Morphological characteristics, yield and quality of black pepper Ciinten variety in three agro ecological conditions

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Abstract. Indonesia has long been known as one of the world major producers of black pepper. Bangka Belitung and Lampung provinces are the main black pepper production regions in Indonesia. In addition, West Java is also one of the pepper-producing regions. This research aims at observing the morphological characteristics, yield and quality of a local variety that has been grown in West Java. The observations were carried out in three agro ecological conditions Sukabumi, Purwakarta and Ciamis districts during two harvesting season at the age of 4 and 5 years on 5 plants/plot, repeated four times. For comparison, Petaling1 has been used but only in Purwakarta. The results showed that pepper Ciinten variety has broad-leaved, long spike, high number of fruits per spike, also big the size of berries. The production of green berries per vine 4.30 kg/tree, with levels of the essential oil, oleoresin and piperine are 2.79%, 12.71% and 4.73% respectively (white pepper), 2.74%, 15.98% and 4.34% respectively (black pepper). The percentage of fruit set is also high. To get the same unit of weight on Ciinten variety requires the number of spikes harvested 1/3 times (66) of Petaling 1 (189 spikes), making this variety more efficient in harvesting costs.

Key words: Piper nigrum L., observation, yield, essential oil, piperin

1. Introduction

Black pepper (Piper nigrum L.) is known as a King of Spice, belongs to the family Piperaceae. It is a perennial climbing vine grown for its berries, mainly used as spices and condiments. Black pepper is also known as one of the oldest and most popular spices in the world. Indonesia has been one of the major exporting countries along with Vietnam, Brazil, India, Malaysia etc.

Acreage of black pepper cultivation in Indonesia in 2017 reached 167 626 ha with the main production centers in seven provinces, namely Bangka Belitung (48 695 ha), Lampung (44 794 ha), then South Sulawesi and Southeast Sulawesi (14 400 ha), South Sumatra (11 000 ha), East Kalimantan (9600 ha) and West Kalimantan (7800 ha). The production of black pepper in Indonesia in 2017 is estimated 82 thousand tons [1]. The highest pepper production was achieved in 2008 around 91.04 thousand tons, but after that it tends to decline [2]. Indonesia's national pepper productivity can be categorized as very low, compared to productivity in other pepper exporting countries, such as Vietnam which reaches 1500 kg / ha, Malaysia > 1300 kg / ha or even Brazil which reaches 2075 kg / ha [3]. The low productivity, among others, because most pepper farming is a community plantation that controls 99.87% of the pepper area in Indonesia with traditional management. Very few farmers apply the recommended technological innovations, such as the use of superior variety.
To improve national production, it is necessary to increase acreage, among which is through extensification, by cultivation of black pepper in a non traditional growing area, such as in West Jawa, using local variety that has been well adapted to the local agro ecological condition. Although black pepper is not cultivated in a large areas, but the trend of famer’s interest to grow pepper in West Jawa is increasing. Besides that, the agro ecological condition of West Jawa is suitable for growing black pepper. Black pepper prefers to grow in a tropical condition with temperature around 23 – 30°C, altitude below 500 m above sea level, annual rainfall 2 000 - 3000 mm, relative humidity 70-90 %, soil pH 5.5 to 6.5 [4]. The soil should have a good structure and water-holding capacity. Well drainage and high humus content are advantageous.

A local black pepper variety has been found cultivated by farmers in West Jawa for a long time, since the Dutch period, probably more than 75 years ago. This variety has been registered asCiinten variety [5]. The plantation of Ciinten variety has spread to many sub districts in the region of Sukabumi [6]. The number of pepper plants owned by each farmer varies, from 10–1000 pepper vines. From Sukabumi this local pepper variety has also been distributed to other districts and sub districts in West Jawa. This may indicate that Ciinten variety is suitable for the agroecological condition of West Jawa. The objective of the research is to observe the morphological characteristics, yield and quality of the Ciinten local pepper variety in several agro ecological conditions in West Jawa.

2. Materials and methods

2.1. Identification of pepper plantation

The plants materials used are local pepper plantation belongs to the pepper famers. The first step is to identify the location of pepper plantations, then observe and analyzed the agroclimatic conditions. Three locations were selected namely Sukabumi, Purwakarta, and Ciamis, where pepper are planted. All pepper plants are planted using Glycidia sp. as living support. The characteristics of the selected locations were shown in Table 1.

| Variable                      | Sukabumi | Purwakarta | Ciamis          |
|-------------------------------|----------|------------|-----------------|
| Location                      | Bantar Kalong village, Warung Kiara sub district | Neglasari village, Darangdan sub district | Cigugur village, Ciguha sub district |
| Altitude (m asl)              | 450      | 650        | 190             |
| Number of pepper vines        | 1000     | 1000       | 200             |
| Plant age (years)             | 2-7      | 3-6        | 4-6             |
| Support type                  | Living   | Living     | Living          |
| Variety                       | Local    | Local and Petaling 1 | Local |
| Soil types                    | Red latosol | Brown latosol | Not identified |
| Temperature (°C)              | 18-32    | 22-32      | 25-33           |
| Annual rainfall (mm)          | 2500-3000 | 2500-4000 | 1380-2670       |
| Dry months                    | < 4      | 3-4        | 3               |
| Relative humidity (%)         | 55-80    | 50-90      | 50-70           |

2.2 Observation on morphological characters

The selected area are blocked into four blocks which are made as replications. In each block five mature vines were selected for samples. The variables observed referred to pepper descriptor [7]. The method of morphological observation referred to descriptor for Piper nigrum L [8]. The
morphological characters observed included qualitative and quantitative characters of the stem (color, shape), leave (color, shape), spikes (size, color, number of fruits) and fruit (shape, weight, color at maturity).

2.3. Observation on yield
Observation of yield was carried out at three harvesting seasons from 2013 to 2015 where plant age was 4, 5 and 6 years old based on IPGRI [8]. The samples observed were five plants/replication, repeated four times. In the plantation in Purwakarta, other pepper variety namely Petaling1 (the superior variety) were grown in the same location as the Cinten variety and used as a comparison.

2.4 Analysis of quality
Pepper quality was analyzed on white and black peppercorns. Samples were collected from each pepper vine and bulk. Analyses was carried out for two harvesting seasons, include essential oil content, oleoresin, piperine in both white and black peppercorns.

3. Result and discussion
3.1. Observation on Morphological Characters
Observation on qualitative morphological characteristics (Table 1) showed that almost all the qualitative characters are the same in each location. Differences were shown on quantitative morphological characters which may be influenced by environmental condition in each the location (Table 2).

The shape and colour of mature leaves are no differences among locations, differences were shown on colour of young leaves and bract. The colour of young leave may be due to anthocyanin content. Level of anthocyanin intencity is influenced by environmental conditions. Anthocyanin may be influenced by a number of environmental factors such as cold temperature dan water stress [9]. The color of the spike is ivory white, with growing orientaion hanging on the leaf arm pit. The fruit shape is round. Colour of young fruit is green (YGG 147 A), however, after ripe the fruit become orange (Figure 1). Fruit aroma is strong. Time taken to fruit maturity around 9-10 months. In Sukabumi takes longer than in other location, may be due to differences in agoroecological condition.

![Image of pepper fruits](image1.png)

Figure 1. Colour of mature and ripe fruits of black pepper Cinten variety
Table 2. Morphological characteristics of Ciinten pepper variety in three observation sites

| Morphological characters | Observation sites | Ciamis                   |
|--------------------------|-------------------|--------------------------|
|                          | Sukabumi          | Purwakarta               |
| **Leaf: Shape**          |                   |                          |
| Lamina                   | Ovate - lanceolate| Ovate – lanceolate       |
| Apex                     | Acute             | Acute                    |
| Base                     | Cordate           | Cordate                  |
| **Leaf: Colour**         |                   |                          |
| Mature Leave             | Green YGG 147 A   | Green YGG 147 A          |
| Young Leave              | Greenish yellow   | Greenish yellow YGG 145 A|
|                          | Greenish red      | Greenish purple          |
| **Stem: Colour**         |                   |                          |
| Mature stem              | Brown             | Brown                    |
| Young stem               | Green             | Green                    |
| **Shoots:**              |                   |                          |
| Number of hanging shoots | Few               | Few                      |
| Number of runner shoots  | Few               | Few                      |
| **Roots:**               |                   |                          |
| Number of adventitious   | Many              | Many                     |
| roots                    | Holding capacity  | Strong                   |
| **Inflorescence:**       |                   |                          |
| Spike orientation        | Hanging           | Hanging                  |
| Spike colour             | Yellowish white   | Yellowish white (YGG 149 A)| Yellowish white (YGG 149 A)| Yellowish white (YGG 149 A) |
| **Fruits:**              |                   |                          |
| Shape                    | Round             | Round                    |
| Colour:                  |                   |                          |
| a.Young fruit            | YGG 137 A         | YGG 137 A                |
| b.Mature fruit           | Orange (ORG 34 B) | Orange group N172        |
|                          | Strong            | Strong                   |
| Aroma                    | Strong            | Strong                   |
| Time to maturity (month) | 10                | 9-10                     |

Quantitative morphological characteristics of Ciinten variety in three different locations were shown in table 2. Differences were shown on the size of leaves, though the seed sources were derived from the same mother trees and propagated vegetatively. These conditions may be attributed to environmental conditions, where in Ciamis agroecologically is the drier and the soil is less fertile than the other two locations. Differences were also shown on color of bract and mature fruits.

The length of spike in Ciamis is longer than the other two locations, while spike length, spike weight, number of fruit spike and spike diameter are not significantly different. The fruit diameter and fruit weight of the Ciinten variety in Sukabumi are higher, it is likely because Sukabumi's environmental conditions are more suitable and Ciinten has adapted for a long time in
Sukabumi approximately more than 75 years [6] compared to the other two locations, which have only been cultivated around 10-20 years.

The spikes of Ciinten variety is long compared to the other Indoensian varieties, but shorter than the Panniyur variety in India. The spike length of Panniyur in India around 17 cm [10]. The length of spike of Ciinten variety reached more than 10 cm and the number of fruits spike\(^{-1}\) is 67 - 85 grains, dry seed weight 4-4.5 g for 100 peppercorns (Table 2).

Table 3. Quantitative morphological characters of Ciinten variety in three observation sites

| Character          | Observation sites |
|--------------------|-------------------|
|                    | Sukabumi | Purwakarta | Ciamis |
| Leave:             |           |           |        |
| Length (cm)        | 15.98\(^a\) | 16.25\(^a\) | 14.77\(^b\) |
| Width (cm)         | 9.24\(^b\)  | 10.16\(^a\) | 9.18\(^b\)  |
| Ratio L/W          | 1.73      | 1.60      | 1.61    |
| Petiole length (cm)| 2.11\(^a\)  | 2.01\(^a\)  | 1.83\(^b\) |
| Spike:             |           |           |        |
| Peduncle length    | 1.37\(^ab\) | 1.12\(^b\)  | 1.73\(^a\) |
| Length             | 11.83\(^a\) | 11.59\(^a\) | 11.35\(^a\) |
| Diameter           | 14.89\(^a\) | 14.40\(^a\) | 13.99\(^a\) |
| Weight             | 11.36\(^a\) | 13.99\(^a\) | 9.61\(^a\)  |
| Fruit:             |           |           |        |
| Number of fruits spike\(^{-1}\)| 84.28\(^a\) | 85.15\(^a\) | 67.50\(^a\) |
| Diameter           | 6.14\(^a\)  | 6.07\(^a\)  | 5.59\(^b\)  |
| Weight             | 0.21\(^a\)  | 0.18\(^b\)  | 0.16\(^b\)  |

Numbers followed by the same letters on each row are not significantly different at P 0.05

![image](image-url)

The fruit arrangement in Ciinten variety is sperical, while in other pepper generally tends to be rather straight. The number of fruits spike\(^{-1}\) may be influenced by genetic and environmental factors. The number of fruits is more sensitive to changes in growing environmental conditions compared to spike length [11]. Panniyur-1 variety pepper has a length of 13 cm when planted on irrigated land, while in rainfed land it has a length of 9.5 cm [12]. Panniyur-1 variety almost fulfills ideal character and with more numerous and denser fruits.

Generally the number of flowers in black pepper varies from 50-150 and the number of hermaphrodite flowers affects the percentage of fruit set [12]. The higher the percentage of hermaphrodite flowers, the higher the percentage of fruit. Possibly the Ciinten variety has higher percentage of hermaphrodite flowers so the spikes are full of fruit.

Based on yield components, namely spike length, spike diameter and weight do not differ between locations. The difference is only seen in the fruit diameter and fruit weight. The fruit diameter in Ciamis is significantly lower, while the fruit weight in Sukabumi is significantly higher than the other two locations (Table 2). Morphological characters that have a direct and positive effect on yield of black pepper are spike length, and number of fruits spike\(^{-1}\), but the most important characters are
the number of fruits vine\(^{-1}\) [13]. When compared to the ideal characteristics of pepper [12], Cinten pepper has several characters that fulfill that with long spike, hight fruit set and number of fruits spike\(^{-1}\).

3.2. Observation on Yield

Cinten variety has already bear fruit at the second year after planting. Yield was observed at three consecutive years at the third to fifth year after planting. Pepper plants should ideally start to bear fruit at the age of 2 years after planting, self pollination flower > 95%, branch angle in the upper branches 45\(^{\circ}\), downward have 60\(^{\circ}\) branch angles, fruit sets evenly distributed along the canopy [12]. Notice from data in the table 3, apparently season affect yield. Average yield from three locations in 2014 is lower than in 2013 and 2015. This may be influenced by environmental condition in 2014, with long dry season.

### Table 4. Yield of Cinten variety from three harvesting seasons in three observation sites

| Location     | Fresh fruit (kg plant\(^{-1}\)) | White pepper (kg plant\(^{-1}\)) | Black pepper (kg plant\(^{-1}\)) |
|--------------|----------------------------------|---------------------------------|----------------------------------|
|              | 2013    | 2014    | 2015    | 2013    | 2014    | 2015    | 2013    | 2014    | 2015    |
| Sukabumi     | 5.89\(^{a}\) | 5.19\(^{a}\) | 10.56\(^{a}\) | 1.88\(^{a}\) | 1.65\(^{a}\) | 3.48\(^{a}\) | 2.65\(^{a}\) | 2.31\(^{a}\) | 4.88\(^{a}\) |
| Purwakarta   | 6.59\(^{a}\) | 5.73\(^{a}\) | 3.78\(^{b}\) | 2.31\(^{a}\) | 2.02\(^{a}\) | 1.33\(^{b}\) | 3.03\(^{a}\) | 2.58\(^{a}\) | 1.74\(^{b}\) |
| Ciamis       | 3.12\(^{b}\) | 3.95\(^{b}\) | 6.48\(^{a}\) | 1.03\(^{b}\) | 1.35\(^{b}\) | 2.18\(^{b}\) | 1.36\(^{b}\) | 1.70\(^{b}\) | 2.88\(^{b}\) |
| Average      | 5.2     | 4.96    | 6.94    | 1.74    | 1.67    | 2.33    | 2.35    | 2.20    | 3.17    |

Comparing yield in three locations, yield in Sukabumi is higher significantly than the other two locations (Table 4). This may be attributed to differences in agroecological condition. Many environmental factors influence yield in black pepper such as elevation, soil fertility, cultural practices, temperature, rainfall, age of the crop and climatic conditions during flowering, fruit set and development [14]. Elevation, annual rainfall in Sukabumi is close to the requirement for black pepper. The suitable agroecological conditions for black pepper plants is below 500 m above sea level, with annual rainfall 2000-3000 mm [4]. Beside that Cinten variety has been well adapted in Sukabumi than in other two locations [6].

### Table 5. Average yield of Cinten variety from three harvesting seasons in three observation sites

| Observation Sites | Yield of green berries (kg vine\(^{-1}\)) | White peppercorn (kg vine\(^{-1}\)) | Black peppercorn (kg vine\(^{-1}\)) |
|-------------------|------------------------------------------|-------------------------------------|-------------------------------------|
| Sukabumi          | 7.21\(^{a}\)                            | 2.46\(^{a}\)                         | 3.28\(^{a}\)                         |
| Purwakarta        | 5.37\(^{b}\)                            | 1.88\(^{b}\)                         | 2.45\(^{ab}\)                       |
| Ciamis            | 4.52\(^{b}\)                            | 1.52\(^{b}\)                         | 1.98\(^{b}\)                        |
| Average           | 5.70                                     | 1.95                                | 2.57                                |
Comparisons were made to the Ciinten pepper plantations in Purwakarta where there was a Petaling1 pepper variety planted together with Ciinten. Comparison of the number of spike and spike weights shows that Ciinten variety is more efficient in harvest costs, because to get the same spike weight only requires 1/3 to 1/2 the number of Petaling 1 spikes. Beside that, yield of green berries, white pepper and black peppercorn from Ciinten variety is higher than from Petaling 1 (Table 5).

Table 6. Yield comparison of white and black peppercorn between Ciinten and Petaling1 varieties

| Parameter                  | Ciinten       | Petaling 1  |
|----------------------------|---------------|-------------|
| White Pepper:              |               |             |
| Numbers of spikes vine⁻¹   | 66            | 189         |
| Weight (g)                 | 500           | 500         |
| Fresh fruits (g)           | 456 (91.37 %) | 432 (86.5 %)|
| White peppercorn (g)       | 159 (35 %)    | 142 (33 %)  |
| Black pepper:              |               |             |
| Numbers of spikes vine⁻¹   | 417           | 836         |
| Weight (kg)                | 2.50          | 2.50        |
| Fresh fruits (kg)          | 2.20 (87.84 %)| 1.92 (76.92 %)|
| Black peppercorn (kg)      | 1.50 (46.15 %)| 1.25 (41.67 %)|

3.3. Analyses on Quality

The main quality components in pepper are the content of essential oil, oleoresin and piperine. The results of the pepper analysis in the form of white and black peppercorns are presented in table 6. Essential oil, oleoresin and piperine of Ciinten variety in Sukabumi are higher than in the other two locations. The essential oil contents of white and black peppercorns in Sukabumi and Purwakarta and Ciamis all meet ISO (959-1:1998) requirements. ISO standard for essential oil content is at least 2% [15]. Essential oil levels affect the aroma and taste of pepper [15]. Oleoresin is a commercially important pepper because of its taste, aroma, antioxidant properties and more stable in storage. This result is in accordance with the opinion of some consumers who stated that Ciinten pepper is spicier and has a stronger aroma compared to the other cultivated pepper varieties.

Essential oil levels in pepper in India vary from 2-5% [16] while in general; pepper essential oil levels generally range from 1-2.4%. The level of piperine in Indian pepper ranges from 2.8% - 3.8% [17]. The content of essential oil of black pepper will be higher if it was instantaneous immersion with hot water before drying, and the acquisition of essential oil content 4.33 - 7.32% [18].

In India, evaluation of several pepper cultivars showed essential oil levels of 1.6 - 6.0%, piperine 1.6 - 4.2% and oleoresin 5.9 - 13.9% [17]. In Panniyur cultivar1 the essential oil content was 2.4 - 5% and oleoresin 6.8 - 8.7% [19], whereas in Panniyur2 oleoresin levels were 6.6%. Based on GCMS analyses, piperine content in 32 Indian varieties ranged from 1.6-12 %, oleoresin 0.1-13.9 % and essential oil 0.3-6.0 % [20]. Differences in chemical contents and compositions may be attributed to genotype, environment, method of processing and analyses.
Table 7. Quality of white and black peppercorn harvested from three observation sites

| Variables (%) | Sukabumi | Purwakarta | Ciamis | IPC Grades |
|---------------|----------|------------|--------|------------|
| White peppercorn |          |            |        |            |
| Water content  | 6.65 ± 0.36 | 6.20 ± 1.08 | 10.88 ± 2.95 | I 12.0   |
| Essential oil content | 2.38 ± 0.39 | 2.93 ± 0.35 | 2.43 ± 0.15 | II 13.0 |
| Oleoresin      | 12.52 ± 0.26 | 13.21 ± 3.36 | 10.69 ± 0.80 | III 14.0 |
| Piperine       | 3.85 ± 0.94 | 4.37 ± 1.03 | 3.23 ± 0.93 |            |
| Black peppercorn |          |            |        |            |
| Water content  | 7.33 ± 0.64 | 6.41 ± 0.92 | 8.05 ± 0.11 | I 12.0   |
| Essential oil content | 2.86 ± 0.18 | 3.33 ± 0.75 | 2.59 ± 0.02 | II 12.5 |
| Oleoresin      | 14.17 ± 2.73 | 16.18 ± 3.34 | 11.52 ± 1.86 | III 13.0 |
| Piperine       | 4.47 ± 1.74 | 4.52 ± 1.91 | 3.38 ± 0.71 |            |

The ideal pepper variety must contain at least 5% essential oil, 5% piperine and 8% oleoresin [12]. Referring to these criteria the level of pepper essential oil of Ciinten variety does not meet the ideal criteria. However, the essential oil and pepper piperine levels in all locations meet IPC [21] and ISO standards [22] [23].

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