Effectiveness of *Chromolaena odorata* as organic manure in promoting plant nutrient uptake and soil nutrient status on mustard rhizosphere

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**Abstract.** *Chromolaena odorata* is an invasive plant that potentially organic manure. This study aimed to evaluate the effect of this weed on plant nutrient uptake and soil nutrient status on the mustard rhizosphere using a completely randomized block design and three replications. Factors examined were the organic manure types (green manure and compost) and doses (5, 10, 15, 20, and 25 Mg ha\(^{-1}\)). The results showed that the compost was more effective than the green manure to improve potassium (K) uptake and soil nutrient (total nitrogen (N), available phosphor (P), and exchangeable K). Increasing doses of the organic manure until 25 mg ha\(^{-1}\) gave a better effect on N and K uptake and soil available P and exch. K but 20 Mg ha\(^{-1}\) on soil total N. The application of 25 mg ha\(^{-1}\) *C. odorata* as green manure gave more N and K content in the mustard. At the same time, 20 mg ha\(^{-1}\) compost increased soil available P. This study indicated that *C. odorata* could be developed as a good ameliorant either as green manure or compost to improve nutrient uptake mustard and soil nutrient status.

1. **Introduction**

Organic manure is becoming an urgent strategy for sustainable crop productivity, especially in suboptimal land. The positive effects of organic amendments on plant yield resulted from changes to the soil [1], including lower bulk density, higher water retention, and plant available water, and increased soil pH and contents of macro-and micronutrients. The quality and quantity of the amendments affect their functioning [2, 3]. Compost and green manure are well-known organic amendments in sustainable agriculture. The application of those organic matters (OM) to the soil for consecutive years, besides influencing the growth and yield of crops, also causes changes in the soil chemical characteristics [4, 5].

Some studies also indicated that organic application to soil increased plant yield similar to or beyond the effects of mineral fertilizer application. Incorporation of green manure with a 20–40% reduction in chemical fertilizer inputs proposed as alternative cropping systems to improve plant productivity and sustainability [6]. Another study [7] showed that 30% replacement of N fertilizer by compost effectively maintained N uptake and maize yield, reduced N loss, and improved soil fertility. Another report [8] proposed that using organic fertilizers in pineapple cropping could substitute the use of inorganic fertilizers.

Besides organic manure types, the application doses are a crucial factor affecting the organic manure effectiveness. Many studies indicated that the higher the application dose of organic manure, the more they have [9, 10, 11].
A variety of plant residues include weeds, are potential sources of organic fertilizers. *Chromolaena odorata*, one of the world’s most invasive weeds, has been reported as a promise organic manure but still not yet managed optimally. They allocate higher biomass to aboveground biomass [12, 13] and increase soil nutrients such as nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), calcium (Ca), and organic matter of fallow land [14, 15]. Therefore, it is likely the main factor governing soil quality improvement [16, 17].

Research information is scarce on comparing *C. odorata* application as green manure and compost and their optimal doses as to their relative effects on nutrient uptake and soil nutrient statuses on mustard rhizosphere. Therefore, the objectives of this study were to determine the *C. odorata* application effects as compost and green manures at different doses (1) the mustard nutrient (N, P, and K) uptake and (2) soil nutrient status (total N, available P, and exchangeable K) on mustard rhizosphere.

2. Materials and methods

2.1. Experimental design

This pot experiment was in a randomized complete block design with a 2 x 5 factorial arrangement of treatments with three replications. The factors were two organic manure types (green manure and compost) and five doses (5; 10; 15; 20; and 25 Mg ha\(^{-1}\)).

2.2. Soil preparation as a growth medium

This experiment used soil samples classified as Entisols from Kajhu Village, Aceh Besar. The characteristics of the soil sample were in table 1. The soil was sieved using a 2 mm mesh screen to remove rocks, soil clumps, and large organic matter pieces. The dry soil as much as ten kilograms put into each experimental pot (12 L in volume).

### Table 1. The characteristics of the soil sample.

| Parameter | Texture | pH | Org. C (%) | Tot. N (%) | Av. P (mg kg\(^{-1}\)) | exch. K | exch. Na | exch. Ca | exch. Mg |
|-----------|---------|----|------------|------------|-------------------------|---------|---------|---------|---------|
|           | Loamy sand | 7.36 | 0.31 | 0.04 | 12.29 | 0.34 | 0.48 | 6.48 | 1.88 |

2.3. Preparation and application of *C. odorata* as organic manure

Organic manure types based on *C. odorata* consisted of green manure (fresh) and compost. The characteristics of both organic material types are in table 2. The green manure type was the upper part of the weed applied directly when sowing the mustard. Otherwise, the compost prepared using effective microorganism (EM) 4 were homogenized (<2 mm) and incubated into the soil for ten days at field capacity before mustard planted.

### Table 2. Characteristics of *C. odorata* as organic material.

| Manure types | Org. C (%) | Tot. N (%) | C/N | Tot. P (%) | Tot. K (%) | Tot. Ca (%) | Tot. Mg (%) |
|--------------|------------|------------|-----|------------|------------|-------------|-------------|
| Green manure | 42.47 | 2.76 | 15.39 | 0.48 | 1.75 | 0.22 | 0.18 |
| Compost      | 18.06 | 2.13 | 8.48 | 2.32 | 1.12 | 0.18 | 0.12 |

2.4. Mustard cultivation

The sterilized mustard seeds were sown in a soil: compost medium (3:1) for three weeks before being cultivated into their growth medium. Three mustard seedlings were planted in each pot and thinned to one per pot after seven days after planting (DAP).
2.5. Plant nutrient analysis
The plant N, P, and K nutrients were analyzed by the wet digestion method. The crop used was all upper part of 20 day-mustard. Analysis of the plant nitrogen content was by the Kjeldahl while phosphorous and potassium uptake by spectrophotometer methods.

2.6. Soil nutrient analysis
Soil sub-samples were from the mustard rhizosphere at the end of the experiment (20 DAP). The air-dried soil samples were sieved at 2 mm and used for the nutrient content analyses. The determination of soil total N (TN) was by Kjeldahl N [18], available phosphorous was extracted as Bray 1 P [19], and exchangeable K was following extraction with ammonium acetate (1 N NH₄OAc) buffer solution shaken with a mechanical shaker for two hours [20].

2.7. Statistical analysis
The effects of treatments, the weed application types, doses, and their interaction, on the soil nutrient status and the nutrient uptake of mustard, were evaluated by variance (ANOVA). The significance of differences between the treatments compared using the Duncan multiple range test (DMRT) at P < 0.05. All statistical analyses used SPSS 25.0 (SPSS Inc., Chicago, Illinois, USA).

3. Results and discussion

3.1. Plant nutrient uptake
This study (table 3) indicated that interaction of type and application doses of Chromolaena odorata as organic manures significantly (P < 0.01) increased N and K uptake. In contrast, the P uptake was only significantly (P < 0.05) influenced by the application dose. Figure 1 showed the effect of the manure types at different doses on the N, P, and K content of the mustard.

Table 3. Significance effects of Chromolaena odorata as organic manures on plant nutrient uptake and soil nutrient.

| Parameter           | Types of manure (T) | Doses (D) | T x D |
|---------------------|---------------------|-----------|-------|
| Plant Nutrient uptake |                     |           |       |
| N                   | ns                  | **        | **    |
| P                   | ns                  | *         | ns    |
| K                   | ns                  | **        | **    |
| Soil Nutrient Status |                     |           |       |
| Total N             | **                  | ns        | ns    |
| Available P         | **                  | **        | **    |
| Exchange K          | *                   | **        | ns    |

Significant at * p < 0.05, ** p<0.01; ns: not significant.
Figure 1. The effect of organic manure types at different application doses on N (a), P (b) and K (c) content of the mustard.

3.1.1. Nitrogen uptake. Nitrogen is one of the most limiting macronutrients in soils for plant growth [21] and required more for developing protein by vegetable crops [22, 23] like mustard. This study indicated that the mustard's N content was between 3.73 % and 6.65%, and the highest N content was after application of 25 Mg ha\(^{-1}\) green manure having more N than compost (table 2). The higher uptake at the increased doses of the green manure was due to the crop's higher efficiency in using the increased levels of N from the manure. The trend in plant N uptake increases concerning or ganic amendments and N levels were similar to the increments in plant growth, yields, and soil nutrient status [24, 25]. Besides, the chemical composition of the organic material also affects N mineralization [26].

3.1.2. Phosphorous uptake. Phosphor is an element required for processes including the storage and transfer of energy, photosynthesis, the regulation of some enzymes, and the transport of carbohydrates [27]. Reduced P content in vegetables decreases the nutritional quality because it diminishes vegetables' contribution to the total P dietary intake [21]. Contrary to nitrogen and potassium, mustard's phosphorous uptake was different only among the dose application treatment. It shows that the P content of all organic manure types was between 0.68 % and 0.86%. The highest P uptake was after application 10 Mg ha\(^{-1}\), and the lower uptake was when higher application doses. Decomposition of organic P from plant materials will release ortho-phosphate, which is available to plants [26]. But, when this nutrient is in excessive amounts to agricultural land, it is not consumed by plants or crops [28]. The effect of compost fertilization on crop yields depends on the factors determining nutrient mineralization from soil and compost and on crop-related factors such as the nutrient requirements and uptake dynamics of the respective crop [29].

3.1.3. Potassium uptake. Potassium is the third macronutrient that plants require in large amounts. This element is essential for many physiological processes associated with the movement of water, nutrients, and carbohydrates in plant tissue [30]. This study showed that mustard K content at all manure types was between 0.85% and 1.15 %. Increasing application doses of Chromolaena odorata either as green manure or compost enhanced this nutrient content. Similar to nitrogen, the 25 mg ha-1 siam weed application also contributed to the mustard's highest K uptake. The plant availability of K in composts can be more than 85% of the total K content [31], and the remainder is easily mineralizable [31].

3.2. Soil nutrient status
This study (table 3) indicated that the total soil nitrogen was affected significantly (P < 0.01) only by the manure type treatment; the available P by all treatments (P < 0.01); and the exchangeable K was by both manure type (P < 0.05) and application doses (P < 0.01) treatments.
3.2.1. Total nitrogen. Nitrogen is one of the most limiting macronutrients in soils for plant growth. This soil nutrient was significantly different between green manure and compost (table 4). The role of compost to increase soil N was also reported by other studies [32, 33]. Mineralization of the organic manure contributed to soil N [34].

Table 4. The effect of organic manure type and dose on soil total N, available P and exchangeable K.

| Treatment                  | Total N (%) | Available P (mg kg⁻¹) | Exchangeable K (cmol kg⁻¹) |
|----------------------------|-------------|-----------------------|---------------------------|
| Organic manure type        |             |                       |                           |
| Green manure               | 0.08 b      | 20.53 a               | 0.31 a                    |
| Compost                    | 0.10 b      | 52.01 b               | 0.33 b                    |
| Organic manure dose (mg ha⁻¹) |           |                       |                           |
| 5                          | 0.87 a      | 22.80 a               | 0.27 a                    |
| 10                         | 0.88 a      | 34.17 b               | 0.31 b                    |
| 15                         | 0.92 a      | 43.42 c               | 0.33 bc                   |
| 20                         | 0.95 a      | 55.74 d               | 0.35 cd                   |

Different letters are significantly different (P < 0.05) among organic manure application types and doses.

3.2.2. Available phosphor. Soil available P was the only soil nutrient significantly (P≤0.01) affected by the interaction of organic manure and the application doses (figure 2). This result suggested that the higher phosphor content in the compost (table 2) provided a better effect on improving soil available P. Application of 20 mg ha⁻¹ compost provided the highest soil av. P. The compost effect on soil av. P was also reported by other studies [35, 36]. It organic manure releases organic acids [37], which can solubilize and transform insoluble P into plant-available forms. Therefore, affect the P bioavailability [38, 39].

![Figure 2](image)

Figure 2. Soil available phosphor after application Chromolaena odorata as organic matter in green manure and compost form and doses.

3.2.3. Exchangeable potassium. It shows that the exch. K of the organic manure was significantly different between the application type of weed Chromolaena odorata. Like the total N, this study showed that the weed application as compost was superior to green manure in improving soil exch. K and the higher the dose showed the higher effectivities (table 4). The release rate of K is varied widely depending on the types of organic matter and their decomposition rate [40]. The acidolysis, chelation, exchange reaction, complexolysis, and organic acid release mechanisms enhance soil K availability [41].
4. Conclusion
The effectiveness of *Chromolaena odorata* as organic manure on plant nutrient uptake and soil nutrient status was affected by the application type and its application doses. Green manure addition was more effective than compost in increasing plant N and K uptake, while compost was more effective on the P uptake and the soil nutrient status (tot. N, av. P, and exch. K). Increasing the application doses enhanced the plant nutrient uptake and soil nutrient status. The application of 25 mg ha\(^{-1}\) *Chromolaena odorata* as green manure provided the best effect on the mustard’s uptake of N and K while 20 mg ha\(^{-1}\) compost on soil available P in the mustard rhizosphere.

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