MINISTY OF EDUCATION AND TRAINING
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STUDY ON THE RESIDUAL EFFECT OF PHOSPHORUS AND POTASSIUM FERTILIZERS FOR ROBUSTA COFFEE IN MATURE STAGE IN DAK LAK

Major: **Crop Science**
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SUMMARY OF DOCTORAL THESIS IN AGRICULTURE

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INTRODUCTION

1. Background

Dak Lak is the key coffee growing province of Vietnam in general and in the Central Highlands in particular with an area of over 202,000 ha. From 2000s to date, coffee production in Dak Lak has increased from 30 - 40% thanks to the application of farmers with new technical advances as well as using new coffee varieties; more balanced and reasonable fertilization; right pruning techniques and IPM application. Among technical measurements for the increase of coffee productivity, rational use of fertilizer is an important technical solution. However, coffee farmers in Dak Lak tend to apply high dose of fertilizer than the obtained productivity and much higher than the recommendations from the protocol issued by the Ministry of Agriculture and Rural Development. That fertilizing for coffee with a higher level than obtained yield in many years resulted in the gradual accumulation (residues) of nutrient content in the soil, causing waste and risks of environmental pollution in soil and water.

To contribute to the scientific basis for rational use of fertilizers, especially inorganic fertilizers with high efficiency, reducing input costs, improving income for coffee growers; limiting the risk of polluting the soil and water environment, contributing to the sustainable development of the coffee industry, it is necessary to conduct a research on the effectiveness of residues of Phosphorus and Potassium fertilizers to coffee. From the practical need, the topic: ***"Study on the residual effect of Phosphorus and Potassium fertilizers for robusta coffee in mature stage in Dak Lak"*** has been implemented.

2. Thesis objectives

2.1. Overall objectives

Identify the scientific basis of nutritional needs of coffee in the mature stage; the residual effect of phosphate and potassium as a basis for proposing solutions to improve the efficiency of using macronutrient fertilizer (N, P, K) for Robusta coffee in the mature stage in Dak Lak.

2.2. Specific objectives

- Determine the current status of macronutrient fertilizer use for robusta coffee in mature stage in Dak Lak province.

- Identify the relationships between the use of macronutrient fertilizer and yield and some soil fertility indicators.

- Determine the amount of uptake - the demand for N, P, K of coffee through different stages.

- Determine the residual effect of phosphate and potassium for robusta coffee in mature stage in Dak Lak.

3. Research materials and scope

3.1. Research materials

Coffee trees in the mature stage and at different ages of 6, 10, 17, and 22.

3.2. Research scope

- Survey on the situation of fertilizer usage for coffee in Dak Lak, focusing in 3 districts: Cu M'gar, Krong Nang and Krong Pak.

- Study on the amount of uptake - the demand for nitrogen, phosphorus, potassium, calcium, magnesium, zinc and boron nutrition of coffee trees at the ages of 6, 10, 17 and 22.

- The research only focused on the studies of the residual effect of phosphate and potassium.

4. Scientific and practical contribution of the thesis

4.1. Scientific contribution

- The thesis contributed in clarifying the scientific basis for the amount of absorption - nutritional needs of coffee trees at different ages in the mature stage; adding more source of database on coffee nutrition research in Vietnam.

- The thesis contributed in clarifying the effect of phosphorus and potassium residues in relation to growth, development, productivity, quality and cost effect of coffee trees in mature stage on basaltic soil in Dak Lak.

4.2. Practical contribution

The outcomes of research would be the scientific basis for orienting the measurements to improve the efficiency of using

macronutrient inorganic fertilizers for robusta coffee trees in mature stage on basaltic soil in Dak Lak; increase productivity, quality, cost effect in order to improve living standards for coffee farmers in Dak Lak in particular and Central Highlands in general. In addition, the improvement of the efficient use of inorganic fertilizer also contributed to limiting the risk of environmental pollution.

5. Thesis limitation

The study only investigated the current situation of fertilizer use for coffee in Dak Lak in 3 districts: Cu M'gar, Krong Nang and Krong Pak; research on the amount of absorption - the demand for nitrogen, phosphorus, potassium, calcium, magnesium, zinc and boron in coffee trees at the ages of 6, 10, 17 and 22; study on the effect of phosphate and potassium residues for robusta coffee trees in the mature stage grown on basaltic soil in Buon Ma Thuot city, Dak Lak province.

6. New contributions of the thesis

- The thesis focused on new issue of determining the effect of phosphorus and potassium residues on robusta coffee trees in the mature stage grown on basalt red soil in Dak Lak which has not been done by any other projects.
- Develop a database on the uptake - nutritional needs of coffee trees in the mature stage of 6, 10, 17 and 22 year old trees, especially the identification of the stage of the highest nutritional needs of robusta coffee trees.
- From the results of the study on the amount of intake - nutritional needs (macro, medium and micro) of coffee trees in each stage and the effectiveness of phosphorus, potassium residues can be used to complete the protocol of fertilizing for robusta coffee trees in the mature stage grown on basaltic soil in Dak Lak in order to reduce input costs, improve the efficiency of fertilizer use and minimize the risk of environmental pollution.

The issues that need to be completed in the fertilization protocol for robusta coffee in the mature stage are as follows:

+ The amount of N and K fertilizer for robusta coffee in the

mature stage increased gradually from 6 to 17 years and decreased from 17 years onward; The amount of P fertilizer for coffee increased gradually to the 14th year, then adjusted down according to the productivity level.

+ Reduce the amount of fertilizer applied for robusta in the mature stage up to 50% or apply fertilizer in alternative years for coffee farms that applying phosphate for many consecutive years; It is possible to reduce the amount of potassium by 50% for coffee farms with many years of applying high potassium fertilizer, then apply 100% in the following year.

CHAPTER 1
LITERATURE REVIEW

1.1. Origin and characteristics of Robusta coffee (*Coffea canephora*)

Robusta coffee belongs to *Coffea* species (*Coffea* L.), *Rubiaceae* family, *Rubiales* and was discovered in Africa in the 14th century.

1.2. Ecological requirements of coffee trees

The most suitable temperature for growth, development, flowering and fruit setting is from 19^{o}C to 26^{o}C.

Suitable annual rainfall is of 1500-1800 mm with a few months of less rain or a short dry period, corresponding to the period when the tree stops growing and before the flowers bloom. For coffee trees, the best annual average humidity is over 75%; preferable to the direct light.

Robusta coffee is more favorable in the condition of heat and humidity and abundant light. It is therefore suitable to grow in areas with altitudes below 800 m above sea level. Robusta coffee can be grown on basaltic soil, gneiss or sandstone, or the soil originated from gneiss and granite.

1.3. Nutritional needs of coffee trees

According to De Geus (1967), annually a mature coffee tree removed from soil about 100 g of N; 13,6 g of P_2O_5; 120 g of K_2O; 48.6 g of CaO and 16.4 g of MgO. According to Ton Nu Tuan Nam and Truong Hong (1999), one ton of Robusta green beans (including

dried husks) in Dak Lak's farming conditions removed from soil 40.83 kg of N; 4.97 - 5.58 kg of P_2O_5; 49.60 kg of K_2O; 8.20 kg of CaO; 3.38 kg of MgO and 4.22 kg of S. Total accumulated N, P, K (g/tree) in the 10-year-old tree was 262.7 g of N; 27,5 g of P_2O_5; 204,3 g of K_2O; 198,0 g of CaO; 122.6 g of MgO.

1.4. Fertilization for coffee

1.4.1. Dosage of nitrogen, phosphorus and potassium for coffee

In India, the study by B. R. V. Iyenga (1972) recommended that with the yield of 1 ton of green bean/ha/year the amount of fertilizer for coffee was 160 kg of N; 120 kg of P_2O_5; 160 kg of K_2O ha/year; In case of the coffee yield was under 1 ton/ha, the amount of fertilizer was 140 kg of N; 90 kg of P_2O_5; 120 kg of K_2O ha/year.

The study by Ton Nu Tuan Nam and Truong Hong (1999) suggested that for coffee at mature stage on good soil condition, it is necessary to apply from 10 to 15 tons of manure every 2-3 years. When the coffee farm has stabilized the yield of 3 tons/ha on basalt red soil, it is necessary to apply 220 to 250 kg of N; 80 to 100 kg of P_2O_5; 200 to 230 kg of K_2O ha/year and in case of the productivity exceeded the threshold, every ton of yield increase, adding 70 kg of N; 20 kg of P_2O_5; 70 kg of K_2O.

Nguyen Van Minh (2014) concluded that nitrogen, phosphorus and potassium doses of 338 kg of N; 95 kg of P_2O_5; 336 kg of K_2O ha/year with manure of 5 tons/ha/year was the most effective for coffee in the mature stage on basalt red soil in Dak Lak.

1.4.2. Efficiency of nitrogen, phosphorus and potassium fertilizers

In India, the efficiency of 1 kg of N when applied on red soil achieved 3.3-8.3 kg of green bean coffee; applying 1 kg of P_2O_5 obtained 3.7-11.1 kg of of green bean coffee and when applying 1 kg of K_2O, 3.3-8.3 kg of green coffee was obtained. In Indonesia, the efficiency of 1 kg of N for coffee was 7.5; that of 1 kg of phosphorus was 15.0 and that of 1 kg of potassium was 9.4. The efficiency of phosphorus and potassium fertilizer decreased gradually in the following years, indicating that the residual effect of phosphorus and potassium fertilizer application for coffee has occurred.

According to Nguyen Cong Vinh et al. (2004), in Nghia Dan, Nghe An, for arabica coffee, the dosage was 150 kg of N; 120 kg of P_2O_5 and 150 kg of K_2O ha/year; efficiency reached 4.40 kg of green bean/1 kg of $N+K_2O$; for the formula of fertilizer of Nitrogen + Phosphorus + Potassium, efficiency reached 4.74 kg of green bean/1 kg of $N+P_2O_5+K_2O$.

Initial research on the effectiveness of phosphorus and potassium residues for robusta coffee in Gia Lai and Dak Lak (Truong Hong, Nguyen Van Bo, Trinh Xuan Hong et al., 2014) found that the formula of applying no phosphorus for 1-year or 2-year gained high yields compared to the experiment with full NPK fertilization. Similarly, the formula of applying no potassium for 1 year or 2 years obtained the same yield as the full NPK fertilizer formula. There was obviously a residual problem of phosphorus and potassium nutrition in the soil. Although applying no phosphorus or potassium for 1 year or 2 years, the yield of coffee did not change over the years.

1.4.3. Efficiency of nitrogen, phosphorus, potassium fertilizer depending on soil conditions and farming regime

For some types of soil in Kenya, research results on fertilizer efficiency showed that nitrogen and phosphorus have increased coffee yield, but the efficiency of combinations of NK, NP, PK was unknown. The research of R. Rivera, J.R. Martin (1987) on fertilizer for Cuban coffee showed that the efficiency of phosphorus only displayed on the base of nitrogen and potassium, but when increasing to higher dosage, its effect declined. In the soil type of latosols in Brazil, Malavolta (1990) found that coffee only reacted with phosphorus about 10%, while that of potassium was up to 90%. The experiments conducted at the Coffee Research Institute from 1987-1994 on basalt red soil showed that applying phosphate on bare base (without nitrogen and potassium) did not raised the coffee yield or even decreased the yield compared to no fertilization. The effect of phosphorus only upheld on the base of low nitrogen and potassium. Increased productivity due to phosphate fertilizer was only 3.8-8.4%.

1.4.4. The studies involving in residual effect of inorganic fertilizers

In Kenya, when a high amount of phosphorus was applied for coffee up to 268 kg of P_2O_5/ha, it was very effective in the first year (Oruko, B.A, 1977). However, with this amount of fertilizer applied for the following years, it did not affect the coffee yield due to prolonged residual effect.

Initial research on the effectiveness of phosphorus and potassium residues for Robusta coffee in Gia Lai (Truong Hong, Nguyen Van Bo, Trinh Xuan Hong and et.al, 2014) found that the formula with no application of phosphorus for one season or 2 seasons gave high yields and was comparable to the experiment with full NPK fertilization. The formula of applying no potassium for 1 year and 2 years had the same yield as the full NPK fertilizer formula. Obviously there was a residual problem of phosphorus and potassium nutrition in the soil. Although no application of phosphate or potassium for 1 year or 2 years, the yield of coffee did not change over the years.

CHAPTER 2
RESEARCH CONTENT AND METHODOLOGY

2.1. The investigation of current situation of fertilizer usage for robusta coffee in Dak Lak

- Investigated locations: Cu M'gar, Krong Pak and Krong Nang districts

- Number of questionnaires: 90 surveys (30 surveys/district)

- Method: Applied the method of Participatory Rural Appraisal (PRA).

- Research sites: Robusta coffee farm at the mature stage from 8 to 20 years old.

- Parameters collected: Area, size, age of tree, productivity; amount of nitrogen, phosphorus, potassium, number of applications, method of fertilization.

2.2. Determination of the amount of uptake - nutritional needs of robusta coffee in the mature stage at the ages of 6, 10, 17 and 22.

For each type of tree age, selected 3 average growth trees which were representative for population. Digging all 3 trees, weighing the leaves, branches, stems, roots and cherries then analyzing the nutrient content of N, P, K, Ca, Mg, Zn, B to determine the amount of uptake of the tree.

Time to dig the tree: in October when the coffee cherry was mature and ready to harvest.

Parameters collected:

- Nutrient intake in stems, branches, leaves, roots, cherries (N, P, K, Ca, Mg, Zn, B):

$$N_t \text{ (kg/ha)} = \frac{AN \times W \times 1110}{10^3}$$

AN: Nutrient content in the stems analyzed (g)
W: Dry weight of stems, branches, leaves, roots, cherries (g)
1110: Number of coffee trees/ha (density of coffee trees/ha)
103: conversion factor from grams to kg.

- Nutritional needs of coffee trees in different stages

2.3. Study on the effect of phosphorus and potassium residues on robusta coffee in Dak Lak

The experiment consisted of 6 formulas, conducted from 2011

CT1. No fertilizer

CT2. Applying NPK

CT3: P residue is 01 season (NPK same as CT2 but applied no P in 01 season)

CT4: P residue is 02 seasons (NPK same as CT2 but applied no P in 02 season)

CT5: K residue is 01 season (NPK same as CT2 but applied no K in 01 season)

CT6: P residue is 02 seasons (NPK same as CT2 but applied no K in 02 season)

Experiment was designed as randomized complete block design (RCBD) with 4 replications; Each formula with 24 trees; parameters were collected from 12 trees grown in the middle.

Year of planting: 2005, Variety: TR4, TR5, TR6, TR9. Density of 1,111 trees/ha. Spacing of 3 x 3 (m); Average productivity (NSBQ) from 2011 to 2014 was 3.5 tons/ha.

Fertilizer dosage:

N = 300 kg/ha; P_2O_5 = 100 kg/ha; K_2O = 300 kg/ha

Experimental conditions

The research was conducted in 2 years 2015 and 2016 and a continuation of the study on effect of phosphate and potassium residues in the period of 2011-2014 at Western Highlands Agriculture & Forestry Science Institute (WASI).

Parameters collected

+ Cherry drop rate (R):

$$R = \frac{Rt_1 - Rt_2}{100} \%$$

Rt_1: Number of cherries at the time t_1; Rt_2: Number of cherries at the time t_2.

+ Accumulation of dry matter of cherry (P)

$$P = \frac{P_t \times 100}{B} \text{ (g/100 cherry)}$$

P_t: Dry mass of sample; B: Number of cherries corresponding to dry weight; 100: The coefficient converted into 100 cherries

+ Productivity:

$$Y = \frac{Y_p \times T_t}{N_t} \text{ (green bean/ha)}$$

Y: Productivity of green bean/ha; Y_p: Productivity of green bean/research experiment plot; N_t: Number of trees in the study plot, 24 trees; T_t: Total coffee trees per hectare, 1110 trees

+ Ratio of R1 bean (on the screen 16)

$$\text{Ratio } R_{1,2} = \frac{W_{R1,2} \times 100}{W_s} \text{ (\%)}$$

$WR_{1,2}$: Weight of green beans of R1 and R2; Ws: Weight of samples analyzed

+ Quality of green beans evaluated according to TCVN 4193-2014

+ Efficiency of fertilizer use (HS): the amount of product obtained when applying 1 kg of fertilizer

Efficiency (HS) = NS (kg/ha)/total fertilizer applied (kg/ha).

$$HS = \frac{\text{Productivity (kg/ha)}}{\text{Total amount of fertilizer used}} \text{ (kg/ha)}$$

+ Residual effect: the effect of fertilizer in the following years of the coffee plot which did not applied fertilizer compared to the plot applied fertilizer.

* Residual effect of phosphate (Ptd):

$$iP = 100 - \frac{(Y_{i\,npk} - Y_{i\,nk}) \times 100}{Y_{i\,nk}} \text{ (\%)}$$

Y i npk: Coffee yield at the formula of applying NPK in year i

Y ik: Coffee yield in the formula of applying NK fertilizer in year i

* Residual effect of potassium fertilizer (Ktd)

$$iK = 100 - \frac{(Y_{i\,npk} - Y_{i\,np}) \times 100}{Y_{i\,np}} \text{ (\%)}$$

Y i npk: Coffee yield at the formula of applying NPK in year i
Y i np: Coffee yield at the formula of applying NP fertilizer in year i
Note: The formula for applying full phosphorus and potassium was considered as 100% residual.
Methods of soil sampling and plant samples
Method of soil sampling: according to TCVN 4046-1985.
Method of leaf sampling: according to TCVN 8551-2010
Methods of chemical analysis: according to the method described in the "Manual for Soil, Water, Fertilizer and Crop Analysis" of the Institute of Soil and Agriculture Research, 1998.
Inheritance method: Continue and inherit the research data on the residual effect of phosphate and potassium from 2011-2014 in order to get sufficient time for analysis and evaluation in a more reliable approach as a basis for recommendation of fertilizer use for coffee to achieve high cost effect and better environment.
Methods of data processing: Applied SPSS and Excel software.

CHAPTER 3

RESULTS AND DISCUSSION

3.1. The investigation of current situation of fertilizer usage for Robusta coffee in Dak Lak

3.1.1. Coffee yield of the surveyed districts

The average yield of coffee in 3 surveyed districts reached 3.89 tons/ha in which, productivity of less than 3 tons/ha accounted for 43.37% of households, productivity of 3-5 ton/ha attributed for 44.43% and productivity of over 5 tons/ha accounted for 12.2% households.

3.1.2. Amount of nitrogen fertilizer

The amount of nitrogen fertilizer used by households varied greatly, from 99 kg N/ha to 757 kg N/ha with an average of 382 kg N/ha, tended to be lower than in 2011.

3.1.3. Amount of phosphate fertilizer

The amount of phosphate fertilizer for farmers was from 190-270 kg of P_2O_5/ha with an average of 220 kg of P_2O_5/ha.

3.1.4 Amount of Potassium fertilizer

The amount of potassium fertilizer used by coffee households varies greatly, from 40 to 675 kg of K_2O/ha, averaging 237 kg of K_2O/ha.

3.1.5. Fertilizer efficiency

The yield of 1 kg N in the surveyed districts reached from 6.57 to 19.85 kg of green coffee/1kg N; average of 11.80 kg of coffee/1 kg of N (Table 3.1).

years continuously would make the soil become acidity resulting in the reduction of fertilizer use due to the decline in quality of CEC.

Table 3.1. The efficiency of using 1 kg of N for robusta coffee in mature stage in the surveyed districts (kg of green bean/1 kg N)

District	Smallest Value	Largest Value	Average	Difference at P = 0.05
Cư M'gar	3.15	30.30	9.01	±1.96
Krông Năng	3.47	100.80	19.85	±7.36
Krông Păk	2.06	14.49	6.57	±1.27

The average efficiency of 1 kg of P_2O_5 in 3 surveyed districts reached 22.18 kg of coffee/1 kg of P_2O_5; higher than that in 2011 (12.50 kg of coffee/1 kg of P_2O_5) (Table 3.2).

Table 3.2. The efficiency of using 1 kg of P_2O_5 for robusta coffee in mature stage in the surveyed districts (kg of green bean/1 kg of P_2O_5)

District	Smallest Value	Largest Value	Average	Difference at P = 0.05
Cư M'gar	4.03	91.00	23.68	±6.91
Krông Năng	4.66	177.55	27.18	±12.01
Krông Păk	3.13	90.00	15.69	±6.08

The average efficiency of 1 kg of K_2O in 3 surveyed districts reached 13.71 – 27.97 kg of coffee (Table 3.3).

Table 3.3. The efficiency of using 1 kg of K_2O for robusta coffee in mature stage in the surveyed districts (kg of green bean/1 kg of K_2O)

District	Smallest Value	Largest Value	Average	Difference at P = 0.05
Cư M'gar	3.29	50.00	13.71	±3.80
Krông Năng	5.48	150.24	27.97	±10.18
Krông Păk	4.52	50.00	14.76	±3.66

3.1.6 Yield and correlation between yield and fertilizer

3.1.6.1. Yield and amount of fertilizer

The average yield of coffee in 3 districts reached 3.89 tons/ha in which, productivity of less than 3 tons/ha accounted for 43.37%, most of them was in the coffee area with age of more than 15 years old and with conditions of unsecured caring following technical protocol, unbalanced fertilizer; yield from 3-5 tons/ha attributed for 44.43% with the amount of fertilizer of 383 kg N, 246 kg of P_2O_5, 245 kg of K_2O/ha and the productivity level of 5 tons/ha was 12.2% with the amount of fertilizer of 387 kg N, 206 kg P_2O_5, 373 kg K_2O/ha (Table 3.4).

Table 3.4. Coffee yield and fertilizer quantity in the surveyed districts

District	Productivity (tons/ha)	Fertilizer quantity (kg/ha)		
		N	P_2O_5	K_2O
Cư M'gar	< 3	339	161	258
	3 - 5	446	236	364
	> 5	361	126	471
Krông Năng	< 3	255	107	187
	3 – 5	327	271	216
	> 5	412	285	275
Krông Păk	< 3	361	186	166
	3 – 5	377	230	154
	> 5	0	0	0
Average	< 3	318	151	204
	3 – 5	383	246	245
	> 5	387	206	373

3.1.6.2. Correlation between yield and fertilizer

Research on the multivariate correlation between nitrogen, phosphorus, potassium fertilizer for coffee and productivity in 3 research sites showed that the higher amount of nitrogen fertilized for coffee, the productivity tended to drop; increasing the amount of phosphorus and potassium, the productivity tended to raised. However, this relationship was not statistically significant ($R^2 = 0.23$; $P = 0.07$; $n = 90$).

Multivariate regression equation had the form:

$y = 3,898 - 0,006N + 0,003P + 0,005K$

y: coffee yield

N, P, K: nitrogen (N), phosphorus (P_2O_5), potassium (K_2O) fertilizer for coffee in 3 studied areas.

3.1.7. The current situation of inorganic fertilizer usage

Approximately 10% of the farmers in Cu M'gar district applied fertilizer less than previous years. The percentage of households applying lessen fertilizer was the same between Krong Nang and Krong Pak districts and reached 3.33%. Although fertilizer application was reduced, at the time of the survey, the coffee trees still grew and developed well and were comparable to the years with high fertilizer application.

3.1.8. Study on the relationship between fertilizer quantity and nutrient content in soil

The increase of nitrogen made the total nitrogen content ($P < 0.001$; $n = 45$) go up, but it made the pH_{KCl} in soil lower ($P < 0.001$, $n = 45$); The application of potassium fertilizer also made the increases of available potassium in the soil ($P < 0.001$; $n = 45$). It is worth noting that when applying nitrogen fertilizer for many years continuously would make the soil become acidity resulting in the reduction of fertilizer use due to the decline in quality of CEC.

3.2. Determination of the amount of uptake - nutrition al needs of Robusta coffee in the mature stage at the ages of 6, 10, 17 and 22.

3.2.1. The amount of dry matter of coffee trees in different ages

The total volume of dry matter in 1 ha of coffee in different ages was highest at the age of 10 years, reaching 53.8 tons of dry matter/ha. This value began to drop gradually from 17 years old; at the year of 22, only reached 44.9 tons/ha (Figure 3.1).

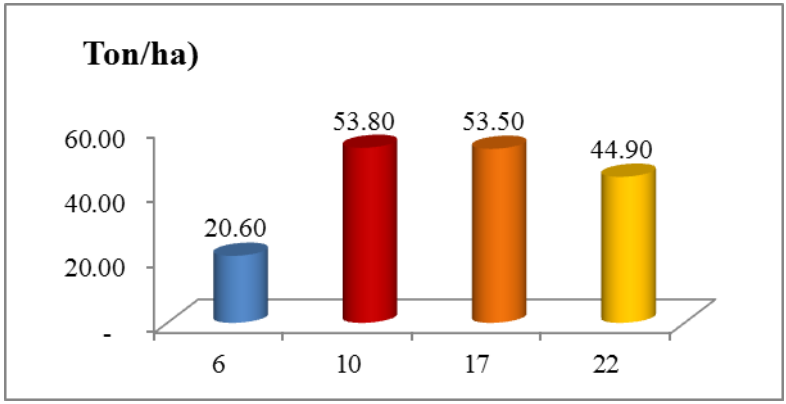

Figure 3.1. The amount of dry matter of coffee trees at different ages

3.2.2. Study to determine the amount of uptake - nutritional needs of coffee trees

3.2.2.1. Amount of uptake - the need for macro-nutrition of N, P, K

The amount of N required for coffee trees increased gradually in the period of 6 years to 17 years with the highest value of 763 g/tree, after 17 years this value gradually diminished. **Tree age (year)**

The amount of P_2O_5 required by coffee trees reached the highest value in the 10th year (81.43 g/tree). At the age of 17, the amount of phosphorus in the tree decreased.

The amount of K_2O required by coffee trees increased rapidly

from the age of 6 years to 10 years, at this time the amount of K in the trees reached 560.68 g K_2O/tree, which surged to 245%; From the age of 10 years to the age of 17, this value increased slightly and gradually dropped to the age of 22 years.

Combined with the calculation from the regression equation, it was determined that the amount of N and K_2O in coffee trees reached the highest value in the period of 15-17 years old; then descending. The amount of P in trees reached the highest value in the period of 10-14 years.

3.2.2.2. Amount of uptake - the need for medium and micronutrition

The amount of CaO in coffee tree increased gradually from year 6 to year 17 reaching 434.41g and gradually decreased in the 22nd year. The amount of MgO in coffee tree raised from the 6th to 17th year (reaching 193.51 g/trees), then gradually reduced to year 22 only attained 136.72 g. The amount of B in coffee plants was highest in the 10-year-old (gaining 1.16 g/tree), then decreasing gradually, in the year of 22 dropped about 50% (0.57 g/tree).

The amount of Zn in coffee trees increased gradually from year 6 and reached the highest value at 17 years of age (0.56 g/tree); At the age of 22, the amount of Zn in tree decreased to only 0.20 g/tree (a reduction of more than 50% compared to 17 years old trees).

Combined with calculations from the regression equations, it was identified that the age at which coffee trees accumulated highest CaO and Zn was 16-17 years of age; that of MgO was in the period of 12-17 years of age; and that of B was in the period of 10-14 years old.

3.3. Effect of phosphorus and potassium residues on robusta coffee in Dak Lak

3.3.1. Effect of fertilizer on cherry drop rate

The formula of no application of fertilizer or only applying nitrogen and phosphate and no potassium fertilizer in 2 years, the rate of cherry drop was the highest (49.93-57.15% in 2015 and 44.55-44.38% in 2016). The formula of applying full nitrogen, phosphorus and potassium fertilizer had the lowest rate of coffee cherry drop (40.95% in 2015 and 38.56% in 2016). The formula of appyling nitrogen, potassium and no phosphate fertilizer in 1 year or 2 years had lower rate of cherry drop than the control. The formula appied no potassium fertilizer in 1 year had the rate of cherry drop higher than the formula of applying full nitrogen, phosphorus and potassium fertilizer, but the difference was not significant. However, the failure to apply potassium continuously in 2 years had increased the rate of fruit drop compared to the control.

Research results in 2 years showed that in the months of May, June and July (the first months of the rainy season), the rate of coffee cherry drop tended to be highest and dropped sharply from August to October (this time the cherry was mature and ready to harvest). The results of this study would be the scientific basis for recommending proper use of fertilizers to provide adequate nutrition for coffee to limit cherry drop rate, and thus contributed to the increase of coffee yield.

3.3.2. Effect of fertilizer to cherry dry matter accumulation

The control formula was not fertilized, the dry matter volume of coffee cherry was the lowest (63.30 g/100 cherries in 2015 and 68.68 g/100 cherries in 2016), followed by the formula of no potassium fertilizer in 2 consecutive years, the dry matter volume of coffee cherries in October 2015 and 2016 ranged from 70.05 to 70.53

g/100 cherries. The two formulas of applying N and K but no P fertilizer in 1 year or 2 years and of applying N and P without K fertilizer in 1 year had lower dry matter than the formula with full NPK fertilizer of about 2-8% (Figuree 3.2).

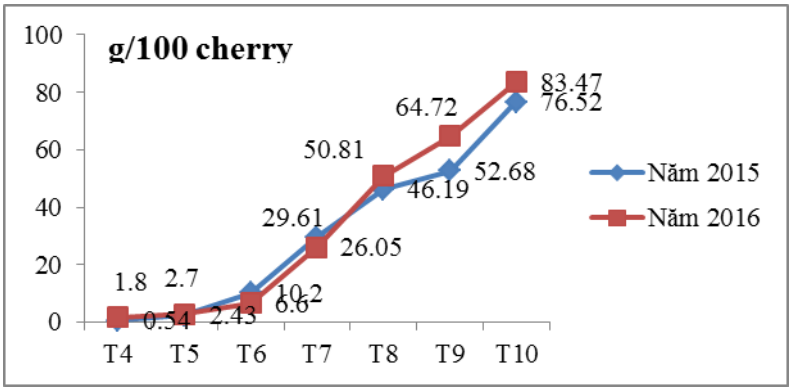

Figure 3.2. Average amount of dry matter of coffee cherries over the months

3.3.3. Effect of fertilizer on yield and quality of green beans

3.3.3.1. Coffee yield in different fertilizer formulas

Table 3.5. Effect of fertilizer on coffee yield

Formula	Productivity (tons of green bean/ha)		
	2015	2016	Average
CT1	2.22 c	2.11 d	2.16 d
CT2	2.91a	3.20a	3.05a
CT3	2.76ab	3.08a	2.92a
CT4	2.51abc	2.71 bc	2.61 bc
CT5	2.63abc	3.00ab	2.81ab
CT6	2.31 bc	2.52 c	2.41 cd
Ave.	**2.56**	**2.77**	**2.66**

In the same column the same letters are not significant difference at P <0.05

In 2016, coffee yield in the treatments tended to be higher than in 2015. The formulas of applying fertilizers were significantly higher than the formula without fertilization (with P <0.05). The formula of fully fertilizing with N, P and K yielded the highest yield (3.20 tons/ha); followed by formula 3 - CT3 (without P fertilizer for 1 year), productivity reached 3.08 tons/ha; CT5 (without K fertilizer), the yield was 3 tons/ha. The difference in coffee productivity between CT2, CT3 and CT5 was not statistically significant. Formula 4 (CT4) did not apply P for 2 consecutive years, yield decreased by 18.1%; CT6 did not apply K for 2 years, the yield declined the most compared to the formula of full N, P, and K (21.3%) (Table 3.5)

From the results of the study, it was shown that phosphorus had a lower effect on coffee yield than potassium. Without applying phosphate and potassium fertilizer for 1 year, the yield was not significant difference compared to full application of N, P, K. The cause of this problem may be due to residual effect in soil. In addition, because the demand for phosphorus for coffee was not high (Malavolta, 1990); Truong Hong, 1999; Nguyen Van Bo, Truong Hong, Trinh Xuan Hong, 2014) only a small amount of phosphate from 20-30 kg P_2O_5/ha was sufficient to ensure coffee yield reached 3-4 tons/ha. Appying no P fertilizer for 1 season made the average yield dropped by 4.3% compared to full fertilization of N, P, K. Appying no K in 1 season had an average yield reduction compared to no P fertilizer in 1 season of 3.8%; 7.9% reduction compared to full application of N, P, K.

3.3.3.2. Quality of green beans in different fertilizer formulas

** Effect of fertilizer on the weight of 100 beans*

CT2 (full fertilization of nitrogen, phosphorus, potassium) had the highest weight of 100 beans, reaching 19.19 g/100 beans. The formulas of applying no phosphate fertilizer in 1 or 2 years or no potassium in 1 or 2 years made the weight of 100 beans decreased slightly compared to CT2. It is noteworthy that CT3 (without P fertilizer for 1 year) weight of 100 beans only slightly decreased compared to CT2 (0.79 g/100 beans or equivalent to 4.2%), CT6 (no

potassium fertilizer for 2 years) weight of 100 beans decreased by 6% compared to CT2 (Figure 3.3).

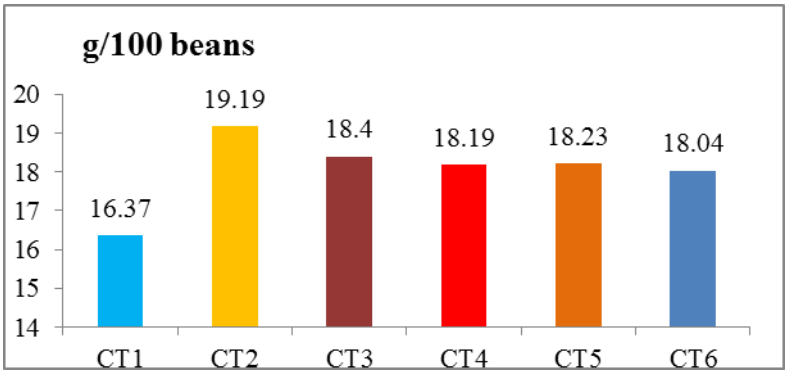

Figure 3.3. Effect of fertilizer on the weight of 100 beans

** Effect of fertilizer on the ratio of R_1 (beans on screen 16)*

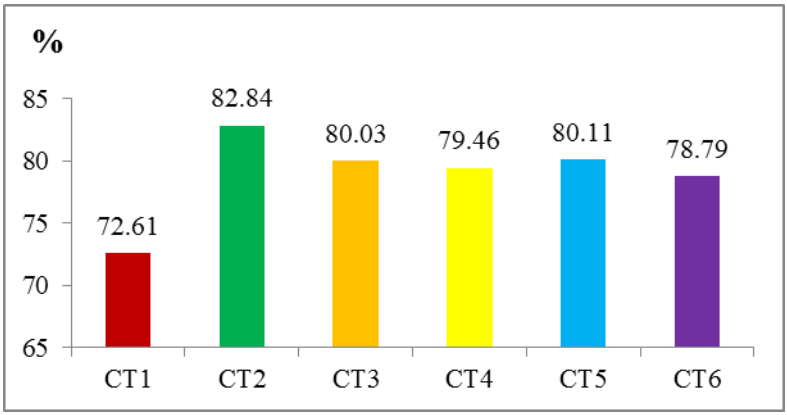

Figure 3.4. Effect of fertilizer on the ratio of R1

Ratio of R1 beans reached the highest in CT2 with 82.84%; For CT3 and CT5 this value achieved over 80%; CT4 and CT6 reached from 78.79 to 79.46%. The control formula (CT1) had the lowest ratio of R1 (72.61%) (Figure 3.4)

3.3.4. Effect of phosphate and potassium residues

3.3.4.1. Effect of phosphate residues

Table 3.6. Effect of phosphorus residues on coffee trees

Formula	Effect of phosphate residues (%)		
	2015	2016	Average
CT2	100.00	100.00	100.00
CT3	-	95.30	95.30
CT4	86.25	84.68	85.47

In 2015 and 2016, the tendency of effect of phosphorus residues became more evident. The effect of phosphorus residues of CT3 (without phosphate application for 1 year) reached 95.30. The residual effect of CT4 in 2015 was 86.25%; in 2016 was 84.68% which gradually reduced (14.53%) because the amount of phosphorus was not continued to be added to the soil.

Average data of 2 years showed that the residual effect of the non-phosphate fertilizer formula (CT3) reached 95.3% compared to the full phosphate fertilizer formula over the years (CT2); the formula of applying no phosphate fertilizer in 2 seasons (CT4) only reached 85.47%; decreased by 14.53% (Table 3.6).

3.3.4.2. Residual effect of potassium fertilizers

Table 3.7. Effect of Potassium residues on coffee

Formula	Potassium residue effect (%)		
	2015	2016	Average
CT2	100.00	100.00	100.00
CT5	-	93.70	93.70
CT6	79.38	78.73	79.06

Potassium residual effect in CT5 was higher than that of CT6 in 2 continuous years. In 2015, the potassium residual effect in CT5

reached 93.7%; CT6 gained 79.38%. In 2016, the potassium residual effect of CT6 was lower than that of 2015, reaching 78.73%. On everage of 2 years 2015 and 2016, the residual potassium effect of CT5 reached 93.70% and CT6 achieved 79.06% (Table 3.7).

CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions

1.1. The investigation of current situation of fertilizer usage for Robusta coffee in Dak Lak

- The average yield in 3 surveyed districts was 3.89 tons of green bean/ha.
- The average amount of nitrogen fertilizer applied to coffee was 368 kg of N/ha; 220 kg of P_2O_5/ha; Potassium 237 kg of K_2O/ha.
- There was no correlation between nitrogen, Phosphate, Potassium and coffee yield.

1.2. Determination of the amount of intake - nutritional needs of robusta coffee in the mature stage at the ages of 6, 10, 17 and 22.

- The amount of N that the coffee trees took from soil was highest in the year of 15-17 and reduced after the 17th year; the amount of P that the coffee trees removed from soil was highest in the year of 10-14, then gradually decreased to the age of 22; The amount of K that the coffee trees took from soil was highest at the age of 16-17, then gradually declined.
- The amount of CaO that coffee trees required/ha was highest at the age of 16-17 years, then gradually dropped with the age of trees; the highest MgO the trees need was at the year of 12-17.
- The amount of B coffee trees absorbed from the soil reached the highest in the period of 10-14 years; then descending; The amount of Zn coffee trees required reached highest in the ages of 16-17 and then gradually decreased with increasing age.

1.3. Study on the effect of phosphorus and potassium residues on robusta coffee in Dak Lak

- Without Phosphate fertilizer application for 1 year, the yield decreased by 4.27% on average, the effect of phosphate fertilizer residues averaged 95.3%; no Phosphate fertilizer application for 2 years, the average yield decreased by 14.43%, the residual effect was on average 85.47%.

- Without applying potassium fertilizer for 1 year, the average yield decreased by 7.87%, the potassium residue effect was 93.7% on average; without applying potassium for 2 years, the average yield declined by 21%, the average residual effect was 79.06%.

2. Recomendation

- Use the results of this study to recommend fertilization for coffee in the mature stage for each specific stage of tree age; each stage of growth and development in the rainy season to improve the efficiency of fertilizer use, to increase cost effect and to contribute to the protection of the ecological environment.

- This result can be used to supplement and complete the fertilization protocol for robusta coffee in the mature stage and for each specific stage of tree in the mature stage.

- Continue to study and supplement data on nutritional needs for coffee through different stages in different ecological regions to serve as a basis for developing the protocol of fertilizing for coffee in the regions to achieve efficiency in economic, social and environmental aspects.

LIST OF WORKS RELATED TO THE THESIS HAS BEEN PUBLISHED

1. Nguyen Huu Luan, Truong Hong (2018), "Stydy on the need of nutrients through stages of mature robusta coffee" *Science and Technology Journal of Agriculture and Rural Development*, 8/2018, pp 53-58.

2. Nguyen Huu Luan, Truong Hong (2018), "Current status of macronutrient fertilizer application on mature robusta coffee in Dak Lak" *Science and Technology Journal of Agriculture and Rural Development*, 8/2018, pp 59-65.