145kg k_2O. Laves need the major part of the uptake - more than the flowers or fruits. The results reported show significant coffee yield increment with increasing level of nitrogen. Significant yield improvement was reported in response to the interaction between nitrogen and phosphorus fertilizers. Several studies have been reported that Phosphorus is known to be one of the most recognized limiting factors for coffee production in most soils of south-western Ethiopia..The study indicated that the highest available P content in the soil was found 80 days after application at a distance of 45cm from the trunk and 15cm depth. Results from some trials involving potassium fertilizer also indicate positive crop responses to potassium application. Fertilizer application & recommendation depends on various factors including: type of production system , soil fertility status and soil reaction, type of coffee variety, age of the coffee tree and plant population. Too much & little fertilizer in the plant will reduce cup quality. Younger leaves have higher alkaloid contents than older leaves & statistically similar to the control treatment, omission of K encourages the greatest increase (12%) of caffeine contents in leaves. The nutrient status of most soils is expected to change after a long period, varieties released and new for users might have different response or requirement to mineral nutrition. Therefore, fertilizer recommendations have been carried out should be updated ted
Keywords: Coffee, Inorganic fertilizer, N, P , K application

1. Introduction

Soil fertility is on a downward twisting, with inputs of nutrients (from organic and inorganic sources) into inactive agriculture insufficient to reverse the trend. Estimated rates of net nutrient depletion are high, exceeding 30 kg of nitrogen (N) and 20 kg of potassium (K) per hectare of arable land per year in Ethiopia, Kenya, Malawi, Nigeria, Rwanda, and Zimbabwe (Stoorvogel et al. 1993).

Arabica coffee (coffea Arabica L), is indigenous still grows wild in the forests of south-western Ethiopia, which remains an important source of genetic resources for the world coffee industry (Gole, 2003). The region is known to be the home of arabica coffee where the rich genetic diversity and wild grown coffee in the forests of the region is still noticeable. It is one of the stimulating crops widely drunk in the world next to tea , contributes to more than 50-60% of the Ethiopia's foreign earning and with 44% of all production consumed domestically

(Mayne et al. 2002; World Bank 2004). It also provides employment opportunity for more than a quarter of the Ethiopian population (Ali, 1999). Coffee is one of the leading commodities in the international trade, providing revenue of over US $10 billion annually to the producing countries and work for an estimate 20 million people who grow, process and distribute the crop throughout the world (Wrigley, 1998).

In Ethiopia, most soils are exposed to nutrient leaching over a long period resulting in low organic matter content and require careful management to support good crop yields. However, 85% of Ethiopian farmers don't use organic fertilizers while the rest add it at levels significantly below the recommended rate (Eyassu, 2002 cited in Solomon *et al.*, 2008). The bulk of coffee soils in the south western region are classified at nitosoils, which are highly weathered and originate from volcanic rock. These soils are deep and well drained having a PH of 5-6, and have medium to high contents of most of the essential elements except nitrogen and phosphorous (Paulos, 1994).

The importance of proper coffee nutrition cannot be over emphasized because nutrition affects bean size (Grade) and bean quality, both of which determine the value of the coffee produced. It is worth remembering that for optimum growth and productivity, the coffee plant requires adequate nutrients. Nutrients are applied to replenish those that are lost through tissue formation, yields, leaching and those that form compounds where they cannot be easily extracted by roots. This calls for application of fertilizers so as to apply the necessary nutrients in the required amounts (Ali, 1999). Coffee farming systems in Ethiopia are conventionally divided in to four categories: forest coffee, semi-forest coffee, garden coffee and modern plantation. In these production systems, the productivity of the crop is very low ranging 450-472 kg ha^{-1} clean coffee (Workafes and Kassu, 2000). Most of the coffee plantations are often managed with shade trees and minimal fertilization. Hence, from the point of view of nitrogen cycling, litter-fall and decomposition play an important role in the maintenance of soil fertility (Hera & Jordan, 1981 cited in Solomon *et al*., 2008).

Fertilization should provide and maintain optimal quantities and combinations of ingredients within the soil so that depletion caused by the activity of coffee trees does not unduly impoverish it or turn it into sterile land which can no longer be used for cultivation purposes. Plant tissues are composed of a number of elements of which 16 are essential to its physiological development. When fertilizing coffee trees, two distinct aspects should be considered: The compensation of the actual deficiencies, the necessary inputs to replace depletion caused by the coffee trees themselves and by lixiviation. Fertilization should also provide for the needs of the various microorganisms which play an active part in the quality of the topsoil. Replacing mineral depletion in the topsoil and neutralizing the effects of toxic elements are basic prerequisites to ensure production & Coffee quality in the coffee plantation (Snoeck & Lambot, 2005).

Caffeine is the most abundant and important alkaloid in coffee. Despite its taste, this alkaloid does not contribute for more than 10% of the coffee bitterness (Clifford, 1985). The importance of caffeine in the coffee beverage seems to be solely as a stimulant, which is the main reason for its popularity over the centuries. Although there are thousands of alkaloids in nature some have economic importance because of their physiological effects on humans. Consequently, in view of commercial interests, many studies have been carried out to investigate the factors that would increase their contents in plant tissues and, especially, in cell suspensions. Depending on the size of the cell aggregate, NaCl can also cause an increase on caffeine contents (Frischknecht & Baumann, 1985). Therefore, it would be interesting to learn more about the environmental and agricultural influences on the caffeine contents of coffee beans and leaves. full control of nutrient deficiencies. Therefore, it would be interesting to evaluate caffeine variation in leaves as a response to mineral supply in seedlings growing in nutrient-agar medium. Therefore the objective of this paper is to review various investigations of coffee inorganic nutrient requirement & its influence on growth, yield and quality.

2. Nutrients and plant growth

Sixteen elements are essential for the growth and development of a healthy coffee bush. These are categorized into Macronutrients & Micronutrients. Macro nutrients are further classified as Primary and Secondary nutrients. Nitrogen, Phosphorus and Potassium constitute the primary nutrients because of the large amounts required by the coffee plant. The growth and development of the bush depends on the sufficient supply of the respective nutrients and the yield is limited by the nutrients which are in short supply. A balanced fertilization of all major and minor nutrients will result in two important functions, namely production of good crops and also production of fresh cropping wood frame work for the succeeding year (Coffee Guide,2000).

The amount of plant nutrient required by coffee trees may vary depending on several factors. The amount of rainfall and its distribution, the species and amount of other plants grown in association with the coffee trees, seasonal variation, the topography, the soil type and the prevailing cultural practices are a few. Estimation of the nutrients required by the new crop is based on soil and plant tissue analysis (Paulos, 1986).

The overall rate of coffee growth and production depends on the least available plant nutrient. Plants will grow and produce only as much as the least available nutrient will allow them to. It does not matter how much of the other nutrients are available to the plant because it is the least available nutrient that limits growth and development. This is well illustrated in the Liebig's 'Barrel diagram Law of the Minimum. Crop yield is limited by the one essential mineral nutrient that is in the relatively shortest supply. Where the barrel can hold only as much water as the shortest plank will allow. This is known as the 'Law of the Minimum' and is explained thus: The level of water in the barrel represents the level of crop yield that is restricted by the most limiting nutrient, nitrogen. When nitrogen is added, the level of crop production is controlled by the next most limiting factor (in this example, potassium). Poor nutrition is a major cause of coffee dieback. Plants lacking sufficient N (nitrogen) and K (potassium) suffer from dieback, especially where there is poor shade cover and insufficient water. Low soil calcium and phosphorus will hinder root development and contribute to dieback. Dieback causes loss of yield. When severe, plants can die, especially high yielding, dwarf Catimor varieties. Each nutrient has unique deficiency symptoms (Edward W. et al., 2005).

Coffee plants have high N and K requirements (Correa *et al*., 1983). There is a close relationship among nitrogen supply, number of leaves, and number of flower buds. Whereas adequate tissue N levels are favorable for starch and other carbohydrate production needed for fruit formation and growth, in deficient plants symptoms develop particularly when the berries grow. Potassium also plays a major role in coffee plant physiology especially during fruit growth and maturation. The K quantity exported at harvest exceeds that of N which helps to explain why it can become limiting after a few years (Mitchell, 1988). Accoding to Malavolta (1986) a good correlation exists between the K status, as measured by leaf content, and stored starch and yield. When tissue K is adequate the proportion of floats and branches with symptoms of overbearing decreases.

Coffee has a very high demand for nutrients and takes up huge quantities from the soil. It has been estimated that harvesting a tone of clean 35 kg coffee removes from the field 35kg N, 7kg P_2O_5 and K2O. Additional nutrients are also required for growth, and it has been estimated that a hectare of fast- growing highly-yielding coffee takes up an annual total of about 135kg N, 34kg P_2O_5, and 145kg k_2O (Mitchell, 1988). Arabica Coffee nutrient removal by the crop at harvest**.**

2.1. Nutrient uptake of a coffee tree and optimum leaf nutrient levels and soil

It is obvious from this table, that leaves need the major part of the uptake - more than the flowers or fruits. However, nutrients are returned to the soil when the leaves drop. The early years of root development are very important as branches and roots store nutrients for a long time. Once the soil and leaf samples have been taken, it is important to analyse the results and compare them to levels that have been determined as optimum in coffee plantations around the world in order to devise a nutrition program for the coffee (Table 1 &2)

Table 1:- Nutrient uptake of a coffee tree parts

	Elements (kg)					
Parts of tree	**N**	**P**	**K**	**Ca**	**Mg**	**S**
Roots	15	2	25	9	2	2
Branches	14	2	20	6	3	1
Leaves	53	11	45	18	7	3
Fruits	30	3	35	3	3	3
Total	**112**	**18**	**125**	**36**	**15**	**9**

Source :- Edward W. *et al.,* (2005).

Table 2:- Optimum leaf & soil nutrient levels

	Leaf	Soil	
Nutrient	Optimum range	Nutrient (extraction method in brackets)*	Suggested optimum soil levels
N	2.5 - 3.0%	pH (1:5 soil/water)	5.5 - 6.0
P	0.15 - 0.2%	Organic matter (Walkley Black)	1 - 3 %
K	2.1 - 2.6%	Conductivity (l:5 soil/water)	< 0.2 dsm
S	0.12 - 0.30%	Nitrate nitrogen (1:5 aqueous extract)	> 20 mg/kg. Leaf tests more relevant
Ca	0.75 - 1.5%	Phosphate (Colwell or bicarb)	60 - 80 mg/kg
Mg	0.25 - 0.40%	Potassium (Ammonium acetate)	> 0.75 mg/kg
Cu	16 - 20 mg/kg	Zinc (DPTA)	2 - 10 mg/kg
Zn	15 - 30 mg/kg	Manganese (DPTA)	< 50 mg/kg
Mn	50 - 100 mg/kg	Iron (DPTA)	2 - 20 mg/kg
Fe	70 - 200 mg/kg	Copper (DPTA)	0.3 - 10 mg/kg
B	40 - 100 mg/kg	Boron (hot calcium chloride)	0.5 - 1.0 mg/kg (sandy loams) 1.0 - 2.0 mg/kg (clay loams)
Na	< 0.05%	Cation exchange capacity	3 - 5 sandy soil > 10 heavy soil types

Source; Edward W. *et al.,* (2005). FAO Arabica coffee manual for Myanmar

2.2. Essential minerals role and deficiency symptom in the coffee plant

The components of mineral fertilizers are divided into macro and micro based on their requirement by the plants. Macro nutrients (N, P, K, Ca, Mg, and S) which are required by plants in large quantity more than 1ppm are most important for the growth of the coffee plant. Besides, there are micro nutrients (Fe, Mn, Zn, Mo, Cu, B, Al) that are demanded by plants in much less quantity (less than 1ppm) but without them problems in growth may arise. Most soils are endowed with sufficient amount of trace elements and thus, there is hardly any need for their application (Ali, 1999). The remobilization and re-utilization of certain nutrients is an important metabolic feature during development or in cases of seed germination, under stress conditions in the period of vegetative growth and the reproductive stage as well and, in the case of perennials, before leaf fall. As indicated by deficiency symptoms which develop in the leaves, the degree of both N and K mobilization is large (Marschner, 1995).

3. Inorganic fertilizer

3.1. Nitrogen

Nitrogen is one of the essential plant nutrients required by the coffee tree in large quantities as compared to other nutrients. The important of nitrogen in coffee nutrition hinges basically on its being present in large extent in dry matter of protoplasm, or living substance, of plant cell. It is, therefore, required in large quantities for several growth processes that take place in coffee plants. Very little work was done on the mineral fertilization of coffee in Ethiopia before the 1970's. One of the first fertilizer experiments on coffee at Jimma Agricultural Research Centre was carried out to supply necessary information for CTDA in connection with the coffee improvement project and replanting program. Different nitrogen, phosphorous and potassium rates were investigated in factorial combination (IAR, 1979).

In an effort to determine optimum nitrogen rate for coffee production in different agro-ecologies, various fertilizer trials were accomplished at Jimma research center (Melko, main centre), and sub-centers or trial sites (Gera, Metu, Tepi, Bebeka, Wonago, and Bedessa). At Melko, the response of coffee trees to applied fertilizer was investigated since early 1978/79 (IAR, 1982/83). The results reported show significant coffee yield increment with increasing level of nitrogen. The most noticeable yield response of coffee was for 150 kg/ha nitrogen (IAR, 1982/83). However, further increases in nitrogen rate did not have significant effect on yield. Similar fertilizer trials were also carried out at Gera, Metu and Tepi in which no significant fertilizer effect on coffee yield was found; whereas at Bedessa, though not statistically significant, there was a positive coffee yield response to fertilizer application (IAR, 1982/83; 1984/85).

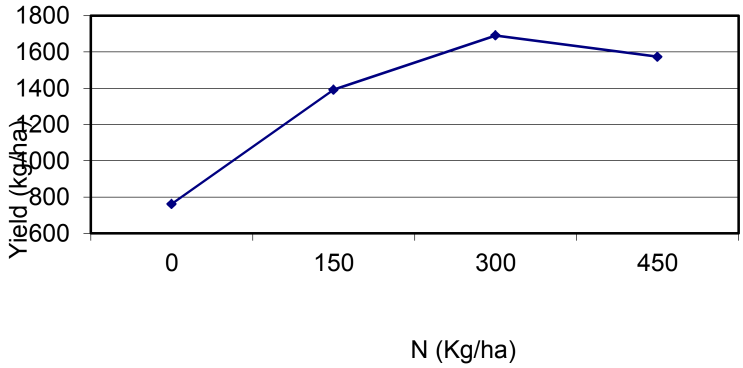

Figure 1:- Effect of Nitrogen on coffee yield at Melko Source:- Paulos (1986)

At Wonago (Southern Ethiopia), the response of coffee to NP fertilizer application was examined for three consecutive years on a thirty year old forest coffee (Fisseha et al., 1993). Significant yield improvement was reported in response to the interaction between nitrogen and phosphorus fertilizers. The optimum NP rate found in the study was 200/66 kg ha-1. Further investigations with varying soil types, slopes, vertical numbers and coffee varieties were finally recommended (Fisseha et al., 1993). Paulos, (1986,1994) has summarized results of previous fertilizer trials at different coffee growing areas of south-western Ethiopia in which the highest yield of coffee was recorded in response to the highest rate of nitrogen (300 kg/ha) (fig. 1), with significant yield reduction for further increases of nitrogen.

3.2. Phosphorus

Phosphorus is known to be one of the most recognized limiting factors for coffee production in most soils of south-western Ethiopia. The soils are highly weathered, low in pH, high in iron and aluminium contents leading to high phosphorus fixation (Sahlemedin and Ahmed, 1983; IAR, 1984). From a field experiment at Melko, a 50% increase in coffee yield was reported when the level of Phosphorus was raised from zero to 33kg/ha, but further increase in the level of this nutrient was not reflected in increased yield (IAR, 1982/83). On the other hand, no significant yield was reported from similar experiments at Gera, Tepi and Metu (IAR, 1982/83; 1984/85).

At Wonago (Southern Ethiopia), the response of coffee to mineral fertilization was examined on a 30 year old forest coffee (Fisseha et al., 1993). The combined analysis over years indicated significant yield response of coffee to NP fertilization. The optimum NP rate found in the study was 200/66 kg/ha. Further investigations with varying soil types, slopes, vertical numbers and coffee varieties were recommended (Fisseha et al., 1993).

In general, a positive correlation between coffee yield and phosphorus fertilizer application at different areas was reported (Paulos, 1986, 1994). Coffee yield increment due to phosphorus (33kg/ha) application at Melko was 597 kg (64.5%) over the control (Figure 2). It was also indicated that the interaction between nitrogen and phosphorus gave better result than the main effects alone.

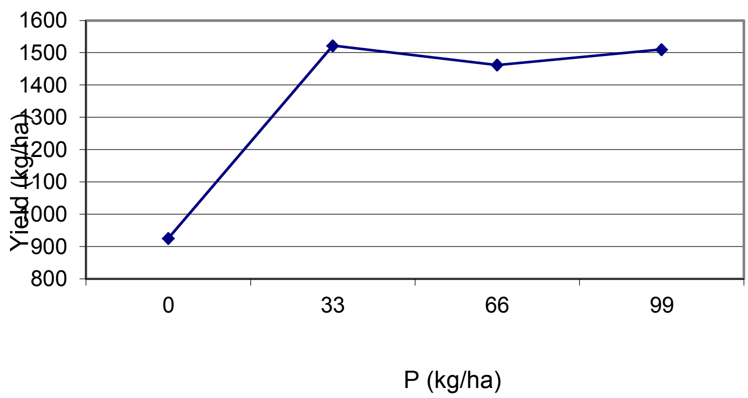

Figure 2:- Effect of Phosphorus on coffee yield at Melko

Source: - Paulos (1986)

3.2.1. Phosphorus placement methods

Apart from the type of fertilizer and time of application, the method of application plays a significant role in the efficient use of phosphorus fertilizer. Hence, a study on different phosphorus placement techniques was carried out to determine the best distance from the coffee trunk and optimal depths for applying phosphorus fertilizer to the coffee tree (Tesfu and Zebene, 2004). The experiment was accomplished in three sets with the first set focusing on horizontal P placement (15cm, 30 cm, 45 cm, 60 cm distances from the trunk of the coffee), the second set on vertical or depth of P placement (7.5cm, 15cm, and 22.5cm), and the last set investigating the combined effects of selected treatments from the first two sets (30cm, 45cm, 60cm horizontal and 7.5cm, 15cm, 22.5cm depths). Control (*without P*), and check (*ring application*) were included in all experiments.

Finally, it was reported that only root biomass (fresh and dry weights) was significantly affected by the treatments investigated (i.e., P placement distances from the trunk) (Tesfu and Zebene, 2004). Hence, applying phosphorus fertilizer at a distance of 45cm from the trunk and at a depth of 15cm was reported to be optimum horizontal and vertical distances respectively. The report also indicated that the highest available P content in the soil was found 80 days after application at a distance of 45cm from the trunk and 15cm depth.

3.2.2. Phosphorus status of long term fertilized soils

Unlike nitrogen, phosphorus is relatively immobile in the soil. Hence, repeated application of phosphorus fertilizers for a long time might result in the accumulation or build-up of the nutrient in the soil where further application of phosphorus fertilizers won't have significant effect on yield. This is especially important for research plots used for fertilizer trials. An experiment was carried out at Melko to examine the status of phosphorus and other nutrients in response to long-term fertilizer application in soils cropped to coffee (Tesfu and Zebene, 2004). The data indicated build-up of phosphorus and reduction in soil pH as a result of long-term fertilizer application . The result therefore confirmed the imbalance of nutrients caused by continuous application of inorganic fertilizers. Such a build-up in phosphorus and the resulting nutrient imbalance might discourage future fertilizer trials in the centre. Hence, fertilizer studies, especially those involving phosphorous need to be carried out at places where the level of P and soil acidity do not present similar problems.

On the other hand, the level of micronutrients was found to increase in long-term fertilized than unfertilized plots indicating the enhancement of solubility and hence availability of these micronutrients with the reduction of the soil's pH. In general, considering the imbalance of nutrients and reduced soil pH, corrective measures should be sought instead of emphasizing the increased micronutrient availability in long-term fertilized soils since visible and critical micro-nutrient deficiency has not been noticed in the area so far (Tesfu and Zebene, 2004).

3.3.1. Requirement and uptake of potassium

The requirement of K is high during the development of coffee berries and is maximum during their ripening. The highest rate of K uptake was observed immediately after harvesting followed by two secondary increases prior to fruit ripening and after flowering, indicating that K absorption increases immediately after main flowering and during the last stage of fruit development and later as the plant recovers from bearing fruit, when water is not limiting. The nutrient removal by the berries in the two important cultivated varieties of coffee has been estimated as 34 kg N, 5 kg P 2 O 5 and 45 kg K 2 per hectare in arabica and 35 kg N, 7 kg O 5 and 89 kg K 2 O in robusta (Nelliat, 1978). The nutrients required for building up the berries are twice the quantity of nutrient removed by the berries. According to Mitchell (1988), coffee has high demand fornutrients and take up high quantities of nutrients from soil.

It was estimated that harvesting a tone of coffee removes from the field 35 kg N, 7 kg P 2 O 5 and 50 kg K 2 O. Additional nutrients are also required for growth and it was estimated that a hectare of fast growing, high yielding coffee takes up 135 kg N, 34 kg P 2 O 5 and 145 kg K 2 O. In another study on crop nutrient removal, Alwar *et al.,* (1991) have estimated that 6000 kg of ripe fruits removes approximately 40 kg N, 5.33 kg P 2 O 5 and 52 kg K 2 O Filho *et al.,* (2003) studied the remobilization and re-utilization of nitrogen and potassium by coffee by tracer technique and observed that fruits are the main sink for K and K reserves are used in higher proportion than N by fruits and other organs. Significant quantities of nutrients may be recycled in coffee leaf litter, pruning, pulp and parchment, and in shade tree leaf litter and pruning. About 317 kg K 2 O was recycled through coffee and shade tree leaf litter and pruning in a year (Carvajal, 1985).

Coffee plants have a high demand for potassium. This nutrient is an essential element for many plant functions such as enzyme activity, the transport of water, nutrients and sugars, and control of stomata cells. The early stage of potassium deficiency is known as "hidden hunger", in which no external visual symptoms develop but plant growth is nevertheless reduced. In advanced stages of potassium deficiency, coffee plants develop chlorosis and necrosis in the leaf tips and margins. Development of visual symptoms begins in the older leaves, as they provide their potassium to feed the younger ones. The net effect of a potassium deficiency is a decrease in crop yield and quality.

An experiment carried out in Brazil from 1999 to 2001 compared the effect of two sources of potassium - sulphate of potash (SOP) and potassium chloride (MOP) - on coffee yield and quality. Application rates of 120, 240, and 480 kg K2O/ha were used. Large yield variations between the years were observed, due to differences in climatic conditions (**Figure 3).** Yields using SOP, averaged over the three application rates, were 11.4%, 19.8% and 4.2% higher, however, for the years 1999, 2000, 2001 respectively, compared to the yields with MOP. The overall average yield with potassium sulphate was 10.2% higher **http:/ / W.W.W.Tessenderlo Group com.**

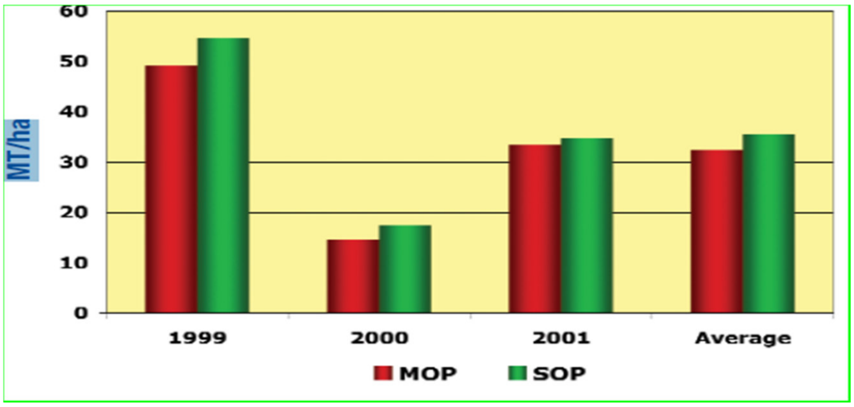

Figure 3:- Effect of SOP and MOP on coffee

Source: - EPAMIG, Brazil (2016)

Potassium fertilizer application is not common in Ethiopian Agriculture, whether in tree crops like coffee or in cereal crops. This is due to the view that potassium is not a limiting nutrient in Ethiopian soils, a conception which is often based on the report by Murphy (1959) and Hofner and Schmitz (1984). However, Ethiopian agriculture is a highly exploitative type in which plant nutrients particularly potassium are heavily extracted or mined from the soil and very little or no crop residues are returned back (Solomon et al., 2008).

Results from some trials involving potassium fertilizer also indicate positive crop responses to potassium application (Paulos, 1986; IAR, 1984/85). In a fertilizer experiment at Melko, significant coffee yield improvement was noticed, when the level of potassium was increased from zero to 62 kg/ha, but further levels of potassium did not result in increased yield (IAR, 1984/85; Paulos, 1986). On the other hand, in a similar experiment at Gera, Metu and Tepi, the results indicated no significant fertilizer effect on coffee yield (IAR, 1982/83; 1984/85). Since the previous assessments on potassium level of Ethiopian soils in general and soils of the major coffee growing areas in particular were accomplished long time ago (Murphy, 1959, 1960; Hofner and Schmitz, 1984), the issue of potassium fertilizer requirement in coffee needs to be entertained as priority in the research agenda of the centre or the national research system. The information to be generated thereof may have significant impact on the nation's fertilizer use as a whole and the coffee industry in particular.

3.4. Fertilizer recommendations & management problems in coffee

In the past three to four decades, extensive fertilizer trials were carried out at Jimma Agricultural Research Centre and its sub-centers that represent the major coffee growing agro-ecologies of the country. As a result, it was possible to come out with a set of recommendations (Table 3) that are of immense value to the grower. Fertilizer application depends on various factors including: type of production system (forest, garden, open, low shade), soil fertility status and soil reaction, type of coffee variety (local, high yielding), age of the coffee tree and plant population. Open and low shaded coffee plantations, high yielding varieties and mature trees on poor soils (low fertility) should be give the full dose of the recommended fertilizers. On the other hand, forest coffee, low yielding and young trees (less than three years), rich soil lower amount than the recommended full dose (IAR, 1996).

Table 3:- Location-specific NPK fertilizer recommendations for coffee

location	recommendation domain	recommended rates (kg/ha)		
		N	P	K
Melko	Jimma, Manna, Seka, Gomma, and Kossa	150 - 172	63	0
Gera	Gera	No fertilizer	No fertilizer	No fertilizer
Metu	Metu, Hurumu, Yayou, and Chora	172	77	0
Tepi	Tepi	172	77	0
Bebeka	Bebeka	172	77	0
Wenago	Wonago, Dale, Aleta Wondo, and Fiseha Genet	170 - 200	33 - 77	0
Bedessa	Habro, Kuni, Darelebu	150 - 235	33 - 77	62

Source: - EARO (1996)

As Solomon *et al., (*2008) reported the fertilizer recommendation in Ethiopia has been given for the commonly used coffee verities that were under production since the trial was carried out decades ago, currently many varieties are released for users which might have different response or requirement to mineral nutrition. Moreover, the nutrient status of most soils is expected to change after such a long period since fertilizer trials have been carried out. Therefore, the challenge faced now is that of updating or recalibrating the fertilizer recommendations already given for the traditional varieties and to the newly released coffee hybrids and selections & application is not a common practice in the small holder coffee production system; when applied, it is even very much below the recommended rates. & management is also very important for increasing the productivity and fertilizer use efficiency. A significant proportion of the applied nitrogen may be lost as ammonia within a few days after application. Therefore, proper management can result in significant reduction of the losses. The efficiency of urea, the most commonly used nitrogen fertilizer is very low. It is however clear that the most prominent problem of fertilizer use in Ethiopia, is the ever increasing of fertilizer cost.

3.5. Foliar analyses

The foliar results show that the nutritional status of the coffee plants was good except for magnesium, which showed marginal (Mg) values (Table 4). The low value of Mg could directly affect the yield of coffee, as the element is essential in green plants as part of chlorophyll and activator of many plant enzymes. (Cambroy, 1992) Probably lack of enough Mg was reflected in reduced yield in all treatment vis-à-vis normal yield of coffee (6tons ha -1 year-1). Cambroy, 1992. But Mg was out of the scope of this experiment.

Table 4:- Coffee foliar nutrients before and 15 months after inorganic fertilizer application

Treatment	%N		%P		% K		%Ca		%Mg	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
N	3.3	3.0	0.29b	0.17	3.49	1.65	0.43	0.26a	0.33	32b
P	2.4	2.3	0.15a	0.15	2.82	1.83	0.31	0.13a	0.24	0.28a
K	2.4	2.5	0.16a	0.18	2.67	1.85	0.28	0.15ab	0.22	0.23a
NP	2.5	2.8	0.14a	0.17	2.92	1.68	0.29	0.29a	0.24	0.18a
PK	3.2	2.6	0.21b	0.14	3.80	1.98	0.40	0.45b	0.32	0.21a
NK	2.8	2.5	0.18a	0.16	3.0	1.88	0.27	0.14ab	0.23	0.29a
NPK	2.3	2.3	0.16a	0.15	2.07	1.45	0.26	0.24a	0.23	0.23a
Control	2.4	2.4	0.21a	0.16	3.56	1.85	0.37	0.23a	0.30	0.12
LSD	NS	NS	0.11	NS	NS	NS	NS	0.26	NS	
C. Value	3.3		0.18				1.50		0.36	

Source: C= Critical; 1st = Foliar analysis before treatment application; 2nd = Foliar analysis after treatments application.

Some soils have minimum element is essential and mobile in nature . For example Magnesium is mobile in plants, mobile in acid soils, and fairly immobile above pH 6.5. Leaches from soil. Magnesium is necessary for formation of sugars, proteins, oils, and fats, regulates the uptake of other nutrients (especially P), is a component of chlorophyll, and is a phosphorus carrier (Barbara J. 2001). The low value of Mg could directly affect the yield of coffee, as the element is essential in green plants as part of chlorophyll and activator of many plant enzymes (Cambroy, 1992, Mukiibi, J.K 2001 and Muyeti Joseph. Z. & Tumuhimbise Ivan, N. 2004). The deficiency symptoms of magnesium are faint yellowing on leaf edges with sunken, yellow-brown to light brown dead spots developing in a wide band along leaf edges; yellowing between veins evident in affected leaves, particularly along the midrib (Edward W. et al., 2005).

3.6. Coffee quality influenced by fertilizing

The results show that the quality of the beverage is especially connected to the altitude of the plots, the rainfall, the soil acidity, the percentage of shade, the yield of the trees, and the bean size. The most appreciated, aromatic and balanced beverages, are associated with the plantations located at high altitudes (1115 m on average), with a medium annual rainfall (1726 mm), a slightly acid and rich soil, a medium percentage of shade (48%), a high yield (464 fruit bearing nodes per coffee-tree) and big beans(Avelino, 2002).

Too much nitrogen (N) or potassium (K) in the plant will reduce cup quality(**Figure 4)**.Too much calcium (Ca) or phosphorus (P) imparts a bitter and 'hard' taste. Yield may not be reduced immediately. Too much manganese reduces yield. Too little of anything reduces yield. Application according to K removal with harvest (soils relatively high in K). However, if yield expectations and/or quality requirements are high, K may be required at higher rates (Jürgen Küsters, 2010).

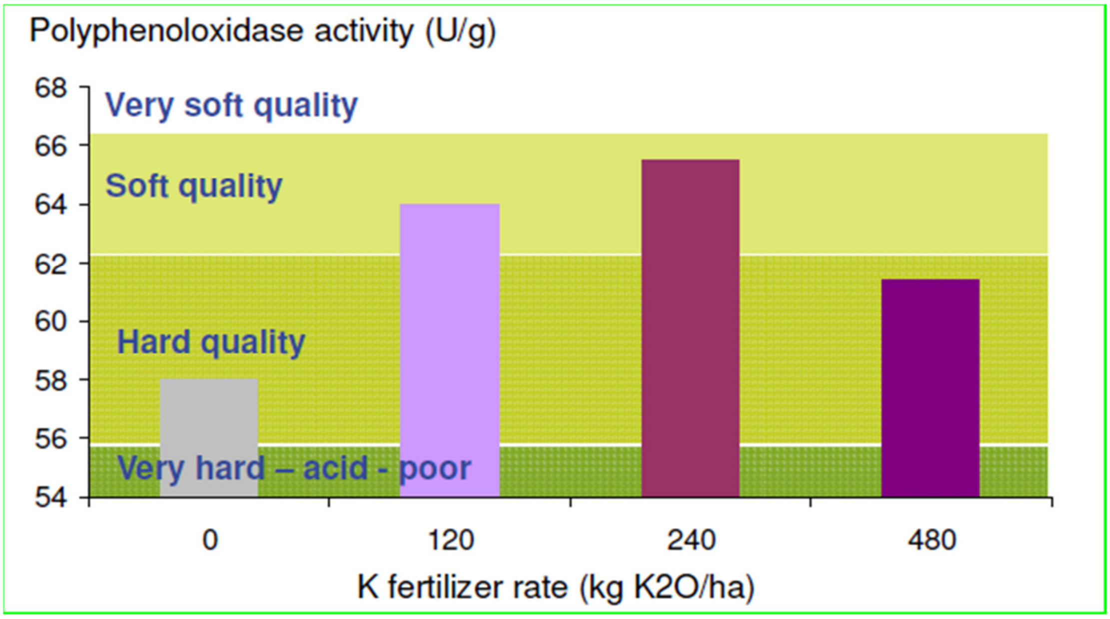

Figure 4:- Potassium and Processed Coffee Quality C- Arabica
Source: - de Barros Silva *et al.,* 2002

3.7. Mineral nutrition and caffeine content in coffee leaves

Two months elapsed before the emergence of the radicles. Probably, this long period occurred because the endocarp was not removed (Válio, 1980), and also because of the sterile conditions, which prevented microbial action on this physical barrier. Usually radicle emergence in germinating coffee seeds takes 15 to 20 days under non-sterile conditions. At harvesting time, the leaves were smaller than usually found on seedlings of the same age growing in greenhouse or nursery. This might have occurred because of the low light intensity of the growth chamber compared to natural day light. The caffeine content found in the leaves (Table 5) was higher than values reported in the literature for *C. arabica* (Mazzafera & Magalhães, 1991). However, this would be expected since it has been demonstrated that younger leaves have higher alkaloid contents than older leaves (Frischknecht et al., 1986). Although statistically similar to the control treatment, omission of K induced the greatest increase (12%) of caffeine contents in leaves. Except for Mo, all other nutrient omissions led to lower values than the control. Treatments -N and -P showed the lowest contents.

Table 5:- Caffeine content in leaves of coffee seedlings grown in nutrient agar media deficient in nutrients

Treatments	Caffeine(1)	Increase/ /Decrease
	g.kg^{-1} dry weight	%
-K	24.5 ± 0.1a	112
-Mo	22.5 ± 0.3ab	103
Complete (control)	21.9 ± 0.3abc	100
-B	21.6 ± 0.5a-d	98
-S	20.2 ± 0.2bcd	92
-Zn	20.0 ± 0.2bcd	91
-Ca	18.5 ± 0.3bcd	84
-Mg	18.2 ± 0.3cd	83
-N	17.9 ± 0.2cd	82
-P	17.5 ± 0.3d	80

(1) Different letters indicate statistical significance by Duncan test ($p< 0.05$).
Source: - Paulo mazzafera (1999)

5. Conclusion and summary

Nutrient management will be another area of focus whereby different plant nutrient source of inorganic will be investigated with appropriate ratios in order to sustain productivity through balanced fertilization.

Fertilization, in particular, needs to be reconsidered and approached from a more scientific angle. It should be based on data generated by soil and leaf analysis and, possibly, enzyme fluctuations. A study of the lifecycle of coffee tree can also reveal cyclic physiological needs which could be met by more suitable fertilization.

The nutrient status of most soils is expected to change after a long period ,varieties released and new for users might have different response or requirement to mineral nutrition. Therefore, fertilizer recommendations have been carried out should be updated ted

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