Growth and fruit panicle responses of shrub pepper (*Piper nigrum* L.) to bio-mulch

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Abstract. Mulch, especially bio-mulch is important to prevent soil erosion, to increase soil organic and to contribute to nutrient supply. Research to know the growth and fruit panicle responses has been conducted in Cikabayan Station, Faculty of Agriculture, IPB University from December 2016 – August 2018. Two varieties of shrub pepper; Petaling 1 and Natar 2, have been planted in three treatments of biomulch, namely without biomulch as control, with *Arachis pintoi*, and with mixed legume cover crop of *Centrosema pubescens*, *Calopogonium mucunoides*, and *Pueraria japonica* in six replications. The number of leaves, plant height, canopy diameter, number of fruits branch, and fruit panicle have been observation monthly, started at 16 months after planting and lasted at 20 months. It was a different response of Petaling 1 and Natar 2 to the treatments. Consistently, the highest of leaves number, plant height, canopy diameter and fruit panicle of Petaling 1 have resulted in *Arachis pintoi*, followed by control and legume cover crop. As the same as Petaling 1, to the Natar 2, *Arachis pintoi* resulted in the highest fruit panicle. For the other parameter of Petaling 1 the influence of bio-mulch was not consistent. For increasing productivity, *Arachis pintoi* is recommended as bio-mulch.

Keywords: *Arachis pintoi*, Bio-mulch, *Calopogonium mucunoides*, *Centrosema pubescens*, *Pueraria japonica*,

1. Introduction

Spice crops first attracted Europeans to the East Indies. In Indonesia, pepper has grown for a long time before the colonial period as a smallholder estate crop and labor-intensive commodity. Black pepper and white pepper is one of the spice commodities exported by Indonesia. In 2016 Indonesia has shipped 53,100 Mt of pepper, valued at US$ 430.1 million [1]. Pepper plant needs soil with high fertility and good drainage. It will be better planted at land slope 3 - 8% with high soil C organic. Generally, the pepper is cultivated with a long stick made from wood as a died stick or some plant (e.g Ceiba pentandra, Gliricidia sepium, Erythrina variegata) planted nearby as a live stick. The died stick should support the plant up to 15 years so the stick with the such as quality becomes more expensive due to a decreasing supply of the wood. Meanwhile, the life stick will compete with pepper plants in capturing light, and absorbing water and nutrition. To overcome such problems the shrub pepper has been developed. It has
been indicated that the soil erosion will be a problem in planting the shrub pepper on the sloping land. Therefore, it needs looking for how to decrease soil erosion.

[2] reported that using a legume cover crop is an effective way of decreasing soil erosion on agriculture land. [3] stated that bio-mulch can be used to increase crop production. Legume cover crops (LCC) are classified as bio-mulch [4]. *Pueraria javanica* (*Pj*), *Colopogonium mucunoides* (*Cm*), and *Centroccema pubescens* (*Cp*) have been used as bio-mulch, insole or in the mixture.

[5] described that *Pj* is a vigorous, dense-growing vine cultivated in tropical countries as cover crop, green manure and fodder for livestock. The stems of *Pj* may root from the nodes and then develop many branches. *Cm* is a vigorous, hairy annual or short-lived perennial trailing legume. The *Cm* can reach several meters in length and form a dense, tangled mass of foliage, 30-50 cm deep. The root system of *Cm* is dense and shallow, at most 50 cm deep. *Cp* is is evergreen perennial climber growing to 0.5 m at a fast rate. The *Cp* is shade tolerant, and can persist even with shade levels as high as 80%.

The LCC in the mixture was more suggested for decreasing some effects of the unfavorable environment such as the present of drought and the attack of pests and disease. Besides the LCC, *Arachis pintoi* have also been known and used as bio-mulch [6]. The *A. pintoi* can be used to control weed, to conserve soil and water, and to decrease soil erosion, and [7] reported that it increased the propagation of soil microorganism such as mycorrhiza and rhizobium, which are antagonistic to *Phytophthora capsici* that caused root rot disease, a major disease of pepper. The research aimed to know the effect of legume cover crop as a soil and water conservation to the growth and yield of a shrub pepper.

2. Method
An experiment had been conducted from Dec 2016 - August 2018 in Cikabayan Field Experiment, Faculty of Agriculture, IPB University, West Java, Indonesia, located at South Latitude of 6o30” - 6o45” and East Longitude of 106o30” - 106o45”. Two pepper varieties of Petaling 1 and Natar 2 respectively had been grown at three levels of cover crops treatment. The experiment was conducted using a nested block design with six replicates. The treatments of each variety were without bio-mulch as a control (B0), with bio-mulch of *A. pintoi* (B1), and with bio-mulch mixed legume cover crop (B2) of *Cp*, *Cm*, and *Pj*. The Petaling 1 and Natar 2 were planted in a different area that was nearby. The size of each area was 25 m x 30 m. In each area, each variety of shrub pepper was planted in 8 rows. In the inner 6 rows of it were applied with the three of the treatment. Each row was used as replicates. The planting space of the shrub pepper was 3 meters between rows and 1.0 meters in rows. The along land of about 0.75 m in the right and left rows of the plant had been cleaned from weed for control (B0), covered with A. Pintoi (B1), and covered with mixed LCC (B2) and formed a strip. In one row had been planted with 30 trees of the shrub pepper.

The shrub pepper trees have been maintained for 16 months before observed. Manure had been applied in the hole at 2 weeks before planting, and surround at the distance of 25 centimeters from the tree base every six months after planting. The dosage of the manure was 5 kg plant\(^{-1}\). Besides the manure, the fertilizers of 75 g plant\(^{-1}\) of NPK Mutiara (15%-15%-15%) was applied every three months. Observation of some variables of growth i.e plant height, canopy diameter, number of leaves; and yield component i.e. number and length of flower panicle, and number and length of fruit panicle started at 16 months after planting (MAP) up to 20 MAP. Data were analyzed using the analysis of variance, then continued with the Duncan’s Multi Range Test. Some data were analyzed by counting the average.

3. Result and Discussion
To know the response of the shrub pepper to bio-mulch, it was observed some variables of growth and component of yield. The variable of growth observed was plant height and canopy diameter. The variable of yield component included fruit branches, length of flower and fruit panicle, number of flower and fruit panicle, and length of flower and fruit panicle. The following is the explanation of the bio-mulch effects.
3.1. Plant height and canopy diameter

Plant height and canopy diameter were observed at 16 – 20 MAP. The plant height of the shrub pepper that was measured from the base above ground to the top of the canopy did not significantly respond to bio-mulch treatment (Table 1). At the end of observation (20 MAP), the average plant height of the three treatments was 44.70 cm. The plant height was significantly affected by varieties. At 16 - 17 MAP, the plant height of Natar 2 was higher than Petaling 1. The effect of the variety to the plant height could be seen until the end of the observation. The average plant height of Natar 2 was 46.11 cm and Petaling 1 was 43.29 cm. The different height might be related to the morphological characteristic of the variety.

The canopy diameter also did not significantly respond to the bio-mulch treatment (Table 2). However, consistently the data indicated that the average canopy diameter of the shrub pepper covered with A. pintoi was wider than covered with mixed LCC and control. The average canopy diameter of Natar 2 (88.33 cm) was also wider than Petaling 1 (83.88 cm). It is also predicted that the different canopy diameters related to the morphological characteristic of the variety.

The height and canopy diameter of the shrub pepper covered with A. pintoi were slightly higher than covered with mixed LCC and control. It will be related to the improvement of soil nutrients and moisture content that covered with the A. pintoi. [3] reported that the total nitrogen (N) in soil with A. pintoi in tomato cultivation was twofold than without A. pintoi. It is predicted that increasing soil N will also happen in the shrub pepper cultivation grown with A. pintoi in this experiment. The increasing soil nutrient and soil moisture content boosted the vegetative growth of the shrub pepper with A. pintoi were higher than other treatments. The legume cover crop included A. pintoi has the capability in nitrogen fixation from the air that enrichment to soil nitrogen [8]. It was also reported that legume cover crop increased soil water content reserves [9].

| Table 1. The response of plant height to bio-mulch |
|-----------------------------------------------|
| Treatment                  | 16 MAP | 17 MAP | 18 MAP | 19 MAP | 20 MAP |
| Bio-mulch                   |        |        |        |        |        |
| Control                     | 38.21a | 40.20a | 42.23a | 42.67a | 43.67a |
| Arachis pintoi              | 41.27a | 43.53a | 46.00a | 45.99a | 45.45a |
| Mixed LCC                   | 37.79a | 41.31a | 42.90a | 42.24a | 44.97a |
| Variety                     |        |        |        |        |        |
| Petaling 1                  | 36.70b | 39.84b | 42.33a | 41.60a | 43.29a |
| Natar 2                     | 41.48a | 43.53a | 45.09a | 45.66a | 46.11a |

Notes: Figures in the column with the same letter in the bio-mulch or variety were not significantly different based on Duncan Multiple Range Test at 5% level; MAP = month after planting.

The shrub pepper grown with mixed LCC has a slightly lower canopy diameter than other treatments (Table 2). The mixed LCC grows faster than A. pintoi. The height of the mixed LCC sometimes the same with the pepper and even higher. So that in this research the mixed LCC was maintained to 25 cm height above the ground by cutting it. The stem of Pj, Cm, and Cp in mixture grown creeper and may twist to other plants up to several meters [10], included twisting to the pepper in this experiment. In the mixed LCC, the stems of Pj may root from the nodes and then develop many branches. The Cm can reach several meters in length and form a dense, tangled mass of foliage, 30-50 cm deep. The root system of Cm is dense and shallow, at most 50 cm deep. The Cp is evergreen perennial climber growing to 0.5 m at a fast rate. The Cp is shade tolerant and can persist even with shade levels as high as 80%. The morphological characteristic of leaves, stem, and root of the mixed LCC have caused the competition in capturing the light, absorbing water and nutrient with the shrub pepper. Finally, the growth of the shrub pepper covered by the mixed LCC decreased.
Table 2. The response of diameter canopy to bio-mulch

| Treatment       | Canopy diameter (cm) | 16 MAP    | 17 MAP    | 18 MAP    | 19 MAP    | 20 MAP    |
|-----------------|----------------------|-----------|-----------|-----------|-----------|-----------|
| Bio-mulch       |                      |           |           |           |           |           |
| Control         | 77.25a               | 82.08a    | 82.17a    | 84.00a    | 85.97a    |           |
| Arachis pintoi  | 84.06a               | 87.94a    | 88.72a    | 89.25a    | 90.50a    |           |
| Mixed LCC       | 72.79a               | 74.90a    | 77.57a    | 79.28a    | 81.85a    |           |
| Variety         |                      |           |           |           |           |           |
| Petaling 1      | 77.23a               | 79.63a    | 82.09a    | 81.85a    | 83.88a    |           |
| Natar 2         | 78.83a               | 83.66a    | 83.55a    | 86.50a    | 88.33a    |           |

Notes: Figures in the column with the same letter in the bio-mulch or variety were not significantly different based on Duncan Multiple Range Test at 5% level; MAP = month after planting.

Natar 2 variety showed the canopy height and diameter higher than Petaling 1 (Table 1 and Table 2). It was related to the morphological characteristic of the variety. [11] has described that the stem internode of Natar 2 (69 mm) was longer than Petaling (38 mm). The length of branches internode of Natar 2 (64 mm) was also longer than Petaling 1 (44 mm). The length of the stem internode and branches internode has contributed to the plant height and canopy diameter.

3.2. Fruit branches

Fruit branches are important for the yield component of the shrub pepper. Flower and fruit panicle will grow from the fruit branches. So that the number of fruit branches as a respond to bio-mulch has been observed. The average number of fruit branches of the shrub pepper did not significantly respond to bio-mulch. However, at all observation (16-20 MAP) the shrub pepper that grown with A. pintoi has fruit branches that were slightly higher than without bio-mulch and with mixed LCC (Table 3). The lower fruit branches of the pepper grown with mixed LCC was correlated to the canopy height and diameter that were lower than other treatments. The twisting stem and leaves of the mixed LCC had restricted to the growth and flowering of the shrub pepper.

The number of fruit branches was significantly affected by the variety at all observations (16-20 MAP). At the end of the observation, the variety of Natar 2 produced 155.4 fruit branches and Petaling 1 produced 109.6 fruit branches. The canopy size of the Natar variety was higher and wider than Petaling 1 (Table 1 and 2). Therefore, the fruit branches produced by Natar 2 variety was higher than Petaling 1 variety. The fruit branches were consistently correlated to the plant height and canopy diameter. The Natar 2 variety with a canopy that was higher and wider than Petaling 1 resulted in more fruit branches.

Table 3. The response of fruit branches to bio-mulch

| Treatment       | Number of fruit branches | 16 MAP    | 17 MAP    | 18 MAP    | 19 MAP    | 20 MAP    |
|-----------------|--------------------------|-----------|-----------|-----------|-----------|-----------|
| Bio-mulch       |                          |           |           |           |           |           |
| Control         | 100.7                    | 111.8     | 117.7     | 123.5     | 138.9     |           |
| Arachis pintoi  | 139.9                    | 141.8     | 153.8     | 132.3     | 142.1     |           |
| Mixed LCC       | 92.6                     | 109.2     | 109.9     | 107.1     | 116.6     |           |
| Variety         |                          |           |           |           |           |           |
| Petaling 1      | 92.92b                   | 104.0b    | 108.5b    | 102.3b    | 109.6b    |           |
| Natar 2         | 129.2a                   | 137.8a    | 145.8a    | 139.7a    | 155.4a    |           |

Notes: Figures in the column with the same letter in the variety were not significantly different based on Duncan Multiple Range Test at 5% level; MAP = month after planting.
3.3. Length of flower and fruit panicle

The bio-mulch treatment did not significantly affect the length of the flower and the length of the fruit panicle of the shrub pepper (Table 4). The average length of the flower and the fruit panicle of the treatments were 6.05 cm and 6.87 cm. For both varieties of Petaling 1 and Natar 2, the using of A.pintoi and mixed LCC did not increase the value of the two variables compared to the control.

The length of the flower and fruit panicle was significantly affected by the variety. The average length of the flower panicle and fruit panicle of Petaling 1 were respectively 4.87 cm and 5.46 cm. For Natar 2, the average value of those variables was 7.22 cm and 8.27 cm. For the two variables, Natar 2 was higher than Petaling 1. The different values of the two variables related to the variety characteristic [12]. [13] reported that the normal length of fruit panicle was 7-10 cm with about 30-70 berries. The length of fruit panicle that cultivated as the shrub pepper of the Natar 2 (8.27 cm) variety was normal and Petaling variety 1 was less than normal (5.46 cm).

Table 4. The response of the length of flower and fruit panicle to bio-mulch

| Treatment      | Variable                        | Lenght of flower (cm) | Lenght of fruit panicle (cm) |
|----------------|---------------------------------|------------------------|-------------------------------|
| Bio-mulch      |                                 |                        |                               |
| Control        |                                 | 5.64                   | 6.61                          |
| Arachis pintoi |                                 | 6.17                   | 6.96                          |
| Mixed LCC      |                                 | 6.33                   | 7.04                          |
| Variety        |                                 |                        |                               |
| Petaling 1     |                                 | 4.78b                  | 5.46b                         |
| Natar 2        |                                 | 7.22a                  | 8.27a                         |

Notes: Figures in the column with the same letter in the variety were not significantly different based on Duncan Multiple Range Test at 5% level; MAP = month after planting.

3.4. Number of flower and fruit panicle

Table 5 shows the number of flower panicles of the shrub pepper without bio-mulch (control) was higher than with A. pintoi and mixed LCC for almost all of the observation (16 – 20 MAP) for the two varieties. Especially for the Petaling 1 variety, the mixed LCC reduced the number of flower panicles. It was indicated that Petaling 1 variety was more susceptible in competition with mixed LCC in capturing light and absorbing water and nutrient than Natar 2 variety.

Table 5. The response of flower panicle to bio-mulch

| Variety        | Bio-mulch          | Average number of flower panicle |
|----------------|--------------------|---------------------------------|
|                |                    | 17 MAP  | 18 MAP  | 19 MAP  | 20 MAP  |
| Petaling 1     | Control            | 8.67a   | 22.33a  | 18.67a  | 13.50a  |
|                | Arachis pintoi    | 7.33a   | 18.08a  | 9.83b   | 14.67a  |
|                | Mixed LCC         | 1.67b   | 5.67b   | 4.58b   | 2.33b   |
| Natar 2        | Control            | 12.50ab | 25.58a  | 27.39a  | 32.06a  |
|                | Arachis pintoi    | 17.58a  | 21.17ab | 24.22a  | 11.67b  |
|                | Mixed LCC         | 8.11b   | 17.75b  | 16.45b  | 12.39b  |

Notes: Figures in the column in the same variety with the same letter were not significantly different based on Duncan Multiple Range Test at 5% level; MAP = month after planting.

The response of the flower panicle to the control treatment was not consistently followed by the number of fruit panicles (Table 6). The number of fruit panicles of the control was less than the shrub pepper covered with A. pintoi. The number of fruit panicles of the shrub pepper covered with mixed LCC was still the lowest. The response was predicted related to drought during 3 months later of the...
experiment. Rainfall during June-August 2018 was low with an average of 84 mm month\(^{-1}\) [14], nearly to the lowest rainfall needed for growing pepper, 83–250 mm month\(^{-1}\) [15].

Table 6. The response of fruit panicle to various bio-mulch

| Variety | Bio-mulch | Average number of fruit panicle |
|---------|-----------|------------------------------|
|         |           | 19 MAP | 20 MAP |
| Petaling 1 | Control     | 8.58\(^{b}\) | 12.17\(^{b}\) |
|          | Arachis pintoi | 10.83\(^{a}\) | 22.33\(^{a}\) |
|          | Mixed LCC   | 2.42\(^{c}\) | 5.42\(^{c}\) |
| Natar 2  | Control     | 5.42\(^{b}\) | 15.70\(^{b}\) |
|          | Arachis pintoi | 16.83\(^{a}\) | 21.17\(^{a}\) |
|          | Mixed LCC   | 7.75\(^{b}\) | 9.11\(^{c}\) |

Notes: Figures in the column in the same variety with the same letter in the bio-mulch or variety were not significantly different based on Duncan Multiple Range Test at 5% level; MAP = month after planting.

In the low level of soil moisture content due to the low rainfall, there were different effects of the treatments. It indicated that A. pintoi could conserved soil moisture better than the mixed LCC. Meanwhile, the mixed LCC that consisted of \(C_p\), \(C_m\), and \(P_j\) has some growth characteristics that compete on the growth of the shrub pepper. The mixed LCC competes in capturing light, absorbing water and nutrients from soil water which was higher than A. pintoi and control. The soil moisture content will be low. In the low of soil moisture content, the translocation assimilates that resulted by leaves photosynthesis to fruit panicles of the shrub pepper that grown with the mixed LCC will decrease.

Soil moisture content is one of the major factors for pepper growing. The growth and yield of pepper were responsive to soil moisture content. The highest number of fruit panicle were produced of the plant with bio-mulch of A. pintoi. It indicated that A. pintoi has conserved the soil from evaporation due to soil coverage [6], [16] stated that soil coverage needs to be conducted for decreasing evaporation during a dry season so that the pepper plant was not favorable to environmental stress. The pepper plantation without soil coverage will be destroyed 50–80\% more than the soil covered with A. pintoi.

At the end of observation June-August 2018, the rainfall was at the low level (84 mm month\(^{-1}\)) for growing the pepper. By using the A. pintoi as a legume cover crop, the soil moisture content could be maintained at a sufficient level during the dry season. Similarly, by using some kinds of legume cover crops (mucuna, cowpea, and dolichos), [17] reported that the soil moisture content increase with the range of 13.6 – 49.0\% compared to the control. [9] also reported the use of Nephrolepis biserrata as cover crops insole and in combination with ridge terrace has improved soil water content reserves by approximately 71\% and 12\%, respectively. The use of N. biserrata as a cover crop has reduced the rate of water loss by percolation and run-off, by approximately 36\%.

The increasing of soil moisture content caused that the assimilate resulted from leaf photosynthesis that translocated to flower panicle to be fruit panicle was higher. It was also in line with [18] that reported the increase of production due to the use of A. pintoi. The A. pintoi tolerant to drought, suitable to various soil and capable to grow on soil with low nutrients and high acidity [6] and tolerant to low light intensity up to 50\% [19]. With some characteristics, A. pintoi is potential to be a legume cover crop in cultivating shrub pepper reduced.

4. Conclusion

For better growing and high productivity of shrub pepper plantation through protection the soil from erosion and maintain the soil moisture, A. pintoi can be used as cover crops. To know further the effect of A.pintoi on the shrub pepper and yield, it is still needed an additional time for observation.
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