Environmental hazard of excess dunder on agricultural land

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Abstract

The use of high biochemical oxygen demand (BOD) organic waste on farming land offers two resource recovery opportunities, first nutrient for plant production and secondly organic matter for soil health. One such waste, dunder from yeast production was tested for its impact on irrigated lucerne hay production. A randomised complete block trial with five treatments (0, 8, 24, 48, 96 L dunder m^{-2}) and three replications was used to test the impact of dunder on total dry matter production. The trial showed that the lower rates of 8 and 24 L m-2 of dunder was not significantly different to the control (0) while the high rates of 48 and 96 L m^{-2} significantly reduced total dry matter. This was significant as it identified limits to dunder application rate. However, more importantly, the trial showed that site characteristics and agronomic management had greater impact than the dunder alone on the plant production. In this trial a sodium hazard not related to the dunder significantly added to the reduction of dry matter. The results show that the assessment of dunder and other similar wastes for land application must include both the direct and indirect site related consequences of application to agricultural land.

Media summary

High strength (BOD) organic wastes have a potential to induce sodium toxicity in plants that are grown using Na hazard land or irrigation water

Key words

lucerne, waste, Sodium, dunder

Introduction

The National Water Strategy (Anon 1994a) contains the Acceptance of Trade Waste Guidelines (Anon 1995) which explicitly targets (BOD) organic waste for removal from sewer streams. The use of this high BOD on farming land offers two resource recovery opportunities, first nutrient for plant production and secondly organic matter for soil health. One such waste (dunder) is from yeast production. A typical analysis of the dunder (Table 1) shows significant levels of K and Ca in comparison with other macronutrients.

Table 1 Analysis of raw dunder from a yeast factory showing typical dunder characteristics.

Test	Value
pH	4.6
BOD (mg L^{-1})	29000
Total Nitrogen (mg L^{-1})	2120
Total Phosphorus (mg L^{-1})	171

Conductivity (dS m^{-1})	31.8
Sodium (mg L^{-1})	570
Calcium (mg L^{-1})	8100
Magnesium (mg L^{-1})	1390
Potassium (mg L^{-1})	8150

Whilst a simple mass balance approach to identify the limiting factor of the waste application indicates 3 L m^{-2} or 240 kg K ha^{-1} to the environment, one of the main environmental issues is the assessment of the impact of an accidental overload. The expected impacts include short term anaerobic conditions, N and P load, and soil salinity. An environmental hazard assessment study was undertaken to assess the impact of excess dunder on plant dry matter and nutrient balance.

Methods

The site selected for the study was a sandy clay loam soil (to 400 mm overlying a sandy clay horizon) with an irrigated *Medicago sativa* (lucerne) crop in its second year of hay production. A randomised complete block design with three replications and five treatments (control with no application of dunder and dunder at 2, 6, 12 and 24 L m^{-2} per week for 4 weeks) was used. The lucerne crop was cut one week prior to initiating the trial to ensure similarity of growth stage for the stands. Each plot was 1.5 X 3.0 m. A wooden border to contain the dunder surrounded each plot. The dunder was applied directly to the soil surface. After each dunder application all plots were irrigated with on-site bore water to a total fluid application rate of 30 L m-2. The irrigation water used on the property had a sodium adsorption ratio of 9.3 and a Ca:Mg of 0.33. The water is normally classified as unsuitable for irrigation because of the high SAR and poor Ca:Mg (Horton and Jobling 1984) but is used in the local area on soils of low clay content.

At the end of the fourth week (total dunder applied 8, 24,48 and 96 L m^{-2}) a 0.25 m^2 quadrat plant sample was taken from each plot. The samples were dried, weighed ground and analysed for Ca, Mg, K and Na. All plant analysis procedures conformed to the standards as outlined by Shamsul-Islam *et al*. (1992). Data were analysed by parametric analysis of variance with least significant differences calculated at the 0.05 level of probability. Where regressions were used all coefficients of determination (R^2) were adjusted.

Results

The dry matter production of the 8 and 24 L m^{-2} rates of dunder applications were similar to the control. The larger application rates (48 and 96 Lm^{-2}) resulted in a significant decline in dry matter production. The yield decline with dunder additions may be described by a linear function (Figure 1).

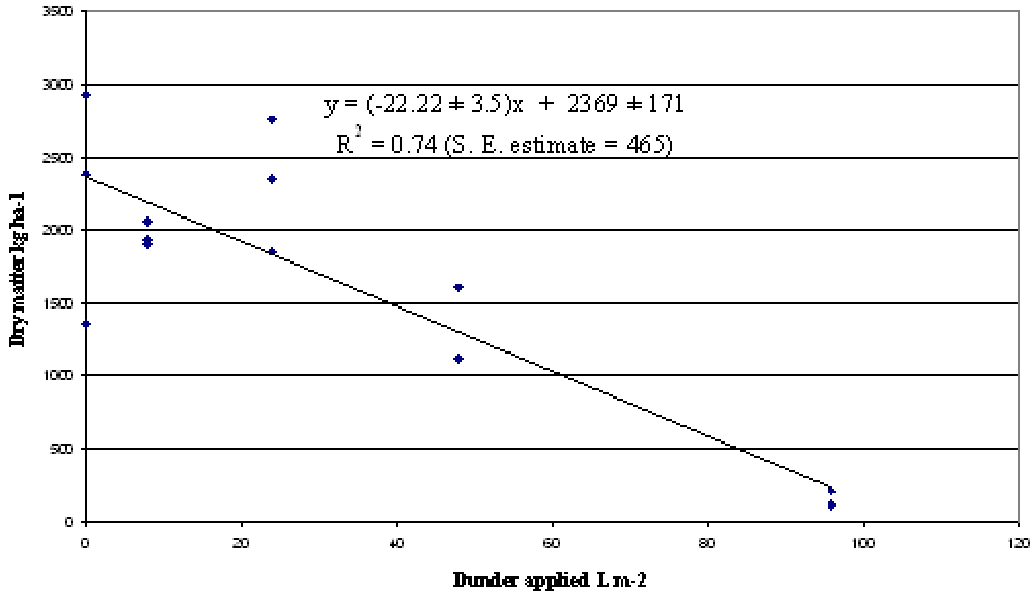

Figure 1 Dry matter production (kg ha^{-1}) as a function of dunder applied (L m^{-2}) to the sandy clay loam (lsd = 691).

No statistically significant differences were detected for the tissue concentration of K, Ca and Mg. Plant tissue Na content demonstrated a linear increase with the rate of dunder applied (Table 2 and Equation 1).

Table 2 Plant tissue Na concentration(%) in relation to amount of dunder applied (L m^{-2})

Dunder applied (L m-^{2})	Na (%)
0 a	0.65
8 a	0.65
24 a	0.58
48 b	0.97
96 b	1.16
lsd	*0.23*

$y = 0.006(\pm 0.001)\ x + 0.59\ (\pm 0.50)$ (Eq. 1)
where y = Tissue Na (%) and x = Dunder applied (L m^{-2})
(R^2 = 0.70; Standard error of estimate = 0.14)

The tissue concentrations for K (0.76-1.0%) and Ca (0.27-0.38) may be called deficient for production purposes (Andrew and Robbins 1969 and Cornforth and Sinclair 1982, respectively). Plant Mg (0.34-0.42%) was adequate (Reuter *et al*. 1997) and Na (0.6-1.20%) was at toxic levels (James 1988).

The data demonstrates a linear relationship between dry matter and Na tissue concentration (Figure 2). As Na concentration increases total dry matter decreases.

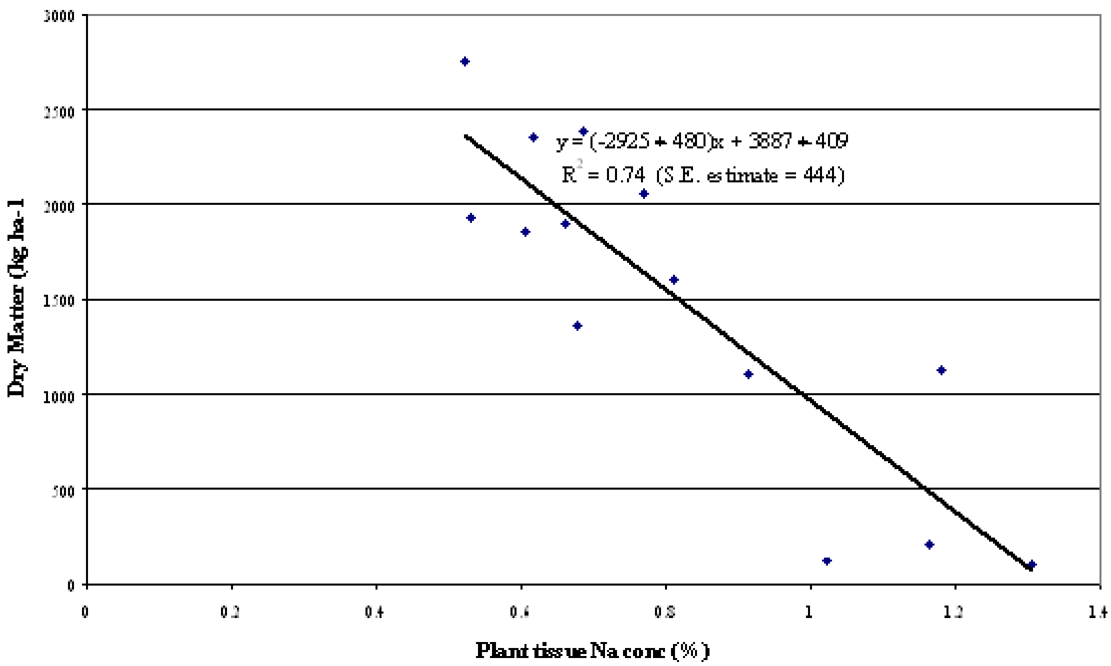

Figure 2 The relationship between dry matter (kg ha^{-1}) and Na tissue concentration (%) of the lucerne whole tops.

Discussion

The results showed a marginal tissue concentrations for Ca and K (even though there were no soil related deficiency of the cations). The data also showed a possible Na toxicity. The Na concentrations were such that inhibition of uptake of other nutrients was probable (James 1988) such as K deficiency (Schroeder *et al* 2001) and inhibition of Ca uptake by plants (Lynch and Lauchi 1985). The trial plant data demonstrated this response.

When a large amount of dunder was applied to the soil surface, there was a significant probability that short-term anaerobic conditions may occur. The dunder had a BOD of approximately 29 000 mg L^{-1}. Under low concentrations of soil oxygen, K selectivity by the plants would decrease in favour of Na (Thomson *et al*. 1989) and this may persist for several days after the anoxic event (Bauer *et al*. 1987).

The dunder was relatively low in Na in comparison with the other cations. The Na source was not the dunder but the irrigation water and the resident Na in the soil from the water. The trial suggests that significant excess dunder will have its greatest effect on soils that are high in Na or in areas where sodic waters are used for irrigation. A simple rule may be used to guide a possible maximum single load based on a 10% reduction in yield as a threshold of ameliorative action. This is a standard practice used in plant nutrition and salinity studies. (Reuter *et al.* 1997). The equation in Figure 1 describes a sensitive site where a 10% reduction in biomass yield corresponds to 10 L m^{-2} of dunder.

The 10% reduction (240 kg ha $^{-1}$) is less than the standard error (465 kg ha $^{-1}$) of the estimate made by the equation. Consequently, the adoption of such a value is open to criticism. However, in environmental, economic, social and risk management terms the use of this limit on sodium sensitive sites is not unreasonable. The Australian environmental legislation and regulations identify the precautionary principle (Calow 1997) as the underlying tenet of environmental management (Harding 1998). In such a legal system it is best to err on the side of conservatism and the reduction in yield proposed here would meet this criterion.

More importantly than the identification of an application limit the trial reinforces the need for experimentation to estimate possible environmental hazards of excessive waste loads. The trial identified an induced Na hazard not related to the Na content of the dunder but the inherent Na hazard of the land management system. This was in addition to the expected hazards of anoxia and salinity.

Conclusion

The application of high BOD waste to land at low levels within the nutrient requirements of a crop (3 L m^{-2} or 240 kg K ha^{-1} in the case of lucerne) poses no difficulty in production or environmental terms. However, high (accidental) applications appears to pose an induced sodium toxicity on sites with inherently high Na levels. The trial also emphasises the need for field experimentation to test the impact and identify critical limits to a waste application.

Acknowledgments

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