Effect of soil management and biofertilizer application on cocoa’s flower and fruit development

Kaimuddin, Nasaruddin, and D Darwis
Department of Agronomy, Universitas Hasanuddin, Jl. Perintis Kemerdekaan KM.10 Makassar, Indonesia

Email: kaimuddin.mole@gmail.com

Abstract. A research aimed to determine the effectiveness of tillage and biofertilizer on the development of flowers and fruit on cocoa (*Theobroma cacao* L.). This research was conducted in Barang Village, Liliriaja Subdistrict, Soppeng Regency. The research was carried out based on a 2-factor factorial design with randomized block design (RBD) as the basic design. The first factor was soil tillage which consisted of 4 levels namely; without tillage and without mulch; organic mulch without tillage; tillage without mulch, tillage and organic mulch. The second factor was biofertilizer application which consisted of 4 levels, namely: without biofertilizer, biofertilizer 1 cc. L\(^{-1}\), biofertilizer 1.5 cc. L\(^{-1}\), and biofertilizer 2 cc. L\(^{-1}\). Therefore, there were 16 treatment combinations that were repeated 3 (three) times and each unit consisted of 4 plants making a total of 192 plants. The results indicated that the biofertilizer g3 (2 cc. L\(^{-1}\)) and g2 (1.5 cc. L\(^{-1}\)) provided the highest average of the formed fruit nipples (127), falling fruit nipples (50.00), survived fruit of 10-12 cm (77), harvested fruit (24.58), dry weight of 100 seeds (96.10) and pod index (22.80). The interaction was shown on the parameter of highest number of seeds with 2 cc L\(^{-1}\) of biofertilizer application (32.96).

1. Introduction
South Sulawesi is one of Indonesia’s main cocoa production centers. The area of cocoa plantations in South Sulawesi in 2017 was around 245,813 ha with a total production of 113,816 tons. The average production achieved was very low at 0.463 tons ha\(^{-1}\) [1]. Cocoa plantations in South Sulawesi are spread across 22 regencies, one of which is in Soppeng Regency. Cocoa is one of the reliable commodities in Soppeng Regency [2].

According to Makarim and Suhartatik [3], to overcome the decline in land production and productivity, cultivation technology is needed by using microbial fertilizer technology as a source of biological nutrients, and the use of organic materials. This technology can increase fertilizer efficiency and sustainability of the cocoa production system. The presence and population of microbes in Rizosper can maintain plant root health, nutrient uptake, and increase plant tolerance to environmental stress [4,5].

This research was to determine the effectiveness of tillage and biofertilizers on the development of flowers and fruit on cocoa plants

1.1. Flowering of Cocoa fruit
Flowering of cocoa plants is strongly influenced by internal (internal) and environmental (climate) factors. In certain locations, flowering is severely hampered by the dry season or by cold temperatures.
However, in a location where rainfall is evenly distributed throughout the year and the temperature fluctuations are small, the plants will flower throughout the year [6].

According to Widiancas [7] mature cacao plants that thrive can produce 5,000-10,000 flowers in a year. Only about 500-1000 flowers (10%) are pollinated, the rest that bloom within 24 hours of non-pollination will fall. Flowers that have been pollinated develop into nipples (cherelle) only about 10-30%, while the other 70-90% will experience wilting or physiological death. Furthermore, the number of nipples that can grow and develop to cook is only about 33-50 pieces [8].

The development of cocoa can be divided into two phases. In the first phase, fruit growth takes place slowly during the first 40 days and then grow rapidly and reaches a peak at 75 days. The second phase is marked by fruit enlargement which takes place quickly at 140 days. At the age of 143-170 days after fruit formation, they reach maximum size and begins to ripen marked by changes in fruit skin color and the release of seeds from the fruit pulp [6].

1.2. Effect of Biofertilizer on Cocoa
Biofertilizer is a substance used to increase soil fertility by using biological waste that is useful in enriching the soil with microorganisms that produce organic nutrients for the soil and is immune to disease [9].

The advantage obtained by utilizing organic fertilizer is to improve the physical, chemical and biological properties of the soil. Compost is raw organic material that has undergone a natural decomposition process. Compost is not only essential for food crop such as rice [8], but also for estate crops. One of the agricultural wastes of estate crops that has not been much utilized is cocoa pods [11]. Furthermore, Opeke [12] stated that cocoa pods contain 9.69% protein, 1.16% glucose, 0.18% sucrose, 5.30% pectin, and Theobromin 0.20%

1.3. Organic Mulch
Utilization of organic mulch will help reduce erosion, and maintain soil moisture, control soil pH, improve drainage, and reduce soil compaction, increase ion exchange capacity, and can increase soil biological activities [13].

2. Methodology
This research was carried out in the farmer's cocoa farm, in Barang Village, Liliriaja District, Soppeng Regency. This experiment was designed using a 2-factor factorial design with Randomized Group Design (RBD) as the basic design. The first factor was soil tillage (P) which consisted of 4 levels, namely: without soil tillage and without mulch (p0), the provision of organic mulch without soil tillage (p1), provision of soil tillage without mulch (p2) and provision of both soil tillage and organic mulch (p3). The second factor was the provision of Biofertilizer (G) consisting of 4 levels, namely: without biofertilizer application (g0), biofertilizer of 1cc.L⁻¹ (g1), biofertilizer of 1.5 cc. L⁻¹ (g2), and biofertilizer of 2 cc. L⁻¹ (g3). This arrangement resulted in 16 treatment combinations. Each combination consisted of 16 experimental units, thus 48 experimental units were obtained. Each unit was repeated 3 times and each unit consisted of 4 plants making a total of 192 plants used in this study.

3. Results and discussion

3.1. Fruit nipple formed
Statistical analysis showed that biofertilizer application had a very significant effect on fruit nipples formed after treatment, whereas the treatment of soil tillage had no significant effect.
Table 1. Average number fruit nipples formed in the biofertilizer treatment

| Biofertilizer | Tillage | Average | LSD 0.05 |
|---------------|---------|---------|----------|
| g0            | p0 87   | p1 121  | p2 115   | p3 114   | Average 109 | 26.65 |
|               |         |         | p0 84   | p1 111  | p2 105   | p3 122   | 88 b   |
| g1            |         |         |         |         |         |         | 110 a   |
| g2            |         |         |         |         |         |         | 113 a   |
| g3            |         |         |         |         |         |         | 127 a   |

Note: Numbers followed by the same letters in the same column show results that are not significantly different in the LSD 5%.

Results in table 1 shows that the application of biofertilizer application of 2cc.L⁻¹ (g3) produced a greater amount of fruit nipple formed (127) and significantly different from no biofertilizer application (g0) i.e. 88 and also significantly different from the treatment of biofertilizer application of 1cc.L⁻¹ (g1) and 1.5cc.L⁻¹ (g2).

3.2. Number of fallen nipples

Statistical analysis showed that the number of fallen nipple after treatment was significantly affected by the biofertilizer application, whereas the soil tillage and the interaction of both had no significant effect.

Table 2. The average number of fallen nipples in the biofertilizer treatment

| Biofertilizer | Tillage | Average | LSD 0.05 |
|---------------|---------|---------|----------|
| g0            | p0 43   | p1 47   | p2 46   | p3 45   | Average 45.25 | 7.08 |
|               |         |         |         |         | 43.75 b   |        |
| g1            |         |         |         |         | 46.50     |        |
| g2            |         |         |         |         | 52 a      |        |
| g3            |         |         |         |         | 50.25 a   |        |

Note: Numbers followed by the same letters in the same column show results that are not significantly different in the LSD 5%.

Results in table 2 show that the treatment of 1.5cc.L⁻¹ biofertilizer application (g2) resulted in a greater number of fallen fruit nipples (50.25) and was significantly different from no biofertilizer treatment (g0), as well as significantly different form the 1cc.L⁻¹ (g1) and 2cc.L⁻¹ (g3).

3.3. Number of survived fruit (10-12 cm)

Statistical analysis showed that biofertilizer application had significant effect on the number of survived fruit (10-12 cm), whereas the treatment of soil tillage and the interactions of both factors did not have a significant effect.

Table 3. The average fruit that survived (10-12 cm) in the biofertilizer treatment

| Biofertilizer | Tillage | Average | LSD 0.05 |
|---------------|---------|---------|----------|
| g0            | p0 44   | p1 74   | p2 69   | p3 69   | Average 64 | 23.44 |
|               |         |         |         |         | 44 b      |        |
| g1            |         |         |         |         | 64 b      |        |
| g2            |         |         |         |         | 61 a      |        |
| g3            |         |         |         |         | 77 a      |        |

Note: Numbers followed by the same letters in the same column show results that are not significantly different in the LSD 5%.
Table 3 shows that the treatment 2cc.L⁻¹ biofertilizer application produced most survived fruit (77) and was significantly different from the no biofertilizer treatment (g0) and not significantly different from the treatment of 1cc.L⁻¹ (g1) and 1.5cc.L⁻¹ (g2) biofertilizer applications.

3.4. Number of harvested fruit
Statistical analysis showed that biofertilizer application gave significant effect on the amount of harvested fruits, whereas the treatment of soil tillage and interactions of both factors had no significant effect.

Table 4. The average amount of harvested fruit in the biofertilizer treatment

| Biofertilizer | Tillage | Average | LSD 0.05 |
|---------------|---------|---------|----------|
| g0            | p0 43.00| 55.00   | 36.00    | 42.75 b |
|               | p1 37.00|         |          |         |
| g1            | p0 69.00| 47.00   | 64.00    | 59.75 a |
|               | p1 59.00|         |          |         |
| g2            | p0 65.00| 56.00   | 59.00    | 57.75 a |
|               | p1 51.00|         |          |         |
| g3            | p0 66.00| 83.00   | 79.00    | 73.75 a |
|               | p1 67.00|         |          |         |
| Average       | 60.75   | 60.25   | 59.50    | 58.50   |

Note: Numbers followed by the same letters in the same column show results that are not significantly different in the LSD 5%.

Table 4 shows that the application of 2cc.L⁻¹ biofertilizer (g3) produced highest amount of harvested fruit (79.00) and was significantly different from no bifertilizer treatment (g0) which produced 36.00 fruit and was also not significantly different from 1cc.L⁻¹ (g1) and 1.5cc.L⁻¹ (g2) of biofertilizer applications.

The fruit formation and survival were greatly supported by macro and micro nutrient conditions. The essential macro and micro nutrient elements work together in supporting the process of plant photosynthesis starting from the time up to the reproductive phase of plants. Mn, Fe, Cl, and Zn are micro nutrients involved in the photosynthesis process. Boron (Bo³⁺) and Iron (Fe³⁺) play a role in protein synthesis and metabolism, while Zinc (Zn²⁺) and Manganese (MN²⁺) and can activate enzymes [14].

3.5. Dry weight of 100 seeds (g)
Statistical analysis showed that biofertilizer application and soil tillage had significant effect on the dry weight of seed.

Table 5. Dry weight average of 100 Seeds (g) with soil tillage and biofertilizer treatments

| Tillage | Biofertilizer | Average | LSD 0.05 |
|---------|---------------|---------|----------|
| p0      | g0 90.88      | g1 95.23| g2 99.55 | g3 88.90 | 93.64 x |
| p1      | 88.04         | 92.54   | 91.39   | 92.62   | 91.15 y |
| p2      | 91.44         | 93.98   | 96.45   | 95.76   | 94.41 x |
| p3      | 95.95         | 93.91   | 97.00   | 98.10   | 96.24 x |
| Average | 91.58 b       | 93.91 a | 96.10 a | 93.85 a | 93.86   |

Note: Numbers followed by the same letters in the same column show results that are not significantly different in the LSD 5%.

Table 5 shows that combination of soil tillage and biofertilizer application p3g3 gave the largest weight of 100 seeds i.e. 98.10 g, whereas the interaction of both had no significant effect.

The results showed that the combination of p3g3 treatment (soil tillage + organic mulch administration) with application of biofertilizer 2cc.L⁻¹ was the best for the dry weight of 100 seeds parameters. This was due to the large number of fruits and seeds that had been greatly affected by the
filling process through photosynthesis. As explained by Nasaruddin [6] Weight of dried seeds is a reflection of the energy capture by plants in the process of photosynthesis. Weight of 100 seeds depends on photosynthesis activity when filling seeds. Plants capable of optimally utilizing light for photosynthesis will produce fully filled seeds and perfect distribution before being stored in plant tissue.

3.6. Number of seeds
Statistical analysis revealed that biofertilizer treatment and its interaction with soil tillage treatment had significant effect on the number of seeds, while the soil tillage treatment alone had no significant effect.

| Tillage | Biofertilizer | p0 | p1 | p2 | p3 | Average | LSD 0.05 |
|---------|---------------|----|----|----|----|---------|----------|
| g0      | p0            | 26.50 | 29.17 | 38.00 | 35.33 | 32.25   |
|         | a               | | | | | | |
| g1      | p1            | 23.70 | 31.70 | 33.27 | 31.67 | 30.08   |
|         | a               | | | | | | |
| g2      | p2            | 25.47 | 31.33 | 29.00 | 30.33 | 29.03   |
|         | a               | | | | | | |
| g3      | p3            | 31.06 | 31.06 | 31.06 | 31.06 | 32.15   |
|         | a               | | | | | | |
| Average | p0            | 26.68 | 30.98 | 32.90 | 32.96 | 30.88   |

Table 6. Average number of seeds in biofertilizer treatment

Note: Numbers followed by the same letters in the same column show results that are not significantly different in the LSD 5%.

The results showed that the treatment of biofertilizer and its interaction with soil tillage affected the number of seeds. This was due to the positive influence on the combination of treatment between organic mulch and biofertilizer. This kind of fertilizer contains several beneficial microorganisms that complement each other for plant needs. Utilization of biofertilizers with the help of Azotobacter microbes applied to the soil will continue to fertilize the soil because the bacteria will propagate in the soil and continue to work in fixing nitrogen and increasing the biomass of agricultural crops.

According to Hanim [15], the use of biofertilizers which contained several bacteria in the form of Azotobacteria, Rhizobium, sp, Lactobacillus sp, Pseudomonas sp, and Trichoderma sp. These bacterial isolates can stimulate plant growth. Biofertilizer aims to increase the number of microorganisms and accelerate microbiological processes to increase nutrient availability, hence plants can utilize the nutrients [16]. Microorganisms also accelerate the composting process, improve soil structure and active substances that can increase plant growth that can stimulate fruit formation and the number of seeds produced [17].

4. Conclusion
There is a very significant effect on the parameters of fruit nipple formed, the number of fruit harvested, and there is an interaction effect on the number of seeds in biofertilizer treatment.

The combination of soil treatment and biofertilizer treatment, has a significant influence on the dry weight parameters of 100 seeds, and there is a significant effect on the surviving fruit (10-12 cm), and pod index on biofertilizer treatment and soil processing.

There is no interaction between tillage and biofertilizer on leaf chlorophyll index and stomata density, and no significant effect on tillage and biofertilizer treatment.
References

[1] Indonesian Statistics bureau, 2017. Statistik Kakao Indonesia 2017. Badan Pusat Statistik.
[2] BPS Soppeng, 2019, Kabupaten Soppeng dalam Angka. Biro Pusat Statistik Soppeng.
[3] Makarim A K and Suhartatik E, 2006 Budi daya padi dengan masukan in situ menuju perpadian masa depan Iptek Tanam. Pangan 1, 1.
[4] Gusmiaty, Restu M, Bachtiar B and Larekeng S 2019 Gibberellin And IAA Production by Rhizobacteria From Various Private Forest IOP Conf. Ser. Earth Environ. Sci. 270 012018
[5] Larekeng S H, Gusmiaty, Restu M, Tunggal A and Susilowati A 2019 Isolation and identification of rhizospheric fungus under Mahoni (Swietenia mahagoni) stands and its ability to produce IAA (Indole Acetid Acid) hormones IOP Conf. Ser. Earth Environ. Sci. 343 012051
[6] Nasaruddin, 2009 Kakao: budidaya dan beberapa aspek fisiologisnya Makassar: Yayasan Forest Indonesia dan Fakultas Kehutanan Universitas Hasanuddin.
[7] Widiancas A P, 2010 Aplikasi ZPT NAA dan unsur mikro untuk mengatasi layu pentil (Cherelle Wilt) pada kakao (Theobroma cacao L.) dengan teknik penyemprotan buah.
[8] Iswanto A, 1999 Perbedaan Produksi dan Karakter Biji Antara Hibrida Kakao F1, Klonal F2 dan Keturunan F2 J War. Puslit Kopi Kakao 15, 2 p. 81–90.
[9] Sembiring H Sembiring E and Siagian D R, 2005 Pola Kerjasama Pengembangan Komoditi Pertanian Organik Dataran Tinggi Tujuan Ekspor di Kabupaten Tanah Karo in Seminar Sehari Peranan Pupuk Organik dan Pupuk Hayati untuk Peningkatan Efisiensi Pemupukan pada Tanaman Pertanian dan Perkebunan. Fakultas Pertanian UISU. Medan.
[10] Stöber S et al., Performance of local rice varieties under various organic soil fertility strategies in Toraja, Indonesia.
[11] Sutanto R, 2002 Pertanian organik: Menuju pertanian alternatif dan berkelanjutan Kanisius.
[12] Opeke L K, 1985 Optimising economic returns (profit from cacao cultivation through efficient use of cocoa by-products in Proceedings, Lome, Togo, 12-18 Feb/Fev 1984/9 International Cocoa Research Conference= Actes, Lome, Togo, 12-18 Feb/Fev 1984/9 Conference internationale sur la recherche cocaoyere.
[13] Jaya A S K, 2019 Pengaruh sistem olah tanah dan pemberian mulsa organik terhadap aliran permukaan dan erosi pada pertanaman cacau (Vigna radiata) musim tanam ke empat di laboratorium lapang terpadu Fakultas Pertanian Universitas Lampung.
[14] Wahyuni M and Sembiring M, 2007 Jenis Pupuk dan Sifat-Sifatnya Sekol. Tinggi Ilmu Pertanian Agrobisnis Perkeb. medan.
[15] Hamim M N R Hanarida I and Sumarni N, 2008 Pengaruh pupuk hayati terhadap pola serapan hara, ketahanan penyakit, produksi, dan kualitas hasil beberapa komoditas tanaman pangan dan sayuran unggulan.[Laporan penelitian KKP3T] Bogor Inst. Pertan. Bogor.
[16] Saraswati R and Sumarno S, 2018 Pemanfaatan mikroba penyubur tanah sebagai komponen teknologi pertanian.
[17] Djuarnani I N, 2005 Cara cepat membuat kompos AgroMedia.