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Planta Tropika

Jurnal Agrosains (Journal of Agro Science)

Planta Tropika focuses related to various themes, topics and aspects including (but not limited) to the following topics Agro-Biotechnology, Plant Breeding, Agriculture Waste Management, Plant Protection, Soil Science, Post Harvest Science and Technology, Horticulture. Planta Tropika published two times a year (February and August) by Universitas Muhammadiyah Yogyakarta in collaboration with Indonesian Association of Agrotechnology / Agroecotechnology (PAGI). The subscriptions for one year : IDR 350.000.

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Editorial

Journal of Planta Tropika ISSN 0216-499X published by Study Program of Agrotechnology, Faculty of Agriculture, Universitas Muhammadiyah Yogyakarta, is journal presenting scientific articles of agricultural science (Journal of Agro Science). With full sense of gratitude to the Almighty Allah, Volume 8 Number 2 for the year of 2020 has been published.

In this edition, Journal of Planta Tropika presents seven research articles in the field of Agro sciences comprising post harvest physiology, crop cultivation system, weeds management, tissue culture, land management, and climate. The scientific articles discuss about:

(1) Pathogenicity of Entomophatogenic Fungi *Lecanicillium Lecanii* Against Predator Insect *Menochilus sexmaculatus*, (2) The potential of *Telenomus remus* Nixon (Hymenoptera: Scelinoidae) as Biocontrol Agent for the New Fall Armyworm *S. frugiperda* (Lepidoptera: Noctuidae) in Indonesia, (3) Physiological Aspect of Cauliflower (*Brassica oleracea* var. Botrytis l.) as Affected by Nitrogen and Liquid Organic Fertilizer on Coastal Sandy Land, (4) The Use of Biofilm Biofertilizer to Improve Soil Fertility and Yield of Upland Kale (*Ipomoea reptans*) in Vertisol, (5) The Application of Filter Cake Compost to Improve The Efficiency of Inorganic Fertilizer in Upland Sugarcane (*Saccharum officinarum* L.) Cultivation, (6) Identification of Changes in Water Catchment Areas in Kulon Progo District Using Geographic Information Systems, (7) Effects of Trenches with Organic Matter and KCL Fertilizer on Growth and Yield of Upland Rice in Eucalyptus Agroforestry System, and (8) Usage of Heat Treatment and Modified Atmosphere Packaging to Maintain Fruit Firmness of Fresh Cut Cavendish Banana (*Musa cavendishii*).

The editors would like to thank the authors, reviewers, executive editors, leaders and LP3M UMY for their participation and cooperation. Our hope, this journal can be useful for readers or be a reference for other researchers and useful for the advancement of the agriculture.

Editors

GUIDE FOR AUTHORS

TYPE OF PAPERS

PLANTA TROPIKA receives manuscripts in the form of research papers in Bahasa Indonesia or English. The manuscript submitted is a research paper that has never been published in a journal or other publication.

SUBMISSION

The submission of the manuscript is done through our journal website http://journal.umy.ac.id/index.php/pt/index. If you need information regarding the process and procedure for sending the manuscript, you can send it via email at plantatropika@umy.ac.id. Editor's address: Program Studi Agroteknologi, Fakultas Pertanian, Universitas Muhammadiyah Yogyakarta, Jl. Ring Road Selatan, Tamantirto, Kasihan, Bantul, Telp (0274) 387646 psw 224, ISSN: 2528-7079.

ARTICLE STRUCTURE

The submitted manuscripts should consist of 15-20 pages of A4 size paper with 12-point Times New Roman fonts, 1.5 spacing with left-right margin and top-bottom of the paper is 2.5 cm each. All manuscript pages including images, tables and references should be page-numbered. Each table or picture should be numbered and titled.

The systematic of the manuscript writing is as follows:

TITLE : The title should be brief and informative and written bold. Only the first letter of the words is written in uppercase. Maximum length should be 14 words.

AUTHOR NAMES : The author names should be written in lowercase letters (only the first letter of the words is written in uppercase) and should be written from the first author and followed by the others along with the marker of each author's affiliation.

AUTHOR AFFILIATIONS : The author affiliation should be written in lowercase letters (only the first letter of the words is written in uppercase) and it is written according to the order of the number marker of each author's affiliation.

EMAIL : Please list one of authors' email address used for paper's correspondence.

ABSTRAK : Abstrak is written in Bahasa Indonesia using single space in a paragraph with maximum length of 200 words. It should contain background, objective, method, results, and conclusion followed by keywords containing maximum of 5 words.

ABSTRACT : Abstract is written in English using single space in a paragraph with maximum length of 200 words. It should contain background, objective, method, results, and conclusion followed by keywords containing maximum of 5 words.

INTRODUCTION : Introduction contains background, hypothesis or problem outline, and the objective of the research.

MATERIALS AND METHOD : Explaining in detail about materials and method used in the research as well as the data collection and analysis.

RESULT AND DISCUSSION : The results of the research should be clear. State the results collected according to analyzed data. Discussion should include the significance of the results.

CONCLUSION : Authors are expected to give brief conclusion and to answer the objective of the research.

ACKNOWLEDGEMENT : If necessary.

REFERENCES : Single space, according to the authors' guide of Planta Tropika.

EXAMPLES ON HOW TO WRITE REFERENCES

References are written in alphabetical order according to the rules below:

REFERENCE TO A BOOK

Gardner, F.P., R.B. Pearce, and R.L. Mitchell. 1991. Fisiologi Tanaman Budidaya (Translated by Herawati Susilo). UI Press. Jakarta.

REFERENCE TO A JOURNAL PUBLICATION

Parwata, I.G.M.A., D. Indradewa, P.Yudono dan B.Dj. Kertonegoro. 2010. Pengelompokan genotipe jarak pagar berdasarkan ketahanannya terhadap kekeringan pada fase pembibitan di lahan pasir pantai. J. Agron. Indonesia 38:156-162.

REFERENCE TO A THESIS/DISSERTATION

Churiah. 2006. Protein bioaktif dari bagian tanaman dan akar transgenic Cucurbitaceae serta aktivitas antiproliferasi galur sel kanker *in vitro*. Disertasi. Sekolah Pascasarjana. Institut Pertanian Bogor. Bogor.

REFERENCE TO AN ARTICLE IN PROCEEDING

Widaryanto dan Damanhuri. 1990. Pengaruh cara pengendalian gulma dan pemberian mulsa jerami terhadap pertumbuhan dan produksi bawang putih (Allium sativum L.). Prosiding Konferensi Nasional X HIGI hal. 376-384.

FIGURE FORMATTING

Title should be given **below each figure**. Additional information (notes) should be written in lowercase letters except the first letter in each sentence. All figures need to be numbered respectively. Figures should be placed close to explanation/ discussion about the figure.

Examples :

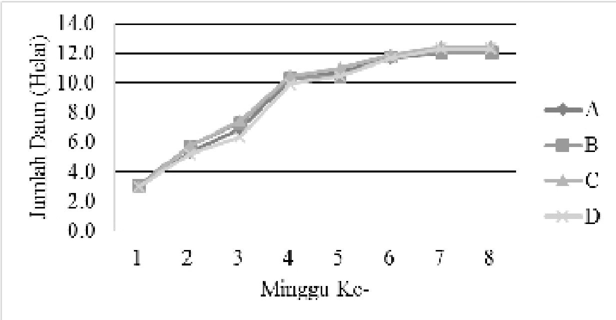

Figure 1. Number of leaves of corn plant

Notes:
A = 250 kg KCl/ha + 0 kg KJP/ha
B = 125 kg KCl/ha + 273,89 kg KJP/ha
C = 62,5 kg KCl/ha + 410,84 kg KJP/ha
D = 0 kg KCl/ha + 547,79 kg KJP/ha

Fig. 1., Fig. 2., and so on. The title of the figure is written with lowercase letters (use uppercase letter at the beginning of the title only) and without full stop (.). Additional information (notes) is placed below the figure.

TABLE FORMATTING

The title of the table should be written **above the table** started from the left (left alignment). Additional information related to the table (notes) is placed below the table. The information is written in uppercase letters at the beginning only as well as the titles inside the table. Table is placed close to the discussion of the table.

Examples :

Table 1. Fruit compost analysis

Variable	Jatropha before composted	Jatropha after composted	SNI (National standard) for compost	Category
Water content	22,49 %	45,79 %	≤ 50 %	Qualified
pH	7,05	8,02	4-8	Qualified
C-Organic content	10,01	5,11	9,8-32 %	Not qualified
Organic matter	17,42 %	8,81 %	27-58	Not qualified
N-Total	0,97 %	2,69 %	< 6 %	Qualified
C/N Ratio	10,44	1.90	≤ 20	Qualified
Potassium	-	9,06 %	< 6 %**	Qualified

Notes: **) Certain materials originated from natural organic matters are allowed to contain P_2O_5 dan K_2O level > 6% (proved with the results of laboratory analysis).

Pathogenicity of Entomophatogenic Fungi *Lecanicillium Lecanii* Against Predator Insect *Menochilus sexmaculatus*

DOI: 10.18196/pt.2020.115.63-68

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ABSTRACT

Lecanicillium lecanii is an insect pathogenic fungus that is often used for pest control and has a wide range of hosts. The L. lecanii is capable of infecting several types of host insects including the Order Orthoptera, Hemiptera, Lepidoptera, Thysanoptera and Coleoptera. The extent of this fungus host range was feared to have a negative effect on predator insects Menochilus sexmaculatus. This study aims were to determined the pathogenicity of the fungus L. lecanii against the imago predatory beetle M. sexmaculatus, to know how the predation ability and the number of eggs fecundity of Imago M. sexmaculatus after application L. lecanii. The research was arranged in Randomized Block Design with 4 replications. The conidia density of L. lecanii used were 10^6, 10^7, 10^8, 109 conidia/ml, 1 ml / l of lufenuron insecticide as positive control and sterile distilled water as negative control. The research showed that the mortality percentage of M. sexmaculatus due to L. lecanii application is low and medium. The L. lecanii was not affected for preying ability on imago M. sexmaculatus but gave effect to the number of eggs fecundity of imago M. sexmaculatus.

Keywords: Predator beetle, Biological control, Entomopathogenic Fungus, Lecanicillium

ABSTRAK

Lecanicillium lecanii adalah jamur patogen serangga yang sering digunakan untuk pengendalian hama dan memiliki kisaran inang yang luas. *L. lecanii* dapat menginfeksi beberapa jenis inang dari golongan serangga diantaranya ordo Orthoptera, Hemiptera, Lepidoptera, Thysanoptera, dan Coleoptera. Luasnya kisaran inang jamur ini dikhawatirkan memiliki efek negatif pada serangga predator *Menochilus sexmaculatus*. Penelitian ini bertujuan untuk mengetahui patogenesitas jamur *L. lecanii* terhadap imago kumbang predator *M. sexmaculatus*, mengetahui kemampuan predasi dan jumlah fekunditas telur imago M. sexmaculatus setelah aplikasi *L. lecanii*. Penelitian menggunakan rancangan acak kelompok (RAK) dengan 4 ulangan. Kerapatan kondia *L. lecanii* yang digunakan adalah 10^6, 10^7, 10^8, 10^9 konidia/ml, 1 ml / 1 insektisida lufenuron sebagai kontrol positif, dan air suling steril sebagai kontrol negatif. Hasil menunjukkan bahwa presentase kematian *M. sexmaculatus* akibat aplikasi *L. lecanii* adalah rendah dan sedang. Aplikasi *L. lecanii* tidak mempengaruhi kemampuan *M. sexmaculatus* dalam memangsa, tetapi berpengaruh terhadap jumlah fekunditas telur imago *M. sexmaculatus*.

Kata Kunci: Kumbang predator, Pengendalian hayati, Jamur entomopatogenik, *Lecanicillium*

INTRODUCTION

The use of entomopathogens for insect pest control is now widely introduced to farmers through various programs. It aims to replace synthetic insecticides that are harmful to the environment. One of the most commonly used entomopathogens is *Lecanicillium lecanii* (Zimmerman) which have wide host range (Shinde et al., 2010). *L. lecanii* produces secondary metabolite compounds that are toxic to insects. The secondary metabolite compounds consist of hydrolytic enzymes such as proteases, chitinases and lipases (Hasan, et al., 2013) and toxin compounds such as dipicolinic acid (Claydon and Grove, 1982), vertilecanin-A1, decenedioic acid and 10-hydroxy-8-decenoic acid (Soman et al., 2001). The *L. lecanii* is capable of infecting several insects orders including Orthoptera, Hemiptera, Lepidoptera, Thysanoptera and Coleoptera (Khoiroh, Isnawati, & Faizah, 2014).

The use of *L. lecanii* as a biological control in agroecosystems should be considered to influence beneficial organisms such as predators. The wide range of hosts from this entomopathogen is feared to infect predatory insects. One of the predatory insects potentially infected by *Lecanicillium lecanii* is *Menochillus sexmaculatus*. M. *sexmaculatus* is one of a kind polyphagous predatory beetle against several insect pests including *Acyrthosiphon pisum* (Harris), *Aphis craccivora* (Koch.), *Aphis fabae* (Theobald), *Aphis gossypii* (Glover), *Aphis ruborum* (Bor), *Myzus persicae* (Sulz), *Rhopalosiphum maidis* (Fitch), *Dialeurodes citri* (Ash), *Diaphorina citri* (Kuw.), and *Tetranychus orientalis* (Mcg) (Irshad, 2001). The wide range of prey of *M. sexmaculatus* makes these predatory beetle found in various agroecosystems of both food crops and horticultural crops (Riyanto et al., 2011).

Wang et al. (2005) reported that the crude toxins have low toxicity against beetle larva of *Delphastus catalinae* (with LC_{50} values of 1942 (1393–2710) and 2471 (1291–4731) p.p.m., respectively (approximately 10- and 12-fold of field rate of application 200 p.p.m.). The adult beetles had less sensitivity to crude toxins with LC_{50} values of 4260 (3376–5375) and 4426 (1734–11298) p.p.m., respectively (approximately 20- and 22-fold of field rate 200 p.p.m.). The consumption and foraging capacity was significantly impaired especially in the second-instar larval beetles which took longer time (more than twice of the control beetles) to consume whitefly eggs after *D. catalinae* exposure to toxins. The study about the impact of *L. lecanii* application on predatory beetle M. *sexmaculatus* has not been widely reported, so further research is needed on the side effects of *L. lecanii* application on M. *sexmaculatus*. The benefit from this research is the information about the impact of application of *L. lecanii* on mortality of adult M. *sexmaculatus*. The preying ability of M. *sexmaculatus* and fecundity of adult M. *sexmaculatus* after application of *L. lecanii*.

MATERIALS AND METHODS

Places and Time

The research was conducted from February to October 2016 at the Pest Laboratory and Biological Control Laboratory of Plant Pest and Disease Department, Faculty of Agriculture, University of Brawijaya.

Research Preparation

Preparation of research is the collection and propagation of predatory beetles M. *sexmaculatus* taken directly from the field of rice crops, corn, beans, and chili. M. *sexmaculatus* obtained was maintained using a cage and fed *Aphis* sp.

Propagation of *L. lecanii* are done on two mediums, solid medium (PDA) and liquid medium (DPE). Propagation of *L. lecanii* on liquid medium using a shaker orbital with 120 Rpm for 48 hours. Isolate *L. lecanii* obtained from the collection of insect pathogens Department of Plant Pests and Diseases, Faculty of Agriculture, University of Brawijaya.

Implementation of Research

The pathogenicity test of *L. lecanii* on M. *sexmaculatus* using Randomized Block Design (RBD) 6 treatment with 4 replications. Each treatment there was 5 adults of M. *sexmaculatus* consisting of 2 males and 3 females. A total of 120 adults M. *sexmaculatus* were sprayed by *L. lecanii* suspension with concentration 10^6, 10^7, 10^8, 10^9 conidia/ml, sterile Aquades (negative control) and IGR pesticide with lufenuron as the active ingredient (positive control).

Variable Observations

The Mortality of adult M. *sexmaculatus applied by L. lecanii*

The observations were made by counting the number of M. *sexmaculatus* died until 7 days after application of *L. lecanii*.

The preying ability of adult M. *sexmaculatus*

The preying ability of M. *sexmaculatus* was observed by counting the number of prey (*Aphis* sp) consumed by M. *sexmaculatus* after application of *L. lecanii*. The amount of *Aphis* sp used as the feed was 20. Observations start 1 day after application and were made daily for 7 days after application. The percentage of imago mortality rate was calculated using the formula:

$$P = \frac{x}{y} \times 100\% \quad (1)$$

P is the percentage of the mortality, x is imago die, y is the total number of imago observed. If in the control of mortality occurs greater than 0% and 20% less than the treatment then mortality corrected by the formula (Abbot, 1987) :

$$P = \frac{p' - c}{100 - c} \times 100\% \quad (2)$$

P is the percentage of corrected mortality rate, p 'the observed mortality rate on each treatment, and c is the mortality rate in the control.

Fecundity of adult M. sexmaculatus

Fecundity of M. *sexmaculatus* females was observed in insects that did not die in each treatment, observations were made by mating male and female of adult M. *sexmaculatus*. after the copulation occurs, the number of eggs produced first then counted.

Data Analysis

The observed data were analyzed using F test at 5% level. If the response of the treatment significantly different, then proceed with BNT test at 5% error level. Concentration and time of death of M. sexmaculatus imago were analyzed using probit software analysis (Chi, 1997) to calculate *median lethal concentration* (LC_{50}) and *median lethal time* (LT_{50}).

RESULTS AND DISCUSSION

Patogenicity of *L. lecanii* on adult *M. sexmaculatus* Mortality

The adult of M. *sexmaculatus* infected by *L. lecanii* showed symptoms of reduced activity before death. Symptoms that appear after death are the growth of white mycelium on the body of M. *sexmaculatus* incubated for 2 days after death (Figure 1). According to (Barson, 1976) thats reported *Scolytus scolytus* (Coleoptera: Curculionidae) infected by *L. lecanii* softened shortly before death, and changed color from white to pale or yellow cream very pale. The death larvae are covered in white mycelium.

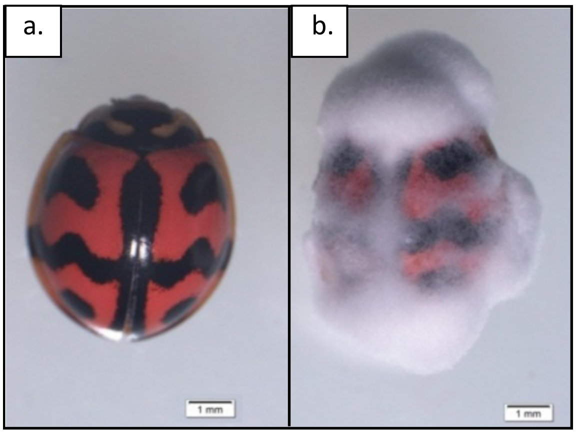

Figure 1. (a) Healthy *M. sexmaculatus* (b) Infected *M. sexmaculatus* by *L. lecanii*

The application of *L. lecanii* with various conidia density did not significantly affect the mortality of M. *sexmaculatus* (Table 1). The *L. lecanii* application was capable of infecting and causing death on adult of M. *sexmaculatus*. However, the mortality of M. *sexmaculatus* based on the classification by (Thungrabeab, Blaeser, & Sengonca, 2006) pathogenicity of entomopathogenic fungi was low and medium, ranging from 15 to 38.75%.

The death of M. *sexmaculatus* suspected due to the influence of secondary metabolite compounds produced by *L. lecanii*. (Claydon and Grove, 1982) and (Soman et al., 2001), states that *L. lecanii* produces secondary metabolite compounds, namely dipicolonic acid, vertilecanin-A1, decenedioic acid and 10-hydroxy-8-decenoic acid which can cause death in some insect pests.

Table 1. Average Mortality of *M. sexmaculatus* 7 days after Application of *L. lecanii*

Treatments	Average mortality of *M. sexmaculatus* (%) ± SE	N
L. lecanii 10^6 conidia/ml	15,00 ± 15,00	20
L. lecanii 10^7 conidia/ml	10,00 ± 05,77	20
L. lecanii 10^8 conidia/ml	22,50 ± 10,31	20
L. lecanii 10^9 conidia/ml	38,75 ± 22,40	20
Positive control (lufenuron 1 ml/l)	25,00 ± 15,00	20

Notes: the data corrected by $P = \frac{p' - c}{100 - c} \times 100\%$

the data transformed by $\sqrt{X} + 0.5$

n = total insects observed

Table 2. Median Lethal Time (LT_{50}) *L. lecanii* on Adult *M. sexmaculatus* with Various Density Level of Conidia

Density level (conidia/ml)	Regretion	LT_{50} value (Days after application)
10^6	y = 2,19 + 0,79 x	150,41
10^7	y = -0,67 + 2,08 x	22,32
10^8	y = -1,29 + 2,54 x	12,43
10^9	y = 0,99 + 1,62 x	12,32
Positive control (lufenuron 1 ml/l)	25,00 ± 15,00	20

Notes: Observation conducted until 7 days.

The LC_{50} value of the *L. lecanii* on adult M. *sexmaculatus* mortality was 7.58 x 10^9 conidia/ml. This value indicates that the *L. lecanii* can infect and cause death on adult M. *sexmaculatus* by 50% at the conidia density level of 7.58 x 10^9 conidia/ml. Based on these results, the application of *L. lecanii* does not endanger the population of M. *sexmaculatus*. In general, the density of the *L. lecanii* used by farmers in Indonesia to control insect pests is below 10^8 conidia/ml. However, the application of the *L. lecanii* is advised not to be done too often because of the potential to increase mortality in beneficial insects (Prayogo & Suharsono, 2005).

The higher density of conidia *L. lecanii* applied to adult M. *sexmaculatus* the more rapidly causing the death of adult M. *sexmaculatus*. The density of *L. lecanii* with fastest LT_{50} is at 1 x 10^9 conidia/ml of 12.32 days after application. High conidial concentration affects the speed of penetration on the walls of the insect body to speed up the infection process. (Masyitah et al., 2017) states that insect pathogenic fungi with a greater number of conidia will provide a faster epizootic response to targeted insects.

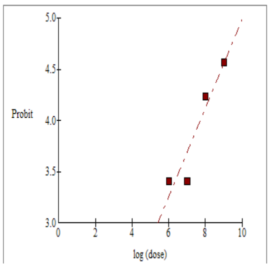

Figure 2. LC_{50} graphic *L. lecanii* on *M. sexmaculatus* Beetle

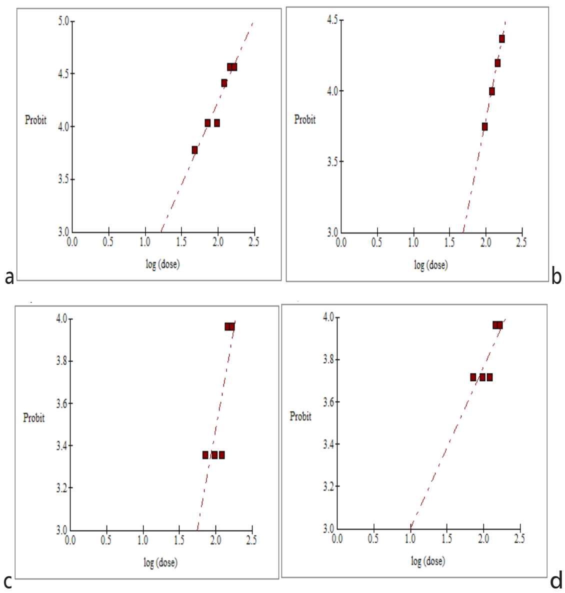

Figure 3. Lethal time graphic of *L. lecanii* with differents concentration on *M. sexmaculatus* Beetle (a) LT_{50} graphic at 10^9 conidia/ml, (b) LT_{50} graphic at 10^8 conidia/ml, (c) LT_{50} graphic at 10^7 conidia/ml, (d) LT_{50} graphic at 10^6 conidia/ml

Table 3. Averages Number of *A. gossypii* that were Preyed by Adult *M. sexmaculatus* until 7 Days After Application

Treatments	Means *Aphids sp* per day ± SE	N
L. lecanii 10^6 conidia/ml	11,67 ± 1,04	17
L. lecanii 10^7 conidia/ml	11,58 ± 0,75	17
L. lecanii 10^8 conidia/ml	12,13 ± 0,89	14
L. lecanii 10^9 conidia/ml	10,49 ± 0,53	12
Positive control (lufenuron 1 ml/l)	11,26 ± 0,75	15
Negative control (Sterill Destilated Water)	11,20 ± 0,97	18

Notes: n = total insects observed.

Table 4. Averages Number of *A. gossypii* that were Preyed by Adult *M. sexmaculatus* until 7 Days After Application

Treatments	Average Number of Eggs + SE	N
L. lecanii 10^6 conidia/ml	4,25 ± 1,44 ab	10
L. lecanii 10^7 conidia/ml	2,00 ± 1,15 a	11
L. lecanii 10^8 conidia/ml	2,00 ± 1,15 a	10
L. lecanii 10^9 conidia/ml	1,00 ± 0,58 a	7
Positive control (lufenuron 1 ml/l)	1,00 ± 0,58 a	9
Negative control (Sterill Destilated Water)	5,25 ± 1,89 b	9

Notes: The number followed by the same letter is not significantly different at the 5% level of the LSD test.

Preying Ability of *M. sexmaculatus*

The application of *L. lecanii* did not have a significant effect on the prey ability of M. *sexmaculatus*. The ability to prey on M. *sexmaculatus* remains high despite the application of the *L. lecanii*, this can be seen from the number of A*phis* sp. which were preyed on by adult M. *sexmaculatus* showed no difference when compared to controls (Table 3).

Fecundity of adult *M. sexmaculatus*

The application of *L. lecanii* affect on fecundity of adult M. *sexmaculatus*. The higher density level of the *L. lecanii* applied, the number of eggs placed by the female M. *sexmaculatus* decreases. The decrease in the number of eggs placed by M. *sexmaculatus* females reached 80.96% compared with controls. Thats indicates that the application of fungus *L. lecanii* affects the fecundity of M. *sexmaculatus*. (Wang, Huang, You, Guan, & Liu, 2005) also reported that the application of the *L. lecanii* was able to decrease fecundity of the predatory beetle *D. catalinae* (Coleoptera: Coccinellidae).

The decrease number of eggs produced by M. *sexmaculatus* due to the application of *L. lecanii* allegedly because M. *sexmaculatus* lost nutrients in the body that support the process of egg formation. According to (Tanada & Kaya, 1993), after the fungus of the entomopathogen successfully penetrated the cuticle, the hyphae in the insect body will develop and multiply by absorbing the nutrients present in the insect's body. Besides, each insect has a different strategy in dealing with nutritional deficiencies. Especially for the Coccinellidae family the efforts undertaken in the face of nutritional deficiency is to reduce the amount of egg production (Hodek, van Emden, & Honek, 1996).

CONCLUSION

The application of *L. lecanii* at density level 10^6, 10^7, 10^8, 10^9 conidia/ml capable to infecting and causing death on adult of M. *sexmaculatus* with mortality value 15,00, 10,00, 22,50, and 38,75% respectively.The application of *L. lecanii* did not have effect on the prey ability of M. *sexmaculatus*. The application of *L. lecanii* is capable to decrease fecundity of adult M. *sexmaculatus*.

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The potential of *Telenomus remus* Nixon (Hymenoptera: Scelinoidae) as Biocontrol Agent for the New Fall Armyworm S. frugiperda (Lepidoptera: Noctuidae) in Indonesia

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ABSTRACT

The fall armyworm Spodoptera frugiperda is an emerging new pest species in several Asian countries including Indonesia. This pest can be a threat to Indonesian agriculture because this pest has been reported to cause many losses in other countries. As a preemptive and ecofriendly control strategy, a research to study the performance of Telenomus remus as potential biocontrol agent of this pest was done in laboratory scale. Research was done by exposing an adult female to 50 eggs of S. frugiperda in a cluster. We also exposed the female parasitoid to another 50 eggs of S. litura in a cluster for comparison since this parasitoid had been reported as S. litura egg parasitoid in Indonesia previously. Results showed that there are no difference in the numbers of parasitized eggs, parasitism rate, survival rates and percent females of T. remus reared from both S. frugiperda and S litura, which implies the effectiveness of T. remus as a candidate for biocontrol agent for S. frugiperda.

Keywords: Biological control, Parasitoid, Spodoptera frugiperda, Telenomus remus

ABSTRAK

Ulat grayak *Spodoptera frugiperda* merupakan hama baru di beberapa negara Asia termasuk Indonesia. Ulat grayak dapat menjadi ancaman bagi pertanian di Indonesia karena hama ini telah dilaporkan dapat menimbulkan kehilangan hasil dalam jumlah banyak di negara-negara lain. Sebagai tindakan pengendalian preemptive yang bersifat ramah lingkungan, sebuah penelitian dengan tujuan mempelajari kemampuan *Telenomus remus* sebagai agen hayati potensial bagi *S. frugiperda* telah dilakukan pada skala laboratorium. Penelitian dilakukan dengan cara memaparkan satu *T. remus* betina dewasa terhadap 50 telur *S. frugiperda*. *T. remus* juga dipaparkan terhadap 50 telur *S. litura* sebagai perbandingan. *S. litura* dipilih karena *T. remus* telah dilaporkan efektif dalam mengendalikan *S. litura*. Hasil penelitian menunjukkan bahwa jumlah telur yang diparasit, tingkat parasitisme, kemampuan bertahan hidup dan jumlah keturunan betina *T. remus* yang dihasilkan baik dari inang *S. frugiperda* maupun *S. litura* tidak berbeda. Dengan demikian, parasitoid telur *T. remus* dapat digunakan sebagai agen hayati potensial bagi *S. frugiperda*.

Kata Kunci: Pengendalian hayati, Parasitoid, *Spodoptera frugiperda, Telenomus remus*

INTRODUCTION

Spodoptera spp. (Lepidoptera: Noctuidae) are the common pest of Indonesia including *Spodoptera litura* and *S. exigua* (Kalshoven, 1981). *Spodoptera litura* is the most voracious among the genus of *Spodopotera* which is commonly found in leguminous plants (Tengkano & Suharsono, 2005) and *S. exigua* is commonly found in onion and other 170 plant species (Zhang, Huai, Helen, & Wang, 2011). In the meantime, *Spodoptera frugiperda* is a newly reported pest species of Indonesia in 2019. This pest was found around Sumatera, Java, and Kalimantan island (BBPOPT, 2019). This pest was found attacking corn in a low population in Java (Maharani et al., 2019). In contrast, Trisyono, Suputa, Aryuwandari, Hartaman, and Jumari (2019) reported the 100% infestation level of *S. frugiperda* in Lampung.. This pest can also attack another crop such as soybean, cotton, rice and other grasses, and weeds (Nabity, Zangerl, Berenbaum, & DeLucia, 2011; Pogue, 2002). *S. frugiperda* originates from America (Sparks, 1979) and widespread to Africa in 2016 (Goergen, Kumar, Sankung, Togola, &

Tamò, 2016) threatened corn yield loss of 8.3 to 20.6 million tons per annum ((Day et al., 2017). In 2018, this pest was reported from China with a quick distribution rate of up to 17 provinces in a month (Jiang, Liu, & Zhu, 2019). *S. frugiperda* was also reported in India, Bangladesh, Thailand, Myanmar, and Sri Lanka in 2018 (CABI, 2019a).

Maharani et al. (2019) stated that the low infestation level of *S. frugiperda* in Indonesia is followed by the presence of natural enemies such as parasitoid and entomopathogenic pathogens in the field with unclear parasitism rate. The presence of natural enemies in the field is an insight for possible natural control taken in the future. One possibility for controlling *S. frugiperda* is the use of natural enemies that is egg parasitoid *Telenomus remus* Nixon (Hymenoptera: Scelionidae) (Kenis et al., 2019).

Telenomus remus is an egg parasitoid of various lepidopteran pest species including genus *Spodoptera* (CABI, 2019b). Buchori, Herawati, and Sari (2017) reported that the release of *T. remus* able to suppress 48% population of *S. exigua* in potted onion plants. Meanwhile, Satyanarayana, Ballal, and Rao (2005) reported 96% parasitism rate of *S. litura* eggs by *T. remus*. Furthermore, Liao et al. (2019) showed that field parasitism incidence of *S. frugiperda* by *T. remus* in the field in China can reach up to 60.19%. Biecological key aspects of parasitoid is an important factor in determining parasitoid performance in controlling a pest in the field (Waage & Hassell, 1982). However, no study reports the bioecological key aspect of *T. remus* in *S. frugiperda*. In this research, we study the performance of *T. remus* on *S. frugiperda* and compare it to *S. litura* under laboratory conditions. This is a preemptive control strategy that can be used for natural and sustainable control of *S. frugiperda* using parasitoid in the future.

MATERIALS AND METHODS

Insect mass rearing

Both *S. litura* and *S. frugiperda* larvae were collected from a corn field in Dramaga, Bogor, Indonesia. Both larvae were taken to the laboratory for further observation. To avoid cannibalism among the larvae, each larva was reared separately in a divided plastic container. Larvae were fed using baby corn which is replaced every two days. The last instar larvae were transferred to a plastic container (35 x 28 x 7 cm) containing sterilized sand as a media for pupation. The pupae were placed in a cylindrical plastic cage (d = 15 cm, h = 10 cm) until the emergence of the moth. The moths were reared in the similar cage for pupation. The moths were fed using a 20 % honey solution.

Meanwhile, collected parasitized larvae of *S. frugiperda* were reared in a 50 ml test tube containing honey droplets as a food source until the emergence of the adult. Two days after emergence, a mated female of *T. remus* was introduced to a petri dish (86 x 13 mm) containing *S. frugiperda* egg cluster. Parasitized *S. frugiperda* larvae were reared using the same method for rearing unparasitized larvae until the formation of *T. remus* pupae. These new emerging parasitoids were used for the experiment.

The performance of *T. remus* on *S. frugiperda*

The performance of *T. remus* on *S. frugiperda* was tested by exposing a mated female to one egg mass consisting of 50 eggs of *S. frugiperda* for 24 h in a 250 ml test tube. Honey droplets were provided as an additional food source. After the test, parasitized eggs were reared until the emergence of the new parasitoids by the similar method for rearing the parasitoid. The test was repeated ten times using different females. Parameter tested including the number of parasitized eggs, parasitism rate, number of emerging parasitoids, survival rate and sex ratio (percent females). These parameters are determined based on the method of Puspitaningtyas, Nurkomar, and Buchori (2019). We used this similar procedure to test the subject on *S. litura* for comparison.

Statistical Analysis

To compare the performance of *T. remus* on *S. frugiperda* and *S. litura*, all data parameters including the number of parasitized eggs, parasitism rate, number of emerging parasitoids, survival rate and sex ratio (percent females) was subjected to two-paired t-test analysis using R-statistic version 3.5.2 (RCoreTeam, 2013).

RESULTS AND DISCUSSIONS

The presence of *S. frugiperda* as a new pest in several Asian countries including Indonesia is a threat that needs attention. The presence of a new pest into a new area can cause attacks at high or low levels. An insect species can cause high attack so that it becomes the major pest in a plant, but also can be a minor pest in other plants. A pest can also be a major pest in one area but can also only be a minor pest in another area (Hill, 2008). In this case, *S. frugiperda* attack has threatened corn production in Africa. However, *S. frugiperda* attack reported has the potential to reduce corn production in Indonesia. In other words, the status of this pest is classified as a minor pest since the infestation level is still low (1 larva per plant) (Trisyono et al., 2019). Pereira and Lee Hellman (1993) concluded that the economic injury level for *Spodoptera* is two larva per plant in Maryland. One of the factors that cause pests to become minor pests is due to the role of natural enemies that are able to control the pest population (I Nurkomar, Manuwoto, Kainoh, & Buchori, 2018). *Telenomus remus* is a natural enemy that can be used as a natural enemy of some lepidopteran eggs (CABI, 2019b). Liao et al. (2019) reported 60.19% field parasitism rate of *S. frugiperda* by *T. remus*.. So far, *T. remus* has been reported to be used as a biological control agent of *S. litura* (Susiawan & Yuliarti, 2017) and *S. exigua* (Buchori et al., 2017), another armyworm pest species that have long been existed in Indonesia (Kalshoven, 1981). In this study, we compare the performance of *T. remus* in parasiting *S. frugiperda* and *S. litura* under laboratory conditions.

The result showed that no differences in the performance of *T. remus* either on *S. frugiperda* or *S. litura* as host. *T. remus* successfully parasitized 69.40% (35/50) eggs of *S. frugiperda* and 80.80% (40/50) eggs of *S. litura* (Paired t-test, P=0.137,

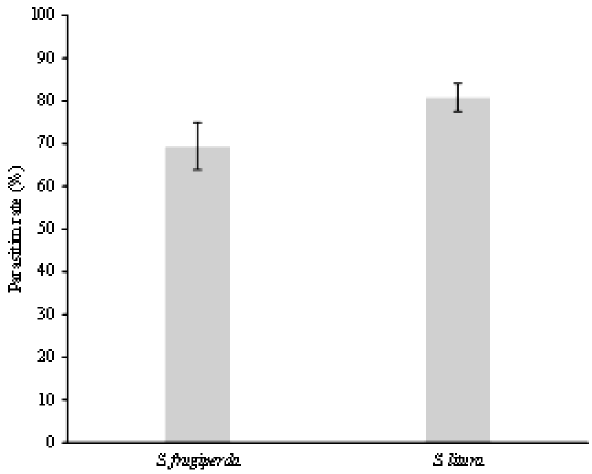

Figure 1. Parasitism rate of *S. frugiperda* and *S. litura* by *Telenomus remus*

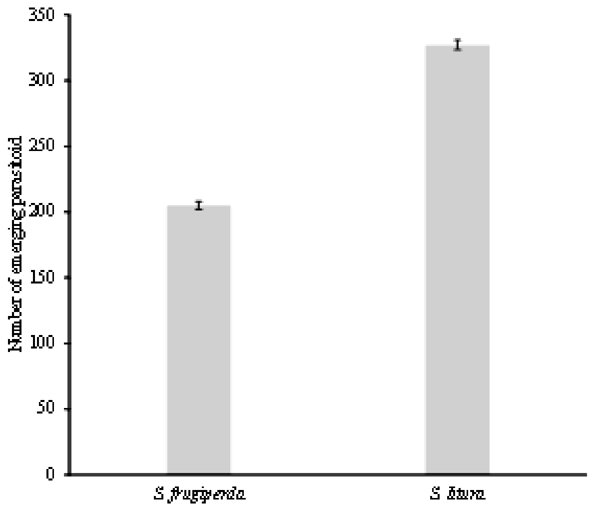

Figure 2. Number of emerging parasitoids reared on *Spodoptera frugiperda* and *S. Litura*

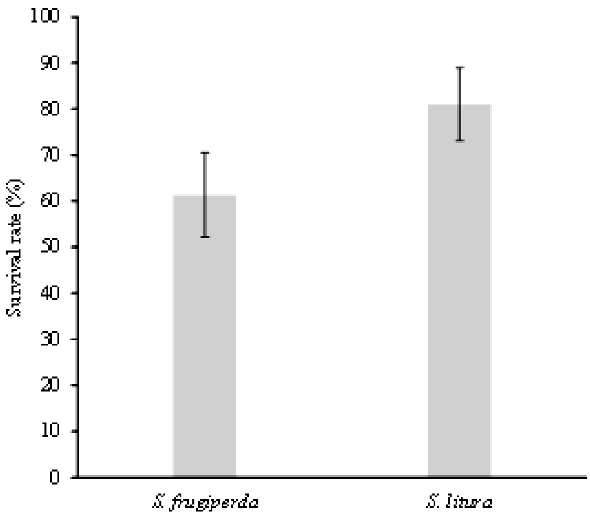

Figure 3. Survival rate of *Telenomus remus* reared on *Spodoptera frugiperda* and *S. litura*

n=10) (Figure 1). However, there is a significant difference in the number of emerging parasitoids (Paired t-test, P=0.048, n=10) (Figure 2). Parasitoid produced from *S. litura* eggs 63% more than those from *S. frugiperda*. *T. remus* showed high survival rate reared both of host (Paired t-test, P=0.07, n=10) (Figure 3). Furthermore, both of host able to produce more than 50% females (Figure 4).

The results showed that there were no differences in the performance of *T. remus* in the two hosts tested. This shows that *T. remus* can be used as a natural enemy for *S. frugiperda* (Figure 5).

Other potential natural enemies for *S. frugiperda* is larval parasitoid *Coccygidium melleum* (Hymenoptera: Braconidae), *Campoletis chlorideae* (Hymenoptera: Ichneumonidae), *Eriborus* sp. (Hymenoptera: Ichneumonidae), *Odontepyris* sp. (Hymenoptera: Bethylidae), *Exorista sorbillans* (Diptera: Tachinidae); *Forficula* sp. (Dermaptera: forficulidae); predatory beetle *Harmonia octomaculata* (Coleoptera: Coccinellidae), *Coccinella transversalis* (Coleoptera: Coccinellidae), and Entomopathogenic fungi *Nomuraea rileyi* (Kalleshwaraswamy, Poorani, Maruthi, Pavithra, & Diraviam, 2019).

No performance differences were shown for all parameters tested except for the number of emerging parasitoids. *T. remus* that is reared in *S. litura* produced more parasitoids than that of reared in *S. frugiperda* as host. This because the number of parasitized *S. litura* eggs is higher than the number of *S. frugiperda* eggs. In addition, *T. remus* showed no difference survival rate in both of host. Our result suggests that *T. remus* can be used as a natural enemy for controlling *S. frugiperda*. However, several factors need to be considered in utilizing a parasitoid as a biocontrol agent such as host selection behavior (Zuim et al., 2017). Host age must be considered for utilization of *T. remus* for controlling *S. frugiperda* since the number of *S. frugiperda* eggs parasitized by *T. remus* decreases with increasing age of the host egg (de Queiroz et al., 2019). In another study, it was also reported that the older the host age, the smaller the number of parasitized host, i.e., the number of eggs of *Botesia botrana* parasitized by *Trichogramma cacoeciae* is greater at the age of 1 or 2 days than that of 3 or 4 days old (Pizzol, Desneux,

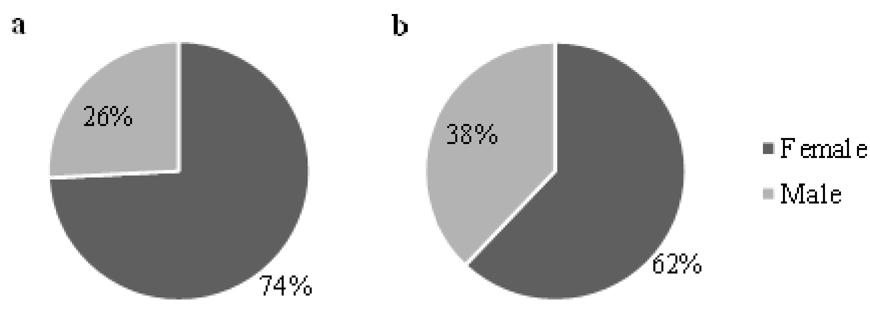

Figure 4. Sex ratio of *Telenomus remus* reared on *S. frugiperda* (a) and *S. litura* (b)

Figure 5. *Telenomus remus* parasitizing *Spodoptera frugiperda*'s egg cluster

Wajnberg, & Thiéry, 2012). However, there are also parasitoids that do not differentiate host age in the parasitization process, i.e., *Trichogramma chilonis* does not show differences in the level of parasitism at the different age of the host *Cytotella cytella* (Zahid, Farid, Sattar, & Khan, 2007).

In this study, *T. remus* was exposed to 50 eggs both of *S. litura* and *S. frugiperda*. The number of parasitized eggs is 34.7 and 40.4 for *S. frugiperda* and *S. litura* respectively. This is in line with the research of (Carneiro, Fernandes, Cruz, & Bueno, 2010) who tested the functional response of *S. frugiperda* with different exposure times that on the number of host eggs by 50 eggs, the number of parasitized eggs was 20-30 eggs. In general, *T. remus* has a type II functional response in which the more the number of hosts is given, the number of parasitized hosts is increasing. The number of parasitic eggs does not increase at a certain host density (150 - 300) eggs exposed.

CONCLUSION

Our finding concluded that *T. remus* as a larval parasitoid of common armyworm *S. litura* can be used as potential biocontrol agent for controlling *S. frugiperda*, a new invasive pest species in several countries including Indonesia.

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Physiological Aspect of Cauliflower (*Brassica oleracea* var. *Botrytis l.*) as Affected by Nitrogen and Liquid Organic Fertilizer on Coastal Sandy Land

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ABSTRACT

Cauliflower is one of the vegetables that have the ability to adapt to coastal sandy land. Cauliflower production can be increased by extensification efforts using coastal sandy land. The research aimed to determine the type of liquid organic fertilizer, the fertilization interval of liquid organic fertilizer, and the appropriate dose of nitrogen fertilizer for the growth and productivity of cauliflower plant on coastal sandy land. The research was conducted in Jetis sandy beach, Banjarsari Village, Nusawungu Sub-district, Cilacap Regency. The study was conducted from August 2017 to November 2017. The experiment was arranged in a Factorial Randomized Complete Block Design (RCBD). Data were analyzed by F test followed by DMRT 5%. The results showed that (1) type of artificial liquid organic fertilizer gave best result on the dry root weight and chlorophyll b. (2) The 9-day-interval of liquid organic fertilizer application interval gave the best result on the fresh root weight and fresh plant weight, while the 4-day-interval of liquid organic fertilizer application gave the best result on dry flower weight. (3) The doses of N fertilizer significantly affected leaf area, root volume, fresh root weight, fresh leaf weight, dry leaf weight, fresh plant weight, dry plant weight, fresh stem weight, dry stick weight, fresh flower weight, flower weight dry, and flower diameter.

Keywords: Cauliflower, Coastal sandy land, Dose, Interval, Liquid organic fertilizer

ABSTRAK

Kubis bunga merupakan salah satu sayuran mempunyai kemampuan beradaptasi dengan lahan pasir pantai. Produksi kubis bunga dapat ditingkatkan dengan melakukan upaya ekstensifikasi memanfaatkan lahan pasir pantai. Penelitian bertujuan untuk menentukan jenis pupuk organik cair, interval pemupukan pupuk organik cair dan dosis penggunaan pupuk nitrogen yang tepat untuk pertumbuhan dan produktivitas tanaman kubis bunga di lahan pasir pantai. Penelitian dilaksanakan di lahan pasir pantai Jetis, Desa Banjarsari, Kecamatan Nusawungu, Kabupaten Cilacap. Penelitian dilaksanakan Bulan Agustus 2017 sampai dengan Oktober 2017. Penelitian menggunakan Rancangan Acak Kelompok Lengkap (RAKL) faktorial. Data dianalisis dengan uji F dilanjutkan dengan DMRT 5 %. Hasil penelitian menunjukkan bahwa (1) Jenis pupuk organik cair buatan pabrik memberikan hasil yang terbaik terhadap variabel pertumbuhan bobot akar kering dan variabel fisiologis pada klorofil b. (2) Interval pemupukan POC 9 hari memberikan hasil yang terbaik pada variabel pertumbuhan bobot akar segar dan bobot tanaman segar, dan Interval pemupukan POC 4 hari memberikan hasil yang terbaik pada variabel hasil bobot bunga kering. (3) Dosis penggunaan pupuk N berpengaruh terhadap variabel luas daun, volume akar, bobot akar segar, bobot daun segar, bobot daun kering, bobot tanaman segar, bobot tanaman kering, bobot batang segar, bobot batang kering, bobot bunga segar, bobot bunga kering dan diameter bunga.

Kata Kunci: Lahan pasir pantai, Kubis bunga, Pupuk organik cair, Interval, Dosis

INTRODUCTION

Cauliflower, as a horticultural commodity, is adapted to be cultivated in the lowlands (Saparso, 2001). The increasing population will increase the demand for foods, including vegetables. PT. Panah Merah already produced cauliflower cultivar suitable for the lowland called PM126F1, which is expected to be a superior product typical of coastal sandy land.

According to Saparso (2008), coastal sandy soil has very low organic matter content (0.39%), total N (0.014%), and available N (26.79 ppm). Rajiman et al. (2008) state that coastal sandy soil is soil dominated by sand fraction, which is classified in sandy texture class.

One way to overcome the problem of coastal sandy land is by providing organic matter such as liquid organic fertilizer. Suriadikarta et al. (2006) explain that liquid organic fertilizer has benefits for plants, including to fertilize plants, maintain nutrient stability in the soil, reduce the impact of organic waste in the surrounding environment, help revitalize soil productivity, and improve product quality. According to the results of the study of Rafli and Marni (2010), the application of liquid organic fertilizer can increase crop yields, accelerate and multiply the formation of flowers and more plant segments, as well as multiply, extend, and strengthen roots. This liquid organic fertilizer has the advantage of being able to overcome nutrient deficiencies quickly, cope with nutrient leaching problems, and provide nutrients quickly (Taufika, 2011) so that it is very suitable for coastal sandy land. According to Munawar (2011), nitrogen is absorbed by plants from the soil in the form of nitrate ($N0_3^-$) and ammonium (NH_4^+). Nitrate is the most preferred form for plant growth, but it is influenced by environmental factors.

This study aimed to determine the right type of liquid organic fertilizer, the appropriate fertilization intervals of liquid organic fertilizer, and the appropriate dose of nitrogen fertilizer for the growth and productivity of cauliflower plants in coastal sandy land.

MATERIAL AND METHODS

The study was carried out in the Jetis coastal sandy area, Banjarsari Village, Nusawungu District, Cilacap Regency. The study was conducted from August 2017 to November 2017.

Experimental Design

The study was arranged in a Randomized Complete Block Design (RCBD) of 3 factors. The first factor was the type of liquid organic fertilizer

Table 1. ANOVA results on variables of growth, yield components, and physiological characteristics of cauliflower plants as affected by the type of liquid organic fertilizer (P), interval of LOF fertilization (I) dose of N fertilizer (N)

No.	Variables	Treatments		
		P	I	N
Growth Variables				
1	Plant Height (cm/plant)	ns	ns	ns
2	Number of Leaves (strands/plant)	ns	ns	ns
3	Leaf Length (cm/plant)	ns	ns	ns
4	Leaf Area (cm^2/plant)	ns	ns	**
5	Root Length (cm/plant)	ns	ns	ns
6	Root Volume (ml/plant)	ns	ns	*
7	Fresh Root Weight (g/plant)	ns	*	**
8	Dry Root Weight (g/plant)	*	ns	ns
9	Fresh Leaf Weight (g/plant)	ns	ns	**
10	Dry Leaf Weight (g/plant)	ns	ns	**
11	Fresh Plant weight (g/plant)	ns	*	**
12	Dry Plant weight (g/plant)	ns	ns	**
13	Fresh Stem Weight (g/plant)	ns	ns	**
14	Dry Stem Weight (g/plant)	ns	ns	*
Yield Components				
1	Fresh Flower Weight (t/ha)	ns	ns	**
2	Dry Flower Weight (g/plant)	ns	*	*
3	Flower Diameter (cm/plant)	ns	ns	**
Physiological Characteristics				
1	Chlorophyll a	ns	ns	ns
2	Chlorophyll b	*	ns	ns

Remarks: ns = not significantly different according to F test at 5%, * = significantly different according to F test at 5%, ** = highly significantly different according to F test at 5%. P = type of liquid organic fertilizer (LOF), I = Interval of LOF fertilization, N = Dose of N fertilizer.

(LOF)(P), consisting of 3 levels, namely factory production LOF (P1), commercial LOF in the market commonly used by local farmers (P2), and LOF produced by farmers (P3). LOF produced by farmers was made from cow urine fermentation, EM 4, rice bran, and sugar cane drops (molasses). The second factor was the LOF fertilization interval (I), consisting of 3 levels, namely 4-day (I1), 9-day (I2), and 14-day (I3) interval. Meanwhile, the third factor was the dose of N fertilizer (N), consisting of 3 levels, namely 20% (N1, 54 kg N/ha), 60% (N2, 162 Kg N/ha), and 100% (N3, 270 Kg N/ha).

Variables observed biweekly included plant height, the number of leaves, leaf length, leaf area, root length, root volume, fresh and dry weight of roots, fresh and dry weight of leaves, fresh and dry weight of the plant, and fresh and dry weight of stems. Meanwhile, variables observed during harvest included the fresh and dry weight of flower, flower diameter, and chlorophyll a and b measured with spectrophotometric methods.

Data Analysis

The data obtained were tested using analysis of variance (ANOVA) with DSAASTAT software. The observational data were analyzed using the F test at an error level of 5% and continued to DMRT test at the error level of 5% if there were significant differences among treatments.

RESULTS AND DISCUSSION

The results of the analysis were showed in Table 1.

Leaf area (cm²/plant)

The dose of N fertilizer showed a significant effect on the leaf area. Regression analysis resulted in the equation of $y = -20.78x^2 + 112.22x - 12$ ($R^2 = 0.8193$). The N dose of 100% gave the best results, which was 141.19 cm^2, followed by the dose of 60% and 20%, resulting in a leaf area of 118.72 cm^2 and 90.05 cm^2, respectively.

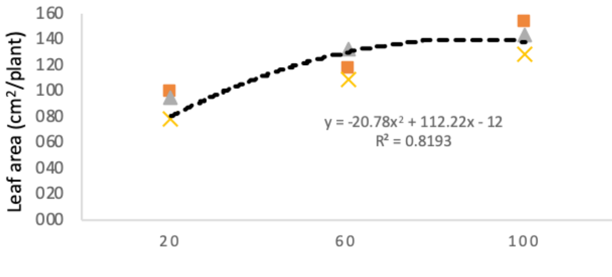

Figure 1. Leaf area of cauliflower plants as affected by various doses of N fertilizer

Figure 1 shows the leaf area of the cauliflower at various doses of N fertilizer. According to Hanum (2008), nitrogen is a constituent component of many essential compounds for plants. The nitrogen element is a nutrient that is needed by plants to form vegetative parts of plants such as leaves, stems, and roots.

Root Volume (ml)

The dose of N fertilizer had a significant effect on the root volume. Regression analysis resulted in the equation of $y = -0.7645x^2 + 3.6688x + 2$ (R^2=0.958). The N dose of 100% gave the best results, which was 6.17 ml, not significantly different from the dose of 60% resulting in 6.15 ml. Both treatments gave significantly different effects compared to the dose of 20%, which resulted in the root volume of 5.03 ml. Hanum (2008) states that nitrogen is used in regulating overall plant growth. With the improved root structure, the process of nutrient absorption will run more optimally.

Fresh Root Weight (g/plant)

The dose of N fertilizer and LOF fertilization interval significantly affected the fresh root weight. Regression analysis resulted in the equation of $y = -1.2717x^2 + 5.884x$ (R^2=0.9794). The application of N fertilizer at doses of 60% and 100% gave the best results, which were 6.55 g and 6.25 g, respectively. Both treatments gave significantly higher fresh root weight compared to the treatment of 20% N fertilizer that produced a fresh root weight of 4.75 g. According to Jumin (2002), the root is the main vegetative organ that supplies water, minerals, and materials that are essential for plant growth and development.

The 9-day-interval of LOF fertilization gave the best results on the fresh root weight of 6.84 g, followed by a 4-day-interval of LOF fertilization and the 14-day-interval of LOF fertilization, resulting in the fresh root weight of 5.38 g and 5.32 g, respectively. Regression analysis resulted in the equation of $y = -1.7383x^2 + 6.972x$ ($R^2 = 0.9694$). According to Rosmarkam and Yuwono (2002), the administration of nitrogen under optimal dose causes an increase in ammonia assimilation and protein content in leaves, and high N administration is thought to cause plants to fall easily because the root system is relatively narrow or undeveloped.

Dry Root Weight (g/plant)

The type of liquid organic fertilizer significantly affected the dry root weight. The LOF produced by the factory gave the best results on the dry root weight, which was 3.95 g, followed by the LOF produced by farmers and the commercial LOF in the market, resulting in the dry root weight of 2.73 g and 2.43 g, respectively.

The type of liquid organic fertilizer produced by the factory gave the best results on the dry root weight because, in addition to containing nutrients, it is also equipped with hormones or growth regulators of gibberellins, cytokinin, and auxins. Meanwhile, commercial liquid organic fertilizer only contains auxin growth regulators. In general, the types of hormones or growth regulators are auxin, cytokinin, and gibberellin. Auxin can be arranged in meristem tissue in the ends of plants such as shoots, flower buds, leaf buds, and others (Dwijoseputro, 2004).

Fresh Leaf Weight (g/plant)

The dose of N fertilizer significantly affected the fresh leaf weight. Regression analysis resulted in the equation of $y = -8.5272x^2 + 62.365x$ ($R^2 = 0.9328$). The application of N fertilizer at a dose of 100% gave the best results (112.55 g), followed by that at 60% and 20% resulting in the fresh leaf weight of 84.04 g and 60.42 g, respectively. According to Gardner and Mitchell (1991), nitrogen fertilization has a significant effect on leaf expansion. The increase in the leaf area will be followed by the increase in the fresh leaf weight.

Dry Leaf Weight (g/tanaman)

Regression analysis resulted in the equation of $y = -1.0553x^2 + 6.4249x$ ($R^2 = 0.8513$). The application of N fertilizer at a dose of 100% produced the highest dry leaf weight (10.02 g), followed by that at 60% and 20%, resulting in the dry leaf weight of 7.89 g and 6.11 g, respectively. According to Harjadi (2002), the leaves become greener when enough nitrogen is available, and the process of photosynthesis rate is higher, producing more photosynthates, thereby increasing the dry weight of the shoot.

Fresh Plant weight (g/plant)

Regression analysis resulted in the equation of $y = -40.18x^2 + 163.72x + 20$ ($R^2 = 0.695$) (Figure 2). The 9-day-interval of LOF fertilization produced the highest fresh plant weight of 178.50 g, followed by the 14-day-interval and 4-day-interval of LOF fertilization, resulting in the fresh plant weight of 152.28 g and 151.76 g, respectively. According to

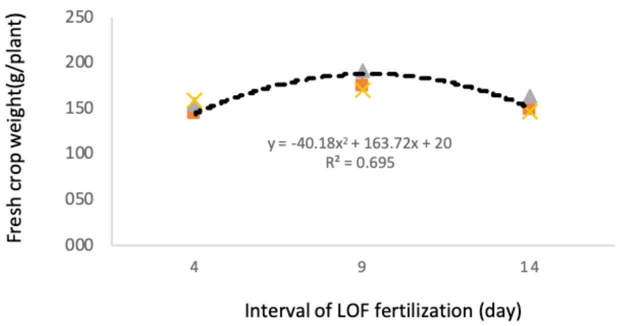

Figure 2. Fresh plant weight of cauliflower plants as affected by intervals of LOF fertilization

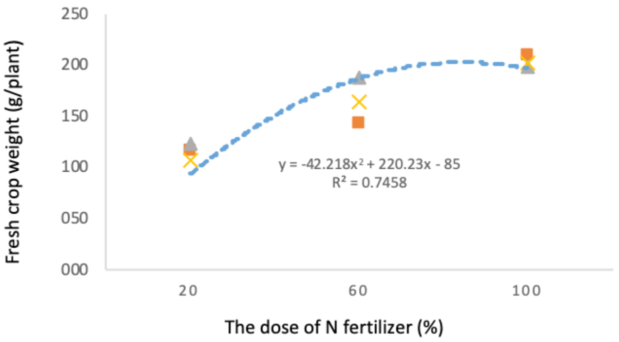

Figure 3. Fresh plant weight of cauliflower plants as affected by various doses of N fertilizer

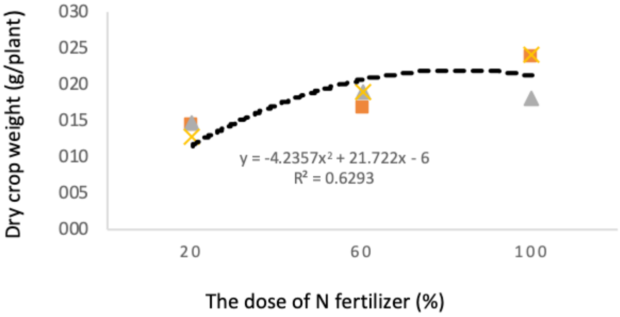

Figure 4. Dry plant weight of cauliflower plants as affected by various doses of N fertilizer

Saragih et al. (2013), an interval in the application of urea fertilizer can optimize the availability of the applied nutrients to plants, thereby fulfilling the needs of the N elements for plants.

The effect of the dose of N fertilizer on fresh plant weight is presented in Figure 3. Regression analysis resulted in the equation of $y = -42.218x^2 + 220.23x - 85$ ($R^2 = 0.7458$). The application of N fertilizer at a dose of 100% gave the best results, which was 202.95 g, followed by that at 60% and 20%, resulting in the fresh plant weight of 7.89 g and 6.11 g, respectively. This result is because N fertilizer applied at a dose of 100% can be absorbed effectively by plants. According to Dwidjoseputro (2004), the photosynthesis process is going well with sufficient N nutrients. Photosynthesis, with the help of sunlight and leaf chlorophyll, can convert inorganic substances into organic substances, which is very influential on the total fresh weight and dry weight per plant.

Dry Plant weight (g/plant)

Regression analysis resulted in the equation of $y = -4.2357x^2 + 21.722x - 6$ ($R^2 = 0.6293$). The application of N fertilizer at a dose of 100% produced the highest dry weight of the plant, which was 21.84 g, followed by that at 60% and 20%, resulting in the dry plant weight of 18.14 g and 13.85 g, respectively. The higher provision of N influences the dry weight due to the adequacy of nutrients absorbed by plants (Suwardi and Roy, 2009) (Figure 4).

Fresh Stem Weight (g/plant)

Regression analysis resulted in the equation of $y = -4.5396x^2 + 26.877x$ ($R^2 = 0.9727$). The application of N fertilizer at a dose of 100% produced the highest fresh stem weight of 40.22 g, followed by the N application at 60% and 20%, resulting in the fresh stem weight of 34.25 g and 23.68 g, respectively. According to Lingga (1998), the main role of the nitrogen element is to stimulate overall plant growth, especially stems, leaves, and the formation of chlorophyll that play a role in photosynthesis as a protein-forming material.

Dry Stem Weight (g/plant)

Regression analysis resulted in the equation of $y = -0.6835x^2 + 3,5114x$ ($R^2 = 0.8872$). The application of N fertilizer at a dose of 100% produced the highest dry stem weight, which was 4.46 g, followed by the N application at 60% and 20%, resulting in the dry stem weight of 4.05 g and 3.06 g, respectively. According to Harjadi (2002), plant growth is indicated by the addition of a measure of dry weight that reflects the increase in protoplasm due to the increase in the size and number of cells.

Fresh Flower Weight (t/ha)

Regression analysis resulted in the equation of $y = -0.6224x^2 + 3.2922x - 1$ ($R^2 = 0.6496$) (Figure 5). The N application at a dose of 100% produced the best result on the fresh flower weight, which was 3.4 t/ha, followed by the N application at 60% and 20%, resulting in the fresh flower weight of

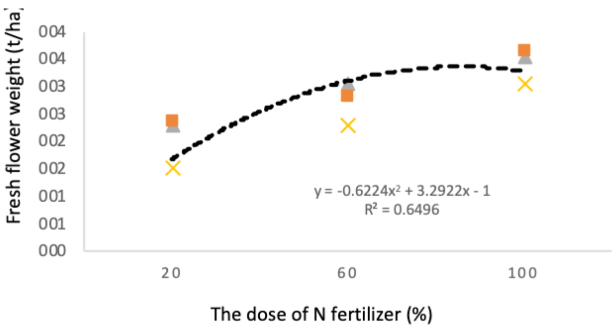

Figure 5. Fresh flower weight of cauliflower plants as affected by various doses of N fertilizer

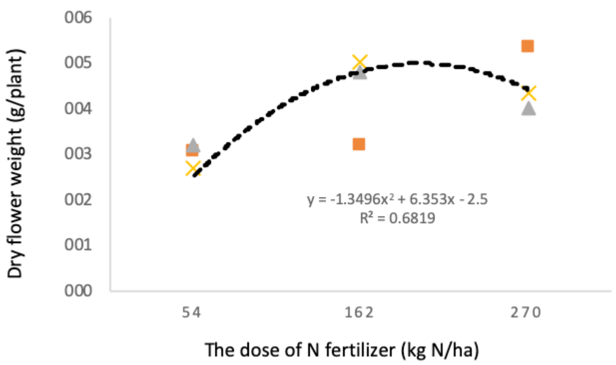

Figure 6. Dry flower weight of cauliflower plants as affected by various doses of N fertilizer

2.71 t/ha and 2.06 t/ha. According to Goldsworthy and Fisher (2000), nitrogen supply has a major influence on flowering and, subsequently, on yield.

Dry Flower Weight (g/plant)

Regression analysis resulted in the equation of $y = -1{,}3496x^2 + 6{,}353x - 2.5$ ($R^2 = 0.6819$). The N application at a dose of 100%and 60% produced the highest dry flower weight, which was 4.57 g and 4.34 g, respectively. Meanwhile, the lowest dry flower weight (2.98 g) was observed in the N application at 20% (Figure 6).

The application of 100% and 60% N fertilizer gave the best results on the dry flower weight due to the availability of nutrients, especially N, which is sufficient for plants so that the photosynthesis rate increase. The value of dry flower weight is directly proportional to the value of fresh flower weight.

Regression analysis resulted in the equation of $y = 1.469x^2 - 6.4396x + 10$ ($R^2 = 0.974$). The 4-day-interval of LOF fertilization produced the highest dry flower weight, which was 4.89 g, followed by the 14-day-interval and 9-day-interval of LOF fertilization, resulting in the dry flower weight of 3.86 g and 3.14 g, respectively. The availability of sufficient nitrogen causes a balanced ratio between leaves and roots, thereby supporting vegetative growth. These conditions will induce the plant to enter its generative phase (Ramadhani et al., 2016).

Flower Diameter (cm)

Regression analysis resulted in the equation of $y = -0.274x2 + 1.6496x + 4.5$ ($R^2 = 0.6613$). The N application at a dose of 100% gave the best result on flower diameter, which was 7.07 cm, followed by the N application at 60% and 20%, resulting in the flower diameter of 6.43 cm and 6.14 cm, respectively. According to Marvelia et al. (2006), N plays a role in flowering. In plants whose growth in the vegetative phase is more dominant than the generative phase, then carbohydrate use is more dominant than its storage (Figure 7).

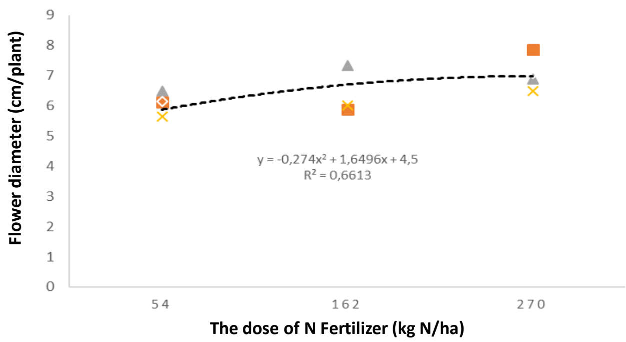

Figure 7. Flower diameter of cauliflower plants as affected by various doses of N fertilizer

Chlorophyll b (mg/l)

The type of liquid organic fertilizer produced by the factory produced the highest content of chlorophyll b, which was 29.81 mg/l, followed by the commercial liquid organic fertilizer in the market and that produced by farmers, resulting in the chlorophyll b content of 21.47 mg/l and 20.02 mg/l, respectively.

Light energy will be converted into chemical energy in the reaction center, which can then be used for the reduction process in photosynthesis. Chlorophyll b functions as an antenna, collecting light to be transferred to the reaction center. The reaction center is composed of chlorophyll a (Taiz and Zeiger, 1991) (Figure 8).

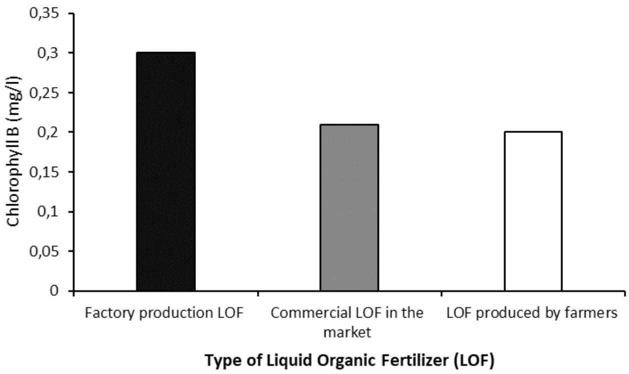

Figure 8. Chlorophyll b of cauliflower plants as affected by the types of liquid organic fertilizer

CONCLUSION

1. The factory-made liquid organic fertilizer gave the best results on the growth of cauliflower plants, which was the dry root weight of 3.95 g/plant and on the physiological characteristic, which was chlorophyll b content of 29.81 mg / l. The type of liquid organic fertilizer did not significantly affect the yield of fresh flower weight, meaning that the types of liquid organic fertilizer used in this study produced relatively the same fresh flower weight.
2. The 9-day-interval of LOF fertilization gave the best results on the growth variable of fresh root weight and fresh plant weight, while the 4-day-interval of LOF fertilization gave the best results on the dry flower weight. LOF fertilization interval had no significant effect on the fresh flower weight, meaning that the LOF fertilization interval tested in this study resulted in relatively the same fresh flower weight.
3. The application of N fertilizer at a dose of 100% gave the best results on the growth variables of leaf area (141.19 cm^2/plant), root volume (6.17 ml/plant), fresh leaf weight (112.55 g/plant or 5.6275 t / ha), dry leaf weight (10.02 g/plant or 0.501 t / ha), fresh plant weight (202.95 g/plant or 10.1475 t/ha), dry plant weight (21.84 g/plant or 1.092 t/ha), fresh stem weight (40.22 g/plant or 2,011 t/ha), and dry stem weight (4.46 g/plant or (0.223 t/ha), as well as on the variables of yield components, including fresh flower weight (3.4 t/ha), dry flower weight (4.57 g/plant or 0.2285 t/ha), and flower diameter (7.07 cm/plant).

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The Use of Biofilm Biofertilizer to Improve Soil Fertility and Yield of Upland Kale (*Ipomoea reptans*) in Vertisol

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ABSTRACT

The application of biofilm biofertilizer is potential to improve soil fertility and increase plant yield. The research aimed to assess the use of organic fertilizer decomposed with biofilm biofertilizer to improve soil fertility and yield of upland kale in Vertisol. The field experiment was conducted in Vertisol at Jaten, Karanganyar, Central Java, arranged in a Randomized Complete Block Design with a single factor, which was organic fertilizer dose consisting of 0, 3, 6, 9, 12, 15, 18, and 21 ton.ha^{-1} organic with NPK fertilizer as comparison treatment. Upland kale seeds were planted in 15 x 15 cm plant spacing. The variables observed were total nitrogen, available P, exchangeable K, soil organic matter, pH, cation exchange capacity, leaf number, plant height, fresh and dry weight. The data obtained were analyzed using F test followed by Duncan Multiple Range Test (DMRT) 95%. The result showed that the organic fertilizer dose had a significant effect on all of the observed variables. Optimal doses of organic fertilizer to improve soil fertility and upland kale yield was 15 - 18 ton.ha^{-1}. The highest yield of upland kale was observed in the treatment of 21 ton.ha^{-1} organic fertilizer (76.5 ton.ha^{-1}), which was increased by 176% compared to control (34.7 ton.ha^{-1}) and by 108.8% (45.78 ton.ha^{-1}) compared to NPK treatments. The application of 3 ton.ha^{-1} organic fertilizer gave better yield of upland kale than NPK fertilizer.

Keywords: Biofilm biofertilizer, Chemical fertility, Ipomoea reptans, Organic fertilizer, Vertisol

ABSTRAK

Penelitian bertujuan untuk menilai penggunaan pupuk organik hasil dekomposisi menggunakan *biofilm biofertilizer* dalam meningkatkan kesuburan tanah dan hasil kangkung darat pada tanah Vertisol. Percobaan lapangan dilakukan di Jaten, Karanganyar, Jawa Tengah, April – Mei 2016 menggunakan rancangan acak kelompok lengkap (RAKL) faktor tunggal yaitu dosis pupuk organik (0, 3, 6, 9, 12, 15, 18, 21 ton ha-1), dan pupuk NPK sebagai pembanding. Benih kangkung ditanam dengan jarak tanam 15 x 15 cm. Peubah yag diamati meliputi N total, P-tersedia, K-tertukar, kadar bahan organik, pH, kapasitas tukar kation, jumlah daun, tinggi, berat segar dan berat kering tanaman. Data dianalisis menggunakan uji F dilanjutkan uji jarak berganda Duncan aras kepercayaan 95 %. Hasil penelitian menunjukkan bahwa dosis pupuk organik berpengaruh nyata terhadap semua peubah yang diamati. Dosis pupuk organik yang optimal untuk meningkatkan kesuburan tanah dan hasil kangkung darat berkisar 15 – 18 ton.ha^{-1}. Hasil kangkung darat segar paling tinggi diperoleh dari dosis pemupukan organik 21 ton.ha^{-1} (76,5 ton.ha^{-1}), meningkat 176 % dibanding control (34,7 ton.ha^{-1}) dan 108,8 % (45,78 ton.ha^{-1}) dibanding pemupukan NPK. Penggunaan pupuk organik 3 ton.ha^{-1} memberikan hasil kangkung yang lebih tinggi dibanding penggunaan pupuk NPK.

Kata Kunci: *Biofilm biofertilizer*, Kesuburan kimiawi, *Ipomoea reptans*, Pupuk organic, Vertisol

INTRODUCTION

Vertisol is one of the soil types with many obstacles in tillage. Vertisol belongs to Montmorillonit mineral clay (2:1) that is dominated by smectite mineral clay (Nursyamsi and Setyorini 2009), darkish grey in color, and it has clay texture (Prasetyo 2007). This type of soil expands when it is wet and shrinks when it is dry. It also has high Cation Exchange Capacity (CEC) and low organic matter content (usually less than 1%). Actually, Vertisol has rich nutrients, but these nutrients are trapped by the clay, thereby lowering the nutrient availability for the plant.

Upland kale planted in Vertisol often has many obstacles related to the difficult tillage and the limited macro nutrients (nitrogen, phosphorus and potassium) availability. One effort to reduce those two major obstacles is by applying organic fertilizer to improve soil fertility, either chemical, physical, or biological fertility (Nelvia, 2012).

Innovation in organic fertilizer manufacture has increased from year to year. One of the innovations is the use of biofilm biofertilizer as a decomposer of organic fertilizer. Biofilm biofertilizer contains many beneficial microorganisms, such as nitrogenfixing bacteria, phosphate solvent fungi, potassium solvent bacteria, and plant disease control fungi. The microbes are formulated in a special carrier so that they can be used as a starter or decomposer (Santoso dan Sajidan, 2013). This research aimed to determine the effectiveness of biofilm biofertilizer as a decomposer and the exact dose of organic fertilizer to improve Vertisol chemical fertility and achieve the optimum yield of upland kale.

MATERIALS AND METHODS

The research was located at Gunung Wijil Village, Jaten, Karanganyar with the coordinates of 7° 32 '57'' South Latitude and 110° 52' 11 '' East Longitude at 90 m above sea level with 54 mm/day annual rainfall (BPS 2015). It was a rainfed lowland with Vertisol soil. The biofilm biofertilizer inoculum was prepared in Laboratory of Soil Biology and Biotechnology. Soil fertility analysis was conducted in Laboratory of Soil Physics and Conservation and Laboratory of Soil Chemistry and Fertility, Faculty of Agriculture, Sebelas Maret University, Surakarta.

The experiment was arranged in a Randomized Complete Block Design with single factor, which was the dose of organic fertilizers decomposed with biofilm biofertilizer, consisting of 0 $tonha^{-1}$, 3 $tonha^{-1}$, 6 $tonha^{-1}$, 9 tonha1, 12 $tonha^{-1}$, 15 $tonha^{-1}$, 18 $tonha^{-1}$ and 21 $tonha^{-1}$, with NPK fertilizer (150 $kgha^{-1}$Urea, 75 $kgha^{-1}$ SP-36 and 40 $kgha^{-1}$ KCl) usually applied by farmer as comparison treatment. Each treatment was replicated three times.

The Biofilm Biofertilizer used contains P-solubilizer bacteria (PSB) isolate (TBH 18 isolate), P-solubilizer Fungi (Aspergillus niger YD17, Aspergillus japonicus MU1 and JPF1), Potassium-solubilizer bacteria isolate (PPH7), Sulfur-oxidizer bacteria isolate (SOB) (HBH12), Beauveria sp., and Trichoderma sp. One agar slant culture of each isolate was inoculated on a liquid medium consisting of 10 L coconut water, 5 L rice water, 0.5 L molasses, 20 grams SP-36, 10 grams KCl, and 10 grams urea. They were mixed homogenously then incubated for a week. The organic fertilizer was made by mixing 160 kg quail manure, 30 kg phosphate rock, 6 kg feldspar, 5 kg calcite, 4 kg plant ash and 20 liters biofilm biofertilizer as inoculum bio-starter composting. The mixture was added with 5% molasses solution (50 ml / L water) to reach field capacity then incubated for 3 weeks. Organic fertilizer was applied by mixing it evenly with topsoil. The upland kale seeds were planted with 15 x 15 cm plant spacing. The variables observed were soil total nitrogen (Kjeldahl), available P (Olsen), exchangeable K (ammonium acetate), organic matter content (Walkley-Black), pH-H_2O (glass electrode 1 : 2.5), cation exchange capacity (KCl 1 N), plant height, shoot fresh and dry weight (Sulaeman et al., 2005). Data were analyzed using F test 95% followed by Duncan Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

The soil analysis showed that the soil has low fertility to be used as cultivation land (Table 1). Vertisol is a dark gray to blackish in color with clay texture (Prasetyo, 2007). Vertisol has 2: 1 clay minerals dominated by smectite. Montmorillonite will expand when wet with a very sticky and firm consistency and shrivel up to form a crack, and it is very hard to tillage when dry. (Buol et al., 2003; Sunarminto and Santoso, 2008). The application of organic fertilizer will improve the soil fertility and make it easy for tillage, thereby increasing the plant growth rate and yield. The use of organic fertilizer will increase soil organic matter content as well (Jauhari, 2010).

Based on the result analysis, this organic fertilizer fulfills the requirements of The Indonesia Ministry of Agriculture Decree No. 261/KPTS/

Table 1. Chemical properties of the soil used for the research

Variables	Value	Rating value	Unit	Criteria
Total N	0.36	0.21-0.5	%	Medium*
Available P	1.69	<5	ppm	Very Low*
Exchangeable K	0.05	<0.1	cmol(+)/kg	Very Low*
CEC	44.72	>40	cmol(+)/kg	Very High*
pH-H_2O	6.6	6.6-7.5	-	Neutral*
Organic matter content	1.36	1-2	%	Low*
Texture				Clay*
(sand)	32.55		%	
(silt)	9.98		%	
(clay)	65.27		%	

Description: *Criteria according to Soil Research Institute 2009

SR.310/4/2019 about Organic Fertilizer, Biofertilizer and Soil Conditioner, in which the pH is 4 – 9, organic C content is ≥ 15%, C/N ratio is ≤ 25 and N + P_2O_5 + K_2O is ≥ 2%.The organic fertilizer is also following the minimum criteria set by Balittan (2009), in which organic C content is at least 12%, pH range is 4-8, and levels of N, P and K is below 6%. The low C/N ratio indicates that this organic fertilizer has decomposed well. The nutrient will be available to upland kale, thereby improving its yield (Jesu, 2015).

Effects of the treatments on the soil fertility

Although not significant (Figure 1), the doses of organic fertilizer decomposed with biofilm biofertilizer tended to increase soil total N until the dose of 15 tonha^{-1}, and the total N decreased as the dose was increased to more than 15 tonha^{-1}, which might be caused by leaching as the soil more porous. However, the total-N of the soil treated with organic fertilizer treatment was higher than that treated with NPK treatment, which might be due to the slow release property of N from organic fertilizer, making it exist longer in the soil.

Phosphorus is the second largest element that is needed by plant after nitrogen. Phosphorus plays a key role in the formation of DNA/RNA and also ADP and ATP (Adenosine di- and triphosphate), which are source of energy for the growth and development of plants. P deficiency causes the plant to collapse easily because the roots are not strongly formed, otherwise flowering and fertilization will be inhibited (Masrchner, 1997; Sutejo et al., 2007). The effect of organic fertilizer on the available P was very significant (P= 0.002), but the value is still very low (Figure 2). This result maybe because the initial available P of the soil was very low (Table 1). The low content of organic carbon of the soil can cause low soil nutrient content including phosphorus. Heavy texture of the soil can also be one of the factors of lower available P. The highest available P was found in 18 tonha^{-1} of organic fertilizer application (2.75 ppm), while the lowest was in control treatment (2.00 ppm). The available P increased concomitantly with the increasing doses of organic fertilizer applied, reaching a maximum dose of 18 tonha^{-1}. The higher dose than 18 tonha^{-1} tended to lower the available P due to the decrease of soil

Table 2. Nutrient content of organic fertilizer used

Variables	Value
pH	7.6
Nitrogen (%)	2.94
Phosphor (%)	0.48
Potassium (%)	1.61
Organic-C (%)	16.1
C/N ratio	5.48

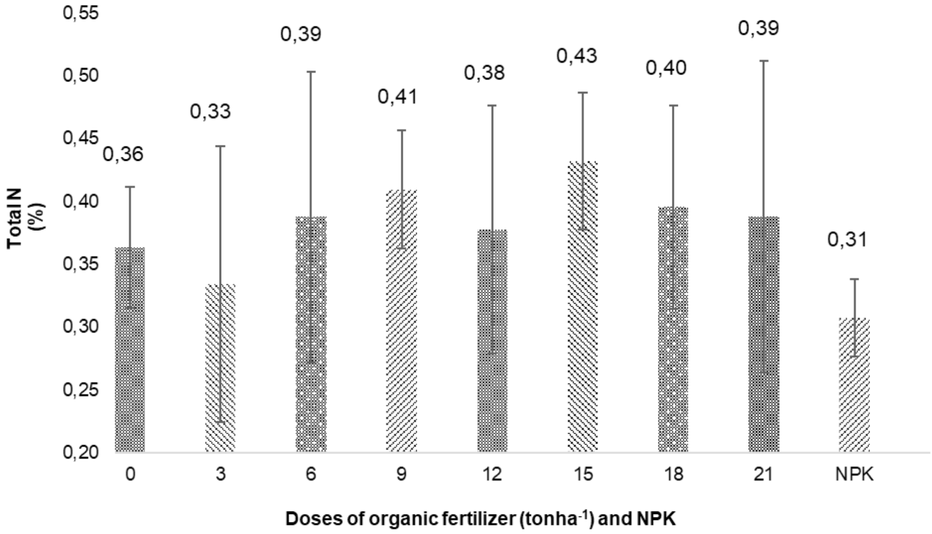

Figure 1. Effect the doses of organic fertilizer decomposed with biofilm biofertilizer on total N of Vertisol soil planted with upland kale. The values followed by the same letters are not significantly different based on the DMRT 95%.

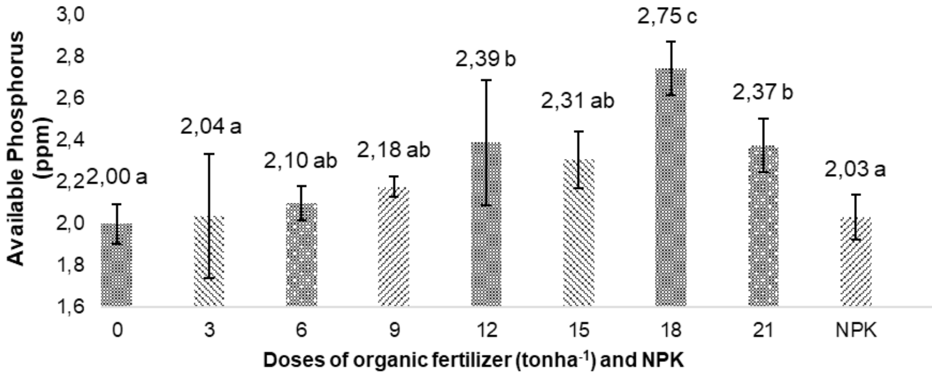

Figure 2. Effect of the doses of organic fertilizer decomposed with biofilm biofertilizer on the available Phosphorus of Vertisol soil planted with upland kale. The values followed by the same letters are not significantly different based on the DMRT 95%.

pH (Figure 4). Available P is strongly correlated positively (r = 0.673 **) with soil pH.

The available P of the soil treated with 75 kgha^{-1} NPK fertilizer was equal to that treated with 3 tonha^{-1} organic fertilizer decomposed with biofilm biofertilizer. Biofilm biofertilizer contains consortium of bacteria and fungi enable to solubilize P and K, oxidize sulfur, fix atmospheeric N2, and decompose organic matter. Chemical fertilizers such as SP-36 is faster available but they also tend to be immediately unavailable for plant. Organic fertilizers usually release their nutrient slowly but they are available longer for plant.

Similar to the available P, the increasing dose of organic fertilizer decomposed with biofilm biofertilizer tended to increase the exchangeable K (Figure 3). Orcutt and Nilsen (2000) suggested that potassium may support leaf formation and increase stomatal resistance, resulting in the larger amount of CO2 that diffuses into plant chlorophyll, and photosynthesis rate will increase. The doses of organic fertilizer have significant effect (P= 0.031) on the exchangeable K that tend to increase with the increasing doses used with the highest value observed in 18 tonha^{-1} organic fertilizer (0.08 cmol(+)kg^{-1}). Meanwhile, the lowest value was in

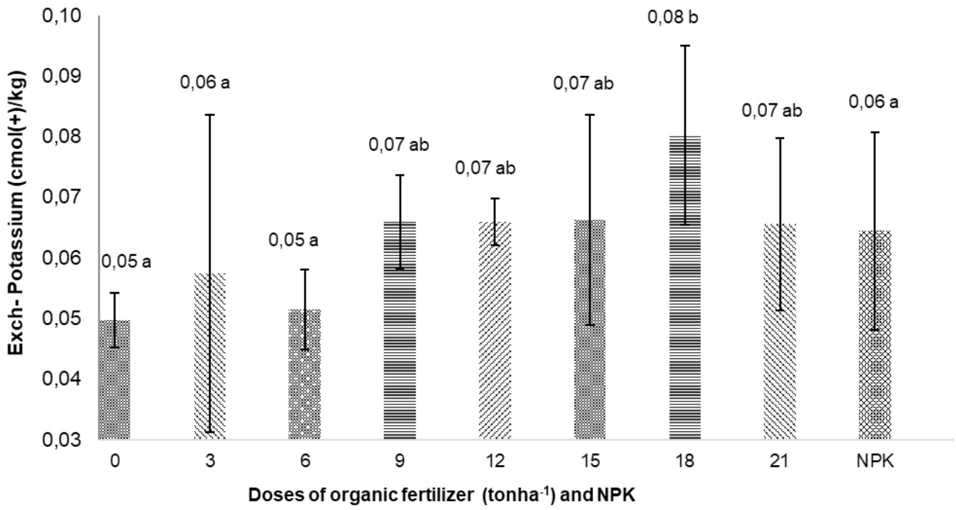

Figure 3. Effect of the doses of organic fertilizer decomposed with biofilm biofertilizer on the exchangeable K of Vertisol soil planted with upland kale. The values followed by the same letters are not significantly different based on the DMRT 95%.

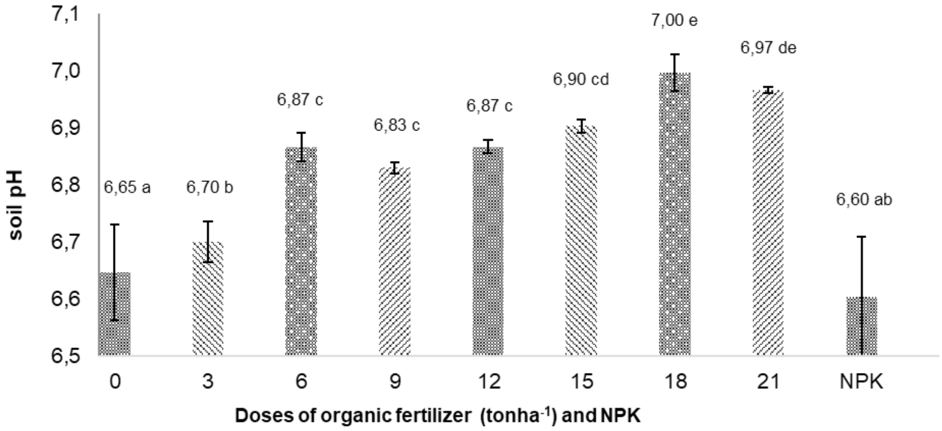

Figure 4. Effect of the doses of organic fertilizer decomposed with biofilm biofertilizer on soil pH of Vertisol planted with upland kale. The values followed by the same letters are not significantly different based on the DMRT 95%.

control treatment (0.05 cmol(+)kg-1). Unlike the available P, the application of 40 kgha^{-1} KCl was equal to the application of 9 – 15 tonha^{-1} organic fertilizer (Figure 3). This result maybe because the exchangeable-K from KCl is available for long time, while organic fertilizer contains relatively small amount of K. The low availability of K can occur because potassium is a very mobile element, and its availability can be lower due to the type of shrunken soil, especially if the soil is dry. According to Borchardt (1989), K availability is often become a problem as K is fixed by a 2:1 clay mineral, such as from the smectite class inon Vertisol.

Similarly, the increasing dose of organic fertilizer used tended to increase soil pH with the maximum value observed in the application of 18 tonha^{-1} (Figure 4). The decreasing pH with the application of organic fertilizer at a dose of more than 18 toha^{-1} maybe due to the higher organic acid produced along with the decomposition process.

This result is in accordance with the statement of Rahmah (2014), mentioning that pH may affect other reactions in the soil, such as decomposition rate of soil organic matter, clay mineral formation, and plant growth. The highest value of soil pH (7.00) was obtained in the application of 18 tons/

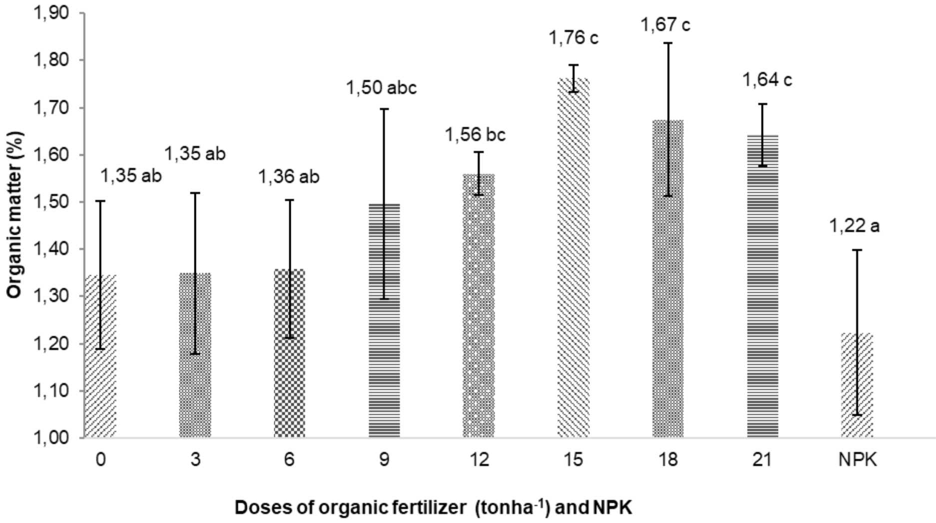

Figure 5. Effect of the doses of organic fertilizer decomposed with biofilm biofertilizer on the organic matter content of Vertisol soil planted with upland kale. The values followed by the same letters are not significantly different based on the DMRT 95%.

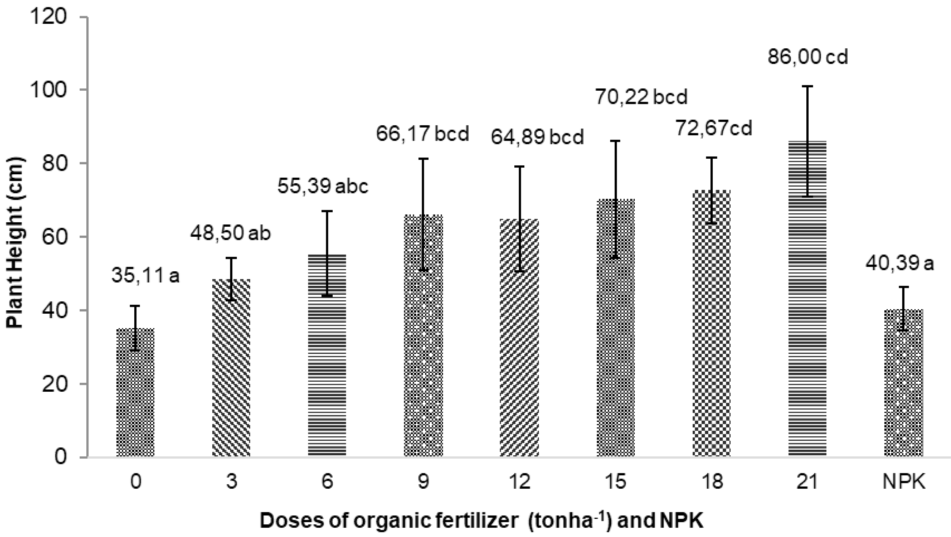

Figure 6. Effect of the doses of organic fertilizer decomposed with biofilm biofertilizer on the plant height of upland kale in Vertisol soil. The values followed by the same letters are not significantly different based on the DMRT 95%.

ha, while the lowest value (6.60) was obtained in NPK treatment. The increase in soil pH is due if the added organic material has been well decomposed. The mineralized organic material releases minerals in the form of basic cations (Suntoro, 2003).

Effect of organic fertilizer decomposed with biofilm biofertilizer on the soil organic matter content was very significant (P= 0.004) although according to Balittan (2009), all of the criteria were low, which might be due to the low initial soil organic matter content (1.36%; Table 1) (Nurdin et al., 2008). Organic fertilizers improve soil chemical fertility and nutrient release (Barbarick, 2006). Different from available-P and exchangeable-K, the highest soil organic matter content (1.76%) was obtained in the application of 15 tonsha^{-1} organic fertilizer, and the lowest organic matter content (1.22%) was in NPK treatment with (Figure 5). Soil organic matter content has strong positive correlation (r= 0.673**) with soil pH. This result suggests that the increase in organic matter applied is closely corelated to the increase in pH. Suntoro (2003) states that the addition of decomposed organic matter will increase soil pH because mineralized organic matter will release minerals in the form of basic cations. Soil organic matter content was the lowest in the treatment of NPK because there was no organic matter added.

Effects of treatments on the growth of upland kale

Effect of the doses of organic fertilizer decomposed with biofilm biofertilizer was very significant (P = 0.002) on the growth of upland kale as indicated by the increase in the plant height, number of leaves, as well as plant fresh and dry weight (Fig. 6 - 8). Lingga and Marsono (2001) stated that organic fertilizer, through its available nutrients (nitrogen, phosphorus, potassium, etc.) content, can stimulate the vegetative growth of plants, especially plant height. Upland kale is a vegetable crop whose height or length is one of the main criteria for good product. The highest plant height (86 cm) was achieved in the application of 21 tonha^{-1} organic fertilizer decomposed with biofilm biofertilizer, while the lowest (35.11 cm) was in the control treatment. The application

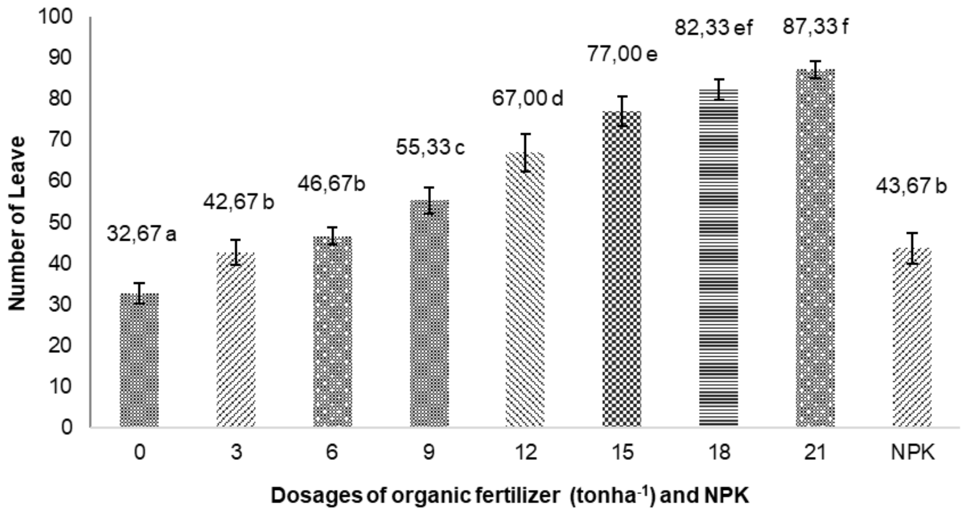

Figure 7. Effect of the doses of organic fertilizer decomposed with biofilm biofertilizer on the number of leaves of upland kale in Vertisol soil. The values followed by the same letters are not significantly different based on the DMRT 95%.

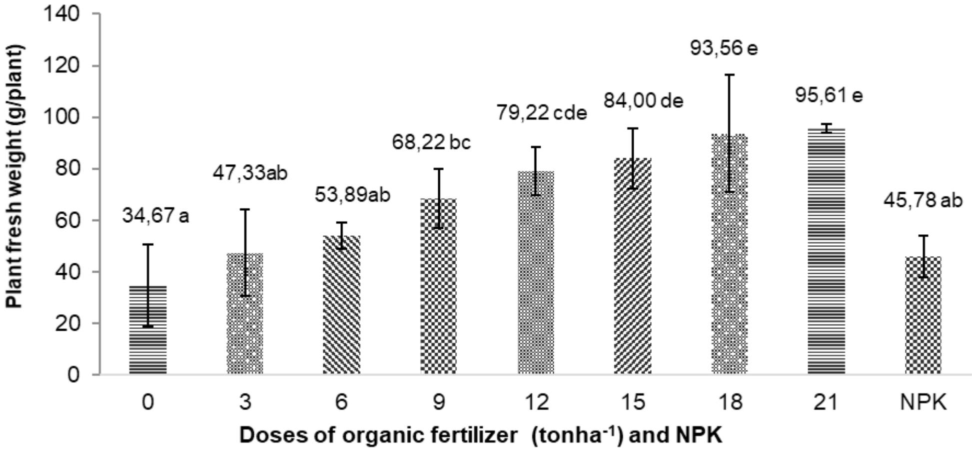

Figure 8. Effect of the doses of organic fertilizer decomposed with biofilm biofertilizer on the plant fresh weight of upland kale in Vertisols. The values followed by the same letters are not significantly different based on the DMRT 95%.

of 3 to 6 $tonha^{-1}$ of this organic fertilizer resulted in the better growth of upland kale compared to the application of NPK as indicated by plant height, fresh and dry weight (Figure 6-8). Organic fertilizer can improve soil chemical, physical and microbiological properties that stimulate better plant growth. NPK fertilizer contains high available nutrients but it cannot stimulate soil physical and microbiological improvement as organic fertilizer. The increasing doses of organic fertilizer tended to increase the plant height linearly up a dose of 21 $tonha^{-1}$, indicating that this soil needs more organic fertilizer to achieve its optimal productivity. This result might be due to the low initial soil organic matter content (Table 1).

Number of leaves per plant significantly (P = 0.000) increased concomitantly with the increasing dose of organic fertilizer used (Figure 7). As well as plant height, number of leaves increase liniearly with the increase of organic fertilizer doses. According to Edi S. (2014), the increasing number of leaves indicate a quantitative increase in the cell development. The higher number of leaves means more carbohydrates produced from the process of photosynthesis. Carbohydrates affect the amount of yield of a plant. The application of NPK fertilizer produced equal number of leaves compared to the application of 3 – 6 $tonha^{-1}$ organic fertilizer. This because as vegetable crop, upland kale needs more organic matter to grow well.

Upland kale is vegetable crop usually harvested for both shoot and whole crop. Thus, plant fresh weight is one of the main indicators of crop yield. The effect of organic fertilizer doses on the upland kale fresh weight was very significant (P = 0.0001) (Figure 8). The increase of upland kale fresh weight was linearly with the increase of the doses of organic fertilizer applied (Figure 8). This result might be caused by the increasing of available plant nutrients from organic fertilizer applied, either directly or indirectly (Parawansa and Hamka, 2014) and especially because of the improvement of the soil physical, chemical, and microbiological properties. The application of NPK fertilizer only resulted crop yield as high as the application of 3 - 6 $tonha^{-1}$ organic fertilizer. Although NPK fertilizer provide high amount of available plant nutrients, but it cannot improve soil physical and microbiological properties as good as organic fertilizer. The highest fresh weight (95.61 $gplant^{-1}$) was resulted by the application of 21 $tonsha^{-1}$organic fertilizer, which was not significantly different from the yield of 18 $tonha^{-1}$ organic fertilizer application (Figure 8). There was an increase in plant fresh weight with the increasing dose of organic fertilizer applied, but the enhancement tended to decrease. This result might because it will reach optimal dose of application. As shown by the effect of the doses on the plant nutrients available (Figure 1 – 5), the optimal dose of organic fertilizer applied was 15 – 18 $tonha^{-1}$, and this was corresponding to the effect on the plant dry weight .

The effect of organic fertilizer dose on the upland kale dry weight was similar to its effect on the plant nutrients available and soil organic matter content (Fig. 1 – 5). There was a very significant effect (P = 0.000) on the dry weight with an optimum dose of 15 $tonha^{-1}$. It showed that there was a high correlation between plant nutrients available and plant growth as indicated by its dry weight. Prawiranata cit. Priyono and Sarwono (2015) stated that plant dry weight depends on the rate of photosynthesis. The plant needs nutrients to carry out photosynthesis. It shows that vegetative growth of upland kale was going well. The best result was obtained at the application of 15 $tonha^{-1}$ (7.22 $gplant^{-1}$) organic fertilizer, while the NPK treatment only produced 3.13 $gplant^{-1}$, and control treatment produced 2.82 $gplant^{-1}$. The yield of upland kale fertilized with NPK was lower than that treated with t 3 $tonha^{-1}$ of organic fertilizer. This result might because organic fertilizer, besides providing plant nutrients, also improves soil physical, chemical and microbiological properties better than NPK fertilizer does. It indicates that upland kale does not only need sufficient plant nutrients, but it also needs a good soil chemical, physical and microbiological conditions. Organic fertilizer can support this improvement of soil properties better than NPK fertilizer. There was strong correlation between plant height and number of leaves (r = 0.784 **), as well as between plant fresh and dry weight (r = 0.918 **).

CONCLUSION

The increasing doses of organic fertilizer decomposed with biofilm biofertilizer significantly enhanced the available P, exchangeable K, soil pH, and soil organic matter content, as well as plant height, numbers of leaves, and fresh and dry weight of upland kale. The optimum dose of organic fertilizer applied was between 15 – 18 $tonha^{-1}$ for plant nutrients available and upland kale growth and yield. The application of 3 $tonha^{-1}$ organic fertilizer resulted better yield of upland kale than NPK fertilizer.

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The Application of Filter Cake Compost to Improve The Efficiency of Inorganic Fertilizer in Upland Sugarcane (*Saccharum officinarum* L.) Cultivation

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ABSTRACT

The production of sugarcane in 2018 decreased due to the change in the cultivation method from lowland to upland. This research aimed to study the responses of growth and yield of two sugarcane varieties to the application of filter cake compost and inorganic fertilizer in upland sugarcane cultivation. This experiment was arranged in a split-split plot design consisting of three-factors, which were sugarcane varieties, the levels of filter cake compost, and the rates of inorganic fertilizer, assigned to the main plot, sub-plot, and sub-sub plots, respectively. The two sugarcane varieties were PS 881 and PS 862. The three levels of filter cake compost were 0, 5, 10 tons ha^{-1}, and the four rates of inorganic fertilizers (percent of recommended dosage) were 25%, 50%, 75%, and 100%. The results showed that the growth and yield of PS 862 was better than that of PS 881, shown in the plant height, stem diameter, number of stems, and the length of internodes. The use of filter cake compost at a dose of 5 tons ha^{-1} was more efficient, and it could provide an efficiency of 0.097 tons per kg of cane at a dose of 76.76% inorganic fertilizer. Yet, it cannot reduce the use of inorganic fertilizer in producing sugarcane yield.

Keywords: Compost, Efficiency, Internode, PS 881, Yield

ABSTRAK

Produksi tebu pada tahun 2018 menurun dikarenakan pertanaman tebu berubah dari lahan sawah menjadi lahan kering. Penelitian ini bertujuan untuk mempelajari respon pertumbuhan dan hasil dua varietas dengan aplikasi kompos blotong dan pupuk anorganik pada pertanaman tebu lahan kering. Penelitian ini telah dilaksanakan di PT Kebun Tebu Mas, Mantup, Lamongan, Jawa Timur. Percobaan disusun dengan rancangan petak-petak terpisah (*split-split plot design*). Perlakuan yang digunakan terdiri dari tiga faktor yaitu varietas , tiga taraf kompos blotong dan empat dosis pupuk anorganik yang tersusun berturut-turut sebagai petak utama, anak petak dan anak-anak petak. Varietas yang digunakan adalah PS 881 dan PS 862, pupuk kompos blotong terdiri dari tiga taraf yaitu 0, 5 dan 10 ton per hektar dan empat dosis pupuk anorganik (persen dosis rekomendasi) yaitu 25%, 50%, 75% dan 100%. Hasil menunjukkan bahwa pertumbuhan dan hasil varietas PS 862 lebih baik daripada PS 881 pada keragaan tinggi tanaman, diameter batang, jumah batang dan panjang ruas. Dosis kompos blotong 5 ton ha^{-1} merupakan dosis terbaik dan dapat meningkatkan efisiensi pupuk anorganik sebesar 0,097 ton kg^{-1} pada dosis 76.76%. Hal tersebut belum mampu mereduksi penggunaan pupuk anorganik dalam menghasilkan tonase tebu.

Kata Kunci: Efisiensi, Hasil, Kompos, PS 881, Ruas

INTRODUCTION

National sugar demand per year is 5.7 million tons in the form of 3.2 million tons refined crystal sugar for industry and 2.5 million tons of white crystal sugar for consumption. National sugarcane production in 2018 was 2.17 million tons lower than in 2016, which was 2.2 million tons (Directorate General of Plantations, 2019). Such problem has occured due to the change in sugarcane cultivation in Indonesia from lowland to suboptimal lands, such as upland. Indonesia has an upland area of 144.5 million hectares consisting of 37.1 million hectares of nonacidic upland, 107.3 million hectares of acid upland, and 10.7 million hectares of dry climate, which are all scattered in various regions (Abdurachman et al., 2008; Indonesian Center for Agricultural Land Resources, 2015).

Upland has a deficiency of cation exchange capacity (CEC) and low organic C content, and total evaporation from the soil is not balanced by the amount of rainfall so that the availability of water and soil nutrients is limited (Budiyanto, 2014; Rahayu et al., 2014). According to the Soil

Research Institute, the organic C content in good soil is at a moderate level of 2-3% (Soil Research Institute, 2009). The limited environmental conditions lead to various activities of sugarcane, such as morphological, physiological, and gene expression responses throught the mechanism of tolerance and avoidance (Jain et al., 2015; Ferreira et al., 2017; Zhao et al., 2017). The plant response to avoid drought stress is water loss at leaf transpiration, stomatal closure, and low leaf chlorophyll concentration, reducing the availability of CO_2 and then inhibiting biomass production (Silveira et al., 2016). Mastur (2016) explains that a decrease in the rate of photosynthesis and the availability of water and soil nutrients can reduce the rate of plant growth and sugar production. Under these conditions, the efforts must be made to add inorganic fertilizers promptly and to use superior sugarcane varieties.

The recommended dose for sugarcane fertilization is 100-120 kg ha^{-1} N, 100-200 kg ha^{-1} P, and 100-200 kg ha^{-1} K to produce 100 ton ha^{-1} of sugarcane (Santos et al., 2015). Sugarcane productivity increased by 5.82% as affected by compound fertilizer packages with Ca and Mg without manure (Supriyadi, Diana, & Djumali, 2018). However, those recommendations are not able to improve the quality of soil in the upland so that additional handling is required. Improving soil quality by adding organic matter is one of the methods in scaling production in plant cultivation. The addition of organic fertilizer was applied to the soil to improve the holding capacity of water, cation exchange capacity, soil structure, nutrient availability, and nutrient storage in the soil (Bot and Benites, 2005). Organic matter is easily made and obtained from sugarcane milling waste as a filter cake. Filter cake is a waste originating from the sap in the process of grinding sugarcane, and not enough research has been done on sugarcane cultivation in Indonesia. The application of 3-5 tons filter cake compost under drought stress conditions can reduce watering time intervals to fulfill the water needs of sugar cane plants and increase water holding capacity in the soil, thereby increasing the yield (Purwono, Sopandie, Harjadi, & Mulyanto, 2011). Reducing inorganic fertilizers in sugarcane and corn cultivation increased the productivity of the plants (Usman et al., 2015; Dotaniya et al., 2016; Jaili and Purwono, 2016). The application of organic fertilizer as mill ash resulted in the highest cation exchange capacity and nutrient concentrations, and these properties could increase nutrient availability in sandy soil in the short and long term contributing to the growth of biomass and sugarcane sucrose yield (Gomez 2013; Shukla et al., 2015; Alvarez-Campos et al., 2018). The analysis of the filter cake compost showed that it contained 0.89% N, 0.17% P, and 0.70% K and 17.46% organic C, which are expected to help improve soil quality and improve sugarcane production. This research aimed to study the responses of growth and yield of two sugarcane varieties to the application of filter cake compos, as well as to determine the efficiency of inorganic fertilizer in upland sugarcane cultivation.

MATERIALS AND METHOD

This research was conducted in the sugarcane field with Vertisol soil type and clay soil texture at 90 meters above sea level from October 2018 to July 2019. This study was arranged in a separated split-split plot design with three factors, namely sugarcane (V) varieties, levels of filter cake compost (K), and doses of inorganic fertilizer (A) as the main plot, sub-plot, and sub-sub plots, repectively. The two sugarcane varieties were PS 881 (V1) and PS 862 (V2). The filter cake compost consisted of three levels, which were 0 (K1), 5 (K2), and 10 ton ha^{-1} (K3), and the treatment of inorganic fertilizers consisted of four doses (percent of recommendation), which were 25% (45 kg Z.A. and 30 kg NPK) (A1), 50% (90 kg Z.A. and 60 kg NPK) (A2), 75% (135 kg Z.A. and 90 kg NPK) (A3) and 100% (180 kg Z.A. and 120 NPK) (A4). Each treatment combination was repliated three times. The additive linear model used in this design is:

$$Yijkl = \mu + \rho i + \alpha j + \delta ij + \beta k + (\alpha\beta)jk + \delta ijk + \gamma i + (\alpha\gamma)jl + (\beta\gamma)kl + (\alpha\beta\gamma)jkl + \delta ijkl$$

The experiment was carried out in the upland, and the land preparation used was Juringan or furrow system with a length of 6 m, and each furrow was separated by a range of 0.5 m. The distance between furrow centers is 1.1 m, with a width of 0.45 m and the ridge of 0.65 m. Each trial unit consiststed of 5 furrows so that the total furrows required were 5 x 72 = 360 furrows. The land area required was around 3 000 m^2.

Planting was carried out using single bud planting seedlings that had been in a nursery for 2.5 months from the plantation of P.T. Kebun Tebu Mas. The plant spacing was 0.5 m with one single bud in each planting hole so that each furrow had 11 single buds. The bud replacement was done one week after planting using the same single bud seeds (seedlings that were grown together when planting). Fertilizing was done according to the recommended doses from P.T. Kebun Tebu Mas, which were 600 kg ha^{-1} Z.A. plus 400 kg ha^{-1} NPK equivalent to 186 kg N ha^{-1}, 60 kg ha^{-1} P_2O_5, 60 kg ha^{-1} K_2O and 144 kg ha^{-1} S. Z.A. The NPK fertilizers were applied three times, namely as the basic fertilization, as supplementary fertilization at four weeks after planting (WAP), and at eight WAP. Fertilization was carried out using placement techniques following the needs of each variety (0.5 kg Z.A. and 0.33 NPK for three times fertilization). Filter cake compost was given one week before planting according to the treatment doses by sowing the compost evenly in the planting hole in each furrow.

The analysis of soil and filter cake compost was carried out in the Laboratory of Soil and Plant, IPB University. The data of the vegetative growth were recorded on six sample plants per plot taken from the 2nd, 3rd, and 4th furrow. The observations were started when the plants were one month after planting (MAP). The agronomic chracters observed included plant height, number of leaves, leaf area, number of tillers, number and length of stems, nunber and range of internodes, and stem diameter. Meanwhile, the physiological charcters observed included leaf pigment content (chlorophyll a and b) and leaf nutrient analysis (on leaves +1). The yield component was observed by taking data of stem length, number of stems per meter, and stem weight. They were used to estimate the efficiency of inorganic fertilizer (formula: $\frac{\text{cane production}}{\text{amount of inorganic fertilizer}}$) and sugarcane yield in ton per hectare. The data obtained were analyzed with analysis of variance at 5%, followed by Duncan multiple range tests (DMRT) to determine the effect of filter cake compost and polynomial orthogonal tests to determine differences in responses to the inorganic fertilizer doses.

RESULTS AND DISCUSSION

The strategy to increase sugarcane productivity expected from this research is the improvement of soil quality through the efficiency of inorganic fertilizer and the application of filter cake compost to achieve an increase in the sugarcane yield. Therefore, the application of organic matter in the form of filter cake compost combined with reduced doses of inorganic fertilizer is expected to increase the number of tillers and the stem diameter in the sugarcane cultivation.

Climate condition in the experimental site is described in Figure 1. There was no rain in Octo-

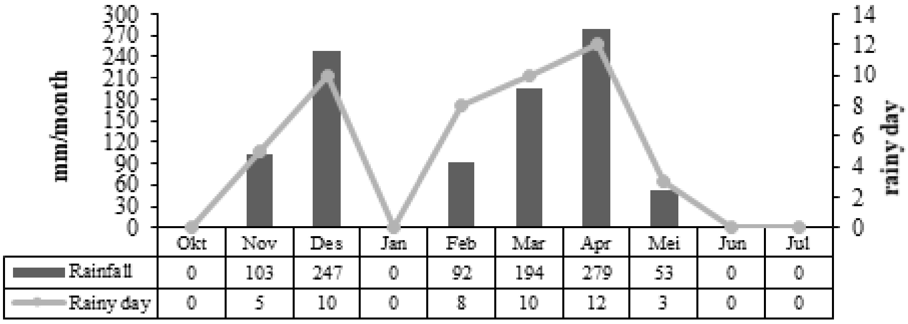


Figure 1. Rainfall data in Mantup District from October 2018 to July 2019

ber 2018, so manual watering was carried out to meet the water requirement for the crops. Rainfall began in November 2018 and lasted to December 2018 with low rainy days. Water deficit conditions cause plant growth to be disrupted, resulting in the inhibition of cell enlargement and extension (Arve et al., 2011; Widiyani and Ariffin, 2017).

The soil analysis before the experiment showed that the soil texture at the experimental site was clay with Vertisol soil type (Table 1). The content of organic matter and nitrogen is very low, the pH is slightly acidic, and the nutrient content of P and K is low, whereas Ca nutrient is very high (Soil Research Institute, 2009). The explanation shows that the condition of the land used is sub-optimal land, which has low nutrient content and low organic matter.

The results of the filter cake compost analysis showed that the water holding capacity was 35.50% (Table 2). Besides, the organic C content of 17.46% (Gravimetric method), which was higher than the organic C content in the soil will help improve the quality of the physical properties of the soil. The C/N ratio of the filter cake compost ratio (19.61) indicated that compost was still undergoing a decomposition process, inhibiting the nutrient availability in the soil. Mature compost standards show a C/N ratio of 8-15 (Soil Research Institute, 2009).

Effects of filter cake compost and inorganic fertilizer on sugarcane growth

The plant height of bith sugarcane varieties increased, which tended to be the same from the age of 4 WAP to 25 WAP (Figure 2). The growth

Table 1. Chemical-physical properties of Vertisol

Soil Properties	Methods	Unit	Value	Criteria
pH	H_2O		6.45	Rather acidic
C-Organik	Walkey & Black	%	0.63	Very low
N total	Khejdahl	%	0.08	Very low
C/N ratio			7.87	Low
P_2O_5	Bray	ppm	10.68	Moderate
K	N NH_4Oac pH 7	cmol(+)/kg	0.28	Low
Ca	N NH_4Oac pH 7	cmol(+)/kg	42.87	Very high
Mg	N NH_4Oac pH 7	cmol(+)/kg	5.61	High
Na	N NH_4Oac pH 7	cmol(+)/kg	0.21	Low
KTK	N NH_4Oac pH 7	cmol(+)/kg	6.76	Low
Texture	Pipette method			
Sand		%	8.00	
Silt		%	23.17	Clay
Clay		%	68.83	

Table 2. Results of filter cake compost analysis

Component of analysis	Methods	Unit	Analysis result
pH	H_2O		7.20
Organic C	Gravimetric	%	17.46
N total	Khejdahl	%	0.89
C/N ratio			19.61
P_2O_5	Wet ashing	%	0.17
K_2O	Wet ashing	%	0.70
Ca	Wet ashing	%	12.20
Mg	Wet ashing	%	0.34
Water content	Gravimetric	%	35.50

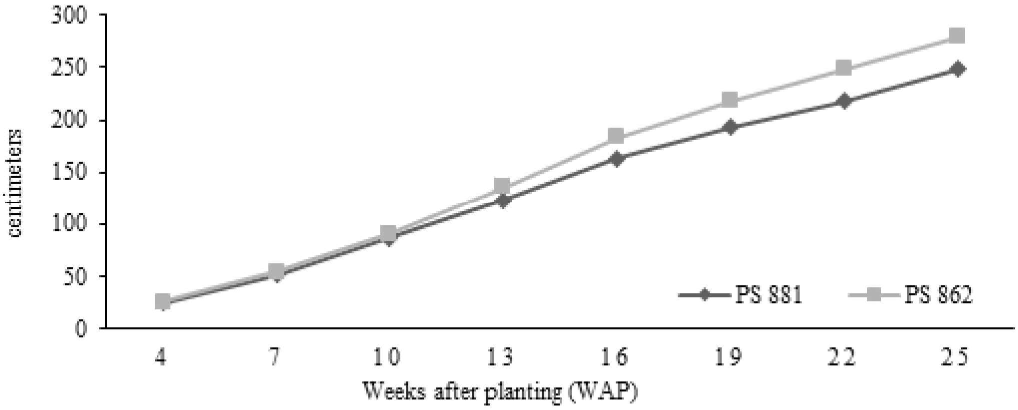


Figure 2. Curve of sugarcane plant height

performance of both varieties has similar morphological characteristics, such as early and middle early maturity types. The analysis result (Table 3) showed that the number of stems was not affected by variety, but the application of filter cake compost significantly affected the leaf area. Meanwhile, the doses of inorganic fertilizer applied significantly affected the number of tillers and stem considerably.

Filter cake compost and inorganic fertilizer treatment did not significantly affect the number of leaves (Table 3). This is opposite to the explanation of Silva et al. (2019), mentioning that the higher dose of N from various fertilizer sources increases the number of leaves in sugarcane. Meanwhile, the application of filter cake compost significantly affected the leaf area at 25 WAP (Table 3) due to the delay in the availability of nutrients in the soil caused by filter cake compost, which is still undergoing a decomposition process.

The application of inorganic fertilizers at doses higher than 50% no longer increased the number of tillers and stems (Table 3). Diana et al. (2016) reported that the application of inorganic fertilizers at different doses affected the number of stems during sugarcane growth.

Interaction betwen sugarcane variety and filter cake compost (Table 4) shows that both varieties are responsive to the internodes formation. PS 881 variety is more responsive in the length of the internodes at 22 and 25 WAP compared to PS 862 variety. The result showed that the length of the internodes of both sugarcane varieties (PS 881 and PS 862) was more determined by genetic traits rather than by fertilizer treatment. However, the application of filter cake compost affected the availability of nutrients and water in the soil so that the nutrient uptake process by plant roots was not hampered. The application of organic matter

Table 3. Average of the growth variable at 25 WAP

Treatment	Number of leaves	Number of tillers	Number of stems	Leaf area
Varieties				
PS 881	19.69 b	6.29 b	6.09	428.67 b
PS 862	21.14 a	7.06 a	6.64	508.75 a
Filter cake compost				
0 ton ha^{-1}	20.37	6.47	6.16	451.78 b
5 tons ha^{-1}	20.50	6.66	6.35	468.80 b
10 tons ha^{-1}	20.38	6.90	6.59	485.56 a
Inorganic fertilizer				
25%	20.04	5.62 b	5.11 b	449.35
50%	20.39	6.93 a	6.80 a	484.18
75%	20.46	7.05 a	6.75 a	469.96
100%	20.77	7.12 a	6.81 a	471.36

Note: Values followed by the same letters within a column are not significantly different at 5%. WAP= weeks after planting

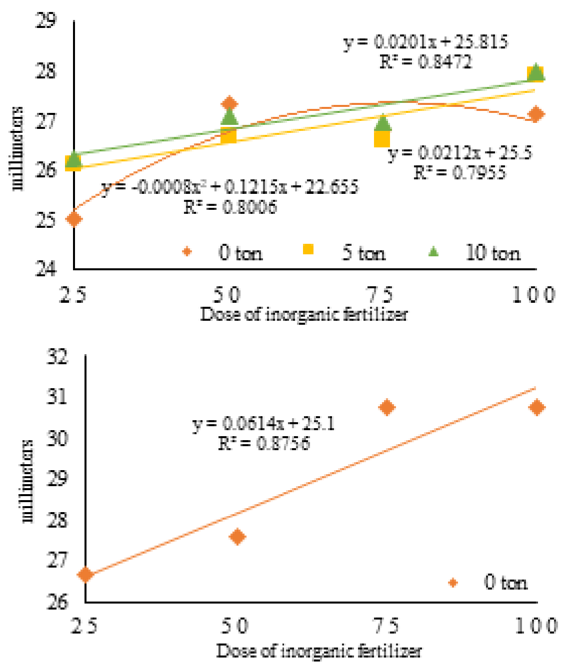
Table 4. Interactions of sugarcane variety and filter cake compost on the number and length of internodes

Filter cake compost	N.I. 22 WAP		LI 22 WAP		LI 25 WAP	
	PS 881	PS 862	PS 881	PS 862	PS 881	PS 862
0 ton ha^{-1}	14.03 c x	14.06 c x	10.13 c y	12.08 a x	9.85 d y	11.97 a x
5 ton ha^{-1}	14.61 b x	14.65 b x	10.35 c y	11.23 b x	10.27 c y	11.00 b x
10 ton ha^{-1}	15.24 a x	14.15 c y	9.28 d y	12.25 a x	9.55 e y	12.22 a x

Note: Values followed by the same letters within a column are not significantly different at 5%. N.I.: number of internodes; LI: length of internodes; WAP: weeks after planting.

could improve soil quality, following Ghube et al. (2017) and Banerjee et al. (2018) that the addition of manure, inorganic fertilizer, and microorganisms could improve the level of water infiltration into the soil better compared to without treatment.

The interaction effect of filter cake compost and inorganic fertilizer on the stem diameter of PS 881 variety at 22 WAP is presented on Table 5 and Figure 3a. The application of 0 tons ha^{-1} filter cake compost is illustrated by a quadratic equation (y= -0.0008x^2 + 0.1215x + 22.655) with an optimum inorganic fertilizer dose of 75.93%. The use of filter cake compost improved inorganic fertilizer efficiency at the treatment of 100% inorganic fertilizer dose in the stem diameter formation of PS 881. The requirements of nutrients and water in the soil for the plant stem cell divisons were sufficiently fulfilled by filter cake compost application.



(a)

(b)

Figure 3. Curve of the interaction effects of sugarcane variety, filter cake compost and inorganic fertilizer on the stem diameter at 22 WAP: a) PS 881 dan b) PS 862

Table 5. Interaction effects of sugarcane variety, filter cake compost and inorganic fertilizer on the stem diameter at 22 WAP

Inorganic fertilizer	PS 881			PS 862		
	Filter cake compost			Filter cake compost		
	0 ton	5 ton	10 ton	0 ton	5 ton	10 ton
	.... millimeters					
25%	25.02	26.12	26.25	26.68	30.20	29.52
50%	27.32	26.68	27.10	27.58	29.48	30.53
75%	26.81	26.59	26.97	30.74	29.67	29.10
100%	27.15	27.92	27.97	30.74	29.79	30.29
Polynomial tests	0.042 * Q	0.027 * L	0.043 * L	0.002 ** L	0.4746 ns	0.816 ns

Note: Polynomial orthoghonal tests: ns: not significant; *:significant; **: highly significant; L: linear; Q: quadratic.

According to Table 5 and Figure 3 b, the effect on the stem diameter of PS 862 variety was shown in the absence of filter cake compost. The increasing size of cane diameter was along with an increase in inorganic fertilizer dose.

Effects of filter cake compost and inorganic fertilizer on the sugarcane leaves nutrient content

Based on he analysis on the dry plant weight (Table 6), both sugarcane varieties showed different responses to the application of inorganic fertilizers. This is thought to be due to the morphological differences between the varieties that affect the nutrient absorption process, which are then used for biomass formation. The availability of water and nutrients at 6 months after planting (MAP) was not inhibited, and plant growth focused on the formation of glucose in the stem.

Nitrogen content in the PS 881 leaves was higher than that in PS 862. Conversely, the phosporus content in was higher in PS 862. Meanwhole, both of the filter cake compost and inorganic fertilizer doses have on effects on the N and P content in the leaves. The plants did not show a nutrient deficiency response, but they are categorized in the optimum criteria according to Mccray et al. (2006) who mention that the critical point value of nutrients in leaves was 1.80% N, 0.19% P, and 0.90% K. The rest of the nutrient content was still used in biomass growth and stored in sinks in

Table 6. Plant dry weight and leaves nutrient content at 6 MAP

Treatment	Plant dry weight (kg)				Leaves nutrient content (%)		
	Root	Stems	Shoots	Leaf	N	P	K
Varieties							
PS 881	145.94 b	1049.1 b	30.22 b	165.19 b	2.14 a	0.19 b	1.39
PS 862	182.23 a	1399.1 a	48.27 a	218.98 a	1.77 b	0.24 a	1.45
Filter cake							
0 ton ha^{-1}	168.04	1252.9	41.39	204.69	1.94	0.21 b	1.42
5 tons ha^{-1}	166.18	1202.8	36.58	190.89	1.93	0.21 b	1.36
10 tons ha^{-1}	158.05	1216.8	39.78	180.68	2.00	0.23 a	1.48
Inorganic fertilizer							
25%	130.59	1040.3	32.77	155.82	1.84	0.22	1.47
50%	195.46	1302.2	47.00	209.77	1.97	0.22	1.42
75%	162.61	1274.6	38.20	201.00	1.97	0.21	1.37
100%	167.70	1279.4	39.01	201.75	2.04	0.22	1.42
Polynomial tests	0.258 ns	0.393 ns	0.686 ns	0.382 ns	0.020 * L	0.953 ns	0.973 ns

Note: Values followed by the same letters within a column are not significantly different at 5%. Polynomial tests for inorganic fertilizer: ns: not significant; *: significant; L: linear; Q: Quadratic; MAP: month after planting.

Table 7. Interaction effects of sugarcane varieties and filter cake compost on the length and weight of cane stems

Filter cake compost	Length of stems (cm)		Stems weight (kg)	
	PS 881	PS 862	PS 881	PS 862
0 ton ha^{-1}	239.25 d y	265.38 b x	0.53 d y	0.60 b x
5 ton ha^{-1}	253.66 c y	263.61 b x	0.52 d y	0.68 a x
10 ton ha^{-1}	236.56 d y	271.74 a x	0.57 c y	0.65 a x

Note: Values followed by the same letters within a column are not significantly different at 5%.

the form of glucose. Filter cake compost applied together with P fertilizer before planting sugarcane could increase the yield of sugarcane per hectare and sugar accumulation (Caione et al., 2015).

Effects of filter cake compost and inorganic fertilizer on sugarcane yield components

Interaction between filter cake compost and sugarcane varieties significantly affected the length and weight of the stem. Table 7 shows that PS 881 variety is more responsive to filter cake compost in producing stem length, while PS 862 variety is more responsive to filter cake compost in providing stem weights. The number of stems per meter in PS 862 variety was higher than in PS 881 variety. This result because soil organic matter content might have been increased so that it could hold soil moisture, increasing soil water retention. Soil physical properties improvement affected the change in soil aggregate and the increase in organic C level in the soil. The addition of filter cake compost and zeolite could inmprove aggregate, cation exchange capacity, and microorganisms in the soil (Kumar et al., 2017; Cairo et al., 2017). Sugarcane production was encouraged by the total nutrients absorbed by plants used in the process of photosynthesis to produce a lot of biomass and high levels of glucose formed in the stems. Vasconcelos et al. (2017) reported that the application of filter cake compost significantly enhanced the availability of P nutrients and plant photosynthetic activity, thereby increasing the stem weight per hectare.

The the application of inorganic fertilizer has a significant effect on the nunber of stems in both PS 881 and PS 862 varieties (Figure 4). Both varieties experienced an increase in the number of stems along with the increasing doses of inorganic fertilizer to the optimum dose. PS 881 showed a more

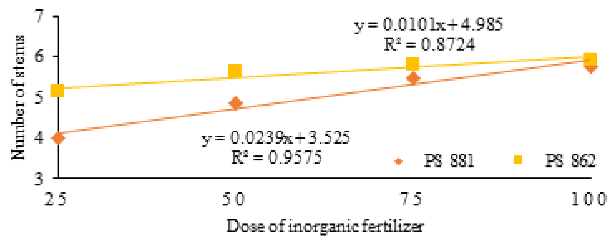


Figure 4. Curve of the interaction effects of sugarcane varieties and inorganic fertilizer on the number of stems

significant increase in the number of stems than PS 862 variety. This phenomenon is presumably due to the influence of plant genetics since that PS 881 variety is an early mature type and PS 862 is a medium mature type. Interaction effects of sugarcane varieties and filter cake compost on the number of stems are presented in Table 8.

Table 8. Interaction effects of sugarcane varieties and inorganic fertilizer on the number of stems

Varieties	Inorganic fertilizer				Polynomial tests
	25%	50%	75%	100%	
PS 881	3.99	4.84	5.48	5.77	0.001 ** L
PS 862	5.12	5.64	5.80	5.91	0.035 * L

Note: Polynomial orthoghonal tests: ns: not significant; *:significant; **: highly significant; L: linear; Q: quadratic.

In the application of filter cake compost at a dose of 0 tons ha^{-1}, the interaction effect of filter cake compost and inorganic fertilizer on the sugarcane yield is illustrated by the quadratic equation (y=-0.0068x^2 + 1.0442x + 24.74) (Table 9 and Figure 5). The equation of the quadratic curve ilustrates that the optimum dose of inorganic fertilizer is 76.76% (use the formula: – (b/2.a)). In contrast, the application of filter cake compost at a dose of 5 and 10 tons ha^{-1}, the interaction effect is illustrated by linear curve with R square of 0.99 and 0.89. Moreover, the application of filter cake compost on soil could reduce the uusesage of inorganic fertilizers due to the improvement of the soil quality through the availability of nutrients and water content. The most efficient inorganic fertilizer was at a dose of 76.76% combined with 5 tons ha^{-1} filter cake compost, producing 75.03 tons ha^{-1} of sugarcane. This data consider that per kg of inorganic fertilizer could produce 0.097 tons cane. However, a combination with 10 tons ha^{-1} filter cake compost produced 72.10 tons ha^{-1} of sugarcane, and the efficiency of inorganic fertilizer to produce cane declined to 0.093.

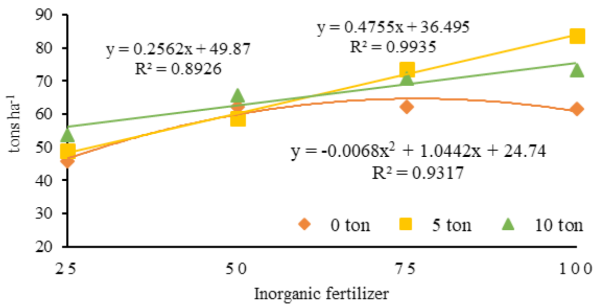


Figure 5. Curve of the interaction effects of filter cake compost and inorganic fertilizer on sugarcane yield

Table 9. Interaction effects of filter cake and inorganic fertilizer on sugarcane yield

Inorganic fertilizer	Filter cake compost		
	0 ton ha^{-1}	5 ton ha^{-1}	10 ton ha^{-1}
		.... Tonne cane per hectar (TCH).............	
25%	45.75	48.98	53.62
50%	62.35	58.72	65.77
75%	62.15	73.47	70.86
100%	61.67	83.69	73.27
Polynomial tests	0.017 ** Q	0.001 ** L	0.037 ** L

Note: Polynomial orthoghonal tests: ns: not significant; *:significant; **: highly significant; L: linear; Q: quadratic.

CONCLUSION

The growth of PS 862 variety was better than that of PS 881 in the plant height, stem diameter, number of stems, number and length of internodes, and yield. PS 881 variety showed a better response than PS 862 in terms of number of internodes and stem length. The optimum dose of inorganic fertilizer was obtained at 75.93% and 76.76% to produce a stem diameter of PS 881 variety and sugarcane yield per hectare, respectively. The combination dose of 5 tons ha^{-1} filter cake compost and 76.76% inorganic fertilizer was more efficient, and it could provide an efficiency of 0.097 tons cane kg^{-1}. However, it wasn't efficient yet to reduce the use of inorganic fertilizer in producing stem diameter and the yield of both varieties of sugar.

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Identification of Changes in Water Catchment Areas in Kulon Progo District Using Geographic Information Systems

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ABSTRACT

Water is the basic needs of living things in this world. Infrastructure development that increased would cause the needs of water. Therefore, it has to be balanced with manage the good plan of water absorption region in an area. This research has been done in Kulon Progo districts that aimed at made maps and map the potential of water absorption region in Kulon Progo districts. The method used in this research was the tiered quantitative analysis survey with Geography Information System (SIG) software with the weighting parameter categorize model using overlap techniques in each parameter. The parameters were kind of rocks, rainfall, used land, and slope of the land. The data of the research was secondary data. Those were administration map, Topographycal map, land used map, rainfall data, Shuttle Radar Topography Mission (SRTM), and soil map. The result of this research showed that water absorption region in Kulon Progo with dominated suitability condition in unsuitable class as wide as 32.804 ha followed by class as wide as 17.124 ha, and the smallest was class condition quite appropriate as wide as 7.976 ha.

Keywords: ArcGIS, Weighting factor, Infiltration

ABSTRAK

Air adalah kebutuhan pokok makhluk hidup di bumi ini. Pembangunan infrakstruktur yang terus meningkat yang juga diimbangi dengan bertambahnya jumlah manusia berakibat pada meningkatnya kebutuhan air bersih. Oleh karena itu harus diimbangi dengan mengelolaan perencanaan tata kelola daerah resapan air yang baik di suatu daerah. Penelitian ini dilaksanakan di Kabupaten Kulon Progo pada bulan yang bertujuan untuk membuat peta dan memetakan potensi daerah resapan air yang berada di Kabupaten Kulon Progo. Metode yang digunakan dalam penelitian ini yaitu adalah survei analisis kuantitatif berjenjang menggunakan perangkat lunak Sistem Informasi Geografi (SIG) dengan model pengkelasan parameter pembobotan menggunakan teknis *overlay* pada masing-masing parameter yaitu jenis batuan, curah hujan, penggunaan lahan, dan kemiringan lahan. Jenis data yang digunakan yaitu data sekunder antara lain peta administrasi, peta Rupabumi Indonesia (RBI), peta penggunaan lahan, data curah hujan, *Shuttle Radar Topography Mission* (SRTM), dan peta tanah. Hasil penelitian menunjukkan bahwa daerah resapan air di Kabupaten Kulon Progo dengan kondisi kesesuaian paling mendominasi pada kelas tidak sesuai yaitu seluas 32.804 ha diikuti oleh kelas sesuai seluas 17.124 ha, dan yang paling kecil adalah pada kondisi kelas cukup sesuai yaitu seluas 7.976 ha.

Kata Kunci: ArcGIS, Pembobotan, Infiltrasi

INTRODUCTION

Current regional development prioritizes economic interests and the need for space to support economic interests, namely infrastructure for economic improvement. Environmental values are often disregarded and neglected, causing land conversion to become more prevalent. Spatial planning carried out prioritizes economic development, such as the development of tourist areas. Other areas considered less profitable that include the environmental sector are often neglected, such as water catchment areas that are still often forgotten (Wibowo, 2006). A water catchment area is an area that has a high capacity as a place for rainwater to absorb into the ground, which then, through natural processes, will become groundwater. Water catchment area has essential benefits in maintaining the sustainability of the function of water sources (Awanda et al., 2017)

Parameters of an area to be used as a water catchment area are soil texture, constituent rocks, rainfall, land slope, and land use types with certain characteristics (Perda Kota Manado, 2014; Permen PU, 2013). Groundwater generally comes from rainwater, which depends on local climatic conditions, including the amount and intensity of the rainfall (Zaidi et al., 2015). Many factors influence groundwater movement in an area, including topography, source rock, geological structure, land use, land slope, land shape, drainage patterns, and climate (Yeh et al., 2016; Prasetyo et al., 2016). Until now, there are no standard and definite criteria to determine water catchment areas. The standard criteria for water catchment areas should be set by the central government so that it can be a preference for local governments in zoning areas that have the potential to infiltrate water into the ground. Water catchment areas are needed because, in addition to functioning as an addition to groundwater reserves, they are also used to reduce the potential for flooding (Wibowo, 2006).

The process of water infiltration into the soil consists of two stages, which are infiltration and percolation stages. The infiltration stage is the movement of water from the earth's surface into the soil body, and the placement stage is the movement of water in the soil body (unsaturated zone) from the topsoil layer to the lower soil layer (water-saturated zone) (Sonaje, 2013). The infiltration and percolation processes play an important role in replenishing soil moisture and groundwater. Groundwater infiltration will determine the amount of base flow that is the minimum river discharge in the dry season (Wibowo, 2003).

Presidential Decree No. 32/1990 concerning Protected Area Management stipulates that water infiltration areas are classified as protected areas to protect the area underneath. It is reinforced by the Decree of the State Minister for the Environment No. 39 / MENLH / 8/1996 concerning Business or Activities that Require an AMDAL study, which states that all activities in protected areas, including those in water catchment areas, must be completed with an AMDAL study. It shows that the Decree of the State Minister for the Environment No. 39 / MENLH / 8/1996 classifies water catchment areas as protected areas because they have the same criteria. A protected area is an area or area whose physical condition and characteristics have a protection function for the preservation of natural resources such as water, flora, and fauna. Meanwhile, conservation areas are generally associated with the function of protecting water and soil systems. Therefore, conservation areas are part of the protected areas. The general criteria for protected areas are an altitude of >1,500 m asl, a land slope of <40%, erosion-prone, rainfall of >1,500 mm/year, land use as forest.

The phenomenon of land-use change that occurred in Kulon Progo is the construction of the New Yogyakarta International Airport (NYIA), the expansion of mining areas, and the proliferation of housing developments. As a result, agricultural land changed from 45,324 ha in 2013 to 45,138 ha in 2017. Besides, the population growth from year to year also threatens the existence of clean water, at a time when infrastructure development is also increasingly prevalent. The construction of NYIA and the infrastructure will increase Regional Original Revenue (PAD), resulting in the construction of hotels, companies, and shopping centers that have sprung up after the airport. It appears because the existence of an airport will attract new investors who have an impact on regional development so that it can cause land changes that will impact the state of water catchment areas (Kustiningsih, 2017).

Infrastructure development that is rapidly increasing is likely to have the potential to damage water catchment areas, affecting the quantity and quality of clean water in the area. The decreasing quantity and quality of groundwater will lead to a negative impact on social, economic, and environment. Therefore, the increasing use of groundwater must be balanced with good management planning. Otherwise, it will gradually result in less groundwater, thereby generating a negative impact on all living things.

Based on the description above, it is necessary to identify changes in the potential for water catchment areas in Kulon Progo Regency due to the changes in infrastructure through water catchment area mapping as an effort to provide information on the water catchment areas that must be maintained.

MATERIALS AND METHOD

This research was conducted from January to May 2019 in Kulon Progo Regency. The method used in this research was a survey method. The data used were secondary data, including the data of land-use (from the Central Bureau of Statistics (BPS)), rainfall (from the Meteorology, Climatology and Geophysics Agency (BMKG)), land slope and rock types (from the Regional Development Planning Agency (BAPPEDA) of Kulon Progo Regency), and base maps of topographical maps of Indonesia, land cover maps, and satellite imagery of Kulon Progo area (from websites such as the United States Geological Survey (USGS), Google Earth, and the Geographic Information Agency (BIG)). The data (2012 and 2018) were used to see the changes in water catchment areas due to land conversion. The analysis used was tiered quantitative analysis using GIS software with overlay analysis, which was done by overlaying each parameter and producing weighted parameter criteria (Wibowo, 2006). The parameters included rock type, rainfall, land use, and land slope. The weighting criteria and the weighted parameters are presented in Table 1 and Tables 2-5, respectively.

Table 1. Parameter Weighting

Criteria	Total score	Suitability
Good	>48	Suitable
Normal	44-47	Suitable
Slightly critical	40-43	Quite suitable
Moderately critical	37-39	Quite suitable
Critical	33-36	Not suitable
Extremely critical	<32	Not suitable

Source: Wibowo, 2006

A weighting analysis was performed, which was the sum of the product values and weights of the four parameters, including constituent rocks, land-use, rainfall, and land slope using overlapping techniques (overlay) with the Geographic Information System application (GIS) in ArcGIS 10.3 software. The analysis resulted in the classification of water catchment areas in Kulon Progo Regency. The formula for the total value of the weighting analysis is as follows:

$$\text{Total value} = ((Kb \times Kp) + (Pb \times Pp) + (Sb \times Sp) + (Lb \times Lp)) \quad (1)$$

Remarks:

K = Rock type
P = Rain
S = Land-use
L = Land slope
b = Weight point
p = Score of parameter class

Table 2. Weight of rock type

Rock type	Score	Weight	Category
Alluvial sediments	5	5	Very high
Young quaternary sediments	4	5	High
Old quaternary sediments	3	5	Moderate
Tertiary sediments	2	5	Low
Intrusive rocks	1	5	Very low
Body of water	0	5	-

Source: Wibowo, 2006

Table 3. Weight of rainfall

Spatial classification of infiltration rain	Score	Weight	Category
>5500	5	4	Very high
4500-5500	4	4	High
3500-4500	3	4	Moderate
2500-3500	2	4	Low
<2500	1	4	Very low

Source: Wibowo, 2006

Table 4. Weight of land-use

Classification	Score	Weight	Category
Forest	5	3	Very high
Plantation/Estate	4	3	High
Meadow	3	3	Moderate
Moor	2	3	Low
Rice field	1	3	Very low
Residential area	1	3	Very low
Open field	1	3	Very low
Body of water	0	3	-

Source: Wibowo, 2006

Table 5. Weight of land slope

Slope	Score	Weight	Category
<8%	5	2	Very high
8-15%	4	2	High
15-25%	3	2	Moderate
25-40%	2	2	Low
>40%	1	2	Very low

Source: Wibowo, 2006

RESULTS AND DISCUSSION

A water catchment area is an area that must be available as a place for water to infiltrate as a water source. According to the Regulation of the Minister of Public Works No. 02/2013 concerning Guidelines for Preparation of Water Resources Management Plans, water catchment areas are areas that have particular characteristic parameters (rock types, rainfall, soil texture, land slope, and land-use) of a water catchment. One of the models for classifying the water catchment area parameters can be differentiated using a scoring method based on four parameters, namely rock type, rainfall, land-use, and land slope, with different weight values ranging from good to extremely critical (Table 1). The highest weight for an area to be used as a water catchment area is the rock type, followed by infiltration rainfall, land-use type, and the last is the land slope.

Based on the geological map and the results of the spatial analysis of Kulon Progo Regency, there were four types of rock, including alluvial sediments, tertiary sediments, young quaternary sediments, and intrusive rocks (Figure 1). The map of the constituent rock types is presented in Figure 2. The analysis results of the rock types show that areas in Kulon Progo mostly cannot be used as a water catchment area, indicated by the constituent

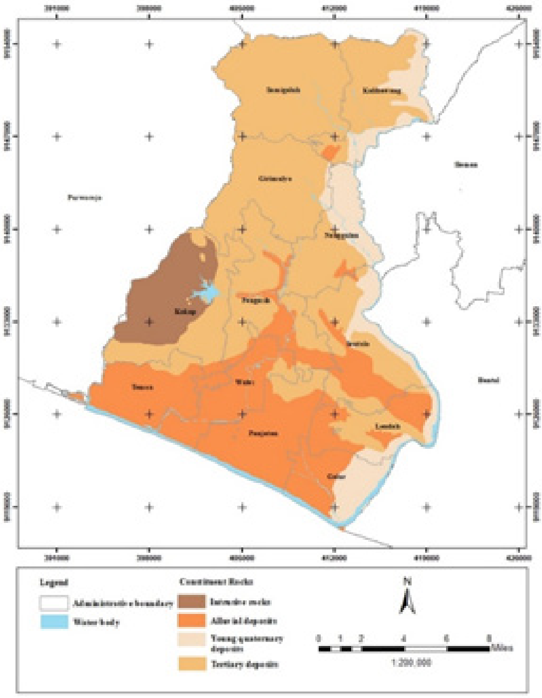

Figure 1. Map of geology in Kulon Progo Regency

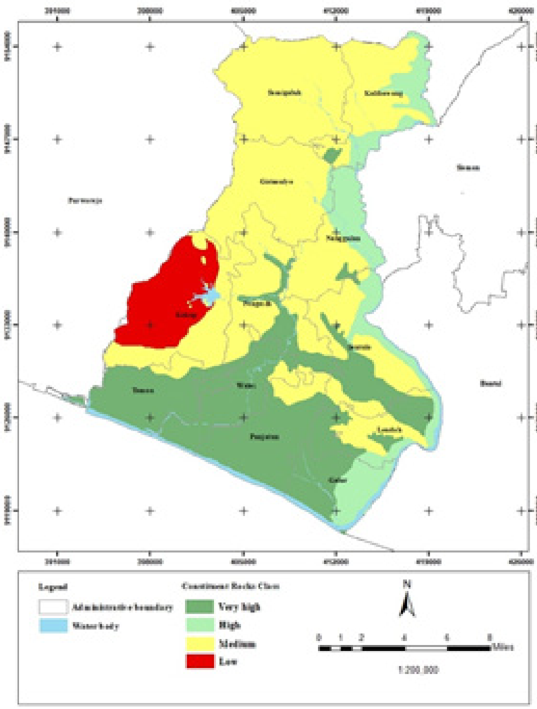

Figure 2. Map of constituent rock classes in Kulon Progo Regency

Table 6. Category of rock type based on the weighting results

Rock type	Score	Weight	Total score	Area (ha)	Percentage (%)	Category
Alluvial sediments	5	5	25	16,889	29.2	Very high
Young quaternary sediments	4	5	20	6,753	11.7	High
Old quaternary sediments	3	5	15	0	0.0	Moderate
Tertiary sediments	2	5	10	29,657	51.2	Low
Intrusive rocks	1	5	5	3,969	6.8	Very low
X3	0	5	0	634	1.1	-
Area of research location (Kulon Progo Regency)				57,904	100	

rocks in the form of tertiary deposits that have a low water absorption capacity (Table 6). These tertiary deposits dominate Kulon Progo area, accounting for 51.2% of the total area. Tertiary sediment, when used as a water catchment area, has a score of 2, indicating a low ability to pass water. An area suitable for a water catchment area is alluvial sediment that has an area of 29.2% with a total score of 25, classified in the very high category (Table 6). Alluvial can easily pass water so that the infiltration process occurs faster, thereby reducing the possibility of surface runoff so that areas with alluvial deposits have a very high potential to pass water. Young quaternary sediments cover 11.7% of the total area. Young quaternary sediments can pass water well, categorized in the high category. The scoring results on rock type parameters, the area that can be used as a water catchment area is 40.8% of the total area. The map of constituent rock classes in Kulon Progo Regency is presented in Figure 2.

The analysis of rainfall was performed using rainfall data taken from the Meteorology, Climatology, and Geophysics Agency (BMKG) for the period of 2012 and 2018. The data were collected from six rain stations located in the Kulon Progo area, which were BPP Kalibawang, BPP Lendah, BPP Singkung / Nanggulan, BPP Kokap, BPP Sentolo, and BPP Temon. The analysis carried out was based on the amount of rain intensity in the area. The greater the rain intensity, the more rainwater can pass into the soil. Rainfall data and rainy days were analyzed using the infiltration rain factor calculated by the following formula:

$$RD = 0{,}01.P.Hh \quad (2)$$

Remarks:

RD = infiltration rain factor

P = annual rainfall

Hh = number of annual rainy days

(Source: Wibowo, 2006)

The results of weighting the rainfall parameters in 2012 and 2018 are presented in Table 7. Based on the weighting results, the amount of rainfall in 2012 was categorized in low (10%) and very low (90%) category. In 2018, the infiltration rainfall in Kulon Progo Regency was moderate (32%) and very low (68%) (Table 7). It is closely related to the amount of water received by the earth, which eventually enters the ground. However, the infiltration that occurs depends on the type of rock, soil type, and vegetation that covers the area. Based on the data obtained, the rainfall in 2012 was lower than in 2018. The change in the rainfall is highly

Table 7. Category of infiltration rain based on the results of the weighting

Classification	Total Score	Land Area (ha)		Category
		2012	2018	
>5500	20	0	0	Very high
4500-5500	16	0	0	High
3500-4500	12	0	18,512	Moderate
2500-3500	8	5,726	0	Low
<2500	4	52,178	39,392	Very low
Area of the location		57,904	57,904	

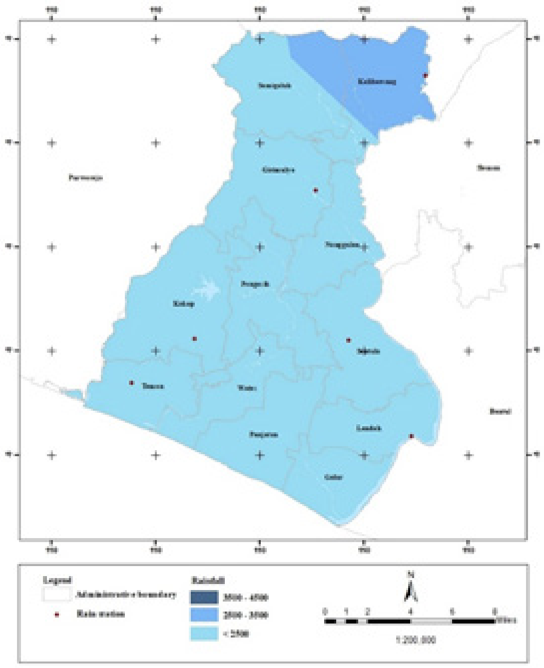

Figure 3. Map of rainfall in 2012 in Kulon Progo Regency

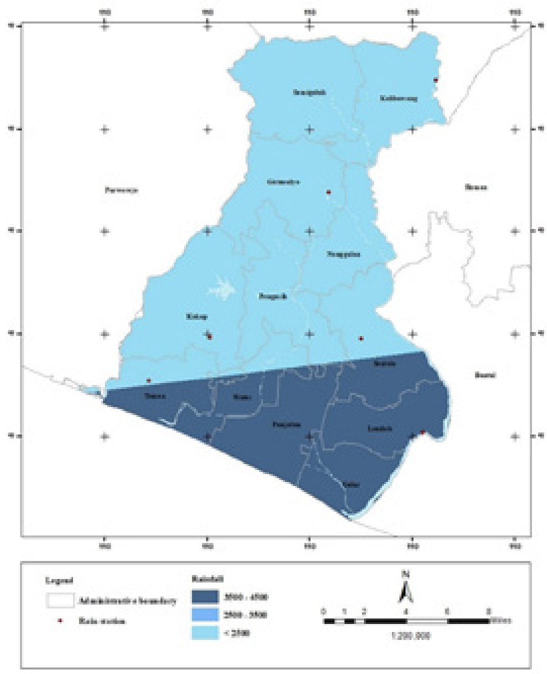

Figure 4. Map of rainfall in 2018 in Kulon Progo Regency

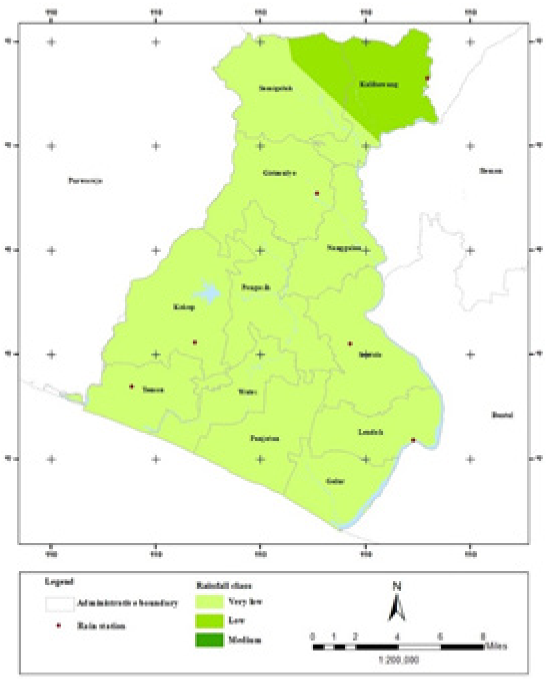

Figure 5. Map of rainfall classes in 2012 in Kulon Progo Regency

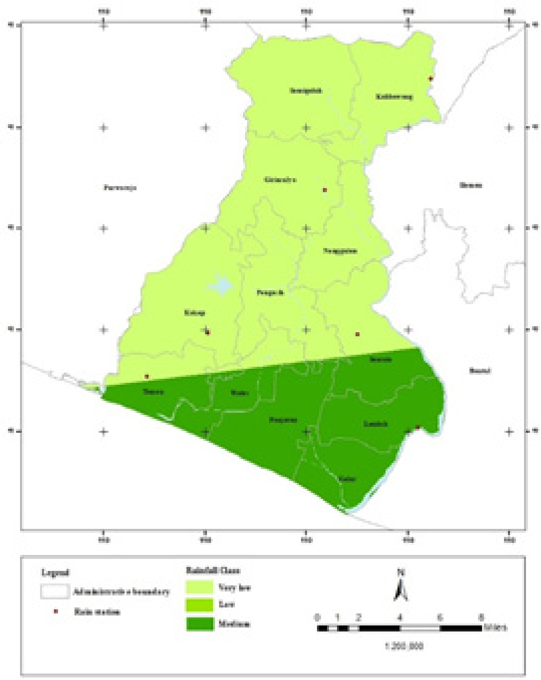

Figure 6. Map of rainfall classes in 2018 in Kulon Progo Regency

dependent on the climatic conditions. The maps of infiltration rainfall and rainfall class in Kulonprogo Regency are presented in Figures 3-4 and 5-6, respectively.

Land-use type is the second parameter that influences water catchment areas. Based on the weighting of land-use, land that has a higher vegetation cover is better to be used as a water catchment area (Table 4). The results of the analysis of satellite imagery showed that in 2012, land-use in Kulon Progo Regency was still dominated by plantations (33%). The total land used for agriculture and open land was 69.7%, while the land used for residential area was 28.34%. In 2018, the land-use in Kulonprogo Regency changed (Table 8). The land-use for agricultural land and open land decreased to 64.21%, while the use of the area for residential area increased to 33.83%.

Table 8. Land-use types in Kulon Progo Regency in 2012 and 2018

Land-use	2012	2018
Forest	751	531
Estate/plantation	19.093	18,191
Meadow	725	549
Moor	9,707	6,320
Rice field	8,924	10,567
Residential area	16,410	19,589
Open field	1,159	1,021
Body of water	1,135	1,135
Total	57,904	57,904

The results of weighting the potential use of land as water catchment areas are presented in Table 9. Based on the land-use types, the land-use type with the highest category as a water catchment area is forest. In 2012, the number of forests in Kulonprogo Regency was remarkably low compared to the area (1.3%). The land that has the highest potential for a water catchment area is plantation (33%/high category). Meanwhile, the lowest potential with a large enough land use area (28.34%) is in the residential area. In 2018, there was a change in land-use so that the potential for water catchment areas in Kulonprogo Regency changed as well. The area that is not potential for a water catchment area is getting larger, used for the residential area (33.83%). Forests and plantations have the highest potential for water catchment areas even though their area changed to 31.42%. Changes in land cover or vegetation cover will affect the changes in soil properties. It is because each type of vegetation has a different root system (Winanti in Utaya, 2008). The ability of the soil to absorb water can be seen from the types of vegetation on the soil surface. Each vegetation has different capabilities and functions in terms of the effectiveness of the soil in absorbing rainwater, maintaining or increasing the infiltration rate, and holding water or water resistance capacity (Setyowati, 2007). Soil physical properties in dense vegetation types tend to be better at absorbing water compared to the land that has sparse vegetation. Vegetation type will affect the type, composition, and density of vegetation due to its effect on the content of organic matter, the amount and thickness of litter, and soil biota that supports and determines the size and extent of the infiltration process (Lee, 1990; Setyowati, 2007). The difference in infiltration capacity is scientifically correct because the effect of vegetation on infiltration depends on different root systems (Winanti, 1996). The decrease in forest area can be due to a change in land functions, as well as several natural and non-natural factors. According to Purwantara (2015), the natural factors decreasing forest area are natural disasters such as forest fires, volcanic eruptions, storms, and flash floods. Kulon Progo Regency itself is part of the natural disaster-prone route because of the position of Kulon Progo Regency, which is partly a plateau with a land slope of more than 25%, namely the Districts of Samigaluh, Kalibawang, Girimulyo, and Kokap, making the area prone to landslides. Meanwhile, the non-natural factors decreasing the land area include illegal logging and shifting cultivation, as well as the increase in the tourism area in Kulon Progo. The results of land-use mapping in Kulon-

Table 9. Category of the land-use based on the weighting results

Classification	Total Score	Land Area (ha)		Category
		2012	2018	
Forest	15	751	531	Very high
Estate/plantation	12	19,093	18,191	High
Meadow	9	725	549	Moderate
Moor	6	9,707	6,320	Low
Rice field	3	8,924	10,567	Very low
Residential area	3	16,410	19,589	Very low
Open field	3	1,159	1,021	Very low
Body of water	0	1,135	1,135	-
Area of the location		57,904	57,904	

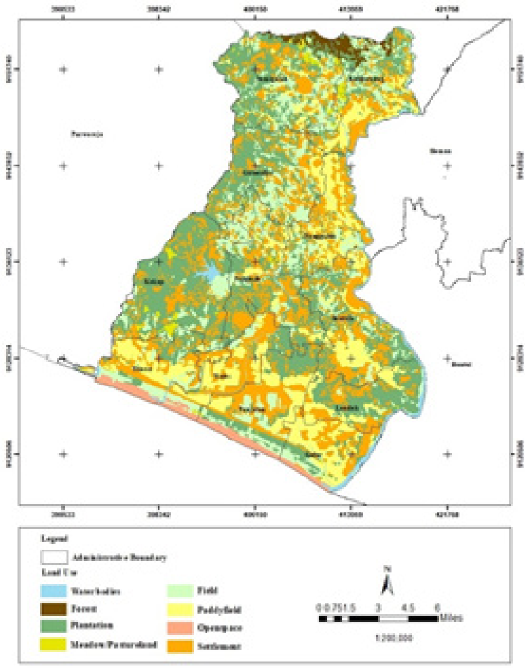

Figure 7. Map of the land-use in 2012 in Kulon Progo Regency

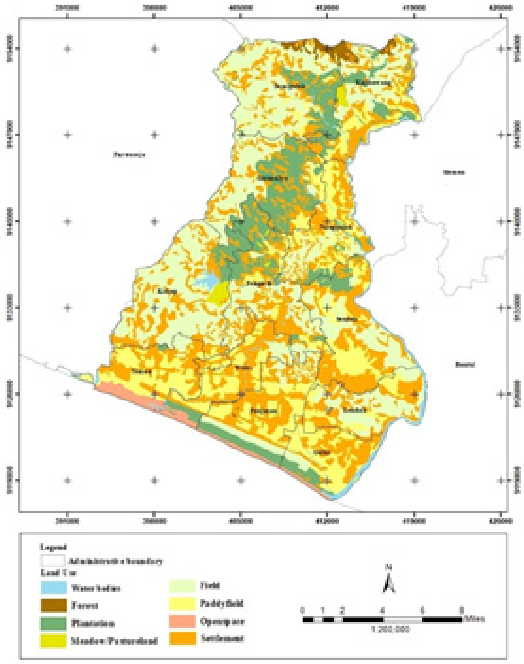

Figure 8. Map of the land-use in 2018 in Kulon Progo Regency

progo Regency are presented in Figures 7 and 8, and the weighted mapping results of land-use are presented in Figures 9 and 10.

Land slope is a determining factor for the third water catchment area with a weight of 2. The slope classes are divided into five classes, namely <8%, 8-15%, 15-25%, 25-40%, and> 40%. Based on the results of the spatial analysis of land slopes in Kulon Progo Regency, it is dominated by land slope class <8% with an area of 31,406 ha (54.2%), followed by land slope class 15-25% with an area of 10,744 ha (18.6%) of the total area (Table 10).

Land slope affects the water catchment area because the greater the land slope, the greater the speed of water flowing on the surface if there are no obstacles. It is because there is a gravitational force that causes water to flow vertically into the soil through the soil profile more quickly. The slope gradient also affects erosion via runoff events. Thus, the steeper the slope, the greater the rate and amount of surface runoff, causing tremendous erosion (Ernawati et al., 2018; Arsyad, 2000). The map of land slope and land slope classes in Kulon Progo Regency are presented in Figures 11and 12, respectively.

Land slope and erosion processes are related to each other concerning the length and steepness of a slope. Land with a steep slope between 30-45% will have a more significant effect on gravity than land with a slightly steep slope, which is between 15-30%. The greater gravity is in line with the inclination of the soil surface from the horizontal plane. This gravity is an absolute requirement for the process of detachment, transportation, and sedimentation (Wiradisastra, 1999). Water infiltration and various types of land slopes as a negative correlation, meaning that water infiltration will increase with the smaller land slope. On the contrary, the infiltration will decrease if the land slope is higher (Arfan and Pratama, 2014).

According to the calculation of the criteria for water catchment areas, there are six criteria for water catchment areas in Kulon Progo Regency,

Table 10. Category of land slope based on the weighting results

Slope	Area (ha)	Category
<8%	31,406	Very high
8-15%	2,998	High
15-25%	10,744	Moderate
25-40%	7,460	Low
>40%	5,293	Very low
Location area	57,904	

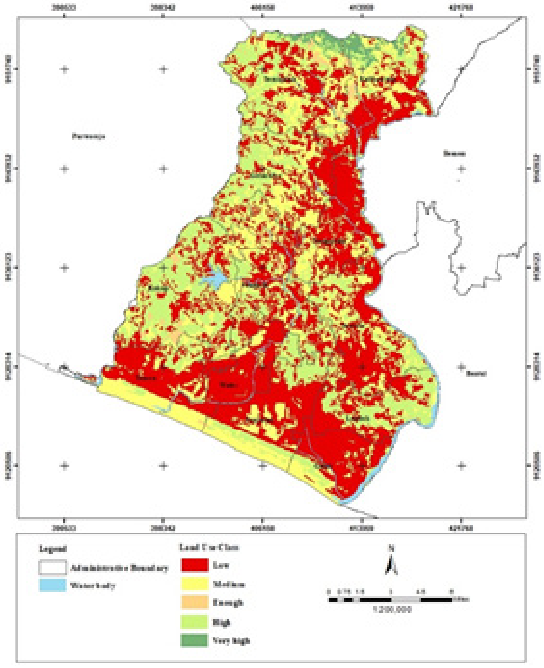

Figure 9. Map of the land-use classes in 2012 in Kulon Progo Regency

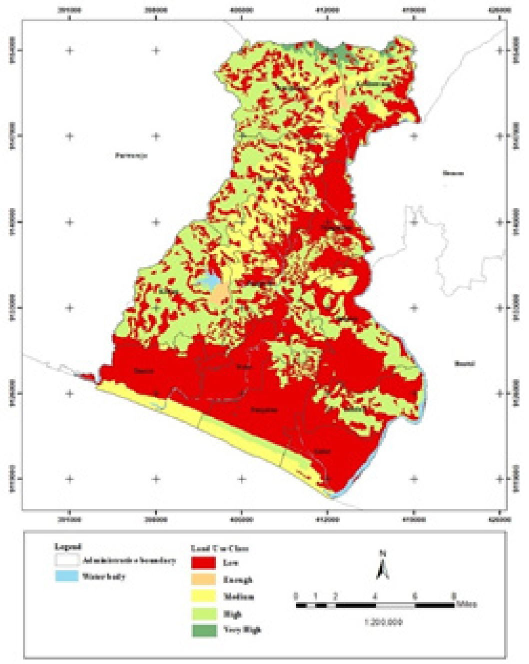

Figure 10. Map of the land-use classes in 2018 in Kulon Progo Regency

namely good, normal, slightly critical, moderately critical, critical, and extremely critical (Table 11). Most areas of Kulon Progo Regency have criteria for water catchment areas ranging from critical to extremely critical, covering 70.43% of the total area. Meanwhile, the area considered normal and good is 29.57% of the total area. Based on the suitability of water catchment areas (Table 12), most areas of Kulon Progo Regency are not suitable for water catchment areas.

Table 11. Criteria for water catchment area

Criteria	Total Score	Area (ha)
Good	>48	12,513
Normal	44-47	4,611
Slightly critical	40-43	4,571
Moderately critical	37-39	3,405
Critical	33-36	5,322
Extremely critical	<32	27,482
Total		57,904

Table 12. Suitability of water catchment area

Suitability	Score	Area (ha)	Percentage (%)
Suitable	44 - >48	17,124	32
Quite suitable	37-43	7,976	13
Not suitable	36 - <32	32,804	55
Total		57,904	100

Based on the results of the analysis of the four parameters, namely rock type, rainfall, land-use, and land slope, the land used must be following the requirements of the water catchment area made by the government, namely a protected area with the conditions of land slope height <40%, rainfall > 1,500 mm / year, and land-use as a rain catchment area. The parameter that has the most significant effect on the water catchment area is the rock type. Rock type significantly affects water resources in terms of water sources, water resources, and water availability. Areas with alluvial rock types tend to be better at absorbing water due to the age of these rocks that are considered the youngest than other rock types. Besides, the type of coarse soil texture and the high organic matter content of the alluvial sediments causes the infiltration process to run optimally. Mother rock can affect soil type due to weathering effects. The older the rock, the greater the clay component. Clay can bind water well, but it is difficult to release it so that the quantity of water infiltration is small.

Infiltration rainfall is also related to water catchment areas. Rainwater is the main source

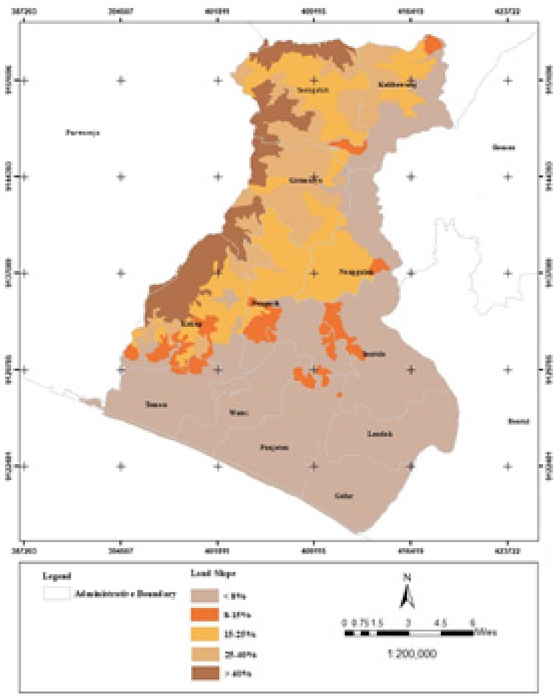

Figure 11. Map of land slope in Kulon Progo Regency

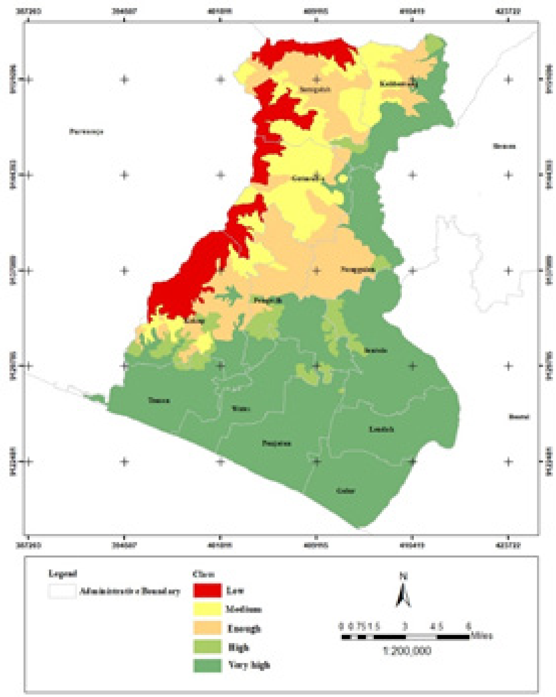

Figure 12. Map of land slope classes in Kulon Progo Regency

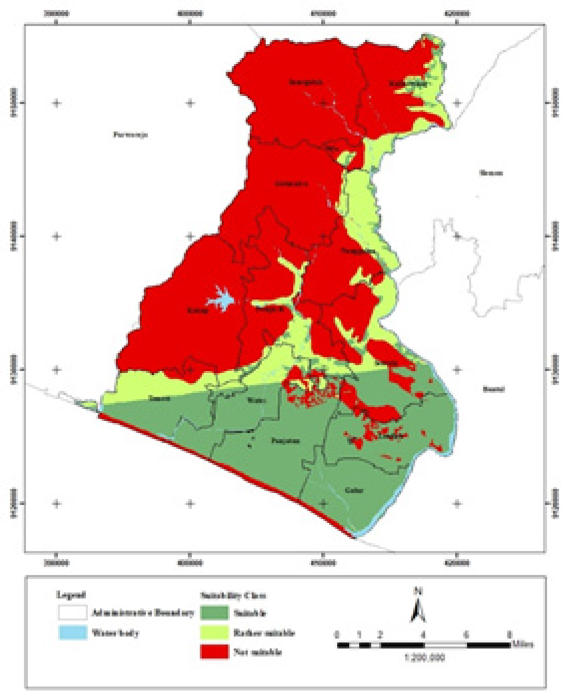

Figure 13. Map of water catchment area criteria in Kulon Progo Regency

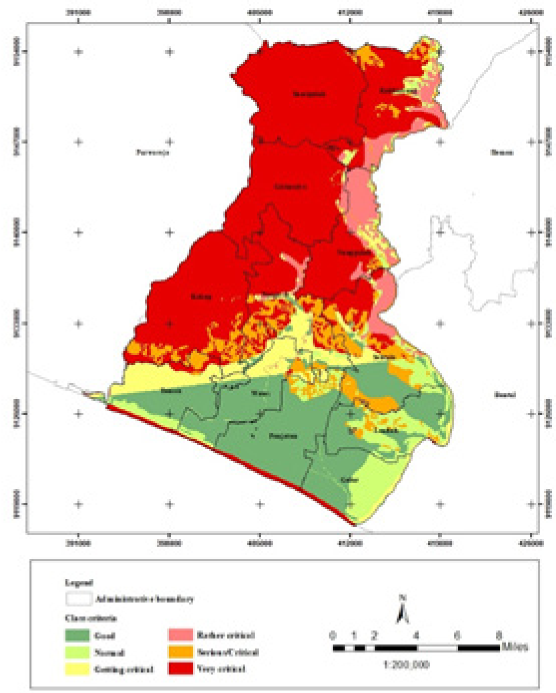

Figure 14. Map of the suitability classes of water catchment area in Kulon Progo Regency

of groundwater. The areas that have low rainfall, below <1,500 mm or with an infiltration rainfall value of less than <3,500 mm / year, cannot be used as water catchment areas.

Land-use type or vegetation type in an area is very influential in the infiltration process. The better the land cover, the better the water infiltration. According to Winanti in Utaya (2008), changes in land cover or vegetation cover will affect changes in soil properties. This is because each type of vegetation has a root system that is different from one another. The ability of the soil to absorb water is shown by the types of vegetation on the soil surface. Each vegetation type has different capabilities and functions in terms of the effectiveness of the soil in absorbing rainwater, maintaining or increasing the infiltration rate, and holding water (water resistance capacity).

The higher the degree of a land slope, the smaller the amount of water that absorbs due to the gravitational force that causes water to flow vertically into the soil through the soil profile more quickly. The slope gradient will also affect erosion through the runoff event. The steeper the slope, the greater the rate and the amount of surface runoff, which causes tremendous erosion (Arsyad, 2000). Thus, the four parameters are related to one another. If there is one parameter that is not suitable, the area can still be used as a catchment area with prior conservation (Figures 13 and 14).

CONCLUSION

The map of the water catchment area of Kulon Progo Regency is dominated by the unsuitable class, covering an area of 32,804 ha (55%), scattered in Samigaluh, Kalibawang, Girimulyo, Nanggulan, Pengasih, and Kokap. The slightly suitable class is 17,124 ha (32%), spread across the Districts of Kokap, Pengasih, Sentolo, Nanggulan, Lendah, Panjatan, and Kalibawang. Meanwhile, the class of moderately suitable covers an area of 7,976 ha (13%), spread across Temon, Wates, Panjatan, Sentolo, Lendah, and Galur.

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Effects of Trenches with Organic Matter and KCL Fertilizer on Growth and Yield of Upland Rice in Eucalyptus Agroforestry System

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ABSTRACT

Rice production can be improved through extensification using sub-optimal lands. One type of land that can be used for extensification of rice production in D.I. Yogyakarta is eucalyptus agroforestry system in Playen, Gunung Kidul. Besides expanding the land use, it can also increase farmers' income and ecological functions. However, this system has limiting factors such as the limited availability of water, which only relies on rain. Thus, proper water management and fertilization are necessary to fulfill water and nutrient requirements for rice growth. This study aimed to determine the effects of the application of trenches with organic matter and the doses of KCl on the growth and yield of upland rice (Situ Patenggang) in eucalyptus agroforestry systems. The study was conducted at the Menggoran Forest Management Resort, Bleberan, Playen, Gunung Kidul in March-August 2018. The study was arranged in a split plot design with three blocks as replications. The first factor was the application of trenches with organic matter, while the second factor was KCl fertilizer at. various doses. The data obtained were analyzed using analysis of variance (ANOVA) at the level of 5%. The optimal dose of KCl fertilizer was determined by regression. The results showed that both factors had a positive effect on soil moisture content, growth, physiology, and yields of upland rice. The treatments significantly increased the availability of water in the soil, thereby supporting the growth and yield of upland rice.

Keywords: Agroforestry, Eucalyptus, KCl, Situ Patenggang, Organic Trenches

ABSTRAK

Produksi padi dapat diupayakan melalui ekstensifikasi, yaitu dengan penggunaan lahan-lahan yang belum dimanfaatkan. Salah satu lahan yang dapat digunakan untuk ekstensifikasi padi di D.I.Yogyakarta adalah lahan kayu putih di Playen (sistem agroforestri). Selain untuk meningkatkan penggunaan lahan, dapat juga meningkatkan pendapatan petani dan fungsi ekologis. Namun, sistem ini memiliki faktor pembatas yaitu ketersediaan air yang hanya mengandalkan air hujan sehingga perlu pengelolaan air dan pemupukan yang tepat untuk memenuhi kebutuhan air dan unsur hara untuk mendukung pertumbuhannya. Penelitian bertujuan mengetahui pengaruh penggunaan parit berbahan organik dan takaran KCl terhadap pertumbuhan dan hasil padi gogo (Situ Patenggang) pada sistem agroforestri kayu putih. Penelitian dilaksanakan di Resort Pengelolaan Hutan Menggoran, Bleberan, Playen, Gunung Kidul pada bulan Maret-Agustus 2018. Penelitian disusun berdasarkan rancangan split plot dengan 3 blok sebagai ulangan. Faktor pertama adalah penggunaan parit berbahan organik, sedangkan takaran KCl sebagai faktor kedua. Data yang diperoleh dianalisis dengan menggunakan analisis varian (Anova) dan regresi untuk memperoleh kombinasi perlakuan terbaik. Hasil menunjukkan kedua perlakuan berpengaruh positif terhadap kadar lengas, pertumbuhan, fisiologis, dan hasil padi gogo dibandingkan tanpa perlakuan. Hal ini disebabkan karena ketersediaan air menjadi lebih terpenuhi, sehingga mendukung pertumbuhan dan hasil yang optimal.

Kata Kunci: Parit Organik, KCl, Situ Patenggang, Agroforestri, Kayu Putih

INTRODUCTION

National rice consumption increased by an average increase of 0.5% / year, namely 98.11 kg / capita / year in 2015, 98.39 kg / capita / year in 2016, and 98.61 kg / capita / year in 2017 (Indonesian Ministry of Agriculture, 2017). To meet these needs, it is necessary to increase rice production through intensification and extensification. Due to land conversion from agriculture to non-agriculture, extensification is more directed to sub-optimal lands, such as peat land, coastal sandy land, dry land, acid land, and swamp land. One of the usable lands that can be used for extensification of rice in D.I. Yogyakarta is eucalyptus forest land in Playen, Gunung Kidul. The crop cultivation by combining rice with eucalyptus is called the eucalyptus-rice agroforestry system.

This system can increase profits, both economically and ecologically. In this system, food crops are planted between forest plants, thereby increasing the income of farmers from both forest plants and food crops. This is consistent with research by Puspasari et al. (2017), stating that independent forest activities (without food crops) provide lower income compared to when combined with food crops due to the higher number of plants per land area. Agroforestry can also diversify the range of outputs to increase self-sufficiency. Diversification can reduce the loss of income that may occur, especially due to bad weather or the influence of biological factors and market factors. Apart from its economic function as one of the main objectives, agroforestry also plays a role in maintaining hydrological functions through the process of interception of rainwater, reducing the power of rainwater, water infiltration, water absorption and landscape drainage. In the field of conservation, agroforestry plays a role in the preservation of plant genetic resources, animal habitats, soil and water conservation and maintaining the balance of biodiversity (Widianto, 2013).

The obstacle of rice planting on agroforestry systems is the limited availability of water, which only relies on rainfall, causing rice cultivation to be quite risky. Rice plants are very sensitive to drought stress, hence it is necessary to apply proper water management by making trenches containing organic matter to increase rainwater infiltration. Trench with organic matter is a rainwater harvesting technology that is designed to increase the entry of water into the soil through the infiltration and filling of water bags in the basin and to reduce water loss through evapotranspiration (Subagyono et al., 2017). Rainwater harvesting is an act of collecting rainwater to be channeled into temporary shelters, which at any time can be used to irrigate cultivated plants. Therefore, with this method, the water needs during the dry season in dry areas can be fulfilled from the harvested rainwater. The level of soil moisture in the presence of rainwater harvesting system will increase by about 5% at a depth of 0-30 cm (Rusli and Heryana, 2015).

The trenches used for water harvesting are also given organic matter because this organic matter provides a lot of benefits, including to reduce evaporation from harvested water. Based on Dien et al. (2017), organic matter provided in the soil will experience a process of weathering and remodeling, which in turn will produce humus. Humus with Hydrophilic colloid layer can agglomerate and become gel, therefore the topsoil is important in the crumbly soil. Humus is so important that the soil will not dry quickly during dry season because it has high water holding capacity. Humus can hold water four to six times its own weight. By holding water, humus can reduce evaporation through soil. Organic matter helps bind the clay grains to form bigger grain bonds, thereby enlarging the water spaces between the grain bonds (Fayyaz et al., 2013). Therefore, the higher organic matter content will result in the higher moisture content in the soil. Organic matter in the soil can absorb water 2-4 times of its weight, playing a role in water transport. The advantages of adding organic fertilizers to the soil are not only in their nutrient element contents but also in their other roles, including improving the structure, , aeration, and water holding capacity of the soil, as well as affecting soil temperature and providing the improved substances for plant growth (Zain et al., 2014).

The organic matter used was corn waste that was the residue from the previous Besides, corn waste can also be used as organic matter for farming system. The parts of corn plant used as organic matter are the leaves, stems, and cobs, which are usually thrown away or resolved at the planting location even though those organic matters contain

Table 1. Gap analysis of upland rice cv. Situ Patenggeng

Area	Actual Result	Potential Result	Difference	Action Plan
Eucalyptus Agroforestry System, Playen, Gunung Kidul	The actual yield of upland rice in eucalyptus agroforestry system is 0.5 – 3.068 ton.ha^{-1}	The potential yield of upland rice in eucalyptus agroforestry system is 2.08 – 4 ton.ha^{-1}	The difference between actual and potential results is 1.58 - 0.932 ton.ha^{-1}	0, 100, and 200 kg.ha^{-1} KCl fertilizerWithout trench and trench with organic matter

important nutrients such as nitrogen, phosphorus, and potassium. Corn organic matter is the building block for granulation in the soil and is very important in tye soil aggregates (Ernita et al., 2017).

According to Table 1, the upland rice cv. Situpatenggang used in this research located in Eucalyptus Agroforestry System, Playen, Gunung Kidul has an actual yield of 0.5 - 3.068 ton.ha^{-1}(Tarigan et al., 2013). Meanwhile, according to the Ministry of Agriculture (2013), the potential yield of the upland rice in eucalyptus agroforestry system is 2.08 - 4 ton.ha^{-1}. Thus, the gap between actual and potential yield is 1.58-0.932 ton.ha^{-1}. In this study, there were two factors to be tested, consisting of KCL fertilizer (at a doses of 0, 100, and 200 kg.ha^{-1}) and the application of trenches (without trench and trench with organic matter)

Potassium affects water content in plants, photosynthesis, and photosynthate translocation. Therefore, K fertilization can increase yield, especially when the moisture content of the soil is low. The role of K is related to the regulation of water status in plant tissue, stomatal regulation and assimilates transport (Wahyuti, 2011). The dose of KCl fertilizer is based on K status in the soil. In soil with a low, moderate, and high K level, the required dose of KCl fertilizer is 100 kg.ha^{-1}, while in the soil with moderate and high K level, the recommended KCl fertilizer is 50 kg.ha^{-1} (Asmin and La, 2014). In upland farming, optimal KCl fertilization is given gradually because when entering the generative phase, K fertilization encourages grain filling (Kartikawati and Nursyamsi, 2013). Accordingly, the application of KCl fertilizer and rainwater harvesting technology (using trenches with organic matter) is expected to fulfill the water needs of plants. Potassium increases the plant's drought resistance through its functions in stomatal regulation, osmoregulation, energy status, charge balance, protein synthesis, and homeostasis. Based on Zain et al. (204), in plants coping with drought stress, the accumulation of K^+ may be more important than the production of organic solutes during the initial adjustment phase, because osmotic adjustment through ion uptake like K^+ is more energy efficient. The lower water loss in plants well supplied with K^+ is due to a reduction in transpiration, which depends not only on the osmotic potential of mesophyll cells, but is also largely controlled by the opening and closing of stomata.

This study aimed to determine the effects of trenches with organic matter and KCl fertilizer doses, as well as to find out the highest yield of upland rice as affected by the interaction of trenches with organic matter and KCl fertilizer. This research is expected provide solution to overcome the drought that usually occurs in the research location. Thus, the decrease in the rice production during the dry season can be minimized. In addition, this research is expected to suggest the best combination of treatments for maximum yields, resulting minimum input (litter, ditch, and fertilizer) used in producing maximum yields.

MATERIALS AND METHODS

This study was conducted in March – August 2018 in plot 83 of RPH Menggoran, BDH Playen of KPH Yogyakarta and Laboratories in Faculty of Agriculture, Universitas Gajah Mada. Gunungkidul Regency is dominated by mountains the western

Table 2. Environmental conditions of the research location

Month	Rainfall (mm)	Humidity (%)	Average Temperature (°C)	Wind Velocity ($m.s^{-1}$)
March	407	83	26.4	3
April	138	82	27.0	2
May	21	79	26.5	2
June	-	80	25.7	3
July	-	81	26.2	2
August	-	81	27.2	3
Average	94,.3	81	26.5	2.5

part of the Pegunungan Seribu or the Pegunungan Kapur Selatan that stretches from the south of Java Island to the east to Tulungagung Regency. Gunungkidul are formed from limestone. Most of the areas in Gunungkidul Regency are highlands with land conditions that have different slopes. Based on the research results, the following is data on climatic conditions in the studied area.

The research location had relatively low rainfall during the research period, reaching an average of 94.33 mm, while the water requirement for the rice plants was 110-115 mm. Therefore, it is necessary to have a report on the need for adequate plant water. The average humidity at the research location was 81% (humid), with an average temperature of 26.5 0C and an average wind speed of 2.5 $m.s^{-1}$ (Table 2).

The materials used were upland rice seeds cv. Situ Patenggang, KCl fertilizer, pesticides, and observation materials. The tools used were cultivation tools and data collection. According to Mawardi et al. (2016), Situ Patenggang cultivar is a variety that is resistant to dry conditions. The yield potential of Situ Patenggang cultivar is 6 $ton.ha^{-1}$ and 4.5 $ton.ha^{-1}$, in paddy fields and upland, repectively. In several studies, the yield of Situ Patenggang cultivar in upland was between 2.08 - 4 $ton.ha^{-1}$. KCl fertilizer at three different doses, namely 0 $kg.ha^{-1}$ (without KCl), 100 $kg.ha^{-1}$, and 200 $kg.ha^{-1}$, was applied three times, which were before planting, 3 weeks after planting, and at the beginning of the generative phase. Pesticides were applied when pests and diseases were considered harmful. The doses of organic matter were based on the size of the trench (2 kg of corn waste in each trench). Anthracol was used to treat grasshoppers and leafhoppers. This study was arranged in a split plot design with three blocks as replications, in which the main plot (vertical plot) was the application of trenches with organic matter, and the sub plot (horizontal plot) was the dose of KCl fertilization. The organic matter used was crop waste, which was the residue from the previous corn planting that was already chopped into small pieces and put into the trenches.

The data collected included soil moisture content, growth component (leaf area, root dry weight, root length, root area, and shoot dry weight), physiology (chlorophyll, photosynthetic rate, and proline content), and yield components (filled grain percentage, weight of 1000 seeds, and productivity). Plant growth data were obtained by observing and measuring the variables every two weeks, physiological data were recorded at the beginning of the generative phase, while the yield data were obtained at harvest. The data were analyzed using analysis of variance (ANOVA) at the level of 5%, and regression analysis was made to determine the optimal dose of KCl fertilizer. The data showing significant differences according to the analysis of variance were further tested using Tukey HSD test.

RESULTS AND DISCUSSIONS

The soil order in the research location is Vertisol. The typical characteristics of Vertisol include the fractures that are periodically open and closed, micro-reliefs and slickenside at a depth of 40 cm, clay content of 30% or more on the entire horizon which lies between a depth of 50 cm, and a Lithic contact (Soil Survey Staff, 2014).

Table 3. Soil analysis of the research location

Analysis	Value	Category
Soil texture		**Vertisol Lithic Haplustert**
Soil physical properties		
a. Soil texture		
Sand (%)	14.56	
Dust (%)	11.97	Clay
Clay	73.47	
Soil chemicalk properties		
Organic Matter (%)	2.19	Low
C/N ratio (%)	11.55	Moderate
Level of K availability (%)	16.71	Low

Based on the observations of the soil physical properties in the field and in the laboratory (Table 3), the soil has a clay texture with a ratio of 14.56% sand fraction, 11.97% silt and 73.47% clay. The soil classified in clay texture has the ability to absorb and store more water than other texture groups. Clay is the smallest size soil particle. Clay has the ability to hold both nutrients and water that can be used by plants. It creates very small pore spaces, resulting in poor aeration and poor water drainage. Clay forms hard clumps when dry, and it is sticky when wet (Dotto et al., 2016). The content of organic matter (2.19%) was classified as low due to the absence of land cover vegetation. The lack of addition of organic matter from vegetation litter caused a low organic matter content. Proportion of carbon and nitrogen content in the soil can be known through the C/N ratio, which in this study, the C/N ratio of the soil was in moderate conditions (11.55%). The availability of K was relatively low (16.71%). K is absorbed by plants from the soil in the form of K^+ ions. The low content of low-potassium is thought to be due to the influence of calcium (Ca2+) content, which has a main material in the form of limestone. The calcareous nature of limestone in vertisol, which is dominated by smectite minerals, greatly influences the availability of soil nutrients, especially potassium and phosphorus (Virmani et al., 2002).

Planting upland rice in eucalyptus forests is classified as a simple agroforestry system, namely an agricultural system in which trees are intercropped with one or more types of annual crops. The benefit of agriculture (upland rice) towards forestry (eucalyptus) is to know the right planting system, so that it can produce more products, reduce land erosion, and increase product diversity. On the other hand, the presence of eucalyptus provides benefits to rice

Table 4. Dry weight of leaf and branch of eucalyptus (kg)

Treatment	Leaf Dry Weight (kg)	Branch Dry Weight (kg)
Trench		
Without trench	0.99 a	1.58 a
Trench with organic matter	0.90 a	1.60 a
Dose of KCl (kg.ha^{-1})		
0 kg.ha^{-1}	0.85 p	1.42 p
100 kg.ha^{-1}	0.93 p	1.57 p
200 kg.ha^{-1}	1.07 p	1.74 p
Trench*Dose of KCl	(-)	(-)

Notes: Values followed by the same letters in the same column and the same treatment are not significantly different based on Tukey at 5%. The sign (-) shows no interaction between the factors tested.

Table 5. Soil moisture content at 12 weeks after planting (%)

Treatment	Dose of KCl			Mean
	0 kg.ha^{-1}	100 kg.ha^{-1}	200 kg.ha^{-1}	
Without trench	40.80 c	41.58 b	42.02 b	41.47
Trench with organic matter	41.60 b	42.15 b	43.61 a	42.45
Mean	41.2	41.87	42.82	(+)

Notes: Values followed by the same letters in the same column and the same treatment are not significantly different based on Tukey at 5%. The (+) sign shows an interaction between the factors tested.

Table 6. Leaf area of upland rice at 12 weeks after planting (cm^2)

Treatment	Dose of KCl			Mean
	0 kg.ha^{-1}	100 kg.ha^{-1}	200 kg.ha^{-1}	
Without trench	1115.33 c	1438.28 c	1854.26 b	1469.29
Trench with organic matter	1299.67 c	2209.48 a	2512.06 a	2007.07
Mean	1207.5	1823.88	2183.16	(+)

Notes: Values followed by the same letters in the same column and the same treatment are not significantly different based on Tukey at 5%. The (+) sign shows an interaction between the factors tested.

plants because it can protect plants from extreme winds and temperatures, reduce pests, maintain moisture, and increase soil moisture content (Nuberk, 2008). In addition, the existence of this system can also make natural preservation more secure and neat (Saikia et al., 2017).

There was no significant effect of all treatments on the dry weight of eucalyptus leaves and branches (Table 4). The application of trenches with organic matter and KCl fertilizer doses did not give a significant effect because the trenches and cultivation plants were located too far from eucalyptus plants, so that they did not give any influence on the dry weight of the eucalyptus leaves and canopy.

The treatment combination of trenches with organic matter and KCl at a dose of 200 kg.ha^{-1} resulted in the highest soil moisture content of 14% , in which the moisture content of the soil ranged from 41-42 % (Table 5). This result is due to the function of the trenches to hold water. Besides, organic matter in the trenches serves to reduce evaporation of the stored water. Thus, the application of trenches with organic matter could increase the moisture content of the soil.

The treatment combination of trenches with organic matter and KCl at the highest dose resulted in the highest leaf area at 12 weeks after planting (Table 6). The wider the leaf, the more sunlight is captured to be used in photosynthesis. In addition, it can increase the number of stomata in the leaves (Idris et al., 2017). Meanwhile, treatment without trenches and without KCl fertilization resulted in the lowest leaf area compared to other treatments. Leaf area and productivity rate per unit leaf area will affect the ability of leaves to produce photosynthate products. Thus, the wider the leaf, the greater the photosynthate products (Haryanti, 2014).

The treatment combination of trenches with organic matter and KCl at a dose of 200 kg.ha^{-1} resulted in the highest dry weight of branches and root compared to other treatments at 12 weeks after planting (Table 7), but not significantly different those resulted by the treatment combination of trenches with organic matter and KCl at a dose of 100 kg.ha^{-1}. The optimum availability of nitrogen, phosphorus, potassium, and magnesium for plants can increase chlorophyll content, thereby increasing photosynthetic activity to produce more assimilates, which support the dry weight of the plant (Sitorus et al., 2014). Dry weight is the result of photosynthesis in a plant, which mean this treatment combination could optimize photo-

Table 7. Root and branch dry weight of upland rice at 12 weeks after planting (g)

Treatment	Dose of KCl			Mean
	0 kg.ha^{-1}	100 kg.ha^{-1}	200 kg.ha^{-1}	
		----- Branch dry weight (g) -----		
Without trench	41.09 d	43.76 cd	47.32 b	44.06
Trench with organic matter	45.26 bc	53.79 a	55.9 a	51.65
Mean	43.18	48.78	51.61	(+)
		----- Root dry weight (g) -----		
Without trench	20.73 d	22.87 c	25.45 b	23.02
Trench with organic matter	21.96 c	26.70 a	26.59 a	25.08
Mean	21.35	24.79	26.02	(+)

Notes: Values followed by the same letters in the same column and the same treatment are not significantly different based on Tukey at 5%. The (+) sign shows an interaction between the factors tested.

Table 8. Root length (cm) and root area (cm^2) of upland rice at 12 weeks after planting

Treatment	Dose of KCl			Mean
	0 kg.ha^{-1}	100 kg.ha^{-1}	200 kg.ha^{-1}	
		----- Root length (cm) -----		
Without trench	150.46 c	181.20 b	195.58 a	175.74
Trench with organic matter	171.23 b	199.61 a	201.05 a	190.63
Mean	160.83	190.41	353.89	(+)
		----- Root area (cm^2) -----		
Without trench	1140.05 d	1396.75 b	1616.94 a	1384.58
Trench with organic matter	1293.48 c	1678.08 a	1691.33 a	1554.30
Mean	1216.77	1537.42	1654.135	(+)

Notes: Values followed by the same letters in the same column and the same treatment are not significantly different based on Tukey at 5%. The (+) sign shows an interaction between the factors tested.

synthesis and produce sufficient assimilates to be used later in the generative phase. This treatment combination also helped rice plants maximize the panicle formation process in accordance with the role of potassium as an element that plays a role in improving plant generative organs (Hasanuzzaman et al., 2018), thereby increasing the dry weight of the shoots, along with increasing panicle number and length and grain weight. The combination of other treatments that showed good results was the treatment of without trenches combined with KCl at a dose of 200 kg.ha^{-1}. The treatment resulting in the lowest dry weight of the shoot is without trenches and without KCl fertilization.

The treatment combination of trenches with organic matter and KCl at a dose of 200 kg.ha^{-1} resulted the longest root length (201.05 cm) that was significantly different from those resulted by other treatments (Table 8). Meanwhile, the treatment without trenches with organic matter and without KCl fertilization resulted in the shortest roots length (150.46 cm). The longer the root, the farther the reach of the root. Root interception occurs as a result of root growth from short to be long, from not branching to be branched, and from branching a little to be branched a lot. As a result of this growth, the roots formed reached parts of the growing media that was not reachable before. Increasing the range of course increases the elements nutrients and water that can come into contact with the surface of the root hairs and then get it absorbed by plant roots (Febriyono et al., 2017).

Based on Table 9, both factors have no interaction, but they have a positive effect on the chlorophyll content. Treatment without trenches resulted in less water availability, making the plants experience drought stress. Plants that lack water experience a decrease in turgor pressure, causing a decrease in chlorophyll content. Meanwhile, the treatment of KCl fertilization at a dose of 200 kg.ha^{-1} gave a higher chlorophyll content compared to other KCl doses. Potassium has a role in the process of opening and closing of stomata, which is influenced by CO_2 content and the process of photosynthesis. Potassium deficiency results in low chlorophyll content. Decreased chlorophyll content and chlorophyll a / b ratio are indicators of chloroplast disturbance (Astuti et al., 2019). According to the research conducted by Jia et al. (2008), the chlorophyll content of rice plants decreased under moderate potassium deficiency level (5 mg KL^{-1}), while under normal potassium dose (40 mg KL^{-1}), the chlorophyll content was higher.

The application of trenches with organic matter increased the rate of photosynthesis (Table 10). Trenches with organic matter increased the moisture content in the soil, so cells become more turgor. In addition, water functions as one of the raw materials in light reactions in photosynthesis. Water molecules will be broken down by Manganese (Mn), forming H^+ ions in the thylakoid lumen (Baglieri et al., 2014). The lower the availability of water, the lower the photosynthetic rate (Table 10), in which the application of water harvesting system could increase the rate of photosynthesis. The trenches with organic matter increased the

Table 9. Chlorophyll content of upland rice at 12 weeks after planting (mg.g^{-1} plant)

Treatment	Chlorophyll a	Chlorophyll b	Total Chlorophyll
Trench			
Without trench	19.03 b	8.72 b	27.74 b
Trench with organic matter	25.10 a	11.88 a	36.98 a
Dose of KCl (kg.ha^{-1})			
0 kg.ha^{-1}	15.7 b	6.79 c	22.49 b
100 kg.ha^{-1}	24.17 a	11.36 b	35.53 a
200 kg.ha^{-1}	26.31 a	12.75 a	39.06 a
Trench*Dose of KCl	(-)	(-)	(-)

Notes: Values followed by the same letters in the same column and the same treatment are not significantly different based on Tukey at 5%. The sign (-) shows no interaction between the factors tested.

Table 10. Photosynthetic rate and proline content of upland rice

Treatment	Dose of KCl			Mean
	0 kg.ha^{-1}	100 kg.ha^{-1}	200 kg.ha^{-1}	
----- Rate photosynthesis (μmol CO_2.cm^2.s^{-1}) -----				
Without trench	89.79 d	124.70 c	154.25 b	122.91
Trench with organic matter	111.62 c	175.02 a	180.76 a	155.8
Mean	100.71	149.86	167.51	(+)
----- Proline content (μmol .g^{-1}) -----				
Without trench	14.89 d	6.64 cd	4.22 c	8.58
Trench with organic matter	11.2 d	3.76 b	3.31 a	6.09
Mean	13.05	5.2	3.77	(+)

Notes: Values followed by the same letters in the same column and the same treatment are not significantly different based on Tukey at 5%. The (+) sign shows an interaction between the factors tested.

Table 11. Percentage of grain content (%) and weight of 1000 seeds (g)

Treatment	Dose of KCl			Mean
	0 kg.ha^{-1}	100 kg.ha^{-1}	200 kg.ha^{-1}	
		----- Percentage of grain content (%) -----		
Without trench	79.81 c	82.27 c	85.52 b	82.53
Trench with organic matter	81.25 c	88.7 a	91.57 a	87.17
Mean	80.53	85.49	88.55	(+)
		----- Weight of 1000 seeds (g) ------		
Without trench	7.20 d	10.03 c	13.81 b	10.35
Trench with organic matter	8.78 c	15.25 a	15.52 a	13.18
Mean	7.99	12.64	14.67	(+)

Notes: Values followed by the same letters in the same column and the same treatment are not significantly different based on Tukey at 5%. The (+) sign shows an interaction between the factors tested.

moisture content in the soil, making them better. Thus, it causes the treatment without trenches to show a lower photosynthetic rate compared to the application of trenches with organic matter.

The lower rate of photosynthesis will inhibit the plant growth, resulting in the stunted plants, thereby decreasing the yield. The wider the leaves, the greater the yield. Leaf is the main photosynthetic organ in plants, in which the main plant metabolic processes occur, such as photosynthesis, transpiration, and CO_2 / O_2 gas exchange. Sufficient plant needs for growth elements will stimulate plant height increase and new leaf formation. the longer and wider the leaf, the more the light absorption by the leaf, thus increasing the rate of photosynthesis. The increased rate of photosynthesis will encourage the growth and development of leaves so that the yield increases (Nurnasari and Djumali, 2010).

The treatment combination of trenches with organic matter and KCl at the highest dose (200 kg.ha^{-1}) resulted in the lowest proline content (3.31 µmol g^{-1}). Meanwhile, the treatment without trenches and without KCl fertilization showed the highest proline content (14.89 µmol g^{-1}), showing that the plants experienced stress. On the other hand, this result shows that potassium plays a role in helping plants cope the stress conditions, but when soil moisture conditions are available, potassium is only used for other metabolism so that the formation of proline continues run normally. The application of trenches with organic matter resulted in lower proline content compared to that without trenches and without KCl. This suggests that potassium plays a role in helping plants cope stressful conditions. Research conducted by Bahrami-rad et al. (2017) showed the same result, reporting that foliar application of potassium could increase the proline content of tobacco leaves. Increased proline content as the result of potassium application is not clearly known yet. Potassium is thought to play a role in metabolism of several amino acids, and it is also thought to direct, directly or indirectly, role in the proline synthesis pathway. Potassium has specific role in the conversion of arginine to proline via increased enzyme activity arginase. Increased activity of the arginase enzyme occurs when the plants experience abiotic stress. The addition of potassium in plants can cause stress, thereby increasing arginase enzyme activity and increasing the arginine role in proline synthesis.

According to Cha-Um (2010), the high rate of photosynthesis will be able to form many assimilates used for cell enlargement and division, and a portion of the assimilates will be stored in the form of food reserves in the form of seeds. In line with this statement, the combination of trench

Table 12. Productivity of upland rice (ton.ha^{-1})

Treatment	Dose of KCl			Mean
	0 kg.ha^{-1}	100 kg.ha^{-1}	200 kg.ha^{-1}	
Without trench	0.432 d	0.919 c	1.738 b	1.030
Trench with organic matter	0.694 cd	2.716 a	3.068 a	2.159
Mean	0.563	1.818	2.403	(+)

Notes: Values followed by the same letters in the same column and the same treatment are not significantly different based on Tukey at 5%. The (+) sign shows an interaction between the factors tested.

treatment with organic matter and KCl at doses of 100 and 200 kg.ha^{-1} resulted in the highest photosynthetic rate, producing higher percentage of filled grain and 1000 seed weight compared to other treatments (Table 11). According to Tarigan et al. (2013) the weight of 1000 seeds of upland rice cv. Situ Patenggang can reach 23 grams, but in this study, the highest weight of 1000 seeds was only 15 grams. This result could be due to several factors, especially environmental factors inhibiting rice growth.

The treatment combination of trenches with organic matter and the highest dose of KCl (200 kg.ha^{-1}) was able to produce the highest grain yield per hectare (3,068 ton.ha^{-1}) . In addition, grain yield per hectare is also influenced by the percentage of filled grain. This figure is lower than the potential of Situ Patenggang cultivar in paddy field, but is considered high at the research location because the average rice production is usually 3 tons.hectare^{-1}. According to Ikhsan et al. (2017), the yield per hectare is determined by seed size, panicle length, number of grains per panicle, number of panicles, number of clumps, number of seeds, and weight of 1000 seeds. Characters are determined by genetic factors and environment. The previously mentioned characters are determined by those special genes activity and built by environment factors. The adaptation ability of plants to the environment is a trait controlled by the genes in plants, allowing plants to be able to produce relatively better at certain environment. Kobayasi (2014) stated that yield component in the form of a complex character controlled by a large number of cumulative, duplicate, and dominant genes are very helpful for the environment.

After the data of yield were obtained, the next step was to carry out regression analysis. The curves formed in the regression analysis might contain critical or extreme points. The critical point is the optimal point, which is the maximum or minimum stationary point in the curve. Based on the regression tests on upland rice productivity, an equation with quadratic curves was obtained from the interaction effect of the application of trenches with organic matter and KCl at a dose of 200 kg.ha^{-1} on the grain yield per hectare (ton.hectar^{-1}), which is Y (grain per hectare) = 0.694 + 0.029 x – 8.353E-5 x^2 R^2 = 0.983 (Figure 1).

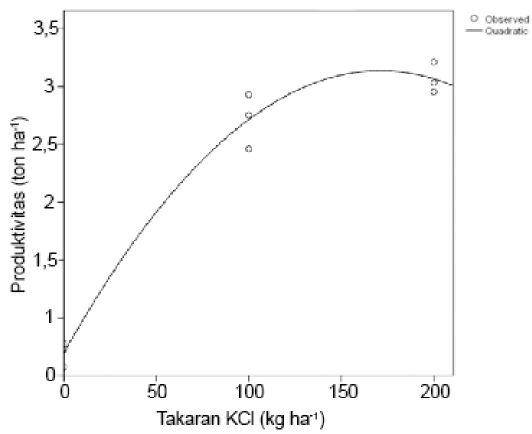

Figure 1. Regression of upland rice productivity as affected by trenches with organic matter

This regression analysis provided data on the best treatment combination to produce the highest productivity (yield) with the right fertilizer efficiency. The optimum KCl dose obtained from the interaction of both factors was 173.65 kg.ha^{-1}, resulting in a productivity of 3.221 ton.ha^{-1}. Based on the analysis of regression results, the fertilizer treatment dose higher than 173.65 kg.ha^{-1} tends to decrease the yield. Hence, through regression analysis, the right dose to produce the greatest yield could be obtained. The application of fertilizer must be carried out at the right dose according to the needs of the plant. The application of too little fertilizer results in the nutrient deficiency, whereas applying too much fertilizer can cause toxicity to to plants and increase output costs.

CONCLUSION

The application of trenches with organic matter increased the moisture content of the soil as much as 14% so that the water requirements of the plant were met, thereby affecting the growth, physiology, and the yield of upland rice plants. The KCl fertilization balanced the osmotic of plant tissue so that the cell becomes turgid. Such conditions improved the growth, physiology, and the yield of upland rice. The increase in plant growth could be seen from the length and area of roots and leaves, in which the combination of KCl fertilization treatment and trenches with organic matter significantly increased the growth of rice plants by an average of 10-21%. Both treatments had interaction effect on moisture content, canopy and root dry weight, root length and area, photosynthetic rate, proline contents, and upland rice productivity. The upland rice plants treated with with a combination treatment of KCl fertilization and trenches with organic matter had the highest productivity, namely 3.068 tons.hectars^{-1}, while those without both treatments had the productivity that was only 0.432 tons. hectars^{-1}. It means that with the combination of both treatments, water in the soil becomes more available to plants, thus increasing growth rate, improving physiology, and finally giving higher yield. Meanwhile, based on the regression analysis, a combination of trenches with organic matter and KCl at a dose of 173.65 kg.ha^{-1} gave the highest yield, namely 3,221 ton.ha^{-1}.

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Usage of Heat Treatment and Modified Atmosphere Packaging to Maintain Fruit Firmness of Fresh Cut Cavendish Banana (*Musa cavendishii*)

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ABSTRACT

Increasingly healthy lifestyles and advances in technology make people tend to prefer consuming fresh-cut fruits. Modified Atmosphere Packaging (MAP) contributes to extending shelf life and improving postharvest product quality. This study was aimed to determine the effects of argon-based MAP combined with heat treatment on the quality of the fresh-cut cavendish. There were four treatments examined, consisting of the combination of MAP with 73.70 % argon gas and heat treatment at 40 °C for 5 minutes (P1), heat treatment at 40 °C for five minutes (P2), MAP with 73.70 % argon gas (P3), and without treatment (P4). Each treatment consisted of three replications, and all experimental units were stored in a storage area at a temperature of 10 °C. The variables of fruit hardness, total titratable acidity, reducing sugar content, and total phenolic compounds were observed at 0, 2, 4, 6, 8, and 10 days of storage. The results of the study showed that MAP and heat treatment could maintain freshness and slow down the degradation of fresh-cut cavendish quality. The combination of MAP treatment with 73.70 % argon gas and heat treatment at 40 °C for five minutes can slow down the degradation of fresh-cut cavendish quality and suppress the total titratable acidity formation until the end of the storage period (ten days).

Keywords: Argon gas, Fresh-cut cavendish, Heat treatment, MAP

ABSTRAK

Gaya hidup sehat dan kemajuan teknologi membuat masyarakat cenderung lebih memilih mengkonsumsi buah – buahan potong. *Modified Atmosphere Packaging* (MAP) memberi kontribusi dalam memperpanjang umur simpan dan meningkatkan kualitas produk pascapanen. Pada penelitian ini pengaruh MAP dengan gas argon dan heat treatment untuk mendapatkan perlakuan yang paling efektif dalam mempertahankan mutu fresh-cut cavendish diteliti. Penelitian ini menggunakan 4 perlakuan yaitu MAP dengan 73,70 % gas argon dan *heat treatment* dengan suhu 40 °C selama 5 menit (P1), *heat treatment* dengan suhu 40 °C selama 5 menit (P2), MAP dengan 73,70 % gas argon (P3), tanpa perlakuan (P4). Semua perlakuan disimpan dalam tempat penyimpanan dengan suhu 10 °C dan setiap perlakuan dilakukan dengan 3 ulangan percobaan. Pengujian berupa kekerasan buah, total asam tertitrasi, gula reduksi dan total senyawa fenolik yang dilakukan 0, 2, 4, 6, 8 dan 10 hari penyimpanan. Kombinasi perlakuan MAP dengan 73,70 % gas argon dan *heat treatment* pada suhu 40 °C selama 5 menit dapat mempertahankan kualitas *fresh-cut* cavendish dengan tingkat kekerasan buah yang baik dan signifikan, tertekannya pembentukan total asam tertitrasi dan fenol fresh cut cavendis hingga 10 hari masa penyimpanan.

Kata Kunci: *Fresh-cut* cavendis, MAP, Gas argon, *Heat treatment*

INTRODUCTION

Consumer demand for fresh, healthy, safe, comfortable, and ready to consume fruits and vegetables has made the industry of fresh-cut fruit and vegetable rapidly grow (Allende et al., 2006). Minimally processed fruit and vegetable products can be classified as fresh products whose freshness is expected to be maintained until they are ready for consumption, but the process given does not deactivate the microbes present in the product. Unlike whole fruit, fresh-cut fruit is susceptible to enzymatic browning, increased respiration, rapid deterioration, and microbial growth (Harker, 2003). Appropriate measures to prevent browning, inhibit tissue softening and ensure microbial safety are needed to extend shelf life and maintain product freshness (Siddiqa et al., 2020).

Banana (M*usa acuminata*) is a most well-known tropical fruit which contains high nutritional and antioxidant content (Wang et al., 1996). According to fixed data, bananas is the largest contributor to production, reaching 7,264,383 tons in 2018 (Badan Pusat Statistik, 2018). High nutrition and antioxidants make bananas the favorite fruit of a highly active modern society who desires a practical diet. Bananas that are minimally processed into fresh-cut fruit products attract consumers because of the uniform size of the pieces, short preparation time, and smaller storage space. The obstacles in producing fresh-cut bananas include short shelf life, the quick change in the composition of the nutritional content, its vulnerability to damage, and quality deterioration. Therefore, it is necessary to develop new methods to extend the shelf life and maintain the quality of bananas during postharvest handling to meet consumer demand for high-quality fresh-cut 'Cavendish' bananas.

The use of Modified Atmosphere Packaging (MAP) has increased over the decades. MAP is an innovative post-harvest approach that have a positive impact on fruit quality and safety, making it an important product to extend shelf life and improve the quality of various post-harvest products (Calep et al., 2013; Calep et al., 2013a; Calep et al., 2013b; Jo et al., 2014; Lyna et al., 2019; Pinto et al., 2020). MAP is a technology that manipulates the oxygen composition by lowering it and slowing down the respiration in the fruit (Kader, 1980; Mathooko, 1996), as well as reducing moisture loss (Calep et al., 2013c). Rocculi et al. (2004) reported that Argon (Ar) gas content in non-conventional MAP combinations (65 % N_2O, 25 % Ar, 5 % CO_2, and 5 % O2) that used immersion treatment in a combined solution of 0.5 % ascorbic acid, 0.5 % citric acid, and 0.5 % calcium chloride for three minutes could maintain fresh quality and secondary metabolite content in apples for 12 days.

In addition, the use of gas and heat treatment (HT) can also extend the shelf life of post-harvest products. Research by Rocculi et al. (2005) showed that MAP that consists of 90 % argon gas and nitrogen dioxide produced a better result in maintaining secondary metabolites and hardness quality in fresh-cut kiwi fruit. Prasad et al. (2015) stated that immersing bananas at a temperature of 40 °C for 5 minutes was proven to inhibit microbial growth and delay ripening. This study was aimed to assess the ability of MAP and HT to maintain the quality of fresh-cut Cavendish banana fruit.

MATERIALS AND METHODS

Sorting and Preparation of Cavendish Banana

The bananas were sorted by their uniform size, freshness, and shape, according to the criteria for A-quality (3-4 bananas with yellowish color in 1 kg). The fruits were also sorted with the same level of ripeness and good packaging. The ripeness level used was phase 2 with the ripeness index based on the color change index of 5, in which the entire surface of the banana peel is yellow, and the tip is green. The ripeness level of bananas consists of two phases, namely phase 1 (unripe banana) and 2 (ripe banana), with a color change index of 1 to 4 and 5 to 8, respectively (Indarto and Murinto, 2017). The bananas were then washed, cleaned, and peeled first before vertically cut into 6 - 8 slices each. They were then put into a package based on the treatments and stored in a cooler at 10 °C for ten days.

Experimental Set Up

The heating treatment was carried out by preparing a water bath filled with water and heated to a temperature of 40 ^{o}C. The sliced banana was then put into the water bath for 5 minutes. A timer and thermometer were used during the heating process to maintain the temperature and time. After being heated for 5 minutes, the bananas were drained and cooled to room temperature before being put into the package.

The treatments tested were MAP with 73.70 % argon gas combined with heat treatment at 40 °C for 5 minutes, heat treatment at 40 ^{o}C for 5 minutes, MAP with 73.70 % argon gas, and without MAP nor heat treatment (control). Argon (Ar) was applied after the heating treatment. After they were cooled, the bananas were put into zip-locked plastic that had been vacuumed to remove their gas composition. After that, argon gas was inserted into the plastic and the plastic was closed. The packaged bananas were then stored in a cooler with a temperature of 10 °C for ten days. The variables examined in this research included fruit hardness, total titratable acidity, total phenolic compound, and reducing sugar content, observed on 0, 2, 4, 6, 8, and 10 days of storage.

Fruit Hardness (N/mm^2)

The fruit hardness test was conducted to determine the change in the level of hardness of the fruit samples under observation. The texture or hardness of the fruit was measured using a penetrometer (Lutron, FR-520, USA). In the tested fruit, the tip of the penetrometer was inserted into the fruit at three different parts. The value obtained shown by the penetrometer is the force value acquired in the calculation.

Titratable Acidity

The total titratable acidity test was carried out to determine the total organic acid in the sample solution using the titration method. This test was carried out by mixing 5 grams of the pureed sample with 70 ml of distilled water in a 100 ml volumetric flask. The sample solution was shaken until homogeneous and 20 ml of it was filtered into Erlenmeyer flasks. After that, 2-3 drops of 1% PP indicator were added to the sample solution and titrated with 0.1 N NaOH until the color of the solution turned pink, and the color did not fade after 30 seconds.

Reducing Sugar Content

The reducing sugar content was tested using the Nelson-Smogiy (NS) method. The NS method uses nelson C and standard sugar solutions to determine the equation for reducing sugar content. The test was carried out by mixing 1 gram of the sample with 100 ml of distilled water and shaking it until it was homogeneous. After that, the sample solution was filtered using filter paper, then 0.1 ml of the filtrate was taken and mixed with 0.9 ml of distilled water and 1 ml of nelson C in a test tube. The mixed filtrate was then put into a water bath with a temperature of 70 °C for 20 minutes and let still for 30 minutes, before added with 1 ml arsenic and 7 ml distilled water and shaken until homogeneous. Next, the absorbance was measured with a spectrophotometer (Thermo, Genesis 30, USA) at a wavelength of 540 nm.

Total Phenolic Compound

According to Singleton and Rossi (1965), total phenolic compounds can be tested using the Folin-Ciocalteu method. In this method, the absorbance measurement is at a wavelength of 750 nm. The extract was made by dissolving 1 g of mashed banana flesh in 10 ml of distilled water. A total of 0.5 ml of the solution was taken and mixed with 5 ml of distilled water, then shaken and let still for 5 minutes. After that, 1.5 ml of 5 % Na2CO3 and 1.5 folin was added to the mixture, which was then shaken. Then measurements were made using a spectrophotometer (Thermo, Genesis 30, USA) at a wavelength of 750 nm (Khadambi, 2007).

Data Analysis

The experiment in this study was arranged in a completely randomized design (CRD) with a single factor. The observation data were analyzed using analysis of variance (ANOVA) with a level of 5%. The data showing significant differences between treatments were then tested with the Duncan multiple range test using SPSS XII software.

RESULTS AND DISCUSSION

Fruit hardness

Fruit hardness is a parameter that is considered the most objective in determining the freshness of a product. the fruit hardness of the bananas decreased in all treatments. The treatments given to the fresh-cut banana fruit resulted in better fruit hardness than the control. Changes in fruit texture are influenced by cellulose and pectin compounds. When it ripens, the fruit will become soft due to a decrease in these compounds (Chauhan et al., 2006; Prasad et al., 2015). MAP treatment with argon gas and heat treatment was thought to be able to maintain cellulose and pectin compounds content during storage. This is because the treatments can suppress uncontrolled cell adhesion in the middle lamellae in the fruit cell walls, as well as inhibiting the breakdown of the pectin compounds.

Argon gas can maintain fruit hardness (Shen et al., 2019). Based on the analysis of variance (Table 1), MAP with argon gas combined with heat treatment showed a significantly better fruit hardness compared to either heat treatment or MAP treatment only. These results indicate that pectin breakdown can be suppressed well with the usage of argon gas and heat treatment. Heat treatment can inhibit fruit softening, lose total titrated acid, increase the antioxidant potential, and maintain the quality of peaches (Huan et al., 2018).

Table 1. Fruit Hardness of Banana as Affected by MAP and Heat Treatment (N/mm^2)

Treatment	The average fruit hardness on n-days					
	0	2	4	6	8	10
P1	0.227a	0.217a	0.200a	0.170a	0.150a	0.147a
P2	0.223a	0.203b	0.200a	0.137c	0.123bc	0.130b
P3	0.233a	0.213ab	0.203a	0.170a	0.137ab	0.123b
P4	0.230a	0.203b	0.183b	0.150b	0.107c	0.090c

Note: values followed by the same letters within the same column are not significantly different according to DMRT at 5 %. Remarks: P1: heat treatment at 40 °C for 5 minutes combined with Argon (Ar) gas of 73.70 %, P2: heat treatment at 40 °C for 5 minutes, P3: Argon (Ar) gas of 73.70 %, P4: without treatment.

Total Titratable Acidity

The total acid content in the sample fluctuated from the beginning to the end of the experiment. During the first eight days of observation, all treatments showed an increase in total acid content (Figure 1). The acid content in the control treatment decreased on day 8, and it increased on day 10 when acid content in other treatments began to decrease. MAP treatment and heat treatment showed no significant difference in the total acid content of the fresh-cut cavendish bananas. However, the treatment showed a stable increase in acid meaning that the condition of the packaging with controlled air suppressed the breakdown of complex materials caused by cellular respiration in the fruit. The acidity of the fresh-cut cavendish bananas was inversely related to the fruit hardness. If the fruit hardness can be suppressed, its acidity will increase (Ghasemnezhad, 2011).

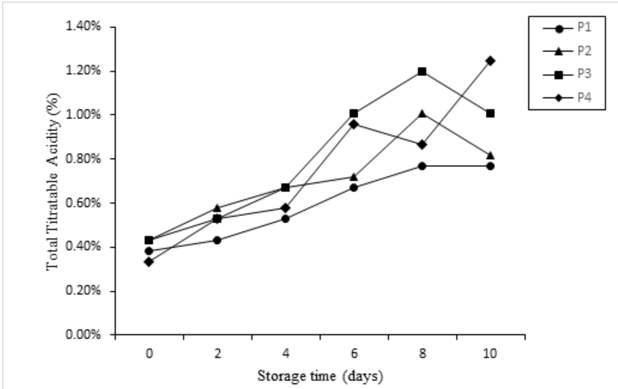

Figure 1. Change of Total Titratable Acidity During Storage of Heat Treatment and MAP. P1: heat treatment at 40 °C for 5 minutes combined with Argon (Ar) gas of 73.70 %, P2: heat treatment at 40 °C for 5 minutes, P3: Argon (Ar) gas of 73.70 %, P4: without treatment.

MAP suppresses fruit respiration, making the resulting organic acids unusable in the respiration process, thereby increasing total acid content. However, cutting the fruit causes the fruit to become damaged and increases the respiration rate. In packaging with the MAP and HT, the respiration rate was suppressed. This result is supported by Shen et al. (2019), who reported that the use of the MAP method in storing figs could suppress respiration during the storage period.

Reducing sugar content

Sugar in fruit generally increases at the beginning of the storage and then decreases at the end of the storage period. The MAP with the addition of argon gas combined with HT showed an increase in reducing sugar on the 6th day (Figure 2). The addition of argon gas can suppress respiration that occurs in fruit (Calep et al., 2013b). The respiration rate suppressed by the argon gas treatment inhibited the degradation of starch into sugar. The use of controlled air packs is better at suppressing the reduction of banana fruit sugar on the 12th day of storage (Zewter, 2012). Pinto et al. (2020) stated that climacteric fruit such as bananas show decreased starch content and increased total sugar during the peak ripening process under normal conditions.

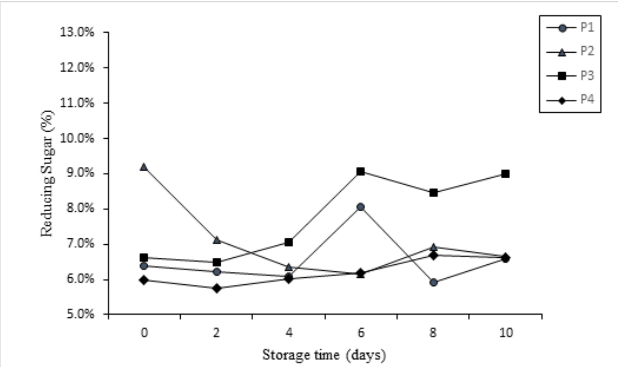

Figure 2. Change of Reducing Sugar During Storage of Heat Treatment and MAP. P1: heat treatment at 40 °C for 5 minutes combined with Argon (Ar) gas of 73.70 %, P2: heat treatment at 40 °C for 5 minutes, P3: Argon (Ar) gas of 73.70 %, P4: without treatment.

The addition of argon gas also showed a positive effect on the fruit hardness. These results show that the respiration rate can be suppressed properly by the MAP method. This rate of respiration increases the amount of reducing sugar in the MAP method, supported by low-temperature storage that affects the increase in reducing sugar in bananas. This result is in accordance with the results of Vilas-Boas et al. (2006), which stated that storing bananas in cold or low temperatures increases the reducing sugar content on the 3rd day of storage when compared to the room temperature.

MAP with argon combined with HT was able to increase the reducing sugar content. The sugar decomposition can be caused by the respiration that takes place in the fruit. In climacteric fruit, changes in sugar content is related to the total acid in the fruit. The total sugar content in climacteric fruit decreases further during the ripening process in the open space. The decrease occurs because the respiration process of the fruit is not suppressed, making starch degrade faster.

Total phenolic compounds

The total phenolic compounds in all treatments fluctuated in each storage day. The cutting caused an increase in the phenolic content in the banana pulp tissue on the 2nd to 4th day of observation (Figure 3). The phenolic content of the fresh-cut banana pulp increased after 6 hours and continued to increase to 3.7 and 4.5 times higher than that of the uncut pulp at 24 and 36 hours, respectively (Chena et al., 2008). Phenolic compounds oxidized by the polyphenol oxidase (PPO) enzyme are the cause of browning in fruits and vegetables, including bananas (Nguyen et al., 2003). The phenolic compounds in MAP with argon gas without HT decreased to its lowest on day 6. Bananas with MAP combined with chemical immersion produced the lowest PPO activity and phenolic compounds in 5 days of storage (Siddiqa et al., 2020). The cutting led to a significant increase in PAL activity. PAL activity in fresh-cut pulp tissue markedly increased from about 1.6 moles of cinnamic acid mg protein-1 hour-1 at 0 hours after cutting to a peak of about 5.6 moles cinnamic acid mg protein-1 hour-1 at 18 hours after cutting (Belay et al., 2019).

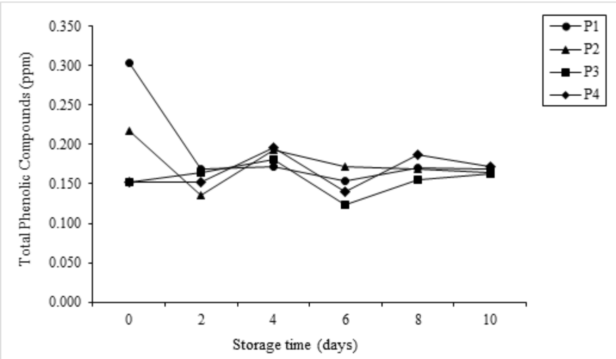

Figure 3. Change of Total Phenolic Compounds During Storage of Heat Treatment and MAP. P1: heat treatment at 40 °C for 5 minutes combined with Argon (Ar) gas of 73.70 %, P2: heat treatment at 40 °C for 5 minutes, P3: Argon (Ar) gas of 73.70 %, P4: without treatment.

The accumulation of phenolic compounds varies depending on the commodity, genotype, oxygen concentration, storage time, and temperature (Ghasemnezhad et al., 2011; Hidayati, 2012). MAP and HT were unable to significantly keep total phenol stable. MAP on fresh-cut fruits under certain conditions causes various effects and responses to the reduced respiration, as well as to the changes in color, texture, and concentration of bioactive compounds as effects of fermentative metabolites (Kudachikar et al., 2011; Belay et al., 2019)

CONCLUSION

Modified atmosphere packaging (MAP) and heat treatment (HT) as an inhibitor to the ripening process could maintain the quality of the fresh-cut cavendish bananas. The treatment of MAP with 73.70 % argon gas combined with heat treatment at 40 °C for five minutes could maintain the fruit hardness level and suppress the total titratable acidity for ten days of storage. These results can be used as the basis for further research regarding the concentration of argon gas as control of gas composition in packaging to maintain the quality of fresh-cut cavendish bananas before the peak maturity period (ripening index of 1-4).

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