Scientific and Social Research, 2022, Volume 4, Issue 1
http://journals.innosciencepress.com/index.php/ssr
ISSN Online: 2661-4332

Evaluation of Crop Recovery of Nitrogen from Lignite-amended Feedlot Cattle Manure

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Abstract: Feedlot cattle manures have for long been considered to be a major source of greenhouse gasses (GHG) in Australia. Lignite coals have been used recently as effective organic nitrification-inhibitors retaining nitrogen in cattle feedlot manure by reducing the emission of nitrogenous gases. This study is aimed at investigating whether lignite-retained nitrogen in cattle feedlot manure can be used as an available nitrogen (N) source for absorption by plants hence contribute to improved plant growth and produce higher yields.

Keywords: Lignite; Feedlot cattle manure; Forage sorghum; Nitrogen recovery

Online publication: January 21, 2022

1. Introduction

Due to the increasing concern over the economic and environment-related issues of nitrogenous fertilizer application, the re-use of organic wastes, particularly animal manure has been encouraged in order to enhance nutrient recycling and reduction of GHG emissions [1]. Apart from being a source of nitrogen, UMass Extension [2] contends that the organic carbon found in the manure can also help improve soil properties by improving infiltration and water holding capacity, reducing water and wind erosion which help increase soil tilth, seedling growth, and root penetration. Lignite (brown coal), which was formed via coalification process from plant remains, is regarded as a relatively stable organic amendment when compared to manures or composts [3]. As Kwiatkowska et al. [4] reported, when added to soil, lignite can enhance the capacity of soil to retain nutrients by influencing soil water and air conductivity as lignite has a complex intra-particle pore structure that increases porosity and the numbers of chemical exchange sites. Also, a lack of scientific studies conducted under field conditions is obstacle to the development of practical recommendations for using lignite, involving the timing, location, rate of application, and whether or not the detrimental effects will evolve [3].

Crop N deficit vs. release of N into nonagricultural ecosystems, which may occur if N availability is not coordinated with crop absorption, must be minimized in order to acquire a successful knowledge of the properties of manure in enhancing its usage [5]. When manure is treated with additives that minimize nitrogen losses, such as lignite, the nitrogen is kept in the manure (so manure holds more N compared to untreated manure). As a result, research is needed to see if N in lignite-amended cattle manure is accessible to crops when applied to the field.

2. Methodologies

2.1. Experimental site

The experiment was conducted at Dookie College farm (36.37° S, 145.70° E) near Dookie, Northern Victoria. Selected paddock was previously under annual rye grass grazed by sheep. Main field activity which is presented below (**Table 1**)

Table 1. Date of each main field activity

Activity	Date
Initial soil sampling	6-December-2013
Land preparation	10- December-2013
Application of treatments	29- December-2013
Sowing	30- December-2013
First destructive sampling	29-January-2014
First biomass harvest	10-February-2014
Second biomass harvest	15-April-2014
Final soil sampling	21-April-2014

2.2. Experimental layout and crop details

The experimental crop was fast growing summer crop-forage sorghum which was a short maturity (Sudan grass hybrid). The experiment contains 4 blocks as replications, and each block contains 11 plots (3×17.5m) representing 11 treatments, totally 44 plots are presented in a randomized complete block design. Also, small buffer plots (2×17.5m) were presented between each treatment plot. The 11 treatments as well as application rates were described as below:

T1=Lignite-amended fresh high protein cattle manure (98t/ha)
T2=Fresh high protein cattle manure (98t/ha)
T3=Aged high protein cattle manure (126t/ha)
T4=Aged low protein cattle manure (126t/ha)
T5=Standard commercial urea (228 kg/ha)
T6=Half of amount of **T5** (114kg/ha)
T7=Lignite (34t/ha) + urea(114kg/ha)
T8=Lignite (48t/ha)+ urea (228 kg/ha)
T9=Lignite (98t/ha) + urea(228 kg/ha)
T10=Lignite only (98t/ha)
T11=Control (without any fertiliser)

2.3. In crop sampling

Sampling depth was 0 - 10 cm. In each plot, samples were randomly taken from 6 points across each plot, and then bulked them into one labeled bag. Later, the samples were stored in refrigerator waiting for the further analysis. Soil sample testing was conducted by the Environmental Analysis Laboratory in the Southern Cross University, NSW at Mid-December 2013.

2.4. Manure sample analysis

The moisture and nitrogen content of feedlot cattle manure samples used in the experiment were examined which is presented below (**Table 2**).

Table 2. Moisture and nitrogen content of manure samples used for the experiment.

Cattle manure	Moisture (%)	N (%)
Lignite treated high protein manure	48	3.0
Fresh high protein manure	33	2.0
Aged high protein manure	19	1.5
Aged low protein manure	18	1.0

2.5. Data analysis

Analysis of variance (ANOVA) was applied to the data using Excel 2013 and Minitab 16 statistical software to determine significance in plant growth, tiller, dry matter yield, post-harvest soil analysis, and nitrogen recovery between treatment variables. The mean separation technique least significant differences (LSD) were used to test for differences among the treatment means. When means were significantly different, letters were assigned to identify groups of statistically equivalent means. Differences were assigned based on a significance of $P \leq 0.05$.

3. Results

Table 3. Dry (DW) weight of forage sorghum biomass yield at 45 DAS and 100DAS, as well as the head yield at 100 DAS

	45 DAS (1st cut)	100 DAS (2nd cut)	Head yield (100DAS)
Treatment	DW(t/ha)	DW(t/ha)	DW(t/ha)
T1	7.6a	15.6a	9.4a
T2	6.8ab	12.4b	7.6ab
T3	6.1bcd	10.4c	7.2ab
T4	6.4abc	9.9c	7.2ab
T5	4.9de	6.6d	3.1c
T6	4.7e	6.3d	3.0c
T7	5.0de	6.8d	4.2bc
T8	5.2cde	9.5c	5.2bc
T9	5.8bcde	10.1c	5.5bc
T10	3.3f	3.9e	2.4c
T11	2.4f	3.6e	2.2c

LSD (0.05): the letters (a-f) means value followed by same letter(s) in the same column are not significantly different at $P \leq 0.05$ level of probability. DAS: Days after sowing. DAS means days after sowing.

Table 4. Crop height (Ht) of forage sorghum at 7DAS, 15 DAS, 22DAS, 29DAS, 60DAS, and 90DAS

	7DAS	15DAS	22DAS	29DAS	60DAS	90 DAS
Treatment	Ht (cm)	Ht (cm)	Ht(cm)	Ht (cm)	Ht (cm)	Ht (cm)
T1	5.7ab	11.5a	36.0a	49.9a	161.2a	216.4a
T2	5.4abc	10.4b	34.5ab	45.8ab	146.5b	210.9b
T3	5.3abc	10.0bcd	33.1abc	46.1ab	145.4bc	210.5bc
T4	5.0c	9.5cd	31.6abc	43.8ab	145.7bc	204.7cd
T5	5.1bc	9.7cd	29.1c	45.8ab	133.0cd	201.8d

T6	4.8c	9.5cd	31.2bc	42.5b	125.5d	185.5e
T7	5.3abc	9.4d	29.2c	41.5b	135.1bcd	201.1d
T8	5.3abc	10.1bc	30.3bc	42.9ab	135.0bcd	202.0d
T9	5.8a	10.4b	33.5abc	47.5ab	136.7bcd	203.7cd
T10	4.9c	9.8bcd	30.3bc	44.1ab	100.3e	176.3f
T11	4.9c	8.6e	24.0d	34.3c	98.7e	162.6g

LSD(0.05): the letters(a-g) means value followed by same letter(s) in the same column are not significantly different at P≤0.05 level of probability. DAS: Days after sowing. DAS means days after sowing. Ht means plant height.

Table 5. Tiller appearance rate of forage sorghum among the treatments at 29 DAS

Treatment	2-tiller %	3-tiller %	4-tiller %	Total-tiller appearance %
T1	16.3c	48.8a	19.4a	84.4a
T2	25.6abc	44.5ab	11.3b	81.4ab
T3	21.3bc	44.4ab	13.1b	78.8abc
T4	28.1ab	40.0ab	12.8b	80.8ab
T5	16.3c	42.5ab	15.0ab	73.8c
T6	23.1bc	38.1ab	13.1b	74.4c
T7	21.3bc	40.0ab	14.4ab	75.6bc
T8	23.1bc	43.8ab	14.4ab	81.3ab
T9	23.1bc	43.8ab	15.0ab	81.8ab
T10	23.8abc	36.9b	15.6ab	76.3bc
T11	34.8a	20.0c	10.0b	64.4d

LSD(0.05): the letters(a-d) means value followed by same letter(s) in the same column are not significantly different at P≤0.05 level of probability. DAS means days after sowing.

Table 6. Total N of forage sorghum plant (leaf, stem, head) at 45 and 100 DAS

Treatment	Total N(%)		
	Leaf	Stem	Head
		45 DAS	
T1	2.8a	2.36a	NA
T2	2.79a	1.84ab	NA
T3	2.45abc	1.34bc	NA
T4	2.37abc	1.47a	NA
T5	2.76a	2.07a	NA
T6	2.35abc	1.57b	NA
T7	2.71ab	1.52b	NA
T8	2.64abc	1.64ab	NA
T9	2.71ab	1.84ab	NA
T10	1.64c	0.98c	NA
T11	1.69bc	1.02c	NA
		100DAS	
T1	2.20a	0.97a	2.60ab
T2	2.16a	0.64a	2.77a
T3	2.04ab	0.79a	2.79a

T4	1.71abc	0.63a	2.78a
T5	1.41c	0.6a	2.42bcd
T6	1.29c	0.47a	2.15ef
T7	1.33c	0.61a	2.51bc
T8	1.47bc	0.85a	2.32cde
T9	1.88abc	0.68a	2.26def
T10	1.49bc	0.59a	2.05f
T11	1.36c	0.55a	1.85g

LSD(0.05): the letters(a-g) means value followed by same letter(s) in the same column are not significantly different at P≤0.05 level of probability. NA means Not Applicable.

Table 7. Removal of nitrogen (kg/ha) by forage sorghum and the percentage of applied nitrogen recovered from nitrogen sources at harvest.

Treatment	Total N uptake (kg/ha)	Crop recovery of N from initial N input %
T1	320.8a	117.9
T2	257.7ab	94.7
T3	224.7ab	82.6
T4	183.4ab	67.4
T5	135.6b	49.8
T6	113.4b	51.6
T7	117.8b	53.7
T8	151.7b	55.8
T9	157.1b	57.7
T10	63.9c	38.2
T11	58.0c	34.7

LSD(0.05): the letters(a-c) means value followed by same letter(s) in the same column are not significantly different at P≤0.05 level of probability.

4. Discussion

4.1. Effect of lignite on dry matter yield

In our study, lignite with nitrogen source treatments showed advantage on plant biomass (**Table 3**). This indicates that the lignite has a significant effect on biomass accumulation, where more nitrogen was retained being an available form for plant uptake in the lignite amended soil, especially when added in manure. However, the dry matter yield was not significantly increased among the lignite with urea treatments, indicating that the high rates of lignite might not be needed. Total dry matter production increased due to nitrogen application at active tillering stage and panicle initiation stage [6].

4.2. Effect of lignite on plant morphology

In our study, the total-tiller appearance rate was higher in lignite with nitrogen treatments (T1, T7, T8, and T9), which were more than 80%, and they also gave quick development on the 4th tiller, particularly, the lignite treated manure treatment (T1), which 19.4% of the plants already had the 4th tiller, higher than the other treatments (**Table 5**). The result indicates that the good nitrogen response of plants from the lignite amended manure plot, where more nitrogen was available and in a sufficient level for plant uptake to sustain growth. Similarly, the plant height in our study also showed better performance in lignite with nitrogen source treatment (**Table 4**). This indicates that lignite amended nitrogen source had a significant effect on plant height, which maintained more available nitrogen for plant uptake. The better plant growth could be also ascribed to the cattle manure as organic amendment improving soil tilth and help build soil organic matter levels and nourish a diverse soil microflora, which in turn helps the soil retain nutrients and improve soil aggregation and structure.

4.3. Effect of lignite on nitrogen recovery

We found that lignite showed obvious advantage on nitrogen removal by the forage sorghum in our present study (**Table 6** and **Table7**). The nitrogen removal in lignite treated manure (T1) was 63.1% higher than that in fresh high protein manure (T2), indicating that extra nitrogen maintained in T1 as compared to T2 was available for plant uptake proving the availability and effectiveness of the nitrogen retained by lignite in cattle manure. Lignite treated manure (T1) also showed 136% higher N removal than that in standard urea treatment (T5), indicating that the manure as nitrogen fertilizer can replace urea for the N requirement of forage sorghum. This is likely due to the gradually mineralization process from cattle manure from which the extra nitrogen available came. The higher N recovery rate in manure treatments, particularly, the 117.9% in lignite treated manure (T1) indicates that the uptake of extra nitrogen by crop out of the initial nitrogen input was from mineralization process during plant growing period, and the mineralized nitrogen was much better retained as available nitrogen in the soil when lignite was added in manure. Although the nitrogen retention capacity of lignite with urea treatments were not as effective as it in manure, the relatively higher nitrogen removal and N recovery percentage by crops as compared to that in urea only treatments (T5 and T6) indicates that the application of lignite retained more nitrogen in the soil by reducing nitrogen loss, which has been removed by the crops increasing the nitrogen use efficiency by forage sorghum.

5. Conclusion

The application of lignite in cattle feedlot manure showed a significant effect on nitrogen removal by forage sorghum than the other treatments due to the extra nitrogen retained by lignite was available for crop uptake. Those increased nitrogen uptake by forage sorghum reflected on increased dry matter and head yield, as well as enhanced growth performance (better tillers appearance rate, plant height). Besides, the highest N recovery by forage sorghum from lignite-amended manure plots indicates that both the nitrogen previously existed in manure and that further became available from mineralization process during growing season was better retained in soil as plant available nitrogen source. Long-term field trials are suggested in the future to investigate the N recovery from lignite-amended cattle manure as the application of lignite in our present study has shown a large potential of maintaining nitrogen released from cattle manure during four-month period. Therefore, the long-term effect of lignite on the nitrogen recovery by crops would be understood.

Disclosure statement

The author declares no conflict of interest.

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