PREPARATION AND UTILIZATION OF DAIRY BIOSOLID FERTILIZER FOR THE CULTIVATION OF MUSTARD

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Abstract

In the present work, biosolids were prepared from dairy sludges. Dairy sludge was treated to form biosolids by processes such as dewatering, sludge pasteurization, anaerobic digestion, aerobic digestion, composting, and storage. The dairy biosolid fertilizer, D1 contained only dairy biosolid and D2 contained the weight ratios of (1:1:1) of dairy biosolid, rice husk ash and cocopeat. Physicochemical properties and micro- and macro nutrients of dairy biosolids fertilizers were qualitatively and quantitatively determined by EDXRF, AAS methods and other conventional methods. By using dairy biosolids fertilizer, a field experiment was conducted to test with mustards. The field experiment was laid out using a randomized complete block design (RCBD), with six treatments (T1-T6). Physicochemical parameters and micro-macro nutrients of soil samples before sowing and after harvesting were analyzed. The highest yield, 9.36 ton/ac, was achieved from the mustard treated only with dairy biosolid. The results from the study indicated that the prepared biosolid fertilizers can effectively be used for the growth and production of mustard.

Keywords: biosolid fertilizer, dairy sludge, mustard, micro- and macro nutrients

Introduction

Farmers have known for centuries that animal manures spread on pastures and cropland can improve soil fertility (Sharma *et al.,* 2017). They began to use sludge from wastewater treatment plants as a fertilizer. “Dairy sludge” refers to the solids separated during the treatment of dairy industry wastewater (Hunt and Bittman, 2021). The scientific and agricultural communities have come to understand that dairy sludge contains valuable nutrients and organic matter that improve the soil. Dairy sludge is organic solids that have been treated to stabilize organic matter and reduce disease-causing organisms or pathogens. The greatest advantage is a reduction in fertilizer costs (Kaur, 2021).

Dairy biosolid also contains nitrogen, phosphorus, and many micronutrients that can be beneficial to crop growth. Another advantage is the addition of organic matter to the soil. Organic matter reduces surface runoff, reduces erosion and improves the water-holding capacity and nutrients of the soil (Carta-Escobar *et al*., 2004). Preparation and utilization of biosolid fertilizer using municipal sewage sludge has been reported recently (Sabai Phyu *et al*., 2023).

Mustards are a nutritionally various food that belongs to the legume family. Other names for mustards include green gram, maash, moong, monggo, or munggo. They are mainly cultivated in Asia, Africa, and South America, but mustards are enjoyed by people all around the world. Mustards are a rich source of plant-based protein, complex carbohydrates, fiber, and other nutrients. Mustards that are usually green but can also be yellow or black. Add them to soups, salads, and casseroles (Jillian, 2024). They are widely used in China to make curries.

The aim of the research work is to prepare effective dairy biosolid fertilizers using dairy sludge for agricultural productivity.

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Materials and Methods

Sample Collection, Preparation, and Application

Dairy sludges were collected from the dairy industry in the Minglardone Industrial Zone, Mingalardone Township, Yangon Region. The raw materials (cocopeat and rice husk ash) were collected from Hlaing Thar Yar Industrial Zone, Hlaing Thar Yar Township, Yangon Region. Dairy sludge was treated by processes that include dewatering, sludge pasteurization, anaerobic digestion, aerobic digestion, composting, and storage. The fertilizers were packaged in bags, stored in a cool place. By using dairy biosolid fertilizers, the trials were carried out in the winter of January 2022 at the Department of Agriculture (Land Use Division), Insein Township, Yangon Region. The average maximum and minimum temperatures of the experimental sites were 32 and 18 ℃, respectively. The experiment was laid out using a randomized complete block design (RCBD). The area of each plot was (3×50) sq ft. The row spacing and plant spacing were 12 inches and 6 inches in six treatments, respectively. The treatments used in this research were

T1 = Control,

T2 = Compound fertilizer (NPK 15:15:15) [50 kg/ac],

T3 (D1) = Dairy biosolid [200 kg/ac],

T4 (D2) = Dairy biosolid: cocopeat: rice husk ash (1:1:1) [200 kg/ac],

T5 = Dairy biosolid [200 kg/ac] + compound fertilizer [33.3 kg/ac],

T6 = Dairy biosolid [200 kg/ac] + compound fertilizer [25 kg/ac].

Determination of Physicochemical Properties, Nutrient Values, Elemental Analysis and Microbial Analysis, of Prepared Fertilizers

Some physicochemical properties (pH, moisture content, electrical conductivity, bulk density, organic carbon, humus, CN ratio and NPK contents) of raw materials (cocopeat and rice husk ash), dairy biosolids (D1), and dairy biosolid fertilizer (D2) were determined. Measurement of pH was carried out by a pH meter, and the moisture content was determined by a moisture analyzer. The electrical conductivity of biosolids fertilizers was determined by a conductivity meter. The nitrogen content was determined by Kjeldahl’s method. The potassium content was determined by flame photometric technique, and the phosphorus content was determined by UV-visible spectrophotometric technique. Elemental contents of raw materials and biosolids fertilizer were semi-quantitatively determined by using the EDXRF technique and also quantitatively determined by the AAS technique. The soil parameters of six treatments T1 to T6 were analyzed by conventional and modern techniques before sowing and after harvesting. Soil texture was determined by using a hydrometer. Available potassium, exchangeable calcium, magnesium, and potassium in the soil were determined by AAS. In the analytical procedures of the experiment, recommended methods and techniques were applied from AOAC, 1990. Microbial population in dairy biosolid (D1) was determined by the total plate count method.

(a) **(b)**

Figure 1. Photographs of (a) dairy sludge (b) dairy biosolid (treated dairy sludge)

Results and Discussion

Some Physicochemical Properties and Nutrients of Cocopeat, Rice Husk Ash, Diary Biosolid (D1) and Dairy Biosolid Fertilizer (D2)

Field experiments were studied on greenhouse plantations at the Department of Agriculture (Land Use Division), Insein Township, Yangon Region. Table 1 represents some physicochemical properties and nutrients of biosolid fertilizers. The acceptable moisture content, electrical conductivity, and pH values were found in dairy biosolids. The pH value (8.80) of dairy biosolid is found to be suitable for the preparation of biosolid fertilizer. The bulk density was found to be 0.29 of dairy biosolids (D1). So, high bulk density in an indicator of low soil porosity and soil compaction. High bulk density impacts available water capacity, root growth, and movement of air and water through soil. The C: N of dairy biosolids (D1) was calculated at the value of 32.85. Humus (97.40 %) plays a very important role in the maintenance and improvement of soil properties. The diary biosolid contains 1.72 % of nitrogen, 1.20 % of phosphorus, and 0.96 % of potassium. It was found that the amounts of nitrogen and phosphorus are high in dairy biosolid. Therefore, diary biosolid are used for preparation of biosolid fertilizers. So, the dairy biosolid (D1) is very suitable for growing leaf crops.

Table 1. Some Physicochemical Properties and Nutrient of Cocopeat, Rice Husk Ash, Diary Biosolid and Dairy Biosolid Fertilizer

Parameter	Rice husk ash	Cocopeat	Dairy biosolid (D1)	Dairy biosolid fertilizer (D2)
moisture (%)	2.67	14.06	22.81	22.81
electrical Conductivity (µS/cm)	172.90	421.00	347.00	256.00
pH	7.60	7.40	8.80	7.80
bulk density (g/mL)	0.27	0.10	0.29	0.20
organic carbon (%)	25.35	54.60	56.50	27.70
humus (%)	43.70	94.13	97.40	47.75
C:N	36.21	89.50	32.85	49.47
nitrogen (%)	0.70	0.61	1.72	0.56
phosphorus (%)	1.10	0.90	1.20	1.30
potassium (%)	1.56	0.17	0.96	0.48

Microbial Population of Dairy Biosolids (D1) Fertilizers

Table 2 shows the results of the determination of microbes in dairy biosolid. It was found that yeast and mold populations were found to be 6×10^3 cfu/g and *Bacillus subtilis* was 5.3×10^5 cfu/g. The dairy biosolid is one of the complex plant microbes that could be beneficial for both crop productivity and the well-being of soil microbiota. The harmful bacteria, such as *E.coli*, coliform, and *Salmonella* were not detected.

Table 2. Microbial Population of Dairy Biosolids (D1)

Microbes	Total plate counts (cfu/g)
yeast and mold	6×10^3
E. coli	0
coliform	0
Salmonella	ND
Bacillus substilis	5.3×10^5

ND = not detected

Relative Abundance of Some Elemental Contents in Raw Materials, Dairy Biosolid and Dairy Biosolid Fertilizer by EDXRF

Five elements (K, Ca, Fe, Zn, S) in cocopeat, eight elements (Si, K, Ca, Mn, Fe, Zn, Cu, Rb) in rice husk ash, ten elements (K, Ca, Mn, Fe, Zn, Cu, Rb, S, Ti, Sr) in dairy biosolids (D1) and eight elements (K, Ca, Mn, Fe, Zn, Cu, Ti, Sr) in dairy biosolid fertilizers (D2) were detected by EDXRF. Dairy biosolid (D1) contained a high amount of Ca (44.17 %) and K (27.58 %) as shown in Figures 2, 3, 4, and 5 and Table 3. It can be said that dairy biosolid (D1) and dairy biosolid fertilizers (D2) can supply multiple nutrients to soil and plants.

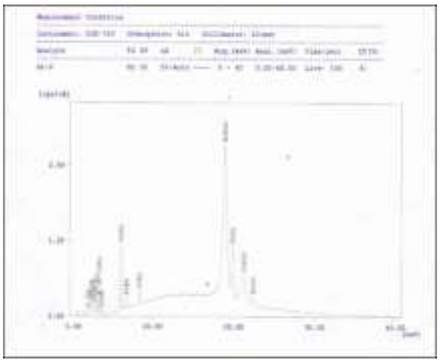

Figure 2. EDXRF spectrum of cocopeat

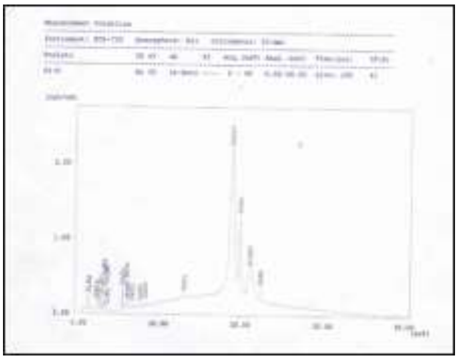

Figure 3. EDXRF spectrum of rice husk ash

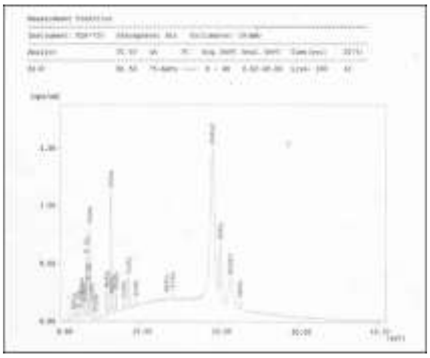

Figure 4. EDXRF spectrum of dairy biosolid (D1)

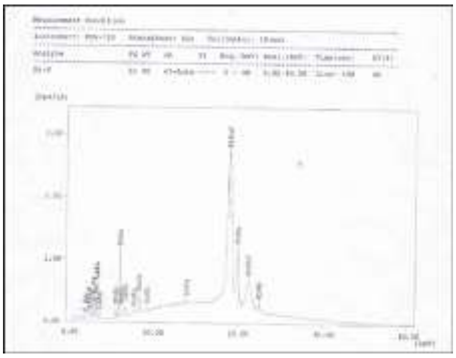

Figure 5. EDXRF spectrum of dairy biosolid fertilizer(D2)

Table 3. Elemental Analysis of Cocopeat, Rice Husk Ash, Dairy Biosolid and Dairy Biosolid Fertilizer by EDXRF

Sr.no.	Elements	**Relative abundance (%)**			
		Cocopeat	Rice husk ash	Dairy biosolid (D1)	Dairy biosolid fertilizer (D2)
1	Si	_	80.45	-	-
2	K	32.85	.10.05	27.58	22.83
3	Ca	29.03	5.64	44.17	41.88
4	Mn	_	1.84	3.68	3.95
5	Fe	27.29	1.68	15.61	20.16
6	Zn	3.28	0.14	2.40	3.19
7	Cu	_	0.13	0.71	1.19
8	Rb	_	1.07	0.20	-
9	S	7.28	_	4.50	-
10	Ti	_	_	0.85	5.91
11	Pb	_	_	_	-
12	Zr	_	_	_	-
13	Sr	_	_	0.29	0.48
14	Ni	_	_	_	-
15	Cr	_	_	_	-

Elemental Contents in Dairy Biosolid(D1) and Dairy Biosolid Fertilizer(D2) by AAS

The exact amounts of some nutrient elements in dairy biosolid (D1) and dairy biosolid fertilizer (D2) were also studied by the AAS method. From this study, the observed results are shown in Table 4. It was found that dairy biosolid contained Fe (4.82 ppm), Mn (0.63 ppm), and K (1.16 ppm) and dairy biosolid fertilizer contained higher amounts of Fe (9.15 ppm), and Mn (1.63 ppm). The sufficient amount of macro- and micronutrients were found to be present in biosolid fertilizers. So, it can be summarized that biosolid fertilizer may be a good source of elemental nutrients for plants.

Table 4. Elemental Contents of Dairy Biosolid and Dairy Biosolid Fertilizer

Nutrient	**Dairy biosolid (D1)**	**Dairy biosolid fertilizer (D2)**
S (%)	0.23	0.20
Ca (ppm)	0.03	0.22
Cu (ppm)	0.43	0.13
Cr (ppm)	0.06	0.09
K (ppm)	1.16	0.06
Zn (ppm)	0.14	0.35
Fe (ppm)	4.82	9.15
Mn (ppm)	0.63	1.63
Pb (ppm)	ND	ND

Analysis of Soil used for Mustard before Sowing

The physicochemical properties of five treated soils (T2-T6) and control (T1) before sowing of the mustard plant were studied. These soils were subjected to five different treatments (T2 – T6) by using dairy biosolid, dairy biosolid fertilizer, and compound fertilizers. The soil without any fertilizer treatment (T1) was kept as a control. These trials were analyzed for their physical and chemical properties. The results are shown in Table 5. From these results, based on the soil texture diagram, all soils (before sowing) are the sandy loam. The pH values of treated soils were found to be in the range of 5.60 to 6.80, slightly acidic types of soil. Soil pH may influence nutrient absorption and plant growth. The electrical conductivity (20-80 µS/cm) was good nutrient uptake, healthy plant growth and good yields for Mustard cultivation.

Table 5. Analysis Data of the Soil before Sowing

Analytical item	Soils					
	T1	**T2**	**T3**	**T4**	**T5**	**T6**
texture- sand (%)	57.40	54.35	55.84	54.62	55.65	56.88
silt (%)	19.94	19.46	23.04	22.54	21.31	21.12
clay (%)	22.66	26.19	21.12	22.84	23,04	22.00
moisture (%)	1.14	1.12	1.11	1.13	1.14	1.12
pH	5.60	5.00	6.50	6.80	5.40	5.00
electrical conductivity (µS/cm)	50.00	74.00	66.50	78.10	42.20	75.10
organic carbon (%)	0.51	0.49	0.48	0.54	0.47	0.46
humus (%)	0.89	0.85	0.83	0.93	0.81	0.79
total N (%)	0.11	0.20	0.18	0.16	0.19	0.18
C/N ratio	4.63	2.45	2.67	3.38	2.47	2.56
available P (ppm)	38.40	47.21	88.06	69.04	65.21	53.14
available K_2O (mg/100g)	9.60	20.00	10.51	14.92	19.84	18.62
exchangeable Ca (meq/100 g)	9.99	15.00	9.36	11.60	14.74	16.80
exchangeable Mg (meq/100 g)	3.33	3.51	8.70	4.07	3.30	3.16
exchangeable K (meq/100 g)	0.20	0.20	0.25	0.14	0.22	0.20

Analysis of Soil used for Mustard after Harvesting

Based on the soil texture diagram, all types of soils (T1- T6) are sandy loam and so they cannot be changed before and after harvesting. It was found that the pH values of all soils were increased in all treatments after harvesting (Table 6). In addition, the amounts of total N, available P and K, and exchangeable Ca. Mg, and K in control and all treatments(T1-T6) were reduced as compared to those before sowing. It can be said that the mustard plants consumed the necessary nutrients from the soils (T1-T6).

Table 6. Analysis Data of Soil Using for Mustard after Harvesting

Analytical item	Soils					
	T1	**T2**	**T3**	**T4**	**T5**	**T6**
texture-sand (%)	58.60	57.45	57.30	56.42	57.60	58.12
silt (%)	16.83	17.02	19.96	19.76	19.54	19.43
clay (%)	24.57	25.53	22.74	23.82	22.86	22.45
moisture (%)	0.89	0.92	1.44	1.40	1.36	1.10

Analytical item	**Soils**					
	T1	**T2**	**T3**	**T4**	**T5**	**T6**
pH	5.70	5.70	7.20	7.30	6.00	5.60
electrical conductivity (µS/cm)	46.10	73.10	62.30	70.00	35.40	71.20
organic carbon (%)	0.41	0.45	0.45	0.50	0.44	0.43
humus (%)	0.70	0.76	0.78	0.86	0.76	0.74
total N (%)	0.08	0.17	0.14	0.13	0.20	0.14
C/N ratio	5.13	2.65	3.21	3.85	2.20	3.07
available P (ppm)	40.01	45.00	86.00	68.10	62.00	51.14
available K_2O (mg/100g)	8.60	16.00	9.00	12.34	17.94	16.54
exchangeable Ca (meq/100 g)	8.90	14.60	9.32	11.56	14.70	16.76
exchangeable Mg (meq/100 g)	2.22	3.10	8.66	4.00	3.26	3.10
exchangeable K (meq/100 g)	0.07	0.15	0.19	0.11	0.18	0.17

Effect of Biosolid Fertilizer on Growth and Yield of Mustards

The time interval from transplanting to harvesting was 21 days (Figure 6). The growth factors of the mustard were evaluated in terms of the plant height (cm), root length, number of leaves, and plant weight. The growth data and yield are shown in Table 7 and were significantly different. Plant weight of mustard produced from control (T1) is less than treated soil (T2-T6). From this research, it was clearly observed that the yields of mustards (T2- T6) were higher than the control (T1). The yield of mustards of T3 was the highest (9.36 ton/ac). The second and third highest yields were observed in T6 and T4. T3 is the only dairy biosolids. So, it can be said that dairy biosolids can be used to reduce the use of compound fertilizers in mustard planting.

(a)

(b)

Figure 6. Photographs of (a) a field of mustard and (b) growing mustard leaves

Table 7. Effect of Biosolid Fertilizer on Growth and Yield of Mustard

Treatment	**Plant height (cm)**	**Root length(cm)**	**No. of leaf**	**Plant weight (g)**	**Yield 3′×1′ (kg)**	**Yield (ton/ac)**
T1	34.40	19.00	5.60	95.00	750.00	3.90
T2	33.80	20.00	6.40	142.00	1160.00	6.03
T3	37.50	19.50	8.50	256.00	1800.00	9.36
T4	38.20	17.90	7.80	178.00	1450.00	7.54
T5	34.60	18.60	5.90	125.00	850.00	4.42
T6	37.90	19.00	7.60	162.00	1540.00	8.01

Conclusion

The three different fertilizers (T4 -T6) were prepared using biosolids from dairy biosolid and compound fertilizer (compound 15:15:15). According to the physicochemical properties and micro-macro nutrients, all fertilizers (T2-T6) are suitable for plant growth. Field experiments using (T1-T6) were conducted to know the effect of biosolid fertilizer on plant growth and yield of mustard. From the results, the yields of T3, T4, and T6 are the leading runners (9.36, 7.54, and 8.01 ton/ac). The yield of T3 was the highest. T4 and T6 (dairy biosolid plus compound fertilizers) were found to have higher yield compared to T2 (compound fertilizer). So, it can be concluded that biosolid fertilizer obtained from dairy biosolid can effectively be used as a partial replacement for compound fertilizer in mustard planting fields. Moreover, the biosolid fertilizer from dairy biosolid only contains beneficial microbes.

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