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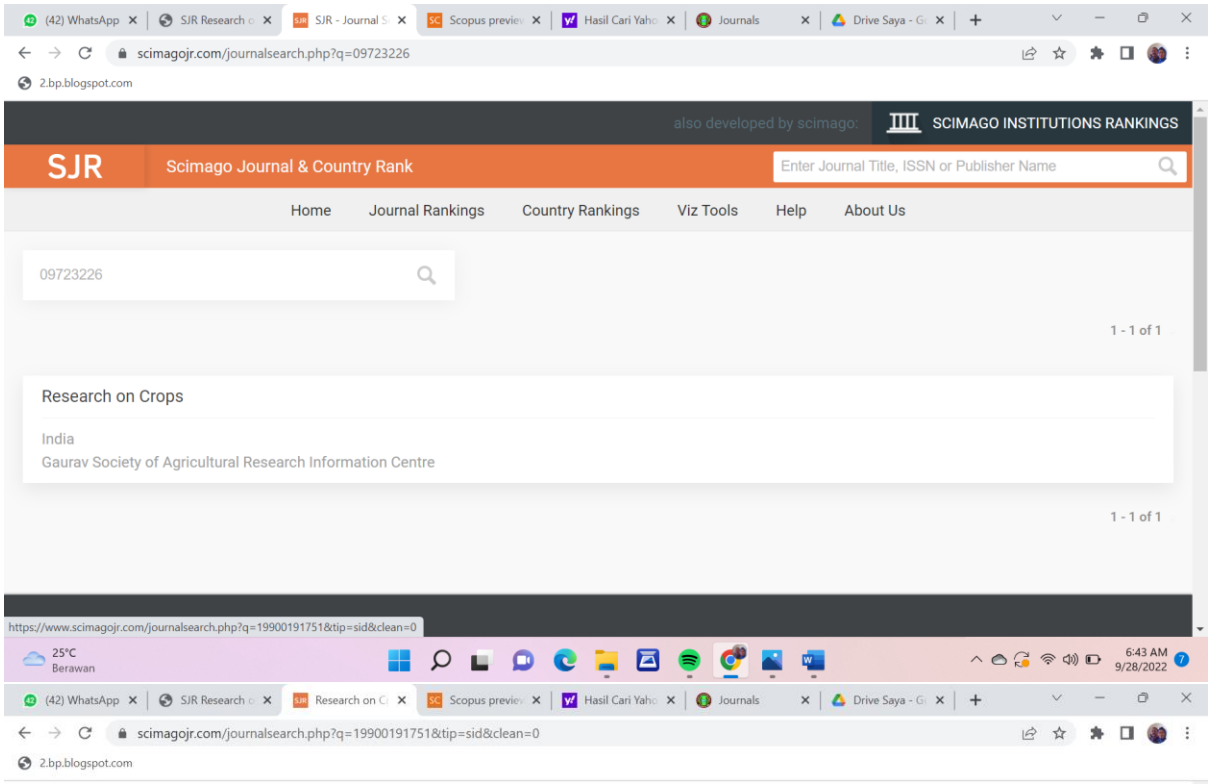

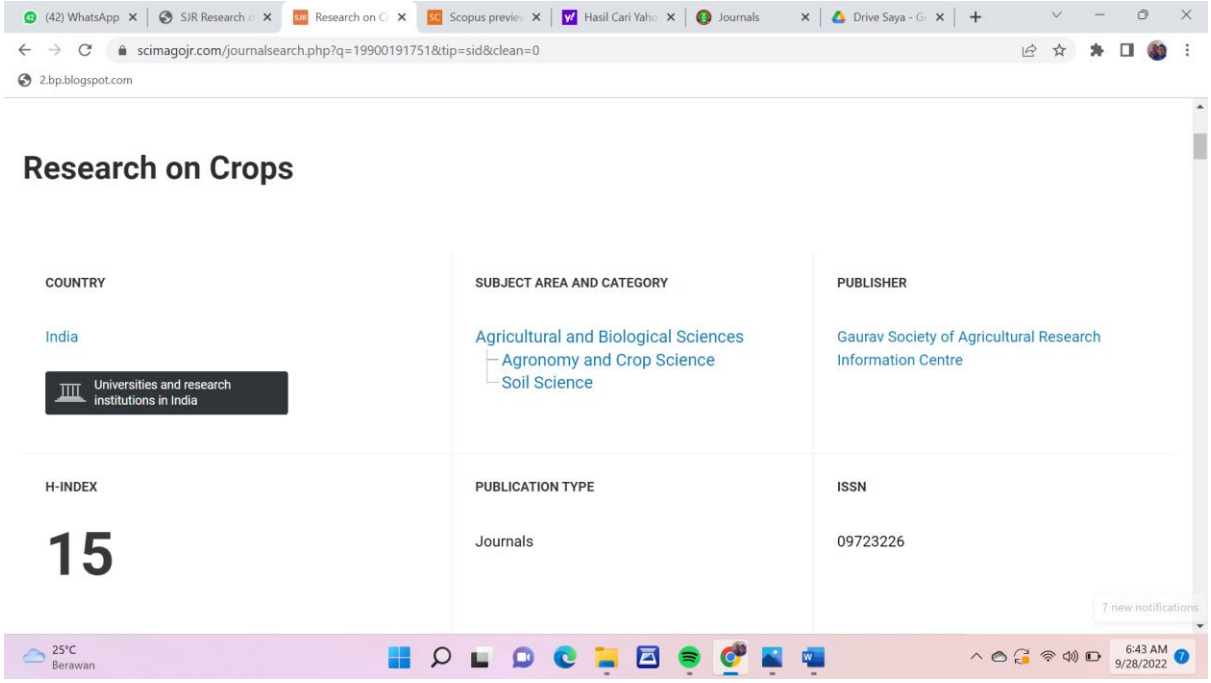

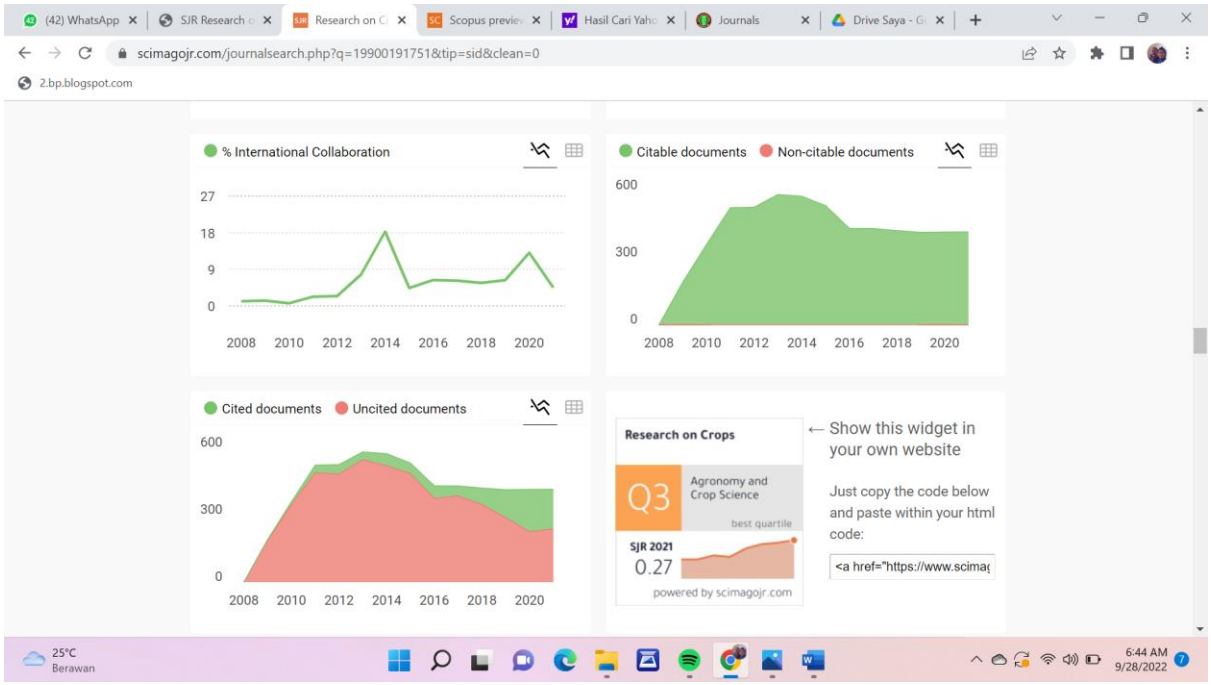

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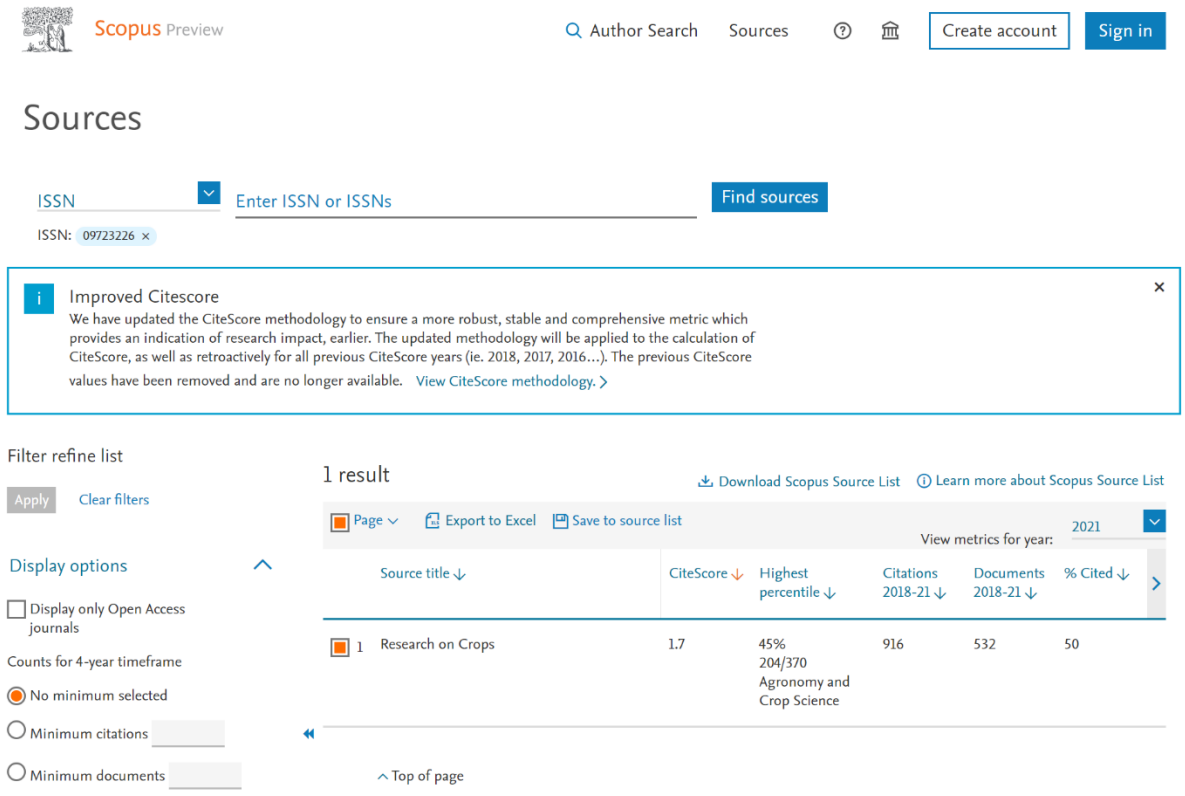

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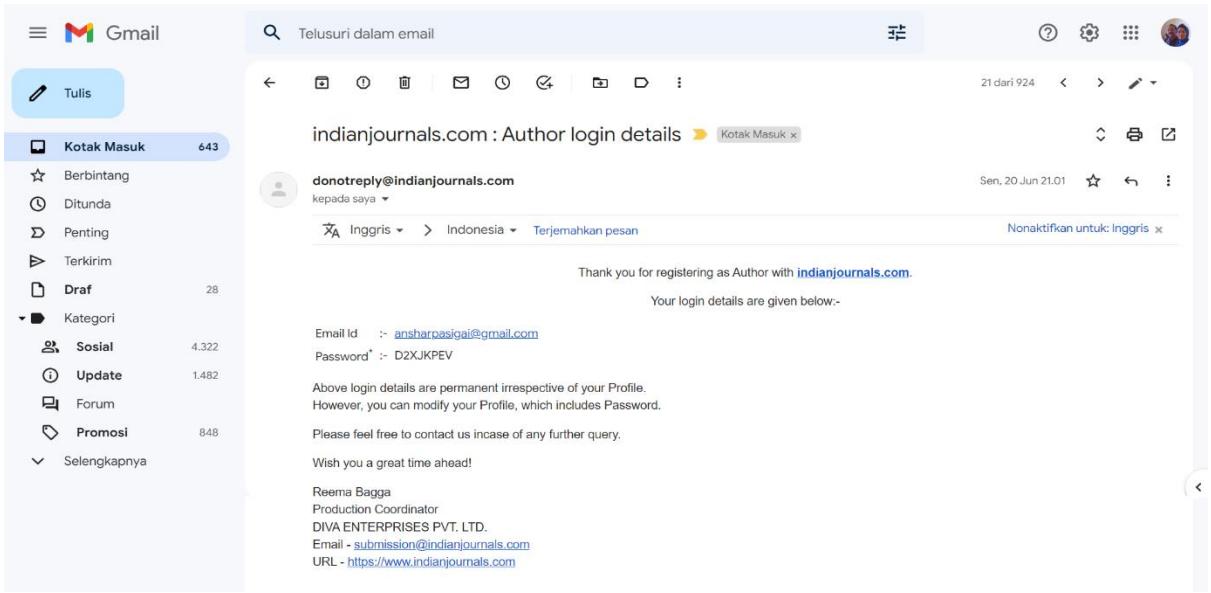

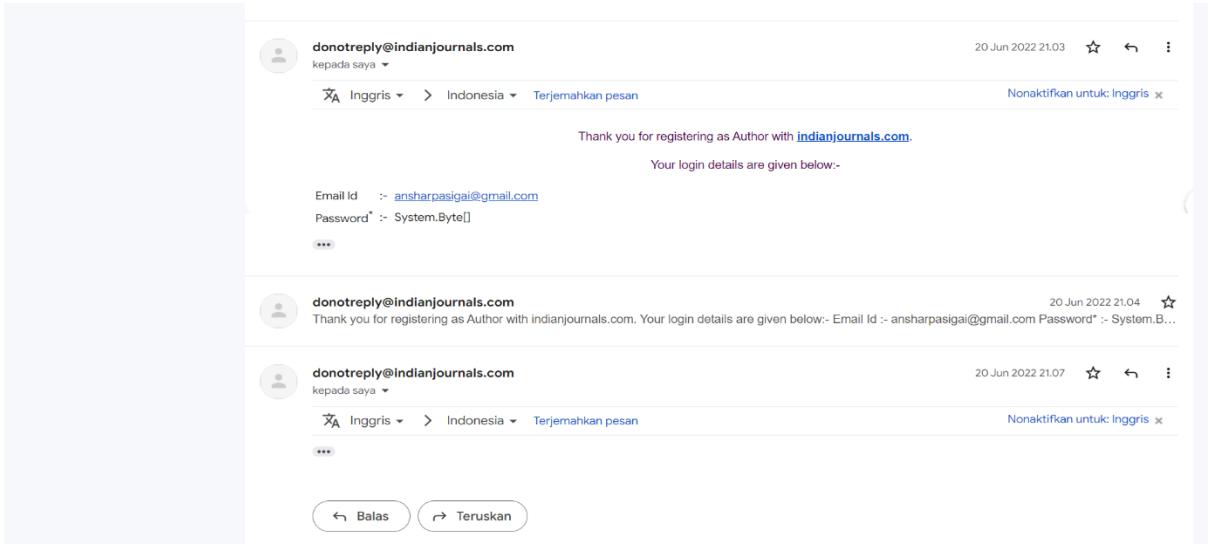

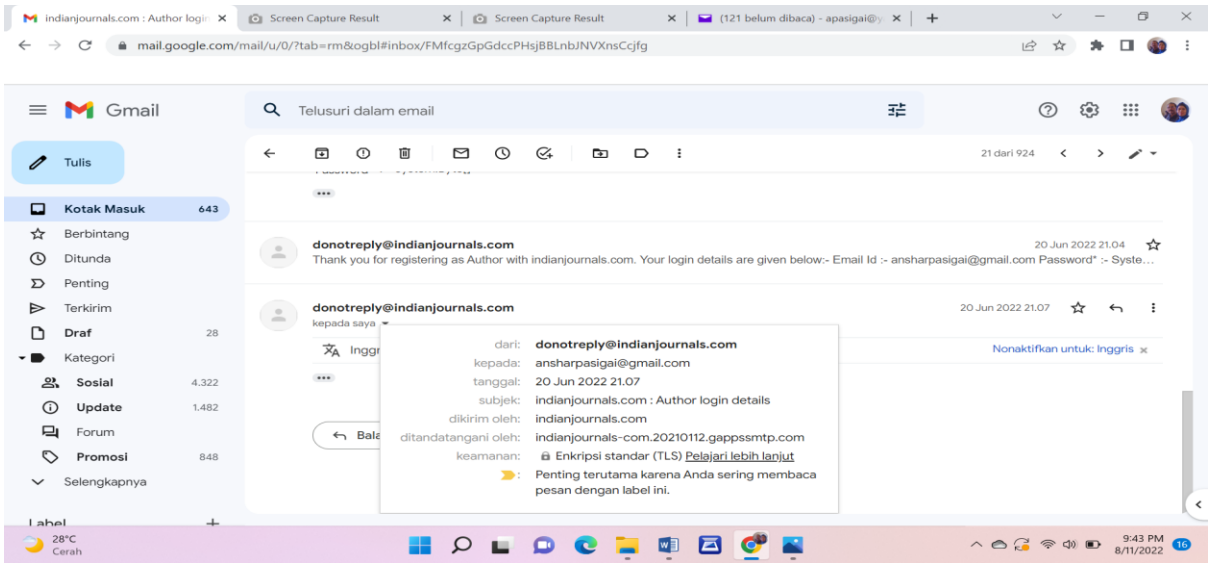

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Application of Cow Urine Fertilizers to Increase Growth and Yield of Mustard Plants (*Brassica rapa* L.)

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ABSTRACT

The mustard plant (*Brassica rapa* var. Chinensis) is one of the main types of vegetables widely consumed in Indonesia. Synthetic fertilizers are always used to increase crop productivity and add environmental residue. Using cow urine is one of the zero waste applications in agriculture. This research aims to know the optimum concentration of cow urine on the growth and yield of mustard. This research was conducted from May 2021 to November 2021 in Olobojo Village, Sigi Biromaru Subdistrict, Sigi Regency, Central Sulawesi, Indonesia. The experiment was arranged in a randomized complete block design with three replications. The treatment of cow urine concentration consisted of five levels, namely 0, 20, 40, 60, and 80%. In this study, 15 plots were needed. For each plot of the experiment, there were 84 plants. The experiment results showed that the application of cow urine affected the growth and yield of mustard plants. Applying cow urine can increase leaf area, plant dry weight, net assimilation rate (NAR), crop growth rate (CGR), relative growth rate (RGR), and harvest yield. The application of 80% cow urine concentration provided the mustard harvest yield higher than other treatments. The study fundings that the application of cow urine has not reached the optimum concentration for the mustard plant in inceptisol soils. We recommend that the application of cow urine with a concentration higher than 80% is required in mustard cultivation.

Keywords: Cow urine, liquid organic fertilizer (LOF), mustard plant, nutrient

Running headline: Cow urine fertilizers to increase yield of mustard

INTRODUCTION

The mustard plant (*Brassica rapa* var. Chinensis) is one of the main types of vegetables widely consumed by the public because it has a high nutritional content (Hanum et al., 2021). However, culturing mustard plants on dry land with limited water conditions is a limiting factor for plant growth. Similarly, excessive and uncontrolled use of chemicals will reduce product quality, soil fertility, and environmental pollution. In general, the cultivation of mustard plants in Indonesia still uses synthetic fertilizers because it has been shown to increase crop productivity. Therefore, fertilizer is a major input factor in increasing crop yields, including mustard crops.

Fertilizer applications can accelerate agricultural production by contributing 50% of crop yield. But over a long period, synthetic fertilizers, especially NPK, will add residue to the environment and cause a decrease in soil quality, and affect crop production (Singh et al., 2020). Now, organic farming is becoming mainstream all over the world. However, since the green revolution, the indiscriminate use of chemicals has adversely affected soil fertility, plant productivity, production quality, etc., especially on environmental systems. In such a situation, the need to adopt environmentally friendly agricultural practices for food production is strongly emphasized, taking into account soil and environmental sustainability. For that, it is necessary to integrate nutrient management by prioritizing using natural materials that can increase plant productivity without reducing soil fertility.

On the other hand, there is an agricultural waste that has the potential to be developed as a source of plant fertilizer. The use of waste can provide added value in maximizing social, environmental, and health and can reduce the cost of investment and plant production operations (Etter et al., 2011). Unfortunately, one agricultural waste that has not been optimally utilized is cow urine.

Using cow urine in agricultural businesses is one of the applications of zero waste management. The use of cow urine can be considered a low-cost agricultural practice and has been widely used in traditional agriculture (Vala and Desai, 2021). Cattle are the main source of waste products in the form of feces and urine that can be useful for agriculture. Cow urine can be used as a basic material for making organic fertilizers (Lubis and Sembiring, 2019). Cow urine is a source of nitrogen, sulfur, phosphate, potassium, sodium, manganese, carbolic acid, iron, silicon, chlorine, salt, enzymes, and hormones (Vala and Desai, 2021). Cow urine contains many microelements. Total N ranges from 6.8-21.6 g/l, which averages 69% in urea

form (Sharma and Rai, 2015). Cow dung contains various groups of microorganisms that are beneficial because it produces various metabolites and increases soil fertility through phosphate dissolution (Gupta et al., 2016).

In organic farming, cow urine is used to prepare several growth promoters and biopesticides, thus effectively improving soil fertility and pest and disease control. However, the use of cow urine provides a better alternative to expensive synthetic chemicals and has the potential to harm farmers, marketers, consumers, and the environment (Vala and Desai, 2021). Cow urine has been used since ancient times and is useful in agriculture, especially organic farming (Rekha et al., 2017). Cow urine has the activity of controlling harmful fungi and promotes growth and crop yields (Ghosh and Guin, 2018). The fungus attacks many plants: *Fusarium oxysporum*, *Pythium aphanidermatum,* and the bacteria *Ralstonia solanacearum* (Rakesh et al., 2013). Cow urine-added neem leaves are an excellent biopesticide, safe to use, do not accumulate in the food chain, and do not cause harmful effects such as chemical pesticides (Rekha et al., 2017). The results showed that 50-100 ml of pure cow urine in beehives at intervals of 10-15 days could recover quickly from bees infected with the disease within 8-10 days after spraying and can increase productivity (Tiwari and Nagar, 2015).

Some studies on the application of cow urine increase growth and improve the quality of crop yields. Spraying of 50, 75, and 100% cow urine concentrations recorded higher grain yields of 2.69, 18.01, and 27.21%, respectively, than control (Sadhukhan et al., 2018). Using cow urine concentration of 5% increased methi plants (*Trigonella foenum-graecum* L.), including protein and chlorophyll content (Soman and Shetty, 2018). The bio-urine applications improved soil pH, fertility, and nitrogen levels and have short-term nitrogen release efficiency (Nwite, 2015). A combination of inorganic fertilizers 120 kg N/ha + 60 kg P_2O_5/ha+ 60 kg K_2O/ha + 40 kg S/ha and 900 l cow urine/ha gave maximum results and proved most beneficial (Pradhan et al., 2016). Spraying a 55% cow urine solution on mango leaves produced fruit weight, volume, and amount of fruit/plant (Damodhar and Shinde, 2010).

Research has shown that using cow urine can increase plant growth and yield. But researchers have previously studied the use of cow urine in wheat, rice, methi, sorghum, and mango crops, while in mustard plants have never been. No studies have been found discussing the effect of cow urine concentration on mustard plant cultivation. Therefore, there needs to be research to know the optimum concentration of cow urine in mustard plants. With the discovery of the right concentration, the application is expected to increase the growth and yield of

mustard plants to the maximum. Therefore, this study aims to know the optimum concentration of cow urine to increase the growth and yield of mustard plants.

MATERIAL AND METHODS

The study area

This research was conducted in Olobojo Village, Sigi Biromaru Subdistrict, Sigi Regency. The research took place from May 2021 to November 2021. The location of the study was at coordinates S 1˚01'14.6532" and E 119˚59'29.0256", at a place altitude of 125 m above sea levels (m ASL), with the average daily air temperature being 30˚C and the average daily air humidity being 67%.

Experimental design

The study was arranged in a randomized complete block design (RCBD) with three replications. Treatment of cow urine concentration, consisting of 0, 20, 40, 60, and 80%. In this study, 15 trials were needed. In each plot of the experiment, there were 84 plants.

Research procedures

The soil was processed to lose to improve the structure and air circulation and encourage microbial activity. The experimental plots were in the size of 210 cm × 300 cm. The distance between the experimental plots was 50 cm. A cow manure dose of 15 t/ha was applied to each experiment plot one week before planting. The planting distance for mustard plants was in the size of 30 cm × 25 cm. Mustard seedlings were ready to move planting at the age of 10 days. Cow urine application was done at the age of five days after planting (DAP). The concentration of cow urine was given according to treatment. A hand sprayer was applied to cow urine on the upper and lower surfaces of the leaves evenly. Spraying was done at ages 5, 10, 15, 20, and 25 DAP.

Data collection

Plant growth was observed to include the leaf area and plant dry weight at ages of 10, 15, 20, 25, and 30 DAP, while crop yields included fresh weight/plant and harvest weight/ha. Furthermore, according to Gardner et al. (1985), plant growth analysis can be calculated with the following equation.

Net assimilation rate (NAR) is the ability of plants to produce dry materials that assimilate each unit of leaf area at each unit of time, as is stated in Eq. 1.

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{\ln LA_2 - \ln LA_1}{LA_2 - LA_1} \text{ (g/cm}^2\text{/day)} \quad \text{(Eq. 1)}$$

Crop growth rate (CGR) is the ability of plants to produce dry materials that assimilate each unit of land area at each unit of time, as is stated in Eq. 2.

$$CGR = \frac{1}{G} \times \frac{W_2 - W_1}{t_2 - t_1} \text{ (g/m}^2\text{/day)} \quad \text{(Eq. 2)}$$

Relative growth rate (RGR) is the ability of plants to produce dry materials assimilated from each unit of initial dry weight at each unit of time, which is expressed in Eq. 3.

$$RGR = \frac{\ln LW_2 - \ln LW_1}{t_2 - t_1} \text{ (g/g/day)} \quad \text{(Eq. 3)}$$

Description: W_1 = total dry weight per plant at the time of t_1. W_2= Total dry weight per plant at the time of t_2. LA_1= Total leaf area per plant at the beginning. LA_1 = Total leaf area per plant at the time of t_2. G = the area of land overgrown with plants. t_1 = harvest time in the beginning. t_2 = harvest time in the end.

Statistical analysis

Observational data were analyzed using analysis of variance (ANOVA) with IBM SPSS Statistic 23. If the treatment had a significant effect, knowing the difference between treatments was done using the honesty significant difference (HSD) test at P=0.05 level of probability (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Soil analysis

The soil type was clay texture with rough sand content (30.3%), fine sand (9.9%), dust (39.2%), and clay (20.6%). The pH of the soil was somewhat sour, but according to the pH requirement range of the mustard plant was 6.0-6.5. The content of essential macronutrients, especially N, included low criteria, while P and K are moderate. The content of Ca, Na, and KTK was medium, and the nutrient content of N-total and the content of C-organic) was relatively low (0.98%). The results description of soil analysis can be seen in Table 1.

Table 1. Preliminary soil analysis data at the research site

Parameter	Value	Unit	Criteria
Rough sands	30.3	%	Clay
Fine sand	9.9	%	
Silt	39.2	%	
Clay	20.6	%	
pH H_2O (1:25)	6.46	-	Slightly
pH KCl (1:25)	4.96	-	sour
C – organic	1.87	%	Very low
N – total	0.10	%	Low
K_2O (HCl 25%)	24.07	Mg/100 g	Medium
P_2O_5 (HCl 25%)	32.30	Mg/100 g	Medium
KTK	18.6	Cmol (+)/kg	Medium
Al-dd	1.00	Cmol (+)/kg	-
H-dd	2.59	Cmol (+)/kg	-
Na	0.62	Cmol (+)/kg	Medium
K	0.43	Cmol (+)/kg	Medium
Ca	10.13	Cmol (+)/kg	Medium
P_2O_5 (Olsen)	32.38	ppm	Very high

Source: Soil Science Laboratory of Faculty of Agriculture, Tadulako University

Cow urine analysis

The cow urine liquid organic fertilizer used in the study contained 0.08% nitrogen, 0.007% phosphorus, 0.85% potassium, 0.21% sodium, 0.15% Calcium and 0.3% C-organic. Soil analysis showed that the soil for the study was included in the category of less fertile soil, so it needs to be added nutrients, especially C and N. The results description of soil analysis can be seen in Table 2.

Table 2. The analysis results of LOF cow urine

Parameter	Value	Unit
Nitrogen (N)	0.08	%
Pospor (P)	0.007	%
Kalium (K)	0.85	%
Natrium (Na)	0.21	%
Calcium (Ca)	0.15	%
C-Organik	0.30	%

Source: Soil Science Laboratory of Faculty of Agriculture, Tadulako University.

Leaf area

Application of cow urine can increase the total area of mustard leaves at the ages of 10, 20, and 30 DAP. The results showed that the application of 60% concentration resulted in a higher total leaf area per plant and decreased leaf area at a concentration of 80% of cow urine. The results of the HSD test on the average leaf area of ages 10, 20, and 30 DAP are shown in Table 3.

Table 3. The average leaf area at ages of 10, 20, and 30 DAP

Cow urine concentration (%)	Observation time (DAP)		
	10	20	30
0	190.37^{b}	775.9^{b}	1,701.1^{b}
20	232.39^{b}	1,044.2^{ab}	2,174.7^{a}
40	385.59^{a}	804.9^{b}	1,372.0^{b}
60	384.78^{a}	1,223.1^{a}	2,285.9^{a}
80	170.01^{b}	1,040.7^{ab}	1,498.2^{b}
HSD 5%	74.85	348.24	416.59

Remarks: The average value in the column followed by the same letter indicates no significant difference based on the HSD test at P=0.05 level of probability.

Table 3 shows that the application of cow urine increases the leaf area of the mustard plant to a cow's urine concentration by 60%. Cow urine contains macronutrients, as well as micronutrients needed for plant growth. Micro and macro nutrient content were important in supporting mustard leaves' dilated growth. Although, as stated by Vala and Desai (2021), that

cow urine retreats macronutrients, especially nitrogen, phosphate, potassium, and sulfur, in large quantities, it also contains micronutrients, especially sodium, manganese, carbolic acid, iron, silicon, chlorine, as well as salts, enzymes, and hormones that all plants need.

Conversely, micronutrients absorbed by plants in large quantities can suppress or inhibit plant growth. It can cause a decrease in leaf area with the administration of cow urine higher than the concentration of 60%. On the other hand, the application of cow urine accelerates various aspects of plant growth. According to Chongre et al. (2020), the application of cow urine can increase the growth of plant leaves as a result of the process, and the rate of photosynthesis increases. The application of cow urine can promote growth, and the quantity and quality of plants, as bio urine, contains macronutrients, essential micronutrients, vitamins, essential amino acids, IAA, GA, and beneficial microorganisms.

Dry weight of mustard plants

The application of cow urine significantly affected the increase in total dry weight per plant at ages 10, 20, and 30 DAP. For example, applying a concentration of 80% of cow urine resulted in a higher total dry weight per plant, although it was no different from a concentration of 60% at 30 DAP. The HSD test on the average dry weight per plant at ages 10, 20, and 30 DAP are shown in Table 4.

Table 4. The average dry weight of mustard plants at ages of 10, 20, and 30 DAP

Cow urine concentration (%)	Observation time (DAP)		
	10	20	30
0	1.13^{b}	7.57^{b}	27.04^{c}
20	1.13^{b}	13.99^{ab}	35.75^{bc}
40	1.36^{ab}	13.32^{ab}	46.09^{b}
60	1.32^{ab}	15.01^{ab}	44.58^{ab}
80	1.43^{a}	21.64^{a}	52.14^{a}
HSD 5%	0.27	8.40	10.29

Remarks: The average value in the column followed by the same letter indicates no significant difference based on the HSD test at P=0.05 level of probability.

Table 4 shows that 80% application of cow urine results in higher dry weight per plant. This result differs from the optimum concentration on observations at leaf area per plant. The dry weight of the plant is largely determined by the results of the photosynthetic process, not just by the size of the leaf area. Cow urine contains many nutrients and plays a role in forming the plant's dry material. Applying cow urine to the soil as much as 20 ml per plant can increase plant growth (Mali, 2021), especially nitrogen. Nitrogen plays a role in forming chlorophyll, amino acids, fats, enzymes, and compounds needed in plant physiological processes to produce photosynthates. The application of cow urine evenly will be directly absorbed by the plant because it is easily soluble, so it quickly overcomes the lack of nutrients for the plant (Haryuni et al., 2018). In addition, the presence of IAA in the urine of cows serves to help the division and enlargement of cells (de Oliveira et al., 2009).

NAR, CGR, and RGR

Applying cow urine can promote plant growth, especially NAR, CGR, and RGR. The growth of mustard plants can be cut with the application of cow urine starting from observation periods 10-15, 15-20, 20-25, and 25-30 DAP. The 40% concentration gives the highest results of NAR, CGR, and RGR up to the observation period of 25-30 DAP. The HSD test results on average NAR, CGR, and RGR on observations of 10-15, 15-20, 20-25, and 25-30 DAP are shown in Table 5.

Table 5. The average NAR, CGR, and RGR on observations at ages of 10-15, 15-20, 20-25, and 25-30 DAP

Cow urine concentration (%)	Observation time (DAP)			
	10-15	15-20	20-25	25-30
	NAR ($g/cm^2/day$)			
0	0.000797^a	0.00113^b	0.00233^a	0.00067^b
20	0.001043^a	0.00184^b	0.00230^a	0.00097^b
40	0.000527^a	0.00189^b	0.00190^a	0.00427^a
60	0.000843^a	0.00177^b	0.00193^a	0.00190^b
80	0.001287^a	0.00394^a	0.00243^a	0.00197^b
HSD 5%	ns	0.0016	ns	0.0015
	CGR ($g/m^2/day$)			
0	0.0397^b	0.0407^b	0.1690^a	0.0743^b

20	0.0623[a]	0.0987[ab]	0.1740[a]	0.0983[b]
40	0.0623[a]	0.0870[b]	0.1357[a]	0.3987[a]
60	0.0653[b]	0.1057[ab]	0.1677[a]	0.2017[b]
80	0.0693[b]	0.1837[a]	0.1803[a]	0.2010[b]
HSD 5%	0.0213	0.0939	ns	0.1302
RGR (g/g/day)				
0	0.2673[b]	0.1117[b]	0.1007[b]	0.0503[b]
20	0.3380[a]	0.1597[ab]	0.1420[ab]	0.0513[b]
40	0.3077[ab]	0.1463[ab]	0.1223[b]	0.1677[a]
60	0.3183[a]	0.1627[ab]	0.1303[b]	0.0913[b]
80	0.3163[ab]	0.2267[a]	0.2053[a]	0.0753[b]
HSD 5%	0.0503	0.1003	0.0723	0.0652

Remarks: The average value in the column followed by the same letter indicates no significant difference based on the HSD test at P=0.05 level of probability, and ns = Non significant

Table 5 shows that cow urine application can increase mustard plants' NAR, CGR, and RGR. NAR values are affected by the rate of photosynthesis in the formation of plant dry materials. The rate of photosynthesis is determined in addition to environmental factors and is influenced by leaf area and nutrient content for chlorophyll constituents. Therefore, the assimilation rate can increase even higher with the application of cow urine. Cow urine contains a wide variety of nutrients, such as K, N, and Cl, which cause an increase in cells, due to the osmotic effect and encourage plant growth (De Oliveira et al., 2009). In addition, cow urine contains a mixture of hormones, enzymes, and mineral salts, such as iron, calcium, phosphorus, potassium, nitrogen, amino acids, cytokines, and lactose that play an important role in plant growth (Mandavgane et al., 2016). In addition, cow urine can increase P in the soil and affect the proline content in the leaves of plants, so plants grow better and are resistant to dryness (Haryuni et al., 2018).

The difference in RGR value is influenced by the rate of the photosynthesis process for the formation of dry material of plants that previously existed. In addition to the nutrient availability factor for plants, other environmental factors also greatly affected the mustard plants' photosynthesis rate. The nutritional influence of cow urine showed an increase in chlorophyll and protein content compared to the control of chlorophyll (Jandaik et al., 2015). Plant RGR is affected by three main factors: the dry weight of the plant, the area of the leaves, and the dry weight of the leaves. Furthermore, there was no significant relationship between

NAR and RGR, but there was a positive relationship between specific leaf areas with RGR and leaf mass ratio with RGR (Poorter and Werf, 1998). RGR becomes increasingly inefficient as plants age, as the process is highly dependent on environmental influences (Hunt, 1984).

Cow urine application concentration of 80% resulted in the highest NAR increase at the age of 15-20 DAP but continued to decrease at the ages of 20-25 DAP and 25-30 DAP. Similarly, other treatments have almost the same NAR pattern in all periods of growth, except for the 40% concentration that previously had a low NAR, then experienced an increase in NAR at the age of 25-30 DAP. The treatment of 80% of cow urine experienced the highest increase in CGR at 15-20 DAP but tended to be constant at 20-25 and 25-30 DAP. In contrast, the treatment without cow urine had a low CGR at almost all observation times. Treatment without cow urine application produces the lowest RGR at ages 10-15 DAP and 15-20 DAP but increases at ages 20-25 and 25-30 DAP. In contrast, the 80% treatment experienced the highest RGR increase at the age of 15-20 DAP but decreased at the ages of 20-25 and 25-30 DAP. For treatments of 20, 40, and 60% had an RGR with almost the same pattern at all observation times.

Harvest yield

The use of cow urine can increase the yield of mustard per unit area. For example, cow urine concentration of 80% can provide higher yields/ha, although it is not a real difference with concentrations of 20, 40, and 60%. The results of the HSD test on the average harvest yield/ha can be shown in Table 6.

Table 6. The average harvest yield/ha

Cow urine concentration (%)	Mustard harvest yield (t/ha)
0	28.044[b]
20	38.844[ab]
40	40.000[ab]
60	42.444[ab]
80	50.666[a]
HSD 5%	16.733

Remarks: The average value in the column followed by the same letter indicates no significant difference based on the HSD test at P=0.05 level of probability.

Table 6 shows that a urine concentration of 80% can provide higher harvest yields per crop, although it is no different from a concentration of 20-60%. Cow urine can increase the concentration of uptake of N, P, and K (Mali, 2021). This increase in fresh weight is due to cow urine containing 95% water, 2.5% urea, and the remaining 2.5% a mixture of salts, hormones, enzymes, and minerals. All these compounds are needed in plant metabolism (Choudhary et al., 2017). The application of cow urine increases the productivity of corn, mustard, and rice crops; cow urine, containing nutrients, also contains enzymes and plant growth hormones. Applying cow urine as a source of organic nutrients improves plant growth and yield parameters (Sadhukhan et al., 2020). After regular use of cow urine in plants, the population of soil microorganisms will increase along with the yield (Mali, 2021).

The growing trend of mustard harvest yields, so using cow urine above 80% can still increase harvest yields. For more details, the effect of cow urine concentration on mustard harvest yield can be seen in Figure 1.

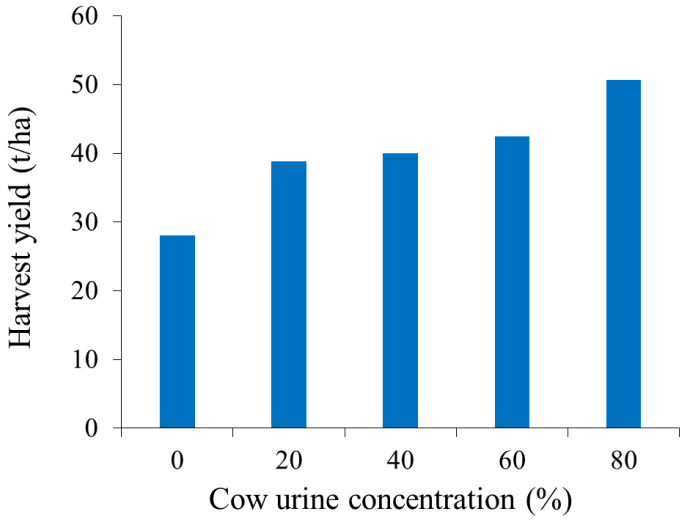

Figure 1. The effect of cow urine concentration on mustard yield

Figure 1 shows that the application of cow urine has not reached the optimum concentration in inceptisol soils for the mustard plant. Therefore, the application of cow urine with a concentration higher than 80% is required for inceptisol soils.

CONCLUSION

Based on the results of research research and discussion above, it can be concluded that the application of cow urine affected the growth and yield of mustard plants. Applying cow urine can increase leaf area, plant dry weight, NAR, CGR, RGR, and harvest yield. The application of 80% cow urine concentration provided the mustard harvest yield higher than other treatments. The study fundings that the application of cow urine has not reached the optimum concentration for the mustard plant in inceptisol soils. We recommend that the application of cow urine with a concentration higher than 80% is required in mustard cultivation.

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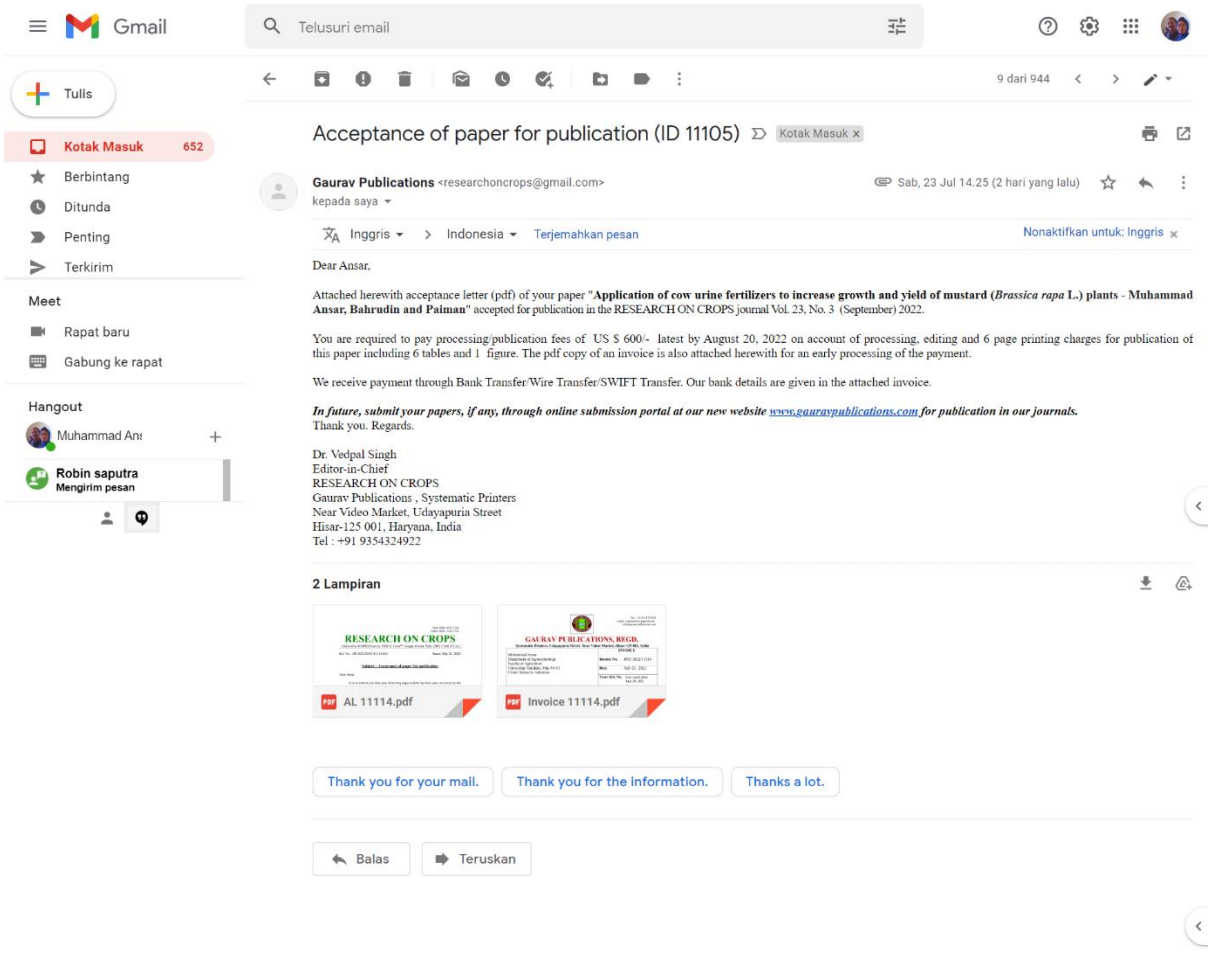

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You are required to pay processing/publication fees of US $ 600/- latest by August 20, 2022 on account of processing, editing and 6 page printing charges for publication of this paper including 6 tables and 1 figure. The pdf copy of an invoice is also attached herewith for an early processing of the payment.

We receive payment through Bank Transfer/Wire Transfer/SWIFT Transfer. Our bank details are given in the attached invoice.

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Dear Ansar,

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Application of cow urine fertilizers to increase growth and yield of mustard (*Brassica rapa* L.) plants - Muhammad Ansar, Bahrudin and Paiman

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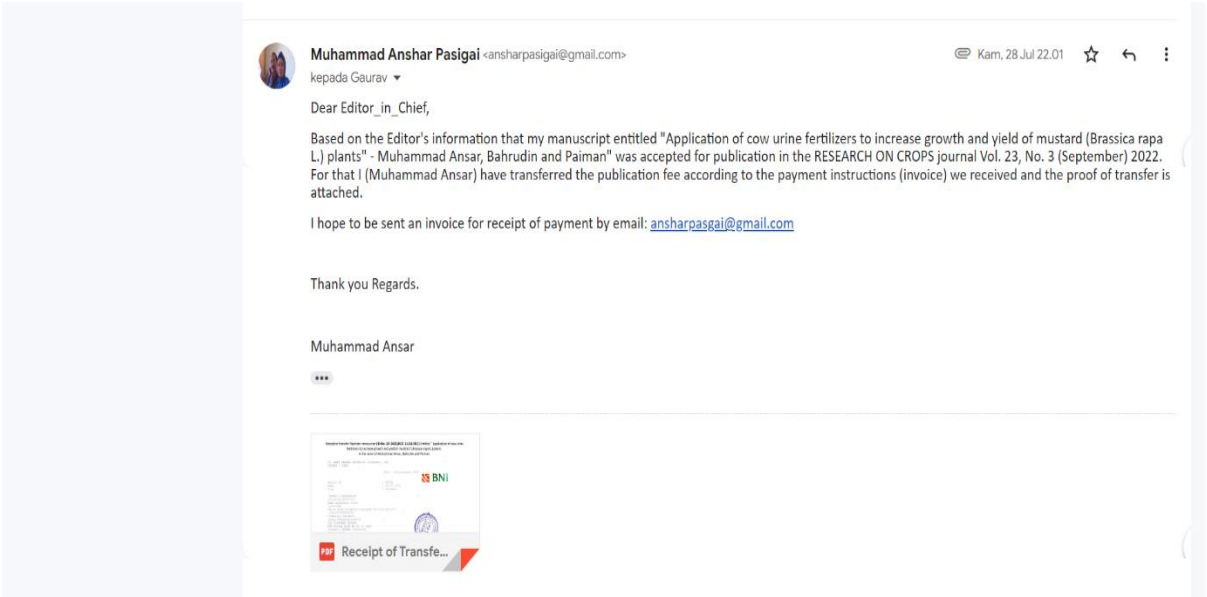

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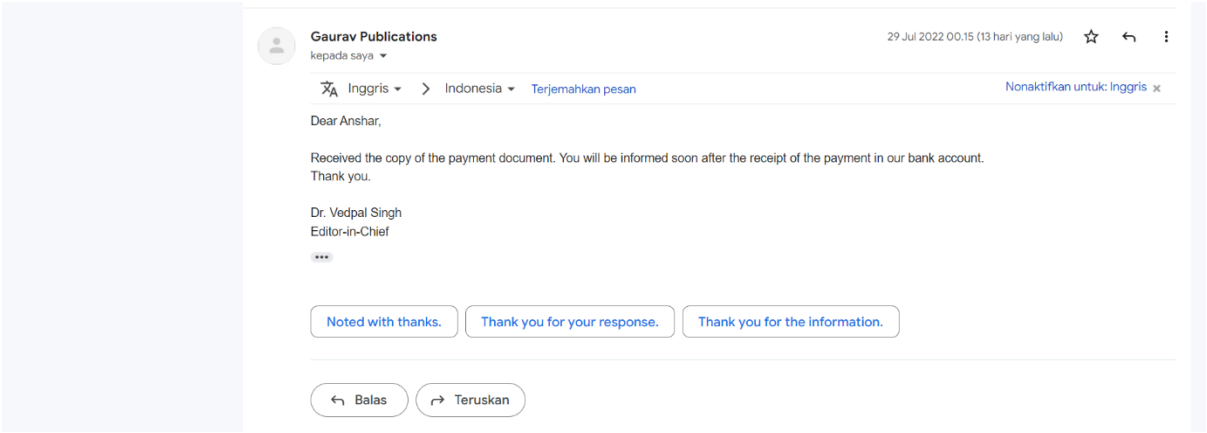

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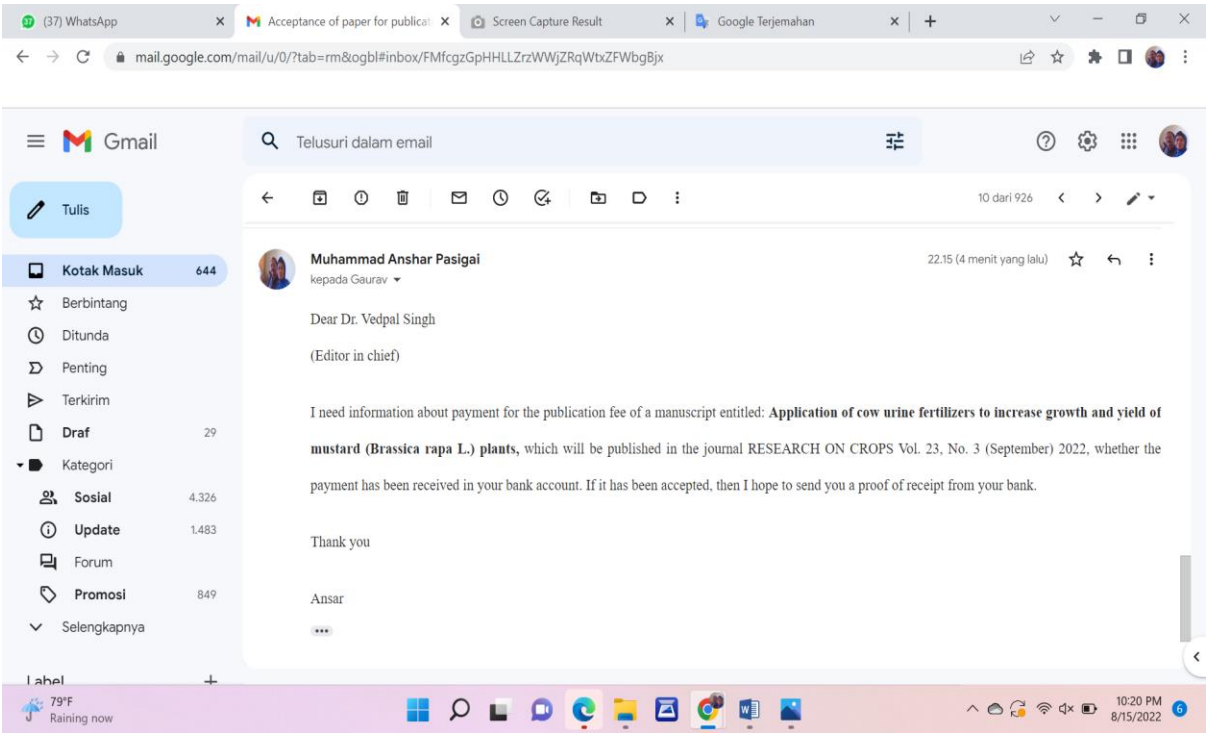

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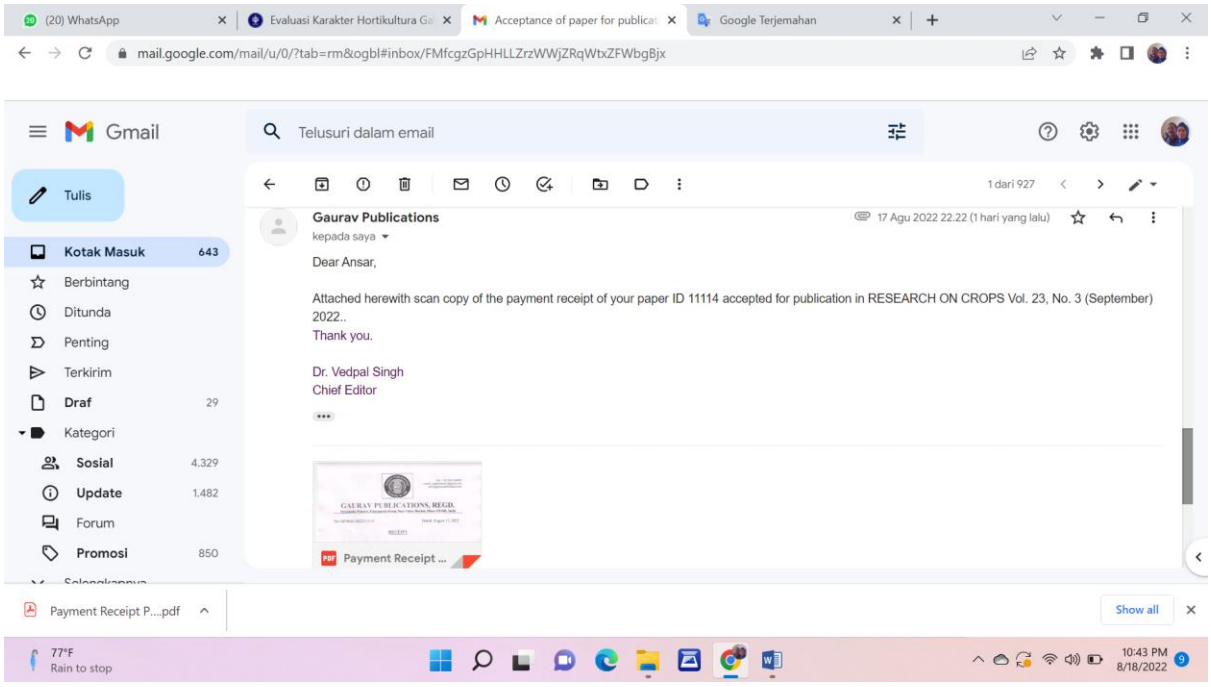

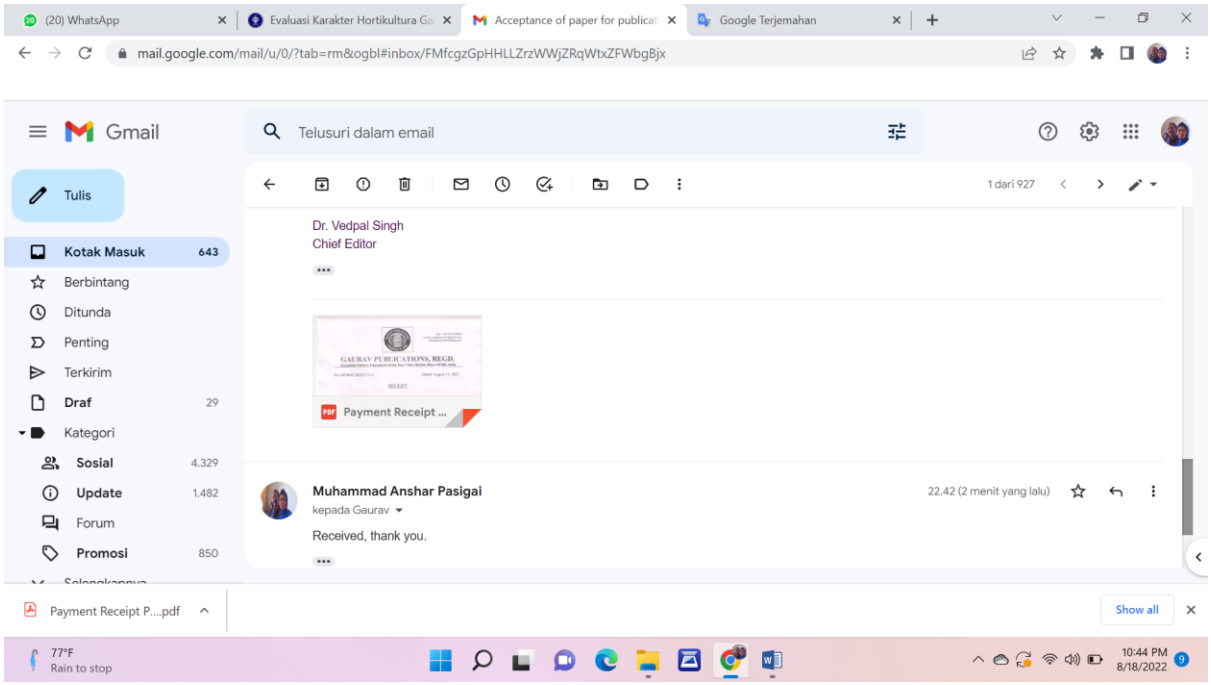

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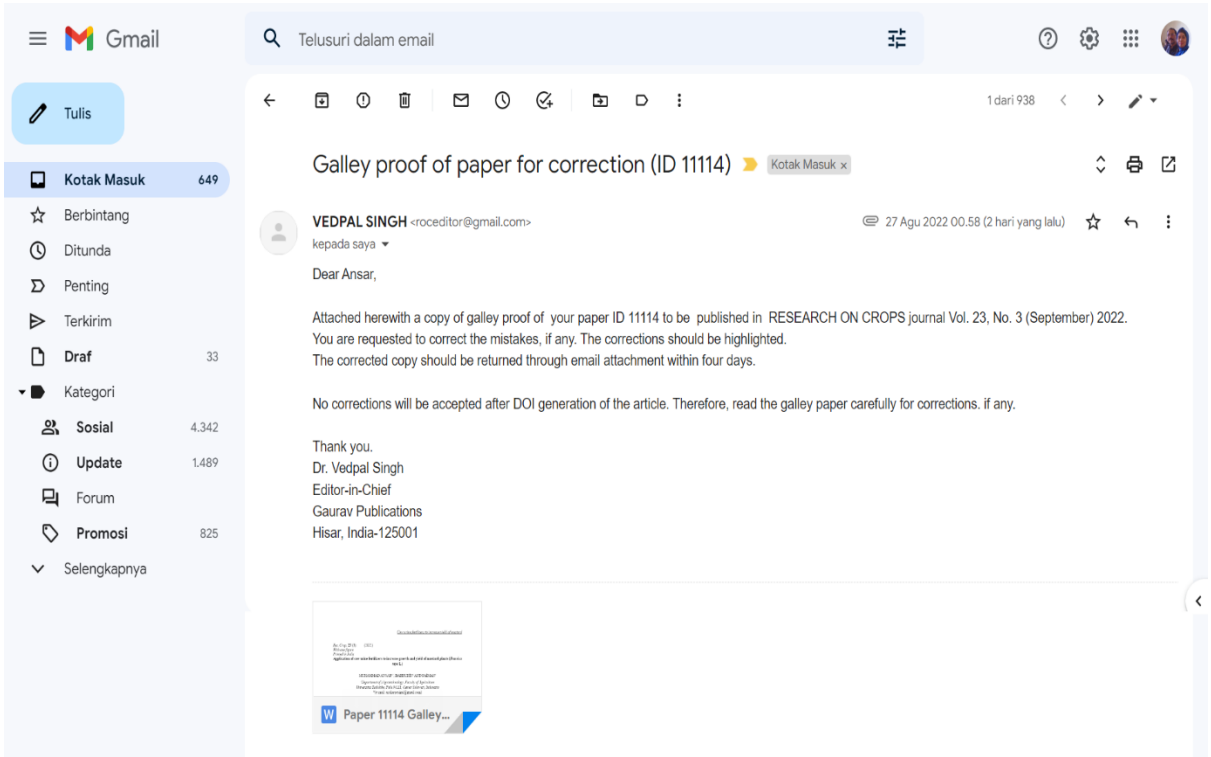

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Application of cow urine fertilizers to increase growth and yield of mustard plants (*Brassica rapa* L.)

MUHAMMAD ANSAR[1,*], BAHRUDİN[1] AND PAİMAN[2]

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(Received: June 20, 2022 / Accepted: August 20, 2022

ABSTRACT

Mustard plant is one of the main types of vegetables widely consumed in Indonesia. Synthetic fertilizers are always used to increase crop productivity and add environmental residue. Using cow urine is one of the zero waste applications in agriculture. This research aims to know the optimum concentration of cow urine on the growth and yield of mustard. This research was conducted from May 2021 to November 2021 in Olobojo Village, Sigi Biromaru Subdistrict, Sigi Regency, Central Sulawesi, Indonesia. The experiment was arranged in a randomized complete block design with three replications. The treatment of cow urine concentration consisted of five levels, namely 0, 20, 40, 60, and 80%. In this study, 15 plots were needed. For each plot of the experiment, there were 84 plants. The experiment results showed that the application of cow urine affected the growth and yield of mustard plants. Applying cow urine can increase leaf area, plant dry weight, net assimilation rate (NAR), crop growth rate (CGR), relative growth rate (RGR), and harvest yield. The application of 80% cow urine concentration provided the mustard harvest yield higher than other treatments. The study fundings that the application of cow urine has not reached the optimum concentration for the

mustard plant in inceptisol soils. We recommend that the application of cow urine with a concentration higher than 80% is required in mustard cultivation.

Key words: Cow urine, liquid organic fertilizer (LOF), mustard plant, nutrient

[2]Department of Agrotechnology, Faculty of Agriculture, Universitas PGRI Yogyakarta, Yogyakarta 55182, Indonesia.

INTRODUCTION

The mustard plant (*Brassica rapa* var. Chinensis) is one of the main types of vegetables widely consumed by the public because it has a high nutritional content (Hanum *et al*., 2021). However, culturing mustard plants on dry land with limited water conditions is a limiting factor for plant growth. Similarly, excessive and uncontrolled use of chemicals will reduce product quality, soil fertility, and environmental pollution. In general, the cultivation of mustard plants in Indonesia still uses synthetic fertilizers because it has been shown to increase crop productivity. Therefore, fertilizer is a major input factor in increasing crop yields, including mustard crops.

Fertilizer applications can accelerate agricultural production by contributing 50% of crop yield. But over a long period, synthetic fertilizers, especially NPK, will add residue to the environment and cause a decrease in soil quality, and affect crop production (Singh *et al*., 2020). Now, organic farming is becoming mainstream all over the world. However, since the green revolution, the indiscriminate use of chemicals has adversely affected soil fertility, plant productivity, production quality, etc., especially on environmental systems. In such a situation, the need to adopt environmentally friendly agricultural practices for food production is strongly emphasized, taking into account soil and environmental sustainability. For that, it is necessary to integrate nutrient management by prioritizing using natural materials that can increase plant productivity without reducing soil fertility (Singh *et al*., 2017; Nahar *et al*., 2021).

On the other hand, there is an agricultural waste that has the potential to be developed as a source of plant fertilizer. The use of waste can provide added value in maximizing social, environmental, and health and can reduce the cost of investment and plant production operations (Etter *et al*., 2011). Unfortunately, one agricultural waste that has not been optimally utilized is cow urine.

Using cow urine in agricultural businesses is one of the applications of zero waste management. The use of cow urine can be considered a low-cost agricultural practice and has

been widely used in traditional agriculture (Vala and Desai, 2021). Cattle are the main source of waste products in the form of feces and urine that can be useful for agriculture. Cow urine can be used as a basic material for making organic fertilizers (Lubis and Sembiring, 2019). Cow urine is a source of nitrogen, sulfur, phosphate, potassium, sodium, manganese, carbolic acid, iron, silicon, chlorine, salt, enzymes, and hormones (Vala and Desai, 2021). Cow urine contains many microelements. Total N ranges from 6.8-21.6 g/l, which averages 69% in urea form (Sharma and Rai, 2015). Cow dung contains various groups of microorganisms that are beneficial because it produces various metabolites and increases soil fertility through phosphate dissolution (Gupta *et al*., 2016).

In organic farming, cow urine is used to prepare several growth promoters and biopesticides, thus effectively improving soil fertility and pest and disease control. However, the use of cow urine provides a better alternative to expensive synthetic chemicals and has the potential to harm farmers, marketers, consumers, and the environment (Vala and Desai, 2021). Cow urine has been used since ancient times and is useful in agriculture, especially organic farming (Rekha *et al*., 2017). Cow urine has the activity of controlling harmful fungi and promotes growth and crop yields (Ghosh *et al*., 2018). The fungus attacks many plants: *Fusarium oxysporum*, *Pythium aphanidermatum*, and the bacteria *Ralstonia solanacearum* (Rakesh *et al*., 2013). Cow urine-added neem leaves are an excellent biopesticide, safe to use, do not accumulate in the food chain, and do not cause harmful effects such as chemical pesticides (Rekha *et al*., 2017). The results showed that 50-100 ml of pure cow urine in beehives at intervals of 10-15 days could recover quickly from bees infected with the disease within 8-10 days after spraying and can increase productivity (Tiwari and Nagar, 2015).

Some studies on the application of cow urine increase growth and improve the quality of crop yields. Spraying of 50, 75, and 100% cow urine concentrations recorded higher grain yields of 2.69, 18.01, and 27.21%, respectively, than control (Sadhukhan *et al*., 2018). Using cow urine concentration of 5% increased methi plants (*Trigonella foenum-graecum* L.), including protein and chlorophyll content (Soman and Shetty, 2018). The bio-urine applications improved soil pH, fertility, and nitrogen levels and have short-term nitrogen release efficiency (Nwite, 2015). A combination of inorganic fertilizers 120 kg N/ha + 60 kg P_2O_5/ha+ 60 kg K_2O/ha + 40 kg S/ha and 900 l cow urine/ha gave maximum results and proved most beneficial (Pradhan *et al*., 2016). Spraying a 55% cow urine solution on mango leaves produced fruit weight, volume, and amount of fruit/plant (Damodhar and Shinde, 2010).

Research has shown that using cow urine can increase plant growth and yield. But researchers have previously studied the use of cow urine in wheat, rice, *methi*, sorghum, and mango crops, while in mustard plants have never been. No studies have been found discussing the effect of cow urine concentration on mustard plant cultivation. Therefore, there needs to be research to know the optimum concentration of cow urine in mustard plants. With the discovery of the right concentration, the application is expected to increase the growth and yield of mustard plants to the maximum. Therefore, this study aims to know the optimum concentration of cow urine to increase the growth and yield of mustard plants.

MATERIALS AND METHODS

The Study Area

This research was conducted in Olobojo Village, Sigi Biromaru Subdistrict, Sigi Regency. The research took place from May 2021 to November 2021. The location of the study was at coordinates S 1˚01'14.6532" and E 119˚59'29.0256", at a place altitude of 125 m above sea levels (m ASL), with the average daily air temperature being 30˚C and the average daily air humidity being 67%.

Experimental Design

The study was arranged in a randomized complete block design (RCBD) with three replications. Treatment of cow urine concentration, consisting of 0, 20, 40, 60, and 80%. In this study, 15 trials were needed. In each plot of the experiment, there were 84 plants.

Research Pprocedures

The soil was processed to lose to improve the structure and air circulation and encourage microbial activity. The experimental plots were in the size of 210 cm × 300 cm. The distance between the experimental plots was 50 cm. A cow manure dose of 15 t/ha was applied to each experiment plot one week before planting. The planting distance for mustard plants was in the size of 30 cm × 25 cm. Mustard seedlings were ready to move planting at the age of 10 days. Cow urine application was done at the age of five days after planting (DAP). The concentration of cow urine was given according to treatment. A hand sprayer was applied to cow urine on the upper and lower surfaces of the leaves evenly. Spraying was done at ages 5, 10, 15, 20, and 25 DAP.

Data Collection

Plant growth was observed to include the leaf area and plant dry weight at ages of 10, 15, 20, 25, and 30 DAP, while crop yields included fresh weight/plant and harvest weight/ha. Furthermore, according to Gardner *et al*. (1985), plant growth analysis can be calculated with the following equation.

Net assimilation rate (NAR) is the ability of plants to produce dry materials that assimilate each unit of leaf area at each unit of time, as is stated in Eq. 1.

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \text{ x } \frac{\ln LA_2 - \ln LA_1}{LA_2 - LA_1} \text{ (g/cm}^2\text{/day)} \qquad \text{(Eq. 1)}$$

Crop growth rate (CGR) is the ability of plants to produce dry materials that assimilate each unit of land area at each unit of time, as is stated in Eq. 2.

$$CGR = \frac{1}{G} \times \frac{W_2 - W_1}{t_2 - t_1} \text{ (g/m}^2\text{/day)} \qquad \text{(Eq. 2)}$$

Relative growth rate (RGR) is the ability of plants to produce dry materials assimilated from each unit of initial dry weight at each unit of time, which is expressed in Eq. 3.

$$RGR = \frac{\ln LW_2 - \ln LW_1}{t_2 - t_1} \text{ (g/g/day)} \qquad \text{(Eq. 3)}$$

Where, W_1 = total dry weight per plant at the time of t_1; W_2= Total dry weight per plant at the time of t_2; LA_1= Total leaf area per plant at the beginning; LA_1 = Total leaf area per plant at the time of t_2; G = the area of land overgrown with plants; t_1 = Harvest time in the beginning; t_2 = harvest time in the end.

Statistical Analysis

Observational data were analyzed using analysis of variance (ANOVA) with IBM SPSS Statistic 23. If the treatment had a significant effect, knowing the difference between treatments was done using the honesty significant difference (HSD) test at P=0.05 level of probability (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Soil Analysis

The soil ty.pe was clay texture with rough sand content (30.3%), fine sand (9.9%), dust (39.2%), and clay (20.6%). The pH of the soil was somewhat sour, but according to the pH requirement range of the mustard plant was 6.0-6.5. The content of essential macronutrients, especially N, included low criteria, while P and K are moderate. The content of Ca, Na, and

KTK was medium, and the nutrient content of N-total and the content of C-organic) was relatively low (0.98%). The results description of soil analysis can be seen in Table 1.

Cow Urine Analysis

The cow urine liquid organic fertilizer used in the study contained 0.08% nitrogen, 0.007% phosphorus, 0.85% potassium, 0.21% sodium, 0.15% Calcium and 0.3% C-organic. Soil analysis showed that the soil for the study was included in the category of less fertile soil, so it needs to be added nutrients, especially C and N. The results description of soil analysis can be seen in Table 2.

Leaf Area

Application of cow urine can increase the total area of mustard leaves at the ages of 10, 20, and 30 DAP. The results showed that the application of 60% concentration resulted in a higher total leaf area per plant and decreased leaf area at a concentration of 80% of cow urine. The results of the HSD test on the average leaf area of ages 10, 20 and 30 DAP are shown in Table 3.

Table 3 shows that the application of cow urine increases the leaf area of the mustard plant to a cow's urine concentration by 60%. Cow urine contains macronutrients, as well as micronutrients needed for plant growth. Micro and macro nutrient content were important in supporting mustard leaves' dilated growth. Although, as stated by Vala and Desai (2021), that cow urine retreats macronutrients, especially nitrogen, phosphate, potassium, and sulfur, in large quantities, it also contains micronutrients, especially sodium, manganese, carbolic acid, iron, silicon, chlorine, as well as salts, enzymes, and hormones that all plants need.

Conversely, micronutrients absorbed by plants in large quantities can suppress or inhibit plant growth. It can cause a decrease in leaf area with the administration of cow urine higher than the concentration of 60%. On the other hand, the application of cow urine accelerates various aspects of plant growth. According to Chongre *et al*. (2020), the application of cow urine can increase the growth of plant leaves as a result of the process, and the rate of photosynthesis increases. The application of cow urine can promote growth, and the quantity and quality of plants, as bio urine, contains macronutrients, essential micronutrients, vitamins, essential amino acids, IAA, GA, and beneficial microorganisms.

Dry Weight of Mustard Plants

The application of cow urine significantly affected the increase in total dry weight per plant at ages 10, 20, and 30 DAP. For example, applying a concentration of 80% of cow urine resulted in a higher total dry weight per plant, although it was no different from a concentration of 60% at 30 DAP. The HSD test on the average dry weight per plant at ages 10, 20, and 30 DAP are shown in Table 4.

Table 4 shows that 80% application of cow urine results in higher dry weight per plant. This result differs from the optimum concentration on observations at leaf area per plant. The dry weight of the plant is largely determined by the results of the photosynthetic process, not just by the size of the leaf area. Cow urine contains many nutrients and plays a role in forming the plant's dry material. Applying cow urine to the soil as much as 20 mL per plant can increase plant growth (Mali, 2021), especially nitrogen. Nitrogen plays a role in forming chlorophyll, amino acids, fats, enzymes, and compounds needed in plant physiological processes to produce photosynthates. The application of cow urine evenly will be directly absorbed by the plant because it is easily soluble, so it quickly overcomes the lack of nutrients for the plant (Haryuni *et al*., 2018). In addition, the presence of IAA in the urine of cows serves to help the division and enlargement of cells (de Oliveira *et al*., 2009).

NAR, CGR and RGR

Applying cow urine can promote plant growth, especially NAR, CGR, and RGR. The growth of mustard plants can be cut with the application of cow urine starting from observation periods 10-15, 15-20, 20-25, and 25-30 DAP. The 40% concentration gives the highest results of NAR, CGR, and RGR up to the observation period of 25-30 DAP. The HSD test results on average NAR, CGR, and RGR on observations of 10-15, 15-20, 20-25, and 25-30 DAP are shown in Table 5.

Table 5 shows that cow urine application can increase mustard plants' NAR, CGR, and RGR. NAR values are affected by the rate of photosynthesis in the formation of plant dry materials. The rate of photosynthesis is determined in addition to environmental factors and is influenced by leaf area and nutrient content for chlorophyll constituents. Therefore, the assimilation rate can increase even higher with the application of cow urine. Cow urine contains a wide variety of nutrients, such as K, N, and Cl, which cause an increase in cells, due to the osmotic effect and encourage plant growth (de Oliveira *et al*., 2009). In addition, cow urine contains a mixture of hormones, enzymes, and mineral salts, such as iron, calcium, phosphorus,

potassium, nitrogen, amino acids, cytokines, and lactose that play an important role in plant growth (Mandavgane *et al*., 2016). In addition, cow urine can increase P in the soil and affect the proline content in the leaves of plants, so plants grow better and are resistant to dryness (Haryuni *et al*., 2018).

The difference in RGR value is influenced by the rate of the photosynthesis process for the formation of dry material of plants that previously existed. In addition to the nutrient availability factor for plants, other environmental factors also greatly affected the mustard plants' photosynthesis rate. The nutritional influence of cow urine showed an increase in chlorophyll and protein content compared to the control of chlorophyll (Jandaik *et al*., 2015). Plant RGR is affected by three main factors: the dry weight of the plant, the area of the leaves, and the dry weight of the leaves. Furthermore, there was no significant relationship between NAR and RGR, but there was a positive relationship between specific leaf areas with RGR and leaf mass ratio with RGR (Poorter and van der Werf, 1998). RGR becomes increasingly inefficient as plants age, as the process is highly dependent on environmental influences (Hunt, 1982).

Cow urine application concentration of 80% resulted in the highest NAR increase at the age of 15-20 DAP but continued to decrease at the ages of 20-25 DAP and 25-30 DAP. Similarly, other treatments have almost the same NAR pattern in all periods of growth, except for the 40% concentration that previously had a low NAR, then experienced an increase in NAR at the age of 25-30 DAP. The treatment of 80% of cow urine experienced the highest increase in CGR at 15-20 DAP but tended to be constant at 20-25 and 25-30 DAP. In contrast, the treatment without cow urine had a low CGR at almost all observation times. Treatment without cow urine application produces the lowest RGR at ages 10-15 DAP and 15-20 DAP but increases at ages 20-25 and 25-30 DAP. In contrast, the 80% treatment experienced the highest RGR increase at the age of 15-20 DAP but decreased at the ages of 20-25 and 25-30 DAP. For treatments of 20, 40 and 60% had an RGR with almost the same pattern at all observation times.

Harvest Yield

The use of cow urine can increase the yield of mustard per unit area. For example, cow urine concentration of 80% can provide higher yields/ha, although it is not a real difference with concentrations of 20, 40 and 60%. The results of the HSD test on the average harvest yield/ha can be shown in Table 6.

Table 6 shows that a urine concentration of 80% can provide higher harvest yields per crop, although it is no different from a concentration of 20-60%. Cow urine can increase the concentration of uptake of N, P, and K (Mali, 2021). This increase in fresh weight is due to cow urine containing 95% water, 2.5% urea, and the remaining 2.5% a mixture of salts, hormones, enzymes, and minerals. All these compounds are needed in plant metabolism (Choudhary *et al*., 2017). The application of cow urine increases the productivity of corn, mustard, and rice crops; cow urine, containing nutrients, also contains enzymes and plant growth hormones. Applying cow urine as a source of organic nutrients improves plant growth and yield parameters (Sadhukhan *et al*., 2020). After regular use of cow urine in plants, the population of soil microorganisms will increase along with the yield (Mali, 2021).

The growing trend of mustard harvest yields, so using cow urine above 80% can still increase harvest yields. For more details, the effect of cow urine concentration on mustard harvest yield can be seen in Fig. 1.

Fig. 1 shows that the application of cow urine has not reached the optimum concentration in inceptisol soils for the mustard plant. Therefore, the application of cow urine with a concentration higher than 80% is required for Inceptisol soils.

CONCLUSION

Based on the results of research research and discussion above, it can be concluded that the application of cow urine affected the growth and yield of mustard plants. Applying cow urine can increase leaf area, plant dry weight, NAR, CGR, RGR, and harvest yield. The application of 80% cow urine concentration provided the mustard harvest yield higher than other treatments. The study fundings that the application of cow urine has not reached the optimum concentration for the mustard plant in inceptisol soils. We recommend that the application of cow urine with a concentration higher than 80% is required in mustard cultivation.

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Table 1. Preliminary soil analysis data at the research site.

Parameters	Value	Unit	Criteria
Rough sands	30.3	%	Clay
Fine sand	9.9	%	
Silt	39.2	%	
Clay	20.6	%	
pH H_2O (1:25)	6.46	-	Slightly sour
pH KCl (1:25)	4.96	-	
C – organic	1.87	%	Very low
N – total	0.10	%	Low
K_2O (HCl 25%)	24.07	Mg/100 g	Medium
P_2O_5 (HCl 25%)	32.30	Mg/100 g	Medium
KTK	18.6	Cmol (+)/kg	Medium
Al-dd	1.00	Cmol (+)/kg	-
H-dd	2.59	Cmol (+)/kg	-
Na	0.62	Cmol (+)/kg	Medium
K	0.43	Cmol (+)/kg	Medium
Ca	10.13	Cmol (+)/kg	Medium
P_2O_5 (Olsen)	32.38	ppm	Very high

Source: Soil Science Laboratory of Faculty of Agriculture, Tadulako University, Indonesia.

Table 2. Analysis results of liquid organic fertilizer cow urine.

Parameters	Value	Unit
Nitrogen (N)	0.08	%
Pospor (P)	0.007	%
Kalium (K)	0.85	%
Natrium (Na)	0.21	%
Calcium (Ca)	0.15	%
C-Organik	0.30	%

Source: Soil Science Laboratory of Faculty of Agriculture, Tadulako University, Indonesia.

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Table 3. Average leaf area at 10, 20 and 30 days after planting (DAP).

Cow urine concentration (%)	DAP		
	10	20	30
0	190.37[b]	775.9[b]	1,701.1[b]
20	232.39[b]	1,044.2[ab]	2,174.7[a]
40	385.59[a]	804.9[b]	1,372.0[b]
60	384.78[a]	1,223.1[a]	2,285.9[a]
80	170.01[b]	1,040.7[ab]	1,498.2[b]
HSD 5%	74.85	348.24	416.59

Remarks: Average value in the column followed by the same letter indicates no significant difference based on the HSD test at P=0.05 level of probability.

Table 4. Average dry weight of mustard plants at 10, 20 and 30 days after planting (DAP).

Cow urine concentration (%)	DAP		
	10	20	30
0	1.13[b]	7.57[b]	27.04[c]
20	1.13[b]	13.99[ab]	35.75[bc]
40	1.36[ab]	13.32[ab]	46.09[b]
60	1.32[ab]	15.01[ab]	44.58[ab]
80	1.43[a]	21.64[a]	52.14[a]
HSD 5%	0.27	8.40	10.29

Remarks: Average value in the column followed by the same letter indicates no significant difference based on the HSD test at P=0.05 level of probability.

Table 5. Average NAR, CGR and RGR on observations at 10-15, 15-20, 20-25 and 25-30 days after planting (DAP).

Cow urine concentration (%)	DAP			
	10-15	15-20	20-25	25-30
NAR (g/cm^2/day)				
0	0.000797^a	0.00113^b	0.00233^a	0.00067^b
20	0.001043^a	0.00184^b	0.00230^a	0.00097^b
40	0.000527^a	0.00189^b	0.00190^a	0.00427^a
60	0.000843^a	0.00177^b	0.00193^a	0.00190^b
80	0.001287^a	0.00394^a	0.00243^a	0.00197^b
HSD 5%	ns	0.0016	ns	0.0015
CGR (g/m^2/day)				
0	0.0397^b	0.0407^b	0.1690^a	0.0743^b
20	0.0623^a	0.0987^{ab}	0.1740^a	0.0983^b
40	0.0623^a	0.0870^b	0.1357^a	0.3987^a
60	0.0653^b	0.1057^{ab}	0.1677^a	0.2017^b
80	0.0693^b	0.1837^a	0.1803^a	0.2010^b
HSD 5%	0.0213	0.0939	ns	0.1302
RGR (g/g/day)				
0	0.2673^b	0.1117^b	0.1007^b	0.0503^b
20	0.3380^a	0.1597^{ab}	0.1420^{ab}	0.0513^b
40	0.3077^{ab}	0.1463^{ab}	0.1223^b	0.1677^a
60	0.3183^a	0.1627^{ab}	0.1303^b	0.0913^b
80	0.3163^{ab}	0.2267^a	0.2053^a	0.0753^b
HSD 5%	0.0503	0.1003	0.0723	0.0652

Remarks: Average value in the column followed by the same letter indicates no significant difference based on the HSD test at P=0.05 level of probability; ns: Not Significant.

Table 6. Average harvest yield per hectare.

Cow urine concentration (%)	Mustard (t/ha)
0	28.044[b]
20	38.844[ab]
40	40.000[ab]
60	42.444[ab]
80	50.666[a]
HSD 5%	16.733

Remarks: Average value in the column followed by the same letter indicates no significant difference based on the HSD test at P=0.05 level of probability.

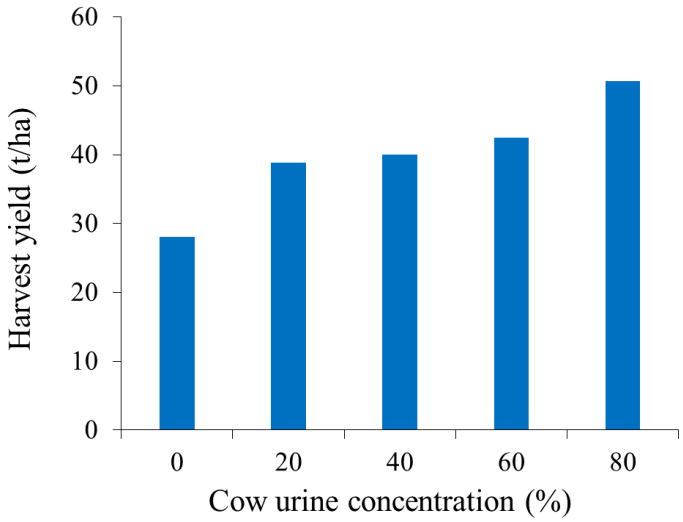
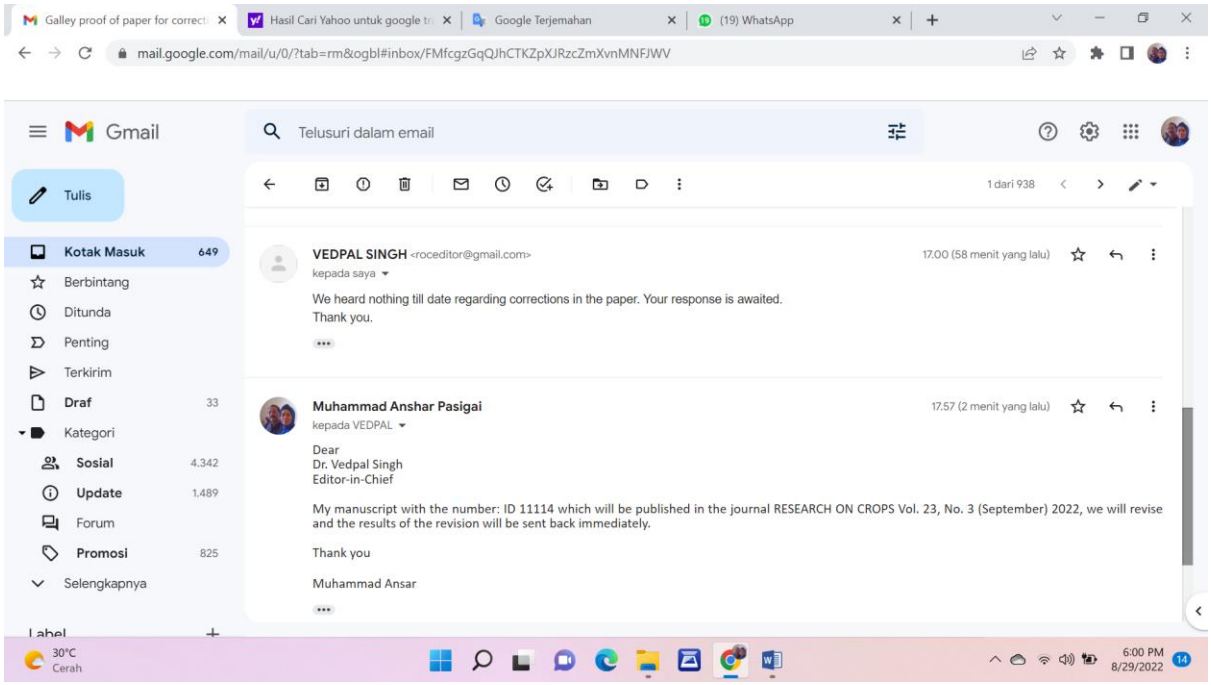


Fig. 1. Effect of cow urine concentration on mustard yield.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My manuscript with the number: ID 11114 which will be published in the journal RESEARCH ON CROPS Vol. 23, No. 3 (September) 2022, we will revise and the results of the revision will be sent back immediately.
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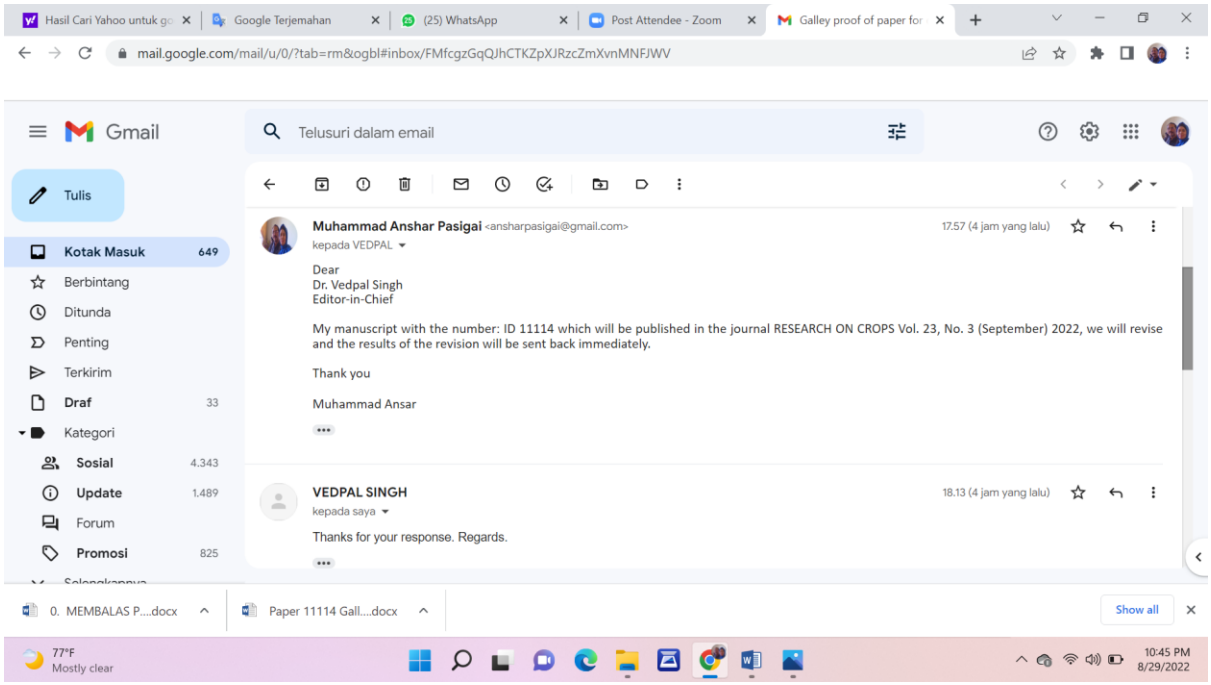
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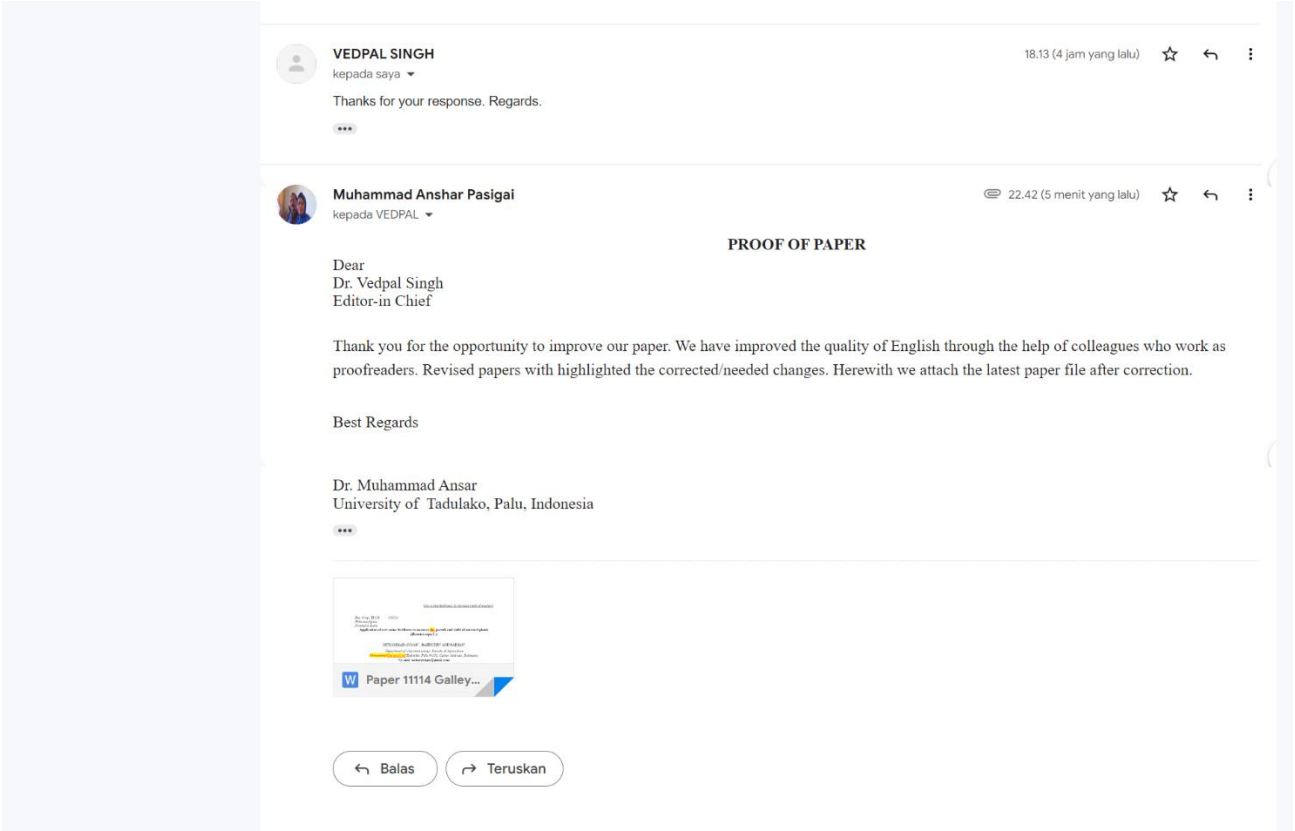

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Dear
Dr. Vedpal Singh
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Application of cow urine fertilizers to increase the growth and yield of mustard plants (*Brassica rapa* L.)

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ABSTRACT

Mustard plant is one of the main types of vegetables widely consumed in Indonesia. Synthetic fertilizers are always used to increase crop productivity and add environmental residue. Using cow urine is one of the zero waste applications in agriculture. This research aims to know the optimum concentration of cow urine on the growth and yield of mustard. This research was conducted from May 2021 to November 2021 in Olobojo Village, Sigi Biromaru Subdistrict, Sigi Regency, Central Sulawesi, Indonesia. The experiment was arranged in a randomized complete block design with three replications. The treatment of cow urine concentration consisted of five levels, namely 0, 20, 40, 60, and 80%. In this study, 15 plots were needed. For each plot of the experiment, there were 84 plants. The experiment results showed that the application of cow urine affected the growth and yield of mustard plants. Applying cow urine can increase leaf area, plant dry weight, net assimilation rate (NAR), crop growth rate (CGR), relative growth rate (RGR), and harvest yield. The application of 80% cow urine concentration provided the mustard harvest yield higher than other treatments. The study findings that the application of cow urine has not reached the optimum concentration for the

mustard plant in inceptisol soils. We recommend that the application of cow urine with a concentration higher than 80% is required in mustard cultivation.

Key words: Cow urine, liquid organic fertilizer (LOF), mustard plant, nutrient

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INTRODUCTION

The mustard plant (*Brassica rapa* var. Chinensis) is one of the main types of vegetables widely consumed by the public because it has a high nutritional content (Hanum *et al*., 2021). However, culturing mustard plants on dry land with limited water conditions is a limiting factor for plant growth. Similarly, excessive and uncontrolled use of chemicals will reduce product quality, soil fertility, and environmental pollution. In general, the cultivation of mustard plants in Indonesia still uses synthetic fertilizers because it has been shown to increase crop productivity. Therefore, fertilizer is a major input factor in increasing crop yields, including mustard crops.

Fertilizer applications can accelerate agricultural production by contributing 50% of crop yield. But over a long period, synthetic fertilizers, especially NPK, will add residue to the environment and cause a decrease in soil quality, and affect crop production (Singh *et al*., 2020). Now, organic farming is becoming mainstream all over the world. However, since the green revolution, the indiscriminate use of chemicals has adversely affected soil fertility, plant productivity, production quality, etc., especially on environmental systems. In such a situation, the need to adopt environmentally friendly agricultural practices for food production is strongly emphasized, considering soil and environmental sustainability. For that, it is necessary to integrate nutrient management by prioritizing using natural materials that can increase plant productivity without reducing soil fertility (Singh *et al*., 2017; Nahar *et al*., 2021).

On the other hand, there is agricultural waste that has the potential to be developed as a source of plant fertilizer. The use of waste can provide added value in maximizing social, environmental, and health and can reduce the cost of investment and plant production operations (Etter *et al*., 2011). Unfortunately, one agricultural waste that has not been optimally utilized is cow urine.

Using cow urine in agricultural businesses is one of the applications of zero waste management. The use of cow urine can be considered a low-cost agricultural practice and has

been widely used in traditional agriculture (Vala and Desai, 2021). Cattle are the main source of waste products in the form of feces and urine that can be useful for agriculture. Cow urine can be used as a basic material for making organic fertilizers (Lubis and Sembiring, 2019). Cow urine is a source of nitrogen, sulfur, phosphate, potassium, sodium, manganese, carbolic acid, iron, silicon, chlorine, salt, enzymes, and hormones (Vala and Desai, 2021). Cow urine contains many microelements. Total N ranges from 6.8-21.6 g/l, which averages 69% in urea form (Sharma and Rai, 2015). Cow dung contains various groups of beneficial microorganisms because it produces various metabolites and increases soil fertility through phosphate dissolution (Gupta *et al*., 2016).

In organic farming, cow urine is used to prepare several growth promoters and biopesticides, thus effectively improving soil fertility and pest and disease control. However, the use of cow urine provides a better alternative to expensive synthetic chemicals and has the potential to harm farmers, marketers, consumers, and the environment (Vala and Desai, 2021). Cow urine has been used since ancient times and is useful in agriculture, especially organic farming (Rekha *et al*., 2017). Cow urine has the activity of controlling harmful fungi and promotes growth and crop yields (Ghosh *et al*., 2018). The fungus attacks many plants: *Fusarium oxysporum*, *Pythium aphanidermatum*, and the bacteria *Ralstonia solanacearum* (Rakesh *et al*., 2013). Cow urine-added neem leaves are an excellent biopesticide, safe to use, do not accumulate in the food chain, and do not cause harmful effects such as chemical pesticides (Rekha *et al*., 2017). The results showed that 50-100 ml of pure cow urine in beehives at intervals of 10-15 days could recover quickly from bees infected with the disease within 8-10 days after spraying and can increase productivity (Tiwari and Nagar, 2015).

Some studies on the application of cow urine increase growth and improve the quality of crop yields. Spraying of 50, 75, and 100% cow urine concentrations recorded higher grain yields of 2.69, 18.01, and 27.21%, respectively, than control (Sadhukhan *et al*., 2018). Using cow urine concentration of 5% increased methi plants (*Trigonella foenum-graecum* L.), including protein and chlorophyll content (Soman and Shetty, 2018). The bio-urine applications improved soil pH, fertility, and nitrogen levels and have short-term nitrogen release efficiency (Nwite, 2015). A combination of inorganic fertilizers 120 kg N/ha + 60 kg P_2O_5/ha+ 60 kg K_2O/ha + 40 kg S/ha and 900 l cow urine/ha gave maximum results and proved most beneficial (Pradhan *et al*., 2016). Spraying a 55% cow urine solution on mango leaves produced fruit weight, volume, and amount of fruit/plant (Damodhar and Shinde, 2010).

Research has shown that using cow urine can increase plant growth and yield. But researchers have previously studied the use of cow urine in wheat, rice, *methi*, sorghum, and mango crops, while in mustard plants have never been. No studies have been found discussing the effect of cow urine concentration on mustard plant cultivation. Therefore, there needs to be research to know the optimum concentration of cow urine in mustard plants. With the discovery of the right concentration, the application is expected to increase the maximum growth and yield of mustard plants. Therefore, this study aims to know the optimum concentration of cow urine to increase the growth and yield of mustard plants.

MATERIALS AND METHODS

The Study Area

This research was conducted in Olobojo Village, Sigi Biromaru Subdistrict, Sigi Regency. The research took place from May 2021 to November 2021. The location of the study was at coordinates S 1˚01'14.6532" and E 119˚59'29.0256", at a place altitude of 125 m above sea levels (m ASL), with the average daily air temperature being 30˚C and the average daily air humidity being 67%.

Experimental Design

The study was arranged in a randomized complete block design (RCBD) with three replications. Treatment of cow urine concentration, consisting of 0, 20, 40, 60, and 80%. In this study, 15 trials were needed. In each plot of the experiment, there were 84 plants.

Research Pprocedures

The soil was processed to lose to improve the structure and air circulation and encourage microbial activity. The experimental plots were in the size of 210 cm × 300 cm. The distance between the experimental plots was 50 cm. A cow manure dose of 15 t/ha was applied to each experiment plot one week before planting. The planting distance for mustard plants was in the size of 30 cm × 25 cm. Mustard seedlings were ready to move planting at the age of 10 days. Cow urine application was done at the age of five days after planting (DAP). The concentration of cow urine was given according to treatment. A hand sprayer was applied to cow urine on the upper and lower surfaces of the leaves evenly. Spraying was done at ages 5, 10, 15, 20, and 25 DAP.

Data Collection

Plant growth was observed to include the leaf area and plant dry weight at ages of 10, 15, 20, 25, and 30 DAP, while crop yields included fresh weight/plant and harvest weight/ha. Furthermore, according to Gardner *et al*. (1985), plant growth analysis can be calculated with the following equation.

Net assimilation rate (NAR) is the ability of plants to produce dry materials that assimilate each unit of leaf area at each unit of time, as is stated in Eq. 1.

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \text{ x } \frac{\ln LA_2 - \ln LA_1}{LA_2 - LA_1} \text{ (g/cm}^2\text{/day)} \qquad \text{(Eq. 1)}$$

Crop growth rate (CGR) is the ability of plants to produce dry materials that assimilate each unit of land area at each unit of time, as is stated in Eq. 2.

$$CGR = \frac{1}{G} \times \frac{W_2 - W_1}{t_2 - t_1} \text{ (g/m}^2\text{/day)} \qquad \text{(Eq. 2)}$$

Relative growth rate (RGR) is the ability of plants to produce dry materials assimilated from each unit of initial dry weight at each unit of time, which is expressed in Eq. 3.

$$RGR = \frac{\ln LW_2 - \ln LW_1}{t_2 - t_1} \text{ (g/g/day)} \qquad \text{(Eq. 3)}$$

Where, W_1 = total dry weight per plant at the time of t_1; W_2= Total dry weight per plant at the time of t_2; LA_1= Total leaf area per plant at the time of t_1; LA_1 = Total leaf area per plant at the time of t_1; G = the area of land overgrown with plants; t_1 = Harvest time in the beginning; t_2 = harvest time in the end.

Statistical Analysis

Observational data were analyzed using analysis of variance (ANOVA) with IBM SPSS Statistic 23. If the treatment had a significant effect, knowing the difference between treatments was done using the honesty significant difference (HSD) test at P=0.05 level of probability (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Soil Analysis

The soil type was clay texture with rough sand content (30.3%), fine sand (9.9%), dust (39.2%), and clay (20.6%). The soil's pH was slightly sour, but according to the pH requirement range of the mustard plant was 6.0-6.5. The content of essential macronutrients, especially N, included low criteria, while P and K are moderate. The content of Ca, Na, and

KTK was medium, and the nutrient content of N-total and the content of C-organic was relatively low (0.98%). The results description of soil analysis can be seen in Table 1.

Cow Urine Analysis

The cow urine liquid organic fertilizer used in the study contained 0.08% nitrogen, 0.007% phosphorus, 0.85% potassium, 0.21% sodium, 0.15% Calcium and 0.3% C-organic. Soil analysis showed that the soil for the study was included in the category of less fertile soil, so it needs to be added nutrients, especially C and N. The results description of cow urine analysis can be seen in Table 2.

Leaf Area

Application of cow urine can increase the total area of mustard leaves at the ages of 10, 20, and 30 DAP. The results showed that the application of 60% concentration resulted in a higher total leaf area per plant and decreased leaf area at a concentration of 80% of cow urine. The results of the HSD test on the average leaf area of ages 10, 20, and 30 DAP are shown in Table 3.

Table 3 shows that the application of cow urine increases the leaf area of the mustard plant to a cow's urine concentration by 60%. Cow urine contains macronutrients, as well as micronutrients needed for plant growth. Micro and macro nutrient content were important in supporting mustard leaves' dilated growth. Although, as stated by Vala and Desai (2021), cow urine retreats macronutrients, especially nitrogen, phosphate, potassium, and sulfur, in large quantities, it also contains micronutrients, especially sodium, manganese, carbolic acid, iron, silicon, chlorine, as well as salts, enzymes, and hormones that all plants need.

Conversely, micronutrients absorbed by plants in large quantities can suppress or inhibit plant growth. It can cause a decrease in leaf area with the administration of cow urine higher than the concentration of 60%. On the other hand, the application of cow urine accelerates various aspects of plant growth. According to Chongre *et al*. (2020), the application of cow urine can increase the growth of plant leaves as a result of the process, and the rate of photosynthesis increases. The application of cow urine can promote growth, and the quantity and quality of plants, as bio urine, contains macronutrients, essential micronutrients, vitamins, essential amino acids, IAA, GA, and beneficial microorganisms.

Dry Weight of Mustard Plants

The application of cow urine significantly affected to increase the total dry weight per plant at ages of 10, 20, and 30 DAP. For example, applying a concentration of 80% of cow urine resulted in a higher total dry weight per plant, although it was no different from a concentration of 60% at 30 DAP. The HSD test on the average dry weight per plant at ages 10, 20, and 30 DAP are shown in Table 4.

Table 4 shows that 80% application of cow urine results in higher dry weight per plant. This result differs from the optimum concentration on observations at leaf area per plant. The dry weight of the plant is largely determined by the results of the photosynthetic process, not just by the size of the leaf area. Cow urine contains many nutrients and plays a role in forming the plant's dry material. Applying cow urine to the soil as much as 20 mL per plant can increase plant growth (Mali, 2021), especially nitrogen. Nitrogen plays a role in forming chlorophyll, amino acids, fats, enzymes, and compounds needed in plant physiological processes to produce photosynthates. The application of cow urine evenly will be directly absorbed by the plant because it is easily soluble, so it quickly overcomes the lack of nutrients for the plant (Haryuni *et al*., 2018). In addition, the presence of IAA in the urine of cows serves to help the division and enlargement of cells (de Oliveira *et al*., 2009).

NAR, CGR, and RGR

Applying cow urine can promote plant growth, especially NAR, CGR, and RGR. The growth of mustard plants can be observed in the period of 10-15, 15-20, 20-25, and 25-30 DAP. The 40% concentration gives the highest results of NAR, CGR, and RGR up to the observation period of 25-30 DAP. The HSD test results on average NAR, CGR, and RGR on observations of 10-15, 15-20, 20-25, and 25-30 DAP are shown in Table 5.

Table 5 shows that cow urine application can increase mustard plants' NAR, CGR, and RGR. NAR values are affected by the rate of photosynthesis in the formation of plant dry materials. The rate of photosynthesis is determined in addition to environmental factors and is influenced by leaf area and nutrient content for chlorophyll constituents. Therefore, the assimilation rate can increase even higher with the application of cow urine. Cow urine contains a wide variety of nutrients, such as K, N, and Cl, which cause an increase in cells, due to the osmotic effect and encourage plant growth (de Oliveira *et al*., 2009). In addition, cow urine contains a mixture of hormones, enzymes, and mineral salts, such as iron, calcium, phosphorus, potassium, nitrogen, amino acids, cytokines, and lactose that play an important role in plant

growth (Mandavgane *et al*., 2016). In addition, cow urine can increase P in the soil and affect the proline content in the leaves of plants, so plants grow better and are resistant to dryness (Haryuni *et al*., 2018).

The difference in RGR value is influenced by the rate of the photosynthesis process for the formation of dry material of plants that previously existed. In addition to the nutrient availability factor for plants, other environmental factors also greatly affected the mustard plants' photosynthesis rate. The nutritional influence of cow urine showed an increase in chlorophyll and protein content compared to the control (Jandaik *et al*., 2015). Plant RGR is affected by three main factors: the dry weight of the plant, the area of the leaves, and the dry weight of the leaves. Furthermore, there was no significant relationship between NAR and RGR, but there was a positive relationship between specific leaf areas with RGR and leaf mass ratio with RGR (Poorter and van der Werf, 1998). RGR becomes increasingly inefficient as plants age, as the process is highly dependent on environmental influences (Hunt, 1982).

Cow urine application concentration of 80% resulted in the highest NAR increase at the age of 15-20 DAP but continued to decrease at the ages of 20-25 DAP and 25-30 DAP. Similarly, other treatments have almost the same NAR pattern in all periods of growth, except for the 40% concentration that previously had a low NAR, then experienced an increase in NAR at the age of 25-30 DAP. The treatment of 80% of cow urine experienced the highest increase in CGR at 15-20 DAP but tended to be constant at 20-25 and 25-30 DAP. In contrast, the treatment without cow urine had a low CGR at almost all observation times. Treatment without cow urine application produces the lowest RGR at ages 10-15 DAP and 15-20 DAP but increases at ages 20-25 and 25-30 DAP. In contrast, the 80% treatment experienced the highest RGR increase at the age of 15-20 DAP but decreased at the ages of 20-25 and 25-30 DAP. For treatments of 20, 40, and 60% had an RGR with almost the same pattern at all observation times.

Harvest Yield

The use of cow urine can increase the yield of mustard per unit area. For example, cow urine concentration of 80% can provide higher yields/ha, although it is not a real difference with concentrations of 20, 40, and 60%. The results of the HSD test on the average harvest yield/ha can be shown in Table 6.

Table 6 shows that a urine concentration of 80% can provide higher harvest yields per crop, although it is no different from a concentration of 20-60%. Cow urine can increase the

concentration of uptake of N, P, and K (Mali, 2021). This increase in fresh weight is due to cow urine containing 95% water, 2.5% urea, and the remaining 2.5% a mixture of salts, hormones, enzymes, and minerals. All these compounds are needed in plant metabolism (Choudhary *et al*., 2017). The application of cow urine increases the productivity of corn, mustard, and rice crops; cow urine contains nutrients and enzymes, and plant growth hormones. Applying cow urine as a source of organic nutrients improves plant growth and yield parameters (Sadhukhan *et al*., 2020). After regular use of cow urine in plants, the population of soil microorganisms will increase along with the yield (Mali, 2021).

The growing trend of mustard harvest yields, so using cow urine above 80% can still increase harvest yields. For more details, the effect of cow urine concentration on mustard harvest yield can be seen in Fig. 1.

Fig. 1 shows that the application of cow urine has not reached the optimum concentration in inceptisol soils for the mustard plant. Therefore, the application of cow urine with a concentration higher than 80% is required for Inceptisol soils.

CONCLUSION

Based on the results of research and discussion above, it can be concluded that the application of cow urine affected the growth and yield of mustard plants. Applying cow urine can increase leaf area, plant dry weight, NAR, CGR, RGR, and harvest yield. The application of 80% cow urine concentration provided the mustard harvest yield higher than other treatments. The study findings that the application of cow urine has not reached the optimum concentration for the mustard plant in inceptisol soils. We recommend that the application of cow urine with a concentration higher than 80% is required in mustard cultivation.

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Table 1. Preliminary soil analysis data at the research site.

Parameters	Value	Unit	Criteria
Rough sands	30.3	%	Clay
Fine sand	9.9	%	
Silt	39.2	%	
Clay	20.6	%	
pH H_2O (1:25)	6.46	-	Slightly sour
pH KCl (1:25)	4.96	-	
C – organic	1.87	%	Very low
N – total	0.10	%	Low
K_2O (HCl 25%)	24.07	Mg/100 g	Medium
P_2O_5 (HCl 25%)	32.30	Mg/100 g	Medium
KTK	18.6	Cmol (+)/kg	Medium
Al-dd	1.00	Cmol (+)/kg	-
H-dd	2.59	Cmol (+)/kg	-
Na	0.62	Cmol (+)/kg	Medium
K	0.43	Cmol (+)/kg	Medium
Ca	10.13	Cmol (+)/kg	Medium
P_2O_5 (Olsen)	32.38	ppm	Very high

Source: Soil Science Laboratory of Faculty of Agriculture, Tadulako University, Indonesia.

Table 2. Analysis results of liquid organic fertilizer cow urine.

Parameters	Value	Unit
Nitrogen (N)	0.08	%
Pospor (P)	0.007	%
Kalium (K)	0.85	%
Natrium (Na)	0.21	%
Calcium (Ca)	0.15	%
C-Organik	0.30	%

Source: Soil Science Laboratory of Faculty of Agriculture, Tadulako University, Indonesia.

Table 3. Average leaf area at 10, 20 and 30 days after planting (DAP).

Cow urine concentration (%)	DAP		
	10	20	30
0	190.37[b]	775.9[b]	1,701.1[b]
20	232.39[b]	1,044.2[ab]	2,174.7[a]
40	385.59[a]	804.9[b]	1,372.0[b]
60	384.78[a]	1,223.1[a]	2,285.9[a]
80	170.01[b]	1,040.7[ab]	1,498.2[b]
HSD 5%	74.85	348.24	416.59

Remarks: Average value in the column followed by the same letter indicates no significant difference based on the HSD test at P=0.05 level of probability.

Table 4. Average dry weight of mustard plants at 10, 20 and 30 days after planting (DAP).

Cow urine concentration (%)	DAP		
	10	20	30
0	1.13[b]	7.57[b]	27.04[c]
20	1.13[b]	13.99[ab]	35.75[bc]
40	1.36[ab]	13.32[ab]	46.09[b]
60	1.32[ab]	15.01[ab]	44.58[ab]
80	1.43[a]	21.64[a]	52.14[a]
HSD 5%	0.27	8.40	10.29

Remarks: Average value in the column followed by the same letter indicates no significant difference based on the HSD test at P=0.05 level of probability.

Table 5. Average NAR, CGR and RGR on observations at 10-15, 15-20, 20-25 and 25-30 days after planting (DAP).

Cow urine concentration (%)	DAP			
	10-15	15-20	20-25	25-30
NAR ($g/cm^2/day$)				
0	0.000797[a]	0.00113[b]	0.00233[a]	0.00067[b]
20	0.001043[a]	0.00184[b]	0.00230[a]	0.00097[b]
40	0.000527[a]	0.00189[b]	0.00190[a]	0.00427[a]
60	0.000843[a]	0.00177[b]	0.00193[a]	0.00190[b]
80	0.001287[a]	0.00394[a]	0.00243[a]	0.00197[b]
HSD 5%	ns	0.0016	ns	0.0015
CGR ($g/m^2/day$)				
0	0.0397[b]	0.0407[b]	0.1690[a]	0.0743[b]
20	0.0623[a]	0.0987[ab]	0.1740[a]	0.0983[b]
40	0.0623[a]	0.0870[b]	0.1357[a]	0.3987[a]
60	0.0653[b]	0.1057[ab]	0.1677[a]	0.2017[b]
80	0.0693[b]	0.1837[a]	0.1803[a]	0.2010[b]
HSD 5%	0.0213	0.0939	ns	0.1302
RGR ($g/g/day$)				
0	0.2673[b]	0.1117[b]	0.1007[b]	0.0503[b]
20	0.3380[a]	0.1597[ab]	0.1420[ab]	0.0513[b]
40	0.3077[ab]	0.1463[ab]	0.1223[b]	0.1677[a]
60	0.3183[a]	0.1627[ab]	0.1303[b]	0.0913[b]
80	0.3163[ab]	0.2267[a]	0.2053[a]	0.0753[b]
HSD 5%	0.0503	0.1003	0.0723	0.0652

Remarks: Average value in the column followed by the same letter indicates

no significant difference based on the HSD test at P=0.05 level of probability; ns: Not Significant.

Table 6. Average harvest yield per hectare.

Cow urine concentration (%)	Mustard (t/ha)
0	28.044[b]
20	38.844[ab]
40	40.000[ab]
60	42.444[ab]
80	50.666[a]
HSD 5%	16.733

Remarks: Average value in the column followed by the same letter indicates no significant difference based on the HSD test at P=0.05 level of probability.

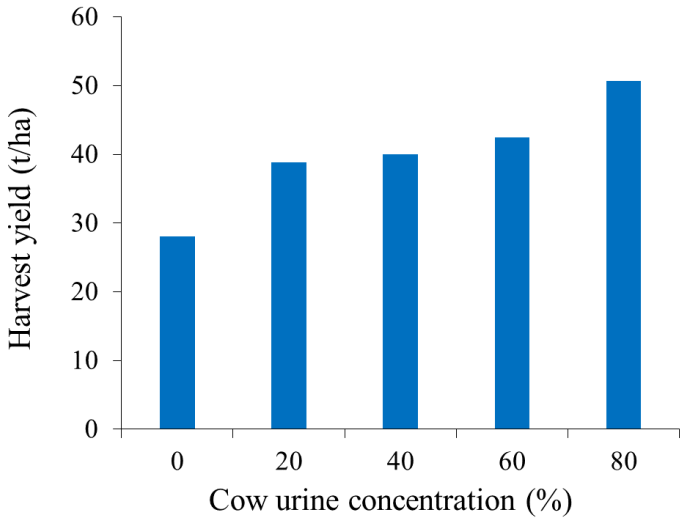

Fig. 1. Effect of cow urine concentration on mustard yield.

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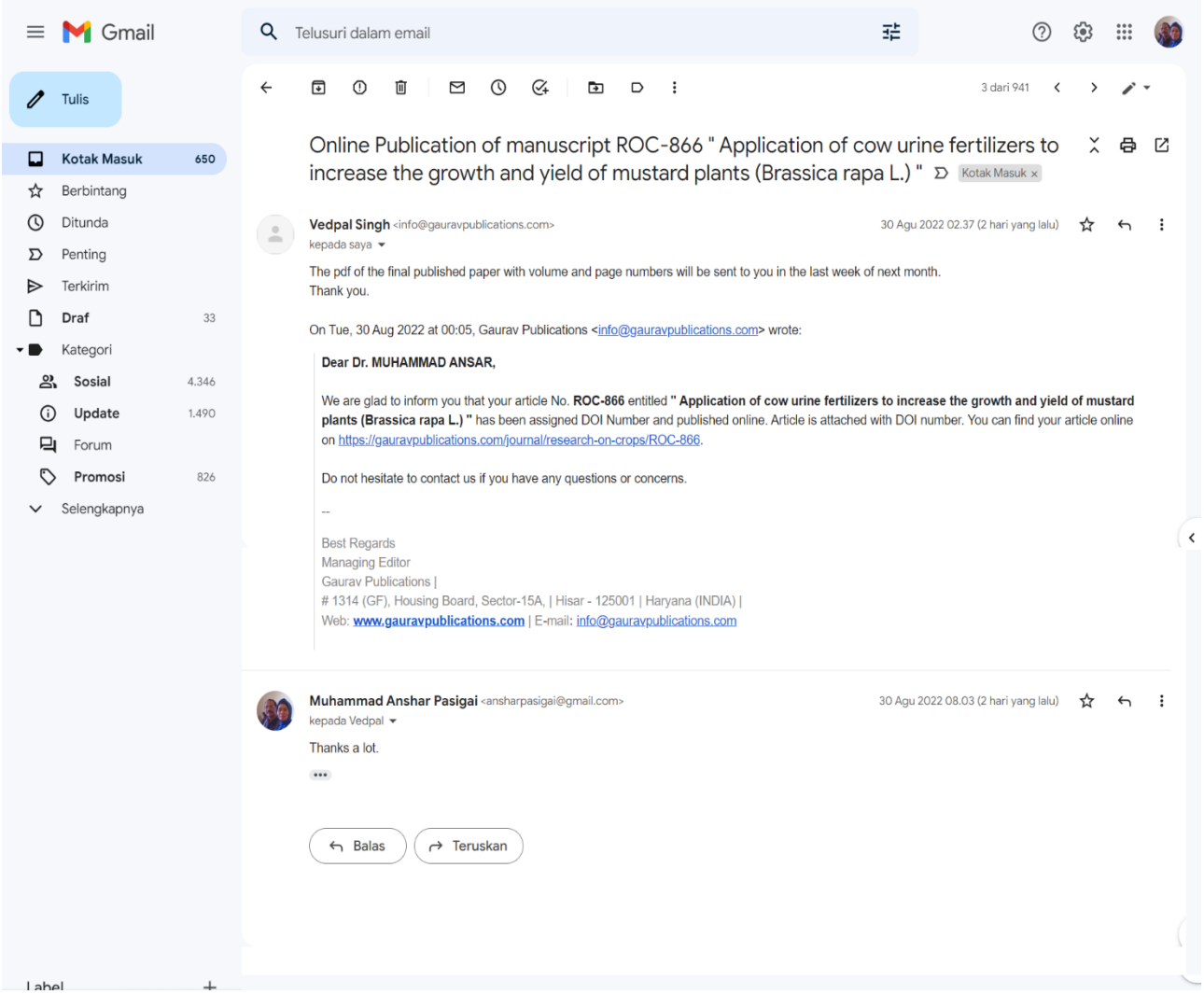

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