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Improved Processing of Poultry Litter Reduces Nitrate Leaching and Enhances Its Fertilizer Quality

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Improper storage, handling and land application of poultry litter result in environmental pollution and loss of plant nutrients. Processing it in a suitable manner will assure the availability of plants nutrients, prevent water contamination and destruction of pathogens. This study was meant to employ different field conditions and new techniques *viz.*, shade, cover, open-air, dumping and concrete-bed, for judicious handling of poultry litter waste. These techniques were compared for both natural as well as composting situation under a three factor factorial design. Data were collected on leaching of NO_3-N, decomposition pattern, nutrients contribution to farmland and yield of wheat. Results revealed that nitrate leaching was maximum (16.6 µg g^{-1}) with dump storage followed by open-air storage (14.9 µg g^{-1}). Over time, leached nitrate concentration in soil also increased being maximum after 90 d (15.7 µg g^{-1}) with natural storage. Moreover, soils under poultry litter stock varied significantly for their NO_3 concentration under natural and composting condition. Land application of composted poultry litter gave significantly higher wheat yield as compared to naturally stocked poultry litter. Covered condition was found advanta-geous over open-air and under-shade processing of poultry litter with respect to fertilizer value for wheat production.

Key Words: Organic waste, Environmental pollution, Composting, Plant nutrition, Wheat production.

INTRODUCTION

Owing to its high nutrients content, poultry litter is considered to be the most valuable organic manure for fertilizing purpose. In addition to the benefits it provides to crop production in the form of nutrients, it can build soil organic matter and structural stability[1]. With the development of poultry industry, large quantities of poultry litter are produced. This litter is being used as fertilizer by the farmers and is considered as a better organic fertilizer than the farmyard manure. Recycling of organic waste in agriculture adds much needed organic and mineral matter to the soil[2]. Presently, farmers in developing countries are not handling poultry litter properly. After removal from the poultry farms, it is heaped in open-air, sometimes left for a year. Leaching losses of nitrogen as nitrate (NO_3) may also occur due to heavy rains. There could be losses through ammonia volatilization from decomposing organic materials[3]. The use of properly stocked and processed organic waste not only brings economic benefits to small-scale farmers, but also reduces pollution because of reduced nutrient run-off and NO_3 leaching to groundwater[4]. The application of compost to farmlands increases soil microbial biomass and organic carbon and nitrogen, reduces soil bulk density, decreases the potential for groundwater pollution. Although poultry litter is used by many farmers, yet no significant research has been done for its handling and processing. So, the present study was conducted with the following objectives (1) estimate the nitrate leaching losses from poultry litter processed through different techniques, (2) assess the effect of poultry litter processed through different techniques on soil fertility and wheat production.

EXPERIMENTAL

Phase-I: Process evaluation: Five techniques were envisaged to process the poultry litter at farm level; their description is in the following:

T1: Shade (poultry litter was piled on bare ground surface under the shade).

T2: Covered (poultry litter was stocked on bare ground surface as a pile and covered with plastic sheet).

T3: Open-air (poultry litter was stocked on bare ground surface and kept in open-air *i.e.,* without any cover/shade over the pile).

T4: Dumping (poultry litter was dumped in pits without any covering/shade).

T5: Concrete-bed (poultry litter was stored on concrete-cement plastered ground surface and kept in the open-air *i.e.* without any cover/shade over the pile).

These techniques were employed as such under natural condition, and also through composting process during the summer. The size of stockpile/dump-pit was 2 m (length) × 2 m (width) × 1 m (height/depth), and the quantity of poultry litter in each one was 500 kg. This was a factorial experiment with completely randomized design. For the process of composting, a minimum of 40 % moisture was maintained fortnightly in the stockpile throughout the study period. Completion of degradation process was evaluated on the basis of change in colour, fall of temperature, change in texture, decrease in C:N ratio and absence of malodors in the processed poultry litter as suggested by Dhanyadee[5]. To estimate NO_3-N leaching from the poultry litter stockpiles, three soil samples were drawn from below each pile for three depths *viz.,* 30, 60 and 90 cm at 15 d interval for 90 d. After collecting, samples were frozen for further processing.

Phase-II: Estimation of fertilizer value: A field study was carried out to grow wheat with the poultry litter processed through various techniques/processes. Field was laid out according to split plot design having two factors. The main-plots receiving poultry litter processed as natural and through composting and sub-plots received poultry litter stocked with different techniques as mentioned above. Poultry litter was incorporated in soil as organic fertilizer to wheat @ 20 t ha^{-1} in each treatment before sowing. The individual treatment sub-plot size was 3 m × 2 m. The soil of the experimental site was sandy loam, with pH 7.6, organic matter 5.5 g kg^{-1}, ECe 0.25 dS m^{-1}, available P 5.45 µg g^{-1} and extractable K 102 µg g^{-1}. All the recommended cultural practices were followed during the growth period of the crop. After the harvest of the wheat, grain yield data was obtained from whole treatment area. This weight was converted to kg ha^{-1}. Soil samples were collected from the depth of 0-30 cm from each sub-plot before sowing and 45 d after sowing of wheat. Nitrate-N in soil profiles was determined through salicylic acid method[6]. Available phosphorus was estimated by Olsen and Sommers[7] procedure and extractable potassium was found with Richards methodology[8].

RESULTS AND DISCUSSION

Nitrate-N leaching: The difference among various stockpiling techniques of poultry litter and its processing for NO_3 leaching is presented in Table-1. Data revealed that nitrate-N leaching was significantly higher under the pit-dumping followed by open-air stockpiling technique both under composting and natural conditions. This could be due to the reason that in open-air and pit-dumps the surface of piles was left uncovered and with rains added water in the poultry litter, which caused enhanced leaching. In case of stockpiling on concrete-beds and under the shade, there was not enough water in the poultry litter to leach down the nitrates. It was also observed that nitrate leaching increased over time, as N mineralization was enhanced to release more nitrates. Reddy *et al.*[9] also reported that application of poultry manure to soil increased soil organic nitrogen, soluble P and soluble organic C and NO_3-N loss increased as manure decomposition period was increased from 60 to 120 d. Similarly, Sönmez *et al.*[10] investigated the seasonal changes in nitrate contents of soils from 0-20 and 20-40 cm depths. During the sampling periods, nitrate contents showed an increase at both depths.

On the average basis there was a non-significant difference between natural and composting process, however, the leached NO_3-N concentration in soil at 90 d was statistically lower with compost processing as compared to stockpiling in natural conditions. These results are in agreement with the findings of Paul and Beauchamp[11], Prusch *et al.*[12] and Nyamangara[4]. It was further observed that with the advancement of stocked time, nitrate concentration in soil below the stockpiles/pit-dumps was increased. However, the NO_3-N concentration in soil was highest in the upper 0-30 cm profile and was reduced significantly in the lower depths.

Fertilizer value of processed poultry litter

Soil organic matter: Contribution of differently processed poultry litter applied to land for wheat production on soil organic matter (SOM) content in soil is given in Table-2. The SOM was increased considerably from its original level of 5.5 g kg^{-1}, as also reported by Khan *et al.*[2]. The increase in SOM due the application of poultry litter could be expected as a result of high organic C concentration in poultry litter[13]. The composted poultry litter gave slightly higher organic matter contents compared to naturally processed one. Poultry litter stocked under cover or pit-dump technique also gave higher SOM content in comparison with other techniques. Open-air stockpile performed the lowest in statistical terms.

TABLE-1
NITRATE-N CONCENTRATION (μg g^{-1}) IN SOIL BELOW THE STOCKPILES AND PIT-DUMPS AS AFFECTED BY VARIOUS PROCESSING TECHNIQUES OF POULTRY LITTER

Treatments	Processing time (d)						Average
	15	30	45	60	75	90	
Process (A)			A × D				A
A1 Natural	7.6 h*	8.4 gh	9.7 f	11.9 c	13.4 b	15.7 a	11.1 NS
A2 Composting	9.4 fg	10.2 ef	10.8 de	11.4 cd	13.1 b	13.9 b	11.5
Technique (B)			B × D				B
B1 Shade	6.7 n-q	7.4 l-p	7.8 k-n	8.3 j-l	8.9 ij	9.9 hi	8.2 D
B2 Covered	7.4 l-o	8.2 j-m	8.8 kj	10.0 h	12.2 fg	13.4 e	10.0 C
B3 Open-air	10.5 h	11.9 e	13.4 e	15.5 d	17.6 c	20.2 b	14.8 B
B4 Dumping	11.7 g	13.0 ef	14.7 d	17.3 c	20.0 b	22.7 a	16.6 A
B5 Concrete-bed	6.0 q	6.3 pq	6.6 o-p	7.0 m-p	7.6 l-o	8.0 j-m	6.9 E
Soil depth (C)			C × D				C
C1 (0-30 cm)	10.3 gh	11.5 ef	12.5 e	14.4 d	17.0 b	19.2 a	14.1 A
C2 (30-60 cm)	8.9 ij	9.7 g-i	10.7 fg	12.5 e	13.9 d	15.8 c	11.9 B
C3 (60-90 cm)	6.3 m	6.8 lm	7.6 kl	8.1 jk	8.9 ij	9.4 hi	7.8 C
A × B			A × B × D				A × B
A1 × B1	6.4 a-d	7.1 yz	7.5 w-z	8.0 v-z	8.4 t-x	9.5 p-s	7.8 EF
A1 × B2	7.0 z-f	7.4 x-z	8.3 u-x	9.6 o-s	10.6 no	12.6 kl	9.2 D
A1 × B3	8.9 r-v	10.2 n-q	12.5 kl	16.6 fg	18.5 cd	23.0 b	14.9 B
A1 × B4	9.8 o-r	11.2 mn	13.8 mn	18.3 d	21.9 b	25.8 a	16.8 A
A1 × B5	5.7 g	6.2 f	6.5 b-f	7.0 z a-d	7.5 x-z	7.7 w-a	6.8 F
A2 × B1	7.1 z	7.6 w-z	8.0 v-z	8.6 s-w	9.4 p-t	10.3 v-z	8.5 DE
A2 × B2	7.9 q-u	9.0 r-v	9.2 q-u	10.5 n-p	13.8 ij	14.3 ij	10.8 C
A2 × B3	12.1 lm	13.5 jk	14.3 ij	14.4 ij	16.7 fg	17.2 ef	14.7 B
A2 × B4	13.7 ij	14.7 hi	15.7 gh	16.4 fg	18.1 de	19.5 c	16.4 A
A2 × B5	6.2 d	6.4 c-f	6.8 a-f	7.0 z	7.6 w-a	8.2 u-y	7.0 F
Average (D)	8.5 E	9.3 DE	10.3 D	11.7 C	13.3 B	14.8 A	

*Values within a treatment factor (A, B, C or D) in a row or column or their interactions not sharing common letter (s) differ significantly at $p \leq 0.05$.
NS = Values are statistically non significant among themselves at $p \leq 0.05$.

TABLE-2
COMPARISON OF DIFFERENTLY PROCESSED POULTRY LITTER FOR THEIR EFFECT ON ORGANIC MATTER CONTENT (g kg^{-1}) IN SOIL

Treatments	Natural	Composted	Average
Shade stockpiled	11.1 ef	12.1 cd	11.6 C
Cover stockpiled	12.9 bc	14.3 a	13.6 A
Open-air stockpiled	9.0 g	10.2 f	9.7 D
Dump stockpiled	12.1 cd	13.5 ab	12.8 AB
Concrete-bed stockpiled	11.3 de	12.6 bc	12.0 BC
Average	12.2 B	12.5 A	

*Values within a treatment factor in a row or column or their interactions not sharing common letter (s) differ significantly at $p \leq 0.05$.

Available phosphorus: Amount of plant available P in soil as given in Table-3 ranged from 13.33 to 28.0 μg g^{-1}. It was significantly higher in the soils treated with composted poultry litter as compared to those left under natural conditions. These results are in agreement with those of Gondek[14]. Preusch *et al.*[12] reported that composting did not have consistent effect on P availability. The results of this study show that application of poultry litter whether composted or uncomposted increased P levels from 5.45 μg g^{-1} to more than 13.3 μg g^{-1} *viz.*, 2.5 folds. These results are in agreement with those of Moore Jr *et al.*[1], Huma and Khan[15] and Khan *et al.*[2]. According to these results land application of poultry litter in present soils could be very useful for improving the deficiency of soil P, which is deficient in almost all soils in Pakistan[16]. However, continuous long term or excessive poultry litter application may result[1] in build up of very high P levels in soil up to 225 mg kg^{-1}, which may create nutrient imbalance in the soil.

TABLE-3
COMPARISON OF DIFFERENTLY PROCESSED POULTRY LITTER FOR THEIR EFFECT ON AVAILABLE PHOSPHORUS CONTENT (μg g^{-1}) IN SOIL

Treatments	Natural	Composted	Average
Shade storage	18.33 f	20.67 de	19.50 B
Cover storage	25.67 b	28.00 a	26.83 A
Open-air storage	13.33 g	15.00 g	14.17 C
Dump storage	23.33 c	26.67 ab	25.00 A
Concrete-bed storage	19.00 ef	21.67 cd	20. 33 B
Average	19.3 B	22.4 A	

*Values within a treatment factor in a row or column or their interactions not sharing common letter (s) differ significantly at $p \leq 0.05$.

Extractable potassium: Potassium levels in the soil under different treatments ranged from 114 to 159 μg g^{-1} (Table-4). Land application of poultry litter composted or uncomposted increased[16] the levels from medium (102 μg g^{-1}) to adequate level of > 125 μg g^{-1}. These results are in agreement with those of Khan and Chatta[17]. The results also indicate that extractable K was more in soils treated with composted poultry litter (142 μg g^{-1}) which was significantly higher than the K level found in naturally processed litter (133 μg g^{-1}). Similarly, higher K was found in soils treated with poultry litter stockpiled under cover or pit-dump technique.

Wheat yield: It was observed that application of composted poultry litter gave significantly higher wheat yield as compared to that with naturally kept poultry litter (Table-5). The increase in yield could be related to the higher organic matter, P and K contents in the compost treated soils. Moreover, it may also be due to more uniform soil application and distribution of composted material resulting in better soil physical condition as compared to the soils treated with naturally kept[18]. The results are in agreement with the finding of Jadoon *et al.*[13]. Ece and Uysal[19] also found that green fertilization plants and organic materials used in organic farming have good effects on yield fruit quality characteristics of tomato. Poultry litter

TABLE-4
COMPARISON OF DIFFERENTLY PROCESSED POULTRY LITTER FOR THEIR EFFECT ON EXTRACTABLE POTASSIUM CONTENT (µg g^{-1}) IN SOIL

Treatments	Natural	Composted	Average
Shade stockpiled	131.7 e	137.3 d	134.5 C
Cover stockpiled	149.0b	159.0 a	154.0 A
Open-air stockpiled	114.7 g	121.7 f	118.2 D
Dump stockpiled	142.7 c	150.7 b	146.7 B
Concrete-bed stockpiled	131.7 e	143.7 c	137.7 C
Average	133 B	142 A	

*Values within a treatment factor in a row or column or their interactions not sharing common letter (s) differ significantly at $p \leq 0.05$.

TABLE-5
COMPARISON OF DIFFERENTLY PROCESSED POULTRY LITTER FOR THEIR EFFECT ON GRAIN YIELD (kg ha^{-1}) OF WHEAT

Treatments	Natural	Composted	Average
Shade stockpiled	2335 g	2696 cd	2516 C
Cover stockpiled	2411 fg	2909 a	2660AB
Open-air stockpiled	2531 ef	2585 de	2558BC
Dump stockpiled	2718 bcd	2783 abc	2751 A
Concrete-bed stockpiled	2679cd	2834 ab	2757 A
Average	2534.8 B	2761.4 A	

*Values within a treatment factor in a row or column or their interactions not sharing common letter (s) differ significantly at $p \leq 0.05$.

composted under cover gave significantly higher grain yield (2909 kg ha^{-1}) as compared to open-air (2585 kg ha^{-1}) or shade stockpiling technique (2696 kg ha^{-1}). Composting with concrete-bed and pit-dump technique also performed satisfactorily. Poultry litter that was kept under natural condition without composting process gave different grain yields under different techniques. In this case pit-dumping and concrete-bed stockpiling were found better as compared to other storage methods.

Conclusion

Leaching losses of nitrate-N were higher with pit-dump stockpiled poultry litter in both natural as well as composting conditions and it increased over time. Land application of composted poultry litter gave higher wheat yield as compared to uncomposted one. Among stockpiling techniques, covered poultry litter gave higher fertilizer value and wheat production as compared to other techniques.

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