Brown coal-urea blend for increasing nitrogen use efficiency and biomass yield

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Abstract
Increasing crop yield combined with minimum application of nitrogenous fertilisers is becoming more important due to detrimental effects of excess N in the environment. Addition of humic rich-brown coal as an organic amendment to urea, and application to soil, can alter nitrogen (N) cycling and availability to crops. However, the effect of brown coal-urea (BCU) blends on the biomass yield and N uptake by plant needs to be studied. Therefore, a glasshouse pot trial was conducted to assess the effects of BCU blends on the growth, biomass yield and N uptake by silver beet. Blending of urea with brown coal showed a promising impact on the behavior of N fertiliser in the soil system. Compared to urea, BCU blends increased biomass yield by 27% and 23% in a neutral (pH 7.24) and acid (pH 5.4) soil, respectively. In addition, incorporation of BCU blends to soil generally suppressed N_2O emissions by 29% compared to urea. Application of BCU blends in soil maintained significantly higher amounts of potentially mineralisable N in soil compared to urea application only. Moreover, addition of BCU blends increased the N uptake by silver beet and organic carbon content of soil. The blends with higher brown coal had higher biomass yield, better N uptake and maintained higher mineral N in soil compared to the blends with lower brown coal. The overall results suggest that blending of urea with brown coal can significantly increase N availability and its uptake by silver beet. As a result a better crop yield can be obtained and at an increased N use efficiency, compared with urea alone.

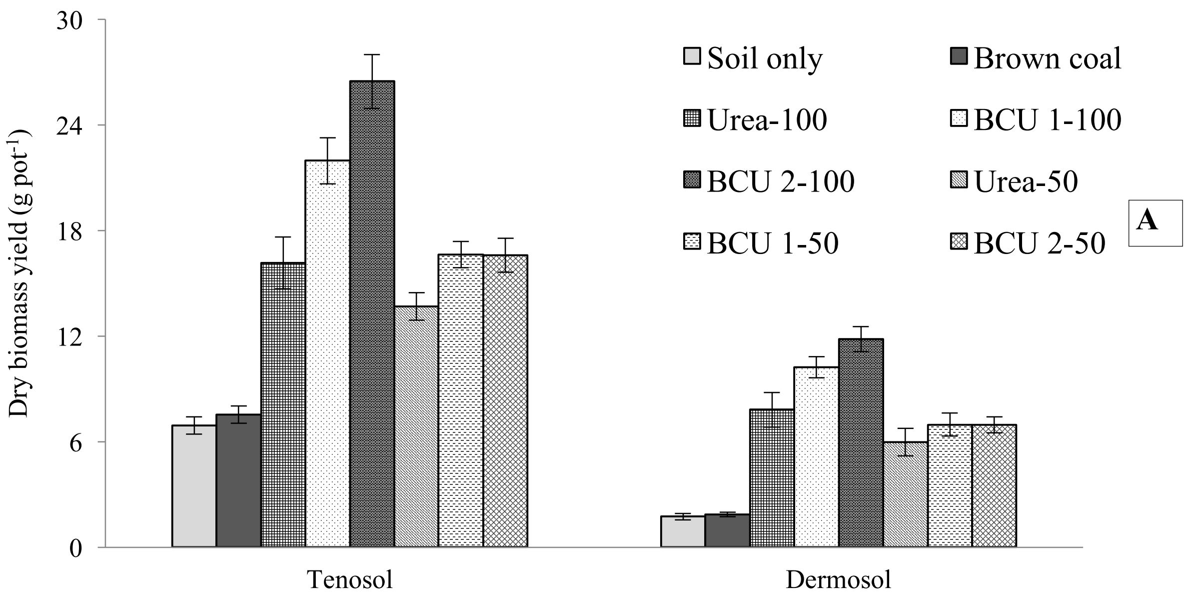
Keywords
Brown coal-urea blend, biomass yield, N uptake, fertiliser N use efficiency, soil health

Introduction
Nitrogen is one of the most important and limiting nutrient elements for ecosystem productivity. Application of chemical fertilisers is the dominant and main source of N input in crop production systems world-wide. However, N fertiliser use efficiency is very poor and recovery of N in the soil-plant system seldom exceeds 50% of applied N (Raun et al., 2002). The low use efficiency of N is associated with its losses by leaching, denitrification and volatilisation (Fageria and Baligar, 2005). The major challenges facing farmers worldwide include improving N fertiliser use efficiency, and reversing the widespread loss of soil organic matter. This lost N represents both an economic inefficiency and an environmental burden, as off-site N transport in water pollutes both surface and groundwater, whilst nitrous oxide contributes to greenhouse gas accumulation in the atmosphere. The loss of soil organic matter has also impacted on crop productivity. Negative effects include reduction in soil water-holding capacity; decreased nutrient availability and cycling; and a reduced capacity to buffer changes in pH, salinity and other chemical stressors. Because soils depleted in organic carbon are often impaired in their ability to retain N by organic matter (adsorbed and NH_4^+ exchangeable), retaining fertiliser applied N in the plant-soil system has become increasingly difficult. Furthermore, recent studies show that the carbon sequestration potential of soil is intricately linked with sequestration of other nutrients, especially N (Dong et al., 2009). Lignite, or brown coal, is a suitable organic material to blend with N-fertiliser and assist in N retention. This is due to the high humic acid content of the brown coal. Consequently, the brown coal is acidic and also possesses a high cation exchange capacity. This assists in the retention of N released from urea hydrolysis as ammonium, rather than being lost as ammonia gas at alkaline pH. Moreover, brown coal is readily available in many countries at a low cost. Excessive use of inorganic N fertilisers is not sustainable for crop production from an economic as well as ecological points of view (Abdel Monem et al., 2010, Wang et al., 2010). Therefore, improving fertiliser N use efficiency and increasing soil organic carbon is an essential goal on a global scale to provide food security, maintain soil health and minimise adverse effects on the environment. Blending of urea with BC could reduce N losses via leaching and gaseous emissions and may increase N availability to plants by retaining more N by the interaction with the functional groups of BC. Therefore, this study assessed the effects of BCU blends on the biomass yield and N uptake by silver beet.

Materials and methods

A pot trial was carried out in the glasshouse of the Plant Science Complex, Monash University, Clayton, Victoria. Two soils with contrasting pH (Dermosol pH-5.4 and Tenosol pH-7.2) were tested in this study. The soil samples were collected to a depth of 0-15 cm. The collected soil samples were mixed, air dried to reduce microbial activity, homogenised by sieving with a 2 mm mesh and stored for the incubation study. Plastic, free-draining pots (16 cm diameter) were filled with 1.9 kg of Dermosol and 2.2 kg Tenosol to match the field bulk densities for the two soils, which were 1.3 g cm^{-3} and 1.4 g cm^{-3}, respectively. The experiment was laid out following completely randomised design with five replicates. The soils were amended with two different rates of straight urea, BCU 1 (22% N) and BCU 2 (17% N). The application rates of urea and each blends were 100 kg N ha^{-1} and 50 kg N ha^{-1}, respectively. Two controls were also included: one contained raw BC and the other was an unfertilised control. In addition, P and K were added at a rate of 40 and 60 kg ha^{-1}, respectively as basal dose. The fertilisers were mixed with top soil (0-5cm) of the pot in granular form and uniformly covered the whole surface area of soil. The pots were then left to equilibrate at field capacity moisture for 3 days before the sowing of seeds. To each pot, 10 seeds of silver beet were sown to ~2mm below the soil surface. Soil moisture was maintained at field capacity by regular addition of tap water as required, usually every 2 days. After germination, only one plant was allowed to grow per pot. Five gas samplings were done at early growth stage of plant to measure the loss of N via N_2O and NH_3 emissions. The greenhouse gas flux was calculated according to the method and equations detailed in Van Zwieten et al. (2010). NH_3 emissions were measured using polyurethane foam absorbers and flux was calculated using the equation of Singh et al. (2009). Plants were destructively harvested 10 weeks after seed sowing. The plant and soil were carefully removed from the pots. The soil was gently shaken from the roots, after which the shoots and roots were separated. The roots were then thoroughly washed with water to remove any adhering soil. The shoots and roots of plant were oven-dried for 7 days at 55°C, following which shoot dry weight (SDW) and root dry weight (RDW) was measured. The dried plant materials were then ground to a fine powder, and N and C concentrations were determined using CHN analyser. Soil samples was collected and taken to the laboratory for chemical analyses. The soil was analysed for pH, soil organic C, ammonium, nitrate, potentially mineralisable N (Stenberg et al., 2013) and total N (CHN analyser). Statistical analyses were performed using statistical software package IBM SPSS, version 20. All tests of significance were carried out at $P < 0.05$. Two way analysis of variance (ANOVA) was performed and the multiple comparisons among the different treatments were done using a Scheffé test.

Results



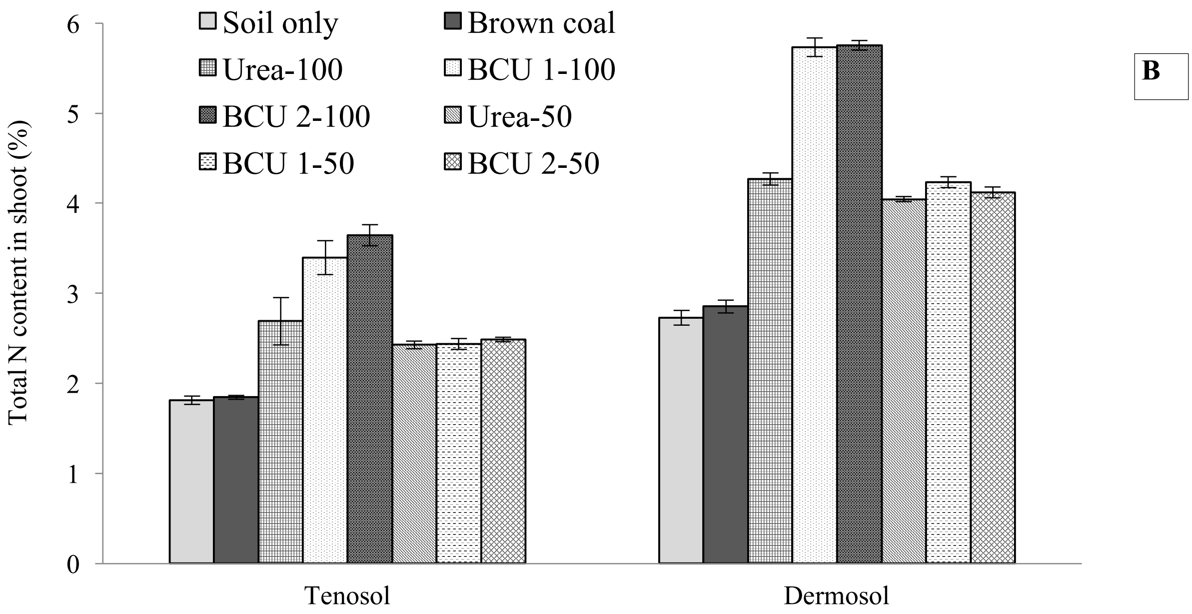


Figure 1. Effect of BCU blends on biomass yield (A) and N content (B) in shoot of silver beet (Bars indicate standard error, n=5).

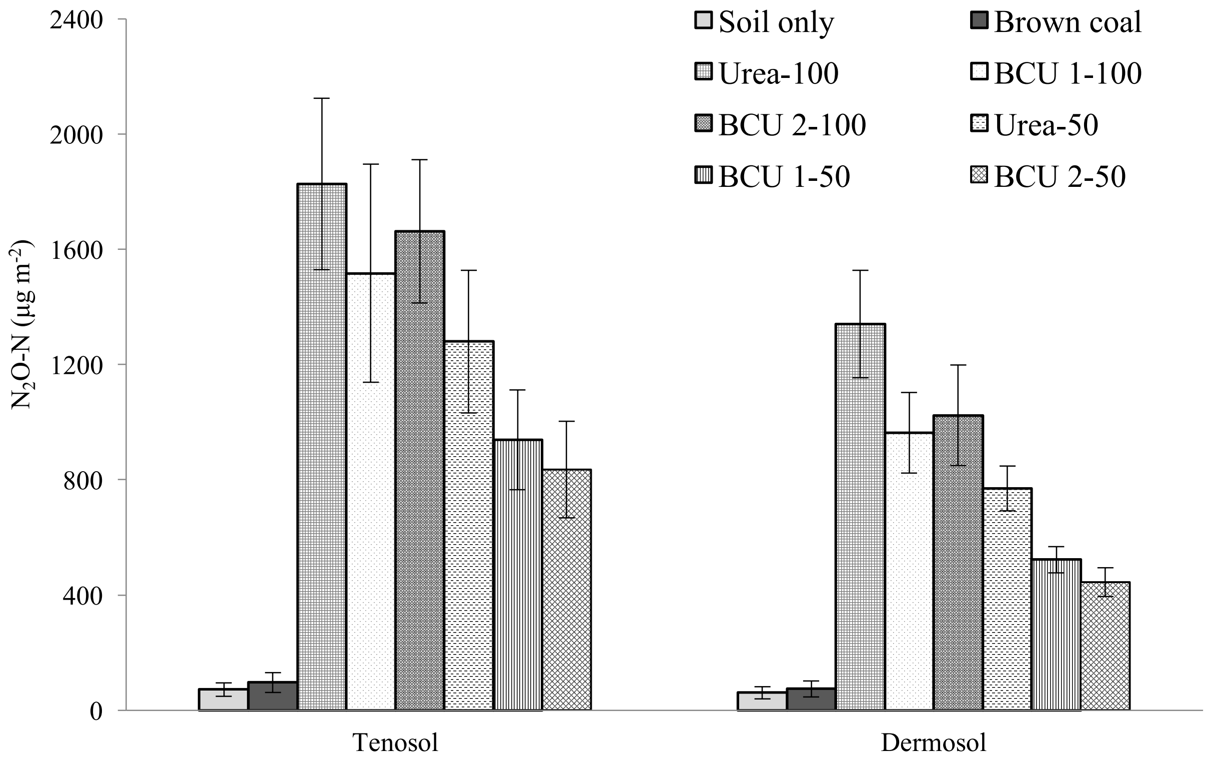


Figure 2. Effect of BCU blends on the total nitrous oxide emissions from soil (Bars indicate standard error, n=5).

Addition of BCU blends to soil had a significant influence on the biomass yield and N content of silver beet in both soils. Significantly higher amounts of biomass yield and shoot N content were measured from the soil fertilised with BCU blends compared to urea, BC and control treated soil (Figure 1 A-B). No significant variation was observed in biomass yield and shoot N content when N was added at 50 kg ha^{-1}. Statistically identical biomass yields were recoded from the soils amended with 50 kg N ha^{-1} from BCU and 100 kg N ha^{-1} from urea. Compared to urea, BCU blends increased biomass yield by 27% and 23% in the Tenosol (pH 7.24) and Dermosol (pH 5.4), respectively. In addition, BCU blends suppressed the total N_2O emissions by 29% and 13% from the Tenosol and Dermosol, respectively (Figure 2).

Conclusions

Blending of urea with BC showed a promising impact on the availability of fertiliser N in soil systems. Incorporation of BCU blends in soil showed significantly higher biomass yield and shoot N content of silver beet compared to urea application only. Blending of urea with brown coal can strongly reduce N losses via gaseous emissions, compared with urea alone. The BCU blends suppressed the total N_2O emissions by 29% and 13% from the Tenosol and Dermosol, respectively. As a result greater amounts of fertiliser N was available to silver beet, increasing the N uptake and use efficiency. The increased N uptake resulted in 27% and 23% more biomass yield from the plants treated with BCU blends compared to urea in the Tenosol and Dermosol, respectively. These findings support the hypothesis that brown coal can be used as a substrate to develop slow release N fertilizer with delayed N losses from the soil system.

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