UDC 633; DOI 10.18551/rjoas.2022-02.09

IMPROVING LAND MANAGEMENT AND PRODUCTIVITY OF CARDAMOM (AMOMUM COMPACTUM) BASED AGROFORESTRY SYSTEM FOR FULFILMENT OF ANTI COVID 19 BIOPHARMACEUTICAL RAW MATERIALS

Reziq Mohammad, Postgraduate Student
Faculty of Agriculture, University of Brawijaya, Malang, Indonesia

Prayogo Cahyo*, **Kurniawan Syahrul**
Department of Soil Science and Forestry, Faculty of Agriculture, University of Brawijaya, Malang, Indonesia

Novi Arfarita
Faculty of Agriculture, University of Islam Malang, Malang, Indonesia

*E-mail: c.prayogo@ub.ac.id

ABSTRACT
The aim of the study was to examine the benefit of combination of organic (manure) and an organic fertilizer (NPK) along with the use of biofertilizer to improve cardamon growth and performance as Covid-19 biopharmaceutical raw material. The results showed that the application of NPK fertilizer in combination with NPK fertilizer had a significant effect on the observed variables, including: plant height, number of leaves, number of shoots per clump, number of flowers per clump, but had no significant effect on the observed variable number of stems. The best treatment was found at P5 treatment (200% NPK fertilizer + 200% manure) for observation variables of plant height, number of leaves, and number of shoots per clump, while the best treatment for the observation variable of the number of flowers per clump was found in the treatment P9 (NPK fertilizer 200%). The use of multivariate analysis has been successfully grouped and positioned each treatment in 2 dimensional graphs.

KEY WORDS
Fertilizer, land management, biopharmaceutical, biofertilizer, agroforestry.

The current threat of COVID 19 which can threaten the human life if it is not handled properly, especially for patients with a history of congenital diseases, it is necessary to anticipate the availability of drugs on the market. The government's efforts to date are using external input in the form of injecting vaccines to strengthen human immunity. Human immunity can also be increased by consuming some natural ingredients available in the surrounding environment, namely drugs derived from herbal plants.

Planting native herbal plants from Indonesia such as cardamom (*Amomum compactum)* which is currently still limited in its development because its productivity is still relatively low (Agoes, 2010). The selection of these herbal plants is in accordance with the government's efforts to reduce the impact of the spread of COVID 19 disease by increasing the immunity of the community internally by consuming natural medicines (herbs) which until now have received little attention because of the low number of raw materials..The problem with cardamom plants today is that very little cardamom fruit is produced, which is detrimental to farmers because of competition for water and nutrients. Farmers who try to cultivate this plant do not understand and understand the existence of competition for nutrients and water so that production is low and needs to be increased. Cardamom *(Amomum compactum)* is a type of herbaceous plant that has potential in agroforestry and functions as medicines (herbs), spices, breath fresheners and anti-inflammatory or cough suppressants (Fachriyah and Sumardi, 2007). Agricultural cultivation in forest or plantation areas by combining food crops and forestry plants, known as the agroforestry system, is an alternative solution to the problem of meeting growing food needs and security. Cardamom cultivation with agroforestry systems has not been widely carried out; research on the effect of shade tree canopy levels and specific land management systems for cardamom cultivation is still very minimal. The yield of cardamom due to different levels of shade in agroforestry systems is not widely known and this condition is due to competition for water and nutrients with previously planted pine trees that already have a fairly large diameter (30 cm) and an intensive root system and provide shade up to 70%.

UB forest is a KHDTK for education and research which is under the management of Universitas Brawijaya where the role of UB Forest in protecting the environment (water, biodiversity and carbon stock) is very large which is beneficial for the surrounding community and the people who live downstream, namely Malang City. Currently, the land in UB Forest is still tightly covered by stands of wood producing building materials such as pine *(Pinus mercusii)* and mahogany *(Swietania mahogany)* which are useful for maintaining soil and water conservation. Forest management is carried out with the community according to the Community Forest scheme. The community planted intercropping plants under stands, including coffee trees, porang, ginger and other medicinal plants as well as a variety of vegetables that have not been implemented optimally. When viewed from the composition of the constituent plants and the level of plant density, the land use system in UB Forest is included in the category of simple agroforestry which consists of 2-3 types of plants. The main problem faced in UB Forest is the low availability of water and high level of shade. Outside the UB-forest area, the common land use systems are vegetable cultivation grown in monoculture, citrus cultivation, and chicken farming activities. Increased human activities both through agriculture and ecotourism on the lower slopes can be a threat to UB Forest's conservation efforts for soil, water and biodiversity conservation. It is necessary to diversify the selection of the right plants that can be cultivated under stress other than coffee. The land use system in UB Forest is included in the category of simple agroforestry which consists of 2-3 types of plants. The main problem faced in UB Forest is the low availability of water and high level of shade. Outside the UB-forest area, the common land use systems are vegetable cultivation grown in monoculture, citrus cultivation, and chicken farming activities. Increased human activities both through agriculture and ecotourism on the lower slopes can be a threat to UB Forest's conservation efforts for soil, water and biodiversity conservation. It is necessary to diversify the selection of the right plants that can be cultivated under stress other than coffee. The land use system in UB Forest is included in the category of simple agroforestry which consists of 2-3 types of plants. The main problem faced in UB Forest is the low availability of water and high level of shade. Outside the UB-forest area, the common land use systems are vegetable cultivation grown in monoculture, citrus cultivation, and chicken farming activities. Increased human activities both through agriculture and ecotourism on the lower slopes can be a threat to UB Forest's conservation efforts for soil, water and biodiversity conservation. It is necessary to diversify the selection of the right plants that can be cultivated under stress other than coffee. The main problem faced in UB Forest is the low availability of water and high level of shade. Outside the UB-forest area, the common land use systems are vegetable cultivation grown in monoculture, citrus cultivation, and chicken farming activities. Increased human activities both through agriculture and ecotourism on the lower slopes can be a threat to UB Forest's conservation efforts for soil, water and biodiversity conservation. It is necessary to diversify the selection of the right plants that can be cultivated under stress other than coffee. The main problem faced in UB Forest is the low availability of water and high level of shade. Outside the UB-forest area, the common land use systems are vegetable cultivation grown in monoculture, citrus cultivation, and chicken farming activities. Increased human activities both through agriculture and ecotourism on the lower slopes can be a threat to UB Forest's conservation efforts for soil, water and biodiversity conservation. It is necessary to diversify the selection of the right plants that can be cultivated under stress other than coffee. Increased human activities both through agriculture and ecotourism on the lower slopes can be a threat to UB Forest's conservation efforts for soil, water and biodiversity conservation. It is necessary to diversify the selection of the right plants that can be cultivated under stress other than coffee. Increased human activities both through agriculture and ecotourism on the lower slopes can be a threat to UB Forest's conservation efforts for soil, water and biodiversity conservation. It is necessary to diversify the selection of the right plants that can be cultivated under stress other than coffee. However, some types of plants such as types of herbal plants such as ginger, turmeric, and cardamom that will be able to overcome the limitations of light/energy intensity because it only requires low intensity to grow and develop and can survive with conditions of lack of water and nutrients.

The increase in cardamom production in UB forest is very necessary during the COVID-19 pandemic because of the shortage of raw material supply in the market so that the price continues to rise. The market price of this commodity reaches Rp. 300,000 per kilo. This good price in the market opens up opportunities for smallholders in UB forest, who at the time of the COVID-19 pandemic needed product diversification other than the coffee commodity that is now grown. Cardamom plants do not require too intensive care, but the adequacy of nutrients in the agroforestry system is very necessary. In one plot with a size of 100 m^2, cardamom plant production can reach 10 kg of dry seed weight, so farmers get a profit of Rp. 3,000,000 which is enough to help the farmer's economy during this COVID 19. Some farmers do not understand how to properly cultivate and fertilize cardamom plants, so that in one area of land their production is still below average. On the other hand, during the COVID-19 pandemic, an adequate supply of biopharmaceutical raw materials is needed as an alternative to herbal medicine raw materials that can be used in addition to manufactured drugs whose prices are also very high in the market. The chemical content of this cardamom plant has not been widely exposed to the general public as an anti-inflammatory, inflammation reliever and other benefits that are in accordance with the symptoms caused by the COVID 19 virus. Currently, manufactured drugs such as Oseltamivir are sold at a price of Rp. 250,000 per tablet. This drug from the manufacturer Oseltamivir comes from a chemical synthesis so its long-term use is not recommended.

It is hoped that with this research related to the provision of sufficient raw materials for COVID-19 Biopharmaceuticals, an optimal increase in cardamom plant production can be achieved without disturbing the growth of existing shade plants. In addition, this study can provide information on how much shade level is suitable for cardamom due to differences in the level of use of nitrogen and phosphorus fertilizers with a combination of biological fertilizers (biofertilizer). Therefore, there is a need for an in-depth study of the effect of the level of shade, fertilization (NPK) and the use of biological fertilizers on the productivity of cardamom plants as intercrops under shade plants in agroforestry systems.

METHODS OF RESEARCH

The research activity will be carried out in June 2021 and is expected to be completed in July 2022. The implementation begins with pre-research activities to determine the location, create plots, and collect initial research data. The research location is in the Forest Area with Special Purposes Universitas Brawijaya (KHDTK-UB) (UB Forest), Sumbersari Hamlet, Tawangargo Village, Karangploso District, Malang Regency. (Figure 1) which is located at the geographic coordinates 7o49'25'' S and 112o34'23 E.

Brawijaya University Special Purpose Forest Area (KHDTK-UB) or commonly known as UB Forest is an educational forest area that has been granted to Brawijaya University in 2016 with the aim of being an education and research forest. UB Forest is located on the slopes of Mount Arjuno, Malang Regency covering within an area of 554 hectares, and is located at an altitude of 900-1300 meters above sea level with soil type dominated by soil with andic properties. This area is divided into three hamlets, namely Sumbersari, Sumberwangi, and Buntoro. UB Forest has complex areas such as protected forest areas, educational forests, and production forests in which there are agricultural commodities.

The soil at the research location belongs to the Andisol order, with soil characteristics developing from volcanic material with a dominant pyroclastic material from Mt. Arjuno which has a soil pH ranging from 5.4 -6.2 at a depth of 0-10 cm. At the same depth the K content can be exchanged between 9-43 cmol kg^{-1}, the Na content can be exchanged between 14-29 cmol kg^{-1}, the Ca content can be exchanged between 13-93 cmol kg^{-1} and the Mg content between 15-112 cmol kg^{-1} (Putri et al, 2019).

Figure 1 – Map of research locations

The research area, which used to be a bushland, was cleared of grass and vegetation on it, then the land was cultivated and cardamom was planted (Figure 2). The land that was previously covered with grass was cleaned manually with a hoe and made beds for the experimental plot. The experimental plot unit was 2 m x 2 m and each bed contained 6 plants. Each planting hole contains one plant seed consisting of 4 rhizomes. After planting the plants are watered and then get fertilization according to the treatment that has been determined.

Figure 2 – Cardamom plant conditions at the research site

Experiments on the effect of doses of NPK fertilizer, biological fertilizers and their combination on the growth and yield of cardamom plants under the pine canopy used pine plants that were 40 years old. This research was conducted using a randomized block design with the following treatment combinations with each treatment having 3 replications:

1. Control (without fertilizer application);
2. 100% NPK Fertilizer;
3. 100% manure;
4. 100% NPK fertilizer + 100% manure;
5. 200% NPK fertilizer + 200% manure;

6. 100% NPK fertilizer + 100% manure + 100% biological fertilizer;
7. 200% NPK fertilizer + 200% manure + 100% biological fertilizer;
8. 50% NPK fertilizer + 50% manure;
9. 200% NPK Fertilizer;
10. Manure 200%.

The observed plant growth variables included: average plant height, number of leaves, number of stems, number of flowers, and number of shoots at week 12 after planting and soil properties and characteristics. Statistical analysis with ANOVA level 5% used to see the real difference between treatments. Multivariate analysis is used to be able to make treatment groupings based on several selected variables above, while Biplot is used to see the close relationship between variables based on their direction and magnitude.

RESULTS AND DISCUSSION

Soil C content in the study area ranged from 2.8% to 9.5%. This is closely related to the decomposition process of organic matter sourced from pine litter and coffee. The C-organic content of Andisol soil, which results from previous research showed that the C-organic content in the Ap horizon was around 4.44%, the AB horizon was around 3.95%, the Bw horizon was around 1.42% and the BC horizon was 0.98%. (Ferdeanty et al., 2019) According to Prasetyo (2005), the C-organic content of Andisols in Indonesia ranges from 6 to 15%. Based on the research of Arabia et al. (2015) also showed that Andosol at University Farm Unsyiah Bener Bener Meriah Regency had organic C-content in all pedons and the horizon was high and decreased to the lower horizon, ranging from 2.00 - 9.85%. Organic matter has an important role in influencing the level of soil fertility. The higher the organic matter content, the relatively high level of soil fertility. According to Brady and Weil (2008), andisol soil (volcanic ash soil) has the highest organic matter content compared to other mineral soils; the possible cause is the association with allophane clay which protects soil organic carbon from oxidation.

The N content of the soil at the study site ranged from 0.2 to 0.6 g 100 g^{-1}. In general, the N content in this study was still in the same range in the previous study, where the total N content of the soil was 0.5% (Fadilla, 2020). Nutrient status in Andisol soil at potato production centers in 27 villages, 9 sub-districts in Karo Regency which was studied showed that the N-total nutrient status was at an average criterion of 11% at very high conditions, 37% at high nutrient status conditions, 48% on medium nutrient status and 4% on conditions with low nutrient status (Tarigan and Hanum, 2019). Nitrogen is a mineral element that plants need in large quantities by the availability of organic matter. During the growing season, a certain amount of nitrogen will be released from the decomposition of organic matter in the soil (Utomo et al., 2016).

The ANOVA results showed that there was a significant effect ($P<0.05$) of the treatment on plant height at 12 WAP (Figure 3a). The highest plant height was produced by the P5 treatment (200% NPK fertilizer + 200% manure) which was not significantly different from the P3 treatment (100% manure), P6 (100% NPK fertilizer + 100% manure + 100% biological fertilizer), P8 (50% NPK fertilizer + 50% manure) and P9 (200% NPK Fertilizer). The lowest plant height was found in treatment P1 (Control (without fertilizer application)which was not significantly different from the P10 treatment (200% manure), P2(100% NPK Fertilizer)and P4 (100% NPK fertilizer + 100% manure).

The results of previous studies on the impact of fertilizer application on the agronomic conditions of cardamom plants are very difficult to obtain. If there is something that is studied, it is the impact of the dose of water on the growth of cardamom plants (Nurzaman et al., 2000). The results of the analysis of variance (ANOVA) treatment of giving water to field capacity did not significantly affect the increase in plant height, as well as the interaction of field capacity with cardamom species but the effect of cardamom type treatment showed significant differences (Nurzaman et al., 2000). The average height increase of sabrang cardamom *(E. cardamomum)* was higher than that of local cardamom *(A. compactum).* The average increase in plant height of sabrang cardamom *(E. cardamomum)* was 9.66 cm, which was significantly different from that of local cardamom *(A. compactum).* Setyawan et al. (2014) stated that local cardamom *(A. compactum)* was only able to grow up to 2.5 meters while Sabrang cardamom *(E. cardamomum)* could grow up to 4 meters. Based on this statement, it can be seen that genetically sabrang cardamom *(E. cardamomum)* has a better height growth than local cardamom *(A. compactum).* The results of the analysis of variance (ANOVA) on the increase in the number of leaves were not significantly affected either by field capacity, type of cardamom, or the interaction of the two (Setyawan et al. 2014). The plant height yields in this study ranged from 110-150 cm which was still below the average cardamom plant height in previous studies (Setyawan et al. 2014).

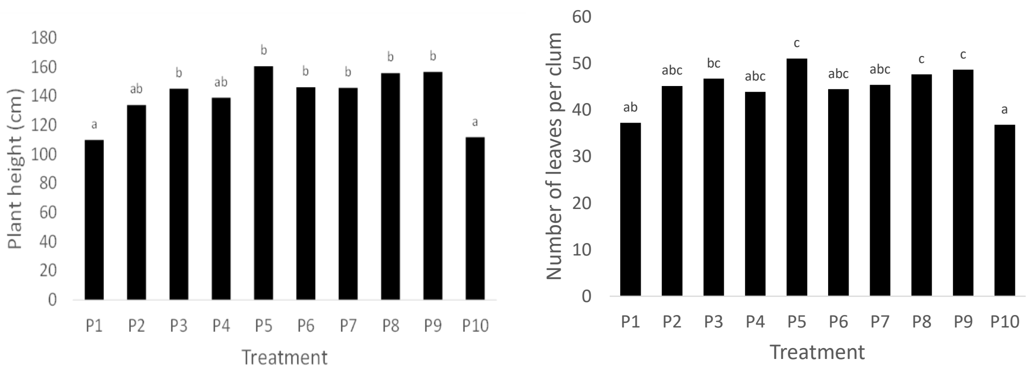

Figure 3 – a: Average plant height and b: number of leaves

The number of leaves in this study ranged from 38 – 52 per clump (Figure 2b). According to Gardner et al. (1991) the number of leaves is influenced by two factors, namely genetic and environmental factors. The genetic factor that affects the number of leaves is through the position of the leaf primordia on the plant, while the environmental factor is the availability of water and nutrients. When viewed from the availability of nutrients such as C, N and existing bases, it can be said to be in sufficient condition. The number of leaves was very significantly (P<0.05) influenced by treatment, where the highest was obtained in treatment P5 (200% NPK fertilizer + 200% manure) and the lowest in treatment P10 (Manure 200%). Giving manure at a dose of 200% actually reduced plant height and number of leaves. (Figure 3b). Prasetya, (2004) reported that the dose of P fertilizer at a dose of 100 kg ha-1 and N fertilizer at the same dose resulted in an average plant height of 75 cm which was lower than the average plant height yield in this study. Leaves are the place where photosynthesis takes place, so the difference in leaf area in plants will have an impact on the ability of these plants to form photosynthetic, the more leaves that can carry out the photosynthesis process, the more photosynthate there will be. Mineral elements in certain balances have many functions in plants, can function as catalysts in tissues, osmosis regulators, buffer systems and membrane permeability (Kramer and Kozlowski, 1979).

The ANOVA results showed that there was no significant effect (P<0.05) of the treatment on the number of stems per clump at the age of 12 WAP (Figure 4a), but the treatment had a significant effect (P<0.05) on the average number of tillers per clump (Figure 4b). The highest number of tillers per clump was produced by treatment P5 (200% NPK fertilizer + 200% manure) which was not significantly different from the P4 treatment (100% NPK fertilizer + 100% manure), P6 (100% NPK fertilizer + 100% manure + 100% biological fertilizer), and P9 (200% NPK Fertilizer). The lowest number of tillers was found in the P10 treatment (200% manure) which was not significantly different from the P1 treatment (Control (without fertilizer application).

According to Prasetyo, (2004) application of N fertilizer at the level of 0 kg ha^{-1} only produced 8 shoots per clump which would increase to 18 shoots per clump if the dose was increased to 100 kg ha^{-1}. The average number of tillers in this study ranged from 2.4 – 4.3 per clump (Figure 4b). Januwati (1999) which states that the contribution of NPK fertilizer provides essential nutrients that have their own functions and roles that will affect plant quality. The role of nitrogen is to stimulate vegetative growth, namely increasing plant height, stimulating the growth of tillers and making plants green because it is an important constituent of chlorophyll which is important in photosynthesis.

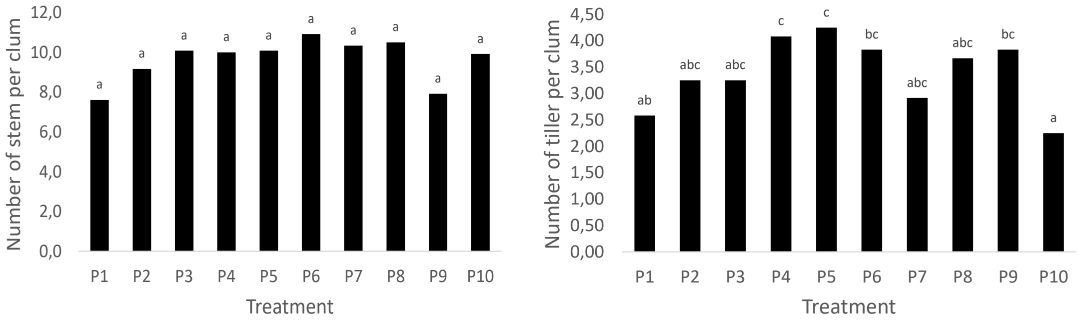

Figure 4 – a: Average number of stems per clump and b: average number of tillers per clump

The ANOVA results showed that the treatment had a significant effect (P<0.05) from the treatment on the number of flowers per cluster at the age of 12 WAP (Figure 5), the highest number of flowers per cluster was produced by treatment P9 (200% NPK Fertilizer) which was then followed by P8 treatment (50% NPK fertilizer + 50% manure) and P4 treatment (100% NPK fertilizer + 100% manure). The lowest number of plant flowers was found in treatment P10 (Manure 200%).

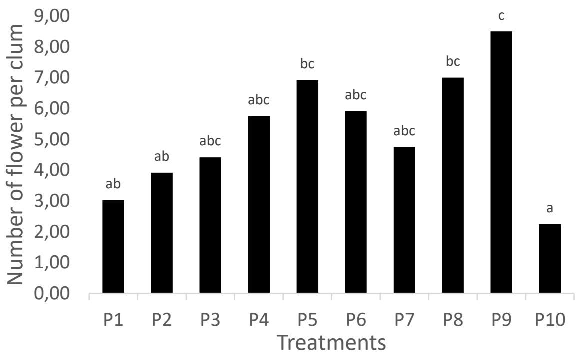

Figure 5 – Average number of flowers per clump

This shows that only using organic fertilizer in the absence of inorganic fertilizers such as NPK will cause low yields that can be seen from the number of flowers formed. Therefore, the combination of organic and inorganic fertilizers (NPK) is an ideal condition for plants because all nutrients are in sufficient condition. There is very little information on the impact of giving a combination of fertilizers on the yield and growth of cardamom. Previous research has focused on other herbal plants such as Ginger *(Zingiber officinale)*. Research prior to the impact of NPK fertilizer application showed that the treatment of seed weight and NPK fertilizer had a significant effect on the observed variables, including: plant height, number of shoots, wet weight of rhizomes, dry weight of rhizomes, but did not significantly affect the observed variables of relative growth rate and tiller ratio of Ginger *(Zingiber officinale)*. Fertilization on Ginger *(Zingiber officinale)* plays an important role in increasing the yield of rhizomes, both organic and inorganic fertilizers that will improve soil texture, fertility and drainage, especially NPK fertilizers (PUSLITBANGBUN, 2007). According to Rosita et al. (2005), to produce optimal growth of ginger plants require quite a lot of nutrients, especially NPK. Marsono and Sigit (2001) suggested that NPK fertilization in ginger plants in sufficient conditions can play a role in improving plant health. Phosphate and potassium fertilizers can help root development, helps the formation of protein and carbohydrates and increases plant resistance to disease. Generally, plants that are deficient in potassium elements will have their resistance components disrupted so that it will make it easier for pathogens to penetrate and attack cultivated plants.

Multivariate discriminant analysis (MDS) was used to explain the grouping of treatments based on several observed variables, namely: plant height, number and, number of stems per clump, number of shoots (tillers) per clump and number of flowers per clump (Figure 6). Figure 6 shows that all scattered treatments can be clearly separated following the X axis (SCORE 1) with a value of 93% while the Y axis (SCORE 2) represents a value of 7%. It is also seen that treatments P9 and P5 are far to the left when compared to positions P1 and P10. This multivariate analysis was also used in previous studies to see the impact of giving NPK on corn (Prayogo et al., 2021) and the impact of changes in land management (Prayogo et al., 2021); (Prayogo et al., 2020).

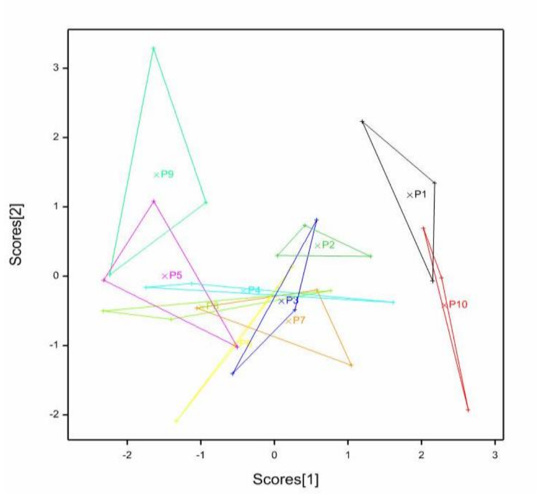

Figure 6 – Multivariate analysis of selected variables as follow: plant height, number of stems per clump, number of shoots (tillers) per clump and number of flowers per clump

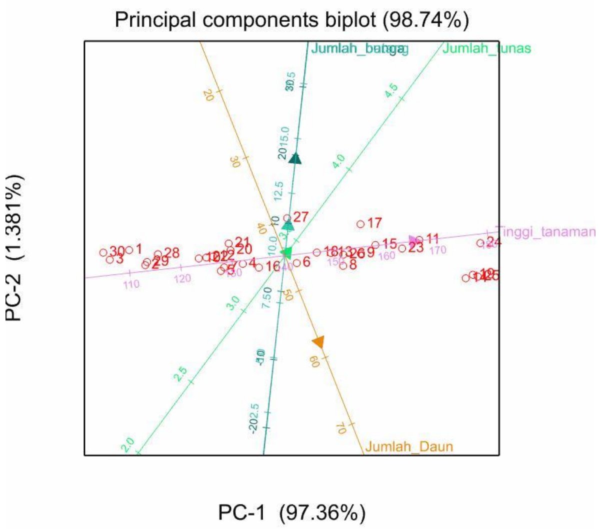

Figure 7 – Biplot multivariate analysis of selected variables as follow: plant height, number of stems per clump, number of shoots (tillers) per clump and number of flowers per clump

A positive relationship and a close relationship between variables found in the number of flowers and number of shoots (tillers) can be explained through multivariate Biplot analysis. Number of flower and number of shoots (tillers) per clump were strongly correlated and having similar direction and magnitude. In the addition, the number of shoots (tillers) per clump and number of flowers per clump which were inversely related to the direction and magnitude of the number of leaves. The higher the number of leaves, the lower the number of flowers and shoots (Figure 7).

CONCLUSION

The application of NPK fertilizer in combination with NPK fertilizer had a significant effect on the observed variables, including: plant height, number of leaves, number of shoots per clump, number of flowers per clump, but had no significant effect on the observed variable number of stems. The best treatment was found at P5 treatment (200% NPK fertilizer + 200% manure) for observation variables of plant height, number of leaves, and number of shoots per clump, while the best treatment for the observation variable of the number of flowers per clump was found in the treatment P9 (NPK fertilizer 200%). Multivariate analysis can classify existing treatments based on several variables that were analysed simultaneously which results in the position of each treatment in a 2 (two) dimensional graph, where treatments that are not significantly different will overlap one another. A positive and close relationship between variables was found in the number of flowers and the number of shoots.

REFERENCES

1. Agoes, A. 2010. Indonesian Medicinal Plants 3rd edition. Salemba Medika. Jakarta.
2. Arabia, T., Karim, A., Zainabun, Sari, IR 2015. Characteristics of Typic Hapludand soil at University Farm UNSYIAH Kab. Really Merry. Agrosamudra, Research Journal Vol.2 No.2 July– December 2015.
3. Brady NC and Weil RR. 2008. The Nature and Properties Of Soil. Personnel Prentice Hall. 443-541 p.
4. Fadilla, U.2020. Identification of Soil and Environmental Chemical Properties in Horticultural Land of Nagari Air Batuumbuak Kab. solo. Sustainable Agricultural Development in Technological, Social, and Economic Perspective ISBN: 978-602-6697-58-5.
5. Fachriyah E., and Sumardi. 2007. Identification of cardamom (Amomum cardamomum) seed essential oil. Journal of Science and Mathematics (JSM) Vol.15. No. 2.
6. Ferdeanty, Sufardi, Arabia, T. 2019. Characteristics Morphology and Soil Classification of Andisols in Dry Land in Aceh Besar District. Scientific Journal of Agricultural Students E-ISSN: 2614-6053 P -ISSN: 2615-2878 Volume 4, Number 4, November 2019 www.jim.unsyiah.ac.id/JFP.
7. Januwati, M. 1999. Optimization of Ginger Plant Farming. Paper Presented in Semi Oration at the Bogor Spice and Medicinal Plant Research Institute, 23 June 1999. 31 p.
8. Marsono and P. Sigit. 2001. Root Fertilizer. Self-help spreader, Jakarta.
9. Nurzaman, M., Pridani, SRD, and Setiawati, T. 2020. Growth Response of Local Cardamom (Amomum compactum Soland Ex. Maton) and Sabrang Cardamom (Elettaria cardamomum (L.) Maton Var. Mysore) to drought stress. Pro-Life Journal, 7(1), 27-41. https://doi.org/10.33541/jpvol6Iss2pp102.
10. Prasetyo.2004. Cardamom cultivation as an intercrop in Sengon stands. Indonesian Journal of Agricultural Sciences. Vol.6 No.1.
11. Prayogo, C., Prasetya, B., Arfarita, N. 2021.Comparative effects of the combination of biofertilizer, NPK, and mycorrhizal application on maize production system. IOP Conference Series: Earth and Environmental Science 905 (1), 012003.
12. Prayogo, C Kusumawati, IA Qurana, Z Kurniawan, S Arfarita N. 2021.Does different management and organic inputs in agroforesty system impact the changes on soil respiration and microbial biomass carbon? IOP Conference Series: Earth and Environmental Science 743 (1), 012005.
13. Prayogo, C Prastyaji, D Prasetya, B Arfarita. N. 2020.Structure and Composition of Major Arbuscular Mycorrhiza (MA) under Different Farmer Management of Coffee and Pine Agroforestry System. AGRIVITY. Journal of Agricultural Science. 2021. 43(1): 146-163.
14. Puslitbangbun. 2007. Superior Technology of Ginger Cultivation Supporting Superior Varieties. Research and Dev. Center. Research and Development of Agriculture. 17 p.
15. Daughter, OH, Utami. SR., Kurniawan S. 2019. Soil Chemical Properties in Various Land

Uses of UB Forest. Journal of Soil and Land Resources, 6(1), pp.1075–1081.
16. Rosita, Mono Raharjo and Kosasih. 2005. Growth pattern and nutrient uptake of N, P and K of bangle (Zingiber purpurium Roxb) plant. Littri Journal. 1:32-36.
17. Samiri, Radian, and Sutarman Gafur. 2019. Effect of Seed Weight and NPK Fertilizer on Growth and Yield of Ginger Plants on Peat Soil. AGROVIGOR 12 (2): 64 – 69.
18. Tarigan, A., Hanum, H. 2019. Nutrient status of soil NP and K and their correlation with potato (Solanum tuberosum. L) production in Karo Regency Journal of Soil and Land Resources Vol 6 No 1: 1105-1111, 2019.
19. Utomo M., Sudarsono, Rusman B., Sabrina T., Lumbanjaya J., and Wawan. 2016. Soil Science and Basic Management. Bandar Lampung. Kencana Pranamedia Group. 433 p.
20. Webb, CT, Hoeting, JA, Ames, GM, Pyne, MI, LeRoy Poff, N. 2010. A structured and dynamic framework to advance trait-based theory and prediction in ecology. Ecol. Lett. 13. 267-283.
21. Wijayanto, N and Nurunjanah. 2012. Light intensity, temperature and humidity and lateral roots of mahogany (Sweitenia macrophylla King) at Babakan Madang RPH, BKPH Bogor, KPH Bogor. Journal of Tropical Silviculture Vol 3. No.1.