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Increasing production of various garlic local cultivars in off season by gliocompost

Meksy Dianawati[1*], Yati Haryati[1], Agus Ruswandi[2], Nana Sutrisna[1], Bambang Susanto[1], Amisnaipa[3], Saidah[4]. Muji Rahayu[5], Olvie Grietjie Tandi[6], Agus Nurawan[1], Yanto Surdianto[1], Iskandar Ishaq[1], Sigid Handoko[7], Rini Rosliani[8]

[1] West Java Assessment Institute for Agricultural Technology, Indonesia
[2] West Java Research and Development Agency, Indonesia
[3] West Papua Assessment Institute for Agricultural Technology, Indonesia
[4] Central Sulawesi Assessment Institute for Agricultural Technology, Indonesia
[5] West Nusa Tenggara Assessment Institute for Agricultural Technology, Indonesia
[6] North Sulawesi Assessment Institute for Agricultural Technology, Indonesia
[7] Indonesian Center for Agricultural Technology Assessment and Development, Indonesia
[8]Indoensian Vegetable Research Institute, Indonesia

ABSTRACT

Garlic in off season will be faced low production with poor quality tubers. Gliocompost which contains active ingredients of gliocladium can function as a biocontrol and biofertilizer. The aim of this research was to increase the bulb production of various cultivars of garlic in off season by using gliocompost. The research was conducted in Cianjur Regency, West Java, Indonesia, with an altitude of 1,320 m above sea level from August 2018 to January 2019 at -6.75908, 107.02897, 1334, 318. The research used a factorial randomized block design with two factors. The first factor of garlic cultivar consisted of five cultivars, namely Lumbu Putih (LP), Lumbu Kuning (LK), Lumbu Hijau (LH), Tawangmangu Baru (TB), and Sangga Sembalun (SS). The second was gliocompost, namely with and without gliocompost with six replications. Gliocompost application was given before planting at a dose of 5 kg per 200 kg of manure for 1 ha. The data observed were shoot emergence (%), plant height (cm), bulb diameter (cm), yield per ha (ton), yield per plot (ton), live plants (%), and production gap (%). Data were analyzed by analysis of variance and if there was a significant difference, then it was followed by the Duncan test at the 95% confidence level. Heatmap analysis was performed using the R Studio program. The results showed that the use of gliocompost did not affect the yield per ha of LK and SS, but it could increase yield per ha of LH, TB, and LB, increase yield per plot and decrease percentage of production gap of LP. Gliocompost increased bulb diameter. LP had a higher bulb diameter and percentage of live plants than LK.

Keywords: Allium sativum L, yield, gliocladium, biofertilizer, biocontrol, heatmap

Corresponding Author:

Meksy Dianawati
West Java Assessment Institute for Agricultural Technology
Jl. Kayuambon 80, Lembang, Bandung Brat, West Java, Indonesia
meksyd@yahoo.com

1. Introduction

Production of local garlic cultivars in Indonesia is still low at 7.29 tons per ha in 2019 [1]. The national garlic production is only 39,300 tons per year, while the need for garlic per year can reach 582,995 tons [2]. This high national need for garlic is due to the use of garlic both routinely for fresh and processed consumption. This causes the Indonesian government to meet the national need for garlic by importing from other countries. However, the import of garlic actually causes local cultivars to disappear due to lack of competition, so that it is difficult to obtain quality garlic seeds in the field. [3] stated that garlic production in Indonesia is low due to the limited choice of cultivars and the unavailability of quality seeds in the field. Garlic in Indonesia is usually planted at the end of the rainy season and harvested during the dry season [4]. Planting at the end of the rainy season is done as an effort to irrigate so that plants can grow well. While harvesting during the dry season is an effort to approach low temperatures so that the tubers are large. [5] stated that low temperatures are needed for garlic plants to form bulbs with short growing periods and higher bulb weights. However, efforts to supply garlic throughout the season must be made to ensure product continuity in the market. If garlic was harvested during the rainy season, the production will be faced low production with poor quality tubers. [6] reported that garlic production in Indonesia which was harvested in rainy season had only 4 ton per ha. It can be caused by poor air temperature and drainage [7], so its disease intensity increased. [8] stated that fungal diseases are the most important limitation for garlic production rate and its productivity throughout the world. Various microorganisms that are good for plant growth have been widely studied. One of the good microorganism products that is widely used by farmers in Indonesia is gliocompost. As a biocontrol, gliocompost had the active ingredient *Gliocladium* sp. which is very active in controlling various pathogens, while as a biological fertilizer, gliocompost is enriched with nutrient-blocking microbes N, P, and K such as *Azotobacter* sp., *Pseudomonas fluorecence*, and *B. Subtilis* [9]. [10] stated that the use of the microbial antagonists *Trichoderma* sp., *Azospirilium* sp *Azospirilium* sp., *Pseudomonas fluorescence*, and *Bacillus subtilis* effectively suppressed Fusarium in garlic. The synergistic combination of various microbes found in gliocompost has been reported to increase plant production and was seen to be superior in chrysanthemums [11], chilies [12], rice [13], and bananas [14]. [15] reported that gliocompost could suppress Fusarium wilt on chrysanthemum and substitute the use of pesticides and chemical fertilizers by 50%. Thus the use of gliocompost in this study was expected to increase garlic production in various local garlic cultivars in off season.

2. Material and methods

2.1. Experimental location

The research was conducted in Cianjur Regency, West Java, Indonesia, with an altitude of 1,320 m above sea level from August 2018 to January 2019 at -6.75908, 107.02897, 1334, 318. The research soil had a sandy clay texture with soil pH neutral, medium nitrogen content (0.38%), very high P (780.7 ppm), very high K (591.8 ppm), and low CN ratio (8). Number of rainfall since August was 83, 51, 493, 624, 320, and 268 mm per month, respectively with the number of rain days of 4, 6, 25, 25, 23, and 26, respectively.

2.2. Experimental design

The research used a factorial randomized block design with two factors. Factor of cultivar consisted of five cultivars, namely Lumbu Putih (LP), Lumbu Kuning (LK), Lumbu Hijau (LK), Tawangmangu Baru (TB) and Sangga Sembalun (SS). Factor for the use of gliocompost namely with and without gliocompost with six replications. The application of gliocompost was given before planting as much as 5 kg per 200 kg of manure for 1 ha. The seeds used came from local seed breeders with warehouse certification according to the regulations in effect at that time because seeds during research were still scarce.

The study consisted of experimental plots with a size of 1 x 1 m^2. Size beds was a width of 1 m and used black silver mulch. The seeds were planted at a spacing of 10 x 15 cm^2, one clove of seed per planting hole. Basic fertilization was given along with soil cultivation, per ha namely 1 ton dolomite, 20 ton manure, and 500 kg NPK 16:16:16. The follow-up fertilization given was NPK 200 kg at one month after planting (MAP), and KCl 200 kg at two MAP. Maintenance was carried out by watering according to the needs of the plants at each growth phase. Weed control was carried out manually by cleaning weeds in each bed and controlling pests and diseases based on the results of scheduled pest and disease monitoring.

2.3. Data analysis

Five plants per plot were determined randomly. The data observed per five plant samples were plant height of 5 and 10 week after planting (WAP) and bulb diameter. Plant height was measured from the highest growing point to the base of the stem. The bulb diameter was measured using a caliper on two sides, namely the widest and narrowest then divided by two. Bulb weight after one week of sun-drying from five sample plants was converted to hectare as yield per ha. Plant observation per 1 x 1 m^2 were shoot emergence (%), yield per plot (ton), and live plants (%). The percentage of shoot emergence was the ratio of the seeds that grow to the total plant population in 1 m^2 at the age of 4 WAP. Yield per plot was the bulb production after one week of sun drying from an area of 1 m^2. The percentage of live plants (%) was the ratio of plants alive at the final harvest to the total plant population at an area of 1 m^2. The production gap was the percentage difference in yield per ha compared to the yield per plot. Data were analyzed by analysis of variance and if there was a significant difference, then it was followed by the Duncan test at the 95% confidence level. Heatmap analysis was performed using the R Studio program [16].

3. Results

Generally, garlic farmers in Indonesia planted at the end of the rainy season and harvest in the dry season. However, this research was conducted in the off-season in general. The first two months of planting, there was little rain below 100 mm per month and in the last four months there was very high rain above 200 mm per month. The interaction of gliocompost and cultivar affected the percentage of shoot emergence, plant height on 5 and 10 WAP, yield per ha, yield per plot, and the percentage of production gap. Cultivar differences individually affected percentage of live plants and bulb diameter, while the use of gliocompost individually affected bulb diameter (Table 1).

Table 1. Analysis of variance for the effect of garlic cultivar and gliocompost application on percentage of shoot emergence (%), plant height on 5 and 10 WAP (cm), percentage of live plant (%), bulb diameter (cm), yield per ha (tons), yield per plot(tons), dan percentage of production gap (%).

	Df	Means of square							
		PSE	PH5	PH10	PLP	BD	YH	YP	PPG
Cultivar	4	857.96***	180.26***	201.01***	1598.67 **	2.44**	34.28***	15.32 ***	185.19*
Gliocompost	1	106.26^{NS}	372.13***	1327.34***	57.13 ^{NS}	3.92*	122.13***	6.03 ^{NS}	3.08
Var*Glio	4	1853.99*	97.56***	114.97**	632.97 ^{NS}	0.21 ^{NS}	19.95**	7.81 *	137.65 *
Repetation	2	640.06 ^{NS}	91.36**	120.55**	194.04 ^{NS}	0.69 ^{NS}	39.15***	3.67 ^{NS}	104.95

*, **, ***, ^{NS} indicate significant at p < 0,05, 0.01, 0,001 or no significant effect, respectively
PSE = percentage of shoot emergence, PH5 = plant height at 5 WAP, PH10 = plant height at 10 WAP, PLP = percentage of live plant, BD = bulb diameter, YH = yield per ha, YP = yield per plot, PPG= percentage of production gap

3.1. Interaction of cultivar and gliocompost

Cultivar and gliocompost interaction affected percentage of shoot emergence (Fig. 1a). LK and LP without gliocompost had the lowest percentage of shoot emergence and there was an increasing in the percentage of shoot emergence when gliocompost was applied. There was no difference in percentage of shoot emergence using gliocompost on TB, LH, and SS. There was no difference in percentage of shoot emergence among cultivars when gliocompost was applied. The interaction of cultivar and gliocompost affected plant height at 5 WAP (Fig. 1b). The use of gliocompost and without gliocompost on LH and LP was not significantly different to the plant height at 5 WAP. LP had the lowest plant height at 5 WAP, both with and without gliocompost. The plant height of TB, LK, and SS with gliocompost was higher than without gliocompost. Plant height at 5 WAP in LK and TB with gliocompost was the highest. The interaction of cultivar and gliocompost affected plant height at 10 WAP (Fig. 1c). LP without gliocompost had the lowest plant height at 10 WAP. Plant height of SS did not significantly differ between with and without gliocompost. The application of gliocompost on LH, LK, LP, and TB increased plant height at 10 WAP. SS with gliocompost had lower plant height than LH, LK, and TB with gliocompost. The interaction of cultivar and gliocompost affected the yield per ha (Fig. 1d). The yield per ha of LK and SS were not significantly different between with and without gliocompost. The gliocompost application on TB, LH, and LP had a higher yield per ha than without gliocompost. The yield per ha of LP and LH applied by gliocompost was higher than that of SS and LK with gliocompost. The interaction of cultivar and gliocompost affected yield per plot (Fig. 1e). The highest yield per plot was LP that was applied gliocompost, while the lowest was LK without gliocompost. The use of gliocompost in LP has higher yield per plot than without gliocompost. The use of gliocompost did not affect the yield per plot of TB, LH, SS, and LK. The interaction of cultivar and application of gliocompost affected percentage of production gap (Fig. 1f). The percentage of production gap for LK without gliocompost was higher than LP with gliocompost, and TB and

LP without gliocompost. The use of gliocompost in each cultivar did not affect the percentage of the production gap

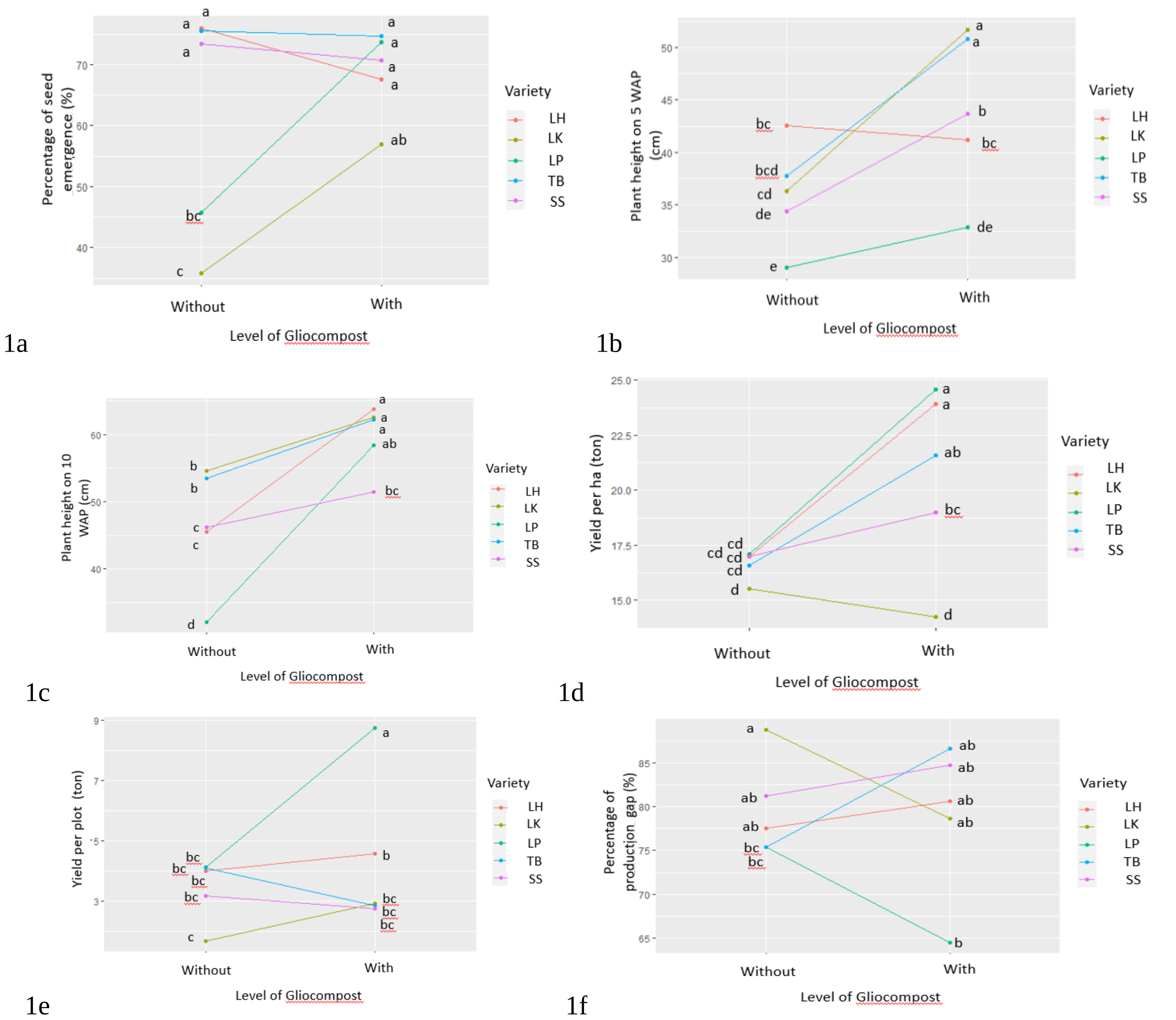
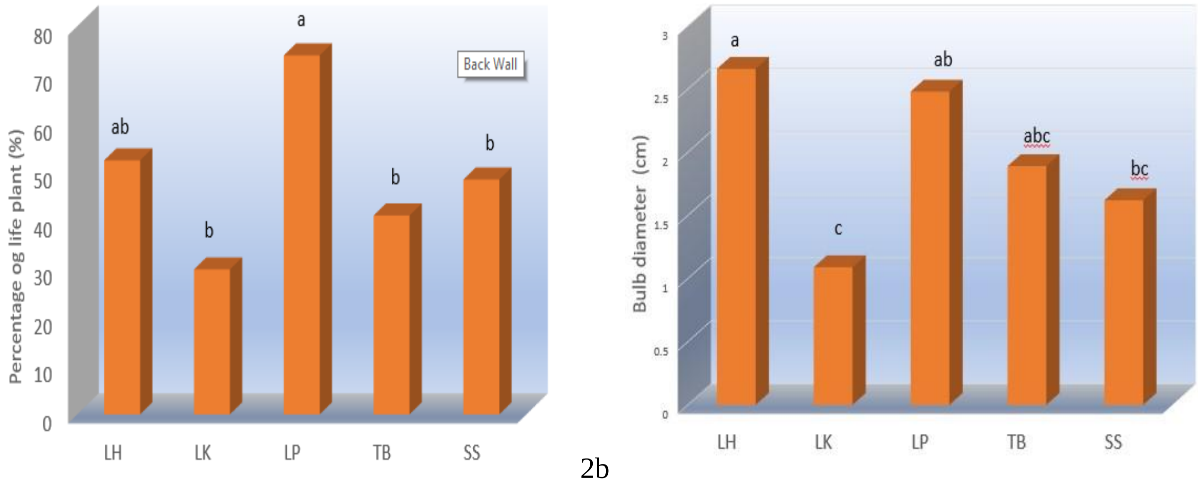


Figure 1. Effect of cultivar and application of gliocompost on percentage of shoot emergence (%) (a), plant height at 5 WAP (b) dan 10 WAP (c), yield per ha (d), yield per plot (e), and percentage of production gap (f)

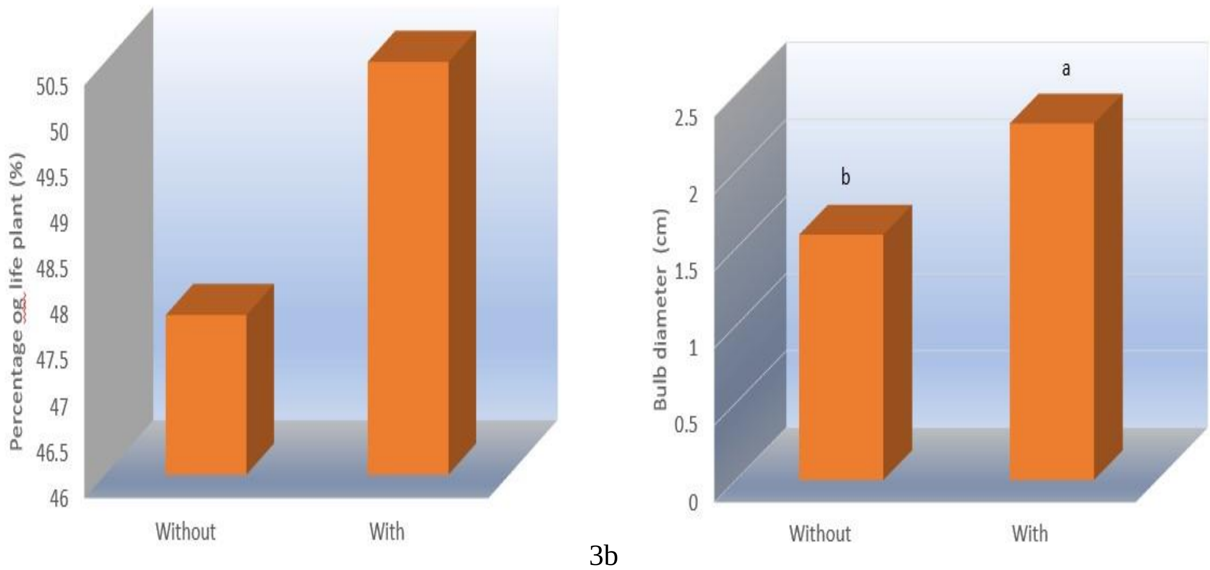
3.2. Single effect of cultivar and gliocompost treatment

LP had a higher percentage of live plants than LK, TB, and SS, but it was not significantly different from LH (Fig. 2a). LP had a higher bulb diameter than LK, but not significantly different from LH, TB, and SS (Fig. 2b). The use of gliocompost did not affect the percentage of live plants (Fig. 3a), but did increase bulb diameter (Fig. 3b).



2a 2b

Figure 2. Percentage of live plants (a) and bulb diameter (b) in various garlic cultivars



3a 3b

Figure 3. Percentage of live plants and bulb diameter with and without gliocompost

3.3. The relationship between the combination of cultivar and gliocompost with variables

In order to sharpen the interaction between cultivar and gliocompost with variables, a heat map analysis was performed. The darker relationship showed the greater influence. There were five groups of combination treatment of cultivars and gliocompost (Fig. 4). The first combination was the best combination of LP with gliocompost because of the high yield per ha, yield per plot, and a high percentage of live plants, while the percentage of production gap was low. The second was TB and LH that were applied gliocompost because yield per ha was also high, but there was not on other bulb variables. TB with gliocompost had high initial plant height at 5 WAP, while LH with gliocompost had high plant height at 10 WAP. TB, LH, and SS without gliocompost and SS with gliocompost were the third group with a high percentage of shoot emergence. LH without gliocompost had a high bulb diameter. The fourth group was LK with gliocompost which had low yield per ha, even though at the beginning at 5 WAP plant height was quite high. Fifth group was no gliocompost in LK and LP with a low yield per ha and percentage of shoot emergence.

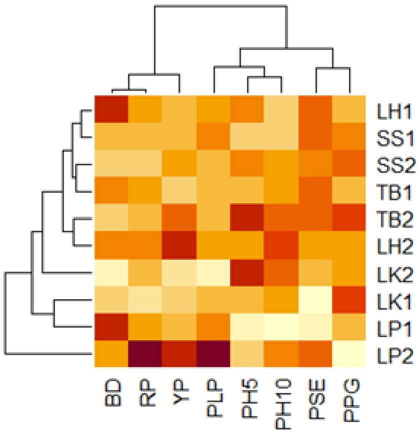


Figure 4. Relationships between interaction cultivar and gliocompost with variables
Bulb diameter (BD), yield per plot (RP), yield per ha (YP), percentage of life plant (PLP), plant height at 5 WAP (PH5), plant height at 10 WAP (PH10), percentage of shoot emergence (PSE), percentage of production gap (PPG), LH1 (LH without gliocompost), LH2 (LH with gliocompost), LK1 (LK without gliocompost), LK2 (LK with gliocompost), LP1 (LP without gliocompost), LP2 (LP with gliocompost), TB1 (TB without gliocompost), TB2 (TB with gliocompost), SS1 (SS without gliocompost), SS2 (SS with gliocompost),

3.4. Discussion

The use of gliocompost increased percentage of shoot emergence of LP and LK because if there were without gliocompost, the percentage of shoot emergence of these two cultivars were very low, below 50% (Fig. 1a). LP and LK seeds used in this research have not sprout yet when planted because it was difficult to get seeds with the same germination conditions due to the limited available seeds. In addition, time of planting was in dry conditions due to the dry season to make its germination in emergence difficulty. Rainfall in the first two months, respectively 83 and 51 mm with the amount of rain days, respectively 4 and 6. The increase in the percentage of shoot emergence due to the use of gliocompost was thought to be the result of the secretion of phytohormones produced [17] and or the enzymes involved in nutrient uptake [18]. Gliocompost was a synergistic combination of gliocompost enriched with N, P, and K nutrient-blocking microbes such as *Azotobacter* sp., *Pseudomonas fluorecens*, and *B. Subtilis* [9]. Some of the phytohormones produced by biocontrol were auxins, cytokinins, gibberillin, and abscisic acid [19]. [20] stated that 80% of beneficial microbes colonized to produce auxin and induced an increase in the production of indogenous IAA. IAA produced by microbes was then absorbed by plants and used to increase cell growth and development [21]. [22] stated *Trichoderma virens* could increase lateral root growth through the auxin formation mechanism. [23] reported that *Pseudomonas fluorescence* and *Bacillus subtilis* could produce endogenous cytokinins and gibberillin. [14] stated *Pseudomonas fluorescence* isolate produced the highest auxin compared to other similar isolates. Thus the germinating of LP and LK in this research that have not sprouted was thought to have occurred due to the activation of germination-supporting hormones such as auxins, gibberillin, and endogenous cytokines, thereby mobilizing carbohydrates that provide energy for the growth of shoots and roots. [13] reported gliocompost application increased rice seed germination compared to without gliocompost due to phytohormone production.

The application of gliocompost to sprouted cultivar seeds (LH, TB, and SS) did not increase percentage of shoot emergence (Fig. 1a). Sprouted cultivars were not affected by the presence of germination support substances from gliocompost because they were endogenously owned, which was indicated by a high percentage of shoot emergence above 50%.

The percentage of shoot emergence that increased due to gliocompost application in LK (Fig. 1a), continued to increase plant height at 5 and 10 WAP (Fig. 1b and 1c), but did not affect yield per ha, yield per plot, or the percentage of production gap (Fig. 1d, 1e, and 1f). Thus, gliocompost in LK only affected vegetative growth, but did not affect bulb growth, so it did not affect bulb yield. As with LK, the use of gliocompost on SS only affected vegetative growth, namely increasing plant height at 5 WAP (Fig. 1b), but did not affect yield per ha (Fig. 1c).

SS and LK were classified as short-lived local Indonesian garlic cultivars (90-110 days) [24]. Short-lived cultivars generally received a shorter bulb development stimulus before achieving maximum vegetative growth

[25]. All the cultivars in this research were harvested simultaneously at the age of 120 days, so LK and SS were harvested too late. In addition, two months before and at harvest time, it often rained with 320 and 268 mm of rainfall per month and 23 and 26 of rainy days, so that the bulb was prone to rot and result in low yield per ha. Excess water or stagnation in garlic also could lead to the development of diseases such as root rot and Alternaria [10] and poor bulb quality [26]. This adverse impact was particularly evident in higher on heigh plant at 10 WAP of LK, so yield per ha was lower than SS (Fig. 1c and 1d). [24] stated LK had a spreading leaf orientation, so that LK in this study was relatively more susceptible to various pathogens. [27] stated that plant growth and structure would affect the microclimate environment in the canopy, thereby encouraging the development of pathogens.

The use of gliocompost on TB and LH increased plant height and yield per ha (Fig. 1b, 1c, and 1d). The seed condition when planting in these two cultivars have sprouted, so that the seeds could grow well without the help of gliocompost. However, gliocompost affected TB faster, namely increasing plant height at 5 and 10 WAP, compared to LH, which the effect of gliocompost was only seen at 10 WAP. Garlic plants as monocot plants with high growth have broad leaves. The broad leaf surface was directly related to the ability to photosynthesize, thereby increasing bulb production [28].

The good effect of gliocompost was shown to be the maximum in LP cultivar. This could be seen from the shoot emergence when the seeds have not sprouted to vegetative growth and bulb. This was indicated by the low percentage of production gap between yield per ha and yield per plot of LP using gliocompost compared to other cultivars. [25] stated the higher plant growth could be caused by the faster emergence of seeds. With rapid growth it could be an important source for food storage and conversion of nutrients to the rapid growth of bulb. [29] stated that the rapid sprouting will increase the growth and production of garlic because the plants got sufficient vegetative growth for longer before entering bulb growth.

Gliocompost was a biofungicide whose main ingredient consists of a mixture of natural organic matter and manure that has been composted and infested with the fungus *Gliocladium* sp. [11]. *Gliocladium* sp. could produce antibiotics, gliotoxin, glioviridin, and viridin which function to inhibit pathogens. Gliotoxin could inhibit fungi and bacteria, while viridin could inhibit fungi [30]. The antagonist mechanism of *Trichoderma* sp. and *Gliocladium* sp. competitively occured because both of them have a high growth rate and can wrap pathogenic hyphae to break [31]. The antibiotics produced by gliocladium resulted in endolysis and autolysis, namely the rupture of the pathogenic cytoplasm followed by death [32]. [11] stated that *Gliocladium* sp. effective in controlling soil borne pathogens caused by *Fusarium* spp, *Phytium* sp, *Ganoderma boninense*, *Ralstonia solanacearum*, and *Rhizoctonia solani* in various horticultural crops. [33] reported that 10^8 spores of *Gliocladium* sp had the same ability as a synthetic fungicide with benomyl active ingredient in controlling Fusarium wilt in gladiolus.

Apart from being a biofungicide, gliocompost also functions as a biofertilizer which could increase nutrient uptake, thereby increasing crop production and reducing the need for chemical fertilizers. [34] stated that the *Gliocladium* sp. mycelium would form a crumbly soil structure, so that roots could develop more easily and water and nutrient absorption was more fulfilled for plant growth. [11] reported the superior properties of gliocompost as a biofungicide and biofertilator, causing the vegetative and generative growth of various plants to increase. [35] reported biofertilizer application increased stem diameter and the number of cloves of garlic in Asbani cultivar. Increasing vegetative growth of garlic with the biofertilizer application could increase the availability of nitrogen and phosphorus elements in the presence of nitrogen fixation in the atmosphere and produce hormones and anti-metabolites in the root zone [36]. However, as stated by [30], the use of biofertilizer on a large scale was not always successful compared to the in vitro test. [9] reported that gliocompost was consistently superior in increasing chilli production in tests in polybags, narrow scale, and area compared to other biofertilizer. This was because many factors in the field affected the working effectiveness of a biofertilizer, such as the availability of organic matter, dossage, method and time of application.

In [11] stated that the success of gliocompost in controlling several diseases was thought to be due to the decomposition of cellulose by antagonists and microbes in the growing media, so that sufficient organic material was needed. However, [37] stated that high hyphae in organic matter could attack and destroy propagules around them. [30] reported that too high a dose of 200 grams of gliocladium reduced the weight of tomatoes, because there were high concentrations of substances that poison plants. The poisoning compounds bind to transmembrane proteins so that they interfered with metabolic processes. In addition, biological agents generally work in a preventive manner, so they must be given at the beginning of planting to provide opportunities for biological agents to colonize roots and rhizozphere first.

Gliocompost in this research did not succeed in increasing the yield per ha of LK and SS, but it could increase the yield per ha of TB, LH, LP (Fig. 1d). Gliocompost could also increase yield per plot of LP (Fig. 1e). In line with the results of the heatmap analysis, there were five groups of treatment combination for cultivar and gliocompost (Fig. 4), namely 1) LP with gliocompost, 2) TB and LH with gliocompost, 3) TB, LH, and SS without gliocompost and SS with gliocompost, 4) LK with gliocompost, and 5) LK and LP without gliocompost. From these five groups, the use of gliocompost did not affect SS cultivar groups. Meanwhile, the use of gliocompost caused LK to be divided into two groups, although the two groups have no effect on yield per ha or yield per plot. The use of gliocompost had a good effect on the LP, TB, and LH groups. This was line with [38] research that TB, LH, and LP were Indonesia local cultivars which had high yield and was not significantly different with introduced cultivar from Taiwan. Gliocompost as a biocontrol in this research has the potential to be used to overcome the obstacles of the rainy season in the off season by taking into account the condition of the shoots, types of cultivars, and planting time. This was a new hope for the development of garlic in Indonesia. Meanwhile the use of gliocompost on short-aged cultivars (SS and LK) which were planted after sprouting and harvested late did not succeed in increasing the yield per ha and yield per plot. [15] reported that the use of biocontrol in the first year could prevent root rot and garlic bulb rot, except for *Bacillus amyloliquefaciens* against Arkus and *Trichoderma asperilium* cultivars for Garpek cultivars. However, in the second year, all disease could be controled including *Phytium oligandrum*. This showed that the ability of each biocontrol was different for each cultivar and required time to obtain the maximum production effect.
As a single effect, LP had a higher percentage of live plants than LK, TB, and SS, but it was not significantly different from LH (Fig. 2a). LP had the character of hard and woody stems, and upright leaves, so it was thought that it could increase resistance to pests and diseases and rain. Meanwhile, LK had a leaf character that spreads, so that the height plant at 10 WAP, caused the plant to be susceptible to pests and diseases in high rainfall and resulting in low bulb diameter (Fig. 2b). [39] stated that high plant growth could increase sensitivity to a disease. Gliocompost did not affect the percentage of live plants, but could increase bulb diameter (Fig. 3a and 3b). Thus gliocompost cannot help increase the percentage of live plants. This might be another factor that affected the percentage of live plants, as discussed earlier that there was the influence of different cultivar group, harvesting age, and planting timing which more affected the percentage of live plants. However, gliocompost could increase bulb diameter (Fig. 3b).

4. Conclusions

The good effect of glicompost was influenced by shoot conditions, types of cultivars, and planting time. But, there was a hope to increase yield of Indonesia local cultivar TB, LH, and LP in off season by gliocompost. The use of gliocompost did not affect the yield per ha of LK and SS, but it could increase the yield per ha of LH, TB, and LP, increased the yield per plot and decrease percentage of production gap of LP. Gliocompost increased bulb diameter. LP had a higher bulb diameter and percentage of live plants than LK.

Conflicts of Interest

We declare that there is no conflict of interest dealing with authors and Indonesian Agency for Agriculture Research and Development (IAARD) that facilitated and funded the research activity

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