Crop Nutrition for Vietnamese Robusta Coffee

By Tassilo Tiemann, Tin Maung Aye, Nguyen Duc Dung, Tran Minh Tien, Myles Fisher, Ezio Nalin de Paulo, and Thomas Oberthür

Tin Maung Aye

Dr. Tin Maung Aye (left) and Dr. Tran Minh Tien (right) inspecting a coffee field in Vietnam.

Vietnam is the world's second largest coffee producer, mostly growing Robusta coffee. About 86% of the country's coffee is produced in the Central Highlands. The total production of 28 to 30 million (M) 60 kg bags is similar to that of the state of Minas Gerais, Brazil's largest producer. Coffee covers 582,500 ha of the Central Highlands, which is only about 10% of the area. It is the most intensive and concentrated area of coffee production in the world (Baker, 2016).

Production of Robusta coffee at this intensity exports substantial amounts of nutrients from the field in the green coffee beans and associated pulp and parchment (**Table 1**, summary by Harding, not dated). There is little information on either nutrient recommendations or actual nutrient use in Robusta coffee in Vietnam. We reviewed the in-country literature available on Robusta coffee nutrition in the Central Highlands over the past 25 years. We also met with farmer focus groups in eight villages in two provinces of the Central Highlands. Our objective was to learn what their current fertilizer practices are and their understanding of nutrient management of the crop.

Table 1. Nutrient withdrawals (kg) for each 1 t of harvested green beans, pulp, parchment, and skin.

	N	P	K	Mg	Ca
Literature average	33	2.3	36	2.4	3.4
Estimated removal by					
2 t	66	4.6	72	4.9	6.8
3 t	98	7.0	108	7.3	10
4 t	131	9.3	144	9.8	14
5 t	164	12	180	12	17

Data are averages of values from sources provided by Harding, not dated), and correspond to the amounts removed for 2, 3, 4, and 5 t of green coffee beans.

SUMMARY
Coffee remains one of the most significant sources of income for many farmers in the Central Highlands of Vietnam, but at the same time, yields have been declining or stagnant. Field insights indicate that farmers attempt to counter this trend by experimenting with varying, often increasing amounts of currently available fertilizers. These changes have not worked but have increased production costs markedly. Not to mention that imbalanced fertilizer dressings cause collateral effects of increased contamination of offsite water resources. Robusta coffee systems in the Central Highlands of Vietnam have potential for improvement that can be realized by closing knowledge gaps on balanced crop nutrition, and at the same time, extending access to appropriate nutrients.

KEYWORDS:
Robusta coffee, Central Highlands, Vietnam, fertilizer use, nutrient imbalances.

ABBREVIATIONS AND NOTES:
N = nitrogen; P = phosphorus; K = potassium; Ca = calcium; Mg = magnesium; S = sulfur; B = boron; Zn = zinc; TE = trace elements; ROI = return on investment.

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Farming Systems in the Central Highlands of Vietnam

The Highland region has two main soils, reddish-yellow Acrisols derived from acidic granites and the less common reddish-brown Ferralsols derived from basic and neutral basalts (Tien, 2015). Coffee is mostly grown on Ferralsols (3,500 km^2, 69%) with pH 4.5 to 5.3. The remaining 1,600 km^2 are on Acrisols (Nguyen and Tran, 2017).

Smallholders produce about 1.06 M t of Robusta coffee annually with an average yield of 2.2 t/ha dry beans. Of the farmers we interviewed, 74% generate 20 to 50% of their income off-farm. Farms are typically 1 to 2 ha, 95% in diversified systems that include black pepper, fruits, nuts, and livestock. Coffee is often planted with black pepper in the same farm, at a density of 850 to 1,200 coffee trees/ha and 1,000 to 2,500 black pepper plants. Major production expenses are fertilizers (40%), pruning (25%), and harvesting (20%). Of all the crops they grow, coffee requires the most labor input.

The region has a tropical savanna climate with a warm wet season between April/May and October/November, and a cool dry season from December to March. Annual rainfall varies between 1,200 to 2,000 mm. Growers commonly irrigate coffee during the dry season mostly by pumping from sub-surface wells (Amarasinghe et al., 2015). Growers harvest the crop and apply some crop management in the dry season but do most crop management in the wet season. They prune the plants in January after harvest, in May and in July/August, each time returning pruned material to the field. Farmers apply fertilizer during the rainy season (April, June, and July/August), while some apply additional dressings during the late rainy season or the dry season. Many growers irrigate 3 to 4 times during the dry season at 20 to 25-day intervals by sprinkler or basin irrigation.

Nematodes and mealybug are main pests and coffee rust is the main disease, especially mealybug and rust in the wettest period during June/July. Growers perceive weather and the cost and availability of fertilizer as their biggest constraints. There is also no diversified market with quality-based pricing, and most farmers sell their beans at a moisture content of 15%.

Coffee production in Vietnam became popular more than 20 years ago when smallholders planted large areas of it. About 60% of all coffee trees are now more than 15 years old and will soon come to the end of their productive cycle. They will need to be replaced over the next few years. Moreover, most of the current varieties are not well adapted to diseases and, as well, climate change will reduce their productivity (D'haeze et al. 2017). Farmers might be able to change to better-adapted varieties when they replant.

Table 2. Existing fertilizer recommendation for Robusta coffee in Vietnam (kg/ha/yr).

	Urea	Ammonium sulfate	Fused Ca/Mg phosphate	Potassium chloride	NPK
Growth stage					Equivalent amounts of straight fertilizers
Planting	130 to 150	-	550	70	
Year 2	200	100	550	150	
Year 3	250	150	550	200	
Productive stage					
Bazan red soils (> 3 t dry beans/ha)	400 to 450	220 to 250	450 to 550	350 to 400	
Other soils (> 2 t dry beans/ha)	350 to 400	220 to 250	550 to 750	300 to 350	
Supplemental application*	150		100	120	

*If yields in the productive stage exceed the above average levels by 1 t/ha or more, additional fertilizer should be applied accordingly.

TAKE IT TO THE FIELD

Fertilizer applications are unbalanced. The motivation of farmers to apply in this manner was not fully explained by field interviews, but it is likely related to limited options within the portfolio of fertilizers available, incomplete understanding of farm economics, and the effort to reduce labor. Any future field trials and nutrient management campaigns need to address these interrelated issues.

Current Nutrient Removal and Fertilizer Management

The data in the few studies on nutrient removal that we found for Robusta coffee vary widely so that the following are only rough estimates. Using the mean of several indicative data sources that Harding (not dated, **Table 1**) cites, the average yield of 2.2 t/ha on the Central Highlands withdraws N: P: K of about 72.1: 5.1: 79.4 kg, ignoring vegetative growth, and nutrient losses to leaching and erosion. These figures indicate the minimum requirements that soil and fertilizer must provide to balance the amounts lost in the harvested beans. Farmers in the survey reported yields almost 5 t/ha of green beans in good years, which accordingly will remove 164: 11.5: 180.5 kg/ha N: P: K. At the same time, we also expect the harvest to export 12 kg Mg/ha, which farmers in the Central Highlands apply only rarely, and 17 kg Ca/ha.

Current government guidelines for coffee include recommendations for nutrient management, which we used as the reference base (**Tables 2** and **3**). These recommendations, however, are based on a relatively small number of research studies, mainly on rates of NPK fertilizers. The rates

Table 3. Approximate amount of nutrients recommended for Robusta coffee in the Central Highlands of Vietnam (kg/ha/yr).

	N	P	K	S	Mg	NPK
Growth stage						Equivalent amounts of straight fertilizers
Planting	60 to 70	110	35	-	65	
Year 2	90 + 20	110	80	25	65	
Year 3	115 + 30	110	105	35	65	
Productive stage						
Ferralsols (red) (> 3 t dry beans/ha)	185 to 210 + 45 to 55	90 to 110	180 to 210	50 to 60	55 to 65	
Acrisol (grey) (> 2 t dry beans/ha)	160 to 185 + 45 to 55	110 to 150	155 to 180	50 to 60	65 to 90	
Supplemental application*	70	20	60		12	

*If yields in the productive stage exceed the above average levels by 1 t/ha or more, the additional amount of fertilizer indicated after "+" should be applied accordingly.

are largely deduced from yield-based estimates of nutrients in the harvested beans while nutrient use efficiencies are unknown. There is little information on the best application schedules, or nutrient sources. Furthermore, growers do not use nutrients such as Mg, Zn, and B. There are therefore important knowledge gaps in applying the 4R concept of the right source, rate, time, and place for managing fertilizer for coffee in the Central Highlands.

Experiments showed that combined application of fused magnesium phosphate (for base application) and diammonium phosphate (for topdressing) gave large and sustainable coffee yields. Diammonium phosphate alone was less suitable as a P source due to its fast release peak of 30 days. Fused magnesium phosphate and diammonium phosphate gave good results in early years, however, single superphosphate was better in mature stands.

Farmers apply NPK and NPK+S mostly using a range of low density compound fertilizers because they require less labor. They rarely apply single nutrient fertilizers and seem to have little information about the characteristics of different NPK formulations. Most farmers lack clarity about nutrient requirements and the role of balanced nutrient supply. Rates and ratios of applied nutrients vary widely (**Tables 4** and **5**). In general, farmers apply nutrients in excess, sometimes by as much as four times the recommended rates. Official recommendations, which aim to provide a balanced supply of nutrients, are seldom followed.

Table 4. Amount of applied nutrients (kg/ha/yr), assuming 1,100 plants/ha.

	% of groups	Minimum	Maximum	Average	Recommended
N	100%	201	817	445	205 to 330
P	100%	23	516	236	90 to 170
K	100%	168	721	321	155 to 270
S	75%	43	279	158	50 to 60
Mg	19%	12	119	60	55 to 100

Table 5. Nutrient ratios applied by farmers based on Table 4.

	Minimum	Maximum	Average	Recommended
N:P ratio	1.1	36	1.7 (3.8)*	
N:K ratio	1.0	2.3	1.4	1.2 to 1.3
P:K ratio	0.03	1.6	0.8	0.6
N:S ratio	1.1	15	5.4**	4.0 to 5.5

*If eliminating the most unbalanced value of 36, the average ratio is 1.7.
**Eight groups apply ratios between 1 and 4, three groups have ratios above 10.

Farmers apply fertilizer 3 to 5 times each year, but the rates vary across times. Rates of N and S are more or less constant at 120 kg N/ha and 70 to 80 kg S/ha. Farmers apply P mainly in the rainy season at about 80 kg/ha. Mg, if applied at all, is given in April/May, at the onset of the rainy season. Farmers apply K starting with 25 kg/ha in the dry season (February) and increasing it to about 140 kg/ha in July to October. Although these are the averages across all the farmers that we interviewed, they show that most of them apply fertilizer during the wet season.

Soils in the Central Highlands are rather infertile, with low cation exchange capacity, which limits their ability to store and provide nutrients (Tien et al., 2015). Applied nutrients leach readily during the rainy season, so that it is advisable to limit fertilizer applications during this season. It might be efficient to apply more fertilizer during the dry season using frequent, careful irrigation. Some nutrients are rarely applied and twenty years of intensive production of Robusta coffee may have mined soil nutrients not supplied by external sources. A sustainable production system must replace nutrient losses in addition to those removed with the crop. Recommendations to farmers must address these requirements and consider also the crop's nutrient use efficiency (NUE).

Understanding the Potential Return on Investment from Fertilizer

We compared the farmers' relative income, fertilizer allocation, and production costs (**Figure 1**), and found a picture of lost opportunity. Relative production costs of coffee are generally higher than the relative contribution of coffee to overall farm income (**Figure 1A**). This indicates that the ROI is currently lower for coffee than for other farm activities. At the same time, the relative amount of fertilizer applied to coffee is much larger than coffee's relative con-

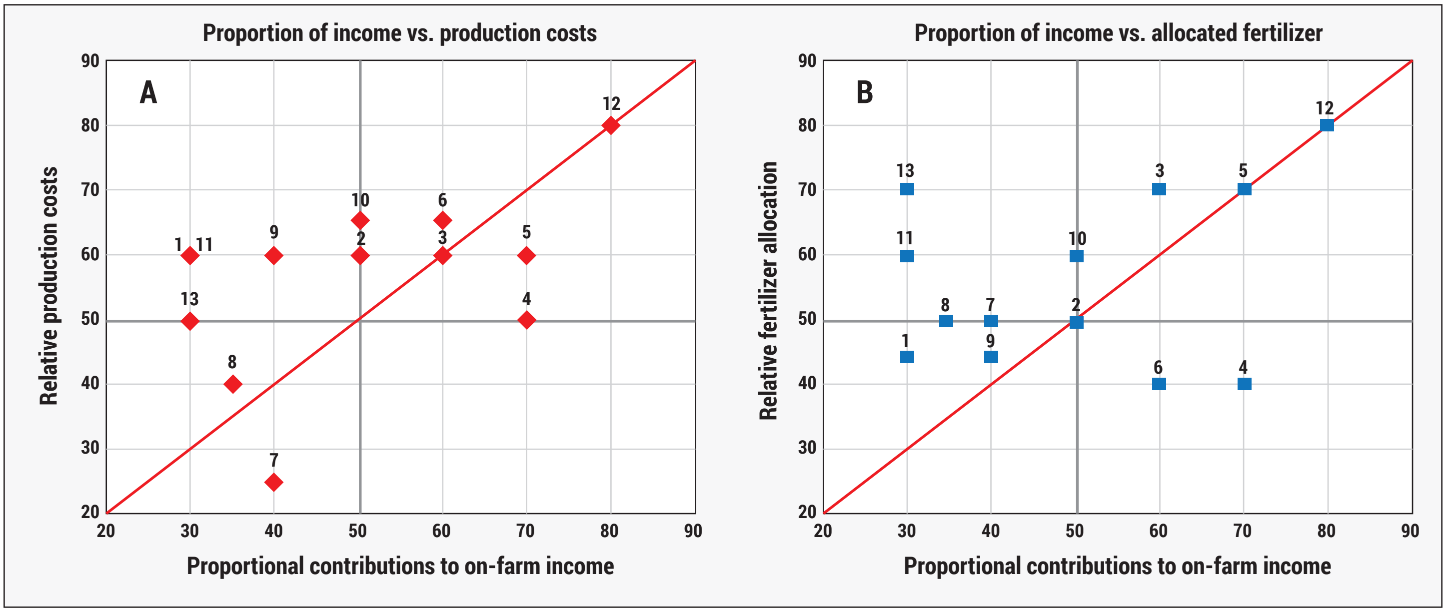

Figure 1. Return on investments to fertilizer use. A) income from coffee versus production costs of coffee, relative to other crops; B) relative income from coffee versus fertilizer allocation to coffee, relative to other crops. Numbers next to each point identify the farmer group that was interviewed.

tribution to household income (**Figure 1B**). This is in line with the perception of farmers that fertilizer application is the most resource intensive amongst the agronomic practices deployed to coffee. Hence, there is potential for large improvement in economic efficiency. The low production cost/high income (lower right) quadrant of **Figure 1A**, which contains no data points, confirms this conclusion.

How Can Improved Economic Efficiency Be Achieved?

It is not entirely clear why growers apply large amounts of fertilizer in an unbalanced manner. Field insights indicate that yields are highly variable, declining or stagnant in recent years, and farmers may attempt to counter this trend by experimenting with varying, often increasing amounts of currently available fertilizers. Some of the decline is likely not even related to nutrient management, but due to trees nearing the end of their production cycle, possibly worsened by increasing pest and disease pressure. These changes in nutrient management have not worked, but increased production costs markedly. Nutrient imbalance is a likely contributor to stagnating variable yields, with sub-optimal Mg, Ca, and micronutrients strong candidates. Farmers do not seem to have access to sufficient fertilizer formulations addressing this. Not to mention that imbalanced fertilizer dressings cause collateral effects of increased contamination of offsite water resources.

We conclude that Robusta coffee systems in the Central Highlands of Vietnam have large potential for improvement. Nutrient management may provide multiple opportunities for change by contributing to stabilized yields (reducing the good - bad year variability), improved crop quality, reduced environmental impacts, and increased climate resistance. Key to success is likely addressing imbalanced nutrition and introducing nutrients into the system that are currently lacking. Additional research is required to generate the knowledge needed to realize this potential. **BC**

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Drs. Tiemann (e-mail: Tassilo.Tiemann@gmx.de), Aye and Fisher are advisors to IPNI Southeast Asia program, Dr. Dung and Dr. Tien work for the Soils and Fertilizers Research Institute, Vietnam, Mr. de Paulo is head of agronomic services for K+S Asia Pacific, and Dr. Oberthür is the director of IPNI Southeast Asia based in Penang, Malaysia.

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