Management of macro and micro nutrients to suppress flower yield fluctuations in productive clove

A Ruhnayat, Setiawan and O Rostiana

Indonesian Spice and Medicinal Crops Research Institute, Indonesian Agricultural Agency for Research and Development (IAARD), Jln. Tentara Pelajar No. 3 Bogor 16111, West Java, Indonesia

Corresponding author email: ruhnayat@gmail.com

Abstract. Yield fluctuations in cloves are still an unsolved problem. This study aimed to increase vegetative and reproductive shoots to stimulate flowering by applying macro and micronutrients using 30 years old clove plant. The treatments tested were: (p0) control, (p1) NPKMg (4:1:3:0.4), (p2) NPKMg (4:1:3:0.4) + 30 g B + 30 g Zn, and (p3) NPKMg (4:1:3:0.4) + 60 g B + 60 g Zn. The dose of NPKMg given was adjusted to the plant-based on the SOP for fertilizing cloves aged 34 years, namely 8.4 kg (N=4 kg, P2O5=1 kg, K2O=3 kg, and MgO=0.4 kg per tree per year). The results showed that fertilizer application could improve canopy and branch conditions after a large harvest season and increase the number of shoots. Meanwhile, micro fertilizers B and Zn (p3) application during the small harvest season can increase the production of fresh flowers 303.27-516.67% higher than the control. During the medium harvest season, it is only 122.37%. In the large harvest season, macro fertilizer (p1) increased the production of fresh flowers by 135.53%, higher than the control. This study indicates that clove plants aged >30 years can still increase their productivity through macro and micronutrient management and suppress yield fluctuations.

Keywords: Syzygium aromaticum, flowering, fertilization

1. Introduction

Clove (Syzygium aromaticum L. Merr. & Perry) is a spice plant with economic value and an important role for Indonesia. It is a source of state income originating from cigarette customs, absorbs labor, and contributes to farmers' income. Clove flowers and peduncles are mostly used as raw materials for kretek cigarettes, while the fallen leaves are mostly used to produce clove oil. Clove plants in Indonesia are currently mostly cultivated by the people (98.7%), and the rest (1.3%) are developed by large state and private plantations [1].

In clove cultivation, it is known that there are large, medium, and small flowering seasons, even no flowering at all, resulting in fluctuations in yield. Big harvests occur every 2-4 years. The difference between large and small yields can be up to 60%. Although clove yield fluctuations occur nationally, Indonesian clove production data for 2005-2011 shows that production declines occur yearly, but after that, production moved up, although with a relatively small number [1]. This fluctuation in yields is very detrimental to farmers because their income becomes unstable. Besides that, the supply of raw materials to the industry, especially cigarette factories, is not continuous, so clove imports are carried out to meet their needs. The yield fluctuations in clove plants have not been resolved because there is no effective way to overcome them. One of the physiological aspects that affect the flowering of clove plants is the...
absence of a balance between vegetative and reproductive growth after a large harvest. Therefore, at the time of heavy flowering, nutrient reserves will be depleted for reproductive development. In addition, the prospective reproductive branches are damaged due to poor harvesting methods and unsupportive physical and chemical fertility of the soil. At the same time, the regeneration power of clove plants is slow.

One of the efforts to increase vegetative and reproductive growth is fertilization. However, the application of NPKMg fertilizer can increase clove yield but cannot suppress yield fluctuations [2][3]. Furthermore, fertilization only with macronutrients NPKMg alone has not increased clove plant flowering optimally after a large harvest. Therefore, other nutrients are needed that can stimulate vegetative and productive shoots and increase flowering. The micronutrients most closely related to flowering are Boron (B) and Zinc (Zn), which have important roles in pollination, development, and fruit yield [4][5]. The main functions of boron are strengthening cell walls, cell development, division, sugar transport, hormone development. Boron also supports RNA metabolism, respiration, Indole acetic acid (IAA) metabolism, and cell membranes and plays an important role as a driving force for many enzymes that promote plant growth and flower production. In addition, boron also plays an important role in pollen formation and pollen tube growth [6].

In comparison, Zn plays an important role in plant physiology to activate several enzymes and is associated with carbohydrate metabolism, auxin, RNA, and ribosomal function. Zn deficiency affects pollen production, pollen physiology, flower anatomy, and yield [7]. Zn application can increase fruit's number, size, and quality [8]. Meanwhile, according to [9], the addition of Zn has a good effect on the development of new leaves. The fulfillment of micro-nutrients such as B and Zn will facilitate physiological processes to compose the structural organs of flowers. Application of micronutrients such as B and Zn can increase vegetative growth, flowering, and production in citrus, tomato, and gladiolus plants [10][11][12][13]. This research aimed to increase vegetative and reproductive shoots to stimulate flowering by applying macro and micronutrients using 30 years old clove-plant.

2. Material and methods
2.1 Plant materials
The study was conducted from 2013-2015 on productive cloves aged ± 30 years, at the farmer garden, in Sumedang Regency, West Java.

a. Experimental design and treatment
The experimental design used was a randomized block design, repeated six times, five trees per treatment. The treatments tested were: (a) control/without fertilizer, (b) NPKMg (4:1:3:0.4), (c) NPKMg (4:1:3:0.4) + 30 g B + 30 g Zn, and (d) NPKMg (4:1:3:0.4) + 60 g B + 60 g Zn. The dose of NPKMg macro fertilizer applied was adjusted to the age of the plant-based on the SOP for fertilizing cloves at the age of 30 years, namely 8 kg (N = 3.8 kg, P₂O₅ = 0.95 kg, K₂O = 2.86 kg and MgO = 0.4 kg) per trees per year. The source of NPKMg is urea, SP-36, KCl, while the source of boron (B) is H₃BO₃ and Zn is ZnO. The dose of fertilizer was divided into two doses, each given half the dose. The first fertilization was applied after harvest at the beginning of the rainy season, and the second was applied four months later. Fertilization was carried out by spreading it around the plant roots in the canopy projection, then covering it with soil. As a basic fertilizer, dung-manure was used, which was applied twice, along with fertilization treatments of 15 kg/tree each.

b. Observation and data analysis
The variables observed were plant growth (number of harvested residual branches that sprouted vegetatively). In addition, observations were performed every 1.5 months after harvest for fresh flower production, chlorophyll content, carbohydrate content, leaf C/N ratio, and plant nutrient content, observed four months after harvest. Data were analyzed using ANOVA followed by DMRT (α= 5%).
3. Results and discussion

3.1. Plant growth

The statistical analysis results showed that fertilizer application significantly increased the number of harvested branches sprouted vegetatively (Table 1). It is sufficient to observe growth on vegetative branches because they are closely related to subsequent flowering. Clove plant flowering is terminal (flowers form only at the tips of the shoots); therefore, harvesting flowers is identical to trimming the ends of the branches. Clove flower harvesting causes stagnation of branch growth. The branches’ shoots are necessary for the flowers to come out the next season. The results of Theron et al.’s [14] research on figs-fruit showed that shoot tip trimming decreased the rate of shoot emergence but increased shoot/branch length.

The application of NPKMg fertilizer (4:1:3:0.4) can significantly increase the growth parameters. The application of NPKMg fertilizer (4:1:3:0.4) + 30 g B + 30 g Zn increased both growth parameters higher than other treatments. Adding a higher micronutrient (60 g B + 60 g Zn) could significantly increase the number of ex-harvested branches that sprouted vegetatively compared to other treatments. Fig. 1 shows ex-harvest branches that produce vegetative shoots. Fig. 2 shows fertilization treatment activities after harvest and four months after harvest. The purpose of giving fertilization treatment four months after harvesting is to increase the growth of reproductive shoots (flowers) that are starting to form. After harvesting, the clove plant is fertilized, then vegetative shoots will form. In the next stage, generative shoots will be formed four months after fertilization (Figure 2). After that, it will develop into a flower bud at five to six months after fertilization (Figures 3 a and b). In unfavorable climatic conditions, flower formation will fail because the generative shoots turn into leaf buds (Figures 3 c and d).

Table 1. Effect of fertilization treatment on the number of remaining harvest branches that sprouted vegetatively in the 30-year-old clove plants.

| Treatments                  | Number of remaining branches harvested that sprouted vegetatively 1.5 months after harvest |
|-----------------------------|------------------------------------------------------------------------------------------------|
| Control                     | 8.10 a                                                                                       |
| NPKMg                       | 12.15 b                                                                                      |
| NPKMg + 30 g B + 30 g Zn    | 14.65 c                                                                                      |
| NPKMg + 60 g B + 60 g Zn    | 14.50 d                                                                                      |

Note: Numbers followed by the same letter in the same column are not significantly different at the 5% DMRT.

Figure 1. Vegetative shoots begin to grow on branches that have been harvested 1.5 months after fertilizers application.
3.2. Flower yield

The statistical analysis results showed that the application of fertilizer significantly increased the production of fresh flowers higher than the control in 2016 (Table 2 and Figure 4). In 2016 at the research site and the surrounding clove plantations, there was a moderate category of the harvest season. During the harvest season, the application of macro fertilizer NPKMg (4:1:3:0,4) with micro fertilizers B and Z at a dose of 60 g/tree/year significantly increased clove flowering (Table 2). This treatment can also increase flower harvests during small harvest seasons, such as in 2013 and 2014. During the large harvest season (2015), where the climatic conditions are very supportive of flowering, macro fertilizer NPKMg (4:1:3:0,4) alone was sufficient to increase flowering, including micro fertilizers B and Z had no significant effect. During the small harvest season, in 2013 and 2014, and the medium harvest season in 2016, NPKMg (4:1:3:0,4) + 60 g B + 60 g Zn fertilization increased fresh flower yield 516.67%, 303, 70%, and 122.37%, respectively. This result was higher than the control. During the big harvest season
in 2015, the application of NPKMg (4:1:3:0.4) without the addition of B and Z fertilizers increased the production of fresh flowers by 135.53%, higher than the control. After the big harvest season (2015), the following year’s harvest (2016) was medium. The addition of micro fertilizers B and Zn each as much as 60 g/plant/year after the big harvest season increased the production of fresh flowers by 44.35%. The climate influences large, medium, and small harvests before flowering and at the time of flowering. The research results [15] showed that the climate affects the fluctuation of clove yield by 37-68%; the rest is influenced by genetic factors and cultivation methods (fertilization, maintenance, and harvesting).

Table 2. The effect of fertilization on the clove fresh flowers yield of 30-year-old productive plant.

| Treatments                        | Fresh flower yield (kg) |
|-----------------------------------|-------------------------|
|                                   | 2013 | 2014 | 2015 | 2016 |
| Control                           | 1.2 a| 2.7 a| 14.1 a| 7.6 a|
| NPKMg                             | 4.4 b| 5.9 b| 31.1 b| 12.4 b|
| NPKMg + 30 g B + 30 g Zn          | 2.3 ab| 5.1 b| 33.4 b| 13.9 bc|
| NPKMg + 60 g B + 60 g Zn          | 7.4 c| 10.9 c| 35.9 b| 17.9 c|

Note: Numbers followed by the same letter in the same column are not significantly different at the 5% DMRT.

Figure 4. The effect of fertilization on the clove fresh flowers yield of the 30-year-old productive plant.

3.3. Chlorophyll content, carbohydrates, and C/N ratio
The highest chlorophyll content, carbohydrates, C/N ratio, nutrient of NPKMg, B, and Zn was shown by the treatment of NPKMg + 60 g B + 60 g/tree/year (Table 3 and Table 4). According to [16], Zn fertilization plays a role in forming chlorophyll and carbohydrates in leaves. The C/N ratio is defined as the ratio of the mass of Carbon (C) to the mass of Nitrogen (N) in a substance. If the carbon content is too high, then the decomposition process will take a long time, otherwise, if the nitrogen content is too high, then the decomposition process will take place quickly, but some of the nitrogen will be released/evaporated into the air. If the C/N ratio is high, the biological activity of microorganisms will be reduced. It takes several cycles of microorganisms to degrade the compost so that it takes a long time for composting and results in lower quality. If the C/N ratio is too low, excess nitrogen that is not used by microorganisms cannot be used assimilated and will be lost through volatilization as ammonia or denitrification. According to [17], the factors affecting decomposition are the C/N ratio, particle size, aeration, porosity, humidity, temperature, acidity, and nutrient content. In our study, clove leaves had a
C/N ratio between 23.20 – 36.10, N, P, K content were between 0.21%-0.53%, 11.23%-18.90%, and 0.47%-0.73%. With the C/N ratio and nutrient content, clove leaves will decompose quickly. This decomposition process is very important for sustainable agriculture.

Table 3. Chlorophyll content, carbohydrates, and C/N ratio of cloves leaves from 30 year age of plantation.

| Treatment                  | Chlorophyll (%) | Carbohydrates (%) | C/N ratio |
|----------------------------|-----------------|-------------------|-----------|
| Control                    | 0.12            | 2.30              | 23.20     |
| NPKMg                      | 0.16            | 3.20              | 31.28     |
| NPKMg + 30 g B + 30 g Zn   | 0.17            | 3.31              | 34.79     |
| NPKMg + 60 g B + 60 g      | 0.20            | 3.93              | 36.10     |

Nutrient content in clove leaves showed that it increased after the plants were given fertilizer treatment (Table 4). The increase in nutrient content is in line with the increase in growth, yield, chlorophyll content, carbohydrates, and C/N ratio (Table 1, 2 dan 3).

Table 4. Nutrient content in 30-year-old clove leaves.

| Treatments                  | N (%) | P₂O₅ (ppm) | K (%) | Mg (%) | B (ppm) | Zn (ppm) |
|-----------------------------|-------|------------|-------|--------|---------|----------|
| Control                     | 0.21  | 11.23      | 0.47  | 1.12   | 3.79    | 117      |
| NPKMg                       | 0.49  | 17.10      | 0.57  | 1.34   | 4.48    | 132      |
| NPKMg + 30 g B + 30 g Zn    | 0.51  | 18.16      | 0.69  | 1.37   | 4.67    | 148      |
| NPKMg + 60 g B + 60 g       | 0.53  | 18.90      | 0.73  | 1.48   | 6.12    | 152      |

4. Conclusion
The growth of productive clove can be increased by applying macro fertilizer NPKMg (4:1:3:0.4) as much as 8.4 kg per year per tree. Approaching the small harvest season and the medium harvest season, fertilizing 8.4 kg NPKMg (4:1:3:0.4) + 60 g B + 60 g Zn increased the production of fresh clove flowers by 303.27-516.67 %, and 122.37%, and were higher than the control. Approaching the big harvest season, 8.4 kg of NPKMg (4:1:3:0.4) fertilization without B and Z fertilizers increased the yield of fresh clove flowers by 135.53%, higher than the control. Chlorophyll content, carbohydrates, C/N ratio, and plant nutrient content can be increased by applying NPKMg fertilizer (4:1:3:0.4) + 60 g B + 60 g/tree/year. Research still needs to be continued to determine the next flower production, at least in one period of fluctuation in clove yield (5 times harvests).

References
[1] Dirjenbun 2020 Statistik Perkebunan Unggulan Naisonal
[2] Setiawan; Rosihan Rosman 2015 Status penelitian, penerapan teknologi dan strategi Research Status of Clove, Application of Technology and Development Strategy with Ecological Basic 14 27–36
[3] Ruhnayat A 2007 Aplikasi model pemupukan berimbang pada tanaman cengkeh ( Syzigium aromaticum ) Agus Ruhnayat Application of Model for Balance Fertilizer on Clove Tanaman cengkeh ( Syzigium untuk tanaman cengkeh berdasarkan matematis yang dapat menghitung do- pupuk sanga XVIII 149–58
[4] Abdollahi M, Eshghi S and Tafazoli E 2015 Interaction of Paclobutrazol, Boron and Zinc on Vegetative Growth, Yield and Fruit Quality of Strawberry (Fragaria × Ananassa Duch. Cv. Selva) J. Biol. Environ. Sci. 4 67–75
[5] Anon 2011 Effect of Foliar Spray With Zinc and Boron on Soil J. Prod. Dev., 16(3)483 506(2011) 16 483–506
[6] Blevins D Role of boron in plant growth  Role of boron in plant growth : A Related papers
[7] Usenik V and Štampar F 2002 Influence of scion/rootstock interaction on seasonal changes of phenols Phyt. - Ann. Rei Bot. 42 279–89
[8] Davarpanah S, Tehranifar A, Davarynejad G, Abadía J and Khorasani R 2016 Effects of foliar applications of zinc and boron nano-fertilizers on pomegranate (Punica granatum cv. Ardejani) fruit yield and quality Sci. Hortic. (Amsterdam). 210 57–64
[9] Razzaq K, Khan A S, Malik A U, Shahid M and Ullah S 2013 Foliar application of zinc influences the leaf mineral status, vegetative and reproductive growth, yield and fruit quality of “kinnnow” mandarin J. Plant Nutr. 36 1479–95
[10] Sajid M, Ali N, Arif M, Ferguson L and Ahmed M 2010 effect of foliar application of zn and b on fruit production and physiological disorders in sweet orange cv. Blood orange 26 355–60
[11] Mohammed N, Makhoul G and Bouissa A-A 2018 Effect of Foliar Spraying with B, Zn and Fe on Flowering , Fruit Set and Physical Traits of the Lemon Fruits (Citrus Meyeri) Int. J. Agric. Environ. Sci. 5 50–8
[12] Meena D C, Maji S, Meena J K, Govind, Kumawat R, Meena K R, Kumar S and Sodh K 2015 Improvement of growth, yield and quality of tomato (Solanum lycopersicum L.) cv. Azad T-6 with foliar application of zinc and boron Int. J. Bio-resource Stress Manag. 6 598
[13] Fahad S, Masood Ahmad K, Akbar Anjum M and Hussain S 2014 The effect of micronutrients (B, Zn and Fe) foliar application on the growth, flowering and corn production of gladiolus (Gladiolus grandiflorus L.) in calcareous soils J. Agric. Sci. Technol. 16 1671–82
[14] Theron K I, Gerber H J and Steyn W J 2011 Effect of hydrogen cyanamide, mineral oil and thidiazuron in combination with tip pruning on bud break, shoot growth and yield in “Bourjasotte Noire”, “Col de Damme Noire” and “Noire de Caromb” figs Sci. Hortic. (Amsterdam). 128 239–48
[15] Pasril Wahid and Agus Ruhnayat 1995 Pengaruh unsur-unsur iklim terhadap fluktuasi hasil cengkeh Agromet 11 48–58
[16] Borowiak K, Gąsecka M, Mleczek M, Dąbrowski J, Chadzinikolau T, Magdziak Z, Goliński P, Rutkowski P and Kozubik T 2015 Photosynthetic activity in relation to chlorophylls, carbohydrates, phenolics and growth of a hybrid Salix purpureaxtriandraxviminalis 2 at various Zn concentrations Acta Physiol. Plant. 37
[17] Budi Nining Widarti, Wardah Kusuma Wardhini E S 2015 Pengaruh Rasio C/N Bahan Baku Pada Pembuatan Kompos Dari Kubis dan Kulit Pisang J. Integr. Proses 5 75–80