Benefits of using biosolid nutrients in Australian agriculture - a national perspective

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Abstract

Biosolids contain plant nutrients that can have beneficial effects on soil fertility and plant growth, and the National Biosolids Research Program (NBRP) conducted a series of trials across a wide range of soil types, climates and cropping systems across Australia to evaluate these benefits. A wide range of biosolids were used across the program, with each State-based program using at least two locally-produced biosolid types applied at multiples of the nitrogen-limiting biosolids application rate (NLBAR). Various crops were grown on the plots depending on local agronomic and climatic conditions – wheat, barley, triticale, canola, grasses, clover, peanuts, sorghum, maize, millet, sugar cane and cotton.

Application of biosolids had a positive effect on crop yields at most sites, with the main benefit from the biosolids probably being due to additions of nitrogen and phosphorus. At some sites in southern Australia there was no benefit from biosolid application to grain crops, or yields were reduced, and we attribute this to the drought conditions experienced at these sites as commercial fertiliser responses were similarly affected. Application of nutrients in any form at these sites caused strong early vegetative growth, exhausting soil moisture, and combined with the lack of good late season rainfall, resulted in restricted grain fill and poor crop production.

In general, biosolids supplied at the NLBAR supplied sufficient nutrients for at least 1-2 annual cropping cycles (averaged across all sites in the NBRP) without the need for mineral fertiliser application. Under reasonable rainfall conditions and with high value broadacre crops, economic returns from one application of biosolids at the NLBAR were up to $1800/ha. Using data for State production of biosolids, conservative assumptions of the total and mineralisable N for each State's biosolids, current fertiliser prices, and fertiliser "farmer practice" as used in the NBRP trials in each State, we calculate the fertiliser substitution value of Australian biosolids to be of the order of $3 million/yr.

Introduction

Biosolids contain a range of plant nutrients that can have beneficial effects on soil fertility and plant growth (King et al., 1974; Cunningham and Keeney, 1975; Sabey and Hart, 1975; Sommers, 1977; King and Morris, 1972; Schumann and Sumner, 1999; Rowell et al., 2001) and several studies of the fertilisation benefit of biosolids have been undertaken in Australia (de Vries and Merry, 1980; Jakobsen and Willett, 1986; Willett et al., 1986; Osborne 1996; Michalk et al, 2004; Joshua et al., 2001; Sarooshi et al., 2002; Weggler-Beaton et al., 2003; Cooper, 2005a; Cooper, 2005b).

The major plant nutrients in biosolids are nitrogen (N), phosphorus (P), sulfur (S) and potassium (K), and the composition of the material is highly dependent on treatment process and influent raw sewage quality (Sommers et al., 1976). Biosolids also contain a wide range of trace elements like copper (Cu), manganese (Mn), molybdenum (Mo) and zinc (Zn) and in highly alkaline soils the benefits of these can be significant.

While some of the N in biooslids is present in inorganic forms such as ammonium (NH_4^+) and nitrate (NO_3^-), much of the N in biosolids is in organic forms, so that plant uptake generally requires mineralisation of the organic N in the material. In the various State and national biosolid guidelines currently in use in Australia (Tasmania Department of Primary Industries, Water and Environment, 1999; National Resource Management Ministerial Council, 2004; New South Wales Environmental Protection Authority, 1997; South Australian Environment Protection Authority, 1997; Western Australia Department of Environmental Protection, 2002), available N in biosolids applied to agricultural land is assumed to equal the content of NO_3^-, 20% of the NH_4^+ content (assumes 50-80% lost by volatilisation) and a variable proportion (0.15-0.25) of the organic N, the latter derived from assumed mineralisation rates in the first year after application. The application rate of biosolids is usually limited by N, and all State and national guidelines have defined a nitrogen limiting biosolids application rate (NLBAR) which uses the above calculation to determine N available in the biosolids, and this must not exceed crop demand (based on published crop N requirements) in the first year after application.

Contrary to popular belief, most of the P in biosolids is inorganic P (see Hedley and McLaughlin, 2005 for a review), and availability of this P can be substantial (Taylor et al., 1978; Kirkham, 1982; McLaughlin, 1988; Kidd et al., 2007). Depending on application rate, biosolids have the potential to be a useful fertiliser material for Australian soils that are generally deficient naturally in N, P, S and micronutrients.

The National Biosolids Research Program (NBRP) was established to assess the benefits and risks from land application of biosolids to a wide range of Australian soils and cropping systems. A national series of coordinated trials was established by CSIRO in collaboration with State agencies and universities to examine crop responses to biosolid applications and to determine and benchmark safe concentrations of metals to protect agricultural productivity. This paper presents an overview of nutritional benefits of biosolids determined in the trials. Full reports of the cropping program and trial results are available in each of the NBRP State reports (Barry and Bell, 2006; Whatmuff et al., 2005; Butler et al., 2007; Heemsbergen et al., 2007; Pritchard and Collins, 2006).

Materials and Methods

Seventeen field sites were established across Australia (Figure 1) on a wide range of soil types (Table 1), and these received both biosolid and metal salt treatments. A wide range of biosolids were used across the program, with each State-based program using at least two locally-produced biosolid types (Table 2). Metal salts were used to define safe limits for metals in agricultural soils and results from these determinations have been reported elsewhere (Broos et al., 2007; McLaughlin et al., 2006, Warne et al., 2007).

Biosolid rates applied were based on the NLBAR. Each trial was designed in a randomised block design, with each treatment conducted in triplicate. All biosolid field trials consisted of eight treatments – a control (un-amended soil), a fertiliser control (according to normal farmers practise), 0.25, 1, 1.5, 3 and 4.5 NLBAR as a single application in time and a 1.5 NLBAR per year repeat application for three years.

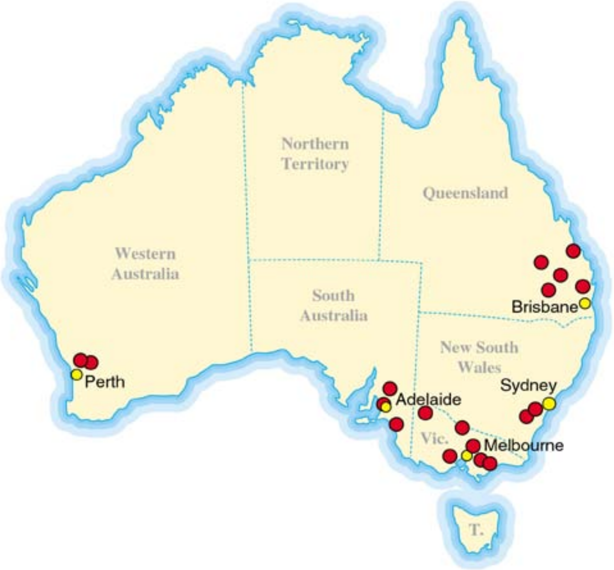


Figure 1. Locations of field experiments in the National Biosolids Research Program.

Table 1. Details of the field trials and selected soil properties (dry weight basis) for sites of the National Biosolids Research Program.

Field site	Location[a]	pH (0.01 M $CaCl_2$)	Organic carbon (%)	Clay content (%)	CEC[b] ($cmol_c$/kg)
Avon	SA	7.6	1.2	12	10.0
Brennans	WA	5.4	0.9	4	3.2
Bundaberg	Qld	4.5	1.4	16	5.0
Cecil Plains	Qld	7.3	1.4	66	61.0
Dookie	Vic	4.9	2.0	23	13.0
Dutson Downs	Vic	4.0	5.7	5	11.6
Esk	Qld	5.0	na	25	1.0
Flat Paddock	NSW	4.4	1.2	17	7.8
Kingaroy	Qld	5.0	1.8	41	16.5
Lowood	Qld	6.2	5.5	58	54.7
Melton	Vic	4.7	2.6	31	14.1
Mildura	Vic	7.9	0.6	11	8.3
Night Paddock	NSW	5.1	3.4	24	17.4
Pakenham	Vic	4.9	5.7	26	16.6
Spalding	SA	6.3	1.9	27	17.7
Tintinara	SA	6.3	1.8	10	10.3
Wilsons	WA	4.8	2.6	6	5.0

[a] SA = South Australia, NSW = New South Wales, QLD = Queensland, VIC = Victoria, WA = Western Australia. [b] CEC = cation exchange capacity.

Table 2: Selected chemical properties of the biosolids used in the NBRP.

Biosolids source and name	Sites applied	EC[a]	pH	Total C	Total N	KCL NH_4-N	KCl NO_3-N	CEC[b]	Total Cu	Total Zn
		(dS/m)	($CaCl_2$)	(%)	(%)	(mg/kg)	(mg/kg)	(cmol(+)/kg)	(mg/kg)	(mg/kg)
Bolivar agitated air dried (AAD)	SA sites	6.29	7.4	6.3	0.77	28	1690	35	315	435
Bolivar dried lagoon (BDB)	SA sites	7.04	7.4	8.6	0.98	49	1370	28	340	500
Goulburn Valley Water	Dookie	3.79	7.1	6.5	0.83	89	1420	24	65	180
North East Water	Dookie	6.47	5.0	11.6	2.03	480	4010	49	100	300
Vic Gippsland Water	Dutson Downs	6.78	5.6	20.4	2.85	3280	3910	61	70	180
Vic East Gippsland Water	Dutson Downs	4.10	4.6	10.6	1.25	82	2580	21	150	290
NSW Malabar STP -LSB 2002	NSW sites	4.06	7.6	20.2	1.55	1480	104	32	420	650
NSW Bondi STP dewatered cake 2003	NSW sites	5.92	6.2	28.7	2.50	3560	357	37	880	870
QLD Noosa	QLD sites	2.86	6.8	27.2	4.79	480	22	84	355	495
QLD Luggage Point	QLD sites	7.61	6.6	32.8	5.72	4660	3	68	830	1705
WA Woodman Point WWTP 2005	WA sites	4.39	6.9	32.2	5.17	4520	4	68	1500	900
WA Beenyup WWTP 2005	WA sites	4.34	6.8	34.7	5.54	4480	3	60	1170	615

[a] EC = electrical conductivity. [b] CEC = cation exchange capacity.

Various crops were grown on the plots depending on local agronomic and climatic conditions – wheat, barley, triticale, canola, grasses, clover, peanuts, sorghum, maize, millet, sugar cane and cotton. Wheat and canola rotations were set up in WA, SA and Victoria; triticale and oats were also established in Victoria; wheat was grown in NSW; and a variety of crops were grown in Queensland, including millet, maize, grain sorghum, forage sorghum and sugarcane. Crop responses from biosolids were compared to both an unfertilised control and conventional fertiliser applied at normal agronomic rates. Crop measurements included plant growth at maximum biomass stage and/or grain yields. In the case of pasture sites a cut and removal process on several occasions throughout the growing season was used. Crops were grown using best agronomic practices, harvested, and then edible portions of crops separated, dried, and after acid digestion, nutrient concentrations in plant shoots and/or edible portions were determined.

Results and Discussion

Application of biosolids had a positive effect on crop yields at most sites, with the main benefit from the biosolids probably being due to additions of N and P. Only examples of the responses can be shown here – full details are available in the State-based reports available from the authors.

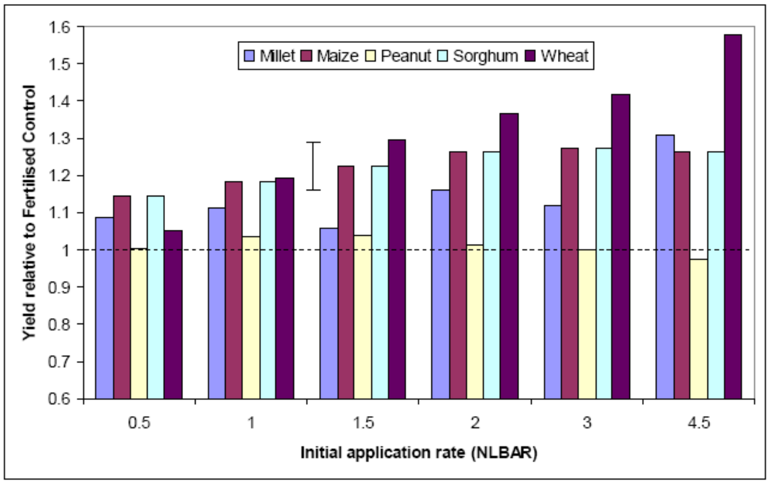
Queensland

Applications of biosolids at rates of 1 NLBAR or greater resulted in either similar or higher yields than the fertilised control standard (traditional farmer recommended rate) at all sites in the year following application (Figure 2). There were few yield advantages in applying biosolids at rates >1 NLBAR in the year of application, with the possible exception of the early grain crops at Kingaroy. Residual effects were negligible after the first sugarcane crop on the sandy soil at Bundaberg (mainly due to leaching losses of N), but lasted for 2 irrigated crops at Cecil Plains and were still evident after 5 crops in the rainfed system at Kingaroy, especially in the higher application rates. There were only small differences in the residual effects of the NLBAR and 3 NLBAR application rates in later crops, suggesting crops were not able to effectively utilise the additional nutrients supplied.

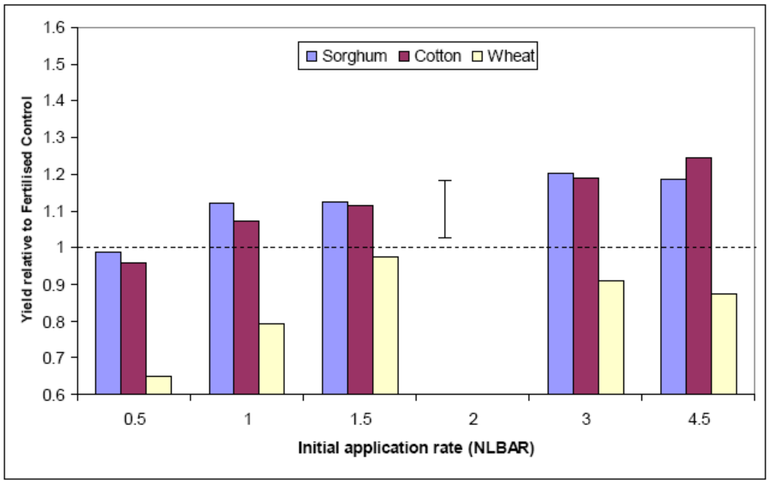
NSW

Crop responses in NSW were severely limited by drought conditions in 2002 and 2003 and crop yields were very variable across the sites. Crop early growth (Table 3) increased with increasing rates of biosolids application on both sites, although wheat performed better on the Night paddock, giving higher herbage yield and plant heights. Biosolids (DWC) applied at rates in excess of 1 NLBAR produced a significant increase in early plant growth compared to the control and fertilised control treatments, while a significant increase in plant growth was seen in the lime-stabilised biosolids (LSB) treatments at rates of only 0.75 NLBAR or above, probably because of the added liming effect of the LSB. Similarly, early plant growth on the Flat paddock site was also stimulated by biosolids application, with DWC application rates of 1.5 NLBAR and above resulting in increased plant growth. The application of LSB at rates above 0.75 NLBAR resulted in significant increases in plant growth. It can also be seen from Table 3 that the eight week herbage yields of the fertilised control treatment, where fertiliser was supplied once at the same time as the initial biosolids application in 2002, were no different from the unfertilised control.

(a) Kingaroy



(b) Cecil Plains



(c) Bundaberg

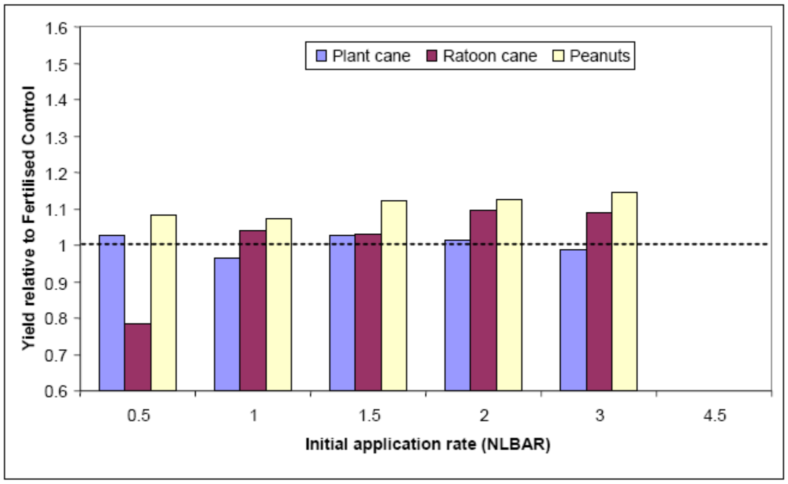


Figure 2. Harvested yields of all crops at (a) Kingaroy, (b) Cecil Plains and (c) Bundaberg, expressed as relative to yields in the fertilised control treatment (1.0 means the yield is equivalent to the yield of the treatment receiving mineral fertiliser). There were no interactions between biosolids type and either rate or crop type, so data are means of treatments with anaerobic and aerobic biosolids.

Table 3. Average herbage weights (g/20 plants DWT) and plant heights (mm), measured eight weeks after germination and final wheat grain yields (t/ha) in 2003 for plants grown on NSW soils (Flat and Night paddock) treated with dewatered biosolids (DWC) and lime-stabilised biosolids (LSB). Included also are the l.s.d values for each growth parameter following analysis of variance at $p<0.05$. Treatments with the same letter * are not significantly different. rpt = repeat application treatment, cont cult = cultivated only, cont fert -= fertiliser plus cultivation only and cont lime = cultivation plus lime only.

	Site					
	Night paddock			Flat paddock		
Treatment	Dry herbage wt (g/20 plants)	Plant ht (mm)	Grain yld (t/ha)	Dry herbage wt (g/20 plants)	Plant ht (mm)	Grain yld (t/ha)
Control (cult.)	7.37^{a}	249^{a}	5.6^{a}	1.36^{a}	121^{a}	0.8^{a}
Control (fert.)	6.68^{a}	229^{a}	6.7^{a}	2.46^{a}	138^{a}	0.7^{a}
DWC 0.5NLBAR	7.28^{a}	255^{a}	5.2^{a}	2.61^{a}	156^{a}	1.6^{a}
DWC 1NLBAR	7.61^{a}	249^{a}	6.1^{a}	1.97^{a}	143^{a}	1.3^{a}
DWC 1.5NLBAR	10.13^{b}	317^{c}	6.2^{a}	3.60^{a}	172^{a}	1.0^{a}
DWC 1.5NLBAR rpt	10.36^{b}	305^{b}	5.8^{a}	6.37^{b}	226^{b}	0.7^{a}
DWC 3NLBAR	11.17^{b}	288^{b}	5.5^{a}	5.90^{b}	218^{b}	2.7^{a}
DWC 4NLBAR	12.52^{c}	222^{a}	5.5^{a}	7.60^{c}	244^{c}	4.0^{b}
LSB Control (lime)	5.12^{a}	250^{a}	5.8^{a}	2.34^{a}	144^{a}	1.1^{a}
LSB 0.25NLBAR	7.58^{a}	238^{a}	5.6^{a}	2.08^{a}	137^{a}	2.4^{a}
LSB 0.5NLBAR	5.84^{a}	281^{b}	5.5^{a}	3.47^{a}	174^{a}	3.0^{b}
LSB 0.75NLBAR	9.74^{b}	281^{b}	5.8^{a}	2.45^{a}	154^{a}	2.8^{a}
LSB 1.5 NLBAR	8.72^{b}	289^{b}	6.3^{a}	5.44^{b}	225^{b}	3.2^{b}
LSB 2NLBAR	10.24^{b}	288^{b}	4.8^{a}	4.67^{b}	186^{b}	2.8^{a}
Control (fert.) rpt			6.0^{a}			1.1^{a}
Control (cult.) rpt			4.5^{a}			2.1^{a}
l.s.d. (p<0.05)	*3.32*	*43.7*	*6.4*	*2.7*	*54*	*2.3*

At the same time, growth responses were still seen on the biosolids treatments (at application rates equal to 1.5 NLBAR and above) two cropping seasons after they were first applied, indicating a significant residual effect of the nutrients applied. Unfortunately the treatment differences seen in early plant growth did not translate into increased grain yields, due likely to poor mid season rainfall.

Victoria

Biosolids applications generally increased plant weight at the mid tillering stage (8-10 weeks) and dry matter yield (t/ha) at harvest compared with the unfertilised control ($P<0.05$; Figure 3, Table 4). Overall biosolids application did not increase grain yield and 100 grain weight decreased at biosolid application rates at and above 1 NLBAR compared with the unfertilised control ($P<0.05$). The grain yield and grain weight data were probably affected, at least in part, by a lack of soil moisture during the growing season.

Rainfall at Dutson Downs and Melton was below long-term averages for all years and Dookie received below average rainfall in the second year. Under such circumstances and compared to an unfertilised control, it could be expected that the addition of nutrients that stimulated early season dry matter production would deplete soil moisture and adversely affect grain production later in the season.

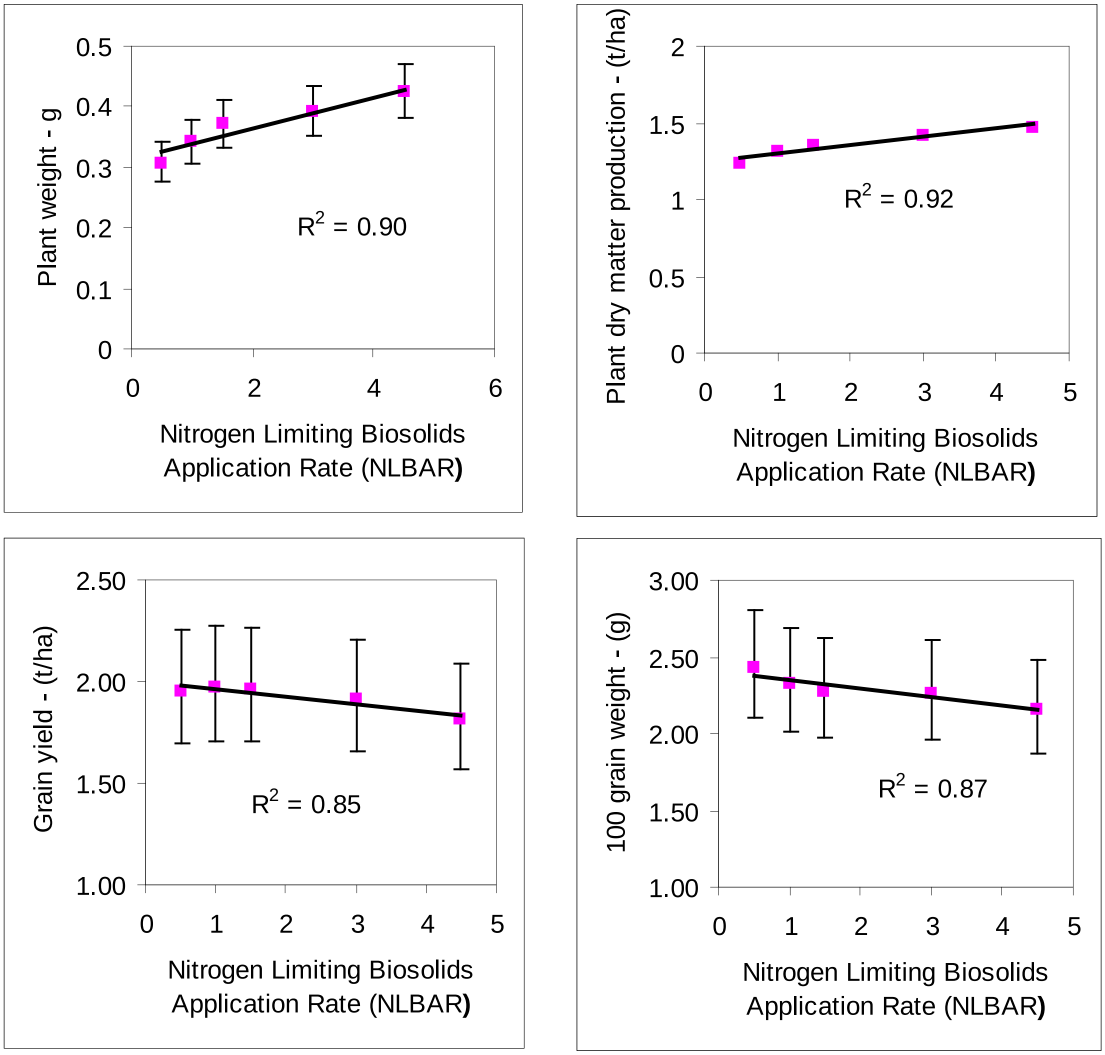


Figure 3 Effect of increasing biosolids application rates on plant weight at the mid tillering stage (8-10 weeks), dry matter at harvest, grain yield at harvest and 100 grain weight at harvest across the three Victorian biosolids cropping trial sites, Dutson Downs, Dookie and Melton over three growing seasons from 2003 to 2005.

Such an explanation was consistent with there being no differences in dry matter production between the biosolids and inorganic fertiliser treatments and neither treatment increased grain production ($P<0.05$).

South Australia

In South Australia biosolids application generally increased plant yields and grain protein content (Figure 4), but only in seasons and at sites with adequate rainfall.

Like Victoria and NSW, field trials were compromised by drought conditions in 2003 and 2004 and application of biosolids caused significant increases in crop shoot dry matter, but failed to increase grain yield due to early use of soil water by the crop (stimulated by nutrient addition in biosolids). This was clearly evidenced by a negative relationship between rate of biosolids application and 1000-grain weight, which indicates that at harvest grains were “pinched” i.e. lack of soil water resulted in incomplete grain fill.

Table 4. Plant weight at the mid tillering stage (8-10 weeks), dry matter at harvest, grain yield and 100 grain weight across the three Victorian biosolids cropping trial sites, Dutson Downs, Dookie and Melton over three growing seasons from 2003 to 2005.

Treatment Number	**NLBAR**[a]	Mid Tillering Plant Weight (g)	Harvest Plant Weight (t/ha)	Harvest Grain Yield (t/ha)	Harvest 100-Grain Weight. (g)
1 (control)	**0.0**	0.27	2.86	1.69	2.41
2	**0.5**	0.31	3.42	1.90	2.43
3	**1.0**	0.34	3.70	1.89	2.33
4	**1.5**	0.37	3.84	1.87	2.28
5	**3.0**	0.39	4.14	1.82	2.26
6	**4.5**	0.42	4.35	1.70	2.15
7	**1.5**[b]	0.40	4.29	1.89	1.99
8 (fertiliser)	**1.0**	0.32	3.34	1.79	2.37

[a] NLBAR: Nitrogen Limiting Biosolids Application Rate

[b] Annual application of biosolids

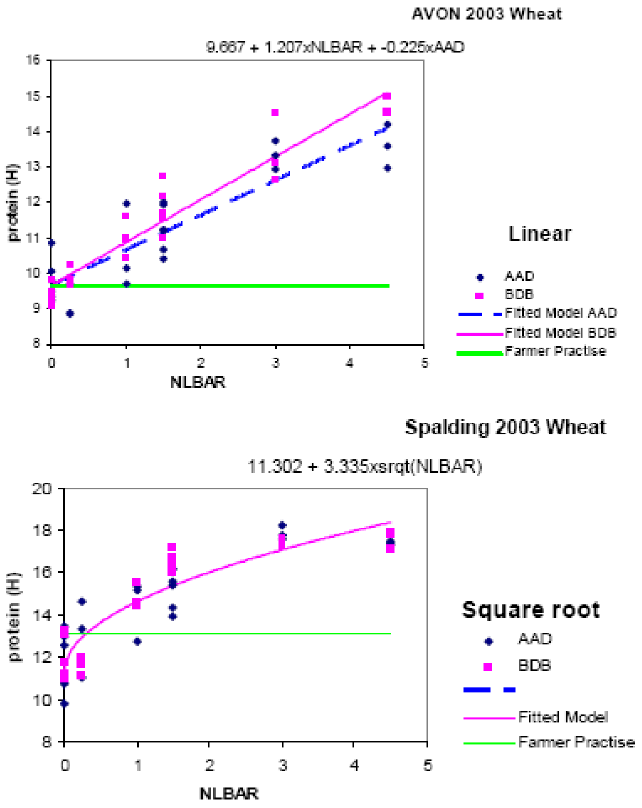


Figure 4. Effect of application of agitated air dried Bolivar biosolids (AAD) and air-dried Bolivar biosolids (BDB), compared to farmer fertiliser practice, on grain protein content of wheat grown at two sites in SA.

Western Australia

The two biosolids products used in WA (Woodman Point or Beenyup) resulted in similar plant responses. Generally there were no significant differences in wheat yield between the 1 NLBAR that had been applied in year 1 and the inorganic fertiliser treatment (100 kg/ha DAP + 100 kg/ha urea) that had been applied annually every year over the 3-year investigation (Figure 5). The response of canola to biosolids was slightly different in that canola yielded higher in the 1 NLBAR than in the fertiliser treatment in year 1 and less than the fertiliser treatment in year 2.

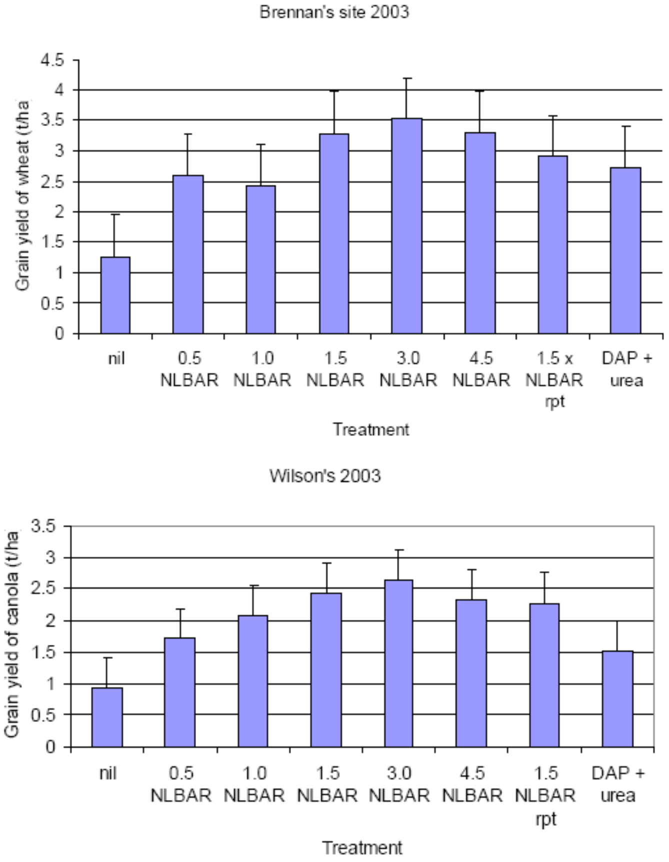


Figure 5. Relationship between rate of biosolids application and yield of wheat in relation to farmer fertiliser practice at two sites in WA in the first year after biosolids application.

Overview

Across all sites it was clear that biosolids applied at the NLBAR can supply sufficient nutrients for crop growth similar to farmer's current fertiliser practices. In general, biosolids applied at the NLBAR supplied sufficient or more nutrients for at least 1-2 annual cropping cycles (averaged across all sites in the NBRP) without the need for mineral fertiliser application.

At some sites, due to drought conditions, it was evident that application of biosolids had a detrimental effect on yield similar to that observed when excess fertiliser N (or other limiting nutrient) is supplied (Van Herwaarden et al., 1998; Ercoli et al., 2008). Limited soil water and excess nutrition stimulated shoot growth and depleted soil moisture to restrict full grain filling. Hence the crop produced a large amount of green shoot material, but because soil moisture has been depleted, grain fill and yield potential were compromised.

Agronomic implications for biosolid reuse recommendations

Results from the agronomic trials presented here for all States, and from more detailed investigations of nutrient release from biosolids in Queensland (Bell et al. 2004), indicate that biosolids provide a valuable amount of plant nutrients to crops. However, the amount of nutrients released appears in some cases to be in excess of crop demand and, depending on seasonal conditions, can adversely impact on yield of grain crops. This is particularly the case for N mineralization, and it should be noted that a good prediction of this process is important as it drives current annual biosolid application rates. Current N mineralization assumptions in NLBAR calculations perhaps require revisiting and validation for a range of growing conditions in Australia. Excess N is particularly problematic where rainfall is variable and crops suffer from moisture stress during the grain fill period. This excess nutrition early in the crop growth cycle is detrimental due to exhaustion of soil moisture required for grain fill and attainment of full yield potential (Ercoli et al., 2008; Saint Pierre et al., 2008.

Where grain crops can be tactically harvested early in their life cycle for fodder production (and not grain production), or where fodder crops are grown, the limitation of rapid N release does not pose a significant problem. Our results also demonstrate that biosolids provide a ready substitute for mineral fertilisers, which are becoming increasingly expensive.

Economic benefit of biosolids at the farm level

Where significant yield increases were observed with application of 1 NLBAR of biosolids and where high value crops were grown with fewer water limitations to growth (Queensland), returns at the farm level were high (Table 5). These returns were achieved with high N/P biosolids – "fresh" dewatered cake materials with N > 5.0% and P ≥ 2.5%.

Table 5. Estimates of the average value of NLBAR applications of Luggage Point and Noosa biosolids to growers at the three main Queensland experimental sites. This value was derived from additional returns from yield or quality benefits plus the value of the fertiliser saved, compared to the fertilised control treatment.

Location	**Fertiliser savings ($/ha)**	**Additional crop returns ($/ha)**	**Total benefit ($/ha)**	**Benefit ($/wet tonne)**
Kingaroy	$946.00	$397.25	$1343.25	$13.04
Cecil Plains	$1232.00	$587.47	$1819.47	$17.66
Bundaberg	$710.80	$203.89	$914.69	$8.88

In southern Australia, drought conditions limited crop production in most States, so a typical economic return could not be calculated. However, returns per hectare were generally much lower than those found in Queensland as the NLBAR treatment generally yielded similarly to the fertilised control treatment at most sites, so only fertiliser savings could be counted as benefit.

National agronomic value of biosolids

Some national assessments of the economic value of biosolids only consider the total nutrient content of the material and calculate value by multiplying by unit nutrient costs. In Australia, if we assume annual production of biosolids is 270,000 dry tonnes and (conservative) average N and P concentrations of 1.5% and 1.0%, respectively, at current unit fertiliser nutrient costs this would value N and P contained in Australia biosolids at over $20 million/yr. This ignores the fact that not all the nutrient in the biosolid is agronomically available to crops (i.e. mineralised or dissolved, and not lost to the environment), and also assumes that there is 100% recovery of biosolid nutrient by crops, which never occurs.

From data in the literature and agronomic results from the NBRP, we know that not all the N and P in Australian biosolids is plant available, nor is 100% of the released nutrient captured by crops under field conditions. Significant losses of N from soils were observed at some sites, both through leaching and probably also through gaseous N losses (this was not confirmed directly, but by inference from laboratory studies and incomplete mass balances in field studies). Rates of biosolid N mineralization observed under sub-tropical conditions were much greater than the 15-25% assumed in current State and national biosolid guidelines. In Queensland sites mineralisation rates averaged 55-60% of the applied organic N in the first 6-9 months after biosolids application, with at least 30% (and in some cases 60%) of the applied organic N mineralised within the first 6-8 weeks after incorporation. These results indicate a need to further examine nutrient release characteristics of biosolids under a range of Australian conditions.

Comparing the performance of crops grown on biosolid-amended soils to those grown on soil treated with manufactured fertilisers, we were able to place the agronomic value of 1 NLBAR of biosolids roughly equivalent to 1 to 2 years applications of manufactured fertilisers (DAP, MAP or urea, or a combination of these). Using data for State production of biosolids (Gale, pers. comm..), conservative assumptions of the total and mineralisable N (NLBAR) for each State's biosolids, current fertiliser prices, and fertiliser "farmer practice" as used in the NBRP trials in each State, we calculate the fertiliser substitution value of Australian biosolids to be of the order of $3 million/yr (Table 6). Note this ignores the value of nutrients other than N and P in the products.

Table 6. Fertiliser substitution values of Australian biosolids calculated using agronomic response data from the NBRP, typical or actual fertiliser application rates to crops in NBRP trials, State biosolid production and conservative assumptions of NLBAR in each State.

State	Highest NLBAR[1] dry t/ha	Annual N rate kg/ha	Annual P rate kg/ha	Value N \$/ha	Value P \$/ha	Cum. Value[2] \$/ha	Biosolid Prod. dry kt/yr	Fertiliser substitution value \$/yr
Qld	20	100	15	\$120	\$86	\$308	50	\$769,798
NSW	35	50	24	\$60	\$137	\$295	90	\$759,570
Vic	30	18	21	\$22	\$120	\$212	80	\$566,087
SA	40	11	13	\$13	\$74	\$131	25	\$81,973
WA	7	64	21	\$77	\$120	\$295	25	\$1,052,795
							270	\$3,230,223

[1] Uses lowest N content of biosolids produced and used in that State in NBRP trials.
[2] Assumes NLBAR equivalent to farmer fertiliser practice in Year 1 and 50% residual value.

Summary

Crop responses to applications of biosolids at rates recommended in current State guidelines generally increased crop production at sites that experienced reasonable seasonal conditions. Significant yield increases could be attained under good rainfall conditions, and with high value crops economic returns to the grower were up to $1800/ha from use of 1 application of biosolids at the NLBAR. This ignores additional costs of spreading for biosolids versus inorganci fertiliser.

In lower rainfall situations or where drought conditions were experienced, application of biosolids to grain crops either produced a small increase in grain yield, had no effect, or in some cases decreased it due to application of nutrients in excess of crop demand. Excessive nutrient addition (especially N) early in cereal crop growth exhausts soil moisture reserves through stimulating early vegetative growth, compromising grain production. In those areas prone to drought, these data indicate that biosolids could perhaps be more effectively used for forage crop production where strong vegetative growth is needed.

Application of 1 NLBAR of biosolids generally provided the equivalent crop production of typical fertiliser application rates by farmers, with a variable residual value in the second year depending on biosolid and site conditions. Using current fertiliser nutrient costs, the agronomic "fertiliser substitution" value for Australian biosolids is estimated to be ~$3 million per year.

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