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The growth of three varieties of black pepper (*Piper nigrum*) under different light intensities related to indigenous hormones role

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Abstract. *Issukindarsyah, Sulistyaningsih E, Indradewa D, Putra ETS. 2020. The growth of three varieties of black pepper (*Piper nigrum*) under different light intensities related to indigenous hormones role. Biodiversitas 21: 1778-1785.* Low light intensity causes the alteration of plant biochemical and morphological as the mechanism of adaptation. The experiment used split-plot design with three replications. The main plots were three light intensity levels, i.e. 100%, 75%, and 50% radiation; while subplots were three varieties namely Nyelungkup, Petaling 1 and Petaling 2. This research was conducted to figure out the effect of shadings on hormones and the growth of three varieties of black pepper (*Piper nigrum* L.). The results showed that in initial vegetative growth, varieties of Nyelungkup and Petaling 1 had higher growth of both ortotroph and plagiotroph branches, leaf number, leaf area, length of root, root surface area, plant dry weight, nett assimilation rate, and plant growth rate than the variety of Petaling 2. The light intensity of 50% and 75% increased the auxin and gibberellin contents of the leaf but they did not affect the zeatin. The maximum gibberellin and auxin contents of leaf were recorded at 75% light intensity. The 50% and 75% light intensity raised the length, diameter, and internode of ortotroph branch; number, length, and internode of plagiotroph branch; leaf number; leaf area; leaf area ratio; length of root; root surface area; plant growth rate and plant dry weight related to indigenous hormones role.

Keywords: Black pepper varieties, growth, hormones, light intensities, morphology

INTRODUCTION

Black pepper (*Piper nigrum* L.) is a perennial climbing crop, so it requires supporting poles for good growth and production. One of common-used poles is stem of living tree (living support). In addition to more economical, the living support is able to play a role as land conservation such as in creating better life for beneficial micro-organisms, minimizing runoff and providing green fertilizers as source of organic matter. However, the cultivation of black pepper with living supports encounters many constraints so that its growth and yield are lower than those with nonliving (deadwood) poles (Wahid 1984). One of factors contributing to lower yield in black pepper with living support is low light intensity (Yudianto et al. 2014).

The use of shade-resistant variety can improve the growth and yield of black pepper using living supports. The information about response and resistance on black pepper variety against shadings is not widely reported. In Indonesia, there are three superior varieties of common-cultivated black pepper, i.e. Petaling 1, Petaling 2 and Nyelungkup. They have different morphological characters so it is assumed that they have dissimilar response and adaptation levels against various light intensity levels.

Plant adaptation on lower light intensity is responded with some mechanisms such as the change in morphological structure (Gong et al. 2015). According to Casal (2012), the mechanisms of plant resistance against shadings were documented in two methods, namely shade-tolerant and shade-avoidance. Shade-tolerant plants display the morphological, anatomy and architecture traits enabling it increases the light interception and adsorption, like high leaf area ratio and specific leaf area (Gommers et al. 2013). In addition, they tend to have low growth rate and thinner leaf as well as decrease apical dominance and large branch number (Martinez-Garcia et al. 2010). In order to avoid the shading, plants raise hight, length of internode, petiole elongation and leaf insertion angle; reduce the branching; and accelerate leaf senescence and flowering (Casal 2013).

The change in morphology due to the alteration of light environment is related to dynamics of plant indigenous hormones. According to Casal (2012), the signal of low light increased the expression of gene synthesizing auxin, gibberellin, and brassinosteroid. The expression of gene for biosynthesis was of auxin on arabidopsis plant increases under low light intensity (Li et al. 2012). The increment of gibberellin and auxin due to low light intensity was also reported on soybean (*Glycine max*) (Wu et al. 2017) and sweet potato (*Ipomoea batatas*) leaves (Wang et al. 2013).

The response of black pepper on shading has been reported by Wahid (1984) in which slight shading provides positive effect on growth and yield on black pepper varieties of Belantung and Lampung Daun Lebar. Furthermore, it is noted that 25%-50% shadings generate significant increment on length of ortotroph branch, number of plagiotroph branches and leaf number of black pepper after seven-month planting. However, heavy shadings inhibit growth and decrease plant production. Number of plagiotroph branch and leaf number of Belantung variety under 50-75% shadings (Wahid 1984). Such information is still limited and important to know the response of some varieties and the role of hormones on morphological change under several shading levels. This research is conducted to figure out the effect of shadings on hormones and growth of several varieties of black pepper (*Piper nigrum* L.).

MATERIALS AND METHODS

Study area

The study was carried out on July-December 2017 in Kemuja Village, Sub-district of Mendobarat, District of Bangka, Province of Kepulauan Bangka Belitung, Indonesia (Figure 1). The experiment was demonstrated under split-plot design with three replications. The main plot was light intensity levels and subplot was black pepper varieties. Three varieties of black pepper plant, i.e. Petaling 1, Petaling 2 and Nyelungkup, were planted in the field under three light intensity levels, namely 100%, 75%, and 50%. The light intensities were regulated by making a shade from black polynet. The light intensity of 100%, 75% and 50% covered by a shade 0%, 25% and 50%, respectively. The light intensity levels of treatments were continuously applied for five months.

The shading was made from black polynet with 2 m in height from soil surface and treatment plot of 5 × 9 m in dimension. One-node and 5-month old cuttings of black pepper were planted with planting distance of 80 × 80 cm. They were supported by deadwood poles with 1.5 m in height. The plants were fertilized according to Wahid (1984) namely 25 g NPK (12: 12: 17) per plant for each distribution of fertilizer. Fertilization was implemented for five times. Other maintenance measures were weed control, binding of ortotroph branch as well as pest and disease management following field condition.

Procedure

Some parameters were recorded, such as microclimates, auxin, gibberellin and zeatin, morphological characteristics of the branch, leaf, and root as well as plant dry weight and plant growth analysis. The intensity of sunlight was observed every week using lux meter. At the same time, the temperature and air humidity were recorded using termohigrometer. The hormones and plant morphological characteristics, such as branch, leaf, and root were noticed five months after planting. The auxin, gibberellin and zeatin hormones were analyzed using method of Linskens and Jackson (1987). A total of 5 g of black pepper fresh leaves was ground using liquid nitrogen in mortal and then homogenized with 20 ml of 65% of MeOH. The extracts were centrifuged at 4,000 rpm for 30 min. The supernatant was filtered using miliphore. A total of 5-10 µl of supernatant was injected using HPLC using mobile phase of MeOH 65%, C18 Column at 40ºC, flow rate of mobile phase about 0.5 ml/min and injection pressure at 900 psi and then detected using UV-VIS (Shimadzu DGU-20A5) at wavelength of 254 nm. The contents of auxin, gibberellin, and zeatin were calculated using the formula:

Content of auxin/gibberellin/zeatin =

$$\frac{\text{Width of sample area in chromatogram}}{\text{Width of standard area}} \times \text{Concentration standard}$$

Leaf area, as well as length and area of root surface, were measured using leaf area meter. Dry weight of leaf, branch, and root was obtained by heating them at 65ºC for 48 h in oven or until their weight was constant. Plant growth analyses included:

Leaf area ratio (LAR) ($cm^2\ g^{-1}$)

$$\text{LAR} = \frac{\text{La}}{\text{W}}$$

Nett Assimilation Rate (NAR) ($g\ dm^{-2}\ week^{-1}$)

$$\text{NAR} = \frac{\text{W2 - W1}}{\text{T2 - T1}} \times \frac{\ln\text{La2} - \ln\text{La1}}{\text{La2 - La1}}$$

Crop Growth Rate (CGR) ($g\ m^{-2}\ week^{-1}$)

$$\text{CGR} = \frac{1}{\text{Ga}} \text{ x } \frac{\text{W2 - W1}}{\text{T2 - T1}}$$

Where: Ga: ground area, W: plant dry weight, W1: plant dry weight at first destructive (g), W2: plant dry weight at second destructive (g), T1: plant age at first destructive (week), T2: plant age at second destructive (week), La1: leaf area at first destructive (dm^2); La2: leaf area at second destructive (dm^2). The first destructive was done at twenty weeks after planting and the second destructive at twenty-five weeks after planting.

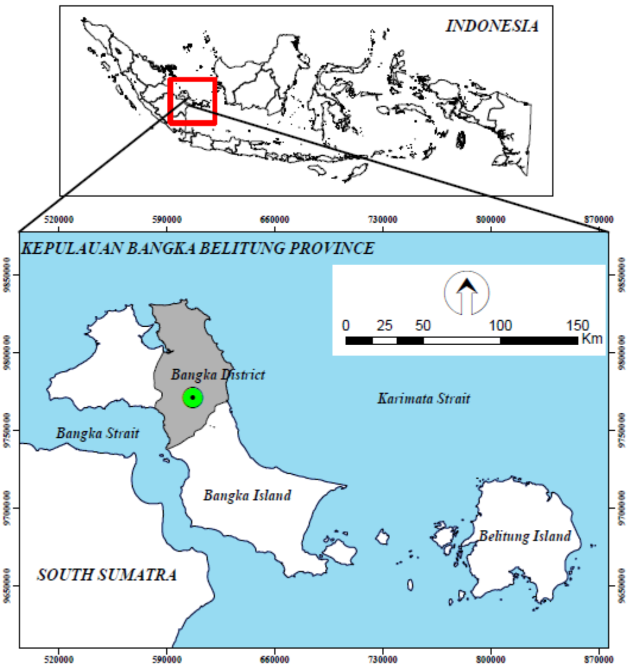

Figure 1. Location of (●) Kemuja Village, Mendobarat Sub-district, Bangka District, Province of Kepulauan Bangka Belitung, Indonesia

Data analysis

Data were statistically analyzed with ANOVA to recognize the interaction between two treatment factors. The significant difference was continued with HSD Tukey test at 5% level. The correlation test to determine the relationship between auxin and gibberellin with plant morphology. The statistical analysis uses SAS 9.4 program.

RESULTS AND DISCUSSION

Microclimate

Microclimates including incidence of light intensity, temperature and air humidity at every light intensities level during this experiment were presented in Table 1. The means incidence of light intensity of 100%, 75% and 50% were 68,000 lux, 48,000 lux and 32,000 lux, respectively. Light contained a number of photon energy generating heat so that it affected the temperature and air humidity. Air temperature and air humidity were relatively same under all light intensity levels. Air temperatures in the morning and noon were above optimum temperature for the growth of black pepper whereas that in the afternoon was in the optimum range. According to Nair (2011), the optimum temperatures for optimum growth of black pepper were in ranges of 21-27^{o}C, 25-32^{o}C and 24-30^{o}C in the morning, noon and afternoon, respectively. Furthermore, it was explained that Air humidity at the noon was over the optimum for the growth of black pepper while those in the morning and afternoon were in optimum ranges. Optimum humidity for the growth of black pepper was 60-80% in range.

Hormone content

Signal of light intensity impacted hormonal biosynthesis. It was indicated by the different contents of gibberellin and auxin among light intensity levels but the content of zeatin was similar. The results showed that the content of leaf gibberellin was influenced by the interaction of variety and light intensity levels (Table 2). The 50% and 75% light intensity increased the content of gibberellin on three varieties of black pepper. Light intensity of 75% raised up the content of leaf gibberellin on varieties of Nyelungkup and Petaling 1, however light intensity of 50% reduced the content of gibberellin in which its value was not significantly different with 100%. Dissimilar to the other two varieties, the content of gibberellin on Petaling 2 was not affected by shading. It revealed that the increment on content of leaf gibberellin of black pepper was not directly proportional to the decrease of light intensity. According to Casal (2013), the expression of genes for biosynthesis of gibberellin was sensitive against light alteration. The change of signal on light intensity was received by phytochrome of photoreceptor. Phytochrome was the pigment of protein on photoreceptors for red and far-red light, therefore the quantity in ratio of red and far-red light (R: Fr) determined the number of light absorption by phytochrome (Possart et al. 2014). The increase of gibberellin content occurred since phytochrome induced the expression of GA 20-oxidases and GA 3^{β}-hydroxylase genes (Yamaguchi et al. 1998). GA 20-oxidases converted GA 53 into GA 20 whereas GA 3^{β}-hydroxylase converted GA 20 into GA 1 (Kamiya and Martinez-Garcia, 1999).

The content of leaf auxin was not affected by interaction of varieties and light intensity levels. The content of auxin was similar among varieties but it was significantly different among light intensity levels. Plants under 50% and 75% light intensities synthesized higher auxin than those 100% light intensity. The highest auxin content was synthesized by plants under light intensity of 75%. Auxin content decreased at 50% light intensity but it was still above the content under 100% light intensity (Table 3). Induction of auxin synthesis at low light intensity had been reported on *Ipomoea batatas* (L.) Lam, and *Vitis vinifera* (Wang et al. 2014; GonzaÂlez et al. 2016). Similar to gibberellin, stimulation of auxin synthesis at low light intensity was determined by activity of phytochrome. Rapid biosynthesis of auxin was required on the shade avoidance response also and its transport to promote elongation growth (Li et al. 2012). According to Tao et al. (2008) and Halliday et al. (2009), the induction of auxin synthesis by phytochrome passed two ways, namely suppressing the expression of SUR2 gene and increasing the expression of TAA1 gene. Furthermore, It was explained that SUR2 was gen inducing enzyme of cytochrome P450 monooxygenase CYP83B1 forming indole glucosinolate while TAA1 was enzyme of tryptophan aminotransferase converting tryptophan into indole-3-acetic acid (IAA). Synthesis of auxin through TAA1 was the main pathway to increase the content of auxin in responding to the alteration of light environment (Tao et al. 2008).

Table 1. Light intensity incidence, temperature and air humidity at several illumination levels

Treatments (light intensity levels (%))	Light intensity incidence (Lux)	Temperature (^{o}C)	Air humidity (%)
Morning (07.00 am-08.00 am)			
100	33,328.96±2,039.39	30.52±0.40	68.24±1.84
75	21,995.03±1,374.60	30.22±0.37	68.54±1.79
50	14,893.10± 938.73	29.90±0.37	68.77±1.80
Noon (11.30 am-12.30 pm)			
100	83,660.57±4,862.16	35.33±0.28	37.84±1.43
75	61,436.32±3,796.03	35.01±0.24	39.40±1.29
50	40,953.90±2,770.07	34.37±0.32	40.43±1.86
Afternoon (16.00 pm-17.00 pm)			
100	18,943.54±2,822.27	30.72±0.66	66.91±2.97
75	13,588.87±2,057.91	30.55±0.60	66.95±2.93
50	8,889.79±1,260.23	30.31±0.59	67.07±2.91

Table 2. Content of leaf gibberellin (ng g^{-1}) on three varieties of black pepper at several light intensity levels

Light intensities (%)	Varieties			Average
	Nyelungkup	Petaling 1	Petaling 2	
100	0.510d	0.635cd	0.885bcd	0.677
75	2.238a	1.779ab	1.725ab	1.914
50	0.540d	0.655cd	1.590abc	0.928
Average	1.093	1.023	1.400	(+)

Note: Numbers followed by similar letters on the same column and row were not significantly different at 5% level. (+) = There was interaction

Table 3. Contents of leaf auxin and zeatin on black pepper under treatments of varieties and light intensity levels

Treatment	Hormone (ng g^{-1})	
	Auxin	Zeatin
Varieties		
Nyelungkup	2.49a	0.08a
Petaling 1	2.17a	0.08a
Petaling 2	2.75a	0.09a
Light intensities (%)		
100	1.59c	0.09a
75	3.65a	0.08a
50	2.17b	0.09a
Interaction	(-)	(-)

Note: Numbers followed by similar letters on the same column were not significantly different at 5% level. (-) = No interaction

Table 4. Leaf number on three varieties of black pepper at several light intensity levels

Light intensities (%)	Varieties			Average
	Nyelungkup	Petaling 1	Petaling 2	
100	39.17ed	34.67ed	20.00e	31.28
75	134.33a	114.33ab	50.00c-e	99.55
50	94.17a-c	75.00cd	63.67b-e	77.61
Average	89.22	74.67	44.56	+

Note: Numbers followed by similar letters on the same column and row were not significantly different at 5% level. (+) = Interaction

Table 5. Leaf area (cm^2) on three varieties of black pepper at several light intensity levels

Light intensities (%)	Varieties			Average
	Nyelungkup	Petaling 1	Petaling 2	
100	926.20b-d	703.20cd	371.70d	667.03
75	3,559.50a	3,274.40a	1,362.30a-d	2,731.90
50	2,550.20ab	1,840.60a-c	2,470.70ab	2,287.17
Average	2,345.30	1,939.40	1,401.57	+

Note: Numbers followed by similar letters on the same coloumn and row were not significantly different at 5% level. (+) = Interaction

Table 6. Leaf area ratio (LAR) (cm^2 g^{-1}) on three varieties of black pepper at several light intensity levels

Light intensities (%)	Varieties			Average
	Nyelungkup	Petaling 1	Petaling 2	
100	48.076bc	56.201a-c	35.874c	46.717
75	61.413a-c	71.189ab	67.077a-c	66.559
50	64.280a-c	56.706a-c	86.207a	69.064
Average	57.923	61.365	63.053	+

Note: Numbers followed by similar letters on the same column and row were not significantly different at 5% level. (+) = Interaction

The content of leaf zeatin was not affected by light intensities, it's expected because of the zeatin content of leaf was low. According to Zdarska et al. (2015), that light is an important factor controlling cytokinin biosynthesis. It has reported by Kohler et al. (1980) that the cytokinin content of amaranthus was significantly affected by light. Therefore in further research, it's necessary to analyze the zeatin content of branches and roots. Hammerton et al. (1998) reported, branch cytokinins content of *Phaseolus vulgaris* seedlings was higher than leaves and roots as well as influenced by light.

Plant morphology

Leaf

Leaf number, leaf area, and leaf area ratio were affected by interaction of variety and light intensity (Table 4, 5, and 6). Light intensity up to 50% increased leaf number, leaf area and leaf area ratio on black pepper. Leaf number and leaf area on varieties of Nyelungkup and Petaling 1 were maximum at 75% light intensity while those three parameters on a variety of Petaling 2 tended to increase at low light intensity up to 50%. This information was parallel with the report of Kim et al. (2011) that leaf morphology on blueberry was significantly different among light intensity levels and it was higher on lower light intensity. Shape and dimension of leaf were the important factors affecting the absorption of sunlight. A plant having largest leaf number or leaf area absorbed more light intensity. Three variety of black pepper tested generated the leaf number and leaf area the same at 50% light intensity so that probably had the same adaptability under low light intensity. The value of leaf area ratio on Nyelungkup and Petaling 2 tended to rase up to 50% light intensity. Different from Petaling 1, the leaf area ratio was maximum at a 75% light intensity and decrease at 50% light intensity. There was not significantly different leaf area ratio of three varieties tested among at 50% light intensity with 75% light intensity.

Ortotroph and plagiotroph branches

The growth of ortotroph and plagiotroph branches was not affected by interaction of s variety and light intensity. Morphological characteristics of ortotroph branch were different among varieties, excluding the length of internodes. There was different dimension of ortotroph dimension between Nyelungkup and Petaling 1 varieties, while Petaling 2 tended to have smaller morphological dimension than two other varieties. The growth of ortotroph and plagiotroph branches was significantly influenced by light intensity. Length, diameter and length of internode on ortotroph increased up to 75% light intensity, but the decrement of light intensity to 50% did not increase the length, diameter of internode and length of internode on ortotroph even they tended to reduce (Table 7).

There was no difference in number of plagiotroph branches and length of internode on plagiotroph among tested varieties. Length of plagiotroph on Nyelungkup variety was not different from that of Petaling 1 and that Petaling 1 was not different from Petaling 2. However, plagiotroph branch on Nyelungkup was longer than that of Petaling 2. The light intensity until 75% increased the number and length of plagiotroph branch. The decrement of further light intensity to 50% did not increase the number and length of plagiotroph even they tended to decrease. Light intensity levels did not provide different effects on length of internode on plagiotroph branch (Table 7).

Similar findings were reported by Wahid (1984) that light intensity up to 50% generated significant effect on length of ortotroph branch and number of plagiotroph branch. Cagnola et al. (2012) reported that low light intensity also increased stem growth, internode length, and leaf area tomato. Light intensity less than 50% or light intensity less than 32,000 lux had the potential in inhibiting the growth of branch. The growth of ortotroph and plagiotroph branches was the mechanism in adaptation against low light intensity. The length of ortotroph and plagiotroph branches, as well as the number of plagiotroph branches, increased by 68%. 54% and 62%, respectively compared to the plants under full light intensity.

The increase in growth of branch was parallel with the increment of auxin content. The content of auxin about 2.17 ppm under 50% shading maximumly increased the growth of ortotroph and plagiotroph branches. The increment of auxin content around 3.65 ppm under 75% light intensity did not significantly increase the growth of branch on black pepper. The content of zeatin was relatively similar among light intensities while auxin was different so that the ratio of zeatin and auxin changed. Under 100% light intensity, the ratio of auxin and zeatin was the lowest and it increased at 75% light intensity. Under 50% light intensity, this ratio decreased again. The content of zeatin was lower than auxin indicated that the growth of shoot was more dominant than roots.

Root

The length of root and root area surface was not affected by interaction of variety and light intensity. Variety of Nyelungkup had the highest length and root area surface and the lowest ones were documented on variety of Petaling 2. The length and root area surface of Petaling 1 variety were not significantly different from those of Nyelungkup and Petaling 2 varieties. Plants under low light intensity (50% and 75%) produced larger length and root area surface than full light intensity (100%) plants. The length and root area surface were maximum at 75% light intensity but they were not significantly different with 50% light intensity (Table 8). Such as on branches, root growth was controlled by hormonal balance especially ratio of zeatin and auxin. Content of zeatin was constant among shadings whereas auxin changed so that ratio of zeatin and auxin changed as well. Under 100% light intensity, ratio of auxin and zeatin was lower and increased at 75% light intensity. Ratio of zeatin and auxin decreased again at 50% light intensity but it was relatively higher than that of 100% light intensity. The zeatin content was lower than auxin content indicated that the growth of roots was lower than shoot.

Table 8. Length of root and root surface area on three varieties of black pepper at several light intensity levels

Treatment	Root length (cm)	Root surface area (cm^2)
Varieties		
Nyelungkup	44.46a	1,919.30a
Petaling 1	28.48ab	1,260.60ab
Petaling 2	17.79b	792.50b
Light intensities (%)		
100	11.22b	523.30b
75	44.70a	1,927.20a
50	34.81a	1,521.80a
Interaction	(-)	(-)

Note: Numbers followed by similar letters on the same column were not significantly different at 5% level. (-) = No interaction

Table 7. Length, diameter, number, and length of internode on ortotroph branch as well as number, length and length of internode of plagiotroph branch on three varieties of black pepper at several light intensity levels

Treatment	Ortotrof length (cm)	Ortotorf diameter (mm)	Ortotrof internode length (cm)	Plagiotrof number	Plagiotrof length (cm)	Plagiotrof internode length (cm)
Varieties						
Nyelungkup	108.81a	6.24a	5.87a	10.22a	24.06a	4.44a
Petaling 1	99.72a	5.68ab	5.51a	9.78a	19.47ab	4.20a
Petaling 2	67.47b	5.32b	5.39a	7.22a	15.00b	4.35a
Light intensities (%)						
100	31.28b	4.83b	3.87b	4.50b	11.22b	3.52a
75	99.56a	6.53a	6.40a	12.00a	24.58a	4.66a
50	77.61a	5.88ab	6.51a	10.72a	22.72a	4.80a
Interaction	(-)	(-)	(-)	(-)	(-)	(-)

Note: Numbers followed by similar letters on the same column were not significantly different at 5% level. (-) = No interaction

Net assimilation rate and crop growth rate

Nett assimilation rate and crop growth rate were not influenced by interaction of variety and light intensity levels. The net assimilation rate of the three varieties tested was not significantly different but the growth rate was significantly different. The highest crop growth rate was noted on Nyelungkup variety, while the lowest ones were found on variety of Petaling 2 but they were not significantly different from those of Petaling 1 variety. Light intensity levels had merely impact on crop growth rate while nett assimilation rate was not significantly different among light intensity levels (Table 9). Light intensity of 75 % increased the crop growth rate but low light intensity of 50 % caused the crop growth rate decreased however it was not significantly different with that of 75% light intensity. Crop growth rate was related to number of assimilates produced by a plant. Leaf area was one of important factors in producing assimilates. The larger leaf area was produced by Nyelungkup variety and on the treatment of light intensities of 50% to 75%. Hence, under similar nett assimilation rates but different leaf areas, crop growth rate was different.

Plant dry weight

There was no interaction between variety and light intensity on dry weights of leaf, branch, root, and total. Three tested varieties had different dry weights of leaf, branch, root, and total. Variety of Nyelungkup had the highest dry weight, while the lowest one was found on variety of Petaling 2. The dry weight of Petaling 1 variety was not significantly different from that of Nyelungkup and Petaling 2 varieties. The dry weights of leaf, branch, root, and total were significantly different among light intensity levels but ratio of root and shoot was not different. The dry weight of plants exposed to 50% and 75% light intensity was higher and significantly different from plants exposed to 100% light intensity. The results showed that black pepper needs a light shade so that its growth optimal, however light intensity is less than 50% decrease plant growth. Maximum dry weight was produced at 75% light intensity. Plant dry weight showed decreasing trend at light intensity of 50% but it was not significantly different from that at 75% light intensity. The dry weight of plants exposed to light intensity of 75% increased three folds of the dry weight of plants exposed to light by 100% while its exposed to light intensity of 50% increased 2 folds (Table 10). Total plant dry weight was related to leaf area and NAR. The 75% light intensity produced the highest leaf area and NAR so that the produced total dry weight was higher. Similarly, variety of Nyelungkup had higher leaf area and NAR so that its dry weight was higher than that of Petaling 1 and Petaling 2 varieties.

Correlation of hormones with plant morphology

Branch

Hormones had important roles in the growth of ortotroph and plagiotroph branches. It was indicated by the value of coefficient correlation between hormone and branch. Correlation analysis revealed that auxin had positive correlation with length of ortotroph branch (r = 0.4938**), diameter of ortotroph branch (r = 0.5572**), number of internode on ortotroph branch (r = 0.3478*) and length of internode on ortotroph branch (r = 0.5408**). Auxin was also positively correlated with number of plagiotroph branch (r = 0.5408**), length of plagiotroph branch (r = 0.4962**) and length of internode on plagiotroph branch (r = 3418*). Gibberellin was only positively correlated with number of ortotroph branches (r = 0.3129*) and number of plagiotroph branches (r = 0.3278*) (Table 4).

Table 9. Net assimilation rate (NAR) and crop growth rate (CGR) on three varieties of black pepper at several light intensity levels

Treatment	NAR (mg dm^{-2} $Week^{-1}$)	CGR (g m^{-2} $Week^{-1}$)
Varieties		
Nyelungkup	4.89a	10.79a
Petaling 1	3.33a	6.28ab
Petaling 2	2.67a	4.65b
Light intensities (%)		
100	4.00a	2.91b
75	3.67a	10.89a
50	3.22a	7.94ab
Interaction	(-)	(-)

Note: Numbers followed by similar letters on the same column were not significantly different at 5% level. (-) = No interaction

Table 10. Dry weights of the leaf. branch, root, shoot, and total as well as the ratio of root shoot on three varieties of black pepper at several light intensity levels

Treatment	Leaf dry weight (g)	Branch dry weight (g)	Root dry weight (g)	Shoot dry weight (g)	Total dry weight (g)	Root shoot ratio
Varieties						
Nyelungkup	20.14a	18.91a	2.80a	39.06a	41.86a	0.074a
Petaling 1	14.52ab	15.75ab	1.91ab	30.27ab	32.18ab	0.059a
Petaling 2	9.88b	9.98b	1.11b	19.86b	20.97b	0.052a
Light intensities (%)						
100	6.43b	6.85b	0.70b	13.27b	13.98b	0.054a
75	22.34a	20.25a	3.05a	42.58a	45.63a	0.072a
50	15.78a	17.55a	2.07a	33.33a	35.40a	0.059a
Interaction	(-)	(-)	(-)	(-)	(-)	(-)

Note: Numbers followed by similar letters on the same column were not significantly different at 5% level. (-) = No interaction

Table 11. The value of Pearson coefficient correlation of auxin and gibberellin with morphological characteristics of black pepper

Parameter	Auxin	Gibberellin
Leaf number	0.5168**	0.3258*
Total leaf area	0.4938**	0.3699**
Leaf area index	0.4938**	0.3699**
Number of ortotroph branch	0.1589	0.3129*
Length of ortotroph	0.3769**	-0.0832
Number of internode on ortotroph branch	0.3478*	-0.1049
Length of internode on ortotroph branch	0.5408**	0.0636
Diameter of ortotroph branch	0.5572**	0.2972
Number of plagiotroph branch	0.5408**	0.3278*
Length of plagiotroph branch	0.4962**	0.0778
Length of internode on plagiotroph branch	0.3418*	0.0340
Length of root	0.4304**	0.2973
Root surface area	0.3995**	0.2672

Note: (*) Significant correlation at 1% level (**) Significant correlation at 5% level

These values exhibited that auxin had larger effect on the growth of branch than gibberellin. Such findings were also reported by Wang et al. (2014) that the elongation of branch on shaded-sweet potato was enhanced by auxin. However, according to Stamm and Kumar (2010), auxin and gibberellin were synergizing each other in controlling the growth of branch, especially under low light intensity.

Leaf

Leaf was formed in apical meristem of shoot so that it was affected by the activities of auxin and gibberellin. Correlation analysis revealed that auxin was positively correlated with leaf number (r = 0.5168**), total leaf area (r = 0.4938**) and leaf area index (r = 0.4938**). Similarly, gibberellin was also positively correlated with leaf number (r = 0.3258*), total leaf area (r = 0.3699**) and leaf area index (r = 0.3699**) (Table 11). Like the branch, based on the value of coefficient correlation, auxin had larger impact on the formation and growth of leaf. However, auxin and gibberellin were synergizing each other in the formation and growth of leaf as reported by Wu et al. (2017).

Root

The growth of root was only influenced by auxin. It was indicated by the correlation between auxin and root morphology. Length of root and root area surface were positively correlated with auxin (r = 0.4304** and r = 0.3995**) (Table 11).

The research found that three varieties of black pepper tested, given the same responses on all light intensity levels. The varieties of Nyelungkup and Petaling 1 generated the best growth. Full light intensity inhibits the growth of black pepper. Light intensity up to 50% increased the leaf formation as well as the growth of branch and root. However, the maximum value was obtained at 75% light intensity. The growth of leaf, branch, and root was controlled by indigenous of auxin synergizing with gibberellin.

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