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Research Article
Effect of Cow Manure Compost on Chemical and Microbiological Soil Properties in Saudi Arabia

Waleed Saleh Alwaneen

National Center for Agricultural Technology (NCAT), King Abdul-Aziz City for Science and Technology (KACST), P.O. Box 6086, Riyadh, Kingdom of Saudi Arabia

Abstract

Background and Objective: The dairy industry in Saudi Arabia is producing huge quantity of Farm Yard Manure (FYM) resulting in potential environmental and health hazards. Raw FYM is processed into usable compost for increasing soil fertility and productivity. The main aim of this study was to analyze the effect of prepared Cow Manure Compost (CMC) on chemical and microbiological soil properties. **Materials and Methods:** A greenhouse experiment was carried out with 3 CMC treatments (control, 25 and 50 t ha^{-1}). The plot size was 2×2 m^2 with three replications and the test crop was corn (*Zea mays*, an American hybrid cultivar). The irrigation source was deep well water. Crop growth parameters, such as plant height and fresh biomass were determined. The microbiological soil properties measured were Soil Microbial Biomass (SMB), Microbial Nitrogen (MN), Dehydrogenase Activity (DHA) and Alkaline Phosphomonoesterase Activity (APA). Standard analytical methods were used for soil analysis and microbiological investigation. **Results:** Addition of CMC increased significantly the mean plant height and fresh biomass. The microbial parameters such as SMB, MN, APA and DHA improved and depended on the doses application. **Conclusion:** The study results showed that the use of CMC improved the soil microbiological properties thus resulting in improved crop production.

Key words: Cow manure, soil microbial biomass, microbial nitrogen, alkaline phosphomonoesterase activity, dehydrogenase activity

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Corresponding Author: Waleed Saleh Alwaneen, National Center for Agricultural Technology (NCAT), King Abdul-Aziz City for Science and Technology (KACST), P.O. Box 6086, Riyadh, Kingdom of Saudi Arabia Tel: 00966555443614

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Saudi Arabia belongs to an arid region where crop production faces lot of problems particularly due to irrigation water scarcity and poor soil fertility[1]. In Saudi Arabia, dairy industry is booming thus resulting in the production of huge quantity of raw cow manure (dairy manure). Improper disposal of raw cow manure causes water pollution, degradation of environment and proliferation of harmful micro-organisms. To avoid and minimize environmental threats, dairy industries are processing the raw cow manure into decomposed organic manure, because it is friendly to the environment, enriches soil fertility and improves microbial activity and crop yield[2-5]. Use of bacterial fertilizer and manure compost is common to rehabilitate the soil bacterial communities and soil nutrients to improve crop production[3]. The addition of green manure with organic fertilizer was important for organic crop production. It also maintained and increased soil microbial activity and enhanced growth of different types of microbes[6].

In China, the soil treatment with organic manure increased the Dissolved Organic Carbon (DOC) content and enhanced the actinomycetes to a greater extent compared to control or mineral fertilizer treatment[7]. Similarly, the addition of liquid bio-fertilizer to soil under banana (*Musa* spp. L.) cv. "Grand Naine" cultivation, improved the soil biological characteristics[8]. The results showed that compost and liquid bio-ferment improved the soil fertility and stimulated microbial activity to metabolize complex organic molecules. In another study, the use of organic fertilizer instead of inorganic fertilizer proved beneficial for sustainable and environment-friendly agriculture[9]. Soil fungi and bacteria stimulated the decomposition of organic fertilizers resulting in improved physical and chemical soil properties for increased crop production. The effectiveness of cattle and swine manure was compared in soil under rice plantation. It was found that cattle manure enhanced the number of microbial species and stimulated copiotrophic microbial groups and proved more efficient as compared to swine manure treatment[4,10].

Recently, the interaction between chemical and biological factors, including microbial composition, controlled the soil quality[5]. They also determined the soil bacterial composition from soil treated with cow manure and poultry manure. An earlier study observed that addition of manures to soil enhanced the soil properties and nutrients availability to plants[11]. Many investigators reported that microbial activity in soil is mainly influenced by bacterial residue accumulation with fertilizer application on long-term basis[12,13]. The effect of organic manure from different sources showed that addition of compost increased the soil pH and available phosphorus to the plants[14]. Literature search has shown that very little has been accomplished on the use of composted cow manure on soil microbial population, soil fertility status and crop production under local conditions. Therefore, the main aim of this study was to determine the effect of prepared Cow Manure Compost (CMC) on chemical and microbiological properties of soils in an arid environment in Saudi Arabia.

MATERIALS AND METHODS

The experiment was conducted in a greenhouse at Almuzahmiyah Research Station, King Abdulaziz City for Science and Technology (KACST), Saudi Arabia under controlled environmental conditions during 2016/2017 cropping season. The soil of the greenhouse was sandy-loam with a pH of 7.35 (saturated paste), electrical conductivity of saturated paste extract (EC_e) was 3.50 dS m^{-1}, while measured values of 60, 8.5, 2.5, 28, 55 and 35.6 mg L^{-1} were recorded for Ca, Mg, Na, K, Cl and SO_4, respectively. Whereas, the soil fertility status was 0.005, 0.002 and 2.54 g kg^{-1} of the Organic Matter (OM), Total Nitrogen (TN) and available P, respectively.

The Cow Manure Compost (CMC) was purchased from a local market. Three treatments of CMC such as 0, 25 and 50 t ha^{-1} were calculated and applied to experimental plots. The 0 CMC treatment was control. The experimental plot size was 2×2 m^2 with three replications. The experiment was laid out by following the Completely Randomized Block Design (CRBD). The CMC was spread and mixed thoroughly in the top 0-15 cm layer of soil. The experimental plots were irrigated with a drip system of irrigation using deep well water with total water salinity of 1,200 mg L^{-1} and sodium adsorption ratio of 2.5. The plots were irrigated to fulfill the field capacity of the top 0-30 cm depth of soil. The physical and chemical characteristics of the cow manure are presented in Table 1.

Crop plantation: Corn crop (*Zea mays*), a local cultivar was planted on October 25, 2016. The plant-to-plant distance was 30 cm and row-to-row distance was 50 cm. The seeds were planted by dibbling method at about 2-3 cm depth. There were 4 rows in each plot having 24 plants per plot.

Table 1: Physical and chemical characteristics of Cow Manure Compost (CMC)

Parameters (%)	Values
EC (dS m^{-1})	3.50
Total organic carbon	17.80
Total organic matter	30.75
Total phosphorus	0.28
Total potassium	0.30
Total nitrogen	0.85

EC: Electrical conductivity

The plots were irrigated after seeding to bring the soil moisture to field capacity level. The crop was harvested after 60 days of planting at the time of cob formation when the plant growth was considered to be at full stage.

Soil analysis: The experimental soil was analyzed for pH and soluble Ca, Mg, Na, K and Cl ions by analytical methods[15] as described in the USDA Handbook 60. The soil available P was determined by $NaHCO^{-3}$ extraction method[16].

Collection of soil samples for microbiological analysis: In order to estimate the microbiological status of soil treated with organic manure, soil samples were collected from the top 0-15 cm depth of soil when the crop root formation and growth reached the maximum stage. The collected samples were sieved by a 2 mm sieve, air dried and stored at 23°C for further analyses. At this stage, the soil microbial activity seemed to reach its full capacity as reported in the previous literature[17].

Soil microbial biomass, microbial nitrogen and dehydrogenase activity: Soil Microbial Biomass (SMB), Microbial Nitrogen (MN), Dehydrogenase Activity (DHA) and Alkaline Phosphomonoesterase Activity (APA) contents were estimated by using the method of Brookes *et al.*[18]. Similarly, the phospholipid fatty acid extracts were analyzed to determine soil microbial community by following the procedure described by many researchers[19,20].

Data analysis: The experimental data were compiled and statistical Analysis of Variance (ANOVA) was performed at p = 0.05 and other statistical techniques given in SAS Institute Inc.[21].

RESULTS

CMC vs. soil properties: The effect of CMC application on physical and chemical soil properties was quite prominent especially on Organic Matter (OM), NO_3-N and available P (Table 2). It was observed that all the three soil fertility components namely OM, NO_3-N and P increased significantly with increasing application of CMC from 0-50 t ha^{-1}. On the other hand, the addition of CMC did not affect the soil pH in all treatments and was not different significantly from the control treatment. The OM was very low in the soil before CMC treatment (1.2% in the control treatment) which increased tremendously from 1.2 to 15.8-20.6% with 25 and 50 t ha^{-1} CMC treatment, respectively. Similarly, the NO_3-N and P contents of 0.005 and 2% were very low, respectively as compared to their values after CMC treatment. These were 15.6 and 25.7 for NO_3-N, 120 and 145 for P receiving CMC at the rate of 25 and 50 t ha^{-1}, respectively (Table 2). The difference between the three treatments was also significant for all these parameters when compared to the control treatment. The concentration of macronutrients (mg kg^{-1}) ranged between 3.5-7.8 for Ca, 12-15 for Mg, 10-15 for Na and 12-18 for K. The difference in concentration was significantly different in all the treatments compared to the control treatment. Although, there was an increasing trend in the macronutrients, but the difference was not significant between 25 and 50 t ha^{-1} CMC application except the K. These results showed that application of organic manure on long-term basis proved beneficial for improving the soil OM content and soil fertility.

CMC vs. crop growth: Mean plant height increased significantly when the application of CMC increased from 0-50 t ha^{-1} (Table 3). The plant height was recorded 24.8 cm in the control treatment, whereas, it increased up to 112.5 and 132.2 cm with 25 and 50 CMC t $ha.^{-1}$, respectively. This shows that increasing the doses of CMC provided more nutrients to the growing plants. Similarly, the increase in the fresh biomass was also significant with increasing application of CMC compared to the control treatment. It was 4.7 kg m^{-3} in the control treatment, whereas, it increased up to 7.2 and 9.4 kg m^{-3} with 25 and 50 CMC t ha^{-1}, respectively (Table 3). The enhanced plant growth is very beneficial for boosting the crop production which might be achieved through the addition of CMC in the agriculture farming lands.

Table 2: Effect of Cow Manure Compost (CMC) on soil chemical properties

CMC (t ha^{-1})	pH	OM (%)	NO_3-N (mg kg^{-1})	P (mg kg^{-1})	Ca (mg kg^{-1})	Mg (mg kg^{-1})	Na (mg kg^{-1})	K (mg kg^{-1})
Control	7.35[a]	1.2[a]	0.005[a]	2.0[a]	3.50[a]	12.0[a]	10.0[a]	12.00[a]
25	7.45[a]	15.8[b]	15.600[b]	120.0[b]	6.30[b]	14.0[b]	13.0[b]	14.00[b]
50	7.55[a]	20.6[c]	25.700[c]	145.0[c]	7.80[b]	15.0[b]	15.0[b]	18.00[c]
Mean	7.45	12.5	13.760	89.0	5.87	14.0	13.0	14.70
Standard deviation	0.10	10.1	12.940	76.0	2.18	1.5	2.5	3.06

OM: Organic matter, within each column, the mean values followed by the same letters do not differ significantly, Least Significant Difference (LSD) test at p<0.05

Table 3: Effect of Cow Manure Compost (CMC) application on plant growth parameters

CMC (t ha^{-1})	Plant height (cm)	Fresh biomass (kg m^{-3})
Control	24.8[a]	4.7[a]
25	112.5[b]	7.2[b]
50	132.2[c]	9.4[c]

Within each column, the mean values followed by the same letters do not differ significantly, Least Significant Difference (LSD) test at p<0.05

Table 4: Effect of Cow Manure Compost (CMC) application on some soil microbiological properties

Treatments	SMB (µg CO_2-C g^{-1} soil)	MN (µg N g^{-1} soil)	DHA (µg TPF g^{-1} soil ha^{-1})	APA (µg CO_2-C g^{-1} soil ha^{-1})
Control	48[a]	6:00[a]	1.20[a]	37[a]
25	140[b]	28[b]	2.52[b]	175[b]
50	196[c]	42[c]	3.87[c]	237[c]

Mean values followed by the same letters in each column show significant difference in each parameter by 0.05% level of significance, SMB: Soil microbial mass, MN: Microbial nitrogen, DHA: Dehydrogenase activity, APA: Alkaline phosphomonoesterase activity, TPF: Total productivity factor

CMC effect on soil microbiological properties: The Soil Microbial Biomass (SBM) was 48 µg CO_2-C g^{-1} soil in the control treatment which increased significantly up to 140 and 196 (µg CO_2-C g^{-1} soil) with the application of 25 and 50 CMC t ha^{-1}, respectively (Table 4). Mean Microbial Nitrogen (MN) increased from 6 (control) to 28-42 µg N g^{-1} soil when the CMC was applied from 25 and 50 CMC t ha^{-1}. Mean Dehydrogenase Activity (DHA) showed a significant increase from 1.2 (control) to 2.52-3.87 of the Total Productivity Factor (TPF) (µg TPF g^{-1} soil ha^{-1}) with application of CMC from 25-50 t ha^{-1}, respectively. Whereas, mean Alkaline Phosphomonoesterase Activity (APA) increased from 37-237 µg CO^2-C g^{-1} soil ha^{-1} (Table 4). The increase in the soil microbiological properties with the increasing dose of CMC, highlights its importance with respect to the soil fertility as well as crop production.

DISCUSSION

Application of CMC proved beneficial for improving the soil fertility status compared to the control treatment. Also an increasing trend was observed on the soil mineral components. The results showed a non-significant trend in soil pH in CMC-treated plots which was in line with the findings of Maeder *et al.*[22], who also observed similar trends for the soil pH after organic treatment. With respect to other soil nutrient parameters, it was reported that the combined use of low chemical fertilizer dose with 20 t ha^{-1} of farmyard manure significantly increased soil Organic Matter (OM) and Total Nitrogen (TN) content without significant difference in crop production[23].

The results of this study are consistent with the findings of other studies where significant effect of Cow Manure Compost (CMC) was observed on growth and biomass parameters compared to the control treatment which ultimately will improve the yield[24]. The corn plant growth increased 4 times with increasing CMC application from 25-50 t ha^{-1} as compared with the control treatment plant growth (Table 3). An increase in the growth of the turmeric plants from 166-204 cm with the addition of 30 t ha^{-1} farmyard manure was also reported by Hossain and Ishimine[25]. Similar findings were reported for the improvement of crop yield and growth in the mung bean, wheat and maize[26,27]. The present results showed that soil microbial parameters were significantly higher with the application of CMC compared to the control treatment. This indicated that CMC addition proved effective to enhance the soil microbial activity. The study findings were in line with the results of Francioli *et al.*[23]. The addition of FYM enhanced the soil MBC, increasing the soil bacterial community. The manure, from chicken, goat or cow definitely provides extra nutrients to soil with the addition of the microbial activity. Ultimately these factors enhance the soil fertility, improves the soil structure and aeration ultimately depending on soil type and manure[25,28-30]. This study has explored several parameters about the soil fertility improvement as well as on crop growth and microbial activities with the soil types found in Saudi Arabia.

CONCLUSION

Mean plant height and fresh biomass increased significantly with addition of CMC compared to the control treatment. However, it increased significantly when the CMC dose was increased from 25-50 t ha^{-1}. This suggests that CMC provided more nutrients for plant growth. The application of CMC considerably improved the various microbial parameters such as Soil Microbial Biomass (SMB), Microbial Nitrogen (MN) content, Alkaline Phosphomonoesterase Activity (APA) and Dehydrogenase Activity (DHA) in soil. The study results showed that the use of CMC improved the soil microbiological properties and crop production.

SIGNIFICANCE STATEMENT

The use of FYM increased the fresh biomass of corn crop and improved the soil microbiological properties. The study findings highlighted the beneficial use of FYM for the improvement of soil fertility and mitigating the environmental issues resulting from raw disposal of FYM.

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