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Vermicompost and Biourine Doses Effect on Soil pH, Shallot Growth, and Yield in Ultisol

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ABSTRACT: *Ultisols have a high potential to improve crop production in dryland environment. On the other hand, Ultisols have high soil acidity, an average pH of 4.50, high Al saturation, low availability of macronutrients, particularly P, K, Ca, and Mg, and low organic matter content. Organic fertilization is necessary to overcome these obstacles. Vermicompost and cow bio-urine are two examples of organic fertilizers. The purpose of this study was to determine the optimal dose of vermicompost and cow bio-urine for shallot (Allium ascalonicum L.) growth and yield in Ultisols and their effect on soil pH. The study took place at the Experimental Station of the Faculty of Agriculture in Kandang Limun Village, Muara Bangkahulu District, Bengkulu City, Indonesia. The study employed a two-factors completely randomized design (CRD). The first factor was the vermicompost dose, consisted of three levels: 0 tons/ha, 10 tons/ha, and 20 tons/ha. The second factor was the cow bio-urine dose, consisted of four levels: 0 L/ha (Control); 5,000 L/ha; 10,000 L/ha, and 15,000 L/ha. Treatment combination was separated using orthogonal polynomial test. An increase in vermicompost dose was followed by an increase in plant growth and yield, whereas biourine application had no significant effect on shallot growth and yield. Vermicompost and biourine both increased Ultisol pH, resulting in increased shallot growth and yield.*

Keywords*- Allium, shallot, biourine, Ultisol, vermicompost*

I. INTRODUCTION

Shallots (*Allium ascalonicum* L.) are a popular vegetable in Indonesia because they provide numerous health benefits. According to data from [1], shallot productivity averaged 4.67 tons/ha in 2018 and 4.99 tons/ha in 2019. This yield remains low in comparison to the national average of 10 tons/ha. Thus, it is necessary to increase shallot productivity in Bengkulu Province.

The acidic nature of the soil in Bengkulu contributes to the low productivity of shallots in the province. Shallots require loose soil, plenty of humus, a pH of 5.5, and an air temperature of 25-32^{o}C with 12 hours of sunlight per day [2] [3] [4]. Shallots are suitable in dry lowland environment [4]. Bengkulu Province has 4.57 million ha of dry land, but the majority of it is acidic. Ultisols is a type of dry acid soil in Bengkulu [5].

Ultisols are unsuitable for plant growth and development due to high soil acidity (pH 3.5-5.5), low organic matter content (less than 2%), low cation exchange capacity (CEC), and low nutrient content, particularly N, P, K, and Ca [6]. The high soil acidity causes nutrient deficiency in plants and high dissolved Al, Fe, and Mn, which affect the plant growth. Therefore, plants cannot grow and produce properly [7] [8]. Adequate organic input is required to solve this problem [9].

Organic matter improves soil fertility by enhancing the soil physical, chemical, and biological properties. Organic matter serves several functions, including providing macronutrients (N, P, K, Ca, Mg, and S) and micronutrients (Zn, Cu, Mo, Co, B, Mn, and Fe) and increasing the cation exchange capacity (CEC) of the soil. It also forms complex compounds with metal ions such as Al, Fe, Mn and acts as a "binder" in the formation of soil aggregates and as a source of energy and food for soil microbe [10]. Some of the organic materials used as fertilizers are vermicompost and cow biourine.

Vermicompost is a solid organic fertilizer made from earthworm excretions. The addition of vermicompost to soil can improve the physical properties of the soil, such as structure, porosity, permeability, and water retention [11]. Vermicompost has a pH range of 6.5 to 7.5 [12], and its use can potentially reduce soil acidity. According to [13], vermicompost at a dose of 14 tons/ha increased the pH of Ultisols by 0.4. Additionally, vermicompost can considerably lower soil acidity, while biourine can supply plant nutrition.

Cow biourine is a liquid organic fertilizer derived from the anaerobic fermentation of cow urine and feces added with nutrients involving microorganisms [14]. Cow biourine contains N (2.7%), P (2.4%), K (3.8%), Ca (5.8%), pH (8.7), and naturally containing plant growth regulators such as auxin and gibberellins [15] [16]. Biourine is an alternative fertilizer to reduce the use of synthetic fertilizers for agricultural production. A 225-250 kg cattle can produce 5-6 liters of cow urine per day [17]. Application of biourine at a dose of 20 ml/plant at a concentration of 40% increased the height of mustard by 77% compared to without biourine [18]. [19] reported that applying biourine at a rate of 7000 L/Ha at a 40% concentration increased shallot bulbs' dry weight and diameter. The study aimed to obtain the optimal dose of vermicompost and cow biourine on the growth and yield of shallots in Ultisols and their effect on soil pH.

II. METHODOLOGY

The experiment was carried out at the Experimental Station and Soil Science Laboratory, Faculty of Agriculture, Bengkulu University, Indonesia, using a completely randomized design (CRD) with two factors, and repeated three times. The first factor was the dose of vermicompost consisting of 3 levels, namely V_0=without vermicompost, V_1=20 g/polybag (10 tons/ha), and V_2=40 g/polybag (20 tons/ha). The second factor was the dose of cow biourine consists of 4 levels, namely B_0 = without cow biourine, B_1 = 10 ml/polybag (5,000 L/ha), B_2 = 20 ml/polybag (10,000 L/ha), and B_3 = 30 ml/polybag (15,000 L/ha).

Biourine Process

Cow biourine ingredients consist of 20 L of cow urine; 1 kg of solid cow dung; 10 L of water; 250 ml decomposer; and 200 ml of molasses. Other ingredients are a mixture of 125 g turmeric (*Curcuma longa*) + 125 g ginger (*Zingiber officinale*) + 125 g kencur (*Kaempferia galanga*) + 125 g lemongrass (*Cymbopogon*) , which has been mashed and dissolved in 1 L of water (Efendi and Kosmana, 2015). All ingredients were placed in the barrel and stirred for 15 minutes before being left closed for 35 days. The mixture was incubated for 35 days and stirre every day. After incubation, biourine was filtered and stored in a sealed container. Before the application, the biourine was mixed for 5 minutes and dissolved in water to a % concentration of 400 mL biourine in1000 mL water.

Planting

The soil sample was collected at the depth of 20-30 cm. The sample was air-dried for 24 hours and the litter was sifted to remove any remaining debris. Additionally, each 30 cm x 30 cm polybag contained 4 kg of soil fertilized by TSP (150 kg/ha) and vermicompost at the treatment dose. Planting spacing between polybags was 15cm x 15cm.

Bulbs plantings were of medium size (diameter 1.5 cm). The bulbs were then soaked in water for 60 minutes, dried for 20 minutes, and coated with 80 percent Mankozeb before planting. Each polybag contained one bulb and palced 3 cm below the soil surface.

TSP and vermicompost were applied three days before planting. Biourine was applied two times, each half of the prescribed dose. The first biourine application was 14 days after planting (DAP), and the second was 21 DAP by pouring onto the soil surface. NPK was applied 10 DAP. Watering was done regularly to keep the soil moist, and weeding was done once a week mechanically. Harvesting took place 62 DAP after the leaves had turned yellow (>70%) and the onion bulbs had emerged to the surface

Observed variables

The variables observed consisted of soil pH, plant height (cm), number of leaves, fresh root weight (g), number of bulb, fresh bulb weight (g), dry bulb weight (g), bulb diameter (mm). Initial soil characteristics such as pH, N, P, and K ware analysed before planting, vermicompost was tested for N, P, K, and C-organic, while biourine for pH, N, P, K, and C-organic.

Data analysis

The data were analyzed statistically using Analysis of Variance (ANOVA) and the F test at a 5% level. The treatment combination was tested using Orthogonal Polynomials.

III. RESULTS AND DISSCUSSION

Figures 1, 2, 3, and 4 show the development of plant height and the number of leaves at 2 to 6 WAP as affected by vermicompost and biourine.

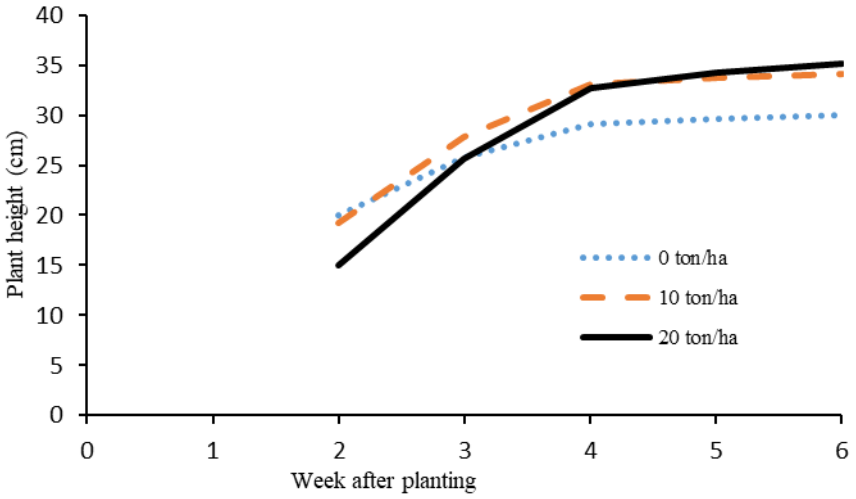

Figure 1. Effect of vermicompost on onion plant height

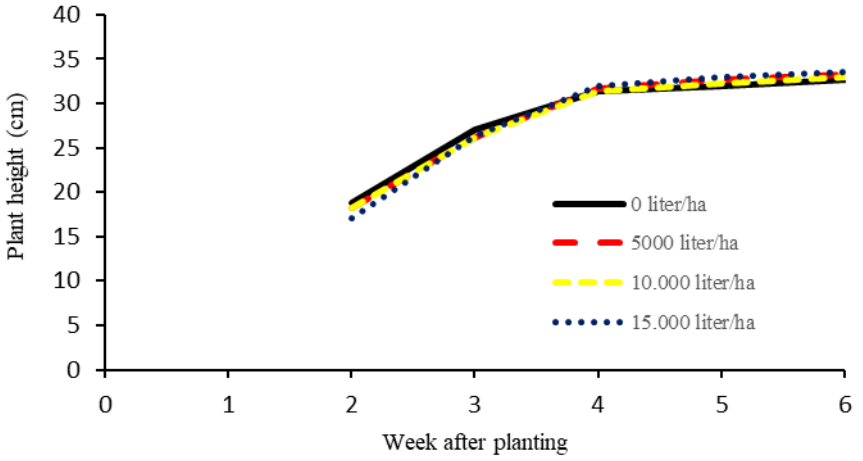

Figure 2. Effect of biourine on onion plant height

Plant growth are dependent on internal factors (genetic and hormonal) and external factors (nutrients and environment). Plant growth is the irreversible process of increasing the volume of a plant by increasing the size of the plant morphology, i.e., plant height [20]. As illustrated in Figure 1 and 2, the plant height increases every week. The plant growth is an indicator of the process of plant development. The division of active meristem cells causes this increase in plant height. Plant height increased rapidly from 1 to 4 WAP and then began to slow down at 5 WAP (Figure 2). Plant height decreases because the tuber filling process starts at 4 WAP. According to [21], photosynthate allocation is intended for tuber filling. The process of filling the tuber causing plant growth to slow down or decline.

The number of leaves is also an indicator of plant growth. Plants depend primarily on leaves as photosynthetic organs. Consequently, if the number of leaves production is low, so is the quantity of photosynthate produced [22].

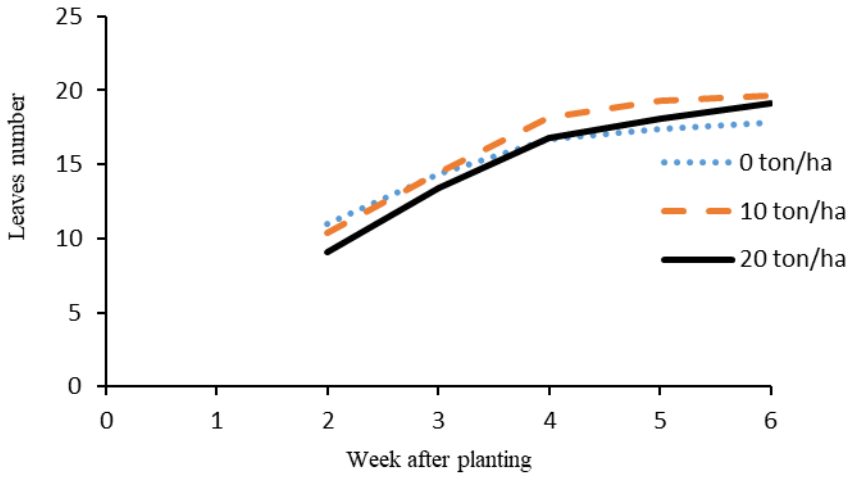

Figure 3. Effect of vermicompost dose on number of leaves

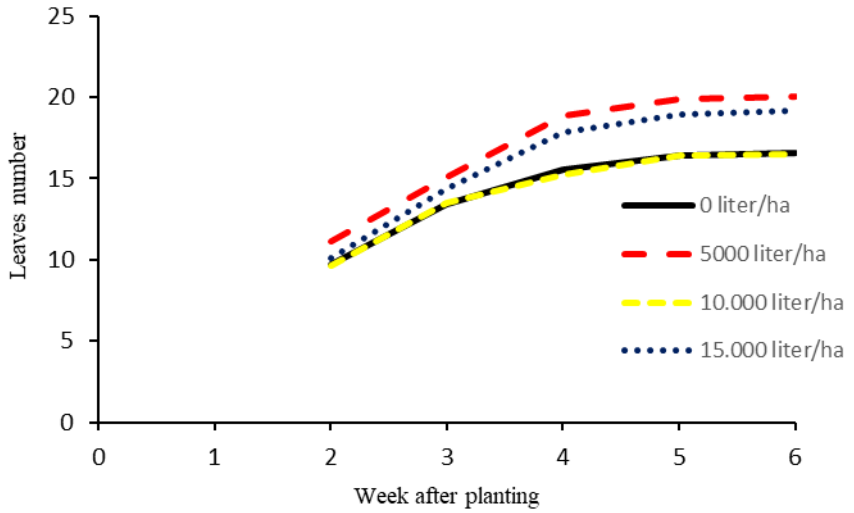

Figure 4. Effect of biourine dose on number of leaves

The increase in the number of shallots at 2-4 WAP indicates normal vegetative plant growth. [23] stated that the number and size of cells play an essential role in leaf formation. It is also influenced by nutrients absorbed by plants to form amino acids in leaf chlorophyll, which is used for photosynthesis. The effect of vermicompost and cow biourine treatment was observed at the 2nd to 4th week after planting.

The variance analysis revealed no interaction between vermicompost dose treatment and biourine dose on any of the shallot plant variables. Vermicompost significantly affected plant height, fresh root weight, fresh tuber weight, dry tuber weight, tuber diameter, and soil pH while Biourine has a significant effect on soil pH but no impact on other variables.

Table 1. Summary of F-calc. treatment of vermicompost and biourine doses on shallot plants

Variables	F-calc.			CV(%)
	Vermicompost	Biourine	Interaction	
Plant height	42.67*	0.7^{ns}	1.99^{ns}	4.36
Leaves number	1.05 ^{ns}	2.86^{ns}	1.56^{ns}	17.1
Fresh root weight	42.19*	0.54^{ns}	0.98^{ns}	22.6
Bulb number	1.56 ^{ns}	0.75^{ns}	0.51^{ns}	21.7

Bulb fresh weight	14.68*	2.74^{ns}	1.38^{ns}	21.5
Bulb dry weight	15.32*	2.26^{ns}	1.78^{ns}	22.3
Bulb diameter	4.07*	0.13^{ns}	2.01^{ns}	11.3
Soil pH	105.62*	10.14*	0.13^{ns}	2.58

Note: * Significantly different, ns: Not significantly different

There is no interaction between vermicompost and biourine. As a result, each factor has an independent effect on plant growth and yield. According to [24], if the interaction effect is insignificant, the treatment factors act independently. Table 2 shows plant height, leaves number, fresh root weight, bulb number, bulb weight, bulb diameter, and soil pH.

Relationship of vermicompost dose with soil pH and plant growth and yield.

The application of vermicompost had a significant effect on the soil pH (Table 1). The pH of the soil is one of the external factors that can affect a plant's growth and yield. Low soil pH reduces the availability of plant nutrients in the soil, resulting in nutrient deficiency and suboptimal plant production [7].

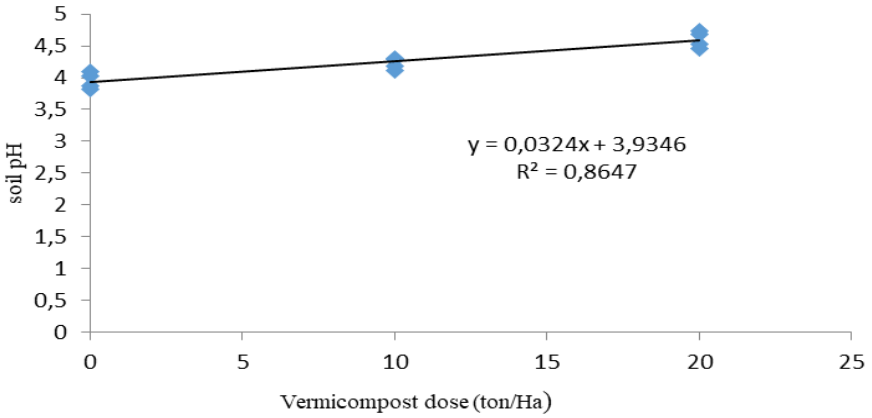

Figure 5. Relationship between vermicompost dose and soil pH

Figure 5 shows, higher dose of vermicompost leads to the higher soil pH. The results showed that the soil pH of vermicompost at 5 tons/ha was 4.10, while at 20 tons/ha 4.58. The incorporation of vermicompost into the soil neutralize Al and Fe, lowering soil acidity. The organic matter in vermicompost decomposes further in the soil, producing organic acids capable of chelating Al metal and increasing soil pH. According to [25], humic acid functional groups (carboxyl groups (COO-) and phenolics (OH-)) form complex compounds or Al chelates, preventing hydrolysis of Al. Non-hydrolyzed Al reduces soil acidity and increases soil pH. In this study, vermicompost with a C-organic content of 15.47 % and a pH of 7.2 was able to raise soil pH, leading to improvement of nutrient availability to plants.

The application of vermicompost also increased the height of onion (Figure 6). The optimum vermicompost dose for plant height was 18.56 tons/ha, resulting in the plant height of 35.2 cm, which was within the Bima variety's 25-44 cm description range.

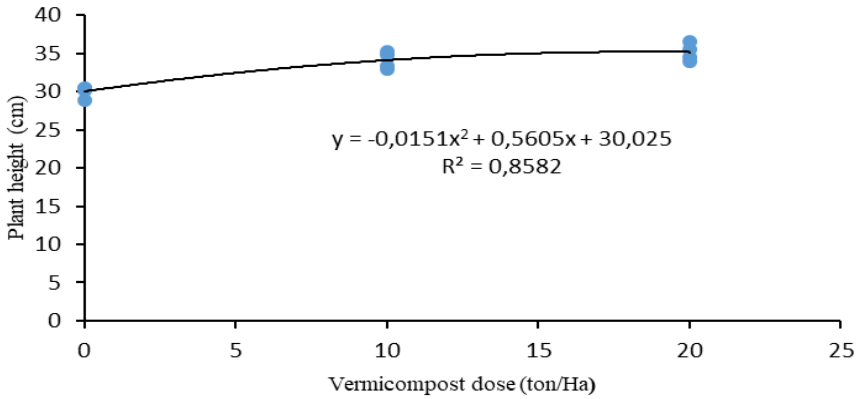

Figure 6. Relationship between vermicompost dose and onion plant height.

This increase in plant height attributes to the rise in the essential nutrient availability to plants. According to [26], vermicompost improves aggregate stability and total soil porosity, allowing plants to absorb nutrients more efficiently. The addition of nutrients to the soil by vermicompost can boost photosynthesis, resulting in higher crop yields [27]. The microbial content in vermicompost also improves soil structure and texture, increasing nutrient absorption by roots into the soil. In addition, the auxin hormone in vermicompost increases plant height [28] and root growth [29].

Aside from increasing plant height, the application of vermicompost also increased the fresh weight of plant roots. Vermicompost at a dose of 20 tons/ha produced a fresh root weight of 2.08 g, whereas that at 5 tons/ha was only 1.15 g (Figure 7).

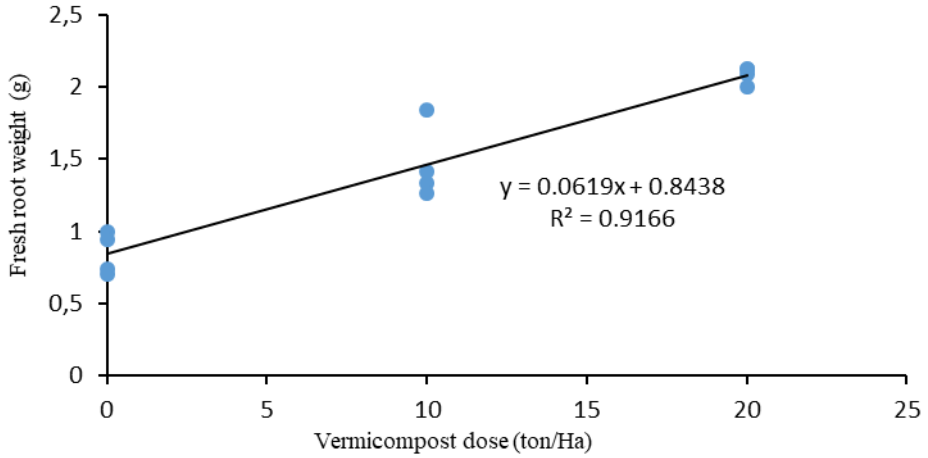

Figure 7. Relationship between vermicompost dose and fresh weight of roots

Root fresh weight is related to root growth and development in soil [30]. According to [31], vermicompost provides the soil more porous, allowing roots to grow and spread quickly to absorb water and nutrients. Vermicompost also contains cytokinin hormones being able to stimulate root formation, causing an increase in fresh root weight.

Vermicompost application increased shallot bulb diameter, fresh weight, and dry weight (Figures 8, 9, and 10). Vermicomposting at a rate of 20 tons/ha resulted in an average bulbs diameter of 14.52 mm, a fresh bulbs weight of 15.42 g, and a dry bulbs weight of 13.88 g.

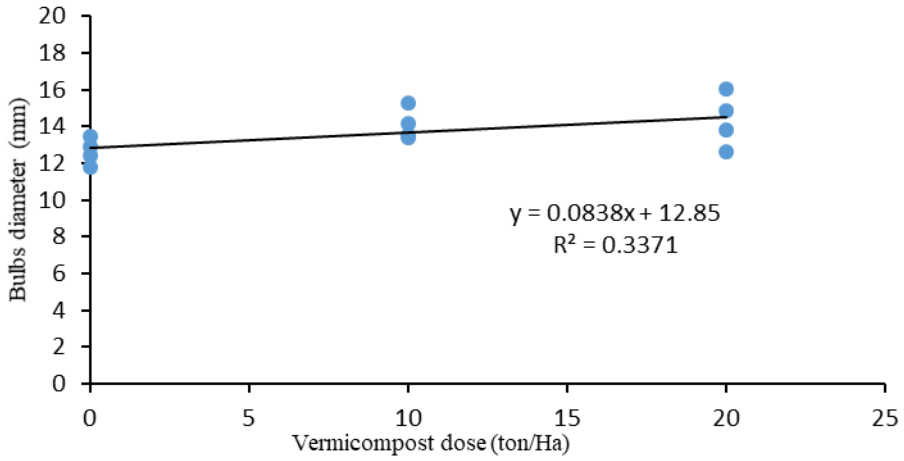

Figure 8. Relationship of vermicompost dose to onion bulb diameter

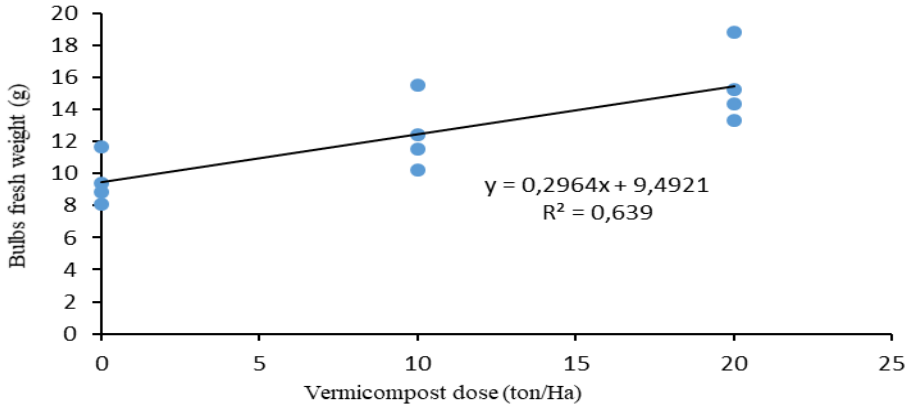

Figure 9. Relationship of vermicompost dose to fresh weight of onion bulbs

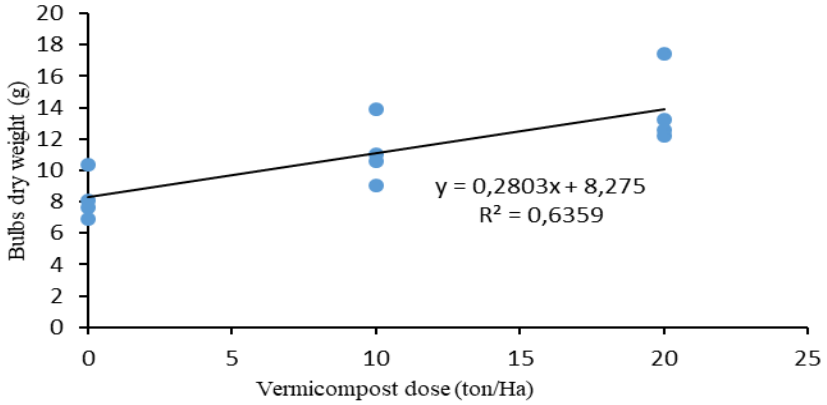

Figure 10. Relationship of vermicompost dose to dry weight of onion bulbs

Vermicompost improves soil physical, chemical, and biological properties to increase soil fertility. Vermicompost contains macro and micronutrients and several growth stimulants that plants require to meet their metabolic needs.

Sufficient nutrient and water will accelerate photosynthesis, resulting in more photosynthate as energy to support cell division and enlargement. As a result, the diameter of the onion bulbs will increase. Bulbs growth is highly related to cell enlargement [32]. [27] stated that higher the photosynthate brings about more food storage. According to Rahayu and Berlian (2004), fertile and loose soil will promote bulbs development resulting in larger and heavier bulbs.

Relationship of biourine dose with soil pH and plant growth and yield.

The use of biourine can raise the pH of Ultisol. The application of biourine at a rate of 15,000 L/Ha increased the pH of the soil to 4.43. (Figure 12).

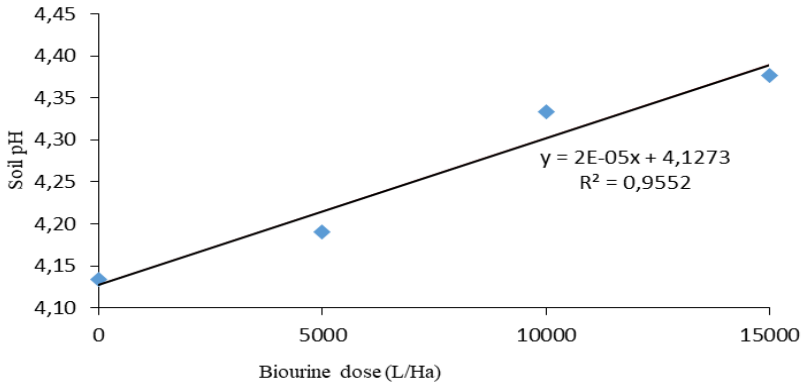

Figure 11. Relationship of biourine dose to soil pH

Higher the dose of biourine leads to higher release of OH^- by the organic acids, increasing soil pH. According to [33], the treatment of 45% biourin or 450 mL/L resulted in a higher pH (7.60) than the control treatment (7.51). Increasing the pH of the soil can improve the availability of nutrients to plants. Biourine can also improve shallot growth and yield [19]. However, the findings of this study revealed that the use of biourine had no significant effect on shallot growth and yield (Table 1). This might be related to high rainfall for shallot growth during the study which was 274 mm/month, while the optimal rainfall for shallots was 25-125 mm/month. High rainfall might cause biourine to leach before being absorbed by plants. Applying fertilizer through the soil has several problems, including nutrient loss due to leaching, evaporation, and soil particle binding.

Table 2. Effect of biourine dose on growth and yield of shallots.

Dose (L/Ha)	Variables						
	PH (cm)	LN	RFW (g)	BN	BFW (g)	BDW (g)	BD (mm)
0	32.64	17.06	1.36	5.06	10.81	9.76	13.89
5,000	33.19	20.31	1.45	5.46	11.73	10.63	13.46
10,000	32.99	17.63	1.49	5.74	13.13	11.19	13.62
15,000	33.60	20.61	1.55	5.90	14.16	12.72	13.78

Note: PH: plant height, LN: leave number, RFW: root fresh weight, BN: bulbs number, BFW: bulbs fresh weight, BDW: bulbs dry weight, BD: bulbs diameter

As indicated in Table 2, cattle biourine at 15,000 L/Ha tended produce higher plant height, leaves, bulbs, fresh bulbs weight, dry bulbs weight, and fresh root weight. [33] on the other hand, discovered that biourine increased soil N-total, growth, and dry weight of spinach plants. Plants require the element N, particularly during the vegetative phase, for photosynthesis. Cell formation, cell extension, and plant tissue thickening require photosynthate.

Correlation between soil pH and onion growth and yield

Correlation analysis was carried to determine the relationship among pH, plant height, number of leaves, number of bulbs, bulbs diameter, bulbs fresh weight, bulbs dry weight, and fresh root weight as shown in Table 3. Positive correlation indicates that the observed characters have a close relationship.

Table 3. Analysis of correlation between variables

Variable	PH	LN	BN	BD	BFW	BDW	RFW
pH	0,83	0,29	0,53	0,50	0,88	0,85	0,92
PH	-	0,55	0,50	0,62	0,87	0,86	0,89
LN		-	0,16	0,13	0,49	0,48	0,35
BN			-	0,39	0,49	0,52	0,39
BD				-	0,62	0,70	0,53
BFW					-	0,98	0,89
BDW						-	0,87
RFW							-

Note: pH: soil pH; PH: plant height, LN: leave number, BN: bulbs number, BD: bulbs diameter, BFW: bulbs fresh weight, BDW: bulbs dry weight, RFW: root fresh weight

The correlation coefficient expresses the strength of the relationship between variables. The correlation coefficients ranged between 0.16 and 0.98. A correlation coefficient of zero indicates no relationship between the two correlated variables.

When the correlation value approaches +1, an improvement in one variable will follow another. The correlation analysis revealed a positive correlation between pH and shallot growth and yield variables (Table 3). Soil pH was positively related to fresh and dry tuber weight with r values of 0.88 and 0.85, respectively. Thus, as the soil pH increased, the fresh weight of shallot bulbs increased.

IV. CONCLUSIONS

An increase in vermicompost dose exhibited higher plant growth and yield, whereas biourine application did not significantly affect shallot growth and yield. Both vermicompost and biourine increased Ultisol pH, resulting in an increase in shallot growth and yield.

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