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ORIGINAL RESEARCH

Poultry feather waste management and effects on plant growth

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Abstract

Purpose Poultry industries produce a lot of feathers which are considered as waste and needs to be managed properly. Poultry feathers are rich with keratin protein and therefore they could be a source for good nitrogen fertilizer. Proper treatment of poultry feather waste (PFW) might be an environmental friendly solid waste management tool and a good source of N-rich organic fertilizer.

Methods PFW was treated under a mixture of both aerobic and anaerobic processes. Treated poultry feather waste (TPFW) was analyzed for different nutrient elements. TPFW was applied to the soil at 4, 8, 12 and 16 t/ha along with control. *Ipomoea aquatica* was grown as the test plant to evaluate the growth performance under different rates of TPFW application. Plants were harvested 7 weeks after seed germination.

Results TPFW contained higher amount of organic matter (35.9%) and total nitrogen (4%). Other major nutrient elements were found to be satisfactory. Color of the plants were observed greener in TPFW applied plants than control plants and the green color was pronounced with increasing rate of TPFW application. Plant height (cm/plant), leaf number per plant and weight of plants (g/plant) was also increased significantly due to the application of TPFW at 12 t/ha and above.

Conclusion Proper treatment of PFW might be an environmental friendly, cost effective and sustainable strategy for PFW management that will also play a vital role in nutrient (especially nitrogen) recycling to the soil.

Keywords Poultry · Feather · Waste management · Compost · Nutrient recycling

Introduction

Commercial poultry production has grown rapidly in Bangladesh and it is one of the emerging and important sectors in Bangladesh that has been contributing progressively to the national economy. Poultry sector is playing a very significant role in the reduction of poverty, malnutrition and unemployment problems. At the same time, poultry farms produce a lot of different types of waste products. A mixture of fecal excreta, bedding material, remaining feed, departed chickens, damaged eggs, packing materials and feathers are the major components of this waste. It also includes waste from poultry carrying materials, conveyer belt and cleaning systems (Kelleher et al. 2002).

Poultry feather constitutes up to 10% of the total chicken body weight (Grazziotin et al. 2006) and produce huge amounts in the poultry slaughterhouses as well as in the household during poultry processing. These billions of kilograms of feather have been creating a serious solid waste problem all over the world (Schmidt 1998; Hegedus et al. 1998). Still now, it is very difficult and expensive to dispose of poultry feather and its present uses are not economically valued (Nahm and Nahm 2004). In past and sometimes at present, feathers are roasted or treated at raised temperature and pressure. After drying it is ground to make powder for further use as a feed supplement for livestock. This process is quite expensive and contains protein with low nutritional value (Ekta and Rani 2012). Disposal methods such as burning (cause air pollution) or burying (require a lot of lands and subsequent soil and water pollution) are also occasionally used but they are not environment friendly. Feather meal is produced in developed countries as the management strategy of poultry feather waste by either steam or chemical treatment (Valtcho and Zheljazkov 2005). This poultry feather meal is a readily available and low-cost source of nitrogen (up to 15% total N) and function as a potential biofertilizer (Jeong et al. 2010). Whether it is fresh or dried,

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feathers are used as fertilizer and also used in landfilling (Pettett and Kurtboke 2004). The consequences of all these processes have some limitations regarding the product quality, cost proficiency, pollution and sustainable environmental quality control (Kim and Patterson 2000). Thus, cost effective and environment friendly poultry feather waste management methods are necessary to mitigate their threat on the environment. Poultry feather, being a rich source of keratin proteins and amino acids, can be converted into valuable N-rich organic fertilizer. Bangladesh being a densely populated country, the soils of the Bangladesh have been subjected of extensive use for cultivation for a long time to meet the future food challenge. Regardless use of high yielding varieties of crops with chemical fertilizer, crop production in Bangladesh is still not enough in comparison to other developed ones due to loss of soils physical health. With the intensification of agriculture, these soils have also witnessed depletion of nutrients and productivity. Composting might be one of the most cost effective and environment friendly approaches of reutilizing the poultry feather waste (Ichida et al. 2001). Composting through anaerobic incorporation is a sustainable and economically viable waste management tool, which drops the greenhouse gases (GHGs) emission, reduces soil and water pollution, lowers the dependence on fossil fuels and produces important nutrient rich organic fertilizer. A good amount of both macro and micro-nutrients retained in organic fertilizers (Gaur 1997; Kalaivanan and Hattab 2016) that improves the physicochemical and biological properties of soil (Adhami et al. 2014; Lim et al. 2015). It is a prerequisite to maintain high agriculture productivity to provide and fulfill the future food demands of fast rising population (Perez-Montano et al. 2014). Chemical fertilizers are being used throughout the world to increase the crop productivity. Excess use of chemical fertilizers enter into the water bodies through rain water causes water pollution too. So, to manage poultry feather waste, composting might be a cheap and easy way of feather-utilization.

The objectives of the present research work were: to manage poultry feather waste through a treatment of a mixture of both aerobic and anaerobic decomposition processes; to examine the influence of treated poultry feather waste on plant growth; and to determine the efficiency of poultry feather waste to be used as nitrogen rich organic fertilizer.

Materials and methods

The research had two parts: (i) poultry feather waste (PFW) was treated as a method of feather waste management, and (ii) pot experiment was carried out in order to evaluate the influence of treated poultry feather waste (TPFW) on growth performance of *gima kalmi* (*Ipomoea aquatica*) as a part of integrated waste management through nutrient recycling.

Poultry feather waste collection

Poultry feather waste was collected from nearby slaughterhouses situated in *Gollamary* green market very close to the Khulna University campus, Bangladesh.

Compost preparation

The collected PFW was first washed well to remove blood and small pieces of meat from feather and the water was removed completely. A small pit (106.7 cm × 76.2 cm × 61 cm) was dug to bury the PFW. The bulk amount of PFW was taken onto the polyethene paper and covered with the polyethene which kept the PFW separated from the soil. Then the PFW which was set inside the polyethene was buried into the soil. The pile was filled with the soil carefully so that soil cannot penetrate to feathers. Again a piece of polyethene was laid on the surface of the soil so that the rain water cannot enter into the pile. The pit was opened at every 10 days interval of time to see the status of PFW decomposition and to control the temperature of feather pile buried into the soil. After 3 months, finally, the pit was opened and the decomposed material was brought out from the pit and was sun dried for 7 days to get final TPFW which was brown in color. Then the TPFW was crushed and passed through 0.5 mm sieve and this sieved material was applied to the soil accordingly.

Soil sample collection

An agricultural field behind the Khulna University campus, Bangladesh was selected for soil sampling. Soil samples at 0–15 cm depth from the surface were collected by following the composite soil sampling method (USDA 2004).

Preparation of soil sample

The collected bulk soils were air-dried spreading on a sheet of paper. The air-dried sample was then broken by crushing it gently using a wooden hammer, mixed thoroughly and were passed through 2-mm sieve. The processed soil was used for plant growth. A tiny portion of the soil was broken again and passed through a 0.5-mm sieve for further laboratory analysis.

Test plant

Gima kalmi (Ipomoea aquatica), a popular vegetable in Bangladesh, was grown as the test plant in the experiment. *Gima kalmi* is a semi-aquatic, tropical plant grown as a vegetable for its tender shoots and leaves. *Gima kalmi* is a leafy vegetable which belongs to the family

Convolvulaceae. The vegetable crop is also known as kangkong, swamp cabbage, water convolvulus, water spinach etc. (Tindal 1983). Use of fertilizer increases the yield of plants, produces high valued foliage and stimulates carbohydrate synthesis (Rai 1981). For successful production, *gima kalmi* requires early and rapidly vegetative growth, which could be influenced by the application of fertilizers. In Bangladesh fertilizer is mostly used as the source of NPK and split application of this fertilizer is commonly practised for leafy vegetable production (Hossain 1990).

Experiment setup

Earthen pots (2-L) containing 1-kg soil in each pot were used. The surface area of the pot was 284 cm^2 and depth was 18 cm. There was a small hole in the bottom of the pots so that the extra water could run away and the roots could free from waterlogging condition. Four rates [4 t/ha (T_1), 8 t/ha (T_2), 12 t/ha (T_3) and 16 t/ha (T_4)] of TPFW were applied along with control (T_0) and there were three replications for each treatment. After mixing TPFW into the soil, the soil was watered well and kept for 2 weeks. About 15–20 seeds of *gima kalmi* were sown in each pot. The pots were arranged in a completely randomized way and the positions were changed every alternative day so that all the pots get equal sunlight. The experiment was carried out under net house condition which is free from birds. The plants were thinned 1 week after seed germination by keeping 10 healthy plants in each pot. As the plant protection measure pesticide (viz. ripcord, bought from local market) was sprayed as needed.

After 7 weeks from the emergence of plants, the plants were harvested by cutting the stems 1-cm above the ground. Visual symptoms were monitored carefully and noted throughout the growing period. After harvest the plant height (cm), number of leaves, fresh weight (g) and dry weight (g) were measured and recorded.

Laboratory analysis of soil and TPFW

Some important properties of soil and TPFW were analyzed in the laboratory by following the recommended protocols (Imamul Huq and Alam 2005).

Agronomic parameters

All the plants in each pot were considered for data collection. Data were collected in respect of the following characters.

Plant height

Plant height was measured in centimeter by using a measuring scale from the ground level to the tip of the stem after harvest. The data was presented as the average height in cm per plant (cm/plant).

Number of leaves

Total leaves of the plants from each pot were counted. The data was recorded and presented as the average number of leaves per plant.

Fresh weight of plant

After harvest the fresh weight (stem plus leaves) of the plants were measured and recorded. The data was presented as the average fresh weight in gram per plant (g/plant).

Dry weight of plant

After taking the fresh weight, the plant samples were dried in an electric oven at 70 °C for 72 h. Then the sample was transferred into desiccators and allowed to cool down to the room temperature. The dry weight of the sample was taken with help of an electric balance and calculated in gram per plant (g/plant).

Statistical analysis

Averages value of three replicated data were expressed as result. A computer built-in statistical software program Minitab-16 was used for data analysis by employing ANOVA technique. Differences between means were statistically analyzed using Fisher method ($p = 0.05$). Computer built-in Microsoft Excel-2010 program was used for all graph preparation.

Results and discussion

Soil analysis

Some basic properties of the soil that was used in the experiment as the medium for plant growth are presented in Table 1. The soil contained low available nutrients including very low total N (0.09%). The soil was silty clay loam in texture and pH of soil was 7.8.

Treated poultry feather waste (TPFW) analysis

The composition of treated poultry feather waste is presented in Table 2. After treatment the poultry feather

Table 1 Some basic properties of soil

Soil textural class	pH	EC (dS/m)	OM (%)	Total N (%)	Available nutrients (μg/g)				
					P	K	S	Zn	B
Silty clay loam	7.8	1.29	1.49	0.09	21.36	0.03	59.39	0.68	0.45

Table 2 Composition of treated poultry feather waste (TPFW)

Nutrients	pH	OM	Total N	P	K	S	Zn	Ca	Mg	C/N ratio
		(%)								
Content	6.75	35.9	4.0	0.50	0.40	0.20	0.02	0.80	0.70	5.21

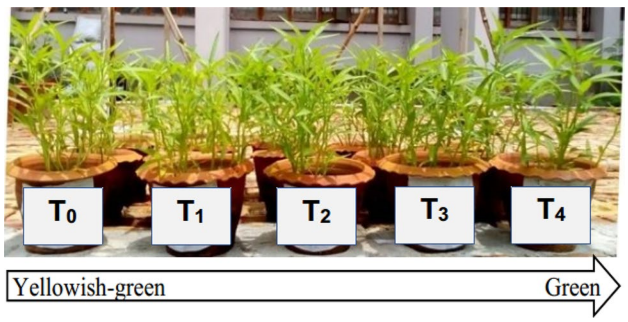

Fig. 1 Growing plants (*gima kalmi*) treated with different rates of TPFW. [T_0 = control, T_1 = 4 t/ha, T_2 = 8 t/ha, T_3 = 12 t/ha and T_4 = 16 t/ha]

waste reduced waste volume significantly converting waste into valuable organic fertilizer. TPFW contained very high (35.9%) (Table 2) organic matter and total nitrogen (4%) which is the focal point of the present research.

Effect of treated poultry feather waste on plant growth

The effect of TPFW at different rate of application on the growth of the plant (*gima kalmi*) is depicted in the following section.

Visual observation

The color of the plants was greener where TPFW was applied as compared to control plant and the green color of leaves was gradually increased with the application of higher rate of TPFW (Fig. 1). On the other hand, leaves of control plants were yellowish-green in colour. This yellowish colour might be due to the deficiency symptoms of nitrogen in soil. High photosynthetic activity, vigorous vegetative growth and dark green color of the plant is determined by the element nitrogen which is an important component of chlorophyll. Silas et al. (2012) reported that plants show chlorosis due to N deficiency which result in yellowish-green leaves, restricted growth, and fall of lower leaves.

Number of leaves per plant

The presence of the highest number of leaves in a plant could be indicative of higher yield in a particular plant. The number of leaves per plant treated with different rates of TPFW is presented in Table 3. The number of leaves in plants increased with the application of TPFW in soil. The maximum number of leaves per plant was counted in T_2 treatment (8 t/ha) and significantly higher than any other treatment (Table 3).

Height of the plant

Plant height is one of the major indicators that is considered for growth performance. The height of the plant *gima kalmi*

Table 3 Effect of TPFW on the number of leaves, plant height, fresh weight and dry weight of *gima kalmi*

Agronomic attributes	Treatment				
	T_0	T_1	T_2	T_3	T_4
No. of leaves per plant	12.0 ± 0.50^{c}	13.0 ± 0.50^{bc}	15.0 ± 1.0^{a}	14.0 ± 1.53^{abc}	15.0 ± 0.20^{ab}
Plant height (cm/plant)	29.3 ± 1.15^{b}	31.4 ± 1.0^{ab}	32.6 ± 1.25^{ab}	34.1 ± 1.0^{a}	32.5 ± 2.19^{ab}
Fresh weight (g/plant)	3.74 ± 0.60^{b}	3.56 ± 0.39^{b}	4.23 ± 0.07^{ab}	4.94 ± 0.46^{a}	4.93 ± 0.39^{a}
Dry weight (g/plant)	0.56 ± 0.08^{ab}	0.51 ± 0.07^{b}	0.59 ± 0.06^{ab}	0.67 ± 0.02^{ab}	0.70 ± 0.06^{a}

Data represents the average ± standard deviations ($n = 3$). Different letters show the significant differences ($p = 0.05$). [T_0 = control, T_1 = 4 t/ha, T_2 = 8 t/ha, T_3 = 12 t/ha and T_4 = 16 t/ha TPFW application] treated with different rates of TPFW is shown in Table 3. The highest height (34.06 cm) was recorded at T_3 treatment (12 t/ha) while the shortest (29.33 cm) was in control. Statistical analysis of the result showed that there was a significant difference of the plant height at T_3 (12 t/ha) (Table 3). So, the agronomic parameter showed that the height of the plant was significantly increased when TPFW was applied at 12 t/ha.

Weight of plants

Both the fresh and dry weight (g/plant) of the plants are also presented in the Table 3. The weight of the plants was increased with increasing rate of TPFW application. The weight was significantly increased when the plants were treated with TPFW at 12 t/ha (T_3) and above. The biomass of the plant was significantly increased having promoted canopy and shoot production when TPFW was applied at 12 and 16 t/ha. This implies that superfluous TPFW application would promote canopy and shoot production. This observation is similar to the findings of Myers (1998). In addition, leafy vegetable crops required more nitrogen which is provided by higher application of TPFW, and these higher nitrogen levels increased the yield and biomass content. Our findings also strongly advocated by Verma et al. (1969).

The effects of compost compared to chemical fertilizers are often misunderstood. The nutrients contained in the chemical fertilizers are used rapidly but completely, whereas the nutrients supplied by the compost are used slowly and kept in the soil over a prolonged period (Kumazawa 1984). Treatment of poultry feather waste reduced the volume of solid waste considerably. Farrell and Jones (2009) claimed composting can reduce the mass of solid wastes by about 40% which support the present results of composting from poultry feather waste. Treatment of poultry feather waste enables the recovery of nutrients and is one of the sustainable strategies for dealing with solid waste. The total nitrogen (N) content in treated poultry feather waste is 4% which is relatively higher than that of others (Table 2). Kim et al. (2001) hypothesized that degraded feather which contains keratin is a rich source of nitrogen. The pH value of the TPFW was 6.75 which may support the view of Hubbe et al. (2010) who assumed that pH of final compost drops to neutral. The organic matter (OM) content in the TPFW is very high (Table 2) which illustrated that application of TPFW perhaps one of the best options to reclaim soil organic matter. The carbon and nitrogen ratio of the treated feather was 5.21. Malone (2004) stated that composting is a biological process by which organic material is broken down and decomposed. Treated poultry feather waste could be applied in growing crops instead of and/or with commercial fertilizer as a supplementary source of nutrients for plant growth. The result in the present research showed that the application of TPFW in soil significantly increased the agronomic parameters of *gima kalmi* at 12 t/ha and above. El-Desuki et al. (2001) also stated that plant height, number of leaves and dry weight of plants was significantly increased by increasing the levels of TPFW up to 12 t/ha which support the present results found in the case of TPFW application in *gima kalmi*. The positive effect of compost on plant height, plant growth, yield, leaves color, the number of leaves and dry mass are also reported (El-Raoof 2001; Abdel-Mawgoud 2006; Olaleye et al. 2008).

To produce compost from poultry feather as soil conditioner and organic fertilizer need a large volume of feather waste, thereby it will certainly reduce the solid waste burden from the poultry industries in the environment. In addition to this, it could help in reducing the wide gap between availability and requirement of organic fertilizer for soils in Bangladesh. So, it can be assumed that treatment of poultry feather waste could unlock a possibility for developing a suitable, environment friendly, cost effective and sustainable strategy for poultry feather waste management that will also play a vital role in nutrient recycling to the soil.

Conclusion

Treatment of poultry feather waste under a mixture of both aerobic and anaerobic decomposition processes has been verified in this study. Feather waste generated from poultry industries can be monitored and efficiently managed by employing this strategy. The process adopted is a viable method of converting the useful nutrient present in feathers to soil nutrient that can be used to enhance the crop yield. Feather waste generated from poultry industries could be considered as resource material for nutrient recycling through composting because every day large quantity of feather waste is being generated, it is a good source of nitrogen which is a growth promoter, and the application of TPFW improve the growth performance of crop which has been shown in the present study. It is expected that proper composting of PFW might be an environment friendly, low-cost and sustainable strategy of PFW management. The role of TPFW in nutrient recycling to the soil will increase crop production and will help to improve the food security in meeting the Millennium Development Goals (MDGs) in the country.

Compliance with ethical standards

Conflict of interest The authors would like to declare that there is no conflict of interest with this research.

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