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Effect of Pole Types and NPK Fertilizer Rates on the Early Growth of Black Pepper (*Piper nigrum* Linn.)

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Black pepper (*Piper nigrum* Linn.) requires a reliable support, which usually called standard or pole, for proper growth and yield. In Thailand, cement pole as a support, has been widely used whereas living and non-living tree have been rarely taken. The aim of the study was to examine effect of pole types and NPK fertilizers rates on the early growth of black pepper. A field experiment was conducted with 3x4 factorials in RCBD with 3 replications where the factorial treatments were 3 types of pole (cement-, wooden- and living tree-pole) and 4 rates of NPK fertilizer (24-24-34, 48-48-68, 72-72-102 and 96-96-136 g N-P_2O_5-K_2O tree^{-1} yr^{-1} as F_{200}, F_{400}, F_{600} and F_{800}, respectively). Soil chemical property was analysed prior to the experiment. The bush width, internode length, leaf width and number of aerial root of black pepper were collected at 6 and 12 months after planting (MAP) whereas the adhesive strength of black pepper's aerial root was collected at 12 MAP.
The results showed that black pepper on both living tree pole and wooden pole had internode length and number of aerial root more than cement pole did, at 6 MAP, additionally, black pepper on both of them resulted of stronger adhesive cling than cement pole did, at 12 MAP. Moreover, black pepper on living tree pole had a wider leaf than wooden- and cement pole did, at 6 MAP. However, black pepper on cement pole had number of aerial root more than wooden- and living tree pole did, at 12 MAP. At 6 MAP, application of NPK fertilizer at the highest rate (96-96-136 g N-P_2O_5-K_2O tree^{-1} yr^{-1}) resulted of wider leaf blade than the other rates did. Our results, so far, can be concluded that the living tree, coral tree *(Erythrina fusca* Lour.), can be used as a pole for black pepper grown in Chanthaburi province and application of NPK fertilizer between 24-24-34 and 48-48-68 g N-P_2O_5-K_2O tree^{-1} yr^{-1} or application of 12-12-17 between 200 and 400 g tree^{-1} yr^{-1}) for early growth of black pepper is recommended. Further research is required to investigate the effect of pole types and NPK fertilizer for successive years until harvest.

Keywords: black pepper, cement pole, living tree pole, NPK fertilizer, wooden pole

Introduction

Black pepper (*Piper nigrum* Linn.) is the most important spice traded internationally and is widely cultivated in many countries. It requires a reliable

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support, which usually called standard or pole, for proper growth and yield. In Thailand, cement pole as a support, has been widely used as it requires closer spacing between plants than living tree pole. Reddy *et al.* (1992) reported that at close spacing (2.0 x 1.0 m), cement pole accommodated 5,000 plants per hectare resulted of a higher yield of black pepper than using other poles where the wider spacing took place. However, the main limitation of concrete pole is the expensive capital investment. Additionally, some studies reported the poor growth and productivity in pepper trailed on concrete poles. Sivaraman *et al*. (1999) reported that apparently concrete poles are likely to heat up during summer resulting in drying of aerial roots and, therefore, affect crop growth and yield. Raising black pepper such the living tree pole can reduce the capital cost, apart from increasing productivity on the long-term basis (Azmil and Yau, 1993). However, poor utilization of nutrients by pepper due the living standard competition should be determined. NPK Fertilizer rate for black pepper is broadly recommended in Thailand and is not specified the suitable rate for each growth stage. Moreover, the presently recommended rates have been published many years ago which may not suit with current situation. The aim of this research was to examine effect of pole types and NPK fertilizers rates on the early growth of black pepper.

Materials and Methods

Experimental Site, Design and Treatments

A field experiment was located in Salaeng Sub-District, Muang District, Chanthaburi Province, Thailand. The mean rainfall in this area is 2,776 mm. The mean maximum and minimum temperature were 35.1 $^{\circ}$c and 22.3 $^{\circ}$c, respectively, in the study year. Generally, the season of the year is classified as following, summer season (Febuary - May), rainy season (May - October) and winter season (October - Febuary). The soil property collected prior the experiment start was showen in Table 1. The experiment was conducted with 3x4 factorials in RCBD with 3 replications. Each plot consisted of 3 rows of 36 trees, with a spacing of 2 m between rows and 2 m within rows. The factorial treatments were 3 types of pole (cement-, wooden- and living tree-pole) and 4 rates of NPK fertilizer (24-24-34, 48-48-68, 72-72-102 and 96-96-136 g N-P_2O_5-K_2O tree^{-1} yr^{-1} as F_{200}, F_{400}, F_{600} and F_{800}, respectively).

Black Pepper Cultivation

The poles were set before black pepper transplanting. Cement poles were soaked in water and were abandoned before use. Living tree (Coral tree: *Erythrina fusca* Lour.) as the living tree pole were planted in the field before experiment start around 2 weeks. The experiment started after new leaf of the living tree emerged. Black pepper (var. Kuching) (2.5 months old, 35 cm tall) in plastic bags (6 cm width x 18 cm depth) were removed into the field in holes 30 x 30 x 30 cm. NPK Fertilizer was firstly applied by mixing well with soil in the hole, at planting date, basing on treatment. NPK fertilizer of 17-12-12 was applied at planting date for 50, 100, 150 and 200 g for F_{200}, F_{400}, F_{600} and F_{800}, respectively. Repeat application of 17-12-12, at the same rate, were done at 3, 6 and 9 months after planting (MAP) by broadcasting on soil surface under the canopy. Sufficient irrigation was made at appropriated time by farmer.

Table 1 Soil property prior the experiment start

Soil Property	Value
pH	6.7
Organic Matter (g kg^{-1})	34.1
E.C. (dS m^{-1})	0.12
Total N (g kg^{-1})	0.7
Available P (mg kg^{-1})	105
Exchangeable K (mg kg^{-1})	61
Exchangeable Ca (mg kg^{-1})	730
Exchangeable Mg (mg kg^{-1})	104

[1/] 1:1, soil:water (Anonymous, 1999); [2/] Walkley and Black method (Nelson and Sommers, 1996); [3/] 1:5, soil:water (Rhoades, 1996); [4/] Wet digestion and Kjeldhal method (Jackson, 2005); [5/] Wet digestion and ascorbic method (5:2, HNO_3:$HClO_4$; (AOAC, 1990); [6/] Wet digestion and atomic absorption spectrophotometer (Jackson and Mahmood, 1994).

Data Collection

One bulk soil sample (0-15 cm depth) from each block was taken before planting for chemical analysis. The bush width, internode length, leaf width and number of aerial root of black pepper were collected at 6 and 12 months after planting (MAP) whereas the adhesive strength of black pepper was collected at 12 MAP. The adhesive strength of black pepper was measured by sense where the very strong, strong, medium, weak and very weak of adhesive strength were rated as 5, 4, 3, 2 and 1, respectively.

Data analysis

Treatments were examined by one-way analysis of variance (ANOVA). Where there were significant effects, *post hoc* analysis was made with Duncan's Multiple Range Test (DMRT) at $P \leq 0.05$.

Results

Effect of pole type

The bush width of pepper on the living tree pole was bigger than those on the cement and the wooden pole did at 6 MAP ($P \geq 0.05$), however, the bush width of pepper on the cement pole was not significantly different with those on either the wooden or the living tree pole did ($P \geq 0.05$) (Table 2).

Table 2 The bush width (cm) of pepper tree at 6 MAP

Pole type	Fertilizer rate [a,b]				Average [a]
	F_{200}	F_{400}	F_{600}	F_{800}	
1. Cement pole	49.0	60.0	57.0	56.0	55.5 ab
2. Wooden pole	49.3	48.0	52.0	52.0	50.3 b
3. Living tree pole	56.7	56.2	50.0	67.3	57.6 a
Average [b]	51.7 A	54.7 A	53.0 A	58.4 A	-

[a] Within a column, values followed by the same lowercase letter (s) are not significantly different at $P \leq 0.05$ by DMRT, when F_{200}, F_{400}, F_{600} and F_{800} refer to 24-24-34, 48-48-68, 72-72-102 and 96-96-136 g N-P_2O_5-K_2O $tree^{-1}$ yr^{-1}, respectively.
[b] Within a row, values followed by the same capital letter (s) are not significantly different at $P \leq 0.05$ by DMRT. P values of pole type, fertilizer rate and their interaction are 0.041, 0.190 and 0.164, respectively. % CV is 12.3.

The internodes length of pepper tree on either the wooden or the living tree pole was longer than the cement pole did at 6 MAP ($P \leq 0.05$), however, the internodes length of pepper tree on the wooden pole was not significantly different with the living tree pole did ($P \geq 0.05$) (Table 3).

The width of pepper leaf on the living tree pole was wider than those on the wooden and the cement pole did at 6 MAP ($P \leq 0.05$), however, the width of pepper leaf on the wooden pole was not significantly different with the cement pole did ($P \geq 0.05$) (Table 4).

The number of pepper's aerial root on either the wooden or the living tree pole was higher than the cement pole did at 6 MAP ($P \leq 0.05$), however, the number of pepper's aerial root on the wooden pole was not significantly different with the living tree pole did ($P \geq 0.05$) (Table 5).

The number of pepper's aerial root on the cement pole was higher than those on either the wooden or the living tree pole did at 12 MAP ($P \leq 0.05$), however, the number of pepper's aerial root on the wooden pole was not significantly different with the living tree pole did ($P \geq 0.05$) (Table 6).

The adhesive strength of pepper's aerial root on either the wooden or the living tree pole was higher than the cement pole did at 12 MAP ($P \leq 0.05$), however, the adhesive strength of pepper's aerial root on the wooden pole was not significantly different with the living tree pole did ($P \geq 0.05$) (Table 7).

Table 3 The internodes length (cm) of pepper tree at 6 MAP

Pole type	Fertilizer rate [a,b]				Average [a]
	F_{200}	**F_{400}**	**F_{600}**	**F_{800}**	
1. Cement pole	7.33	7.77	7.93	7.93	7.74 b
2. Wooden pole	7.83	8.20	8.30	8.03	8.09 a
3. Living tree pole	8.33	8.20	8.27	8.47	8.32 a
Average [b]	7.83 A	8.06 A	8.17 A	8.14 A	

[a] Within a column, values followed by the same lowercase letter (s) are not significantly different at $P \leq 0.05$ by DMRT, when F_{200}, F_{400}, F_{600} and F_{800} refer to 24-24-34, 48-48-68, 72-72-102 and 96-96-136 g N-P_2O_5-K_2O tree^{-1} yr^{-1}, respectively.
[b] Within a row, values followed by the same capital letter (s) are not significantly different at $P \leq 0.05$ by DMRT.
P values of pole type, fertilizer rate and their interaction are 0.001, 0.145 and 0.489, respectively. % CV is 4.03.

Table 4 The width (cm) of pepper leaf at 6 MAP

Pole type	Fertilizer rate [a,b]				Average [a]
	F_{200}	**F_{400}**	**F_{600}**	**F_{800}**	
1. Cement pole	6.00	6.13	6.37	6.63	6.28 b
2. Wooden pole	5.93	6.07	6.40	6.43	6.21 b
3. Living tree pole	6.00	6.67	6.80	6.97	6.61 a
Average [b]	5.98 C	6.29 B	6.52 AB	6.68 A	

Within a column, values followed by the same lowercase letter (s) are not significantly different at $P \leq 0.05$ by DMRT, when F_{200}, F_{400}, F_{600} and F_{800} refer to 24-24-34, 48-48-68, 72-72-102 and 96-96-136 g N-P_2O_5-K_2O tree^{-1} yr^{-1}, respectively.
[b] Within a row, values followed by the same capital letter (s) are not significantly different at $P \leq 0.05$ by DMRT.
P values of pole type, fertilizer rate and their interaction are 0.006, 0.000 and 0.641, respectively. % CV is 4.53.

Table 5 The number of pepper's aerial root at 6 MAP

Pole type	Fertilizer rate [a,b]				Average [a]
	F_{200}	**F_{400}**	**F_{600}**	**F_{800}**	
1. Cement pole	3.10 cA	4.33 bA	3.46 aA	5.50 bA	4.10 b
2. Wooden pole	11.7 aA	7.36 aBC	5.45 aC	8.56 aB	8.27 a
3. Living tree pole	7.35 bA	10.3 a A	3.97 aB	7.82 abA	7.37 a
Average [b]	7.38 A	7.33 A	4.29 B	7.29 A	

[a] Within a column, values followed by the same lowercase letter (s) are not significantly different at $P \leq 0.05$ by DMRT, when F_{200}, F_{400}, F_{600} and F_{800} refer to 24-24-34, 48-48-68, 72-72-102 and 96-96-136 g N-P_2O_5-K_2O tree^{-1} yr^{-1}, respectively.
[b] Within a row and column, values followed by the same capital letter (s) are not significantly different at $P \leq 0.05$ by DMRT.
P values of pole type, fertilizer rate and their interaction are 0.000, 0.050 and 0.030, respectively. % CV is 26.7.

Table 6 The number of pepper's aerial roots at 12 MAP

Pole type	Fertilizer rate [a,b]				Average [a]
	F_{200}	**F_{400}**	**F_{600}**	**F_{800}**	
1. Cement pole	12.3 a A	13.5 a A	13.8 a A	11.2 a A	12.7 a
2. Wooden pole	8.30 b AB	5.80 b B	7.60 b B	10.6 a A	8.09 b
3. Living tree pole	10.4 ab A	8.10 b AB	7.33 b B	9.81 a AB	8.91 b
Average [b]	10.3 A	9.13 A	9.57 A	10.5 A	

[a] Within a column, values followed by the same lowercase letter (s) are not significantly different at $P \leq 0.05$ by DMRT, when F_{200}, F_{400}, F_{600} and F_{800} refer to 24-24-34, 48-48-68, 72-72-102 and 96-96-136 g N-P_2O_5-K_2O tree^{-1} yr^{-1}, respectively.
[b] Within a row and column, values followed by the same capital letter (s) are not significantly different at $P \leq 0.05$ by DMRT.
P values of pole type, fertilizer rate and their interaction are 0.000, 0.136 and 0.021, respectively. % CV is 16.3.

Table 7 The adhesive strength of pepper's aerial root at 12 MAP

Pole type	Fertilizer rate				Average [a]
	F_{200}	**F_{400}**	**F_{600}**	**F_{800}**	
1. Cement pole	4.00	4.55	2.80	3.45	3.70 b
2. Wooden pole	7.00	7.95	7.01	7.10	7.27 a
3. Living tree pole	6.67	6.70	7.90	6.35	6.91 a
Average [b]	5.89 AB	6.40 A	5.90 AB	5.63 B	

[a] Within a column, values followed by the same lowercase letter (s) are not significantly different at $P \leq 0.05$ by DMRT when F_{200}, F_{400}, F_{600} and F_{800} refer to 24-24-34, 48-48-68, 72-72-102 and 96-96-136 g N-P_2O_5-K_2O tree^{-1} yr^{-1}, respectively.
[b] Within a row, values followed by the same capital letter (s) are not significantly different at $P \leq 0.05$ by DMRT.
P values of pole type, fertilizer rate and their interaction are 0.000, 0.153 and 0.080, respectively. % CV is 12.0.

Effect of NPK fertilizer rate

Either bush width or internode length of pepper tree was not significantly different when NPK fertilizers rates increased ($P \geq 0.05$) (Table 2, 3) at 6 MAP. Whereas application of NPK fertilizer at 96-96-136 g N-P_2O_5-K_2O tree^{-1} yr^{-1} resulted of the widest pepper leaf blade followed by 48-48-68 and 24-24-34 g N-P_2O_5-K_2O tree^{-1} yr^{-1}, respectively, at 6 MAP ($P \leq 0.05$) (Table 4). However, application of 96-96-136 g N-P_2O_5-K_2O tree^{-1} yr^{-1} was not significant different with 72-72-102 g N-P_2O_5-K_2O tree^{-1} yr^{-1} on pepper leaf width ($P \geq 0.05$).

Application of 72-72-102 g N-P_2O_5-K_2O tree^{-1} yr^{-1} gave the smaller number of pepper's aerial root than the other three rates did at 6 MAP ($P \leq 0.05$) (Table 5). However, the number of pepper's aerial root was not significantly different when NPK fertilizer rate increased at 12 MAP ($P \geq 0.05$) (Table 6).

Application of 48-48-68 g N-P_2O_5-K_2O tree^{-1} yr^{-1} resulted of a stronger adhesive strength of pepper's aerial root than application of 96-96-136 g N-P_2O_5-K_2O tree^{-1} yr^{-1} at 12 MAP ($P \leq 0.05$) (Table 7).

Interactive effect

Interactive effect between pole type and NPK fertilizer rate was shown on the number of pepper's aerial root at 6 and 12 MAP (Table 5, 6). It showed that increase NPK fertilizer rates up to 72-72-102 g N-P_2O_5-K_2O tree^{-1} yr^{-1} resulted of a negative effect when the pepper tree was planted on either the wooden or the living tree pole at 6 MAP ($P \leq 0.05$) (Table 5). Moreover, at 12 MAP, it showed that application of 72-72-102 g N-P_2O_5-K_2O tree^{-1} yr^{-1} resulted of a negative effect when the pepper tree was planted on the living tree pole ($P \leq 0.05$) (Table 6).

Discussion

Main factor affecting pepper grown on the living and non-living tree poles

Light and temperature

Black pepper grown on the living tree pole showed a greater growth on internode length, leaf width, number of aerial's root at 6 MAP and adhesive strength of aerial root at 12 MAP than cement pole did. It can be explained that leaf of living tree pole prevent pepper tree from directly exposed sunlight. Vijayakumar and Mammen (1990) reported that black pepper vines exposed to direct solar radiation developed physiological disorders even under favourable soil moisture conditions. Moreover, Senanayake and Kirthisinghe (1983) found that 50% shade boosted the growth of black pepper cutting in the nursery.

However, Sivaraman *et al*. (1999) suggested that control shade when using the live standard for pepper growth is important to do. As during rainy/cloudy weather, the live standard are well growing then prohibited sunlight for black pepper and resulted of crop reduction. Prunning of mature live standards tree need to be done many times a year. At the beginning of rainy season, heavy pruning need to be carried out followed by moderate pruning and leaving 3 or 4 twigs at the top of live standard (Zaubin and Manohara, 2004).

Additionally, either living tree pole or wooden pole resulted of greater internode length at 6 MAP, number of aerial's root at 6 MAP and stronger adhesive strength of aerial root at 12 MAP than cement pole did. It can be explained that both the living tree pole and wooden pole were made from tree. The surface temperature of these materials is lower than cement surface, especially at summer season. Sivaraman *et al*. (1999) resported that during summer, concrete pole and stone pillars absorb heat and become hot resulting in drying of cling roots and poor growth of black pepper vines under exposed situation.

Symbiosis of plant

Our resulted showed that black pepper grew well on the living tree pole, coral tree *(Erythrina fusca* Lour.) which has been widely used in many countries as they falled within the ideal concept of living support suggested by Sivaraman *et al*. (1999). Moreover, Dinesh *et al*. (2010) reported that the role of support trees assumes great significance as it should not only provide good physical support but also sustain soil quality and benefit rhizosphere. One possibility of the better growth of black pepper grown on the living tree pole over cement pole are that rhizosphere soils under living tree are more active and root exudates have profound influence on the soil properties. Consequently, the living tree may modify the conditions in the rhizosphere in order to maximize nutrient acquisition from organic matter (Dinesh *et al.*, 2010).

Plant nutrient

Our results showed that the suitable NPK fertilizer for early stage of black pepper is 24-24-34 g N-P_2O_5-K_2O g tree^{-1} yr^{-1} (application of 12-12-17 at 200 g tree^{-1} yr^{-1}). This rate is lower than the recommended rate suggested by Suksawad (1999). He suggested that at first year, application of 60-60-85 g N-P_2O_5-K_2O g tree^{-1} yr^{-1} is recommended for black pepper. This might be due to our soil properties is near neutral pH, high of organic matter (34 g kg^{-1}), high exchangeable Ca and Mg which suit for black pepper growth and may enhance the productivity (Mathew *et al*., 1995). However, it showed that application of the highest NPK fertilizer rate (96-96-136 g N-P_2O_5-K_2O g tree^{-1} yr^{-1}) resulted of the biggest leaf blade. Application of fertilizer, especially N, enhance leaf growth but if excessive supply it may lead to a negative effect (Barker and Bryson, 2007). Due to N assimilation uses carbohydrates for carbon skeleton and energy supply hence if receive excessive N, plant may enlarge leaf size but reduce total non carbohydrate (TNC) (Tayler *et al.,* 1975) which in turn limiting TNC translocation to fruit biomass (Xia and Cheng, 2004). Changthom and Chaikul (2016) also found that application of high N fertilizer rate (4-times of recommended rate) increased longan leaf length but decreased fruit size and weight. However, further research on NPK fertilizer rates on the vegetative growth and yield of black pepper need to be clarified.

The negative effect of pole types and NPK rates on number of aerial's root showed up at 6 MAP. Application of 72-72-102 g N-P_2O_5-K_2O g tree^{-1} yr^{-1} especially on the living tree poles reduced number of aerial's root. This could be explained that black pepper compete nutrient with the living tree when 72-72-102 g N-P_2O_5-K_2O g tree^{-1} yr^{-1} was applied. Kurien *et al.* (1994) reported that the highest competition between living standards and black pepper at 2 x 2 m was found and then the recommended spacing is 2.5 x 2.5 m.

Investment

Black pepper vines require the support for their establishment. Both the living and non-living standard are commonly used (Thangselvabal *et al*., 2008). However, the cost of standard or pole is necessary for determination. The cost of cement pole-, wooden pole- and living tree used in this study were 104,000, 260,000 and 98,000 (including pruning and labour cost for 15 succesive years) Baht rai^{-1}, respectively. Although, the cost of living tree pole at first establishment is cheaper than cement- and wooden poles. The living tree need frequent pruning each year. The labor cost need to be taken into account.

Conclusion

Our results can be concluded that the living tree, coral tree *(Erythrina fusca* Lour.), can be used as a pole for black pepper grown in Chanthaburi province and application of NPK fertilizer between 24-24-34 and 48-48-68 g N-P_2O_5-K_2O tree^{-1} yr^{-1} or application of 12-12-17 between 200 and 400 g tree^{-1} yr^{-1}, for early growth of black pepper is recommended.

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