The role of organic fertilizer and plant material in the growth of pepper seeds for sustainable agriculture

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Abstract. Pepper (Piper ningrum L.) is one of Indonesia's most important spice commodities with high economic value. Pepper plants are propagated by vegetative methods using cuttings. Factors The origin of planting material and the application organic fertilizer can support the development of technology to provide good pepper propagation material. This study used Completely Randomized Group Design with two factors: the origin of planting material and organic fertilizers. The origin of planting materials was 2nd (S2), 3rd (S3), 4th (S4) and 5th (S5) node cuttings, while organic fertilizer used were fulvic acid (P1) and biological fertilizer. The results showed that organic fertilizers did not affect all observed parameters, while the origin of plant material affected the percentage of life cuttings, seed height, number of leaves, number of internodes and nodes, and number of branching plants. The origin of plant material that had the best results was the 3rd node cuttings (S3), while the best interaction of fertilizers and cuttings showed by combination of fulvic acid and 3rd node cuttings (P1S3). Further research was needed on the dose and frequency application of organic fertilizer.

Keywords: Growth Optimization; Piper nigrum L; Plant material; Organic fertilizer.

Introduction
Pepper (Piper ningrum L.) is one of Indonesia's most important spice commodities with high economic value. Indonesia is one of the main producers of pepper. There was a decrease in pepper crop plantation area and production in 2012-2015. The decline in pepper plantation area in Indonesia in 2012, 2013, 2014 and 2015 was 177,787 thousand ha, 171,920 thousand ha, 16,751 thousand ha and 167,590 thousand ha, respectively. Similarly, the decline in production was 87,841 thousand tons, 91,039 thousand tons, 87,448 thousand tons and 81,501 thousand tons, respectively. The decline was probably because this commodity was cultivated by smallholder farmers in the form of small plantations which was cultivated for generations and highly labour intensive. So that pepper cultivation activities became less intensive. Several regions that were the production centres of pepper commodities were Bangka Belitung, Lampung, South Sumatra, East Kalimantan and South Sulawesi [1].

Pepper as one of mainstay exported commodities requires technological support that can improve its cultivation efficiency and increase national productivity. Pepper cultivation needs high quality planting material as the determining aspect of growth and production. Pepper planting material can be propagated vegetatively and generatively.
Propagation with stem cuttings is generally easier and cost effective because the stem provides a sufficient source of energy to support growth in the early stage. [2] explained that the selection of stem cuttings should consider the age of the stem. When stem used as planting material is too old, it will be difficult to form roots, when it is too young, the rate of transpiration is high so that the cuttings will be weak and die. In addition, there are several factors that influence the success of stem cuttings, namely the origin of cuttings, cuttings length, and environment (rooting media, humidity, temperature and light).

The best source of pepper planting material is climbing tendrils, originating from plants less than 3 years old (have not producing), free of pest and pathogen. The planting material of climbing pepper cuttings comes from stem cuttings that have sticky roots. Single leafed, one node cutting has the advantage of efficient planting material utilization. Seeding and transplant technique is used when using one node cutting as planting material, so the use of short cuttings can reduce mortality rate by up to 10% [3].

Nursery activities are important preparing good planting material. One of the supporting factors for the success of planting materials to grow well is to use the appropriate composition of the planting media. [4] explained that a good planting medium must have the ability to hold water, have loose structure, aeration and good drainage, a pH that is suitable for the type of plant and contains nutrients to support plant growth. [5] added that good planting medium for the growth of pepper seedling is the combination of soil, sand, and manure with ratio of 2: 1: 1, that composition of planting medium produces 96% cuttings viability.

One technology in accelerating the growth of pepper seeds is by adding fertilizer as nursery activity. The use of fertilizer which is considered safe for the growth of pepper cuttings is organic fertilizer. Organic fertilizers are fertilizers which mostly or entirely consist of organic material derived from plants and or animals that have been through an engineering process, can be solid or liquid which is used to supply organic materials to improve the physical, chemical and biological properties of the soil [6]. The application of humus and liquid biological fertilizer is expected to accelerate the growth of plants.

The origin of planting material and the application of organic fertilization are expected to be a consideration in conducting pepper nurseries. Therefore, information regarding research on the origin of cuttings and the application of appropriate organic fertilization is needed. It is expected that the growth and success of vegetative pepper propagation in nurseries with a single leafed node can be accelerated, thus supporting the development of pepper cultivation business.

2. Materials and Methods

2.1. Experimental Site

This research was conducted from January to June 2018, located at Gunung Gede Experimental Field, Bogor Agricultural University. Planting medium analysis was conducted at ICBB Environmental Biotechnology Laboratory, while leaf nutrient analysis, chlorophyll destructive observation, and dry weight were conducted at Agronomy and Horticulture Department Laboratory, Faculty of Agriculture, Bogor Agricultural University.

This research used cuttings of Natar pepper variety and the cuttings were originated from different position on mother plant. Planting medium used was a combination of soil, sand and manure with ratio of 2:1:1. The soil type used was red-yellow podzolic soil from Jasinga Bogor area. The fertilizers used as treatment were organic fertilizer 1 contained fulvic acid and organic fertilizer 2 that was biological fertilizer containing microbes. The tools used were common agricultural tools, measuring tapes, scales, polybags sized 15 x 20 cm, cutting scissor, camera, and laboratory equipment.

2.2. Experimental Design

Experimental design used was Completely Randomized Block Design with two factors. First factor was organic fertilizer, with three treatments that were without application of organic fertilizer (P0), application of organic fertilizer 1 (P1), and application of organic fertilizer 2 (P2). The second factor was origin of planting material (four treatments) which was 2nd (S2), 3rd (S3), 4th (S4), and 5th (S5) node.
There were 12 combination of treatments, with three replications, which made 35 experimental unit. Each experimental unit consisted of 15 sample plants, which made 540 observed sample plants.

The research was conducted in nursery building with area of 10 x 5 m. There were three confinement units with area of 4 x 1.2 m each for pepper seedling initiation stage. Planting medium was mixed in closed condition inside the nursery building with composition of soil, sand and manure (2:1:1), and then put inside polybags sized 15 x 20 cm.

Pepper seedling cuttings were planted in prepared medium and arranged in accordance with the experimental design. Seedling initiation was conducted under hoods for 4 weeks. Maintenance included checking medium humidity by watering the medium twice a day and opening the hood for one hour in the morning to keep temperature from going too hot. At 3 weeks after planting (WAP), one side of the hoods were opened gradually, until opened completely at 4 WAP. Fertilizer application was conducted every week from 4 WAP to 19 WAP, with dosage of 10 ml per seedling.

Observations were conducted from 5 WAP to 20 WAP or after one week from fertilizer application. Observations were conducted on agronomic aspects such as original cutting length, percentage of live plants, seedling height, number of leaves, number of branching plants, number of internodes for 20 WAP. Environmental observations included humidity (RH), temperature (°C), sunlight intensity (%), luminous emittance (lux), and pest and disease found in pepper plant. Obtained data was analyzed using SAS 9.4 software for analysis of variance test-F with alpha of 5 % and 1 %. If the data was significantly different, further test of Duncan Multiple Range Test (DMRT) was conducted to compared average of every variable [7].

3. Results And Discussion

3.1. Pepper Seedling Growth Response

Pepper propagation usually use single node cutting that was planted under hood for 4 weeks. Environmental requirements for climbing pepper seedling nursery based on BSN Indonesia are sunlight intensity of 50 – 70%, temperature of 22-30 °C, and humidity (RH) > 80% (BSN 2006). Observation of micro-climate showed that research location had met those requirements (Table 1). The diseases found were stem rot caused by fungi Phytophthora capsici and leaf curls cause by green or white aphids (Aphis sp.) as vector. Pests found were stem borer (Lophobaris piperis) and grasshopper that caused rotten and broken tip. The severity of pest and disease attack in nursery was low, but pest management was conducted by spraying fungicide and insecticide every two weeks with dosage of 2 g l⁻¹ to prevent outbreak.

| Location                  | RH (%) | Temperature (°C) | Sunlight intensity (%) | Luminous emittance (lux) |
|---------------------------|--------|-----------------|------------------------|--------------------------|
| Nursery hood (0-4 MST)    | 93.2   | 23.0            | 32.0                   | 1704                     |
| Nursery building (5-20 MST)| 83.2   | 25.3            | 59.6                   | 3494                     |

Result of anova of growth and physiology of climbing pepper seedling was not significantly different on original cutting length, number and density of stomata. These parameters were not affected as was shown by the low coefficient of determination (R²) that was ≤ 50%. Significant difference from treatments was shown on percentage of live plants, seedling height, number of leaves, number of branching plants, and number of internodes and nodes. Those parameters were significantly affected as was shown by high low coefficient of determination (R²) that was ≥ 50% (Table 2). Value of R² determined the effect of other variables (error) outside of treatments free variables (x) against result (y). Parameters with R² ≤ 50% were mostly affected by other variables (error) thus had insignificant value on every treatment, while parameters with R² ≥ 50% were dominantly affected by treatment (x) thus had significant value on one of the treatments.
3.2. Percentage of live plants

Surviving pepper seedling at 20 WAP had different percentage of live plants. The effect of treatments showed that the average of live plants was higher than 77% (Table 3). Treatment of organic fertilizer 2 (P2) had only improved percentage of live plants by 7.38% compared to without application of organic fertilizer (P0). The improvement was because of higher availability of C-organic, nutrients, and microorganism in the P2. This was in accordance with [8] that showed application of rhizobacteria *Bacillus cereus* in pepper cutting could improved percentage of live plants to 96% compared to control of no application of *B. cereus*.

[9] explained that biological fertilizer was utilization of active biological product containing soil enhancer bacteria to increase fertilizer efficiency, soil health and fertility. Fertilizer efficiency could be improved by using N2 fixation, P and K solvent microbes. Application of soil enhancer bacteria could improve the availability of soil nutrients and plant metabolites for plants, and also protect plant roots from pest and disease.

Treatment of the origin of cutting materials had a significant effect on the percentage of live plants. Table 3 shows that the lowest percentage of live plants came from the 5th node (S5) cutting, which was 77.38%, while the highest percentage of live plants came from the 3rd node (S3) cutting which was 95.56%. The low percentage value of live plants on the S5 was thought to came from the length of the cutting. This could be seen in the length of the original cutting, S5 was the shortest compared to the others. The ability of cuttings to survive was affected by the availability of nutrients in the cutting material in the early stage of growth, where the shorter cuttings would lose nutrients faster. [10] added that the pepper cuttings originated from the middle, that were 2nd and 3rd node were the optimum cuttings, and were able to initiate roots better and survive better.

| Observation parameter       | Fertilizer (P) | Cutting (S) | Interaction (PxS) | CV   | R²  |
|----------------------------|----------------|------------|-------------------|------|-----|
| Original cutting length (cm)| ns             | ns         | ns                | 15.65| 0.38|
| Percentage of live plants (%)| ns             | *          | ns                | 12.14| 0.52|
| Seedling height (cm)        |                |            |                   |      |     |
| 10 WAP                      | ns             | **         | *                 | 23.21| 0.80|
| 12 WAP                      | ns             | **         | ns                | 17.22| 0.73|
| 14 WAP                      | ns             | **         | *                 | 12.37| 0.81|
| 16 WAP                      | ns             | **         | ns                | 13.08| 0.68|
| 18 WAP                      | ns             | **         | ns                | 11.27| 0.70|
| 20 WAP                      | ns             | **         | ns                | 10.52| 0.69|
| Number of leaves            |                |            |                   |      |     |
| 14 WAP                      | ns             | **         | ns                | 18.88| 0.73|
| 16 WAP                      | ns             | **         | ns                | 15.33| 0.71|
| 18 WAP                      | ns             | **         | ns                | 10.96| 0.68|
| 20 WAP                      | ns             | **         | ns                | 11.52| 0.61|
| Number of internodes        |                |            |                   |      |     |
| 14 WAP                      | ns             | **         | ns                | 14.77| 0.77|
| 16 WAP                      | ns             | *          | ns                | 12.34| 0.71|
| 18 WAP                      | ns             | *          | ns                | 10.02| 0.65|
| 20 WAP                      | ns             | *          | ns                | 9.01 | 0.65|
| Number of branching plants  |                |            |                   |      |     |
| 14 WAP                      | ns             | **         | ns                | 25.24(t)| 0.58(t)|
| 16 WAP                      | ns             | **         | ns                | 17.51(t)| 0.68(t)|
| 18 WAP                      | ns             | **         | ns                | 16.41(t)| 0.61(t)|
| 20 WAP                      | ns             | *          | ns                | 16.40(t)| 0.56(t)|

Notes: (ns): not significant, (*): significant at alpha 5%, (**): significant at alpha 1%, CV: coefficient of variation, (t): transformed value of √(x+0.5).
Table 3. Average of percentage of live plants and original cutting length

| Treatment                | Percentage of live plants (%) | Original cutting length (cm) |
|--------------------------|-------------------------------|-----------------------------|
| **Organic fertilizer**   |                               |                             |
| P0                       | 84.70                         | 3.93                        |
| P1                       | 88.61                         | 4.44                        |
| P2                       | 92.08                         | 4.14                        |
| **Notation**             | ns                            |                             |
| **Origin of plant material** |                             |                             |
| S2                       | 91.67 a                       | 4.38                        |
| S3                       | 95.56 a                       | 4.21                        |
| S4                       | 89.25 a                       | 4.13                        |
| S5                       | 77.38 b                       | 3.96                        |
| **Notation**             | *                             |                             |

Notes: (ns): not significant, (*): significant at alpha 5%, numbers followed by the same letter was not significantly different on DMRT 5%.

3.3. Seedling Height

Organic fertilizer treatment did not affect seedling plant, while origin of planting material significantly affected seedling height from 10 WAP to 20 WAP. Interaction between fertilizer and origin of planting material affected seedling height from 10 WAP to 14 WAP (Table 2). Organic fertilizer treatment did not significantly affect seedling height. This was shown by the small difference on variables on fertilizer treatment. Significant difference was observed on origin of planting material treatment from 10 WAP to 20 WAP. Cutting that originated from 3rd node had the best seedling growth from 12 WAP. Significant difference also observed on cutting originated from 5th node (S5) that had the lowest seedling height (Table 4). The use of S3 cutting that was relatively young can increase seedling height by 5.07 cm.

Table 4. Average of climbing pepper seedling height

| Treatment                | 10 WAP | 12 WAP | 14 WAP | 16 WAP | 18 WAP | 20 WAP |
|--------------------------|--------|--------|--------|--------|--------|--------|
| **Organic fertilizer**   |        |        |        |        |        |        |
| P0                       | 6.00   | 10.34  | 13.77  | 17.97  | 24.34  | 31.05  |
| P1                       | 5.65   | 9.90   | 14.04  | 18.34  | 24.07  | 31.05  |
| P2                       | 5.98   | 10.19  | 14.10  | 18.11  | 23.63  | 29.49  |
| **Notation**             | ns     | ns     | ns     | ns     | ns     | ns     |
| **Origin of planting material** |        |        |        |        |        |        |
| S2                       | 7.05 a | 11.50 a| 15.85 a| 19.40 ab| 25.53 ab| 32.24 ab|
| S3                       | 6.84 a | 11.57 a| 15.60 a| 20.13 a| 26.29 a| 32.89 a|
| S4                       | 5.65 a | 9.53 b | 13.24 b| 17.40 bc| 22.88 bc| 29.17 bc|
| S5                       | 3.99 b | 7.96 b | 11.19 c| 15.63 c| 21.35 c| 27.82 c|
| **Notation**             | **     | **     | **     | **     | **     | **     |

Notes: (ns): not significant, (**): significant at alpha 1%, numbers followed by the same letter was not significantly different on DMRT 5%.

3.4. Number of Leaves

Fertilizer treatment did not affect the number of leaves, shown in Table 5. The difference of number of pepper leaves was observed on origin of planting material treatment. Very significant difference was observed on 14 WAP to 20 WAP. Cutting from 3rd node (S3) had the highest number of leaves while S5 had the least. High number of leaves on S2 and S3 was because younger planting material origin, making faster cell and organ development.
3.5. Number of Nodes and Internodes

The average number of nodes and internodes did not appear to be significantly different in the treatment of organic fertilizer, but has a very significant difference in the treatment of origin of planting material. Cutting from the 3rd node had higher number of nodes and internodes than the others, amounting to 8 at 20 WAP, while the number of internodes in fertilizer and other cutting treatments amounted to 7 (Table 6). The number of nodes and internodes became a reference in the selection of seedling that would be ready for planting. The quality of the climbing pepper seedlings ready for planting according to BSN Indonesia is to have 5-7 segments [11].

**Table 5.** Average of number of pepper leaves

| Treatment                  | Number of leaves |          |          |          |
|----------------------------|------------------|----------|----------|----------|
|                            | 14 WAP           | 16 WAP   | 18 WAP   | 20 WAP   |
| Organic Fertilizer         |                  |          |          |          |
| P0                        | 3.14             | 4.89     | 6.94     | 9.04     |
| P1                        | 3.16             | 5.26     | 7.18     | 9.27     |
| P2                        | 3.28             | 5.19     | 7.09     | 9.02     |
| Notation                  | ns               | ns       | ns       | ns       |
| Origin of planting material |                  |          |          |          |
| S2                        | 3.68 a           | 5.61 a   | 7.59 a   | 9.71 a   |
| S3                        | 3.64 a           | 5.82 a   | 7.74 a   | 9.88 ab  |
| S4                        | 2.93 b           | 4.81 b   | 6.77 b   | 8.75 bc  |
| S5                        | 2.52 b           | 4.20 b   | 6.18 b   | 8.10 c   |
| Notation                  | **               | **       | **       | **       |

Notes: (ns): not significant, (**): significant at alpha 1%, numbers followed by the same letter was not significantly different on DMRT 5%.

**Table 6.** Average of number of nodes and internodes of pepper seedling

| Treatment                  | Number of nodes and internodes |          |          |          |
|----------------------------|--------------------------------|----------|----------|----------|
|                            | 14 WAP                        | 16 WAP   | 18 WAP   | 20 WAP   |
| Organic Fertilizer         |                                |          |          |          |
| P0                        | 3.12                          | 4.55     | 6.01     | 7.64     |
| P1                        | 3.12                          | 4.71     | 6.17     | 7.81     |
| P2                        | 3.09                          | 4.56     | 6.00     | 7.34     |
| Notation                  | Ns                             | ns       | ns       | ns       |
| Origin of planting material |                                |          |          |          |
| S2                        | 3.47 a                        | 4.75 a   | 6.30 a   | 7.89 a   |
| S3                        | 3.55 a                        | 5.05 a   | 6.48 a   | 8.00 a   |
| S4                        | 2.94 b                        | 4.56 ab  | 5.99 ab  | 7.51 ab  |
| S5                        | 2.48 c                        | 4.07 b   | 5.47 b   | 6.98 b   |
| Notation                  | **                            | *        | *        | *        |

Notes: (ns): not significant, (*): significant at alpha 5%, (**): significant at alpha 1%, numbers followed by the same letter was not significantly different on DMRT 5%.

3.6. Number of Branching Plants

Pepper seedling started to branch at 14 WAP. Number of branches was mostly one, but there was small amount of seedling that had 2 to 3 branches at 16 to 20 WAP. Average of number of branching plant was not significantly different in organic fertilizer treatment and was significantly different in origin of planting material treatment. Highest number of branching plants was found on S3 cuttings. Showed in Table 7, in the end of observation at 20 WAP, number of branching plants of S3 was 11 seedlings. Branches in pepper plant was affected by the age of cutting origin, where the younger the faster cell differentiation and development.
Table 7. Average of number of branching plants in pepper

| Treatment                      | Number of branching plant |
|--------------------------------|---------------------------|
|                                | 14 WAP | 16 WAP | 18 WAP | 20 WAP |
| Organic fertilizer             |        |        |        |        |
| P0                             | 3.92   | 6.83   | 7.92   | 8.58   |
| P1                             | 5.00   | 7.17   | 7.58   | 8.00   |
| P2                             | 5.25   | 7.67   | 9.00   | 9.17   |
| Notation                       | ns     | ns     | Ns     | Ns     |
| Origin of planting material    |        |        |        |        |
| S2                             | 6.22 a | 8.22 a | 8.56 a | 8.67 ab|
| S3                             | 6.44 a | 9.44 a | 10.44 a| 11.00 a|
| S4                             | 4.00 ab| 7.56 a | 8.33 a | 8.56 ab|
| S5                             | 2.22 b | 3.67 b | 5.33 b | 6.11 b |
| Notation                       | **     | **     | **     | *      |

Notes: (ns): not significant, (*): significant at alpha 5%, (**: significant at alpha 1%, numbers followed by the same letter was not significantly different on DMRT 5%.

Table 8. Recapitulation of highest average value from treatments interactions of climbing pepper seedling

| Interaction                 | Parameters |
|-----------------------------|------------|
|                             | 1   | 2   | 3   | 4   | 5   |
| Interaction code            | P2S3| P1S2| P1S3| P1S3| P1S3|
| Value                       | 98.33 | 32.51 | 10.50 | 8.34 | 11.00 |

Notes:
1. Percentage of live plants (%);
2. Seedling height (cm);
3. Number of leaves;
4. Number of internodes and nodes;
5. Number of branching plants;

Recommendation from this research was found in treatment of origin of planting materials. Cutting from 3rd node (S3) was the best recommendation for origin of planting materials. The highest value of number of leaves, number of nodes, and number of branching plants was found in the interaction between fulvic acid and cutting from 3rd node (P1S3) (Table 8). The effect of cutting from 3rd node (S3) was supported by [12] who stated that there was plenty undifferentiated meristematic tissue in younger plant part, making this tissue easily differentiated into root primordial and shoot formation. [13] added that the growth of root and shoot was determined by the condition of cutting used. Cutting from older stem could ended up with yellowish and then dry seedling. In contrast, cutting from younger stem was light green and often ended up rotten.

4. Conclusion
There was no effect of organic fertilizer treatment to observed variables. There was a significant effect of origin of planting materials to percentage of live plants, seedling height, number of leaves, number of nodes and internodes, and number of branching plants. Cutting from 3rd node was the best recommendation for origin of planting materials, while the best interaction was the combination between fulvic acid and cutting from 3rd node (P1S3). The interaction effect was observed in number of leaves, number of internodes and nodes, and number of branching plants.

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