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AGRONOMIC BIOSOLIDS APPLICATION RATES FOR DRYLAND WHEAT ACROSS A RANGE OF NORTHWEST CLIMATE ZONES

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ABSTRACT

Predicting agronomic rates is important to derive optimum economic and environmental benefits from biosolids fertilizer applications. We conducted this research to 1) evaluate dryland wheat response to biosolids applications over a range of climate zones in the Pacific Northwest and 2) compare agronomic application rates predicted from yield curves with those predicted from published extension guidance. We applied a range of biosolids rates during the fallow year in ten on-farm dryland wheat experiments located in five counties in central and eastern Washington and in one county in north-central Oregon. Grain yield, protein, and post-harvest soil nitrate were determined. Recommended nitrogen rates for each site were calculated from Extension nutrient management guidance, and compared with biosolids agronomic rate estimates based on 95% maximum yield from the regressions generated for each site. Eight of the ten sites had quadratic yield responses. The two non-responsive sites had high pre-application levels of soil nitrate-N. Protein response was linear at most sites, while soil nitrate accumulation was variable, with the greatest increases at the least responsive sites. Field agronomic rates were within 20 lb N/acre (0 to 0.6 dry tons biosolids/acre) of recommended rates at six of the 10 sites. Greater differences at the other sites resulted from leaching, drought, or high pre-application soil N. At the eight sites that responded to N application, a median biosolids application rate of 2.2 dry ton/acre (approx 200 lb biosolids total N per acre) was required for 95% of maximum grain yield. This research demonstrated that the use of a WA fertilizer guide together with a PNW worksheet for estimating available N from biosolids gave reasonable estimates for biosolids application rates. We suspect that one of the benefits of biosolids for dryland wheat production is that wet crop years increase both grain yield potential and N mineralized from biosolids.

INTRODUCTION

Biosolids can replace inorganic N in dryland grain rotations, and farmers perceive benefits from biosolids organic matter. Biosolids application rates need to be based on agronomic, economic, and environmental criteria. Farmers and biosolids managers must be confident that biosolids applications will produce grain yield and quality equivalent to that obtained with inorganic fertilizer applications. At the same time, biosolids applications should not increase the potential for nitrate accumulation and leaching. The objectives of this study are to:

1. Evaluate dryland wheat response to biosolids applications over a range of climate zones in the Pacific Northwest
2. Compare agronomic application rates predicted from yield curves with those predicted from published extension guidance.

METHODS

We established ten experiments on commercial wheat farms in the dryland grain production area of Washington and Oregon (Tables 1 and 2). Four sites were located in central Washington (Douglas and Kittitas Counties), four in eastern Washington (Adams, Lincoln, and Spokane Counties) and two in north-central Oregon (Sherman County). All experiments were laid out in a randomized complete block design with three or four replications. Treatments included two to five biosolids rates (Table 3) at least one inorganic N rate, and a zero-N control. Inorganic N rates were chosen based on those typically used by the cooperating farmers (45 to 60 lb N/acre). The crop at all sites was soft white winter wheat grown in a 2-year wheat-fallow rotation. Each site received anaerobically digested biosolids applied during the fallow year. Cooperating farmers at each site managed the plots: planting, tilling, and managing weeds according to their normal practices. Grain was harvested in July or August of the crop year, and soil samples (0 to 36-inch depth) were collected before biosolids application and after harvest for nitrate. Grain yield, grain protein, and post-harvest soil NO_3-N response curves were calculated for each experimental site using regression equations (SAS Version 8 and Sigmaplot Version 9)

Data for each field location-year was input into an Extension worksheet that estimates agronomic application rates for biosolids for the Pacific Northwest (PNW 511; Cogger and Sullivan, 2007). We used the Washington winter wheat guide EB1987 (Koenig, 2005) to estimate fertilizer N requirements for our research sites. We calculated the biosolids N rate needed to achieve 95% maximum yield from the yield regressions, and compared those results to the recommendations based on PNW 511 and EB 1987.

Table 1. Description of on-farm biosolids experiment sites.

Site[1]	County	Soil series	Parent material	Organic matter (g/kg)	Initial Soil NO_3-N (lb/acre)	Wheat variety
			Washington Small Plot			
K-91su	Kittitas	Mozen sil	loess	22	41	Sprague
K-92	Kittitas	Vollinger sil	loess	30	68	Eltan
S-92su	Spokane	Phoebe sl	outwash	-	71	Basin
			Washington Large Plot			
A-92	Adams	Ritzville sil	loess	13	33	Tres
A-93	Adams	Ritzville sil	loess	14	33	Moro
D-92sp	Douglas	Touhey loam	loess/till	12	44	Eltan
D-94	Douglas	Touhey loam	loess/till	19	28	Eltan
L-92su	Lincoln	Hanning sil	loess	28	203	Rely
			Oregon Large Plot			
O-95	Sherman	Walla Walla sil	loess/ basalt	12	14	Rohde
O-96	Sherman	Walla Walla sil	loess	15	45	Stephens / Madsen

[1] The site code stands for the location and year of biosolids application. A lower case “su” indicates sites with biosolids applications during the summer of the fallow year, and "sp" indicates biosolids application during the spring of the fallow year. At Oregon locations (O-95

and O-96), both fall and spring biosolids application treatments applied during fallow year. All other sites received biosolids during the fall of the fallow year.

Table 2. Precipitation measured at stations near on-farm sites.

Site	Precipitation			Observations
	Normal Annual	Fallow (Oct-Aug)	Crop Total (Sep-Jul)	
K-91su	8.9[1]	6.8	7.7	Dry fallow & crop year
K-92	8.9[1]	9.7	6.6	Lodging without excessive vegetative growth (disease?)
S-92su	16.5[1]	12.8	15.6	Nitrate leached below rooting depth during winter of crop year
A-92	11.3	12.7	7.8	Dry crop year
A-93	9.9	5.6	13.3	Timely spring rain
D-92sp	11.2	10.6	12.7	Wet spring
D-94	11.2	14.3	11.7	Timely spring rain
L-92su	14.4	10.4	15.1	Nitrate retained in top 30 inches during wet winter
O-95	11.1	13.9	15.1	Shallow soil (30 to 40 in depth)
O-96	11.1	13.5	12.2	Above average precipitation (3.1 in) during May of crop year

[1] Rainfall at K and S average about 2 inches per year more than at the closest weather stations

Table 3. Biosolids applications at on-farm sites.

Site	Biosolids Source	Biomass	Total Nitrogen
		Dry ton/acre	Lb N/acre
K-91su	Ellensburg	1.5, 3, 4.5, 6	121, 242, 363, 484
K-92	Ellensburg	1.1, 2,2, 3.4, 5.2, 6.8	102, 204, 306, 459, 612
S-92su	Spokane	1.9, 3.7, 5.6, 7.4, 9.2	148, 296, 444, 592, 740
A-92	Renton	3, 6, 9	257, 513, 770
A-93	Renton	3, 4.5, 6	330, 445, 660
D-92sp	Renton	3, 6	311, 622
D-94	Renton	2, 3, 4.5	198, 322, 458
L-92su	Spokane	3, 6, 9	242, 363, 484
O-95	Rock Creek	1.4, 2.3, 4.4	135, 221, 423
O-96	Rock Creek	1.7, 3.4, 5.1	143, 286, 429

RESULTS AND DISCUSSION

Eight of the ten sites had quadratic yield responses (not shown). Sites K-92 and L-92su were non-responsive, probably because of high pre-application levels of soil nitrate-N. Site A-92 had a weak yield response, which may have been caused a dry crop year.

Estimated N requirements for the wheat crops ranged from 0 to 97 lb N/acre based on EB1987, the Dryland Winter Wheat Nutrient Management Guide for Eastern Washington (Table 5). Biosolids available N calculated from PNW 511, the biosolids agronomic rate worksheet, ranged from 25 to 40 lb available N/dry ton (Table 4). Recommended biosolids application rates ranged from 0 to 3.4 dry tons per acre over all sites, and from 2.1 to 3.4 dry tons per acre when including only the eight responsive sites (Table 5).

Field agronomic rates were calculated as the rate of N needed to reach 95% of maximum yield based on the quadratic yield response regression equations. Field agronomic rates were within 20 lb N/acre (0 to 0.6 dry tons biosolids/acre) of recommended rates (EB1987) at 6 of the 10 sites (Table 5). At the other sites, greater differences between N recommended by the WSU guide, and that demonstrated by grain yield response resulted from leaching or drought. At Site S-92, the higher biosolids application rate needed to reach 95% of maximum grain yield (6.8 dry tons supplying an estimated 169 lb/acre of plant-available N) was the result of loss of profile N by leaching during a wet crop-year. At S-92, it appears that additional N mineralized during the spring of the crop year provided the observed yield response. Site A-92 had a flatter response curve than the other sites (probably because of dry conditions), leading to a low agronomic rate predicted from the yield equations.

At two sites with higher fertilizer guide N credits (L-92 and K-92), no yield response to biosolids application was observed, in agreement with fertilizer guide predictions. Site K-92 was non-responsive to both biosolids and fertilizer N. This site had relatively high credits for pre-application profile nitrate-N and relatively high organic matter (3%), resulting in a low recommendation for fertilizer N from the WSU guide. Grain yield without N at this site was 76 bu/acre, reflecting higher than normal N credits. Site L-92, with very high pre-application profile nitrate-N and high organic matter (2.8%) showed no yield response to biosolids or fertilizer. The lack of yield response at sites with high fertilizer guide N credits supports the conclusion that N is the major nutrient affecting crop yield response to biosolids at our sites.

SUMMARY

At the eight sites that responded to N application, a median biosolids application rate of 2.2 dry ton/acre (approx 200 lb biosolids total N per acre) was required for 95% of maximum grain yield. For practical biosolids management, it is important to consider other aspects of crop response to biosolids in addition to the grain yield data presented here. Increased straw production and increased grain protein was generally observed as biosolids rate increased from 2 to 4 dry ton/acre (data not shown). Postharvest nitrate-N for biosolids treatments was generally similar to that observed for the farmer N fertilizer rate at biosolids application rates less than 4 dry tons per acre (data not shown). Therefore, a reasonable rate of biosolids application was typically between 2 and 4 dry ton/acre. Some biosolids spreaders are not capable of even spreading at rates below 3 dry ton/acre (approx. 15 wet ton/acre). This study showed that a 3 dry ton/acre biosolids application rate supplied approximately 90 lb of plant-available N per acre.

REFERENCES

Cogger, C. and D. Sullivan. 2007. Worksheet for calculating biosolids application rates in agriculture. Revised. PNW 511. Washington State University Extension. Pullman, WA.

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Table 4. Biosolids available N estimated from Extension Agronomic Rate worksheet.

		Biosolids analysis					
Site	Biosolids Type	Total N	NH_4-N	Solids	Mineralization estimate[1]	NH_4-N retention estimate[2]	Available N estimate[3]
		------ $g\ kg^{-1}$ -------			%	%	lb/dry ton
K-91su	Anaerobic digestion, lagoon, drying bed	40	10	820	15	100	29
K-92	Anaerobic digestion, lagoon, drying bed	45	7	900	15	100	25.4
S-92su	Anaerobic digestion, dewatered	40	10	240	35	20	25
A-92	Anaerobic digestion, dewatered	43	12	280	35	20	26.5
A-93	Anaerobic digestion, dewatered	55	11	240	35	20	35.2
D-92sp	Anaerobic digestion, dewatered	52	14	200	35	50	40.6
D-94	Anaerobic digestion, dewatered	52	13	220	35	50	40.3
L-92su	Anaerobic digestion, dewatered	40	10	170	35	50	31
O-95	Anaerobic digestion, dewatered	48	14	170	35	20	29.4
O-96	Anaerobic digestion, dewatered	42	12	190	35	20	25.8

[1]Mineralization estimates from PNW 511 are 35% of organic N for dewatered biosolids, and 15% for biosolids stored in lagoon for 2 to 10 years.

[2] NH_4-N retention estimates from PNW 511 are 20% for biosolids left on surface, 50% for incorporation 1 day after application, and 100% for dried biosolids.

[3] Plant-available N estimate is the sum of organic N mineralized and ammonium-N retained.

Table 5. Comparison of recommended biosolids application rate (Nutrient Management Guide) and agronomic (95% maximum yield) application rate calculated from regression equations.

	Biosolids	N recommendation from WSU guide			Agronomic rate from yield regression			
Site	Avail N[1]	Yield Goal	WSU guide N[2]	Biosolids rate	95% maximum grain yield[3]	Biosolids rate	N supplied	Difference[5]
	lb/dry ton	bu/acre	lb/acre	dry ton/acre	bu/acre	dry ton/acre[4]	lb/acre	lb/acre
K-91su	29	60	77	2.7	42	2.3	67	-10
K-92	25.4	60	34	1.3	76	0.0	0	-34
S-92su	25	75	82	3.3	66	6.8	169	88
A-92	26.5	55	90	3.4	52	1.7	46	-44
A-93	35.2	50	74	2.1	43	1.6	57	-17
D-92sp	40.6	60	94	2.3	82	1.2	49	-45
D-94	40.3	60	96	2.4	64	2.0	82	-14
L-92su	31	70	0	0.0	49	0.0	0	0
O-95	29.4	50	97	3.3	48	2.7	78	-19
O-96	25.8	60	87	3.4	65	3.6	92	5

[1] From Table 4
[2] N recommendation from EB1987 is N requirement in lb/acre (2.7 * yield goal) minus N credits (soil nitrate N in 0-3 ft depth [Table 1] and contribution from soil organic matter 20 * % organic matter [Table 1]).
[3] 95% of maximum yield calculated from quadratic yield regression equations (not shown). 100% maximum yield is shown for non-responsive sites (K-92 and L-92s).
[4] Biosolids rate that produced 95% of maximum yield based on quadratic yield regression equation.
[5] Difference = (Fertilizer guide recommended N rate) minus (N supplied by agronomic biosolids rate)