Saudi Journal of Biological Sciences 26 (2019) 1423–1428

Contents lists available at ScienceDirect

Saudi Journal of Biological Sciences

journal homepage: www.sciencedirect.com

Original article

Nutritional status of different biosolids and their impact on various growth parameters of wheat (*Triticum aestivum* L.)

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ARTICLE INFO

Article history:
Received 2 August 2018
Revised 19 August 2018
Accepted 2 September 2018
Available online 4 September 2018

Keywords:
Agriculture
Cereal crops
Nutritional requirements
Biosolids
Plant growth

ABSTRACT

Biosolids can be effectively recycled and applied as soil amendments for agricultural crops because they contain several important micro and macronutrients including nitrogen, phosphorus, potassium, manganese. In the current study, we evaluated the effectiveness of seven biosoilds on different growth parameters of wheat crop. The biosolids used were lime stabilized, composted, liquid mesophilic anaerobically digested (liquid MAD), thermally dried mesophilic anaerobically digested (thermally dried MAD), thermally hydrolyzed mesophilic anaerobically digested (thermally hydrolysed MAD), dewatered mesophilic anaerobically digested (dewatered MAD) and thermally dried raw biosolids. We also analysed biosolids for their nutrient contents before application. The results revealed that different types of biosolids differed in nitrogen and phosphorous contents with highest contents observed in dewatered (5.70% nitrogen, 2.32% phosphorous) and liquid biosolids (2.35% phosphorous). The plant height, plant diameter and dry weight yield of wheat was increased with the increase in concentrations of biosolids. Liquid MAD resulted in maximum plant height of 120.35 ± 3.23, 133.2 ± 3.67 and 147.25 ± 3.11 at 3.33, 6.66 and 9.99 tons/ha concentration. The highest plant diameter was recorded (1.05–1.45 cm) where mineral nitrogen was applied. The study will be helpful in replacing the synthetic fertilizer with biosolids to fulfil the nutritional requirements of agricultural crops.

1. Introduction

Biosolids are by-products obtained after the treatment process of wastewater. These are one of the important type of solid wastes. They contained organic wastes or insoluble biological residues resulting from different processes (Marguí et al., 2016; Usman et al., 2012). Biosolids are the substances produced worldwide in huge quantities due to accelerated industrialization and urbanization (Sharma et al., 2017).

Biosolids contain many toxic chemicals including heavy metals, as such their improper usage poses a threat to the environment

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Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

https://doi.org/10.1016/j.sjbs.2018.09.001
1319-562X/

(Sidhu and Toze, 2009). These threats encompass ground water contamination, soil quality deterioration etc. (Semblante et al., 2015; Sharma et al., 2017). Modern world has developed guidelines for the disposal of biosolids for example; USA enacted Clean Water Act (CWA) of 1972 and made multiple amendments with time (EPA, 2017). Canada introduced, Canadian Environmental Protection Act, 1999 and then Clean Water Act S.O. 2006 which is a law enacted by the Legislative Assembly of Ontario, Canada. In 2010, Canadian Council of Ministers of the Environment (CCME) developed a Canada-wide approach for the management of wastewater biosolids (CCME, 2010).

In spite of prohibition, in many countries they are usually dumped into oceans causing water pollution that affect beneficial organisms such as fish. The harmful effects of biosolids on the environment led the scientists to think about the reprocess. They contained different organic materials hence can be used for various purposes on sustainable basis like energy production and soil conditioning (Marguí et al., 2016).

The effective management of such biosolids has been a topic of debate among scientists. CCME (2012) introduced land application as one of the beneficial options for the disposal of biosolids. In agriculture, biosolids are very important as their constituents are mostly materials of prospective environmental value. Biosolids consist of different elements i.e. Nitrogen (N), Phosphorus (P) and Potassium (K) (Cheremisinoff, 2001; Henze et al., 2001; Song et al., 2014). Sludge produced by human is very important and using for agricultural purposes (Delibacak and Ongun, 2016). Biosolids consist of micronutrients as Nitrogen (N) and Phosphorus (P) that are helpful in agricultural production (Brisolara and Qi, 2015; Rigby et al., 2016). In comparison to organic soil amendments, the positive effects of biosolids have better effect on growth and yield of agricultural crops (Rouch et al., 2011; Singh et al., 2008).

Wheat (*Triticum aestivum* L.) is considered staple food all over the world, and contains large proportion of carbohydrates for human being. Wheat straw contains diet of livestock (Malik et al., 2009). Wheat crop is considered forage and grain crop (Hunt et al., 2016; Pinchak et al., 1996) in Australia, Argentina, Pakistan and Syria (Abdullah et al., 2016). The present study was aimed to improve fodder and forage qualities of the wheat straw.

Dry stalk of wheat is big source of wheat straw that is prepared after winnowing and threshing (Singh et al., 2009). Dry stalk is usually stored in the form of hay or straw bales for the purpose of feeding animals and other uses. The wheat straw is also used for various purposes after fermentation (Mojsov, 2010; Singh et al., 2009) and pulp industry (Gübitz et al., 1998; Singh et al., 2009) for preparation of biochar (Goodall, 2010), medicine, and bioremediation (Dupont et al., 2006; Javed et al., 2012).

Based on the fertilizer value of biosolids, they can help reduce usage of synthetic fertilizers or biosolids can efficiently be applied to enhance wheat yield as fodder crop. However, different biosolids have different nutritional values. Literature is silent regarding impact of biosolids upon growth and yield of wheat. As such, the aim of the current research was to investigate the nutritional status of different types of biosolids materials and examine the impact of these biosolids on the growth and yield of most important crop, wheat (*T. aestivum*) under field conditions.

2. Materials and methods

2.1. Biosolids used in the study

Seven biosolids were used in the study: (1) Lime stabilized biosolids, (2) Composted biosolids, (3) Liquid Mesophilic Anaerobic Digestion (MAD) biosolids, (4) Thermally dried MAD (5) Thermally Hydrolyzed MAD, (6) Dewatered MAD, (7) Thermally-dried raw biosolids (8) mineral fertilizers as control

2.2. Characterization of soil and biosolids

The soil and biosolids samples were analysed at the postgraduate laboratory of Institute of Pure and Applied Biology, Bahauddin Zakariya University, Multan, Punjab, Pakistan and at Soil and Water Testing Laboratory, Dera Ghazi Khan. For setting up the trial, soil samples were taken from the trial site just before the onset of cropping system. Three different soil samples were taken from the trial area at different depths of 30, 60, and 90 cm. The samples from all the depths were pooled together and analysed. However, each biosolid was sampled thrice and the samples were pooled together. Nutrients variation between the batches was tested for uniformity. It was observed that nutrient contents of biosolids had little variation within batches. Therefore, one-one sample was subjected to analysis.

Sodium sulphate and sulphuric acid were used to digest nitrogen and phosphorous in the presence of mercury catalyst by following the methodology of Sparks et al. (1996). The by-products (e.g. ammonium hydroxide and sodium hydroxide) formed during analysis were removed by steam distillation. Total nitrogen and carbon contents in the samples were determined by Dumas technique. Digestion of the samples was done by complete combustion in the presence of oxygen.

The measurement of oxides of each element was done through chromatographic column for which thermal conductivity is working principal. However, for phosphorous determination in samples, Olsen's extractable phosphorus method was followed (Olsen, 1954). The amount of available phosphorous in the biosolids was extracted with the help of sodium bicarbonate (Na_2CO_3) solution at 8.5 pH and 20 °C temperature. As a result of this process, a blue complex was obtained that was analysed by spectro-photometer at the absorbance rate of 880 nm.

For the extraction of ammonium from the samples, potassium chloride solution and de-ionized water were used and quantity of ammonium nitrogen in the samples was determined by calorimetric method. During this extraction, the test material was reacted with phenol and alkaline hypochloride. The indophenol blue was obtained from this reaction and nitrates and nitrites were extracted with the help of de-ionized water.

Cadmium reduction method was used to find out the quantities of all above substances in the samples. This method involves the use of spectro-photometer with the formation of a diazo product between sulphanil amide and sulphanil-amnde nitrite. The total elements and mineral contents were also determined from the samples. For this purpose, samples were digested in concentrated acids (hydrochloric acid or nitric acid). All of this process was carried out at high pressure and temperature obtained by microwave digestion. All elements from the digested solution were determined with the help of ICP-ES (Inductively Coupled Plasma Emission Spectroscopy). The elements determined through analysis were metal like magnesium, calcium, iron, cadmium etc.

2.3. Effect of biosolids on the growth, biomass and other physiological attributes

The trials were conducted at Shah Sadar Din (latitude 30.275° and longitude 70.730°), Dera Ghazi Khan, Pakistan. The soil of the study site is categorized as Bagshot Sands type which is sandy loam, slightly alkaline and free drained.

The crop was grown in split plot design with four plots for each treatment. The rate of the biosolids application (dry weight) in the sub plots was 0, 3.33, 6.66 and 9.99 tons/ha. Mineral fertilizer consisting of mineral N (@ 0, 30, 60, 90, 120 kg/ha), mineral nitrogen along with single phosphorous dressing as super triple phosphate (@ 50 kg/ha), mineral phosphorus (@ 0, 25, 50, 75 and 100 kg/ha) and mineral phosphorus with solitary N dressing (@ 60 kg/ha).

The experimental land was left fallow for at least two years before the start of the trial. The naturally grown plants like weeds were managed by the application of herbicides (glysophate). The land was prepared by following the recommended procedure like ploughing, and harrowing. After ploughing and harrowing potash fertilizer (in the form of P_2O_5) was broadcasting at the rate of 50 kg/ha. After application of potash fertilizer, biosolids were applied and mixed into the soil with manual rotavator. Once the seed bed got prepared, wheat crop was sown at the seed rate of 75 kg/ha.

2.3.1. Effect on growth parameters

In order to estimate the impact of different amount of biosolids on growth factors four plants were sampled from each treatment and replication for data collection. Collected data includes; plant height, leaf area and stem diameter, and the data were analysed to compute the mean differences between different groups and the control group.

2.3.2. Dry weight yield (DWY)

For this purpose, a specific area (80 × 120 cm) from each plot was selected and all the plants were harvested. The plants (from each harvested plot) measuring 100 g were oven dried at 80 °C and weighed for dry matter contents.

2.4. Data analysis

The data of growth parameters and dry weight yield was analysed using split plot design Analysis of Variance (ANOVA).

3. Results

3.1. Nutritional status of biosolids used in the study: chemical analysis of biosolids

In this study, chemical analysis approach was applied to determine the nutritional status of biosolids.

3.1.1. Nitrogen contents

From the analysis of biosolids, it was found that the level of total Phosphorus (P) was as low as 0.38% DS in Lime Stabilized biosolids which is considerably lower than the level of Nitrogent (N) in biosolids as it appeared 14.95% TN in Dewatered MAD biosolids. The total nitrogen and its quantities in chemical form varied insignificantly between two years of the trials. Similarly, the dewatered cake contained highest amount of total nitrogen (i.e. 5.70% DS) with most proportion as Ammonium-N (NH_4^+) ions (Table 1).

In contrast, thermally dried biosolids contained slightly lower nitrogen content as compared to the biosolids that were mechanically dewatered. Thermally treated biosolids showed lower total N. Lower total N can be related with the potential loss mineral nitrogen due to thermal oxidation. Total nitrogen content of TAD, MAD, and thermally hydrolyzed sludge was quite similar to thermally treated sludge but they contained higher amounts of mineral N (i.e. approximately 14.95%). Liquid biosolids contained 1.98% of total nitrogen most of which was in the form of mineral. The lime stabilized and compost treated biosolids contained low total N contents of 1.03% and 1.32% respectively (Table 1).

3.1.2. Phosphorus content of biosolids

The highest total phosphorus content was observed in dewatered biosolids (2.32%) and liquid biosolids (2.35%) respectively. Lime stabilized and composted biosolids had the lowest total phosphorus content at the values of 0.38% and 0.61% respectively. Thermally hydrolyzed MAD also showed higher P content (Table 1).

3.2. Soil analysis

The results of the soil analyses are illustrated in Table 2. The soil was alkaline as its pH ranged from 7.4 to 8.9. The total N content of the soils ranged between 0.051% (w/w) and 0.213% (w/w) and it was higher than the nitrogen content of the first trial. Initially, the value of ammonical-N was measured to be 8.7% (Table 2) and it was between 3.9% and 19.1% for the second trial. The nitrate level on the surface of the soil ranged from 18.1% to 29.3% in the first trial but they were between 3.6% and 25.2% in the second trial (Table 2).

3.3. Effect of biosolids on plant height

The plant height differed significantly among different biosolids ($F_{7,21} = 66.30$; $P < 0.001$), concentrations ($F_{3,\ 72} = 482.23$; $P < 0.001$) and the interaction ($F_{21,\ 72} = 15.71$; $P < 0.001$). It was increased with the increase in concentrations of biosolids. At control i.e. 0.00 tons of biosolids applied, the mean value was approximately 95.05 ± 3.14 cm. The results showed that liquid MAD application resulted in maximum plant height of 120.35, 133.2, 147.23 cm in 3.33, 6.66 and 9.99 tons/ha treatment. Almost similar plant heights were recorded in mineral fertilizer treatments in all plots. In comparison, plant height was minimum in treatment where thermally dried raw biosolids was applied (Fig. 1).

3.4. Effect of biosolids on plant diameter

The plant height was significantly different among different biosolids ($F_{7,21} = 16.74$; $P < 0.001$), rates of biosolids ($F_{3,\ 72} = 272.60$; $P < 0.001$) and the interaction ($F_{21,\ 72} = 9.13$; $P < 0.001$). The results showed that the mean stem diameter was 1.08 cm for control. The mean stem diameter values for mineral N were 1.21 ± 0.08, 1.315 ± 0.0125 and 1.25 ± 0.032 cm for three

Table 1
Nitrogen & phosphorus contents of different biosolids applied to fields.

Biosolids	DS%	TN (%DS)	NH_4^+-N (mg/kg DS)	NO_3-N (mg/kg DS)	Org-N (%DS)	Mineral N (%TN)	Total P (% DS)	(Extracted P (mg/kg DS)
Dewatered MAD	26.7	5.70	8734	<0.01	4.73	14.95	2.32	1135
Thermally Dried MAD	87.5	4.15	967	<0.01	4.31	2.31	2.07	523
Thermally dried raw biosolids	85.6	4.10	254	7.49	4.48	0.53	1.61	183
Liquid MAD	1.98	1.47	0.77	–	0.87	39	2.35	8171
Lime Stabilized	39.7	1.03	506	<0.01	1.05	4.45	0.38	1527
Composted Biosolids	55.3	1.32	113	1073	1.26	7.9	0.61	394
Thermally Hydrolyzed MAD	2.24	1.65	0.67	–	0.97	31	1.92	1053

Where DS = Dry Solids, TN = Total Nitrogen, MAD = Mesophilic Anaerobically Digested.

Table 2
Results of soil analysis.

Organic Matter %	pH meq 100/g	CEC	Nitrates-N	Ammonium-N	Extractable concentrations mg/kg⁻DS			SO_4^{2-}
					P	K	Mg	
2.6	7.4	8.5	18.1	8.7	34	92.1	52.6	24.3
3.2	8.1	8.9	19.3	9.2	32.8	95	76	

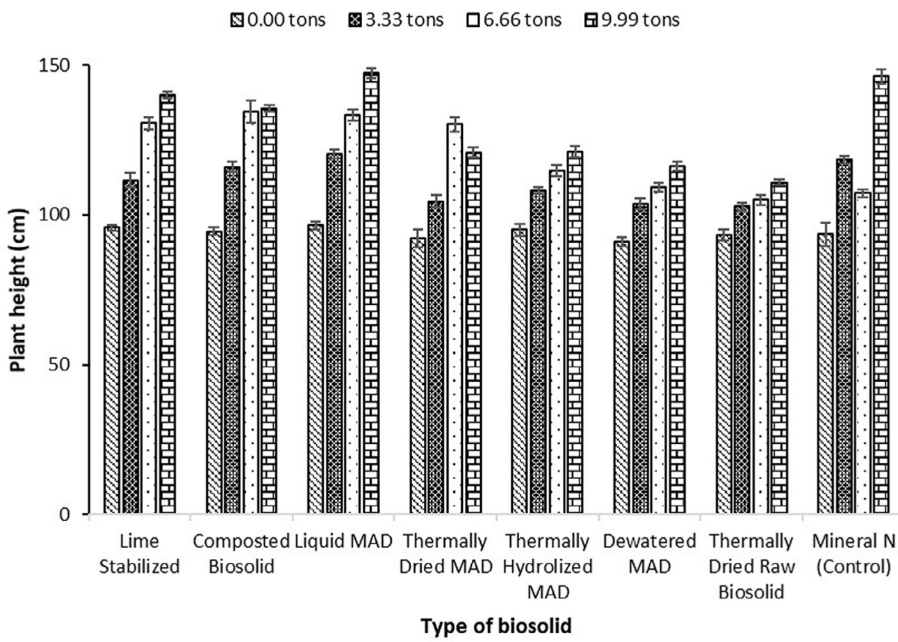

Fig. 1. Plant heights (cm) when different amounts of different biosolids were applied.

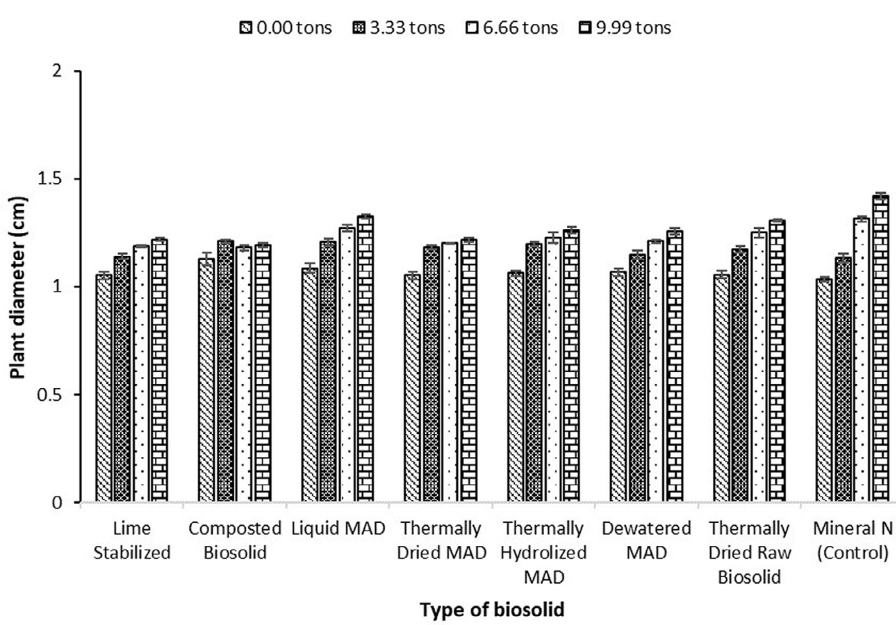

Fig. 2. Stem Diameter of wheat plants with application of all treatments at different quantities.

applications of the mineral N. For lime stabilized biosolids, the mean stem diameter was the lowest of all treatments at 1.14, 1.18 and 1.21 cm with 3.33, 6.66 and 9.99 tons of biosolids applied respectively (Fig. 2).

3.5. Effect of biosolids on dry weight yield

The results showed that there was a significant difference of mean dry weight yield of wheat (tons/ha) in biosolids applied to

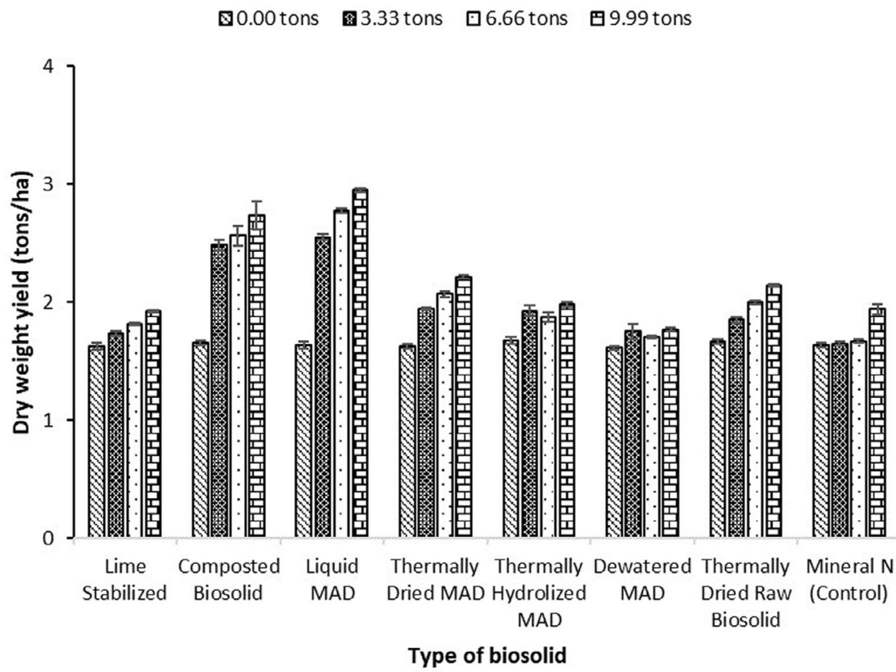

Fig. 3. Dry weight yield (DWY) of wheat plants with application of all treatments at different quantities.

the crop ($F_{7,21} = 162.55$; $P < 0.001$), application rates ($F_{3,\ 72} = 423.06$; $P < 0.001$) and interaction ($F_{3,\ 72} = 36.72$; $P < 0.001$). The highest DWY was recorded in liquid MAD biosolid with values of 2.54, 2.77 and 2.95 kg/ha under 3.33, 6.66 and 9.99 tons of biosolid application. The minimum values of DWY were observed in plants where dewatered MAD was applied (Fig. 3).

4. Discussion

Land application of biosolids acted as a low-priced and useful option for effective management and disposal of biosolids. In the current study, we explored the value of seven different biosolids as soil amendment for wheat crop. The highest nitrogen contents were found in dewatered MAD biosolids while phosphorous contents were maximum in liquid MAD biosolids. The Ammonium-N was the most abundant in dewatered MAD while mineral N was high in liquid MAD. The plant height, stem diameter were more in plants where liquid MAD was applied than the option where mineral N control were applied. The maximum dry weight yield was observed in liquid MAD applied plants as compared to other biosolids.

The highest concentration of ammonium N in dewatered MAD could be the result of mineralization in sewage sludge which convert N to ammonium N (Cabrera et al., 2005). Moreover, the process involved is chemical oxidation of N and loss of N could also be due to thermal drying ultimately reducing the amount of mineral The results indicated that lime stabilized biosolids contained the lowest amount (1.03%) of total N which necessitates additional amount of lime for treatment.

The biodegradation and decomposition of biosolids or sewage sludge depends upon their stabilization. The amount of extractable P is different biosolids varied depending upon the types. The amount of available P will be low if biosolid has low extractability and vice versa. Our findings are in line with the results of Shober and Sims (2003) who stated that availability of P depends upon the stability of biosolids. Moreover, the treatment process of sewage sludge also affects amount and forms of P in biosolids.

In the current study, the application of biosolids to wheat crop resulted in the significant impact on the growth parameters like plant height, stem diameter and dry weight yield. The results clearly showed that the mean plant heights and stem diameter were significantly different between plants sown in soil where different bioslodis were applied. Dessalew et al. (2017) also reported increase in productivity and nutritional quality of wheat and teff crops by the application of brewery spent diatomite sludge. Our results are also in line with the findings of Malik et al. (2009) and Afshan et al. (2015) who reported significant and positive effects of biosolid and fertilizer amendments on plant height, stem width of different crops. Bozkurt and Yarilgaç (2003) observed significant increase in apple fruit yield in their two years study after application of sewage sludge (barnyard manure) into calcareous soil.

5. Conclusion

The results clearly revealed that all of the biosolids have fertilizer value and can be easily replaced with synthetic fertilizer for agricultural use. This will not only results in effective use of such solid wastes as soil amendments but also cause less environment contamination. However, they should be used in agriculture after extensive studies to avoid toxicity of heavy metals that will accumulate in soil.

Acknowledgements

The authors are thankful to Higher Education Commission, Pakistan (Indigenous 500 Scholarship Program) for providing funds for this study.

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