

Combined application of mulches and organic fertilizers enhance shallot production in dryland

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Abstract. The objective of this study was to determine the type of mulch and organic fertilizer that can induce suitable changes in the microclimate and chemical properties of soil for the promotion of growth and yield of shallot on dryland. A factorial randomized block design experiment with two factors and three replications was constructed. The first factor was mulches consisting of rice straw, coconut husk, silver-black plastic mulch, and without mulch. The second factor was the organic fertilizers composed of either composted cow manure, *Gliricidia* leaf compost (each applied at 5 t ha⁻¹), and no organic fertilizer. Among all treatments tested, straw mulch with 5 t ha⁻¹ cow manure (L₁P₁) decreased the soil temperature from 36 °C to 30 °C and increasing the soil moisture from 7% to 37%. This, in turn, increased the cation exchange capacity by 24.32 meq 100 g⁻¹, pH by 6.83, C organic from 0.74 to 2.72%, C/N ratio by 13.27%, total N by 0.29%, total P from 20.02 to 28.86 mg 100 g⁻¹ and K₂O by 39.16 mg 100 g⁻¹. In addition, the growth and yield of shallot were positively affected, as assessed by plant height, leaf number, root length, root dry weight, total leaf area, number of bulbs per hill, bulb diameter, weight of fresh bulbs, and bulb yield. The yield of bulbs increased from 4.27 to 10.22 t ha⁻¹ after L₁P₁ treatment. This study demonstrates the application of straw mulch and 5 t ha⁻¹ cow manure could enhance the yield of shallot cultivation on drylands.

Key words: *Allium cepa* var. *aggregatum*, rice straw, coconut husk mulches, cow manure.

INTRODUCTION

Palu valley shallot (*Allium cepa* L. var. *aggregatum* G. Don), cultivated in the Palu Valley, Central Sulawesi, Indonesia, is an economically important horticultural plant, used as a raw material in the preparation of fried shallots. Although the potential yield of Palu valley shallot can be as high as 10–12 t ha⁻¹ (Maskar et al., 2001; Central Bureau of Statistics Central Sulawesi, 2016), generally the yield obtained by farmers is only about 5.3 t ha⁻¹ (Central Bureau of Statistics Central Sulawesi, 2016). The low yield of Palu valley shallots is because they are cultivated on less fertile dryland, with low content of soil organic matter and limited water resources (Mulyani & Hidayat, 2009). In addition, the high intensity of sunlight and low rainfall also contribute to the reduced yield of shallots by directly affecting the microenvironment of the plants, especially the soil temperature, which influences the environment around the plants, from their roots to the aerial part.

Soil fertility is closely related to rainfall and climate (Kandiannan et al., 2011; Ann, 2012). It has been suggested that rainfall and the ability of soil to retain water are crucial for improving the quantity and quality of shallot bulbs (Yudiyanto et al., 2014; Rop et al., 2016).

The yield of shallots grown on drylands can be improved by modification of the microclimate by mulching and application of organic matter, as well as by increasing the input of biomass into the soil (Hani et al., 2016). This will help to optimize the use of drylands for shallot cultivation. Mulching helps in stabilizing the soil temperature and promotes moisture retention around roots (Ramakrishna et al., 2006; Hernández et al., 2016; Kader et al., 2017). It also protects the soil surface from the effects of rain and can improve soil physical properties by increasing the soil water infiltration rate and decreasing the erosion (Bhatt & Khera, 2006; Mulumba & Lal, 2008; Gholami et al., 2013). Moreover, the use of mulch as soil cover helps in the control of weeds, and it can improve the availability of soil water by reducing evaporation and increasing the soil organic matter content (Thankamani et al., 2016; Brown & Gallandt, 2018).

The addition of organic matter plays an important role in improving, and sustaining land productivity by improving the physical, chemical, and biological properties of soil. Although no single application can improve the plant growth, the use of organic fertilizers and microclimate management, together with drip irrigation system, can save water and enhance the utilization of organic residues (Sanchez-Martín et al., 2010; Reganold & Wachter, 2016). Previous studies have shown that shallot production in dryland increased by adding bokashi compost and NPK fertilizer (Lasmini et al., 2018). Application of cow dung can be used as organic fertilizer to increase grain yield and effectively reduce soil evaporation (Polthanee et al., 2008; Chang et al., 2016). The application of organic fertilizers to peas and oats significantly increased the dry weight of nodules, the rate of photosynthesis, N₂ fixation, N accumulation in pea plants, N concentration in the grain, carbon (C), N, and P content in the microbial biomass, and fungal ergosterol in soil and CO₂ production (Jannoura et al., 2014).

The improvement of soil biological properties as a result of organic fertilization is indicated by an increase in soil organic C, total N, and abundance of soil microarthropods, as well as by a decrease in soil pH. The abundance of soil microarthropods is positively correlated with soil C and N and negatively correlated with pH (Wang et al., 2015).

The present study aimed to determine the type of mulch and organic fertilizer that can be used to change the microclimate, soil chemical properties, and growth and yield of shallot cultivated on dryland.

MATERIALS AND METHODS

Experimental site and meteorological conditions

This research was conducted at Oloboju village, Sigi Regency, Central Sulawesi, Indonesia, located at an altitude of 120 m above sea level. Soil is of Inceptisol type, and the climate is characterized by air temperature around 34 °C, annual average air humidity of 72.5%, and annual average rainfall of 41.10 mm³. The study was carried out from January 2017 to November 2017.

Plot preparation, seedling, and crop treatments

The experimental field was first cleaned of plant debris and garbage and then plowed with a tractor, then dried and dried, hoed and flattened. Then the soil is spilled again then flattened and made beds (plots) with a size of 300 × 120 (length × width) with a plot distance between 30 cm and a depth of 20 cm. While the 50 cm replicate plot distance with 40 cm depth also functions as a drainage channel. The beds are made in the north south direction.

The experiment was performed in a factorial randomized block design, consisting of two factors. The first factor was the type of mulch used (L_0 = no mulching, L_1 = rice straw mulch, L_2 = coco husk mulch, and L_3 = silver-on-black plastic mulch); the second factor was the type of organic fertilizer used (P_0 = no fertilizer used, P_1 = 5 t ha⁻¹ cow manure, and P_2 = 5 t ha⁻¹ *Gliricidia sepium* compost). In total, there were 12 treatments and each treatment was repeated three times, resulting in 36 experimental units. The number of plants per unit was 120; thus, the total number of plants used was 4,320.

Shallot seedlings used were of the local variety from Palu (*Allium cepa* var. *aggregatum*), obtained from local seed growers in Palu. The seeds were chosen uniformly, and has a shelf-life 2 months. A 5 grams seed were placed into each planting hole in the plot in 20 and 15 cm row and column distances respectively. Cow manure and *G. sepium* compost (5 t ha⁻¹ of each) were applied a week before planting by mixing with the soil of the trial plots. A day before planting, 150 kg ha⁻¹ NPK basic fertilizer was added in all plots as a non-treatment. It is conducted to provide a similar nutrition for the plant in all plots to help the plant growth in the dryland. Rice straw mulch and coconut husk mulch (5 t ha⁻¹ of each), cut to a length of 10 cm, were applied on the surface of the plot directly after planting, whereas silver-on-black plastic mulch was installed on the plot surface one day before planting, with the left and right sides tied with bamboo. Watering was done in the morning and afternoon, or as needed depending on soil conditions. Weeding was performed manually every two weeks after planting.

Data collection

The parameters recorded were plant growth components, namely plant height, leaf number, root length, root dry weight, total leaf area, and bulb diameter; these were measured every week until the of 7 weeks after planting. The number of tillers per hill, bulb weight per clump, and bulb yield per hectare were noted at 8 weeks after planting.

The plant height and root length was measured using a ruler. The number of leaves and bulbs were counted manually per plant, total leaf area was counted as cm² per leaf. The bulb diameter was measured by callipers. The fresh weight of bulbs was measured using balance then air-dried per shallot clump until we had a constant dry weight. Shallot bulb harvested was weighted. The weight of fresh bulbs that had been separated from the leaves and roots, then converted to t ha⁻¹.

Chemical analysis of the soil was carried out in the Laboratory of Soil Science, Faculty of Agriculture, Tadulako University, Palu, Indonesia. Soil was sampled before and after the experiment for each experimental plot. Before the plot constructed and before cow manure and basic fertilizer applied, the soil sample was collected using soil corer (10 cm diameter and 10 cm depth). After harvested, soil sample was collected again using the same soil corer from each plot based on treatments. Chemical soil properties were determined by a combined glass calomel electrode (Ghosh, 1983); soil organic content was measured by wet oxidation method (Jackson, 1973); total

P measured by the method introduced by Olsen et al. (1954); soil total N estimated using modified after Kjeldahl method (Page et al., 1989); available K (Black, 1965); soil temperature, measured with a soil thermometer; air humidity, measured with a thermohygrometer; and light intensity, measured with a flux meter (van-Reeuwijk, 1993).

Statistical analysis

The data were analyzed by *F*-test. In case of significant differences between the treatments, the results were further tested by Tukey honestly significant difference (HSD) test at 5%.

RESULTS AND DISCUSSIONS

Effect of mulch and organic fertilizer on the microenvironment of growing crop

The application of rice straw mulch and cow manure were observed to reduce the soil temperature (Fig. 1) and increased the soil moisture levels (Fig. 2). The highest average temperatures were measured in the L₀P₀ treatment and the lowest in the L₁P₁ treatment (Fig. 1). The highest soil water content was determined in the L₁P₁ treatment and the lowest in the L₀P₀ treatment (Fig. 2). We also found that all of the uncovered plots with mulches had a similar trend to have lower humidity.

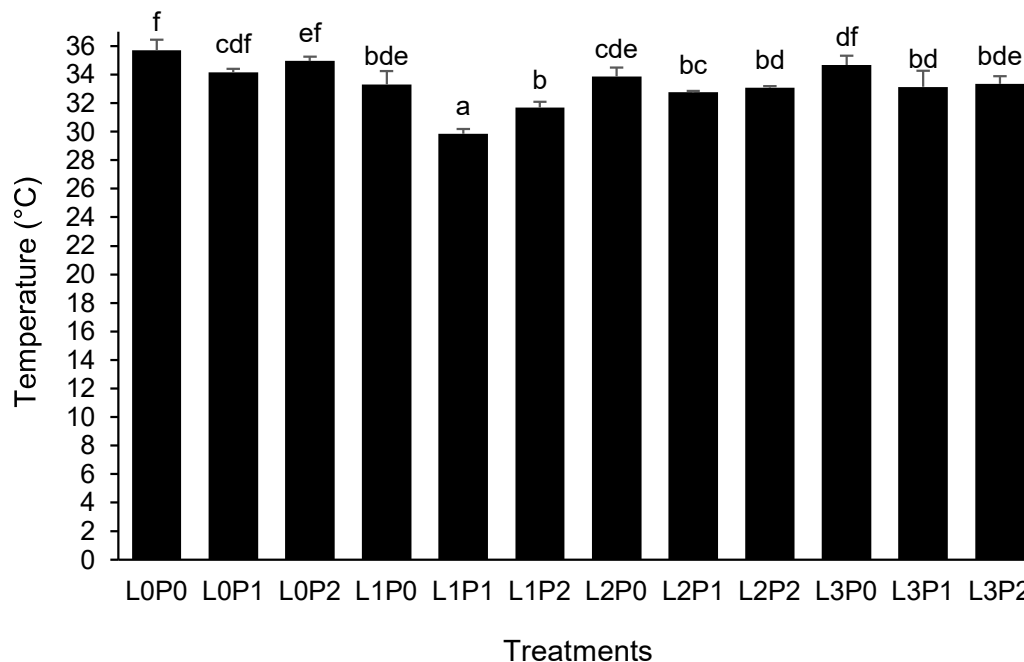


Figure 1. Effect of mulch and organic fertilizer on the average soil temperature. Data shows means ($n = 3 \pm SD$). L₀ = no mulching; L₁ = rice straw mulch; L₂ = coco husk mulch; L₃ = silver-on-black plastic mulch; P₀ = no fertilizer used; P₁ = 5 t ha⁻¹ cow manure; and P₂ = 5 t ha⁻¹ *Gliricidia sepium* compost. Different letters indicate significant differences between treatments after Tukey HSD test with $P < 0.05$.

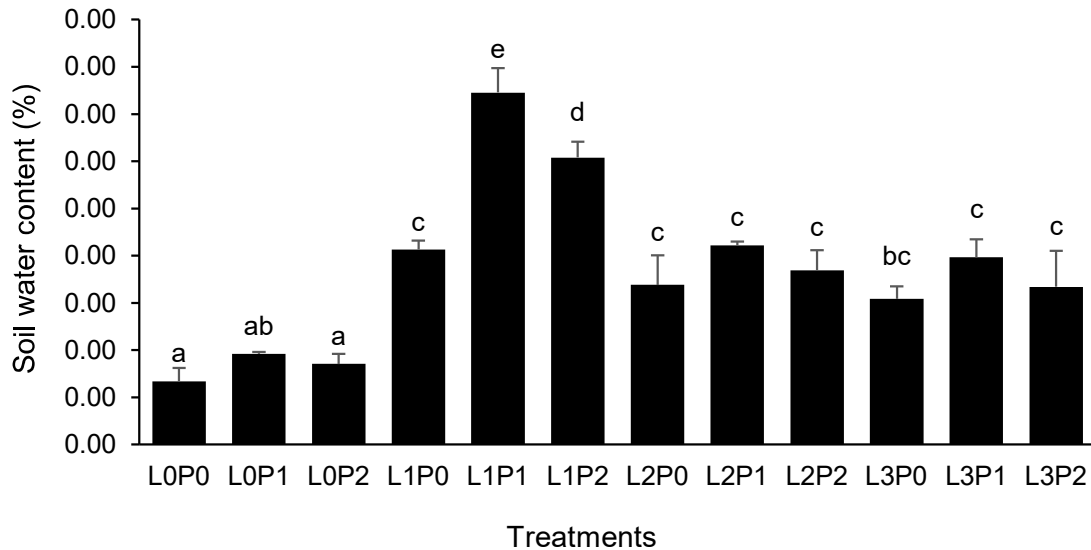


Figure 2. Effect of mulch and organic fertilizer on the soil water content. Data shows means ($n = 3 \pm SD$). L₀ = no mulching; L₁ = rice straw mulch; L₂ = coco husk mulch; L₃ = silver-on-black plastic mulch; P₀ = no fertilizer used; P₁ = 5 t ha⁻¹ cow manure; and P₂ = 5 t ha⁻¹ *Gliricidia sepium* compost. Different letters indicate significant differences between treatments after Tukey HSD test with $P < 0.05$.

In this study, we found that mulches application decrease the temperature and soil water content. Decreasing soil temperature from 3 °C to 30 °C after mulches application showed a favourable growth condition for shallot production (Grubben, 1990; Sumiati, 1994; Okubo et al., 1999). Mulches application also preserved water than uncovered plant soil. Straw mulch indicate a good performance compared to the silver plastic mulch as presented by L₁P₁ treatment. Organic mulches have been reported in controlling soil temperature, increase water holding, and modified microclimate condition needed for the plant growth (Zhao et al., 2014; Abouzienna & Radwan, 2015; Biswas et al., 2015; Pramanik et al., 2015). Paddy straw abundant in central Sulawesi, it also easy to applied as a mulch. Straw mulch will stick to the soil surface, reflect the sunlight (Ranjan et al., 2017), and reduce the temperature (Noorhadi & Supriyadi, 2003). The effectiveness of rice straw has been studied. It can maintain the stability of soil moisture by reducing water loss from the surface of the soil (McMillen, 2013) and reduce evaporation Dewantari et al. (2015). In addition, straw mulch able to protect the soil from erosion (Unger, 1978; Woldetsadik, 2003; Manickam et al., 2016).

Effect of Mulch and Organic Fertilizer on Soil Chemical Properties

The application of rice straw mulch and cow manure (5 t ha⁻¹ each) increased the cation exchange capacity (CEC), total N content, available P, K, soil organic C, C/N ratio, and pH of the soil (Table 1). The increasing of CEC in the soil with the application of straw mulch and cow manure was caused by the increase of C-organic content in soil (Table 1).

The amendment of straw mulch and cow manure (L₁P₁) showed a significant effect ($P < 0.05$) on organic C, C/N ratio, N-total, P-total, available K and CEC, but not

significantly different on soil pH (Table 1). Organic C increased by 411%, C / N ratio 85%, N total 222%, P total 44%, K₂O 42% and CEC 84% compared to L₀P₀. This finding was also reported by Meena et al. (2016), organic materials in the form of compost and straw mulch increase the soil fertility as indicated by increasing organic C, N, P, and K.

The application of straw mulch and cow manure also provided the highest levels of P and K (Table 1). Besides releasing inorganic P, decomposition and mineralization of organic matter may release molecules such as nucleic acids and organic P, which can be utilized by the plants. This was in agreement with the results of a previous study in which rice straw mulching (6 t ha⁻¹) in the red chili crop in dry season could increase soil moisture, nutrient content of N, P, and K, organic C content, and soil organic matter and reduce soil temperature (Harsono, 2012).

Table 1. Effects of application of mulch and organic fertilizer on chemical properties of soil

Treatments ^a	pH (H ₂ O)	Organic C (%)	C/N ratio	Total N (%)	Total P (mg 100 g ⁻¹)	K ₂ O (mg 100 g ⁻¹)	CEC ^b (meq 100 g ⁻¹)
Bare soil plots	6.17a	0.75 g	7.58 fg	0.14 ab	21.54 h	27.64 gh	14.30 h
L ₀ P ₀	6.03 a	0.74 g	7.16 g	0.09 b	20.02 i	27.55 gh	13.21 h
L ₀ P ₁	6.10 a	1.44 de	8.94 e	0.13 b	20.12 i	29.73 ef	17.91 e
L ₀ P ₂	6.14 a	1.93 c	8.64 e	0.12 b	22.63 gh	28.85 fg	17.64 ef
L ₁ P ₀	6.29 a	0.97 gf	9.16 e	0.18 ab	24.28 def	27.08 h	16.36 fg
L ₁ P ₁	6.83 a	2.72 a	13.27 a	0.29 a	28.86 a	39.16 a	24.32 a
L ₁ P ₂	6.10 a	2.33 b	12.69 ab	0.23 ab	26.84 b	31.01 e	20.43 b
L ₂ P ₀	6.05 a	0.79 g	8.36 ef	0.12 b	23.19 fg	27.62 gh	16.17 g
L ₂ P ₁	6.25 a	1.81 c	11.13 cd	0.17 ab	25.85 cd	35.53 bc	20.13 bc
L ₂ P ₂	6.40 a	1.28 ef	10.83 d	0.21 ab	24.73 ce	36.64 b	18.49 de
L ₃ P ₀	6.02 a	0.68 g	8.37 ef	0.13 b	23.51 ef	28.47 fh	15.73 g
L ₃ P ₁	6.37 a	1.78 de	12.04 ef	0.22 ab	24.98 fg	33.26 e	19.38 eg
L ₃ P ₂	6.30 a	1.31 bc	11.83 ef	0.23 ab	24.19 def	34.53 ef	18.85 def

^aBare soil plots (soil in the plots before planted), chemical properties were determined for soil in plots before planting of shallot plants and application of mulch and fertilizer. L₀ = no mulching; L₁ = rice straw mulch; L₂ = coco husk mulch; L₃ = silver-on-black plastic mulch; P₀ = no fertilizer used; P₁ = 5 t ha⁻¹ cow manure; and P₂ = 5 t ha⁻¹ *Gliricidia sepium* compost. ^bCEC: cation exchange capacity.

Values followed by the same letter in the same column are not significantly different at 5% level as assessed by Tukey honestly significant difference test.

The increasing of soil pH from 6.17 to 6.83 and C-organic from 0.75 to 2.72 (Table 1) may relate to the amendment of straw mulch with cow manure. Cow manure in its decomposition process will produce organic acids, such as humic acid and fulvic acid (Stevenson, 1994). Organic acids will react with metal cations such as Al, Fe, Mn, Zn, and Cu to form chelates so that they can become buffers which causes pH stability. In addition, organic matter is also reported to increase soil pH since organic acids produce alkaline cations (Djuniwati et al., 2007).

The role of cow manure on increasing CEC and nutrients N, P and K in the soil is related to the mineralization process which releases complete nutrient minerals (N, P, K, Ca, Mg and S, and micronutrients) that can be used by plants (Tisdale et al., 1985). The use of straw mulch will decompose to be organic matter and CEC (Chen & Weil, 2010).

Effect of Mulch and Organic Fertilizer on Shallot Growth and Yield

The application of mulch and organic fertilizer in shallot cultivation improved the plant growth (Table 2) and bulb yield of shallot (Table 3). Compared with other treatments, straw mulch and cow manure treatments increased more effectively the plant height, leaf number, total leaf area, root dry weight, root length, number of bulbs per hill, weight of fresh bulbs, and bulb yield per hectare.

Table 2. Changes in growth of shallot plants as a response to the application of mulch and organic fertilizer

Treatment	Growth				
	Plant height (cm)	Number of leaves	Leaf area (cm ²)	Root dry weight (g)	Root length (cm)
L ₀ P ₀	20.41 c	22.41 c	208.76 g	1.01 bc	13.49 b
L ₀ P ₁	20.43 c	23.80 bc	227.27 g	0.71 cd	13.12 b
L ₀ P ₂	23.68 ab	23.67 bc	271.03 f	0.98 bc	13.31 b
L ₁ P ₀	22.57 b	25.13 bc	283.01 ef	1.02 bc	13.20 b
L ₁ P ₁	26.05 a	37.63 a	569.32 a	1.63 a	16.67 a
L ₁ P ₂	24.91 a	30.87 b	476.89 b	1.34 ab	13.45 b
L ₂ P ₀	22.41 b	25.73 bc	278.59 f	0.63 d	12.65 bc
L ₂ P ₁	23.00 b	25.87 bc	338.01 d	1.27 b	12.62 bc
L ₂ P ₂	24.96 a	24.97 bc	319.62 de	1.18 b	11.20 c
L ₃ P ₀	22.86 b	23.60 bc	210.56 g	1.01 bc	11.89 bc
L ₃ P ₁	22.43 b	25.13 bc	382.79 c	1.23 b	12.46 bc
L ₃ P ₂	23.29 b	27.45b	324.95 de	0.98 bc	13.58 b

Values followed by the same letter in the same column are not significantly different at 5% level as assessed by Tukey honestly significant difference test. L₀ = no mulching; L₁ = rice straw mulch; L₂ = coco husk mulch; L₃ = silver-on-black plastic mulch; P₀ = no fertilizer used; P₁ = 5 t ha⁻¹ cow manure; and P₂ = 5 t ha⁻¹ *Gliricidia sepium* compost.

Table 3. Changes in yield of shallot plants as a response to the application of mulch and organic fertilizer

Treatment	Yield			
	Diameter of bulbs (cm)	Number of tillers (bulb)	Fresh weight (g plant ⁻¹)	Yield of bulbs (t ha ⁻¹)
L ₀ P ₀	1.47 d	7.33	22.48 d	4.27 d
L ₀ P ₁	1.69 bc	7.33	28.35 d	7.56 c
L ₀ P ₂	1.69 bc	7.00	30.00 d	8.00 c
L ₁ P ₀	1.70 bc	7.67	34.55 bc	9.21 b
L ₁ P ₁	2.06 a	8.00	39.27 a	10.22 a
L ₁ P ₂	1.99 a	8.00	35.57 b	9.48c a
L ₂ P ₀	1.77 b	7.33	29.64 d	7.90 c
L ₂ P ₁	1.60 cd	7.33	33.75 bc	9.00 b
L ₂ P ₂	1.50 cd	7.00	28.31 d	7.55 c
L ₃ P ₀	1.70 bc	7.33	30.81 bc	8.02 c
L ₃ P ₁	1.53 cb	6.33	29.70 d	7.92 c
L ₃ P ₂	1.63 b	7.67	34.28 bc	9.14 b

Values followed by the same letter in the same column are not significantly different at 5% level as assessed by Tukey honestly significant difference test. L₀ = no mulching; L₁ = rice straw mulch; L₂ = coco husk mulch; L₃ = silver-on-black plastic mulch; P₀ = no fertilizer used; P₁ = 5 t ha⁻¹ cow manure; and P₂ = 5 t ha⁻¹ *Gliricidia sepium* compost.

The plant growth (plant height, leaf number and area, root length and dry weight, and bulb diameter) and yield of shallot (weight of fresh bulb) increased with the increase in soil moisture content, CEC, and N, P, K, and organic C contents in the soil in treatments after rice straw and cow manure amendments. Mulch can store and provide water for plants, especially under conditions of water scarcity, thus improving the conservation of water. The application of cow manure increased the growth (Table 2) and yield of bulbs (Table 3) because the N, P, and K contained in cow manure promoted the growth of shallot crop.

Compared to other treatments L1P1, indicate a promising number of tillers, bulb diameter, plant fresh weight, and bulb yield. The increase in of growth parameters may affect by N in cow manure combined with higher straw mulch compared to without organic fertilizer, which contributes to the increasing of vegetative growth of the plants. This is in agreement with Liu et al. (2017) that N elements can encourage the growth of plant organs to increase the number and size of plant cells. Abdissa et al. (2011) also reported that N plays role in the formation of amino acids, proteins, nucleic acids, enzymes, nucleoproteins, and alkaloids, which are needed in the process of plant growth, especially the development of leaves and plant saplings. In addition, the role of P in stimulating root growth and as a basic component in the formation of certain proteins for accelerating tuber formation. Phosphorus is a component of enzymes, proteins, ATP, RNA, and DNA, which have important functions in the photosynthesis. Adequate P can improve the development of roots and plant carbohydrate content, which ultimately increases plant growth and yield (Singh et al., 2000).

Nitrogen, phosphorus, and potassium also has been reported able to increase the size of tuber, total fresh weight of plants and number of tuber products per hectare. Potassium is important for the formation of proteins and carbohydrates, facilitating photosynthesis and increasing photosynthate translocation to plant parts, subsequently, improve the crop yields (Ali et al., 2007; Mozumder et al., 2007; Islam et al., 2008; Faten et al., 2010).

CONCLUSIONS

The application of rice straw mulch and cow manure (5 t ha⁻¹ of each) to shallot crop lower the soil temperature and improve the moisture, pH, content of N, P, K, and organic C, CEC, and the C/N ratio in the soil. This study has shown that the application of mulches and organic fertilizers increase the yield of shallot bulbs significantly from 4.27 to 10.22 t ha⁻¹.

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