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Research Article

Biochemical Characterization of Partially Stabilized *Parthenium hysterophorus* L. and Cow Dung Consortium and Its Effect on the Growth Performance of Maize (*Zea mays* L.)

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Parthenium (*Parthenium hysterophorus* L.) is a major anxious weed found in pastures, wastelands, and agricultural lands. It usually competes very well and reduces crop yield. Up-rooting and herbicides have long been used as management options for weeds. However, these methods are neither economically nor environmentally sound. Another approach is to make compost of it, transforming a problem into an opportunity. Four treatments viz. *Parthenium* (100%) and *Parthenium* to cow dung ratio (75 : 25, 50 : 50, 25 : 75 w/w) were partially stabilized for 60 days under aerated conditions. The physical and chemical characteristics of partially stabilized organic materials were analyzed and the effects of the partially stabilized organic materials on the germination and growth performance of maize (*Zea mays* L.) were assessed. The results revealed that pH, EC, OC, OM, TN, *P* availability, and C/N were not significantly different; this showed an insignificant difference ($P > 0.05$) among the treatments. However, particle densities, *P* availability, EC, OC, and TN were found to be higher in 75 : 25 *Parthenium* cow dung ratios than in 25 : 75 ratios. Root length, shoot length, and germination index were significantly different among the treatments ($P \leq 0.05$). The seed germination index of maize was the highest (113%) in 75 : 25 ratios of *Parthenium* and cow dung followed by 50 : 50 ratios (95%) and 25 : 75 ratios (86%); relatively, low germination indices (84.86%) were recorded from partially stabilized organic materials prepared from *Parthenium* alone. The findings revealed that partially stabilized *Parthenium* mixed with cow dung could be promising for organic farming and an option for weed management.

1. Introduction

Parthenium hysterophorus L. (hereafter *Parthenium*) is an aggressive herbaceous plant native to the American continent that has already been documented in over 45 nations around neotropical countries [1, 2]. Currently, it is widely distributed in Australia, Pakistan, India, China, and Africa [2, 3]. It is one of the major invasive species in Ethiopia [4]. The plant grows readily in any habitat because of its several adaptation mechanisms such as simple seed dispersal mechanisms, drought tolerance, rapid seed production rates, avoidance of its natural enemies, and allelopathic properties [5–7]. Allelochemicals such as sesquiterpene lactones and phenolic acids (gallic acid, chlorogenic acid, and ferulic acid) [8] found in *Parthenium* are toxic to grazing animals and have negative effects on crop production as well as the diversity and distribution of local flora and fauna [9]. Moreover, chemicals released from *Parthenium* to the substratum via its roots have inhibitory effects on both the germination and growth of a wide variety of crops [10–12].

The plant was introduced in Ethiopia in the 1970s [13]. However, there is no complete agreement so far on when and how it was introduced into the country. There are two speculationsthe weed was introduced during the Ethio-Somalia War in 1976 and the weed was introduced to Ethiopia together with the wheat seed donation from abroad [13]. The plant was first reported in Ethiopia in the 1980s from the eastern (Dire Dawa and Harar) and northeastern (near Dessie) parts of the country. Both of these places were important food aid distribution centers, and there is substantial evidence that during the 1980s famine, *Parthenium* seeds were imported from subtropical North America as a contaminant of food assistance and were distributed with the grain [14]. Since its introduction, it has expanded persistently over Ethiopia's agricultural land, woodland, poorly managed arable crop land, and rangeland [15]. It also poses a health risk to humans and animals [16]. The weed negatively impacts food security and biodiversity. It is already threatening the crop production in Ethiopia [17, 18], and its rapid spread would further aggravate the risk of expansion and sustainable production of many crops. Therefore, controlling this aggressive invasive plant is critical for increasing the agricultural output and preventing environmental destruction.

Parthenium weed is widely spread in rangelands and cultivable fields and has negatively affected the composition and diversity of the rangeland vegetation in southern Ethiopia (Figure 1). Hence, the purpose of this research was to use invasive *Parthenium* weed as an input for preparing a partially stabilized organic material and reducing the invasion of the plant within the study area.

Many countries have been trying to control weeds, especially *Parthenium,* using a variety of tactics [4, 19, 20]. However, they were not economically feasible for most small-scale farmers [21]. This is because it colonizes new lands faster than it can be controlled [2]. Moreover, most single applications were not effective or had only short-term effects [7], and this does not easily fit into the broad category of weed control in the specific cropping patterns or systems of smallholder farmers [21].

The Ethiopian government has faced many challenges in eradicating this plant. Several physical and chemical treatments employed in the past are ineffective, expensive, and environmentally unfriendly. The chemical control has supremacy over other control methods for quick relief; however, the effect is always temporary and repeated operations will not be cost-effective for smallholder farming systems [22]. The repeated application of herbicides can affect other beneficial plants in addition to changing soil characteristics and polluting the environment due to cumulative residual effects [10]. Similar to many other weeds, *Parthenium* weeds are beneficial. The search for more effective utilization of *Parthenium* will render it suitable for effective management on the one hand and it can also be used for many different purposes besides eradication on the other hand [13]. Similarly, Saini et al. [23] suggested that large-scale utilization of *Parthenium* would also be an effective method for weed management. The most promising method for controlling *Parthenium* weeds is management through utilization. Long-term control requires the combined application of many technologies [24]. Ghadge et al. [25] proved that *Parthenium* can be used for the preparation of compost and vermicompost that contain high nutrients. Ameta et al. [26] also indicated that seeds of *Parthenium* did not germinate after composting, which could also encourage end-users of the compost.

Parthenium has the potential to be used as a green manure, compost for crop plants, biopesticides, and soil amendments [27–29]. This study aimed to assess the physicochemical characteristics of partially stabilized *Parthenium* and cow dung consortium and evaluate its effect on the germination and growth performance of maize.

2. Materials and Methods

The study was conducted in Mirab Abaya District, southern Ethiopia. The *Parthenium* weed was collected from the fallow lands before the flowering stage for its soft stem and leaves and cow dung was collected from the farmers' houses. Experimental plots were established with equal sized partially stabilizing organic material pits of $1 \times 2 \times 1\,m^3$ (width × depth × length). The pits were established in dry and elevated places to prevent water runoff from entering the pits. The sidewall and surface of the pit were compacted to prevent leaching of essential nutrients from the organic material to the soil surface. The following four treatments were prepared for partially stabilized organic material production*Parthenium* biomass + cow dung (CD) (75 : 25) w/w, *Parthenium* biomass + CD (50 : 50) w/w, *Parthenium* biomass + CD (25 : 75) w/w, and *Parthenium* biomass alone (100) w/w as an experimental control (Table 1). The organic materials in all piles were kept the same, i.e., 50 kg. Each treatment was performed in triplicate.

The collected *Parthenium* weed and cow dung were spread and piled layer by layer. In the stabilizing pits, sticks were placed vertically into the organic material to allow air to circulate in various layers. Sticks were placed at each corner and at the center of the pit before piling up the materials. After piling up the layers, the sticks were joggled to expand the space between the sticks and materials to create ventilation holes to keep the layers properly aerated. After three weeks of partial decomposition, the pits were turned periodically to maintain aeration and the decomposed material was mixed from the bottom to the top and vice versa. The temperature and moisture content of partially stabilized organic materials were measured periodically using a soil temperature moisture meter (RS485 4–20 mA).

The total biomass used for partial stabilizing process was 375 kg *Parthenium* and 225 kg cow dung.

2.1. Analysis of Physical Characteristics. The bulk density and moisture content of the 60^{th} day partially stabilized *Parthenium* with different proportions of cow dung organic materials were measured. The bulk density was measured as the ratio of the dry weight of the partially stabilized organic material to the volume of the iron ring. The iron ring was filled with the partially stabilized organic material and slightly compacted to ensure the absence of large void spaces. The moisture content of the partially stabilized organic material was measured after drying at 105°C for approximately 24 h or after the partially stabilized organic material was measured at a constant weight.

Figure 1: Infestations of *Parthenium* weed in Mirab Abaya Woreda, south Ethiopia.

Table 1: The composition of raw materials in each treatment pits.

Treatments	*P. hysterophorus*		Cow dung		Total material	
	Kg	%	Kg	%	Kg	%
T1	50	100	—	—	50	100
T2	37.5	75	12.5	25	50	100
T3	25	50	25	50	50	100
T4	12.5	25	37.5	75	50	100

$$\text{Moisture content}\,(\%) = \frac{\text{Weight of moist organic material} - \text{weight of oven dry organic material}}{\text{Weight of oven dry organic material}} \times 100. \tag{1}$$

2.2. Chemical Analysis. Partially stabilized organic material samples were collected in plastic bags from well-mixed composites of 200 g from each experimental pit for chemical analysis. The electrical conductivity (EC), pH, organic carbon (OC), organic matter (OM) total nitrogen (TN), C/N ratio, available phosphorus (P_{avail}), and available potassium (K_{avail}) were analyzed. The pH was measured with a digital pH meter (Beckman model 72 pH meter) in a supernatant suspension of 1 : 2.5 soil : H_2O [30]. The electrical conductivity (EC) was measured using an EC meter based on a 1 : 2.5 extract from a soilH_2O suspension [31]. The total organic carbon was determined using the Walkey–Black rapid titration method [32]. The organic matter was obtained by multiplying the percentage of carbon by 1.724 [33]. Available phosphorus was determined using the Olsen procedure [34]. Total nitrogen (TN) was measured using the Kjeldahl method [33]. Available potassium was quantified using flame photometry [33, 35].

2.3. Seed Germination Test. Maize seed germination and shoot and root growth performance tests were conducted in triplicate in five plastic pots (10.8 cm height × 20 cm diameter) with 75% of garden soil and 25% of the partially stabilized organic material from each pile and an equal amount of pure water was added every morning and evening time. Twelve uninfected healthy maize seeds were sown in cylindrical plastic pots and then placed in a shaded place. The same setup was used for garden soil as an experimental control. After 20 days, the percentage of seed germination, root and shoot lengths, and seed germination index [36] were estimated. The germination index (GI) is a measure of relative seed germination (RSG) and root growth (RRG). The root length was measured from the root collar to the root tip, and the shoot length was recorded from the root collar to the shoot apex [36].

RSG is calculated as follows:

$$\frac{\text{Mean number of seed germinated in partialy stabilized organic material}'}{\text{Mean number of seed germinated in the garden soil}} \times 100. \tag{2}$$

RRG is calculated as follows:

$$\frac{\text{Mean root length of seedling in the partially stabilized organic material}}{\text{Mean root length of seedling in the garden soil}} \times 100. \tag{3}$$

Therefore, GI is the value obtained from

$$\frac{\text{RSG}}{\text{RRG}} \times 100. \tag{4}$$

3. Results and Discussion

3.1. Physical Properties of Partially Stabilized Organic Materials. The results indicated that the bulk density of the partially stabilized organic material did not show statistically significant variation among treatments ($P > 0.05$) (Table 2). The range of the bulk densities of this study (1.23–1.27 gcm^{-3}) was comparable to that of the research performed by Hunt and Gilkes [37]. The bulk density (BD) of the partially stabilized organic material was suitable for root growth and soil permeability. According to Nyéki et al. [38], the optimal bulk density for the plant growth is <1.6, <1.4, and <1.10 gcm^{-3}insand, silt, and clay soils, respectively.

The mean value of the moisture content was higher in *Parthenium* (100%) treatment pits and lowest in *Parthenium* + cow dung (25 : 75) (Table 2). The moisture content of this study was less than that of the research carried out by Christian et al. (1977) (45–65%).

The porosity values ranged from 0.360 ± 0.51 to $0.440 \pm 0.51\%$ (Table 2). It depends on the bulk density and moisture content of the partially stabilized organic material [39]. The porosity was under that of the result obtained by Ahn et al. [40] (0.60–0.72%). However, according to Cresswell and Hamilton [39], the typical range of porosity in compost prepared from commonly used composting materials was 0.5–0.7%.

3.2. Chemical Properties of the Partially Stabilized Organic Material. The mean pH values of the treatment pits were found in the range between 7.90 ± 0.99 and 8.30 ± 0.99 (Table 3). The partially stabilized organic material was alkaline and which is in agreement with research conducted by Travis et al. (2003). The highest pH (8.3 ± 0.99) was found in T3, *Parthenium* biomass + CD (50 : 50) w/w while the lowest value of pH (7.9 ± 0.99) was obtained for T2, from *Parthenium* biomass + CD (75 : 25). However, there was no statistically significant difference ($P > 0.05$) in the pH values among the treatments (Table 3).

The electrical conductivities (EC) of treatment pits were in the ranges between 0.86 ± 0.137 and 1.10 ± 0.137 mScm^{-1}. However, the highest value of EC (1.10 ± 0.137 mScm^{-1}) was found for T2 (75% *Parthenium* with 25% cow dung), and the lowest value of EC (0.86 ± 0.137 mScm^{-1}) was found for T1 (*Parthenium* weed alone). The range of EC (<4 mScm^{-1}) revealed that the partially stabilized organic material prepared from *Parthenium* and cow dung support the agronomic application. The result was in line with the finding of Wang et al. [41].

The total organic carbon result was found between ranges from 2.57 ± 0.443 to 3.54 ± 0.443 and the lowest value was 2.54 ± 0.443 in T4 (*Parthenium* + CD; 25 : 75), and the highest value was 3.54 ± 0.443 in T2 (*Parthenium* + CD; 75 : 25). This result was lower than that was reported by Sivakumar et al. [42]. Conversely, the highest total organic matter content ($6.11 \pm 0.766\%$) was found in T2 (*Parthenium* + CD; 75; 25), and the lowest total organic matter ($4.41 \pm 0.766\%$) was found in T4 (*Parthenium* + CD; 25; 75) (Table 3). Previous studies reported that the total organic matter of *Parthenium* compost was between 17.33% and 16.31% [43–46], which is higher than the result obtained in this study.

The total nitrogen content of the partially stabilized organic material ranged from 0.221 ± 0.38 in T4 to 0.306 ± 0.38 in T2 (Table 3). Travis et al. [47] reported that the total nitrogen content ranged from 0.5 to 2.5%. Low total nitrogen results from highly alkaline compost pits [48]. Composts with a relatively high pH are found to have a lower quantity of total nitrogen due to the loss of nitrogen through volatilization in the form of ammonia [47].

The highest available phosphorus content was recorded in T1 (135.85 ± 13.072 ppm), which was the organic material prepared from *Parthenium* weed alone and the lowest was in T4 (77.10 ± 13.072 ppm) (0.25% *Parthenium* with 75% cow dung). Similarly, the quantity of available potassium was higher in T1 (403.33 ± 34.50 ppm) and the lowest in T4 (71 ± 34.50 ppm) (Table 3). Available phosphorus and potassium levels were higher than those reported by Ballardo et al. (2020). The exchangeable potassium contents of partially stabilized organic materials in the four treatment pits were statistically significant ($P < 0.05$) (Table 3). A study conducted in India by Channappagoudar et al. [49] indicated that composting *Parthenium* alone before the flowering stage has higher available potassium than mixing it with other organic matter, which is in agreement with the results of this study.

The C : N ratio ranged from 11.587 ± 0.005 to 11.60 ± 0.005 (Table 3). The C : N ratio is mostly used as a measure of compost maturity, stability, and N availability [50]. According to Antil et al. [51], a C : N ratio of less than 20 is thought to indicate compost maturity, whereas a C : N ratio of 15 or less is ideal [44, 50]. The results indicated that there was no statistically significant variation ($P > 0.05$) in the C : N ratio among treatments (Table 3). This showed that all treatment pits contained easily biodegradable matrices and the transformation process might have been similarly carried out in all treatment pits. The results of the C : N ratio were inconsistent with those obtained by Travis et al. (2003) who found that the C : N ratio was between 10.82 ± 0.79 and 11.42 ± 0.21. Except for available potassium, all the chemical properties of partially stabilized organic materials showed insignificant statistical differences ($P > 0.05$) among the treatments (Table 3).

Table 2: The mean values of physical properties of the partially stabilized organic material.

Parameter	Treatments T1 *P* (100%)	T2 *P* + CD (75 : 25)	T3 *P* + CD (50 : 50)	T4 *P* + CD (25 : 75)	*P* value
BD (g/cm^3)	1.25 ± 0.087	1.27 ± 0.087	1.23 ± 0.087	1.277 ± 0.087	0.982
MC (%)	35.67 ± 2.12	31.22 ± 2.12	28.80 ± 2.12	24.24 ± 2.12	0.030
p (%)	0.43 ± 0.51	0.44 ± 0.51	0.43 ± 0.51	0.36 ± 0.51	0.697

P, *Parthenium*; CD, cow dung; BD, bulk density; MC, moisture content; *p* (%), porosity.

Table 3: The mean values of chemical properties of the partially stabilized organic material.

Parameter	Treatments T1 *P* (100%)	T2 *P* + CD (75 : 25)	T3 *P* + CD (50 : 50)	T4 *P* + CD (25 : 75)	*P* value
pH (H_2O)	8.06 ± 0.099	7.9 ± 0.099	8.3 ± 0.099	8.23 ± 0.099	0.078
EC (mS/cm)	0.86 ± 0.137	1.1 ± 0.137	0.9 ± 0.137	0.96 ± 0.137	0.654
OC (%)	2.80 ± 0.443	3.55 ± 0.443	3.13 ± 0.443	2.57 ± 0.443	0.463
OM (%)	4.84 ± 0.766	6.12 ± 0.766	5.40 ± 0.766	4.41 ± 0.766	0.467
TN (%)	0.242 ± 0.38	0.306 ± 0.38	0.270 ± 0.38	0.221 ± 0.38	0.475
P_{avail}. (ppm)	135.85 ± 13.07	120.80 ± 13.07	116.60 ± 13.07	77.10 ± 13.07	0.063
K_{avail}. (ppm)	403.33 ± 34.5	365 ± 34.5	230.41 ± 34.5	71 ± 34.5	0.002
C/N	11.58 ± 0.005	11.59 ± 0.005	11.6 ± 0.005	11.59 ± 0.005	0.370

P, *Parthenium*; CD, cow dung; EC, electrical conductivity; OC, organic carbon; OM, organic matter; TN, total nitrogen; P_{avail}, available phosphorus; K_{avail}, available potassium; C/N, carbon to nitrogen ratio.

Table 4: The mean value of shoot and root lengths and the germination index of maize seeds.

Treatments	Mean no. of seedling ($n = 12$)	Root length (cm)	Shoot length (cm)	GI (%)	*P* value
Garden soil (control)	8 ± 0.632	14.14 ± 0.458	13.03 ± 0.567	100	0.000
P compost	7 ± 0.632	14.58 ± 0.458	13.60 ± 0.567	84.86	0.000
P + CD (75 : 25)	10 ± 0.632	15.70 ± 0.458	14.65 ± 0.567	112.61	0.000
P + CD (50 : 50)	9 ± 0.632	18 ± 0.458	15 ± 0.567	95.01	0.000
P + CD (25 : 75)	8 ± 0.632	16.3 ± 0.458	15.76 ± 0.567	86.37	0.000

3.3. Seed Germination and Seedling Growth. Maize seed germination index (GI) was found to be highest (112.61%) in *Parthenium* + CD (75 : 25) and lowest (84.86%) in *Parthenium* alone (Table 4).

The seed germination test is an effective method for determining the potential toxicity of plants [36]. GI and phytotoxins have an inverse relationship; a decrease in GI reveals the presence of phytotoxins in the partially stabilized organic mixture of *Parthenium* and cow dung, whereas an increase in GI indicates the absence of phytotoxic chemicals [36, 52].

A seed germination test on maize revealed considerable variance in root length, shoot length, and germination index in 60 days partially stabilized organic materials ($P < 0.05$). The results of GI in any of the treatments were within the acceptable limit (>80%) with no toxic effect on the growth of plants as suggested by Tiquia [52] for completely maturate compost [52, 53].

4. Conclusions

Parthenium is mostly known for its traits in natural ecosystems and for its adverse effects on human and animal health. Various techniques have been used to control this toxic weed. The most promising method is to manage the weed by proper utilization. The partially stabilized *Parthenium* weed with cow dung has higher nutritional values and germination index in contrast to their controls. The results of the experiments and laboratory analyses revealed that among the treatments of partially stabilized organic materials prepared from *Parthenium* alone showed the highest value of the moisture content, available phosphorus, and available potassium although there were no significant differences among the treatments. The highest proportion of cow dung combined with *Parthenium* (75 : 25) had the lowest moisture content, porosity, organic carbon, total nitrogen, available phosphorus, and available potassium. Partially stabilized organic materials prepared from the high concentration of *Parthenium* mixed cow dung (75 : 25) showed the highest values of porosity, electric conductivity, organic carbon, total nitrogen, and organic matter, while the same showed the lowest pH. Organic carbon, total nitrogen, and organic matter values were lower in this study. This might be the short stabilization process. The seed germination and growth test on maize indicated that the partially stabilizing unflowered *Parthenium* weed with cow dung can be used as a rich source of nutrients and its toxicity is relatively minimized. More field research studies and seed germination tests with other crops are needed to translate this research into a wider eco-friendly approach.

Based on the findings of this study, enhancing farmers' knowledge by training on quality matured compost making and working further to improve the nutrient content of *Parthenium* are essential. These practices require the integration of the community and responsible governmental and nongovernmental organizations. More field research studies and seed germination tests with other crops are recommended with *Parthenium* and cow dung matured compost.

Data Availability

All data generated and analyzed during this study are included within the article.

Consent

Not applicable.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Shetie Gatew focused on invasive plant species and soil science, interpreted the results, analyzed the data, and reviewed and edited the manuscript. Andargachew Mengistu conceptualized, designed, and conducted the fieldwork, analyzed data, and drafted the manuscript. The final version of this manuscript has been communicated to and approved by the authors.

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