Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

ISSN: 0972-6268	Vol. 12	No. 1	pp. 163-166	2013

Original Research Paper

Effect of Distillery Spent Wash on Carbon and Nitrogen Mineralization in Red Soil

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Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 31-7-2012
Accepted: 17-10-2012

Key Words:
Distillery spent wash
Mineralization
Nutrients
Red soil

ABSTRACT

Distillery spent wash contains nutrients and organic matter used in agriculture as a source of plant nutrients and irrigation water. Carbon and nitrogen play an important role in increasing the agricultural production. A laboratory incubation experiment was carried out to study the different concentrations of distillery spent wash on soil carbon and nitrogen dynamics. The treatments consisted of T_1-Soil alone, T_2-Spent wash @ 20 kilo L ha^{-1}, T_3- Spent wash @ 40 kilo L ha^{-1}, T_4- Spent wash @ 60 kilo L ha^{-1}, T_5- Spent wash @ 80 kilo L ha^{-1} and T_6- Spent wash @ 100 kilo L ha^{-1}. Among the different levels, the amounts of NH_4-N, NO_3-N and carbon were greater in soil that received 100 kilo L of spent wash compared to soil alone. Results shown that application of spent wash not only adds mineral N and carbon to soil, but also promotes the mineralization of soil organic C and N, thus resulting in large amounts of carbon, NH_4-N and NO_3-N in soil.

INTRODUCTION

Distilleries, one of the most important agro-based industries in India, produce alcohol from molasses. They generate large volume of foul-smelling coloured wastewater known as spent wash. For producing one litre of alcohol, 12-15 L of spent wash is produced. In India, 40 billion L of spent wash is generated per annum from 319 distilleries (Kanimozhi & Vasudevan 2010). The spent wash is referred as biomethanated distillery spent wash (BDS) after recovery of the biogas. Being originated from a plant source, it contains large amounts of organic carbon, K, Ca, Mg and S and moderate levels of N and P and small quantities of micro nutrients and plant growth promoters namely gibberellic acid and indole acetic acid (Murugaragavan 2002). Organic carbon and nitrogen play major roles in maintaining the soil physical condition, sustaining soil microbial activity and enabling high crop yields to be achieved and sustained (Johnston & Poulton 2005, Lal 2007). The spent wash, being loaded with organic and inorganic compounds could bring remarkable changes on the physical, chemical and biological properties of soils and thus influences the fertility of soil significantly (Mahimairja & Bolan 2004). Information is scarce on carbon and nitrogen dynamics in soil under spent wash application and its environmental significance. Hence, the present study was carried out to study the effect of spent wash on carbon and nitrogen dynamics in soil.

MATERIALS AND METHODS

Collection and characterization of spent wash: The biomethanated distillery spent wash was collected from the distillery unit of M/s Bannari Amman Sugars Ltd., Periyapuliyur, Erode district, Tamil Nadu and characterized for its physico-chemical properties by standard methods as presented in Table 1 (APHA 1998).

Experimental details: The soil surface samples (0-15 cm) were collected from the Research and Development Farm of M/s Bannari Amman Sugars Ltd. The soil samples were dried, powdered using a wooden mallet and sieved through a 2 mm sieve and the important soil characteristics are given in Table 2. Effect of spent wash on carbon and nitrogen dynamics was assessed through laboratory incubation experiment at Tamil Nadu Agricultural University, Coimbatore. The experiment consisted of six treatments with four replications with factorial completely randomized design. The treatments consisted of T_1-Soil alone, T_2-BDS @ 20 kilo L ha^{-1}, T_3- BDS @ 40 kilo L ha^{-1}, T_4-BDS @ 60 kilo L ha^{-1}, T_5-BDS @ 80 kilo L ha^{-1} and T_6-BDS @ 100 kilo L ha^{-1}. The data on various characters studied during the investigation were statistically analysed by the method given by Panse & Sukhatme (1985). The critical difference was worked out at 5 per cent (0.05) probability level.

Mineralization: Hundred grams of air dried soil (< 2 mm) was weighed in 250 mL conical flask. The calculated quantity of BDS was added and thoroughly mixed with soil. Distilled water was added to achieve a moisture content equivalent to 60 per cent of field capacity and a scintillation vial containing 5 mL of 1.5 N NaOH was tied to trap the evolved CO_2 and incubated at 25±2°C for 90 days. At the end of 0, 15, 30, 45, 60, 75 and 90 days, the mineralization rate of organic carbon was determined in terms of CO_2 evolution per 100 g of soil by back titration with hydrochloric acid (Pramer & Schmidt 1966). The organic carbon content of the soil was determined after CO_2 evolution using the procedure given by Walkley & Black (1934). A known weight of (250g) air dried soil was weighed in plastic containers. The calculated quantity of BDS was added and thoroughly mixed with soil. Distilled water was added to achieve a moisture content equivalent to 60 per cent of field capacity and it was maintained throughout the incubation period. At the end of 0, 15, 30, 45, 60, 75 and 90 days, samples were collected and the mineral nitrogen (ammonical-N and nitrate-N) was analysed by the method described by Bremner & Keeney (1966).

RESULTS AND DISCUSSION

Influence of distillery spent wash on carbon mineralization: The application of different doses of BDS significantly influenced the carbon dioxide evolution. The mean CO_2 evolution of the soil ranged from 94 to 242 mg/kg. The CO_2 evolution significantly increased from 0^{th} day to 30^{th} day and thereafter it decreased (Fig. 1). A significant maximum CO_2 evolution was recorded by BDS @ 100 kilo L ha^{-1} (242 mg/kg) and control (T_1) recorded the lowest CO_2 evolution (94 mg/kg). The interaction effect between various treatments and the incubation periods were non significant. The distillery effluent which is a good source of plant nutrients enhanced the mineralization process. The higher rate of mineralization during early stages of incubation and decreasing rates at the later stages were also reported by Patil (1999). Organic carbon present in the spent wash in soluble form might have been released as CO_2 due to the microbial activity (Bustamante et al. 2006, Sarode et al. 2009). Further, the microbial activity might have been accelerated by the influence of labile organic N thereby a high mineralization at early stages of incubation (Griffin & Laine 1983). As more labile organic N disappeared and more recalcitrant organic N might be predominated in the organic nitrogen pool that could have resulted in lower organic carbon content (Zaman et al. 1999).

Influence of distillery spent wash on nitrogen mineralization: Application of different levels of spent wash had significant influence on NH_4-N and NO_3-N content in soil. After application of spent wash, the NH_4-N content was increased from 4.51 mg/kg to 6.90 mg/kg and the content increased up to 60^{th} day and thereafter it decreased (Fig. 2). Among the different levels, BDS @ 100 kilo L ha^{-1} recorded the highest NH_4-N content (7.67 mg/kg) and the lowest by soil alone (5.30 mg/kg). The interaction effect between various treatments and the incubation periods were non significant. During 90 days of incubation, the concentration of NO_3-N progressively increased at all the treatments. Increase in the rate of application had significantly increased the

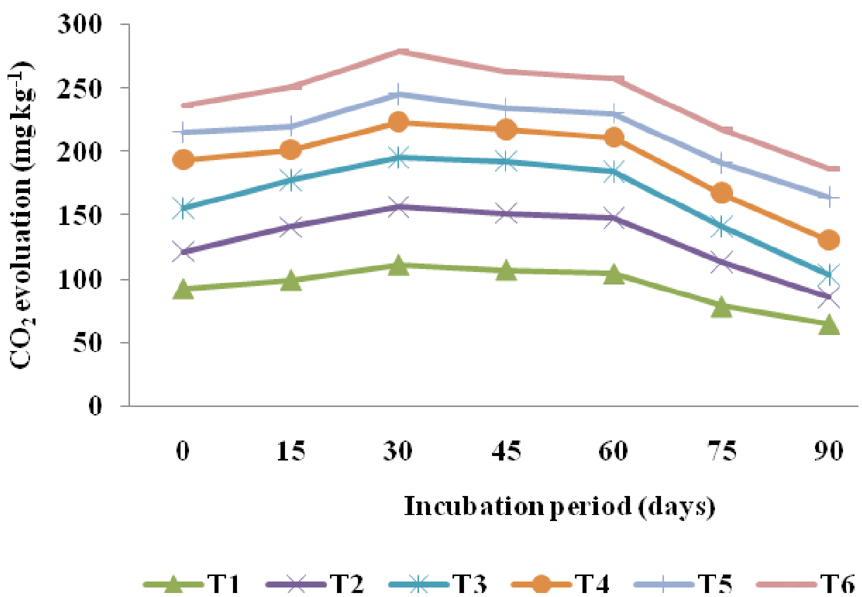

Fig. 1: Effect of BDS on carbon dioxide evolution in laboratory experimental soil.

Table 1: Characteristics of biomethanated distillery spent wash (BDS).

Parameters	Values*
pH	7.42
EC (dS m^{-1})	32.5
Bichemical Oxygen Demand	6,545
Chemical Oxygen Demand	34,476
Organic Carbon	13,110
Total Nitrogen	2,116
Total Phosphorus	52.8
Total Potassium	8,376
Total Sodium	585
Total Calcium	2,072
Total Magnesium	1,284
Total Sulphur	5,232
Total Chloride	8,120

Values are in mg/L unless otherwise stated.

Table 2: Characteristics of soil used in the incubation experiment.

Parameters	Values
pH	7.22
EC (dS m^{-1})	0.26
Organic carbon (g kg^{-1})	3.52
Available N (mg kg^{-1})	60.4
Ammonical nitrogen (mg kg^{-1})	4.42
Nitrate nitrogen (mg kg^{-1})	5.26
Available P (mg kg^{-1})	9.52
Available K (mg kg^{-1})	123
Chloride (mg kg^{-1})	151
Sulphate (mg kg^{-1})	102
Exchangeable Ca (cmol (p^+) kg^{-1})	5.64
Exchangeable Mg (cmol (p^+) kg^{-1})	2.65
Exchangeable Na (cmol (p^+) kg^{-1})	0.67
Exchangeable K (cmol (p^+) kg^{-1})	0.29

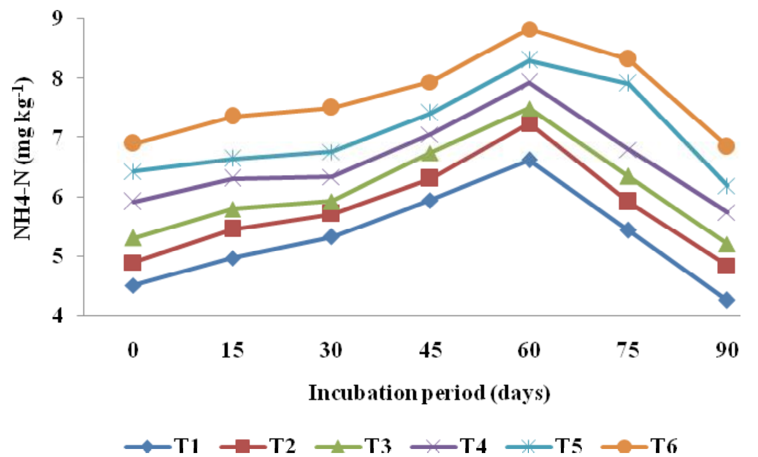

Fig. 2: Effect of BDS on NH_4-N evolution under laboratory experimental soil.

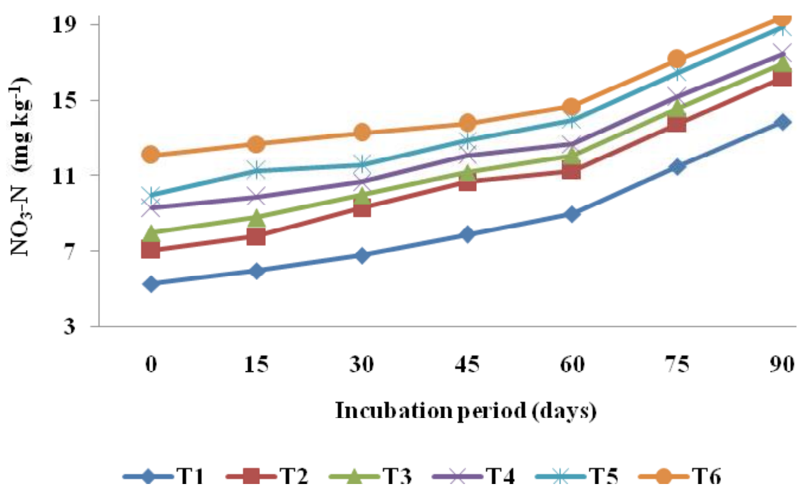

Fig. 3: Effect of BDS on NO_3-N evolution under laboratory experimental soil.

NO_3-N content of soil. Among the treatments, BDS @ 100 kilo L ha^{-1} recorded the highest NO_3-N content (12.3 mg/kg) and the lowest by soil alone (6.1 mg/kg) (Fig. 3). The effect of treatments and incubation period had significant impact on NO_3-N in soil, but the interaction effect was non significant.

The N dynamics in soil was significantly influenced by the application of spent wash. Increase in the levels of spent wash markedly increased the rate of mineralization of N during the incubation and this might be due to the inorganic N present in the distillery spent wash (Myers et al. 1982). After 60^{th} day of incubation a decline in the NH_4-N fraction was observed, probably due to the N transformation process through which the NH_4-N is converted into NO_3-N and due to immobilization and microbial uptake. This is in line with the findings of Chantigny et al. (2001). The reduction in NH_4-N could also be due to ammonia volatilization as well as resulting NO_3-N lost during incubation through biological denitrification, a microbial process through which NO_3 is reduced to nitrous oxide (N_2O) and molecular N (N_2) and lost from soil (Van Kessel et al. 2000). Nitrification of NH_4-N added through spent wash, mineralization and nitrification of soil organic N might have increased the NO_3-N formation in soil. An increase in the rate of spent wash markedly increased the rate of both mineralization and nitrification in soil (Marschner et al. 2003). However, greater amount of NO_3 than NH_4-N was evident particularly at the later stage of incubation. The spent wash contained large amount of organic carbon thereby it increased the soil organic carbon content which in turn stimulated the soil microbial activity by providing a carbon substrate (Cookson et al. 2006)

CONCLUSION

The results of the experiments have shown that the transformation of carbon and nitrogen in soil was greatly influenced by the spent wash application. The levels of spent wash application significantly influence the carbon and nitrogen dynamics. Highest doses of BDS significantly increased the content. The spent wash not only adds nutrients to soil, but also promotes the mineralization and/or solubilization of nutrients in soil.

ACKNOWLEDGEMENT

The authors are grateful to authorities of TNAU, Coimbatore and M/s Bannari Amman Sugars Distillery Division Ltd., Erode for their support and financial assistance provided during the course of investigation.

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