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Original Research

Tree neighbourhood effect on the growth and production of nutmeg (*Myristica fragrans* Houtt) in Ternate Island, Indonesia

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ABSTRACT:

Nutmeg is an agriculture product from Ternate which contributes the highest amount to the income of Ternate people. Nutmeg is planted as the main plantation along with other side plants such as clove plant, coconut, durian, etc, creating adjacent system with plants' canopy mutually intercepting. The production of nutmeg highly depends on the spaces between plants and the type of side plants. The spacing should also be determined based on the type of the side plant preferences since any intra-plant interaction and inter-plants interaction might trigger overlapping nutrient consumption, causing low nutmeg production. When the food is running out, the plants will be competing to get more sunshine, water and nutrients. In order to understand the adjacent crop system of nutmeg, soil fertility, type of the closest side plants, and the production of nutmeg were measured in this research. This research employed observation method conducted to 30 paired-plant samples which were purposively determined. Target nutmeg of each pair was determined as the center-point. The space between plants at four quadrants were measured using the point-centered quarter sampling method. The result of this research showed that plants' canopies were overlapping each other. The status of soil fertility was low to intermediate in which organic carbon, Mg, pH, Ca and C/N ratio were known to give major contribution to the amount and the weight of nutmeg. The type of side plants determined the nutmeg plant production. The highest nutmeg production was obtained by the nutmeg plants which were planted with coconut as the side plants, better than those with other nutmeg or cloves as the side plants.

Keywords:

Tree neighbourhood, Nutmeg production, Ternate Island.

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INTRODUCTION

Ternate island has nutmeg farm (*Myristica* sp.) in the altitude of 0 m up to 700 m above sea level, around area with flat topography up to steep mountain area (Hadad, 1991). The seed and the fuli of nutmeg have have high economic value since they produce essential oil that contains high polyphenol and trimyristin (Somaatmadja, 1984; Hadad, 1991; Marzuki *et al.,* 2006; Bustaman, 2007 and Nurdjannah, 2007). Nutmeg is also a conservation plant (Abdul-Madiki and Tjokrodiningrat, 2013) with year-long production period and twice big harvest times in a year.

The planting of nutmeg applied the mixed-planting method in which nutmeg is planted along side with other side plants such as coconut, cloves, durian, jack-fruit tree, mango tree, palm tree, banana tree, breadfruit tree, and other forest plantation such as canary, lingua tree, etc. Space among the plants is irregular and the number of plants within the crop area varies across farms. The variation of the number and the type of the side plants in three native-owned nutmeg farms in Ternate were the focus of this study. Those three nutmeg farms were located in Ngade village where plant population was 100 trees/ ha^{-1} (59% nutmeg), Sulamadaha village 200 trees/ ha^{-1} (54% nutmeg), and Fitu village 300 trees/ ha^{-1} (51% nutmeg). The criteria of land suitability (climate and soil), as seen by Rosman *et al.* (1989) mentioned that Ternate island is highly appropriate for nutmeg farming. However, the fact showed that Ternate had relatively low nutmeg production around 15 – 30 kg per $tree^{-1}$ $year^{-1}$ (DANM, 2009; Hadad, 2009). The low productivity was assumed to be caused by intra-interaction and specific interaction that occurred in the adjacent system which was also related to the food sharing among the plants.

The interaction that occurs in within the adjacent system intraspecifically gives different influences from interspecific interaction among individuals or among groups which interaction might shift from competition to facilitation (Saha, *et al.,* 2013, Pugnaire and Luque, 2001) depending on the condition of the environment around the plants (Cervigon *et al*., 2013). The success of adjacent system is determined by the ability and the type of the plants related to how they absorb food and nutrients effectively from a certain limited amount of food for every growth phase (Saha *et al*., 2013; Stoll and Prati, 2001). If the food is running out and the spaces among the plants are narrow, plants will directly compete each other to obtain more sunshine, water and nutrients (Damgaard, 2011; Wright, 2002), in which the size of the side plants determine the ability of the target plants to get enough food when competition occurs (Futakuchi, 2007; Ong and Huxley, 1996). Interaction that occurs among nutmegs and interaction between nutmeg and other plants are different in terms of canopy placement up to the nutrient fulfillment. The canopy between nutmegs- nutmeg and cloves, nutmeg and coconut, nutmeg and other plants are usually narrow even overlapping (including the root system). This close adjacent planting system does not only influence the characteristic of the plant growth, but it also has certain influence to the micro climate created by inter-vegetation interaction (Swank dan Schreuder, 1974; Salazar *et al*., 2010). The population and the type of plants also influence the coverage of soil surface, the amount as well as the type of organic nutrients absorbed by the plants (Giller *et al*., 1997). Different number and plant types have certain effects toward chemical litter, biomass litter, temperature and soil humidity tanah (Eviner and Chapin, 2003; Eviner, 2004; Barbier *et al*., 2008) which gave major effect on the plant productivity. Nutmeg productivity is the key aspect to evaluate the function of the ecosystem. Optimum number of plant which relates to the optimum spacing of intra and inter-specific are important to comprehend in order to improve the production and the productivity of the plant. This research was conducted to see the effect of the adjacent planting system by measuring the intra and

Table 1. Type of the closest side plant, average space between the main plant to the side plant and the relative domination of each type

S. No	Type of the closest side plants	Closest space (m)	Crown diameter (m)	Relative domination (%)
1	Nutmeg	5.11	5.03	56.52
2	Clove	4.84	4.95	17.79
3	Coconut	5.64	4.78	9.24
4	Durian	3.80	8.95	9.07
5	Cempedak	8.55	4.06	1.86
6	Palm	4.58	3.07	1.61
7	Breadfruit	3.85	6.00	1.11
8	Linggua	4.70	4.83	0.94
9	Banana	3.45	2.01	0.67
10	Mango	10.10	5.89	0.62
11	Water apple	5.54	3.47	0.58

interspecific interaction on the nutmeg production of nutmeg farms at Ternate island. The productivity of nutmeg plant seen from the spacing among plants was used as the basic information of the agronomy and ecology aspects of nutmeg plant which provide insights for future researcher to develop and farm nutmeg plants for broader farming scale (Figure 1).

MATERIALS AND METHODS

Location and time

This research was conducted in natives' nutmeg farms at Ternate Island, Northern Maluku Province which is located in the altitude of 57-358 m above sea level. The farm was located in the coordinate of 127'20'51" – 127'20'55" EL dan 0.46'16" – 0.46'21". The species of the nutmeg plant in the farm was the productive nutmeg plant of *Myristica fragrans* around 20-60 year old. The age of the plant was measured from the stable nutmeg production which occurs when the plant reach 15-70 years old (Marcelle, 1995; Hadad *et al*., 2006).

This research was conducted in two steps; location determination and sampling which was done in July and August 2013, and measurement of growth components and nutmeg production in October 2014 until June 2015. The average monthly rainfall was around 96 to 308 mm/month and yearly rainfall of around 2.601 mm/year, and rainy days of around 2 – 16 days/month with 104 rainy days in a year. The nutmeg farm lies on inceptisols and entisols soil (Soil Survey Staff, 1999), with pH 5.3 – 5.6 (Laboratory of Soil Science, Faculty of Agriculture, Brawijaya University, 2015).

Sample plants

Thirty paired-plant samples were chosen from 30 ha nutmeg farm. The chosen plants (nutmeg and the closest side plant) had a diameter of ≥ 10 cm. Target nutmeg was chosen as the center point of each pair which space to the side plant within the four quadrants was measured using the point-centered quarter sampling method (Elzinga *et al*., 1998). The spaces between the side plants and the main plants can be seen in Table 1. The target nutmeg of each pair was then observed to analyze its growth components and its productivity. Observation variables included:

- Stem diameter (DBH, cm), by measuring the stem circumference (LB) at 130 cm from the stem base (DBH_{130}) (Pretzsch, 2009; Mitchell, 2010). After that, the value of the stem diameter was calculated by dividing the stem circumference (LB) with the constants value p (3,1416). DBH = LB/p (Ministry of Environment) (KLH), 2004).
- Basal area (BA, cm^2) was measured from the DBH based on this equation $BA = pDBH^2/4$ (KLH, 2004).
- Canopy width (m) was measured from the projection of the tree crown from east-west and north-south

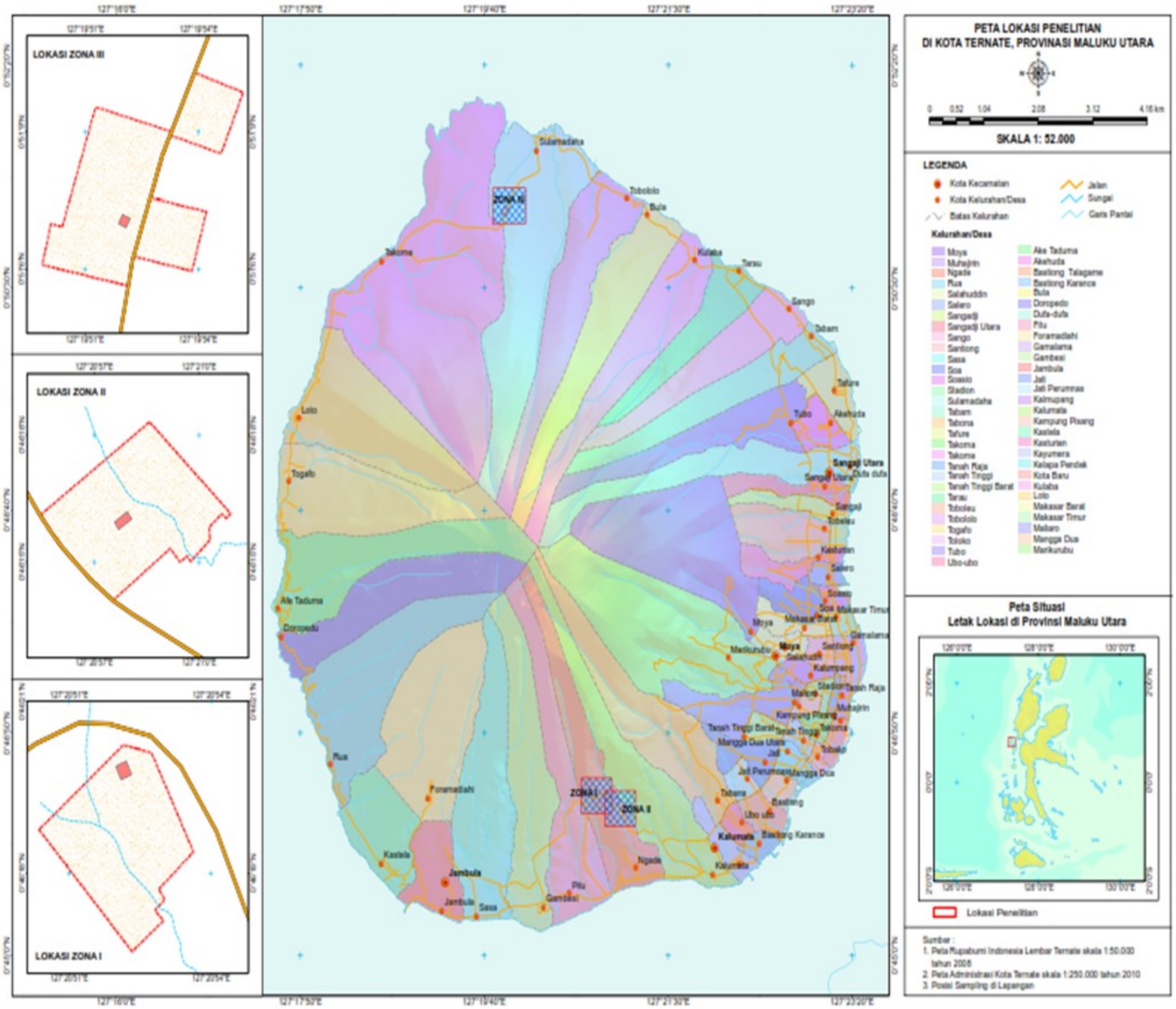

Figure 1. Ternate Island map, showing the study area of nutmeg plantation (insert: North Moluccas Province)

sides (Pretzsch, 2009).

- The number of fruit (tree^{-1} year^{-1}) was measured from the number of fruit produced by a tree in 12 months. Fruits are ready to harvest when some part of the fruit chap, or some fruits from a trunk chap.
- Seed weight (kg^{1} tree^{-1} year^{-1}) was measured from fruit produced within 12 months. The seeds were weighed right after they were harvested before they were dried under sunlight to leave only 10% water. The dried seed were then weighed.

Characterization of soil fertility

Based on the vegetation analysis (Table 1), soil samples were obtained from the target nutmeg with the most dominant side plants such as nutmeg-nutmeg, nutmeg-clove, nutmeg-coconut. The samples were collected using simple random sampling technique under the tree canopy (Jones, 2001) of target nutmeg and the soil outside nutmeg area as the control sample including 12 samples which consisted of three samples of dominant pairs (nutmeg-nutmeg, nutmeg-clove, nutmeg-coconut) and one control sample with three repetition (4 x 3 repetition = 12 samples). Samples of the soil were taken from four points (northern, southern, eastern, western parts) under the canopy line of target nutmeg from each pair (4 x 3 x 4 = 48 sampling points). From each sam-

Table 2. Soil texture of the farm

S. No	Texture class	Frequency	%
1	Clay	5	31.25
2	Loamy clay	4	25.00
3	Dusty clay	4	25.00
4	Dusty Loamy clay	1	6.25
5	Sandy Loamy clay	1	6.25
6	Sandy clay	1	6.25

pling point, 100 g of soil were obtained (4 x 100 = 400 g) from 0 - 50 cm depth. Soil sample from each sampling point undergone single composite procedure to represent each adjacent pair which was then put into polythen bag and then brought to the labroratory. Components of soil fertility to observe included soil texture, pH (H_2O), organic carbon (%), total nitrogen (%), C/N ratio, P Bray I (mg kg^{-1}), K (me 100 g^{-1} soil), Ca (me 100 g^{-1} soil), Mg (me 100 g^{-1} soil), CEC (me 100 g^{-1} soil) and basalt saturation (%). Analysis of soil texture was done using pipes/hydrometer method, soil pH was measured using buffer liquid pH 7.0 (pH H_2O); organic carbon was measured using spectrophotometer; total nitrogen was analyzed using Kjeldahl method; P was measured using fluoride acid method (Bray) with bicarbonate extraction; K, Ca, Mg, and KTK were measured using ammonium acetate extract; KB was measured using the extraction of NH_4OAC. The analysis of the soil was conducted in the labroratory of Soil Science major, Faculty of Agriculture, Brawijaya University, Malang, Indonesia.

Data analysis

In order to find out the effect of side plants on growth components and the production of target nutmeg, variety test (anova) was administered. The correlation between spaces in adjacent farming in the pairing of nutmeg was measured using correlation analysis and simple regression analysis. to see the influence of vegetation composition on soil fertility and nutmeg production, variety analysis (anova) was administered. If real effect was found, least significantly difference test would be administered at the level of significance α = 0.05. To estimate the contribution of soil fertility components on the components of nutmeg production, linear regression test in the form of stepwise procedure was

Table 3. Soil chemical characteristic of the paired-plants and control plants

S. No	Characteristics	Unit	Value	Criteria*
	Paired-Plants			
1	pH (H_2O)		5.3 – 5.6	Acid – rather acid
2	Organic carbon	%	1.64 – 3.16	Low – high
3	Total nitrogen	%	0.17 – 0.30	Low – medium
4	C/N ratio	-	9.0 – 11.0	Low – medium
5	Phosphorus (P) Bray I	mg kg^{-1}	2.25 – 4.38	Very low
6	Potassium (K)	me 100 g^{-1}	0.12 – 0.29	Low
7	Calcium (Ca)	me 100 g^{-1}	5.40 – 9.35	Low – medium
8	Magnesium (Mg)	me 100 g^{-1}	0.31 – 1.70	Low – medium
9	Cation Exchange Capacity (CEC)	me 100 g^{-1}	17.80 – 27.72	Medium – high
10	Base saturation (BS)	%	37.0 – 44.0	Low – medium
	Control			
1	pH (H_2O)		5.4 – 5.8	Acid – rather acid
2	organic carbon	%	1.24 – 2.51	Low – medium
3	Total nitrogen	%	0.13 – 0.26	Low – medium
4	C/N ratio	-	10.0	Low
5	Phosphorus (P) Bray I	mg kg^{-1}	2.18 – 2.24	Very low
6	Potassium (K)	me 100 g^{-1}	0.14 – 0.30	Low
7	Calcium (Ca)	me 100 g^{-1}	5.98 – 6.32	Medium
8	Magnesium (Mg)	me 100 g^{-1}	0.15 – 0.63	Very low – low
9	Cation Exchange Capacity (CEC)	me 100 g^{-1}	14.99 – 15.60	Low
10	Base saturation (BS)	%	42.0 – 49.0	Medium

Note: * (Department of Agriculture, 2005).

Table 4. The effect of neighbour plant to P and CEC values of the soil under the target nutmeg plant

S. No	Pair	P (mg kg^{-1})	CEC (me 100 g^{-1})
1	N-N-N-N	2.48 b	25.24 a
2	N-N-Ce-Ce	2.26 b	24.89 a
3	N-N-Ct-Ct	3.76 a	21.82 a
4	Control	2.21 b	15.30 b

Note: Means with the same letters within columns indicate significant differences at the LSD 0.05. All other variables are non-significant. N = Nutmeg, Ce = Clove, Ct = Coconut.

administered (Sarle and Goodninght, 1982). The data of this research were analyzed using SAS program ver 9.1 (SAS, 2004).

The competitive and intraspecific interaction level was measured using the nearest neighbour technique (Pairunan, 1977) following the operational definition proposed by Yeaton and Cody (1976). One nutmeg tree as the central point and its nearest neighbour within the four quadrants were calculated as the amount of nearest neighbour coverage area of each pair (Shaukat *et al.,* 2009). The space and the DBH of each pair was recorded. If these two variables (space of intra/interplant and plants' components) showed positive correlation, then there were interferences among the neighbouring individuals (Yeaton and Cody, 1976; Shaukat *et al*., 2009).

RESULTS AND DISCUSSION

Vegetation and soil analysis

The type of the nearest neighbour plant of the target nutmeg, average space to the target nutmeg, and the relative domination of each type can be seen in Table 1. It is shown in Table 1 that the most dominant neighbour plant is nutmeg (56.52%), followed by clove (17.79%), coconut (9.24%) and durian (9.07%), while the other plants showed less than 2% domination. The average space between the target nutmeg and the neighbour plants is 4.62 m (Table 1) and it requires minimum space of 9.24 m. It indicates that the canopies of the target nutmeg and the neighbour plant are overlapping. The physical and chemical analysis of the soil are presented in Table 2 and 3, showing six classes of soil texture including clay soil to sandy clay soil (Table 2) which are suitable for nutmeg farming. Nutmeg plants grow in clay soil or sandy clay soil (Rosman *et al*., 1989).

The soil fertility status of the neighbour plants and the control plants (outside the nutmeg agroecosystem) are presented in Table 3. Based on the data, it can be seen that the soil under the target nutmeg and the neighbour plant is relatively similar to the soil outside the agroecosystem area (control). The pH level of the soil around nutmeg agroecosystem is found around 5.3 – 5.6 (acid – rather acid) (Table 3) which is quite favorable for nutmeg to grow. Nutmeg plants are known to grow on soil with pH level of around 5-6 and grow better on soil with pH of around 6 – 7 (Rosman *et al.,* 1989). pH level is the parameter of soil fertility reaction upon the decomposition degree which is quite influential toward the actual soil fertility (Syekhfani, 2010), chemical soil characteristics including phosphate nutrients, basalt cations, and so on (Arifin, 2011).

Nutmeg farms require high amount of natural nutrients from plant litters including leftover nutmeg flesh. The organic carbon soil content under the nutmeg tree varies around 1.64 – 3.16% (medium to high). The variation of organic carbon content in this condition might be caused by the different variety of neighbour plants around the target nutmeg (Table 1 and 4). The different average of organic carbon value under nutmeg stand which rather higher than those outside agroecosystem of nutmeg (1.24 – 2.51%) is categorized low to medium, indicating that plant litters have dominant contribution to the organic nutrients. The organic food in the soil come from decomposition of nutmeg leaves and leftover fruit flesh. Organic nutrients in the soil refer to any carbon found in the soil which comes from plant litters or dead animals. Source, amount and continuity

Table 5. Stepwise procedure and optimum model between the number and the seed weight to soil fertility components

Step	Variable entered	Number Vars. In	Pertial R-square	Model R-square	F	*p > F*
			Number of Fruits (NF) (grain tree^{-1} year^{-1}):			
1	Organic carbon	1	0.6469	0.6469	12.82	0.0090**
2	Mg	2	0.1986	0.8455	7.71	0.0321*
3	pH	3	0.0757	0.9212	4.81	0.0798^{ns}
4	Ca	4	0.0587	0.9799	11.68	0.0268*
5	C/N	5	0.0155	0.9954	10.21	0.0495*
NF = -51604.00 + 10933.00 pH + 1517.15 Organic carbon + 979.68 C/N – 1185.03 Ca – 5493.96 Mg (R^2 = 0.9954; p > F = 0.0010) .... [1]						
			Weight of Kernel (WK) (Kg tree^{-1} year^{-1})			
1	Organic carbon	1	0.5810	0.5810	9.71	0.0170*
2	Mg	2	0.2373	0.8182	7.83	0.0312*
3	pH	3	0.0887	0.9070	4.77	0.0808^{ns}
4	C/N	4	0.0661	0.9730	9.81	0.0351*
WK = -241.40 + 37.27 pH + 7.12 Organic carbon + 5.59 C/N – 14.82 Mg (R^2 = 0.9730; p > F = 0.0021) .... [2]						

Note: ns = not significant and ** = high significant at the level of a = 0.05. Variables with p > F = > 0.10 were not included in the model.

of this organic nutrients are the key that affect the amount of organic content in the soil (Sale and Agbidye, 2011; Rahmi and Biantary, 2014; Soewandita, 2008).

Nutrients contained in the nutmeg farm were considered low-medium (Table 3). Plants which are growing in soil with limited amount of nutrients tend to decrease the amount of nutrients distributed to the leaves. Instead, they give higher amount of nutrients to the root, increasing the volume of the root. Yet, generally, the total growth rate is decreasing (Poorter and Nagel, 2000; Sage and Pearcy, 1987).

Total nitrogen in the soil under nutmeg stand was found around 0.17 – 0.30% (Low – Medium) similar to the condition outside agroecosystem (Table 3). This condition might be caused by two factors; plants' litter from nutmeg and its neighbour plant as the main materials of soil organic which contained low N element (fruit 0.60 – 1.125%, leaves 1.17 – 1.75%, complete data is not presented), and character of the nutmeg plant itself which blooms and produces fruits year long, absorbing huge amount of N element from the soil. The ratio of C/N determines the rate of litter decomposition which later determines the amount of organic elements in the soil (Mubarak *et al*., 2008). Syekhfani (2010) stated that the ratio of C/N is generally used as the indicator to make decomposition easier in which the higher the ratio C/N, the more difficult the decomposition process to occur. It is also mentioned that C/N ration of pure soil is 12:1. At this ratio, the population of decomposer bacteria is at the most stable level. Soil C/N ratio in the agroecosystem was around 9:0 – 11:0 (Table 3) which indicates that the decomposition process in the farm soil occurred effectively.

The P element found in the soil was around 2.25 – 4.38 mg kg^{-1} (very low), similar to the one found outside the nutmeg agroecosystem (Table 3). This result indicates that the basic soil elements and the P contained in the organic elements were also low. Besides, nutmeg plants which bloom and produce fruit year long absorb P at a high amount. The acid pH level (Table 3) also caused the unavailability of P element. In an acid soil (low pH), dissolved P element reacts with Al, Fe

Tabel 6. Results of observation and variance test on the influence of neighbour plant toward the growth factors and the production of nutmeg plants

S. No	Variables	Mean	Standard deviation	Minimum	Maximum	p > F
1	Diameter at Breast Height (DBH)	30.54	6.79	25.22	39.81	0.0003**
2	Basal Area (BA)	764.24	347.81	499.41	1244.00	0.0082**
3	Canopy Width (CW)	10.77	2.56	7.85	15.67	0.0530*
4	Sum of Branch (SB)	60.11	20.55	29.00	93.00	0.0753tn
5	Number of Fruits (NF)	5049.00	4569.00	756.00	12435.00	0.0014**
6	Weight of Kernel (WK)	18.010	13.498	1.57	38.860	0.0013**

Notes: ns = not significant and ** = highly significant at the level of a = 0.05.

and other hydro oxidants, forming compounds of Al-P and Fe-P which are relatively hard to dissolve (Syekhfani, 2010).

Basalt cations might have been exchanged under the nutmeg stand, showing K^+ at 0.12 – 0.29 me 100 g^{-1} soil (low), Ca^{++} at 5.40 – 9.35 me 100 g^{-1} soil (low to medium), Mg^{++} at 0.31 – 1.70 me 100 g^{-1} soil (very low - medium) (Table 3). This indicates that minerals forming the soil in the farm lacked of basalt cations besides it is also caused by the characteristic of Ternate island which receives high amount of rain that washes the basalt cations. As stated by Pairunan *et al.* (1985), high weathering level and high amount of rain that washes the cations decrease the amount of cations and minerals that contain cations. Plants might also absorb the cations before they are harvested and bring the cations away from the farm without any exchange either from fertilization or from liming.

Syekhfani (2010) explained that CEC value can be used as the parameter to measure the ability of soil in buffering the nutrients. CEC value found under the nutmeg stand was medium-high (17.80 – 27.72 me 100 g^{-1} soil) while the value from the control soil was low (14.99 – 15.60 me 100 g^{-1} soil). CEC value from the nutmeg stand also indicated the role of plant litters as the source of organic food and nutrients for the soil. Generally, CEC value is strongly bounded to soil pH, clayish soil, and organic nutrients (Syekhfani, 2010). Besides organic nutrients from leaves, trunk, or fallen sticks from nutmeg, around 80% nutmeg flesh are left back to the soil (Abdul-Madiki *et al.,* 2015). In a year, nutmeg leftover flesh reaches up to 129.72 kg (complete data are not presented). Farmers usually left the flesh under the tree which appear to have positive effect for the soil to maintain its organic nutrients for the nutmeg itself. Soil saturated basalt under nutmeg stand was found around 37.0 – 44.0% (low-medium), and outside the stand was around 42.0 – 49% (Medium) (Table 3). Saturated basalt showed that base relative proportion can be exchanged in the colloidal soil. There is a direct relationship between CEC and BS (Syekhfani, 2010). Thus, there exchange process might be dominated by

Table 7. The influence of neighbour plant to the stem diameter, basalt area, canopy width, number of fruit and the kernel weight of target nutmeg plant

S. No	Pair	DBH (cm)	BA (cm^2)	CW (m)	SB	NF (grain $tree^{-1}$ yr^{-1})	WK (kg $tree^{-1}$ yr^{-1})
1	N-N-N-N	39.49a	1224.36a	13.69a	41.67b	3468b	16.00b
2	N-N-Ce-Ce	26.43b	549.77b	8.83b	58.00ab	870b	3.83c
3	N-N-Ct-Ct	25.69b	518.59b	9.80ab	80.67a	10808a	34.20a

Note: Means with the same letters within columns indicate significant differences at the LSD 0.05. All other variables are non-significant. DBH = Diameter at Breast Height, BA = Basal Area, CW = Canopy Width, SB = Sum of Branch, NF = Number of Fruits, WK = Weight of Kernel. N = Nutmeg, Ce = Clove, Ct = Coconut.

Al, while the Ca, Mg and K take a little part in the process.

Variance analysis showed that neighbour plants has a strong influence toward P (p > 0.0051; R^2 = 0.8709) and CEC (p > 0.0054; R^2 = 0.8776) does not have any direct influence to other components of soil fertility (pH, organic carbon, total nitrogen, C/N ratio, K, Ca, dan Mg). The result of LSD test shows that there is no significant difference between P value found in the nutmeg-nutmeg pair (N-N-N-N) and nugmeg-cloce (P-P -Ce-Ce). However, the P value of nutmeg-coconut (N-N -Ct-Ct) appears to have significant difference. The control group also does not show any significant difference on the CEC (Table 4). The level of nutrient in a soil is affected by the condition of organic materials from the surrounding vegetation (Hermansyah, *et al.,* 2009). It can be seen that coconut as the nearest neighbour plant of nutmeg has been able to improve the P value of the soil compared to the cloves or nutmeg.

Double regression analysis using the stepwise procedure was administered to identify the components of soil fertility, while the amount of nutmeg production showed that the components of nutmeg production (number of fruit, seed weight) can be measured through the components of soil fertility using linear regression method, which summary is presented in Table 5. Soil fertility components (organic carbon, Mg, pH, Ca, dan C/N ratio) simultaneously give strong contribution to the production components of nutmeg especially to the number of the produced fruit (R^2 = 0.9954; p > F = 0.0010) and the seed weight per tree (R^2 = 0.9730; p > F = 0.0021), the optimum model is presented in equation 1 and 2. It can be implied that around 99-97% of the number and weight of the seed can be simultaneously explained by the ratio of organic carbon, Mg, pH, Ca, dan C/N, while the other 1-3% are determined by other nutrients and other growth factors.

The summary of the observation on the growth components and nutmeg production is presented in Table 6. The result of variance test showed that the neighbour plant has a direct effect to the stem diameter, basalt area, number of seed, seed weight per tree which also strongly affect the width of target nutmeg canopy. Yet, they do not share any significant relationship to the number of trunk (Table 6). The result of the LSD test on the influence of neighbour plants to stem diameter, canopy width, number of fruit, fruit weight of the target nutmeg are presented in Table 7.

Table 7 shows that the Stem diameter (DBH), Basal Area (BA) and Canopy Width (CW) were found in the nutmeg-nutmeg pair (N-N-N-N) which is significantly different from the pair of nutmeg-clove (P-P-Ce-Ce) or nutmeg-coconut (N-N-Ct-Ct). yet, the the Highest Number of Trunk (SB), Number of Fruit (NF) and kernel weight were obtained by nutmeg-coconut pair, and are significantly different form the pair (N-N-N-N) or N-N-Ce-Ce. Abdul-Madiki *et al.* (2015) reported that nutmeg trees grown within close spaces do not have any

Table 8. Correlational coefficient (r) between the space and the growth components and nutmeg production components (N = 30)

	D	DBH	BA	CW	NF	WK
D	1.000	0.414*	0.406*	0.253^{tn}	0.512**	0.503**
DBH		1.000	0.997**	0.469**	-0.287^{tn}	-0.016^{tn}
BA			1.000	0.436*	-0.212^{tn}	-0.012^{tn}
CW				1.000	0.110^{tn}	0.072^{tn}
NF					1.000	0.976**
WK						1.000

Note: D = Neighbour distance, DBH = Diameter at Breast Height, BA = Basal Area, CW = Canopy Width, NF = Number of Fruits, WK = Weight of Kernel.

significant difference to the nutmeg without canopy intersection with the neighbour plants. It is also presented that the lowest number of fruit and kernel weight in a tree was found in the pairing of nutmeg and clove. It might happen due to the effect of neighbour plant shading to the nutmeg plant which is lower than the effects from nutmeg or cloves as the neighbour plants.

Intra/Inter-specific Interaction

There is a positive significant correlation between spacing system and the stem diameter ($r = 0.4137$, $p > r = 0.0231$) and basalt area (BA) ($r = 0.4064$, $p > r = 0.0258$) of the target nutmeg (Table 8). More space between the target nutmeg to the other plant improves its stem diameter and basalt area as seen in the equation 3 and 4

DBH = 20.808 + 1.748 D .... [3]

BA = 258.716 + 90.278 D .... [4]

Variance analysis (ANOVA) using simple regression test showed that there is a significant linear regression ($F = 5.78$, $p > F = 0.0231$) with determination coefficient $R^2 = 0.1711$ for DBH and $F = 5.54$, $p > F = 0.0258$ at $R^2 = 0.1652$ for BA. This result showed that around 17% of stem diameter and basalt area variance can be explained by the space to the nearest neighbour plant. Significant relationship was also found between the space of the neighbour plants (D) and the number of fruit (NF) ($F = 9.94$, $p > F = 0.0038$), while the dried kernel weight per tree per year (WK) ($F = 9.47$, $p > F = 0.0046$) (Table 5). The linear regression equation of those two corrections are presented as follow (equation 5 and 6):

NF = -3376.751 + 1752.049 D ($R^2 = 0.2620$; n = 30). …….............................. [5]

WK = -12.438 + 5.699 D ($R^2 = 0.2527$; n = 30). .... [6]

Around 26% of nutmeg variability in the forms of the number of fruit and kernel weight can be explained by the space between the target nutmeg and the nearest neighbour plant (equation 5 and 6). It is obvious that the space to the nearest neighbour plant determines the growth and the production of the nutmeg (equation 3, 4, 5, 6). Yeaton and Cody (1976) in Shaukat *et al.,* (2009) stated that if two variables (space among the plants) showed a positive correlation, it indicates that there is inferences that occur among individuals. Narrow space triggers competition to obtain sunshine and nutrients. Low nutmeg productivity is not mainly caused by the absence of coconut around it, yet it is more likely to be caused by intraspecific competition that occur as the consequence of having narrow space among the plants (Abdul-Madiki, *et al.,* 2015). It is also obvious that the number of fruit and kernel weight of the nutmeg per tree are higher in the nutmeg plant with coconut as the neighbour plant compared to other nutmeg or clove as the side plants (Table 7).

CONCLUSION

The findings can be concluded as follows:

- Space and type of the nearest neighbour plants determine the growth and the production of nutmeg plant. In a condition in which canopies are overlapping, nutmeg that grew close to coconut showed higher production compared to the nutmeg that has other nutmeg or clove as the side plants.
- The chemical characteristics of the soil under nutmeg stand shows: acid – rather acid pH level of the soil, low – high organic carbon nutrient, low – medium total nitrogen, low – medium C/N ratio, low amount of P element, medium – high CEC, low – medium basalt cations, and low – medium basalt saturation.
- Chemical components of soil fertility have major contribution toward the production of nutmeg (number of fruit and kernel weight) including organic carbon, Mg, pH, Ca, and C/N ratio.

- Improvement on nutmeg production can be done by enhancing the chemical components of the soil through intensive organic fertilization.

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