

## Greenhouse gas Emissions in Saline and Waterlogged

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### ABSTRACT

An experiment was conducted to study the impact of water logging and addition of organic amendments on green house gas (GHG) emissions in a saline soil. The treatments comprised of water levels maintained at three levels viz., complete saturation, 10 cm and 15 cm below the soil surface. Organic amendment at the rate of 7.5 t ha<sup>-1</sup> was added. Gas samples were collected at periodic intervals and analysed. The results revealed that CO<sub>2</sub>, N<sub>2</sub>O and C<sub>2</sub>H<sub>2</sub> emissions were lower under a water logged condition and were found to be higher at water levels 10 cm / 15 cm below the soil surface. There was an increase in emissions from 100 to 400 mg kg<sup>-1</sup> at 7 days after incubation (DAI). Methane emission was found to be higher in completely saturated soil. Soils at 10 cm water level and amended with the organic material registered a higher value of soil microbial biomass – C of 1320 mg kg<sup>-1</sup>. Emissions of GHG were enhanced with the addition of organic material. This suggests that lack of C substrate is the dominant limitation for GHG emissions on saline soil. Lower q CO<sub>2</sub> values in water logged soils indicate low microbial activity.

**Key words: Green House Gas, Organic amendment, Saline soil, Microbial biomass, Water logging**

### INTRODUCTION

Soil organic matter levels and forms of soil carbon determine the availability of C substrate for microbial mediated reactions of soils. Salinity can affect physiological processes by ion toxicity and ion imbalance (Klados and Tzortzakis 2014; Kahlaoui *et al.* 2011; Munns and Tester 2008). As a result, saline soils are characterised by low organic matter content and reduced organic matter turnover due to poor plant growth and low microbial biomass and activity (Muhammad *et al.* 2006; Tripathi *et al.* 2006). Salinity has been shown to decrease soil organic C (SOC) mineralisation. C mineralisation is higher at low EC<sub>e</sub> compared to high EC<sub>e</sub> and confirms the strong negative effect of salinity on microbial activity (Setia *et al.* 2011). In addition, salinity changes the microbial community composition because microbial genotypes differ in their ability to adapt to salt stress (Nelson and Mele 2007; Pankhurst *et al.* 2001). Water logged soils are regarded as potentially large sinks or sources of C (Goreau and De Mello 2007). An anaerobic environment under water logging facilitates a high C storage value in the soil

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profile. There is considerable interest in revegetating saline soils to increase biological productivity and reduce water logging (Bramley *et al.* 2003; Gardner 2004). The hypothesis of the research was that greenhouse gas emission would be limited on saline soils by low availability of decomposable C as a substrate for microorganisms. The objectives of this experiment were to: (i) quantify the rate of emission of GHG at various water levels; (ii) to evaluate GHG flux as influenced by the organic amendment; and (iii) to study the effect of water levels and organic material addition on soil microbial biomass, C and N dynamics ( $\text{NO}_3$  - N and  $\text{NH}_4$  - N).

## MATERIALS AND METHODS

### *Column Study*

Soil used in the laboratory experiment was collected from 0-15 cm depth of a salinised Grey Sodosol (Aquertic Natrustalfs) from Wallethin creek (Latitude: 33.315, Longitude: 117.738 33°) Western Australia about 400 km East of Perth. The initial soil had a pH (saturation paste) of 7.51 and EC of 587 m S  $\text{cm}^{-1}$  and a chloride concentration of 0.45 % (dry wt. basis). Further properties of the soil are shown in Table 1. In sealed PVC columns (10 cm diameter) of 0.44 m height, soils were packed at a bulk density of 1.33  $\text{Mg m}^{-3}$  leaving 5 cm headspace. In the organic amendment treatment, the chopped Oldman saltbush leaf was mixed with 0-15 cm surface soil at a rate of 7.5  $\text{t ha}^{-1}$ . The Oldman saltbush leaf had 32.8 % total C, 2.58 % N, C: N ratio of 12.7 and 11.2 % chloride content. Water level was maintained at three levels viz., complete saturation, 10 cm and 15 cm below the soil surface by allowing water by capillary movement from the bottom side of the column. At the bottom of the column, tubes were fitted for the flow of deionized water from cans placed at a raised level. Water was allowed inside the sealed

TABLE 1  
Initial characteristics of experimental soil

Property	Value
pH (Saturation paste)	7.51
Electrical conductivity (Saturation paste)	587 m S $\text{cm}^{-1}$
Chloride	0.45%
Organic carbon	0.20%
Microbial biomass carbon	360 $\mu\text{g g}^{-1}$
$\text{NH}_4$ -N	5.50 $\mu\text{g g}^{-1}$
$\text{NO}_3$ -N	1.65 $\mu\text{g g}^{-1}$

PVC columns, up to the soil surface (complete saturation), 29 cm (10 cm water level) and 24 cm (15 cm water level) below the soil surface. The treatments were replicated 4 times. The level of water in the column was maintained as per the treatment schedule throughout the study period. The top side of the column was tightly closed with the provisions for collection of gas samples and to maintain pressure inside the column. Soils were maintained at 25°C and the columns were opened to the atmosphere for 30 min every day to allow replenishment of ambient gas conditions and then resealed.

#### *Gas Sampling and Analyses*

Gas samples were collected from the closed columns in Tedlar air sampling bags on 1, 3, 5, 7, 9, 11, 13 and 15 days after incubation and analysed for CO<sub>2</sub> and CH<sub>4</sub> using Gas chromatography (Wang and Wang 2003) and for N<sub>2</sub>O and C<sub>2</sub>H<sub>2</sub> using Infra Red Analyzer (Beek *et al.* 2004). The values were corrected for background CO<sub>2</sub>, CH<sub>4</sub> and for N<sub>2</sub>O and C<sub>2</sub>H<sub>2</sub>. Cumulative GHG emissions were calculated by adding the emission on day 1 with day 3 and so on.

#### *Soil analysis*

Soil samples collected at initial and final stages of the experiment were analysed for NH<sub>4</sub>-N and NO<sub>3</sub>-N contents using 2 M KCl extraction by Bremner method (Black 1965) and determined by auto analyser .

#### *Soil Microbial Biomass (SMB)*

The SMB was measured by the chloroform fumigation-extraction procedure described by Vance *et al.* (1987). The amount of SMB-C present in the samples was determined according to Eq. (1) and expressed as mg-C kg<sup>-1</sup> oven-dry soil. The SMB values were expressed on oven-dry mass of soil.

$$\text{SMB-C (mg-C kg}^{-1}\text{)} = 2.64 C_{\text{Ex}} \rightarrow \quad (1)$$

where C<sub>Ex</sub> = Extractable C in non-fumigated soil - Extractable C in fumigated soil

#### *Metabolic Quotient*

The metabolic quotient, q CO<sub>2</sub> was determined according to Eq. (2).

$$q \text{ CO}_2 (\mu \text{ g CO}_2 \text{-C day}^{-1} \text{ mg}^{-1} \text{ SMB-C}) = \frac{r}{\text{SMB}} \rightarrow \quad (2)$$

where r = respiration rate (μ g CO<sub>2</sub> -C day<sup>-1</sup>) and SMB-C = SMB-C (mg C kg<sup>-1</sup>)

#### *Statistical Analysis*

Data were statistically analysed using SPSS version 20.0 statistical program. The GHG emission data were square root transformed in order to satisfy the

assumptions of ANOVA with back-transformed means presented. The transformed data were analysed as two-way ANOVA and just one-way ANOVA for initial or final soil measurements. Where GHG emissions displayed trace amounts (negligible release of gases), a dummy value of 0.01 was inserted.

## RESULTS

### *GHG Fluxes*

The CO<sub>2</sub> emissions from the completely saturated soil were low throughout the period of incubation. There was a modest increase from 1000 to 4000 mg kg<sup>-1</sup> at 7 DAI, but thereafter CO<sub>2</sub> emission declined to less than 500 mg kg<sup>-1</sup> on 15 DAI. Lowering water level to 10 or 15 cm had little effect on CO<sub>2</sub> emissions (Table 2). Emission of CO<sub>2</sub> was significantly increased even from 1 DAI in organic matter amended and completely saturated soil. Lowering water level to 10 or 15 cm in soil amended with organic matter stimulated CO<sub>2</sub> emission threefold at 1-3 DAI. An increase in CO<sub>2</sub> emission at water level 15 cm below soil surface was recorded at 7-9 DAI. However, at water levels of 10 cm / 15 cm, much higher CO<sub>2</sub> emissions were observed than the completely saturated soil.

In completely saturated soil, low levels of N<sub>2</sub>O emissions were measured throughout the incubation period. However, at water levels of 10 or 15 cm, stimulated N<sub>2</sub>O emission was registered at 1-3 DAI, but thereafter emission levels dropped close to zero.

Adding organic matter increased N<sub>2</sub>O emission substantially in saturated soil at 1 DAI but the level of N<sub>2</sub>O emission dropped to zero at 5 DAI. In soils at water levels of 10 cm /15 cm, organic matter addition stimulated N<sub>2</sub>O emission initially and was higher than in water logged soil.

Over the period of incubation, emission of N<sub>2</sub>O was significantly different due to the water levels, organic material addition and stage of incubation. The interactions between the stage of incubation and treatments were also significantly different. The soils amended with organic material had significantly higher rates of N<sub>2</sub>O emission compared to that of unamended soils (Table 2).

In waterlogged soil, C<sub>2</sub>H<sub>2</sub> emissions were < 10 mg kg<sup>-1</sup> throughout the incubation period and remained consistently low. Lowering water level to 10 cm from soil surface increased C<sub>2</sub>H<sub>2</sub> emissions to > 10 mg kg<sup>-1</sup> up to 3 DAI.

Adding organic matter to waterlogged soil caused a 5-fold increase in C<sub>2</sub>H<sub>2</sub> emissions at 1 DAI. Treatments that received water level at 10 or 15 cm from soil surface and amended with organic matter maintained C<sub>2</sub>H<sub>2</sub> emissions of 20 mg kg<sup>-1</sup> at 3 - 15 DAI. Cumulative C<sub>2</sub>H<sub>2</sub> emissions increased at all water levels in soil amended with organic matter (Table 3). Manures stimulate microbial respiration and increase CO<sub>2</sub> partial pressure (Chorom and Rengasamy 1997)

In unamended soil, CH<sub>4</sub> emission in water logged soil produced spikes at 9 to 15 DAI. At water levels of 10 /15 cm, increased levels of CH<sub>4</sub> in spikes were observed at 5 and 9 DAI.

TABLE 2  
Cumulative CO<sub>2</sub> emissions (g kg<sup>-1</sup>) at different stages

Water level	Organic amendments	Days after incubation														
		1	3	5	7	9	11	13	15							
Complete saturation	7.5 t ha <sup>-1</sup>	6.36	13.33	21.26	44.69	51.86	56.61	59.33	60.98							
	Un amended	1.05	2.43	4.57	8.32	10.45	12.21	13.03	13.69							
10 cm water level	7.5 t ha <sup>-1</sup>	17.28	37.87	50.60	65.64	80.89	95.03	110.27	119.63							
below soil surface	Un amended	1.45	3.20	5.11	6.73	8.63	10.43	12.14	12.79							
15 cm water level	7.5 t ha <sup>-1</sup>	17.59	38.20	65.93	121.81	176.59	217.34	235.15	246.54							
below soil surface	Un amended	1.26	3.25	5.78	10.00	13.55	16.39	17.26	78.62							
CD (P:0.01)		S	T	S x T												
		1.22	1.06	3.00												

TABLE 3  
Cumulative N<sub>2</sub>O emissions (µg g<sup>-1</sup>) at different stages

Water level	Organic amendments	Days after incubation														
		1	3	5	7	9	11	13	15							
Complete saturation	7.5 t ha <sup>-1</sup>	8.99	13.58	13.71	13.89	13.99	14.09	14.19	14.33							
	Un amended	0.36	1.12	8.11	8.89	9.27	9.64	10.50	10.90							
10 cm water level	7.5 t ha <sup>-1</sup>	11.79	29.79	30.75	31.72	31.96	33.43	33.70	34.15							
below soil surface	Un amended	0.10	3.27	10.08	10.18	10.28	10.38	10.40	11.03							
15 cm water level	7.5 t ha <sup>-1</sup>	21.24	85.14	100.10	100.86	123.96	124.21	124.31	124.46							
below soil surface	Un amended	5.07	9.76	10.04	10.48	11.59	12.54	13.35	19.96							
		S	T	S x T												
CD (P<0.01)		1.30	1.13	3.19												

### *Soil Microbial Biomass-C (SMB-C)*

The SMB-C increased over a period of time. SMB-C was higher at 10 cm water level below surface soil than in water logged conditions and at 15 cm water level below soil surface. Soils at 10 cm water level amended with the organic material registered a significantly higher value of SMB-C ( $1320 \text{ mg kg}^{-1}$ ) while soils at 15 cm below soil surface amended / unamended with organic material registered a lower SMB-C value.

### *Metabolic quotient ( $q \text{ CO}_2$ )*

Irrespective of water levels and organic material addition, the  $q \text{ CO}_2$  was higher in soils at 1 DAI compared to 15 DAI. Treatment that received water level 10 cm below the soil surface recorded higher  $q \text{ CO}_2$  than 15 cm water level and water logged soil (Table 8). Organic amendments also enhanced the value of  $q \text{ CO}_2$ .

### *$\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ .*

Soil N forms viz.,  $\text{NH}_4\text{-N}$  and  $\text{NO}_3\text{-N}$  were lower at 10 cm water level below soil surface indicating a higher rate of mineralisation of N at this water level. This fact is further supported by the higher SMB at this water level (Table 7). Addition of organic material increased  $\text{NH}_4\text{-N}$  levels in the treatments that received water levels at 10 cm/15 cm below soil surface.

## **DISCUSSION**

### *Effect of Water Level and Organic Material on GHG Fluxes*

Maximum emission of GHG was recorded at water level of 15 cm below soil surface. This was also seen in a study by Tiemeyer *et al.* (2016), where the response of  $\text{CO}_2$  emissions to groundwater level was highly site-specific. Emission of  $\text{CO}_2$  was the lowest at water logging. Anaerobic habitats have lower  $\text{CO}_2$  emissions than aerobic soils even though they have much higher C content (Goreau and Mello 2007). A lowered water table increases  $\text{O}_2$  and C substrate available for microbial activity for releasing  $\text{CO}_2$  (Jauhainen *et al.* 2005). The rate of emission of  $\text{CO}_2$  was higher when soils were well aerated and the water level was at 15 cm below the soil surface.  $\text{CO}_2$  emissions are doubled by lowering the groundwater level from 30 to 80 cm below the ground surface (Renger *et al.* 2002). Despite high organic matter content in organic amended treatment,  $\text{CO}_2$  fluxes were fairly low because lack of  $\text{O}_2$  forced organic matter decomposition into thermodynamically inefficient anaerobic pathways. Submerged soils with prolonged anoxic periods store more OC than upland soils due to less efficient decomposition under anoxic conditions (Kalbitz *et al.* 2013). The decomposition or destruction of organic materials is lessened and incomplete, and the humification of organic matter is decreased under flooded conditions (Sahrawat 2003).

Production of  $\text{N}_2\text{O}$  is primarily due to denitrification. Emission of  $\text{N}_2\text{O}$  was higher at 1 DAI in the water logged soil. Denitrification is an obligatively anaerobic heterotrophic process in which denitrifiers use  $\text{NO}_3$  as a terminal e-acceptor after  $\text{O}_2$  is exhausted. Hence in the water logged soil,  $\text{N}_2\text{O}$  production was

observed immediately after water logging. However  $N_2O$  emission was unstable and probably proceeded to complete denitrification in the form of  $N_2$  emission in the waterlogged condition from 3 DAI as lower rates of  $N_2O$  emission was recorded. Organic material addition increased  $N_2O$  emission as reported by Zaehle *et al.* (2011). Methane is converted to  $CO_2$  by methanotrophic microorganisms. More than 80% of  $CH_4$  produced in soils is converted to  $CO_2$  in the oxidised zone. Only a trace amount of  $CH_4$  was produced during the first week of incubation. This could be due to the conversion of C to  $CO_2$  and then reduced to  $C_2H_2$ . For the maximum release of  $C_2H_2$  and  $CH_4$ , 7 and 9 DAI are required. The rate of reduction of C to  $C_2H_2$  and  $CH_4$  at well aerated soils was slower (Tables 3 and 4). Slow decomposition rates of organic carbon in anaerobic wetland soils have been reported by Mitsch *et al.* (2013). With increasing content of soil organic matter  $CH_4$  emission rates were increased (Serrano-Silva *et al.* 2014). A lower C: N ratio of organic matter in the soil may increase organic matter liability by decreasing nitrogen limitation for decomposers (Hodgkins *et al.* 2014). When the water table approached the soil surface, the  $CH_4$  emission rates increased. This is in agreement with the findings of Zhu *et al.* (2014), who reported that seasonal  $CH_4$  emissions are highly linked to water table fluctuations. The important effect of water table on  $CH_4$  emission rates is in agreement with observations in other studies (Bridgham *et al.* 2006; Couwenberg *et al.* 2011; Le Mer and Roger 2001; Serrano-Silva *et al.* 2014). Common anaerobic conditions are expected to lower  $CO_2$  emissions but increase those of  $CH_4$  (Treat *et al.* 2015), but emissions from aerobic soils will likely dominate the permafrost C feedback (Schadel *et al.* 2016).

#### *GHG Flux and SMB*

GHG emission and SMB were found to be the lowest in the soils. Over a period of time, SMB can adapt to soil conditions and in stabilised conditions, the size of the microbial biomass will reach equilibrium with substrate supply in the soil (Liu *et al.* 2006); Soil microbial biomass also increased in response to increased C substrate from organic amendments. This study also indicated that the dormant population of SMB tolerant to water logging could have adapted to such environmental conditions over time.

The  $qCO_2$  was higher in soils at 1 DAI as compared to 15 DAI. Irrespective of the water levels,  $qCO_2$  was enhanced in soils amended with organic material. Lower  $qCO_2$  values in water logged soil indicate low microbial activity in this zone. Accumulation of inorganic salts as osmolytes can be toxic; therefore it is confined to halophytic microbes which evolve into salt-tolerant enzymes to survive in highly saline environments. (Wichern *et al.* 2006).

#### *$NH_4$ -N and $NO_3$ -N*

Irshad *et al.* (2005) reported that nitrification of  $NH_4$  to  $NO_3$  was reduced by salinity. Salinity level adversely affected even the first step of nitrification thus leaving behind greater  $NH_4$ -N (Muhammad Akhtar *et al.* 2012). At 10 cm water level below soil surface, a higher rate of mineralisation of N was registered. A

TABLE 4  
Cumulative C<sub>2</sub>H<sub>2</sub> emissions (µg g<sup>-1</sup>) at different stages

Water level	Organic amendments	Days after incubation														
		1	3	5	7	9	11	13	15							
Complete saturation	7.5 t ha <sup>-1</sup>	48.50	96.00	120.99	152.00	169.91	183.68	189.10	192.60							
10 cm water level below soil surface	Un amended	6.57	8.87	11.01	19.32	23.21	28.08	33.24	35.47							
15 cm water level below soil surface	7.5 t ha <sup>-1</sup>	71.21	106.38	128.71	168.61	207.21	245.61	274.58	308.61							
	Un amended	10.24	26.21	28.65	32.17	35.54	38.79	43.13	43.77							
	7.5 t ha <sup>-1</sup>	97.35	170.85	204.45	225.25	369.45	393.35	419.75	463.65							
	Un amended	10.68	23.98	27.85	40.43	46.52	51.93	54.09	55.20							
CD (P:0.01)		S	T	S x T												
		1.71	1.48	4.19												

higher level of  $\text{NH}_4\text{-N}$  was registered in the treatments that received organic amendment. The increase in the level of exchangeable  $\text{NH}_4\text{-N}$  might be due to mineralisation of organic sources by microbial biomass (Niladri Paul *et al.* 2014)

### CONCLUSIONS

Our study indicates that GHG emissions can be reduced by restoration of saline water logged soil through tree plantations, agroforestry biodrainage approach, irrigation practices with minimum flooding the surface and proper leveling of the surface. Thus multiple approaches are needed to tackle the problem. To enhance SOC levels and SMB and to minimise the ill effects of salinity, incorporation of organic material is needed. Our results demonstrate that water logging reduces emission.

TABLE 5  
Cumulative  $\text{CH}_4$  emissions ( $\mu\text{g g}^{-1}$ ) at different stages

Water level	Organic amendments	Days after incubation		
		9	11	15
Complete saturation	7.5 t ha <sup>-1</sup>	0.31	0.46	0.89
	Un amended	0.10	0.27	2.38
10 cm water level below soil surface	7.5 t ha <sup>-1</sup>	0.10	0.20	0.30
	Un amended	1.88	1.98	2.40
15 cm water level below soil surface	7.5 t ha <sup>-1</sup>	0	0.10	0.20
	Un amended	1.60	3.20	4.80
CD (P:0.01)		S	T	S x T
		NS	NS	NS

TABLE 6  
Effect of water logging and organic amendments on soil organic carbon (g kg<sup>-1</sup>) and soil microbial biomass carbon (µg g<sup>-1</sup>)

Water level	Organic amendments	SMB-C
		Initial
Complete saturation	7.5 t ha <sup>-1</sup>	486 <sup>c</sup>
	Un amended	115 <sup>a</sup>
10 cm water level below soil surface	7.5 t ha <sup>-1</sup>	143 <sup>a</sup>
	Un amended	225 <sup>b</sup>
15 cm water level below soil surface	7.5 t ha <sup>-1</sup>	709 <sup>d</sup>
	Un amended	206 <sup>b</sup>
		15 DAI
		977 <sup>c</sup>
		264 <sup>a</sup>
		1320 <sup>d</sup>
		396 <sup>b</sup>
		343 <sup>ab</sup>
		317 <sup>ab</sup>

Note: Within each column means followed by the same letter are not significant at P<0.05

TABLE 7  
Effects of water logging and organic amendments on metabolic quotient ( $q\text{ CO}_2$ )

Water Level	Organic amendments	$\text{NH}_4\text{-N}$			$\text{NO}_3\text{-N}$			$q\text{ CO}_2$ ( $\text{mg kg}^{-1}\text{ day}^{-1}$ )	
		Initial	15 DAI	Initial	15 DAI	Initial	15 DAI		
Complete saturation	7.5 t ha <sup>-1</sup>	10.30 <sup>a</sup>	6.55 <sup>a</sup>	2.36 <sup>a</sup>	2.46 <sup>a</sup>	13.08	1.66		
	0	7.00 <sup>b,d</sup>	2.10 <sup>b,c</sup>	0.55 <sup>a</sup>	0.42 <sup>a</sup>	9.13	2.13		
10 cm water level below soil surface	7.5 t ha <sup>-1</sup>	2.15 <sup>a,c</sup>	5.35 <sup>a,b</sup>	0.15 <sup>a</sup>	0.14 <sup>a</sup>	120.85	7.58		
	0	5.90 <sup>b,d</sup>	1.15 <sup>c</sup>	0.39 <sup>a</sup>	0.13 <sup>a</sup>	6.44	1.45		
15 cm water below soil surface	7.5 t ha <sup>-1</sup>	1.15 <sup>c,d</sup>	7.25 <sup>a</sup>	2.70 <sup>a</sup>	2.04 <sup>a</sup>	24.81	35.42		
	0	1.90 <sup>b</sup>	1.11 <sup>c</sup>	3.90 <sup>a</sup>	1.71 <sup>a</sup>	6.30	2.48		
S.E						12.99	3.87		

TABLE 8  
Effects of water logging and organic amendments on  $\text{NH}_4\text{-N}$  ( $\mu\text{g g}^{-1}$ ) and  $\text{NO}_3\text{-N}$  ( $\mu\text{g g}^{-1}$ )

Water Level	Organic amendments	$\text{NH}_4\text{-N}$		$\text{NO}_3\text{-N}$		$\text{NH}_4\text{-N} + \text{NO}_3\text{-N}$	
		Initial	15 DAI	Initial	15 DAI	Initial	15 DAI
Complete saturation	7.5 t $\text{ha}^{-1}$	10.30 <sup>a</sup>	6.55 <sup>a</sup>	2.36 <sup>a</sup>	2.46 <sup>a</sup>	12.66 <sup>a</sup>	9.01 <sup>a</sup>
	0	7.00 <sup>bd</sup>	2.10 <sup>bc</sup>	0.55 <sup>a</sup>	0.42 <sup>a</sup>	7.55 <sup>a</sup>	2.52 <sup>b</sup>
10 cm water level below soil surface	7.5 t $\text{ha}^{-1}$	2.15 <sup>ac</sup>	5.35 <sup>ab</sup>	0.15 <sup>a</sup>	0.14 <sup>a</sup>	2.30 <sup>a</sup>	5.46 <sup>ab</sup>
	0	5.90 <sup>bd</sup>	1.15 <sup>c</sup>	0.39 <sup>a</sup>	0.13 <sup>a</sup>	6.29 <sup>a</sup>	1.28 <sup>b</sup>
15 cm water below soil surface	7.5 t $\text{ha}^{-1}$	1.15 <sup>cd</sup>	7.25 <sup>a</sup>	2.70 <sup>a</sup>	2.04 <sup>a</sup>	3.85 <sup>a</sup>	11.10 <sup>a</sup>
	0	1.90 <sup>b</sup>	1.11 <sup>c</sup>	3.90 <sup>a</sup>	1.71 <sup>a</sup>	5.80 <sup>a</sup>	2.82 <sup>b</sup>

Note: Within each column, means followed by the same letter are not significant at  $P < 0.05$

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