Improving Nutritional Value of Cow Manure with Biomass Ash and Its Response to the Growth and K-Ca Absorption of Mustard on Inceptisols

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Abstract. Cow manure is widely used by Indonesia vegetable farmers but the nutrients content is relatively low (particularly for K and Ca). Wood and husk ash as a by-products from the pottery burning process are widely available in the villages and have not been fully utilized. The ash is rich in K and Ca nutrients, so it is useful for increasing the nutritional value of cow manure. This study was aimed to determine the effect of enrichment cow manure (ECM) on soil chemical properties, growth and K-Ca uptake by mustard on Inceptisols. The greenhouse experiment conducted by using 5 kg of soil, with a completely randomized design. As treatment 1: Mixed cow manure (CM)+Husk Ash (HA) with doses of 0+100, 900+100, 925+75, 950+50, 975+25 g/pot); Treatment 2: CM+Wood Ash mixture (WA) with the same dose. While there are 3 controls, namely: soil without fertilizer, soil + CM 1000 g/pot, and soil + CM 123 g/pot. The results showed that ECM significantly increased the soil fertility and plant growth. The highest K and Ca uptake in the shoot was obtained at CM + HA treatment with dose of 925 + 75 and 900 + 100 g/pot, respectively. This research is part of a step towards grounding the organic agriculture concept, so there is still an opportunity to research other materials as materials for manure fortification.

1. Introduction

Inceptisols are one of 12 soil orders in the world that is characterized by a cambic horizon on its endopedons [1]. Inceptisols support approximately 20 percent of the world's population, the largest percentage of any of the soil orders, and in Indonesia cover 40.8 million ha [2]. As the name implies, the term inceptisol comes from the Latin "inceptum" which means "beginning" to develop. This soil is more developed than Entisols because it already possesses a diagnostic horizon feature, namely the cambic horizon (Bw). This soil can be derived from igneous, sedimentary and metamorphic rocks and is widely distributed from wet to dry climates, with flat to steep topography, with soil reactions (pH) from acid to alkaline, so that the vegetation that grows on it is very diverse. This condition has implications for varying the level of physical, chemical and biological fertility of the soil.

In general, Inceptisols in the Yogyakarta area derived from three parent material types, namely volcanic material from Mt. Merapi, Alluvial which comes from river overflows and limestone which is mostly located in the southern Jogjakarta area. Inceptisols formed in flat areas are usually characterized by a gray color, sandy texture, slightly neutral soil reaction (pH-H2O), low cation exchange capacity, and low macro-micro nutrients content [3-4]. Soil, which is dominated by sand fraction, has the main problem of having low water and nutrient holding capacity so that nutrients are easily leached from the
soil adsorption complex. One strategy to overcome the soil fertility problem by adding organic manure to improve the physical, chemical and biological properties of the soil. The use of cow manure in order to have a more significant effect is often enriched with microbes or biomass waste. Kartika et al. [5] used mycorrhizae mixed with cow dung compost at a dose of only 50% of the recommended dosage to significantly increase the growth and yield of oil palm. Meanwhile, Lestari [6] combines cow manure with coconut husk ash to increase the growth of broccoli.

Manure contains sufficiently complete nutrients [7], the decomposition process by microbes can release macro nutrients (N, P, K, Ca, Mg, S) and micro (Fe, Zn, B, and Mo). However, the levels of K and Ca are relatively low, so that they are not sufficient to meet the needs of one plant life cycle. Manure is also useful for increasing aggregate stability, total pore percentage, permeability, water holding capacity, microbial activity and soil cation exchange capacity values [8-10]. The weakness of the manure can be increased its nutritional value, especially for the base cations content by adding materials that are widely available in the village, namely ash as by-product of pottery burning process.

Kasongan pottery handicraft center located in Bangunjiwo Village, Yogyakarta has a large enough ash potential, which is more than 7500 kg per month. In 2014, Indonesia produced 70,832,000 tons of rice, with the potential for rice husk and husk ash as much as 14,166,400 and 2,833,280 tons, respectively [11]. A lot of wood ash is also produced from the pottery burning process. Until now, the husk and wood ash has not been fully utilized, especially for agriculture. Levels of K, Ca, Mg and Na the husk ash ranged from 250-770, 410-880, 250-260, and 60-680 mg kg⁻¹, respectively [12], while for wood ash they ranged from 0.1-13, 2.5-33, 0.1-2.5, 0-0.54% [13]. The nutrient content in the ash varies depending on the plant variety, the soil type as a growing medium and the input of fertilizers applied to the plant.

The high levels of K and Ca in the both ashes can be used to increase the nutrient value of cow manure. Potassium plays an important role in the process of carbohydrate metabolism, enzyme activity, osmotic regulation, water use efficiency, nitrogen uptake, protein synthesis, assimilation translocation, increased resistance to disease, and crop yields quality [14-15]. K-deficient plants show a chlorotic symptom on old leaves, green only on interveinal leaves, then the leaves dry out [16]. Calcium plays an important role as a constituent of cell walls, cell membranes, and cell division. Plants that are deficient in Ca reveal symptoms of abnormal leaf growth, and the tips of the leaves turn brown or black [17].

Considering the large number of vegetable farmers, especially mustard, have implemented the organic farming concept which only relies on nutrient sources from manure, the quality needs to be improved. The enrichment of K and Ca content in mustard can be done using fortification techniques, namely by adding materials such as wood ash or husk ash which are rich in K and Ca nutrients in cow manure, which notifies that all of these materials are widely available in the village. Therefore, this study was aimed to determine the effect of the biomass ash-enriched cow manure on the soil chemical properties, growth and K-Ca uptake by green mustard on Inceptisols.

2. Materials and Methods

The pot experiment was carried out in a greenhouse using 5 kg of Inceptisols taken from paddy fields at Tirtonirmolo, southern Yogyakarta. The design was completely randomized with 2 treatments, namely: as Treatment 1: mixed cow manure (CM) + Husk Ash (HA) with doses of 0 + 100, 900 + 100, 925 + 75, 950 + 50, 975 + 25 g / pot; Treatment 2: CM + Wood Ash mixture (WA) with the same dose. While there were 3 controls, namely: soil without fertilizer, soil + CM 1000 g / pot, and soil + CM 123 g / pot. Mustard plants were transplanted from seedlings of 7 days, their growth was observed for 28 days, then the harvest was carried out at the age of 35 days. Growth parameters measured included: plant height, leaves number, leaf area, shoot fresh weight, shoot dry weight, root fresh weight, root dry weight, shoot/root dry weight ratio. K-Ca content in shoots and roots was determined by wet digestion (HClO₄: HNO₃/1: 3). This method was also used for analysis of total Ca, Mg and K concentrations in cow manure, while for wood and husk ash using 25% HCl extract [18]. The value of nutrient uptake was obtained from multiplying nutrient content in plant tissue by weight of plant biomass.
Chemical characterization was carried out on the materials used for ameliorant (wood ash, husk ash, cow manure) and soil before and after treatment. Analysis of soil physical properties was carried out only on the original soil sample before treatment which included: texture using pipetting method, bulk density with sample ring, particle density with pycnometer. Soil pH-H2O was measured by pH-meter and electrical conductivity was determined by conductometer, both use a 1: 2.5 ratio for soil: water. Organic C contents were analyzed by the Walkley and Black method. Cation Exchange Capacity (CEC) was measured by the NH4OAc 1N saturation method, the first aliquot obtained from extraction with NH4OAc was used for determination of Ca, Mg, and K contents, Ca and Mg concentration were measured by Atomic Absorption Spectrophotometer, while K was measured by Flamephotometer. Total nitrogen was determined by the Kjeldahl method. Available phosphate was measured with Olsen extract and measured with a spectrophotometer at λ = 889 nm [18].

The experimental data were analyzed using one-way analysis of variance (ANOVA) with software R. If the variety of treatments showed a significant effect at the 5% level, it was continued with Duncan's Multiple Range Test (DMRT) to determine the significant difference in treatment.

3. Results and Discussion

3.1. Soil chemical and physical properties of inceptisols

The results of the initial soil test before being treated are presented in Table 1. The actual soil reaction was categorized as a slightly acidic pH (5.74), while its potential pH was lower (5.2). The positive ΔpH value obtained from subtracting the pH-H2O value with pH-KCl, this indicates that this soil was not classified as a variable charge soil. Soil with a pH value of around 6 and a very low electrical conductivity value (0.11dS m-1) provides a conducive environment to support mustard growth. However, because of the soil was dominated by the sand fraction (56.58%), the water holding power and soil nutrients were low. Normally, the sandy-textured soil has a high level of porosity so that the leaching and evaporation process proceed faster. Therefore, the macro nutrients content such as N, K, Ca and Mg have a low-very low status. Meanwhile, the available P content was classified as very high, possibly it came from intensive fertilization by farmers. In fact, farmers in addition to providing P fertilizers also added N (urea) and K (KCl) fertilizers, because these two nutrients are very mobile in the soil so they are easily leached from the soil absorption complex.

This soil has a proportion of the fraction of sand> silt> clay, so its texture is categorized as sandy loam. The advantage of textured soil is that it is easy to plow. However, because it has a low CEC value, the soil buffering capacity is also low. One of the manners to increase the soil buffering capacity is by adding organic matter. Another benefit of organic matter is that it can increase soil aggregation and become a source of nutrients for plants, especially N which comes from organic N compounds such as proteins and amino acids.

3.2. Chemical properties of cow manure, wood ash and husk ash.

Cow manure used in this study has met the minimum technical requirements for organic fertilizers based on the Minister of Agriculture Decree no: 28 / Permentan / SR.130 / B / 2009. Nutrients available to plants come from the decomposition of organic matter into simpler compounds that are easily utilized by soil microorganisms [20]. According to Nainggolan et al. [21] that nutrient supply by organic fertilizers is very low and slowly available. So that in organic farming, large amounts of fertilizer are needed. In general, cropping will produce better production in the second season since the application of organic fertilizers, especially the availability of N, P and K nutrients compared to inorganic fertilizers. The slow availability of organic fertilizers will affect the state of pH, C-organic, N-total, P-available, and the availability of K, Ca, Mg. Organic fertilizers can maintain soil moisture and absorb nutrients that are easily lost and help provide soil nutrients, so that fertilization efficiency is higher [21-22].

The results of the chemical analysis of wood ash and husk are presented in Table 2. Based on the table, it is known that the pH value, electrical conductivity (DHL), K, Ca, and Mg nutrient content in wood ash are higher than husk ash. However, the water content is lower, maybe because the result of the combustion process causes the wood ash to be hydrophobic. Base cations resulting from the
The combustion process are usually in the form of oxides such as K₂O, CaO, MgO and Na₂O. When dissolved in water, there will be hydrolysis which releases OH⁻ so that the soil pH increases. The high levels of alkaline cations in this ash are then used to enrich the Ca, Mg and K levels of cow manure, so that the value of the quality of the nutrients increases. The composition of plant ash varies greatly depending on the type of material, and the pyrolysis temperature used.

Table 1. Soil chemical and physical properties of inceptisols without the application of CM

| Parameters                              | Unit          | Value | Characteristic (SRI, 2009) |
|-----------------------------------------|---------------|-------|----------------------------|
| pH-H₂O                                  |               | 5.74  | Slightly Acid              |
| pH-KCl                                  |               | 5.2   |                            |
| C-org                                   | %             | 2.61  | Moderate                   |
| EC(Electrical Conductivity)             | dS m⁻¹        | 0.11  | Very Low                   |
| K-available                             | cmol(+)kg⁻¹   | 0.05  | Very Low                   |
| Ca-available                            | cmol(+)kg⁻¹   | 0.34  | Very Low                   |
| Mg-available                            | cmol(+)kg⁻¹   | 0.05  | Very Low                   |
| Na-available                            | cmol(+)kg⁻¹   | 0.16  | Low                        |
| N-total                                 | %             | 0.2   | Low                        |
| P-available                             | mg kg⁻¹       | 29.89 | Very High                  |
| CEC (Cation Exchang Capacity)           | cmol(+)kg⁻¹   | 15.44 | Low                        |
| Texture                                 |               |       |                            |
| Sand                                    | %             | 56.58 | Sandy Loam                 |
| Silt                                    | %             | 26.77 |                            |
| Clay                                    | %             | 16.65 |                            |
| Bulk Density                            | g cm⁻³        | 1.22  |                            |
| Particle Density                        | g cm⁻³        | 2.09  |                            |
| Total Porosity                          | %             | 42    |                            |

Table 2. Comparison on chemical properties between cow manure, wood ash and husk ash

| Parameters                              | Unit          | Cow Manure | Wood Ash | Husk Ash |
|-----------------------------------------|---------------|------------|----------|----------|
| Moisture                                | %             | 49.1       | 0.55     | 16.52    |
| pH                                      |               | 9.69       | 11.76    | 9.78     |
| DHL                                     | dS m⁻¹        | 0.10       | 2.19     | 0.29     |
| Organic Matter                          | %             | 56.0       |          |          |
| C-organic                               | %             | 32.5       |          |          |
| N-total                                 | %             | 1.83       |          |          |
| C/N ratio                               |               | 17.8       |          |          |
| P-total                                 | %             | 0.20       |          |          |
| K-total                                 | %             | 0.14       | 6.69     | 1.85     |
| Ca-total                                | %             | 0.33       | 11.65    | 1.02     |
| Mg-total                                | %             | 0.34       | 3.25     | 0.51     |
3.3. Effect of the ECM on the soil chemical properties after 2 weeks incubation

The results of the soil chemical analysis after being incubated and treated with a mixture of manure and wood ash/husk ash are presented in Table 3. The results of ANOVA showed that at the 5% level, the combination of manure and the two ashes had a significant effect on pH-H₂O. Organic matter, cation exchange capacity, P-available, K, Ca, Mg and Na, except for electrical conductivity and N-total. In the DMRT test at the 5% significance level, it can be seen that the highest pH-H₂O value is obtained at the CM900+WA100 treatment. Addition of husk ash combined with cow manure did not show significantly different results.

Table 3. Effect of ECM on the soil chemical properties after 2 weeks incubation

| Treatments                        | pH-H₂O | EC (ds m⁻¹) | OM (%) | CEC cmol (kg⁻¹) | N-total (%) | P-avail (mg kg⁻¹) | K (mg kg⁻¹) | Ca (mg kg⁻¹) | Mg (mg kg⁻¹) | Na (mg kg⁻¹) |
|-----------------------------------|--------|-------------|--------|-----------------|-------------|------------------|-------------|-------------|-------------|-------------|
| No cow                            | 6.63 g | 0.11 cd     | 4.68 e | 5.49 g          | 0.16 d      | 25.67 d          | 0.06 i      | 0.35 f      | 0.04 e      | 0.42 e      |
| **Cow manure only (g/pot)**       |        |             |        |                 |             |                  |             |             |             |             |
| 1000 g                            | 8.04 cde | 0.60 a   | 8.31 d | 11.04 e         | 0.29 ab     | 63.72 a          | 0.48 fg     | 0.59 f      | 0.13 d      | 0.75 d      |
| 123 g                             | 6.94 f | 0.26 bc     | 5.46 e | 8.14 f          | 0.19 c      | 35.53 cd         | 0.13 hi     | 0.35 f      | 0.06 e      | 0.14 f      |
| **Cow manure : husk ash (g/pot)** |        |             |        |                 |             |                  |             |             |             |             |
| 975 : 25                          | 7.99 cde | 0.21 bcd  | 11.55 a | 21.54 b       | 0.26 b   | 60.67 a          | 1.42 e      | 1.86cd      | 0.37b      | 1.37c      |
| 950 : 50                          | 7.99 de | 0.36 b     | 12.13 a | 27.26 a       | 0.27 ab  | 35.84 cd         | 1.87 d      | 1.80cd      | 0.35 b      | 1.37c      |
| 925 : 75                          | 7.95 c | 0.24 bcd   | 11.28ab | 22.47 b       | 0.29 ab  | 49.87 b          | 2.11bc      | 1.67d       | 0.33b      | 1.47c      |
| 900 : 100                         | 8.02 cde | 0.26 bc  | 11.41ab | 22.84 b       | 0.27 ab  | 35.48 cd         | 2.04cd      | 1.88cd      | 0.36b      | 1.70ab     |
| 0 : 100                           | 6.91 f | 0.10 cd     | 5.03 e | 17.61 c       | 0.16 d   | 26.19 d          | 0.32 gh     | 1.06 e      | 0.17d      | 0.34 e      |
| **Cow manure : wood ash (g/pot)** |        |             |        |                 |             |                  |             |             |             |             |
| 975 : 25                          | 8.14 cd | 0.35 b     | 10.09bc | 23.21 b       | 0.29 ab  | 32.35 cd         | 1.88d       | 2.23ab      | 0.42a      | 1.61b      |
| 950 : 50                          | 8.62 b | 0.09 d     | 10.81abc | 22.71 b      | 0.30 a   | 35.15 cd         | 2.40 a      | 2.53 a      | 0.45a      | 1.80a      |
| 925 : 75                          | 8.64 b | 0.08 d     | 9.63cd  | 21.50 b       | 0.27 ab  | 33.82 cd         | 2.30ab      | 2.10bc      | 0.41a      | 1.69ab     |
| 900 : 100                         | 8.79 a | 0.22 bcd   | 9.46cd  | 18.23 c       | 0.27 ab  | 38.99 c          | 2.52 a      | 2.49 a      | 0.45a      | 1.43c      |
| 0 : 100                           | 8.14 c | 0.08 d     | 5.13 e | 13.47 d       | 0.15 d   | 28.61 cd         | 0.56f       | 2.07bc      | 0.25c      | 0.08 f      |

The numbers followed by the same letter in the column show no significant difference at the 5% Duncan test significance level. OM = organic matter, EC = Electrical conductivity, CEC = Cation exchange capacity.

The highest cation exchange capacity value was obtained in the CM950 + HA50 treatment, namely 27.26 cmol (-) kg⁻¹. This revealed that in addition to manure, husk ash also contributed in increasing the CEC value, because when the dose of manure was reduced from 975 g to 950 g but the dose of husk ash was increased from 25 to 50 g, the CEC value increased. Wood ash did not increase the CEC even though the dose was increased, in fact the CEC value decreased as the manure dose also decreased. Manure plays an important role in increasing CEC [23] because it contains many functional groups such as carboxylates and phenonates as a source of negative soil charge.

The combination treatment of manure and the two ashes had no significant effect on soil N content. The main source of N in soil comes from organic matter, because the levels are relatively low so that the effect is not significant. In addition, the N nutrient in the soil is very mobile so that it is easily leached from the soil absorption complex. Nitrogen can be used by plants after the organic fertilizer undergoes a mineralization process [24]. Soil microbes play a role in optimizing the conversion of N-organic compounds into ionic forms (NH₄⁺ and NO₃⁻) which can be absorbed by plants [25]. Nitrogen is one of the essential nutrients for plants, so its availability is needed for plant growth and development. Nitrogen
is the main component of various compounds in plants such as protein, chlorophyll, growth hormones, especially cytokinins and auxins. Sufficient N availability will result in better protein and chlorophyll synthesis so that the photosynthesis rate will also be better. Chlorophyll is very useful for absorbing light for the photosynthesis process [26].

From table 3, it shows that the highest available P content was obtained in single manure treatment with the highest dose (1000 g). This indicates that organic matter has a very important role in increasing the P availability in the soil. Based on the results of the original soil analysis before treatment, the P content in this soil has a very high rate. It is possible that the manure contains organic acids which play a role in dissolving P which is absorbed by the soil mineral colloid into available forms. One of the unavailable P forms is the orthophosphate ion bound by Ca [27]. Ca ions derived from husk ash also play a role in reducing the solubility of phosphate ions in the soil [28].

The levels of alkaline cations (K, Ca, Mg and Na) in the soil tended to increase significantly with the increase in the amount of husk ash and wood ash. However, in the treatment of manure mixed with wood ash, the increase was higher than that of a mixture of manure and husk ash. This can be understood because the content of base cations in wood ash is higher than husk ash. Potassium is the third important nutrient after N and P, usually this ion is uptaken by plants in the K⁺ form. Potassium is needed by plants in relatively large quantities, so this nutrient deficiency will cause plants to grow unhealthy and low crop production [20]. The availability of Ca and Mg nutrients is synergistic, where the higher the solubility of Ca is followed by the higher the solubility of Mg [27]. Sodium is not an essential nutrient, but its presence in the soil can affect the chemical and physical properties of the soil. High levels of Na can increase the solubility of potassium from minerals to the soil solution. Too high a Na content can affect the physical properties, especially the soil structure which tends to become dense. In addition, it can also interfere with the plant's metabolic system, because it can increase cell osmotic pressure so that plants undergo plasmolysis [29].

3.4. Effect of ECM on the Agronomic Traits of Mustard

ANOVA test results showed that at the 5% level the ECM treatment had a significant effect on leaf area. The widest leaf area was obtained in the CM900 + HA100 treatment (Table 4). Leaves are part of the mustard plant that is consumed, so efforts to increase production are made to produce large, wide, and green leaves. The most important nutrient used for leaf development is nitrogen. Nitrogen functions to increase vegetative growth so that the leaves become wider and quality, characterized by greener leaves [30]. Husk ash can supply potassium nutrients which are also needed by mustard plants. Potassium functions to activate various enzymes, metabolic processes, maintain turgor, regulate the movement of stomata, form ATP, increase nitrogen absorption and protein synthesis and starch synthesis. Plants that are deficient in potassium will cause their resistance to be disturbed, so that it will be easier for pathogens to penetrate into the leaves [31].

The highest fresh and dry root weight was obtained in C2 treatment (recommended CM dose) compared to other treatments. Based on Table 3, the impression is obtained that the combination treatment of cow manure (CM) with husk ash (HA) produces better agronomic properties than the combination of cow manure (CM) and wood ash (WA). From agronomic parameters such as leaves area, fresh shoot weight, dry shoot weight, fresh roots weight, and dry roots weight, shows better results in the combination of CM + HA. This possibility is related to the addition of WA which causes the soil pH to increase to alkaline conditions. Mustard plants are less suitable for alkaline soil pH. In addition, the magnesium content in wood ash is higher which can interfere with the physiological characteristics of the roots [31]. Therefore, the mustard root in the wood ash treatment was smaller and looked more dwarf than the other treatments.
Table 4. Effect of ECM on the agronomic traits of mustard growth

| Treatments                        | LA (mm²) | Weight (g) of plant parts |         |         |         |
|----------------------------------|----------|---------------------------|---------|---------|---------|
|                                  |          | fresh shoot | dry shoot | fresh root | dry root |
| No cow manure                    | 1433 cde | 81.7 de     | 6.44 def  | 6.67 b    | 1.76 b   |
| Cow manure only (g/pot)          |          |             |           |           |         |
| 1000 g                           | 1953 ab  | 178.0 ab    | 11.17 ab  | 7.02 b    | 1.95 b   |
| 123 g                            | 1610 bcde| 136.2 bc    | 7.67 cde  | 13.16 a   | 4.31 a   |
| Cow manure : husk ask (g/pot)    |          |             |           |           |         |
| 975 : 25                         | 1946 ab  | 180.8 ab    | 11.51 a   | 7.53 b    | 1.78 b   |
| 950 : 50                         | 1887abc  | 186.8 a     | 10.51 ab  | 7.55 b    | 1.73 b   |
| 925 : 75                         | 2023 ab  | 179.7 ab    | 11.19 ab  | 7.26 b    | 1.70 b   |
| 900 : 100                        | 2130 a   | 180.65 ab   | 10.64 ab  | 6.51 b    | 1.06 b   |
| 0 : 100                          | 862 f    | 64.4 e      | 3.97 f    | 3.57b     | 0.602 b  |
| Cow manure : wood ash (g/pot)    |          |             |           |           |         |
| 975 : 25                         | 1686abcd | 140.4 abc   | 10.16 abc | 5.38 b    | 0.873 b  |
| 950 : 50                         | 1200 ef  | 98.4 cde    | 5.40 ef   | 4.11 b    | 0.610 b  |
| 925 : 75                         | 1680abcd | 123.3 cd    | 8.41 bcd  | 5.97 b    | 1.29 b   |
| 900 : 100                        | 1412 de  | 110.2 cd    | 7.61 cde  | 4.79 b    | 0.93 b   |
| 0 : 100                          | 1188 ef  | 89.6 de     | 5.44 ef   | 3.96 b    | 0.778 b  |

The numbers followed by the same letter in the column show no significant difference at the 5% Duncan test significance level. LA= Leaves area, FSW = Fresh shoot weight, DSW = Dry Shoot Weight, FRW = Fresh Roots Weight, DRW = Dry roots weight.

3.5. Effect of ECM on the K-Ca uptaken by Mustard

The results of the analysis of variance (ANNOVA) showed that at the 5% level the treatment had a significant effect on the K and Ca uptake by mustard. The highest K absorption value in the shoots of the plant was obtained in the CM925 + HA75 treatment, while the roots were obtained in the C2 control treatment (only manure with the recommended dose). Most of the potassium in the soil is absorbed by plants through a diffusion process [21].

K ions are free in cell plasma and in plant growth points which can stimulate plant growth at the initial stage. Apart from spurring growth, K also plays a role in increasing drought tolerance and plant resistance to pests and diseases. Its role in increasing tolerance to dry conditions is because it is able to control stomata in leaves so that transpiration can be controlled [29]. Plant growth on wood ash and husk ash treatment showed a healthy appearance. This is related to the role of potassium as plant resistance to pathogens. Plants that are deficient in potassium will cause silica production in epidermal cells to decrease so that pathogens can easily penetrate plant cell tissues [30]. The addition of potassium will increase lignin levels in mustard plants and result in pathogens being unable to reproduce in host plants.

The highest Ca uptake (256.2 mg/shoot) was obtained in the CM900 + HA100 treatment, while the roots were obtained in the C2 control treatment. Calcium plays a role in the hardening of the stems so that the plant looks stronger. Lack of potassium can cause the leaves to easily become chlorosis, the young buds will die. Calcium is able to increase plant resistance to diseases such as bacterial leaf blight [29].
Table 5. Effect of ECM on the K and Ca absorption by mustard shoot and root

| Treatments                           | Absorption (mg plant⁻¹) by plant parts |
|--------------------------------------|-----------------------------------------|
|                                      | K–shoot       | K-root       | Ca–shoot       | Ca-root       |
| No cow manure                        | 352.9 def     | 77.7 abcd    | 173.2 f        | 3.73 c        |
| Cow manure only (g/pot)              |              |              |                |                |
| 1000 g                               | 884.3 ab      | 118.1 abcd   | 181.2 d        | 8.74 c        |
| 123 g                                | 509.7 cde     | 243.6 a      | 177.2 e        | 38.14 a       |
| Cow manure : husk ash (g/pot)        |              |              |                |                |
| 975 : 25                             | 877.7 ab      | 86.5 abcd    | 147.6 i        | 17.83 abc     |
| 950 : 50                             | 786.9 abc     | 105.9 ab     | 79.3 l         | 22.50 ab      |
| 925 : 75                             | 1012.5 a      | 101.9 abc    | 217.2 c        | 38.09 a       |
| 900 : 100                            | 873.1 ab      | 56.7 bcd     | 256.2 a        | 8.57 c        |
| 0 : 100                              | 184.1 f       | 38.1 d       | 109.8 j        | 2.28 c        |
| Cow manure : wood ash (g/pot)        |              |              |                |                |
| 975 : 25                             | 869.8 ab      | 45.2 bcd     | 168.5 h        | 2.54 bc       |
| 950 : 50                             | 342.3 ef      | 34.3 cd      | 30.0 m         | 1.96 c        |
| 925 : 75                             | 732.3 abc     | 91.2 abc     | 234.5 b        | 4.42 c        |
| 900 : 100                            | 628.1 bcd     | 60.8 bcd     | 86.9 k         | 1.93 bc       |
| 0 : 100                              | 381.8 def     | 38.8 bcd     | 168.9 g        | 4.49 c        |

The numbers followed by the same letter in the column show no significant difference at the 5% Duncan test significance level.

4. Conclusions

Enriched cow manure (ECM) with wood ash and ash significantly improved chemical properties, availability of macro nutrients and growth of mustard greens. Both types of ash were able to increase the K and Ca uptake of mustard greens with an optimal dose of 900 g of cow manure and 100 g of husk ash. This opens up research opportunities to develop organic agriculture with plant nutrient fortification technology through enrichment of manure with natural ingredients.

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