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A Study of the Efficacy of Various Nutrient Sources on the Growth and Yield of Cabbage

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ABSTRACT

Research evaluated various nitrogen sources, and a supplementary foliar fertilizer or biochar on cabbage. It was conducted from July to October 2014 in Poncokusumo, Malang ca. 600 meters above sea level. The experiment used a randomized block design with four replications. The treatments were fertilized with different concentrations of urea, goat manure and selected substances i.e. 100% N urea (controls); 75% N urea + 25% N goat manure; 50% N urea + 50% N goat manure; 75% N urea + 25% N goat manure + foliar fertilizer (6-30-30), 50% N urea + 50% N goat manure + foliar fertilizer (6-30-30); 75% N urea + 25% N manure + biochar; and 50% N urea + 50% N goat manure + biochar. The dose of N fertilizer used was 69 kg ha^{-1}. The results showed that a higher yield was recorded in the application of 75% N urea + 25% N goat manure and 50% N urea + 50% N manure with an addition of foliar fertilizer that was not significant with the application of 75% N urea + 25% N goat manure with the addition of biochar, resulting in a marketable yield of 68.84, 66.5 and 64.75 t ha^{-1}, respectively.

INTRODUCTION

Indonesia is one of the top five producers of cabbage in the world, on the fifth rank after China, India, Russia and the United States. Although it is among the top five producers in the world, Indonesia still produces less than the average volume of cabbage worldwide. The data from the Ministry of Agriculture (2013) showed that from 2010 to 2013, the average volume of cabbage production in Indonesia ranged from 20.51 to 22.56 t ha^{-1}. This amount was far below the volume production in Australia, which produced more than 30 t ha^{-1}, Japan (more than 40 t ha^{-1}) and Germany (more than 50 t ha^{-1}) (Adiyoga et al., 2004).

One cause of the cabbage low production in Indonesia is the decline of soil fertility. Soil fertility is a major obstacle to increase agricultural productivity (Kearney, Fonte, Salomon, Six, & Scow, 2012). According to Setyowati, Muktamar, & Puspitasari (2015), a conventional agriculture has made synthetic fertilizer an important agrochemical ingredient to increase plant productivity as it allows a quick release of plant nutrients. However, a continuous agrochemical application would reduce soil fertility. The increased use of chemical fertilizers in crop fields creates environmental problems such as water, air and soil pollution (Hossain et al., 2015). Chen (2006) suggested that the basis for an integrated-nutrient management system rested on the optimal level of soil fertility and nutrient supply for a crop. It is urgent to strengthened the fertilizer management and improve fertilizer use for efficiency of an agricultural system (Guo et al., 2011).

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Integrated-nutrient management systems can enhance the growth and yield of cabbage with a proper environment maintenance. Considering the limited use of organic nutrients, the use of mineral fertilizers is a way to meet the need of plant nutrients and reduce depletion of soil nutrient (Twomlow et al., 2010). A study by Setyowati, Muktamar, & Puspitasari (2015) showed that utilization of synthetic fertilizer combined with organic fertilizer was necessary to facilitate the availability of nutrients to plant and to improve soil properties. Olaniyi & Ojetayo (2011) suggested that for sustainable crop production, an integration of chemical and organic fertilizers is beneficial. Organic fertilizers play multiple roles, such as increasing soil productivity and yields as well as improving crop quality (Pour, Moghadam, & Ardebili, 2013). Sridhar, Rajesh, Omprakash, Prathyusha, & Devi (2014) highlighted that preserving soil health had become a prerequisite for maintaining higher productivity in intensive agricultural production systems. Developing a suitable nutrient management system by integrating various nutrient sources has become a challenge in achieving the goal of sustainable agriculture (Chen, 2006).

Cabbage is a heavy feeder crop, requiring a high rate of N for growth and head yield development. N-deficiency has a negative effect on growth and yield of cabbage (Hasan & Solaiman, 2012). According to Chaudhary, Bhanvadia, & Parmar (2015), the nitrogen supply results in more chlorophyll content, which accelerates the photosynthetic rate, thereby increasing the supply of carbohydrates. The better availability of nitrogen also favors metabolic and auxin activities and vegetative growth, head weight, TSS, dry matter percentage and head diameter. Nitrogen increases the growth and yield on most crops, particularly leafy vegetables including cabbage. The application of nitrogen was found in inorganic fertilizers can enhance the growth and yield by a considerable extent, but soil fertility and productivity cannot be retained over a longer period. Therefore, it is important to supplement urea with organic sources of nitrogen (Dalal, Bharadiya, & Aghav, 2010). Chatterjee (2008) stated that the excess nitrogen increases the total of dry biomass but reduces head quality, causing coarse and loose heads, enhances nitrate nitrogen content in the head and above all, deteriorates soil health. Therefore, nitrogen management significantly influences crop growth, head yield and soil health (Chatterjee, Bandhopadhyay, & Jana, 2014).

Farm yard manure is a good organic fertilizer. Hardjowigeno (1985) claimed that manure from different animals has different properties. Goat manure contains two times more N and K content than cow manure. Goat manure undergoes fermentation and heats up more quickly than cow manure or pig manure. (Kowaljow, Mazzarino, Satti, & Jiménez-Rodríguez (2010) suggested that organic fertilizers could enhance soil organic C, total N, extractable P and mineralization of N. Organic amendments are able to provide a balance and regular plant nutrition through gradual decomposition by microorganisms, slower mineralization and slower release. Farm yard manure can improve the property of soil physics, good for root development and plant growth, in order to obtain yields with higher quality (Chatterjee & Paul, 2014). According to Hossain et al. (2015), the use of organic manure improved soil texture and structure, color, aeration, water holding capacity and microbial activity of the soil.

Some efforts to improve the quality of soil can be done by utilizing a soil-fixing agent. Such agents should be selected from biochar, in order to retain longer in the soil (Rostaliana, Prawito, & Turmudi, 2012). The materials that are difficult to decompose, for example, potential for application of charcoal or biochar in Indonesia is high because of the abundant raw materials, such as wood residue, coconut shell and rice hull (Gani, 2009). Biochar improves the quality of the soil due to its high pH, as well as its high C-dependent content and surface area (Latuponu, Shiddieq, Syukur, & Hanudin, 2011). According to Nair & Lawson (2016), the benefits of biochar application in soil were organic matter addition, retention of nutrient and its recycling, increased the activity of microbial and long-term sequestration of carbon. Utilization of biochar by farmers is low due to the lack of information on the influence of biochar on crop production in the long term.

Nutrient availability for cabbage can be increased through the application of foliar fertilizer. One way to increase crop production and fertilizer efficiency is by fertilization through the leaves of a plant. Some nutrients that are effectively absorbed through the leaves of plants are N, P, K, S, Ca and Mg. One benefit of using foliar fertilizers is the immediate response of the crops because these fertilizers contain micro elements that can be quickly utilized by the crops (Munir & Arifin, 2010). Foliar applications are commonly recommended to correct nutritional deficiencies in crops. Also note that additional fertilization during plant growth improves plant mineral status, and this can increase the yield of crops (Sady, Rozek, Domagała-Świsątkiewicz, Wojciechowska, & Kołton, 2008). Rosmarkam & Yuwono, (2002) suggested that the acceleration of nutrient absorption is also affected by the nutrient status of the soil. If the nutrient content in the soil is low, nutrient absorption through the leaves is quick, and vice versa. Meanwhile, according to Buckman & Brady (1982), another benefit for using foliar fertilizers is that if the fertilizer drops on the soil, it can still be utilized by the crops. Foliar fertilization will assist in nutrient absorption, particularly if the roots of the crops are subjected to less favorable conditions, such as cold air and nematode infection (Miller & Donahue, 1990). Supplementary foliar fertilizer can reduce the application of fertilizer through soil and may appear attractive as a more environmentally-friendly practice (Kolota & Osinska, 2001).

This research aimed to: evaluate the efficacy of various nitrogen sources on cabbage; evaluate the use of a supplementary foliar fertilizer or biochar on a combination of inorganic and organic sources of nitrogen on cabbage; and determine the combination and proportion of nutrient sources suitable for cabbage production.

MATERIALS AND METHODS

The research was conducted from July to October 2014 on the paddy field in Wononomulyo Village, Poncokusumo Subdistrict, Malang Regency, at the altitude of 600 m asl (meter above sea level). The type of soil was andosol with pre-plant soil tests showing an acidity level of pH (H_2O) = 5.4 (acid), C-Org (%) = 1.13 (low), total N (%) = 0.11 (low), C/N = 10 (low), P Bray1 (mg kg^{-1}) = 30.67 (high), K = (me.100 g^{-1}) = 0.48 (medium). Materials used in the research included cabbage Grand 11 variety, goat manure (1.28 % N, 0.25 % P_2O_5, 0.53 % K_2O, C-org 16.83 %, C/N 13), biochar composed of burnt rice hull, inorganic fertilizers using urea (46 % N), SP-36 (36 % P_2O_5) and KCl (60 % K_2O) and foliar fertilizer (6-30-30).

The research used a randomized block design with four replications. The treatments were K_0 = 100 % recommended N fertilizer dose (control), K_1 = 75 % N urea + 25 % N goat manure, K_2 = 50 % N urea + 50 % N goat manure, K_3 = 75 % N urea + 25 % N goat manure + foliar fertilizer (6-30-30), K_4 = 50 % N urea + 50 % N goat manure + foliar fertilizer (6-30-30), K_5 = 75 % N urea + 25 % N goat manure + biochar, and K_6 = 50 % N urea + 50 % N goat manure + biochar.

The plot size used for the research was 3.6 m x 4.8 m. The dosage of N fertilizer was 150 kg ha^{-1} urea (69 kg N ha^{-1}), SP-36 and KCl as basic fertilizer at the dosage of 139 kg ha^{-1} (50 kg P_2O_5 ha^{-1}) and 84 kg ha^{-1} (50 kg K_2O ha^{-1}), respectively, which was applied 7 DAP (days after planting). Urea was applied three times i.e. 7, 28 and 49 DAPs, of which each was a third of the treatment dosage. Application of goat manure was done during soil cultivation by dosage in accordance with each treatment by scattering the manure evenly over the soil surface and then tilling thoroughly. Biochar was applied simultaneously during soil cultivation at the dosage of 20 t ha^{-1}, scattering evenly all over the soil surface and then tilling thoroughly. The seedlings (at about 3 weeks old) were transplanted at 40 cm x 40 cm spacing.

Observation was recorded on growth parameters and yield attributes. Observation on growth parameters included the number of leaves and height and diameter of stem. Observation on yield was conducted during harvest (85 DAP), and included the weight of crop (per plant and per hectare) and diameter of crop.

Data were analyzed by analysis of variance (ANOVA) to compare the effect of the treatments. If there was a significant difference, the Highest Significant Difference (HSD) test 5 % would be conducted.

RESULTS AND DISCUSSION

Crop Growth

Various combinations of nutrient sources have significant differences on the growth of cabbage. This shows that cabbage responds differently to different combinations of nutrient sources. The results showed that the combination of urea + goat manure with biochar or foliar fertilizer significantly increased the vegetative growth of cabbage including number of leaves, plant height and stem diameter (Table 1, Table 2, Table 3). The same nutrient may be applied using various sources with a possible different effect on the crops. Application of goat manure and other nutrient sources reduces the dependence on inorganic sources of nitrogen for good plant growth.

Table 1. Number of leaves of cabbage as a result of using various combinations of nutrient sources at various ages of the plant

Combination of Nutrient Sources	Ages (DAP)				
	14	21	28	35	42
K_0 (100 % urea)	4.87 a	9.75 a	14.35 a	17.60 a	22.03 a
K_1 (75 % urea + 25 % goat manure)	5.27 ab	10.23 ab	17.07 ab	18.99 ab	23.90 ab
K_2 (50 % urea + 50 % goat manure)	5.13 ab	9.88 a	16.00 bc	18.61 ab	23.37 ab
K_3 (75 % urea + 25 % goat manure + foliar fertiliser)	5.47 b	10.88 b	18.29 c	21.07 b	25.74 b
K_4 (50 % urea + 50 % goat manure + foliar fertiliser)	5.43 b	10.63 ab	17.44 bc	20.37 ab	24.54 ab
K_5 (75 % urea + 25 % goat manure + biochar)	5.33 ab	10.38 ab	17.09 bc	19.31 ab	24.33 ab
K_6 (50 % urea + 50 % goat manure + biochar)	5.23 ab	10.13 ab	16.27 ab	18.88 ab	23.74 ab
HSD 5 %	0.53	0.98	1.95	3.10	2.76

Remarks: Numbers followed by different letters in each column are significantly different at p = 0.05; DAP = days after planting

Table 2. Plant height of cabbage (cm) as a result of using various combinations of nutrient sources at various ages of the plant

Combination of Nutrient Sources	Ages (DAP)				
	14	21	28	35	42
K_0 (100 % urea)	10.62 a	13.11 a	19.96 a	26.13 a	34.14 a
K_1 (75 % urea + 25 % goat manure)	11.04 ab	14.65 ab	21.72 ab	26.63 ab	34.95 ab
K_2 (50 % urea + 50 % goat manure)	10.88 ab	13.84 ab	20.41 a	26.27 ab	34.20 a
K_3 (75 % urea + 25 % goat manure + foliar fertiliser)	11.36 b	16.12 b	24.53 b	27.63 b	37.12 b
K_4 (50 % urea + 50 % goat manure + foliar fertiliser)	11.29 ab	16.00 b	23.00 ab	27.17 ab	36.30 ab
K_5 (75 % urea + 25 % goat manure + biochar)	11.24 ab	15.61 ab	22.24 ab	26.93 ab	35.40 ab
K_6 (50 % Urea + 50 % goat manure + biochar)	10.96 ab	14.07 ab	21.03 a	26.40 ab	34.50 ab
HSD 5 %	0.68	2.73	3.26	1.39	2.84

Remarks: Numbers followed by different letters in each column are significantly different at p = 0.05; DAP = days after planting

Table 3. Stem diameter of cabbage (cm) as a result of using various combinations of nutrient sources at various ages

Combination of Nutrient Sources	Ages (DAP)				
	14	21	28	35	42
K_0 (100 % urea)	0.54 a	0.96 a	1.40 a	1.68 a	2.32 a
K_1 (75 % urea + 25 % goat manure)	0.63 ab	1.03 ab	1.43 ab	1.75 abc	2.45 bc
K_2 (50 % urea + 50 % goat manure)	0.59 ab	0.98 ab	1.41 ab	1.70 ab	2.35 ab
K_3 (75 % urea + 25 % goat manure + foliar fertilizer)	0.67 b	1.08 b	1.50 b	1.82 c	2.53 c
K_4 (50 % urea + 50 % goat manure + foliar fertiliser)	0.66 b	1.04 ab	1.48 ab	1.80 bc	2.51 c
K_5 (75 % urea + 25 % goat manure + biochar)	0.64 ab	1.04 ab	1.47 ab	1.78 bc	2.49 c
K_6 (50 % urea + 50 % goat manure + biochar)	0.61 ab	1.01 ab	1.42 ab	1.72 ab	2.43 abc
HSD 5%	0.09	0.10	0.09	0.10	0.12

Remarks: Numbers followed by different letters in each column are significantly different at p = 0.05; DAP = days after planting

A higher number of leaves was recorded in the application of 75 % urea + 25 % goat manure (K_3), 75 % urea + 25 % goat manure + foliar fertilizer (K_4), 75 % urea + 25 % goat manure + biochar (K_5) and 50 % urea + 50 % goat manure + biochar (K_6) at 14 and 21 DAP. At 28-42 DAP, application of 75 % urea + 25 % goat manure + foliar fertilizer (K_3), 50 % urea + 50 % goat manure + foliar fertilizer (K_4) and 75 % urea + 25 % goat manure + biochar (K_5) caused the growth of a higher number of leaves. The reason for the increase in the number of leaves per plant might be caused by adding goat manure, biochar and foliar fertilizer in relation to the nutrient solubilization (Maghfoer, Soelistyono, & Herlina, 2014). The addition of foliar fertilizer or biochar to the combination of urea and goat manure helped to promote nitrogen supply. Nitrogen supply resulted in higher chlorophyll content, which accelerated the photosynthetic rate, thereby increasing the amount of carbohydrates. The availability of more nitrogen also favored vegetative growth (Chaudhary, Bhanvadia, & Parmar, 2015).

The effect of using a combination of chemical N fertilizer and organic fertilizer was the same as using urea 100 % (Table 1, Table 2 and Table 3). It might be due to the joint action of the manure and chemical fertilizer, which acted as complementary and supplementary elements and resulted a slow but steady adequate supply of nutrients for plant growth. The beneficial effects of using organic fertilizers along with inorganic fertilizers to promote plant growth associated with the synergistic effect of organic fertilizers supplied an adequate amount of plant nutrients, improved the soil's physical condition and solubilized the nutrients in the soil. It should be noted that organic fertilizers are a significant source of macro and micronutrients that are needed by plants (Dalal, Bharadiya, & Aghav, 2010).

The addition of foliar fertilizer and biochar to a combination of urea + farmyard manure can increase nutrient availability and improve nutrient uptake that can increase crop growth. Utilization of various nutrient sources can reduce the application of inorganic fertilizers, reducing the negative effect on the environment as a result of excessive application of inorganic fertilizers. Palm, Myers, & Nandwa (1997) explained that using a combination of both inorganic and organic nutrient sources was a deserved approach in overcoming the problem of soil infertility in small-scale farming. It has been proven that a combination of organic and inorganic nutrient sources can result in synergy that helps growth and increases synchronization of nutrient release and absorption.

The application of foliar fertilizers can promote the growth of cabbage plants. Table 1, Table 2 and Table 3 show that the crop growth characteristic of cabbage increases with the addition of foliar fertilizer to the combination of urea and goat manure. It might be caused by the addition of foliar fertilizer besides increasing the supply of N also increasing the supply of P and K. Potassium played a role in enzyme activation, synthesis of protein, carbon assimilation, osmo-regulation, which were indicated by plant growth, transfer of energy, phloem transport, balance of cation-anion and resistance to stress. Phosphorus played a role in the process of catching and transporting solar energy during carbon assimilation and the formation of phospholipids (Jasim, 2015). According to Yildirim, Guvenc, Turan, & Karata (2007), the advantages of application of foliar fertilizer were rapid and efficient response to plant needs, the need for less of the product and independence of soil conditions. Supplementary foliar fertilization during crop growth can improve the mineral status of plants and increase crop yield.

Biochar application followed by the addition of fertilizer can lead to a better plant growth than if 100 % urea is used. Cabbage grown on soil treated with 75 % urea + 25 % goat manure + biochar (K_5) showed a higher number of leaves and greater plant height than cabbage grown on soil without goat manure and biochar treatment (Table 1 and Table 2). Latuponu, Shiddieq, Syukur, & Hanudin (2011) reported that application of biochar could reduce nitrogen leaching in soil and enable more effective N intake. Better vegetable growth achieved by increasing nitrogen fertilizer is probably due to the increase of nitrogen absorption and the role of nitrogen in chlorophyll synthesis. However, this improves the photosynthesis process and carbon dioxide assimilation, leading to an increase in vegetative growth, such as in the stem diameter (Ng'etich, Niyokuri, Rono, Fashaho, & Ogweno, 2013). Through solubilization of ash in biochar residues caused the nutrients to be readily available, while other nutrients available with the microbial uses (Carter, Shackley, Sohi, Suy, & Haefele, 2013).

Table 4. Weight and diameter of head as a result of using various combinations of nutrient sources

Combination of Nutrient Sources	Marketable Yield		Diameter of Head (cm)
	kg plant^{-1}	t ha^{-1}	
K_0 (100 % urea)	1.28 a	55.69 a	15.67 a
K_1 (75 % urea + 25 % goat manure)	1.40 ab	60.87 ab	18.00 bc
K_2 (50 % urea + 50 % goat manure)	1.32 ab	57.23 ab	16.33 ab
K_3 (75 % urea + 25 % goat manure + foliar fertiliser)	1.58 b	68.84 b	19.17 c
K_4 (50 % urea + 50 % goat manure + foliar fertiliser)	1.53 ab	66.55 ab	19.00 c
K_5 (75 % urea + 25 % goat manure + biochar)	1.48 ab	64.75 ab	18.33 bc
K_6 (50 % urea + 50 % goat manure + biochar)	1.39 ab	60.64 ab	17.67 abc
HSD 5 %	0.28	11.99	2.28

Remarks: Numbers followed by different letters in each column are significantly different at p = 0.05; DAP = days after planting

Yield of Head Cabbage

The yield of cabbage was affected by the nutrient source applied (Table 4). Reducing application of urea to 50 % and substituting with goat manure at the same dosage of N and supplementing with foliar fertilizer (K_3 and K_4) or biochar (K5) resulted in higher yield of head cabbage than was obtained using a combination of other nutrient sources. This showed that with such combination, the crop obtained sufficient nutrients, and the production increased. Among the many factors that led to the better cabbage yield, nutrient supply was one of the essential factors for producing higher quality and production of cabbage.

The yield attributes to cabbage affected by the application of organic-inorganic matter. A higher amount of organic manure and lower levels of inorganic fertilizer influenced the head yield of cabbage. As shown in Table 4, a combination of 75 % urea + 25 % goat manure + foliar fertilizer (K_3), 50 % urea + 50 % goat manure + foliar fertilizer (K_4) and 75 % urea + 25 % goat manure + biochar (K_5) led to an increase in head weight and diameter. The increase in yield might be due to better root development, nutrient and soil water consumption, higher leaves number and larger surface area for photosynthesis and increased food accumulation, uptake of nutrients and water from the soil, a higher number of leaves and a greater surface area for photosynthesis as well as enhanced food accumulation. Head size is directly influenced by the availability of major nutrients to the plant and for satisfactory yield, there must be adequate levels of plant nutrients (Chatterjee, 2010).

Supplemental foliar fertilizer used together with a combination of urea and goat manure increased diameter head and marketable yield per plant, per hectare. Supplemental foliar fertilizer at a dosage of 6-30-30 in combination with urea and goat manure had higher marketable yield per plant, per hectare (Table 4). This might be because besides N, the foliar fertilizer of dosage 6-30-30 contained a high level of P and K. An increase in the supply of soil P and K may be responsible for increasing the head weight of cabbage. (Khan, F., Khan, T., Namatullah, & Tajudin, 2015). Haque et al. (2006) recorded an increase in head diameter of cabbage that had occurred with an increase in the use of N and P fertilizers.

The combination of 75 % urea + 25 % goat manure + foliar fertilizer (K_3) significantly increased marketable yield and head diameter than did the use of 100 % urea (Table 4), but the result was not significantly different from that obtained using a combination of 75 % urea + 25 % goat manure + biochar. (K_5). The combination of 75 % urea + 25 % goat manure + biochar (K_5) increased marketable yield (kg plant^{-1} and t ha^{-1}) by 16.27 % higher than that of the control (K_0). According to Lehmann et al. (2003), the addition of biochar can increase the productivity of plants directly, or indirectly through improved nutrient resistance. Biochar can alter the physical properties of the soil, including aeration and water holding capacity of certain soils the addition of biochar can improve plant productivity or indirectly through improved nutrient retention. Biochar influenced the properties of soil physic, including aeration and water holding capacity (Carter, Shackley, Sohi, Suy, & Haefele, 2013). This is supported by Nzanza, Marais, & Soundy (2012), who argued that the addition of biochar to soil altered the physical-chemical characteristics of soil, leading to increased soil nutrient availability and enhanced mychorrizal root colonization.

CONCLUSION

The application of nitrogen in combination with urea and goat manure was at par with the growth and yield of cabbage using only urea (100 % urea). The addition of foliar fertilizer or biochar in combination with urea and goat manure increased growth and yield of cabbage. A higher yield was recorded with the application of nitrogen 75 % from urea + 25 % from goat manure and 50 % from urea + 50 % from manure with addition of foliar fertilizer statistically at par with the application of nitrogen 75 % using urea + 25 % using goat manure with addition of biochar. The application of 75 % urea + 25 % goat manure + biochar resulted in a marketable yield of 64.75 t, while the application of 50 % urea + 50 % urea + foliar fertilizer obtained a marketable yield of 66.5 t and the application of 75 % urea + 25 % goat manure + foliar fertilizer obtained a yield of 68.84 t. These figures were better than those yielded by the controls by 16.27 %, 19.41 % and 23.61 %, respectively.

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