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Fertilization and pruning improve vegetative growth and architecture of tropical lowland Borneo Prima Mandarin citrus

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Abstract

Vegetative growth of citrus can be increased through a combination of fertilization and pruning. Borneo Prima Mandarin (*Citrus reticulata* cv Borneo Prima) is a superior local commodity that is grown in lowlands. It has an interesting orange skin, while normally the tropical lowland citrus has a green skin colour. As a new commodity, Borneo Prima Mandarin has to be developed in order to increase production and improve quality. There is no specific cultural practices, so it needs to be developed, especially on fertilizing and pruning. The first experiment aims to observe the plant growth and architecture of plants grown in the orchard. The first factor was the nitrogen fertilization rate (0, 20, 40, 60 g N per tree per application) and the second was pruning (without pruning, open center pruning, hedge pruning). In the second experiment, the plants were applied with the same factors of experiment 1, but were grown on a root observation chamber sized 40 x 20 x 60 cm (length x width x height) which aims to observe the shoot root's growth and the plant's biomass. Nitrogen fertilizer had a significant effect to the growth of the Borneo Prima Mandarin, i.e number of shoots and leaves. Twenty grams of nitrogen fertilizer per aplication was efficient to produce new shoots and leaves. Pruning treatments had significant effects towards the plant architecture (i.e reducing plant height, canopy shade projection and canopy length). Open center pruning and hedge pruning made the crown more open which increased the light interception. The shoot grew rapidly two weeks after fertilizing and also pruning. While the root grew rapidly after shoot dormancy.

Keywords: hedge pruning, light interception, open center pruning, lowland citrus

1. Introduction

Optimal growth at each stage of plant growth is very important. Vigorous vegetative growth is necessary in order to increase plant production. Vegetative growth of citrus could be stimulated by various factors, such as temperature, light intensity, nitrogen and water (Roux & Barry, 2010). Fertilizing and pruning ways to improve said stimulation. Research on nitrogen fertilization and pruning has been conducted, nevertheless the combination between nitrogen fertilization and pruning has never been done before.

Numerous experiments have been carried out on nitrogen fertilizing within the vegetative growth of citrus (Boughalleb, et al., 2011; Alcantara et al., 2011; Hifni et al., 2013). On vegetative period, nitrogen fertilizer could increase branch growth (Utami et al., 2019), leaf area index (Rahayu & Poerwanto, 2014). Nitrogen fertilizer causes vigorous growth of plants (Alcantara et al., 2011). The vigorous plant produces more shoots that are located irregularly and results in larger trees that increase shading inside the canopy. Pruning is then needed to manage the canopy shape.

Pruning can improve the vegetative growth of citrus (Dhaliwal et al., 2013). Pruning is used to maintain the shoot growth and to shape the canopy in order to develop a strong framework and expose many leaves to sunlight (Krajewski & Krajewski, 2011). Light is one of the limiting factors in citrus plant (Ahmad et al., 2006). In order to maximize the light interception, the ideal citrus architecture should have an open canopy shape.

Borneo Prima Mandarin (*Citrus reticulta* cv. Borneo Prima) is the new local citrus variety from East Borneo, Indonesia. The speciality of this citrus is being grown in lowland but has an interesting orange skin. As a new variety, Borneo Prima Mandarin has to be developed in order to increase the production and improve the quality. Currently there is no specific dose of nitrogen fertilizer for the Borneo Prima Mandarin.

Borneo Prima Mandarin has an erect tree growth habit with narrowed branch angle. This architecture does not support the plant to obtain optimum sunlight. Hence, pruning should be done to open the canopy in order to increase sunlight interception. Sunlight is the main factor in the photosynthesis process to produce biomass.

Open center pruning is a common pruning form applied on citrus. This type of pruning follows the ideal form of branching; a single main trunk, three primary branches and nine secondary branches. Open center pruning will result in a broad canopy surface that will receive more sunlight. Hedge pruning is an unsual pruning form on the citrus tree. Branches in the east and west are cut off, in this type of pruning, while the north and south branches are maintained so the sunlight can penetrate optimally in the morning until late afternoon. Plants will be shaped in a hedge and is suitable to be applied on narrow areas (i.e yard).

The research conducted was (1) to determine the appropriate dose of nitrogen fertilizer used to achieve optimum growth of young Borneo Prima Mandarin; (2) pruning in order to attain proper tree architecture in order to support plant growth

2. Materials and Methods

A. Plant material and site location

The research was conducted in IPB research station, Bogor (230 m above sea level). The experiments were conducted on a three years old Borneo Prima Mandarin (*Citrus reticulta* cv Borneo Prima) grafted on Rough lemon (*Citrus jambhiri* Lush.) rootstock (Fig 1).

Fig. 1. Borneo prima mandarin citrus

Experiment 1: In experiment 1, the Borneo Prima Mandarin was planted in an orchard (4 x 4 m spacing) in order to observe its growth and architecture. The experiment was conducted from June 2014 to February 2015. Fertilizing and pruning was done every three months, in June (1st period), September (2nd period), and December (3rd periode).

In the open center pruning, the main trunk was prune to 30-40 cm above the soil surface. Furthermore, select three branches that are evenly spaced around the trunk. In the hedge pruning, branches in the east and west were cut off while the north and south branches were maintained. The north and south branches were train on an espalier. The pruning was done in a day.

Number of shoots and leaves were determined by the new growth of shoots and leaves after each treatment application. Plant height, length of the North-South and East-West canopy, and land occupation were observed every two months in the end of the shoot's growth period. The leaf's greeness was measured using a chlorophyll meter (SPAD-502 plus; Konica Minolta, Japan). Light intensity was measured with lux meter (HS1010; Sunche). Leaf area was measured with leaf area meter (model Li-3000C; Li-Cor, USA).

Experiment 2: In experiment 2, three years old Borneo Prima Mandarin was grown in a root observation chamber sized 40 x 20 x 60 cm (length x width x height) in order to observe root shoot growth and plant biomass. The experiment was conducted from June to December 2014. Fertilizing and pruning was applied once during the experiment. Shoot length was determined by measuring ten shoots per plant in every shoot growth period. Visible root growth was

observed on the root observation chamber. The pattern of new roots was drawn by copying it on transparant plastic using different colored pens for each observation. Then, the pattern of the root was measured using a curvimeter (Silva, Sweden). The length of shoots and roots were measured every week and represented in shoot and root growth curve. Dry mass was examined by destructive sampling. Destructive sampling was carried out six months after planting. The plant was removed, cut and separated from roots, trunk and leaves then heated on an oven with 80oC temperature until dry mass was obtained.

B. Statistical analysis

Randomized Completely Block Design (RCBD) with two factors used as an experimental design. The first factor was the nitrogen fertilizer dosage (0, 20, 40, 60 g N per plant per application) and the second was pruning forms (without pruning, open center pruning, hedge pruning).

3. Results and Discussion

A. Plant Growth

There was no interaction between fertilizing and pruning treatments for all parameters, but there was a single factor that gave a significant effect to the parameters. Table 1 shows that nitrogen rate had a significant effect on the number of shoots and new leaves. Twenty grams of nitrogen fertilizer per aplication is more efficient to produce new shoots and leaves. As stated by Sorgona et al. (2006) there is a positive correlation between shoots growth and nitrate availability on the plant. Shoots were grown and developed into leaves. Further, Boughalleb et al. (2011) and Hifni et al. (2013) noted that the increasing rate of nitrogen fertilizer can increase the number of leaves on citrus.

Pruning treatment gave a significant effect to the number of shoots and new leaves. Based on observation, open center pruning produced more new leaves than other pruning treatments. By breaking dormancy through pruning initiation, new shoots grew and developed becoming new leaves to substitute the pruned ones.

Table 1. Effect of nitrogen fertilizing and pruning on number of shoots and leaves

Treatments	Shoots growth periods					
	1		2		3	
	Shoot	Leaves	Shoot	Leaves	Shoot	Leaves
Nitrogen rate						
0 g N	15.50 a	117.33	8.58	87.43	11.08 b	103.33 b
20 g N	14.08 ab	93.00	7.83	75.44	24.09 ab	240.78 a
40 g N	10.46 b	70.00	9.27	86.00	24.90 a	239.22 a
60 g N	10.42 b	67.58	6.50	65.63	23.54 ab	219.50 a
Pruning form						
without pruning	4.19 b	41.88 b	4.19	74.55	6.25 c	105.00 b
open center pruning	15.94 a	111.56 a	10.75	106.91	38.77 a	326.00 a
hedge pruning	18.33 a	110.00 a	6.60	54.00	20.13 b	120.80 b
Interaction	ns	ns	Ns	ns	ns	ns

Note: Different letters within columns indicate significant differences at 5% level; ns indicates non-significant at 5%

Both fertilization and pruning treatment affected the growth rythm of root and shoots (Fig. 2). The number of shoots increased after being fertilized and pruned. Shoots grew rapidly two week after treatments (WAT) whereas the roots grew slower. Roots growth increased just after shoots dormancy and reached its peak before the next shoots growth period took over. Hidayat et al. (2005) reported that rapid roots growth increasing before shoots growth is the result of roots being the main organ in the synthesis of cytokines. Cytokines is translocated by roots to shoots through xylem. Cytokines stimulates cell division followed by breaking the dormant period thus new shoots will develop. Furthermore, Janick (1972) noted that pruning changes the balance between shoots and roots. Increased shoots growth after pruning is caused

by water and nutrients from the undisturbed root system to the shoot area. This increase indicates that pruning has a rejuvenating effect, although it can not compensate the removed portion of the plant .

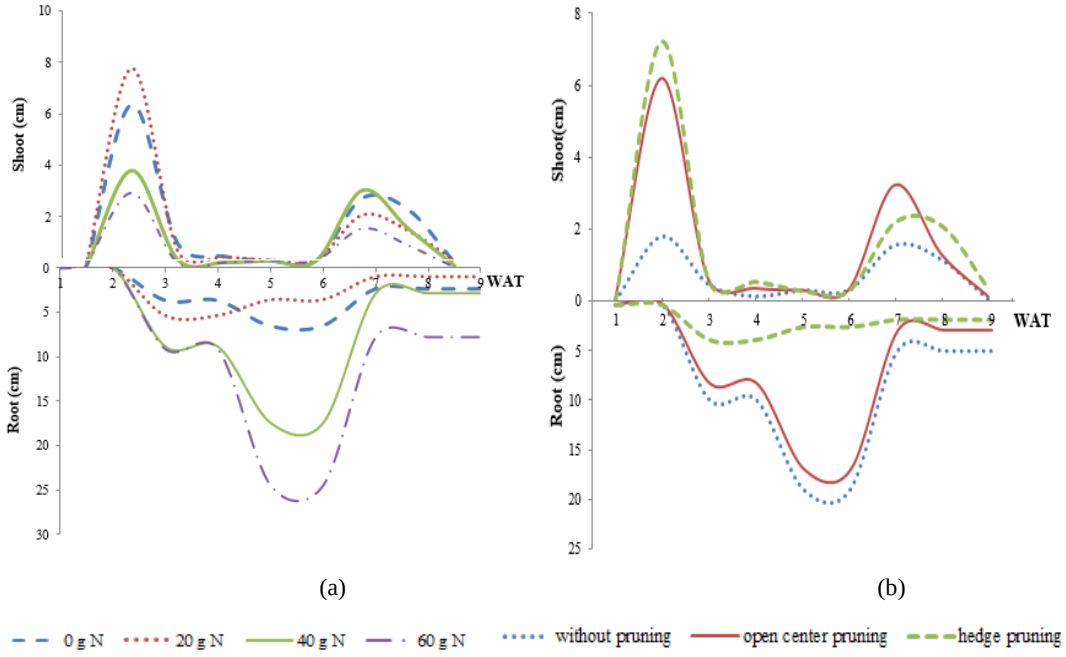

Fig. 2. Effect of (a) fertilizer and (b) pruning on the rhythm of shoot and root growth

Dried weight reflects the growth of a plant as the result of photosynthesis. The destructive analysis of Borneo Prima Mandarin citrus, as shown in Table 2, represents that different rates of nitrogen fertilization did not give a significant effect on the plant's dry weight. Meanwhile, pruning treatment solely affects the dry weight of the leaves. In every pruning, plants would lose a huge number of leaves. On the other hand, there was an excessive amount of leaves on plants with no pruning treatment, resulting in insufficient sunlight attained by leaves on the below part for photosynthesis and thus ended up functioning as a mere sink. Generally, it can be seen that the trunk is the dominant part of plants followed by roots and leaves. It was similar with Morgan et al. (2006) and Roccuzzo et al. (2012) experiments which showed that woody plants had the biggest citrus dried weight proportion.

Table 2. Effect of nitrogen fertilizing and pruning on dry mass

Treatments	Dry weight (g)			
	Root	Trunk	Leaf	Total
Nitrogen rate				
0 g N	35.22	73.22	27.00	135.44
20 g N	35.67	71.67	29.89	137.23
40 g N	35.89	78.22	36.00	150.11
60 g N	29.22	66.67	33.22	129.11
Pruning form				
without pruning	38.08	79.33	39.08 a	156.49
open center pruning	32.33	69.50	29.17 ab	131.00

hedge pruning	31.58	68.50	26.33 b	126.41
Interaction	ns	ns	ns	ns

Note: Different letters within columns indicate significant differences at 5% level; ns indicates non-significant at 5%

Table 3. Effect of nitrogen fertilizing and pruning form on plant height

Treatments	Plant height (cm)		
	1	2	3
Nitrogen rate			
0 g N	101.33	111.83	131.08
20 g N	106.18	116.42	141.92
40 g N	102.09	115.36	134.00
60 g N	103.58	113.25	126.58
Pruning Form			
without pruning	138.50 a	154.00 a	171.31 a
open center pruning	89.80 b	103.13 b	124.00 b
hedge pruning	79.13 b	83.53 c	102.93 b
Interaction	ns	ns	ns

Note: Different letters within columns indicate significant differences at 5% level; ns indicates non-significant at 5%

B. Tree Architecture

On the plant height parameter, nitrogen rate gave no significant effect as shown in Table 3. The increase of height in the plants was greatly affected by the pruning treatments. Plants without pruning were taller than those with pruning. The shoots of Borneo Prima grew vertically above which then led to its increased height. Thus, pruning is one way to control apical dominance of the citrus. It was noted by Coombs et al. (1994) that pruning can break the apical dominance on shoots and support lateral growth of shoots. As a result, horizontal growth can directly delay vertical growth.

In addition to shorter plants, pruning affected land occupation as shown on Table 4. Land occupation is the area covered by the plant's canopy. A larger land occupation means more space required for plants to grow. The occupation area is reflected by the plant's shade, both height and width of its canopy shadow. Pruning treatment on the plant may reduce its land occupation and planting space between others. This will directly impact its population and later on affect its productivity. Based on the data shown in Table 4, plants with hedge pruning treatment inhabitated the least land occupation compared to other pruning treatments.

Table 4. Effect of pruning form on height and wide of canopy shade

Treatments	Canopy shade projection					
	Height (cm)			Width (cm^2)		
	Morning (9 AM)	Day (12 PM)	Afternoon (3 PM)	Morning (9 AM)	Day (12 PM)	Afternoon (3 PM)
Without Pruning	173.00	104.33 a	155.33 a	10918	5338	4322
Open Center Pruning	129.67	108.00 a	129.67 a	8820	4759	3789

Hedge Pruning	115.00	53.00 b	58.00 b	4922	1434	2439

Note: Different letters within columns indicate significant differences at 5% level; ns indicates non-significant at 5%

Land occupation is related to the width of the canopy growth. The wider the canopy is, the larger the land occupationneeded. Based on the observation on the canopy's width of Borneo Prima Mandarin, rates of nitrogen fertilization gave no significant effect as presented on Table 5. The width of the North-South canopy as well as the West-East canopy were both influenced by pruning treatment.

Based on Table 5, open center pruning made a narrower North-South canopy compared to trees without pruning treatment. Further, controlling the number of branches was also applied on open center pruning by choosing three branches as the primary branches. These three primary branches were separated in order to reduce shade for new leaves. There were three secondary branches for each primary branch thus the branches and tree structure was well-arranged.

Table 5. Effect of fertilizing and pruning on long of canopy

Treatments	North-South			West-East		
	August	October	December	August	October	December
	..... cm					
Nitrogen rate						
0 g N	52.70	58.42	58.58	44.25	60.50	51.67
20 g N	61.73	58.17	65.58	52.73	56.83	58.08
40 g N	51.09	56.64	57.00	51.27	61.00	61.27
60 g N	59.67	62.67	65.00	51.83	60.08	59.33
Pruning						
Control	72.81 a	71.31 a	79.25 a	72.63 a	75.88 a	81.13 a
Open Center Pruning	42.80 c	52.88 b	56.31 b	45.53 b	52.31 b	53.31 b
Hedge Pruning	52.20 b	52.47 b	48.53 b	30.13 c	49.93 b	36.80 c
Interaction	ns	ns	ns	ns	ns	ns

Note: Different letters within columns indicate significant differences at 5% level; ns indicates non-significant at 5%

On the other hand, West-East branches were the narrowest in hedge pruning compared to other pruning treatments. While the branches from West-East were being pruned, the branches from North-South were kept to grow. Its purpose was to let the canopy obtain optimum sunlight from morning to afternoon since optimal sunlight intereception on the canopies might influence its photosynthesis. Instead it came to cause the shrink of the West-East canopy's length.

Hedge pruning generated narrower West-East branches compared to Borneo Prima Mandarins without pruning. A narrowed West-East occupation can reduce spacing thus more citrus plants could be planted, which would then increase the number of citrus per hectare. As a result, hedge pruning was able to reduce half of the West-East spacing.

As shown in Table 5, plants grow naturally in a larger occupied area compared to plants with pruning treatment. Plants with open center pruning reduced about 25% of both the North-South and West-East canopy width. Whereas plants apllied with hedge pruning treatment induced the width of the canopy for both the West-East and North-South by 24% and 38% compared to plants without pruning treatment.

C. Light Interception

Pruning will open the canopy of citrus plantation and bring an increase to the sunlight absorption. Sunlight is one of the main component needed for photosynthesis. Buler and Mika (2009) stated that light interception is related to the leaf area index (LAI). LAI is the comparison between the total width of leaves to the area occupied by the canopy. Plants with open center pruning treatment had a 0.38 LAI or 12% lower

than the ones grown naturally (control) while hedge pruning treatment had a 0.35 LAI or 20% lower than control (0.43).

Increasing the LAI value on plants affected the sunlight interception absorbed into the canopy. Plants without pruning had a bigger LAI compared to plants with pruning application. a greater LAI value means lower light interception into the canopy. Rahayu and Poerwanto (2014) mentioned that plants after pruning had fewer number of leaves so the land ocupation and LAI were low. A lower LAI value means the plant is able to intercept more sunlight. It was shown that an open canopy, as the result of pruning, can increase the light intensity received by plants, particularly leaves as the main component of photosynthesis.

Observation on sunlight interception was conducted on the final periode of the research, three months after the last pruning. Observation was conducted to search for pruning response in maintaining its open canopy form in order to keep achieving optimum sunlight interception. In the morning, the sun rises from the east so there was an abundant amount of sunlight coming from the east. Open center pruning could intercept more sunlight from the east compared to other directions and thus reaching a level about 86.02% sunlight (Fig. 3). During the day, where the sun's position was straight above the plants, less sunlight reached the canopy compared to morning time. Open center pruning could intercept sunlight higher from the west and south. In the afternoon, when sun was positioned in the west, leaves from plants with pruning treatment intercepted higher sunlight from the west and north.

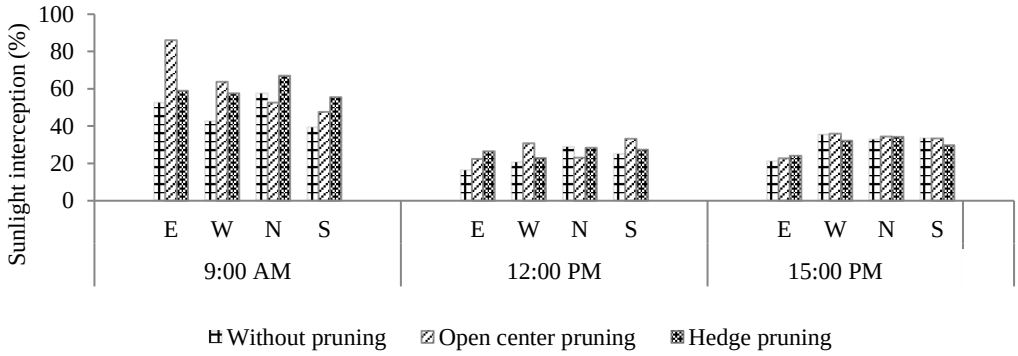

Fig. 3. Percentage of sunlight interception in different pruning form and leaf position (E = east, W = west, N = north, S = south)

Pruning on Borneo Prima Mandarin citrus plants influenced not only the tree architecture but also the leaves color. There was a significant effect on the greenness index of the leaves as shown on Table 6. Leaves on plant without pruning had a greener color which was assumed to be related to the bud initiation during pruning treatment. However, during the observation, leaves growing from new shoots were immature and thus had a slightly light green color. On plants without pruning treatment, buds rarely grew and the dominant leaves were dominated by a dark green colored mature leaves. Rupp and Traenkle (1995) noted that the amount of clorophyll molecules are influenced by the leaves' age. Chlorophyll's content would increase along with age. Besides, the dark green colored leaves on plants without pruning treatment was the respond of low sunlight intensity. Low light intensity is the result of over numbered leaves that forced the leaves to shade each other.

Table 6. Effect of nitrogen fertilizing and pruning on leaf greenness index per plant

Treatments	Leaf greenness index		
	1	2	3
Nitrogen Rate			
0 g N	67.74 b	64.20	68.74
20 g N	72.29 a	66.98	69.11
40 g N	71.31 a	68.22	68.72
60 g N	69.94 ab	63.66	69.62

Pruning			
Control	73.34 a	69.85 a	71.14 a
Open Center	69.64 b	63.51 b	70.13 a
Hedge	68.47 b	64.07 b	66.00 b
Interaction	ns	Ns	ns

Note: Different letters within columns indicate significant differences at 5% level; ns indicates non-significant at 5%

Nitrogen rate difference had a significant effect to the leaves' greeness index during the second period of observation (Table 6). Plants without nitrogen fertilization application had a less green color compared to plants with nitrogen fertilizer. Rates of 20 g N and 40 g N had greener leaves compared to others. Jifon et al. (2005) mentioned that leaf chlorophyll index define N concentrations in citrus cultivars when grown in the same environment.

4. Conclusions

There was no interaction between fertilizing and pruning treatments for all parameters. Nitrogen rate at 20 g N was the best result for shoot growth of young Borneo Prima Mandarin. To obtain an optimum vegetative growth of Borneo Prima Mandarin, open center pruning application gave the best result.

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