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Effect of Fertilizers on Growth, Yield and Quality of Embryo-cultured Sap Coconuts (*Cocos nucifera* var. sap)

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ABSTRACT

Background: The study was carried out to assess how different fertilizers and their application cycles affected the development and productivity of coconut trees grown in embryos.

Methods: The experiment was conducted in an entirely randomized manner with five treatments performed continuously for three years on sap coconut at 5-year-old embryo-cultured trees in Tra Vinh province, Vietnam.

Result: It was observed that 7-year-old embryo-cultured sap coconuts did not change in size and girth. The number of newly formed leaves ranged from 24.7 to 25.3 leaves/tree/year. The average number of newly formed inflorescences ranged from 16.1 to 18.5 inflorescences/tree/year. Fertilizers and their application time did not affect the fruits/bunch on embryo-cultured sap coconut trees. Fertilization of embryo-cultured sap coconut trees over 5 years old with 118 N-42 P_2O_5-54 K_2O once a month recorded 72.3-93 fruits/tree/year and 7-year-old embryo-cultured sap coconuts recorded wax fruits/bunch ratio of 94-96%.

Key words: Embryo-cultured sap coconut, Fertilizer application time, Growth, Inorganic fertilizer, Organic fertilizer, Yield.

INTRODUCTION

Coconut trees are grown in more than 94 nations around the world. Coconut trees are grown in sea shoreareas between 20° north latitude and 20° south latitude. Coconut trees are a livelihood for 64 million households around the world. The need for coconut products continue to increase until 2030 (APCC, 2017; Rodrigues *et al*., 2018). The total coconut growing area worldwide was 12,303,924 hectares with a production of 60,773,435 tons in 2018 (FAO, 2020). Over 20 million farmers and their families rely on the earnings from coconut crops (Pham, 2016; Rethinam, 2006). Flowering starts at about 3-6 years for the tall coconut group and 3-5 years for the dwarf coconut group (Mike Foale *et al*., 2020). Coconut trees grow well well with adequate water and nutrient supplements (Bandyopadhyay *et al*., 2019). According to Thai *et al*. (2018), coconut trees have a high salt tolerance of up to 10 %0.

Today's rare and highly economically valuable coconut varieties include sap coconut (Macapuno coconut), pineapple coconut, striped coconut, bung coconut, etc. Natural coconut trees capable of producing wax fruits are all heterozygous (Mm), but coconut wax fruit is homozygous recessive (mm). Coconut trees have only 20-25% wax fruit (Rillo and Paloma, 1992) when propagated by fruit using the traditional method. The technique for propagating sap coconut using the embryo-cultured method has > 80% wax fruits (Thuy, 2022). According to a survey by Thuy *et al*. (2020b), farmers cultivating embryo-cultured sap coconuts had an income of 3.9 times higher than farmers cultivating traditional sap coconuts.

Vietnam has about 2,00,000 hectares area under coconut and Tra Vinh province has about 25,000 ha (Thuy, 2020). According to Tra Vinh's Agriculture and Rural Development Department, in 2020, Tra Vinh province had 500 hectares of sap coconut growing area, of which 30 hectares were dedicated to cultivating sap coconuts by embryonic culture. There is limited research on fertilizer dosage for sap coconut trees. Currently, the fertilizer dosage of other coconut trees is used to apply for sap coconut trees.

In Sri Lanka, application of potassium fertilizers increased the number of fruit bunches, flowers, pollination rate, total number of fruits and fruit weight. Coconut trees without potassium fertilizer had reduced productivity and signs of potassium deficiency appeared clearly on the leaves after 4-5 years. The nut yield gradually increased with the application of potassium fertilizer from 0.5 kg, 0.8 kg and 1.0 kg KCl/tree/year. Fertilization treatment with 1.0 kg KCl/tree/year achieved the highest yield of 1,000 kg of dried copra /ha/year (Ouvier and Ochs, 1980).

Potassium (K), chlorine (Cl), nitrogen (N), calcium (Ca), sodium (Na), phosphorus (P), magnesium (Mg) and sulfur (S) are vital elements for coconut trees. Replacing 25% of inorganic fertilizers with microbial organic fertilizers (KOMIX) increased fruit yield/tree and economic efficiency of coconut orchards by 2 times as compared to control (Hai, 2017).

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Coconut trees fertilized with 2 tons/ha of coir dust (coconut peat) increased fruit yield by 10%, pH from 5.5 to 5.7 and improved soil density (Long, 2007a). The fertilizer dosage of 70 kg N + 40 kg P_2O_5 + 110 kg K_2O/ha/year applied to Ta and Strawberry coconut trees recorded 80 fruits/tree/year in the Mekong River Delta.

In hybrid coconut varieties JVA1, JVA2 the application of 110 kg N + 57 kg P_2O_5 + 140 kg K_2O/ha/year, increased productivity to 155 fruits/tree/year and the oil content was as high as 68% (Research Institute for Oil and Oil Plants, 2012).

Application of fertilizers twice a year helped the tree grow, develop well and bear fruit early (Long, 2007b). The optimum amount of fertilizer for juice-drinking coconut trees during the fruit production period was observed to be 0.8 kg urea + 1.2 kg super phosphate + 0.8 kg KCl/tree/year (Research Institute for Oil and Oil Plants, 2012).

The appropriate amount of nitrogen and potassium fertilizer was applied for in the development stage from year 1 to year 4. In the 4th year, fertilizer/plant/year was Application of 500 g urea + 400 kg super phosphate + 600 kg KCl/plant/year was found optimum for 1 to 4 year old hybrid coconut trees (Hanh, 1999).

Ben Tre Provincial Agricultural Extension Center. (2014) showed that the fruit bearing coconut trees fertilized with 0.8 kg of urea + 1.5 kg of super phosphate + 1.5 kg of KCl/tree/year tilized twice a year at the beginning and the end of the rainy season was found optimum. Thuy (2018) opined that fertilizer dose, application time, season, organic fertilizer and seedlings impacted the productivity and quality of embryo-cultured sap coconuts. Thus, it is imperative to study how fertilizers affect sap coconut development, yield and quality.

MATERIALS AND METHODS

An experiment was conducted at the sap coconut farm of 5 years age at Luong Hoa commune in Chau Thanh district of Tra Vinh province, Vietnam, between January 2018 and December 2020. The experimental plot was located at 9°53′32″N latitude and 106°18′3″E longitude at an average altitude of 0.1 meters and experienced a tropical climate. The physico-chemical properties of experimental soil are presented in Table 1.

The experiment comprised of 5 treatments viz., inorganic fertilizer, applied once a month (T_1), inorganic fertilizer, applied every 3 months (T_2), inorganic fertilizer, applied every 6 months (T_3), replace inorganic nitrogen fertilizer with 100% manure, applied once a month (T_4) and replace 50% inorganic nitrogen fertilizer with 50% organic from decomposed cow manure, applied once a month (T_5). It was conducted in a randomized block design replicated 5 times. Each replication had 2 sap coconut trees.

Organic fertilizer comprised of decomposed cow manure. The organic fertilizer had 0.45% N, 0.23% P_2O_5, 0.5% K_2O and 30% moisture. The amount of fertilizer was applied according to tree age (Table 2).

Fertilizer was applied evenly around the trunk base of the tree. The manure was dispersed across the soil's surface in the shape of a circle, the size of which varied according to the tree's age and leaf canopy. The fertilizer was mixed into the soil with a hoe.

The circumference of the trunk base was measured uniformly at the scar of the 13th leaf (Fig 1). The number of coconut leaves/tree, bunches/tree and fruits/bunch were collected once a month for 12 months. Data on fruit weight and the thickness of the coconut meat were gathered once a year.

The data collected was statistically analyzed using IBM SPSS Statistics 16 and Microsoft Office Excel 2010 as per Duncan test at 5% and 1% significance levels.

RESULTS AND DISCUSSION

Effect of fertilizer on sap coconut growth and production

The trunk base circumferences of the 7-year-old sap coconut trees after 3 years of experiment in all the treatments were not significantly different from month 1 to month 11 and the growth rate between months too was not much different. The trunk base circumference of a 7-year-old embryo-cultured coconut tree ranged from 139-166 cm. This value was higher than the research of Duong (2013) in Tra Vinh and Ben Tre provinces, where the trunk base circumference of 7-year-old coconut trees ranged from 103 cm to 107 cm. The circumference of the coconut trunk base and trunk did not change in size due to the diversion of nutrients for growing flowers and fruits (Thuy *et al*., 2020a). The circumference in this study was lower than the findings of Mike Foale *et al*. (2020). The trunk base circumferences were generally 200-250 cm and remained the same as the trunk extended.

The circumferences of 5-year-old embryo-cultured sap coconut trees and 6-year-old trees had statistically significant differences in some treatments (Table 3). But by the 3rd year, the trunk base circumference of the 7-year-old coconut tree was not different and the growth rate of the trunk base circumference was prolonged. The reason may be that the amount of fertilizer for 2 consecutive years did not meet the growth needs of embryo-cultured sap coconut trees. It is shown by the soil analysis values of total and available N, P and K, which are lower than the analysis results at the beginning of the season before the experiment was set up (Table 1). The circumference of the trunk base did not increase and there were no differences between treatments. It may be attributed to reduction in nutrients and energy to support the trunk when the plant started to flower.

Number of new leaves

There was no increase in the number of newly formed leaves/trees over the 3 years of the experiment (Table 4). The number of new leaves for embryo-cultured sap coconut trees ranged from 23.0-25.3/tree/year and there were no significant differences among the treatments. The rate of new leaf growth was speedy on an average of 14.3-15.9

days/new leaf. Duong (2013) reported that in (not embryo-cultured) sap coconut trees in Tra Vinh and Ben Tre provinces, on an average, there were 14-16 leaves/year (or one new leaf/24-26 days) for the tall coconut group and 16-18 leaves/year (or one new leaf/20-22 days) for the dwarf coconut group. The life cycle of a leaf on a healthy coconut tree is 2 years. If the coconut tree produces a new leaf each month, the coconut tree will have 12 new leaves/year. However, the frequency of leaf production depends on the tree's age, climate and farming techniques (Mike Foale *et al*., 2020).

Flowering rate of the embryo-cultured sap coconut tree

The flowering rate of embryo-cultured sap coconut ranged from 19.8 to 21.7 days/inflorescence (Table 5) and there were no significant differences among treatments. The

Table 1: Soil physical and chemical properties of experimental area in Chau Thanh district, Tra Vinh province.

Analysis criteria	Soil at the beginning of the crop (5-year-old sap coconut)		Rating scale	Soil after fertilizing for 2 years (6-year-old sap coconut)		Rating scale
	Sample1	Sample 2		Sample 1 Embryo-cultured Sap coconut	Sample 2	
pH-H_2O	6.7	6.7	Neutral	6.8	6.0	Neutral
pH-KCl	6.0	5.9	Neutral	6.0	6.0	Neutral
CHC (%OM)	1.6	1.6	Medium	1.1	1.0	Medium
C.E.C. (meq/100 g)	16.6	16.3	High	6.5	6.7	Low
N-Total (%)	0.13	0.11	Medium	0.06	0.06	Poor
P- Total (%)	0.13	0.14	Rich	0.09	0.1	Medium
K- Total (%)	1.61	1.36	Medium	0.79	0.6	Poor
N- available (mg/kg)	19.3	23.9	-	14.9	12.8	-
P- available (mg/kg)	67.1	66.9	High	57.5	56.5	High
K- available (%)	0.23	0.24	-	0.24	0.22	-

Sample 1,2: Land for planting embryo-cultured Sap coconut at 5 and 7 years of age in Luong Hoa commune, Chau Thanh district, Tra Vinh province, Vietnam.

Table 2: Amount of fertilizer applied according to tree age.

Tree age (year)	Amount of inorganic fertilizer (g/tree/year)				Amount of manure to replace inorganic fertilizer	
	Urea	Super phosphate	KCl (Potassium chloride)	General dose (N-P_2O_5-K_2O) /160 trees/ha	100% manure	50% manure
5	800	800	800	59 - 21 - 77	61.3 kg manure + 289 g potassium	30.7 kg manure + 400 g super phosphate + 545 g potassium
6	1,000	1,000	1,000	74 - 26 - 96	76.7 kg manure + 3.6 g super phosphate + 361 g potassium	38,4 kg manure + 400 g Urê + 400 g Super phosphate + 660 g KCl
7	1,600	1,600	1,600	118 - 42- 54	122,6 kg manure + 568 g potassium	61,4 kg manure + 800 g super phosphate +1,090 g potassium

Table 3: Effect of fertilizer on average trunk base circumference (cm) of embryo-cultured sap coconuts in 3 years of experiment.

Treatments	Trunk base circumference (cm) average of 12 months of embryo-cultured sap coconuts		
	5 year old	6 year old	7 year old
T1	153.7[a]	155.8[a]	169.0
T2	117.8[b]	123.1[b]	145.8
T3	142.2[ab]	146.2[ab]	153.5
T4:	126.2[b]	131.7[ab]	162.8
T5	125.3[b]	124.6[b]	146.8
F	**	**	NS
CV (%)	15.8	15.7	15.4

Note: In the same column, numbers followed by the same letter do not have a statistically significant difference by duncan test (5%), *: Significant difference at 5% level, **: Significant difference at 1% level, NS: Not difference.

results were similar as the inflorescence growth rate/month as shown in Fig 2. Meanwhile, the average number of inflorescences/tree/year of 6-year-old Sap coconut trees was lower than that of 5 and 7-year-old trees. It may be attributed to the fact that the fertilizer did not meet the nutritional needs of the embryo-cultured sap coconut tree.

Fruits yield

On average, the number of fruits/tree of a 7-year-old tree was higher than that of 6-year- old and 5-year-old trees by 26.7 and 16.9 fruits, respectively (Table 6). Upon comparision of treatments, it was found that 100% inorganic fertilizer once a month had the highest efficiency, a significant difference was observed compared to the remaining treatments on 5, 6 and 7 old sap coconut trees. The coconut-growing soil belonged to the sandy loam soil group, so the nutrient mineralization rate was fast. Therefore, fertilizing once every 1-2 months was more effective than every 3 or 6 months (Table 6). Application of 50% (T_4) or 100% (T_5) of decomposed manure was not different from other treatments (Fig 3). It may be due to slow nutrient availability in manure and it did not provide

Table 4: Effect of fertilizers on the number of new leaves formed on embryo-cultured sap coconut trees.

Treatments	New leaves/plant/year of embryo-cultured sap coconut		
	5 year old	6 year old	7 year old
T1	24.9	24.6	25.3
T2	24.6	23.0	24.7
T3	24.9	24.2	25.3
T4	25.4	24.6	24.8
T5	25.2	24.2	25.3
F	ns	ns	ns
CV (%)	11.7	10.4	8.1

Note: In the same column, numbers followed by the same letter do not have a statistically significant difference by duncan test (5%), *: Significant difference at 5% level, **: Significant difference at 1% level, NS: Not difference.

Table 5: Effect of fertilizers on the average number of inflorescences per 5, 6 and 7-year-old sap coconut.

Treatments	Average number of inflorescences/tree/year		
	5 year old	6 year old	7 year old
T1	17.1	13.7[a]	18.5
T2	16.6	11.6[b]	17.4
T3	18.2	12.9[ab]	18.1
T4	17.8	14.0[a]	17.3
T5	17.3	11.1[b]	16.1
Average	17.4	12.7	17.5
F	ns	*	ns
CV(%)	15.2	17.1	15.4

Note: In the same column, numbers followed by the same letter do not have a statistically significant difference by duncan test (5%), *: Significant difference at 5% level, **: Significant difference at 1% level, NS: Not difference.

Fig 1: Location for measuring root circumference (13th leaf scar).

enough nutrients in time for coconut trees. Coconut trees grow continuously and bear fruits all year round. Therefore, if fertilized many times a year, the tree will grow well, flower continuously increase the number of inflorescences and have high productivity. If divided and applied many times, the same amount of fertilizer will help trees absorb it more effectively and avoid losses (Tran and Nguyen, 2011). A high yielding year for coconut trees frequently translate into a decreased yield the following year, according to Abeywardena (1962), as the tree's internal energy reserve get deplete due to the previous year's high production. Coconut productivity is influenced by fertilizer, soil quality and irrigation water. It is reported that fertilizing for 3 consecutive years for embryo-cultured sap coconut trees of 5 years of age or older with the fertilizer dose of 118 N-42 P_2O_5-54 K_2O applied evenly 12 times/year, recorded the highest efficiency in achieving productivity ranging from 72.3-93 fruits/tree/year. Bandyopadhyay *et al*. (2019) reported that fertilizer can be reduced by 25% if coconut farming uses drip irrigation with 3.2 times more water than traditional irrigation methods. On a 7-year-old coconut tree, fertilizing with 90 kg N + 60 P_2O_5 + 130 kg K_2O/ha/year recorded a higher number of

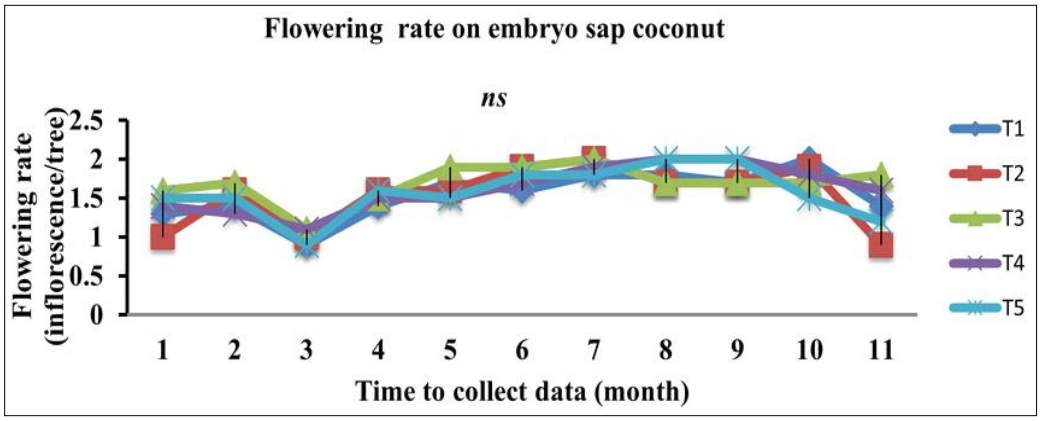

Fig 2: Effect of fertilizer on the flowering rate of embryo-cultured sap coconut.

Fig 3: 7-year-old embryo-cultured sap coconut trees in the treatment with 100% inorganic fertilizer, applied once a month.

Table 6: Effect of fertilizer on the number of fruits/tree/year.

Treatments	Number of fruits/tree/year of embryo-cultured Sap coconut		
	5 year old	6 year old	7 year old
T1	79.4^{a}	62.1^{a}	96.3^{a}
T2	55.7^{b}	56.4^{ab}	91.6^{a}
T3	53.7^{b}	46.3^{ab}	76.4^{b}
T4	59.1^{b}	42.5^{b}	72.3^{b}
T5	49.1^{b}	40.8^{b}	79.6^{b}
F	**	**	*
CV (%)	27.7	26.9	23.2

Note: In the same column, numbers followed by the same letter do not have a statistically significant difference by duncan test (5%), *: Significant difference at 5% level, **: Significant difference at 1% level, NS: Not difference.

Table 7: Effects of fertilizers on the weight of embryo-cultured sap coconut fruit components over an average of 3 years.

Treatments	Effects of fertilizers on the weight of embryo-cultured Sap coconut fruit components over an average of 3 years (g)				
	Weight fruit	Weight of peeled fruit	Fruit weight without juice	Weight of coconut shell	Volume of coconut meat
T1	2,482^{a}	1,294^{a}	1,051^{ab}	298	753^{a}
T2	2,191^{a}	1,108^{ab}	877^{abc}	223	654^{a}
T3	1,461^{b}	824^{b}	636^{c}	236	400^{b}
T4	1,966^{ab}	1,147^{ab}	926^{bc}	285	642^{a}
T5	1,559^{b}	883^{b}	709^{bc}	318	390^{b}
Level of significance	**	*	*	ns	*
CV (%)	24.0	22.6	22.3	22.7	32.1

Note: In the same column, numbers followed by the same letter do not have a statistically significant difference by duncan test (5%), *: Significant difference at 5% level, **: Significant difference at 1% level, NS: Not difference.

Table 8: Effect of fertilizer on the growth of embryo-cultured Sap coconut trees on average over 3 years.

Treatments	Effect of fertilizer on the growth of embryo-cultured sap coconut on average over 3 years				
	Stem circumference (cm)	Number of leaves/tree/ year	Number of inflorescences/ tree/year	Number of fruits/tree/ year	Average of rate wax fruit /tree (%)
T1	159.5	24.9	16.3	79.3	96
T2	129.9	24.1	15.2	68.0	95
T3	147.0	24.8	16.4	59.0	96
T4	140.0	24.9	16.4	58.0	94
T5	132.0	24.9	14.8	56.5	95
Level of significance	ns	ns	ns	ns	ns
CV (%)	11.1	2.4	15.5	26.9	5.7

Note: In the same column, numbers followed by the same letter do not have a statistically significant difference by duncan test (5%), *: Significant difference at 5% level, **: Significant difference at 1% level, NS: Not difference.

leaves, fruit set rate and high yield than other treatments under saltwater intrusion conditions (Nguyen *et al*., 2020). In particular, 4 times/year fertilized plots recorded high yields with a statistically significant difference as compared to 2 times/year fertilized (Nguyen *et al*., 2020).

Average weight of fruit components of embryo-cultured sap coconut trees in 3 years of 5, 6 and 7-year-old trees

The highest efficiency was recorded with inorganic fertilizer, applied once a month (T_1) and it was significantly different with other treatments about the average fruit weight in 3 years (Table 7). It may be due to frequent fertilization (once a month), well timed to facilitate good growth and production of sap coconut trees. Duong (2013) reported that the average weight of sap coconuts in Tra Vinh and Ben Tre provinces ranged from 1.73 to 1.94 kg/fruit.

Effect of fertilizer on wax fruit ratio of embryo-cultured sap coconut trees in 3 years of 5, 6 and 7-year-old trees

The wax fruit/bunch ratio was 94-96% (Table 8). The results are consistent with the findings of Ramirez and Mendoza (1998), who who also reported a ratio of wax fruit of 98-100%.

CONCLUSION

Coconut trunk base and trunk are usually stable in size when the embryo-cultured sap coconut tree is over 7-years-old. The number of newly formed leaves ranged from 24.7-25.3 leaves/tree/year and the average number of newly formed inflorescences fluctuated from 16.1-18.5 inflorescences/tree/year. Fertilizer and its application time did not affect the wax fruits/bunch ratio on embryo-cultured Sap coconut trees.

A fertilizer dose of 118N-42 P_2O_5 - 54K_2O applied at one-month intervals on embryo-cultured sap coconut trees over 5 years old recorded the highest yield ranging from 72.3-93 fruits/tree/year and the ratio of wax fruits/tree from 94-96%.

It is necessary to continue studying many other fertilizer formulas for embryo-cultured sap coconut trees under different soil types, watering techniques, tree age and planting density to improve the productivity and quality of embryo-cultured sap coconut trees.

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Author contributions

Conceptualization: Thuy P.T.P. and Nhu C.T.; Methodology: Thuy P.T.P. and Nhu C.T; Software: Thuy P.T.P., Nhu C.T., Nga S. T. and Tron T.T.T.; Formal analysis: Thuy P.T.P. and

Nhu C.T; Investigation: Thuy P.T.P.; Resources: Thuy P.T.P. and Nhu C.T; Data curation: Thuy P.T.P.; Writing and original draft preparation: Thuy P.T.P. and Nhu C.T.; Writing, reviewing and editing: Thuy P.T.P. and Nhu C.T.; Visualization: Thuy P.T.P. and Nhu C.T.; Project administration: Thuy P.T.P.; Fund acquiring: Thuy. P.T.P. Each author has reviewed and approved the published version of the work.

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Conflict of Interest

The authors have disclosed no conflict of interest.

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