Technical Report TR05-06 March 2005

Agricultural Experiment Station

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Biosolids Application to No-Till Dryland Rotations: 2003 Results

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The Cities of Littleton and Englewood, Colorado and the Colorado Agricultural Experiment Station (project number 15-2921) funded this project.

INTRODUCTION

Recycling of biosolids on dryland winter wheat (*Triticum aestivum*, L.) can supply a reliable, slow-release source of nitrogen (N) and organic material (Barbarick et al., 1992). Barbarick and Ippolito (2000) found that continuous application of biosolids from the Littleton/Englewood, CO wastewater treatment plant to dryland winter wheat-fallow rotation provides 16 lbs N per dry ton. This research involved tilling the biosolids into the top 8 inches of soil. A new question related to soil management in a biosolids beneficial-use program is: How much N would be available if the biosolids were applied in a no-till dryland agroecosystem?

Our objective was to compare agronomic rates of N fertilizer to an equivalent rate of biosolids in combination with winter wheat-fallow (WF), winter wheat-corn (*Zea mays*, L.)-fallow (WCF), and winter wheat-winter wheat-corn-sunflowers (*Helianthus annuus*, L.)-fallow (WWCSF) crop rotations. Our hypotheses are that biosolids addition compared to N fertilizer:

1. Will produce similar crop yields.
2. Will not differ in grain P, Zn, and Cu levels (Ippolito and Barbarick, 2000) or soil P, Zn, and Cu AB-DTPA extractable concentrations, a measure of plant availability (Barbarick and Workman, 1987).
3. Will not affect soil salinity (electrical conductivity of saturated soil-paste extract, EC) or soil accumulation of nitrate-N (NO_3-N).

MATERIALS AND METHODS

We established our research on land owned by the Cities of Littleton and Englewood (L/E) in eastern Adams County, approximately 25 miles east of Byers, CO. The Linnebur family manages the farming operations for L/E. Soils belong to the Adena-Colby association where the Adena soil is classified as an Ustollic Paleargid and Colby is classified as an Ustic Torriorthent. No-till management is used in conjunction with crop rotations of WF, WCF, and WWCSF. We installed a Campbell Scientific weather station at the site in April 2000 (see Table 1 for precipitation data).

With biosolids application in August 1999, we initiated the study. Wheat planting occurred in September 1999 (see Table 2). We designed the experiment so that every phase of each rotation is present during each year (10 plots total /replication). We used two replications of each rotation (20 plots total) and we completely randomized each replicated block. Each plot was 100 feet wide by approximately 0.5 mile long. The width was split so that one 50-foot section received commercial N fertilizer (applied with the seed and sidedressed after plant establishment; Table 2) and the second 50-foot section received biosolids (applied by L/E with manure spreader). We randomly selected which strip in each rotation received N fertilizer or biosolids. We provide the characteristics of the L/E biosolids in Table 3. We based the N fertilizer and biosolids applications on soil test recommendations determined on each plot. The Cities of L/E completed biosolids application for the summer crops in March 2000, 2001, 2002, and 2003. We planted the first corn crop in May 2000 and the first sunflower crop in June 2000. We also established wheat rotations in September 2000, 2001, and 2002, corn rotations in May 2001, 2002, and 2003, and sunflower plantings in June 2001, 2002, and 2003.

We completed wheat harvests in July 2000, 2001, 2002, and 2003 and corn and sunflowers in October 2000 and 2001 and sunflowers in December 2003. We experienced corn and sunflower crop failures in 2002 and a corn failure in 2003 due to lack and timing of precipitation (Table 1). For each harvest, we cut grain from four areas of 5 feet by approximately 100 feet. We determined the yield for each area and then took a subsample from each cutting for subsequent grain analyses for protein or N, P, Zn, and Cu content (Ippolito and Barbarick, 2000).

Following each harvest, we collected soil samples using a Giddings hydraulic probe. For AB-DTPA extractable P, Zn, and Cu and EC, we sampled to one foot and separated the samples into 0-2, 2-4, 4-8, and 8-12 inch depth increments. For soil NO_3-N analyses, we sampled to 6 feet and separated the samples into 0-2, 2-4, 4-8, 8-12, 12-24, 24-36, 36-48, 48-60, and 60-72 inch depth increments. We were not able to collect samples from the WWCSF rotation.

For the wheat and corn rotations, the experimental design was a split-plot design where type of rotation was the main plot and type of nutrient addition (commercial N fertilizer versus L/E biosolids) was the subplot. For crop yields and soil-sample analyses, main plot effects, subplot effects, and interactions were tested for significance using least significant difference (LSD) at the 0.10 probability level. Since we only had one sunflower rotation, we could only compare the commercial N versus L/E biosolids using a "t" test at the 0.10 probability level.

RESULTS AND DISCUSSION

Precipitation Data

Table 1 presents the monthly precipitation records since we established the weather station at the Byers research site. The plots received more than 11 inches of total annual rainfall in 2000 and 2001, only 5 inches in 2002, and about 12 inches in 2003. The critical months for corn are July and August (Nielsen et al., 1996). The Byers site received 6.0, 3.8, 1.3, and 2.6 inches of precipitation in July and August 2000, 2001, 2002, and 2003, respectively.

2003 Grain Data

As shown in Figure 1, the biosolids-amended WCSFW rotation produced significantly larger wheat yields than all other rotations. The N fertilizer treatment produced larger yields than biosolids additions in the WF rotation.

Grain protein (Figure 2) and grain P content (Figure 3) were not affected by any treatment or rotation. Biosolids addition produced higher grain Zn (Figure 4) but treatment or rotations did not affect Cu concentrations (Figure 5).

Sunflower yields were 635 and 734 pounds per acre for the biosolids and commercial N fertilizer treatments, respectively. The yields were not statistically significantly different. Due to lack of July-August precipitation (Table 1), we experienced a corn crop failure in 2003.

2003 Soil Data

As shown in Figure 6, biosolids addition produced the largest surface AB-DTPA-extractable P in the WCF treatment, having at least 15 mg kg^{-1} more AB-DTPA P than any other treatment. Biosolids addition actually resulted in lower AB-DTPA P than with N fertilizer in the 2 to 4 inch soil depth. Biosolids resulted in larger AB-DTPA-extractable Zn (Figure 7) at all depths except 2 to 4 inches and in the surface for AB-DTPA Cu (Figure 8). While the N source, type of rotation, and the rotation by N source interaction affected the EC (Figure 9) at various depths, we did not observe any consistent trends. Biosolids did produce higher NO_3-N than commercial N fertilizer at the 2-24 inch soil depths (Figure 10).

For the corn rotations, biosolids application resulted in higher AB-DTPA-extractable P concentrations in the soil surface (Figure 11). None of the treatments affected the AB-DTPA-extractable Zn (Figure 12). Despite the significant impacts of the N source and type of rotation on AB-DTPA Cu (Figure 13), the EC (Figure 14), and soil NO_3-N (Figure 15) we did not observe consistent trends. Biosolids did produce higher NO_3-N than commercial N fertilizer in the 0-2-inch soil depth.

As shown in Table 4, biosolids produced higher EC at all depths except for 2-4 inches. For soil NO_3-N, biosolids addition resulted in higher concentrations at 4-8 and 36-48 inches.

CONCLUSIONS

Relative to our three objectives listed on page 2, we have found the following trends:

1. Application of biosolids has produced the same crop yields as those of commercial N fertilizer.
2. We have not observed consistent trends regarding biosolids effects on grain or soil levels of P, Zn, and Cu after biosolids application.
3. We have not observed consistent trends regarding biosolids effects on soil salinity or the soil accumulation of NO_3-N.

We have also found some grain and soil differences associated with crop rotation or the interaction of rotation and type of nitrogen addition; but, we have not observed consistent trends in most cases.

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Table 1. Monthly mean maximum (Max) and minimum (Min) temperatures and precipitation (Precip) in inches at the Byers research site, 2000-2004. (Weather station was installed in April, 2000).

Month	2000			2001			2002			2003			2004		
	Max °F	Min °F	Precip inches	Max °F	Min °F	Precip inches	Max °F	Min °F	Precip inches	Max °F	Min °F	Precip inches	Max °F	Min °F	Precip inches
January	†	†	†	41.0	20.7	0.2	44.1	17.0	0.1	50.4	23.3	0.0	44.9	20.2	0.0
February	†	†	†	42.1	19.0	0.1	48.2	19.7	0.2	39.9	17.1	0.1	42.6	20.4	0.1
March	†	†	†	49.9	27.5	0.2	46.5	17.7	0.2	55.0	29.6	1.0	61.2	31.3	0.1
April	68.9	38.4	0.6	64.2	36.4	1.5	65.8	35.2	0.3	65.0	37.5	1.5	61.9	35.6	0.9
May	78.4	47.0	0.9	70.0	43.7	2.4	73.5	41.8	0.7	71.3	45.3	1.8	75.8	44.8	1.4
June	80.4	49.3	0.9	85.9	53.5	2.4	89.0	56.9	1.2	76.8	51.1	4.7	78.3	51.1	4.1
July	91.9	61.0	2.5	92.2	61.1	1.9	93.3	62.2	0.2	97.4	62.1	0.2	86.9	57.6	1.0
August	90.8	60.2	3.5	88.8	59.0	1.9	88.2	57.0	1.1	91.0	60.5	2.4	85.2	54.6	1.5
September	80.6	49.8	0.8	82.0	51.6	0.8	78.1	50.5	0.7	76.2	45.6	0.1	80.8	50.7	0.6
October	65.9	38.7	1.6	68.0	37.2	0.2	58.6	33.0	0.2	72.3	41.2	0.1	67.3	38.6	0.4
November	40.8	20.0	0.3	56.2	28.9	0.8	50.2	27.1	0.1	51.3	24.3	0.0	48.0	26.6	0.3
December	41.7	17.0	0.3	45.4	21.4	0.0	47.1	22.8	0.0	47.2	20.8	0.0	46.4	22.4	0.1
Total			11.4			12.4			5.0			11.9			10.5

† We installed the weather station in mid-April, 2000.

Table 2. Biosolids and fertilizer applications and crop varieties used at the Byers research site, 1999-2004.

Year Planted	Date Planted	Crop	Variety	Biosolids tons/acre	Bio/N equiv. lbs	N lbs/acre with seed	N lbs/acre after planting	Total N lbs/acre	P_2O_5 lbs/acre	Zn lbs/acre
1999	Early Oct.	Wheat	Halt	2.4	38.4	5	40	45	20	0
2000	May	Corn	Pioneer 3752	4	64	5	40	45	15	5
2000	June	Sunflowers	Triumph 765, 766 (confection type)	2	32	5	40	45	15	5
2000	9/25/00	Wheat	Prairie Red	0	0	4	0	4	20	0
2001	5/11/01	Corn	DK493 Round Ready	5.5	88	5	40	45	15	5
2001	6/20/01	Sunflowers	Triumph 765C	2	32	5	40	45	15	5
2001	09/17/01	Wheat	Prairie Red	Variable	Variable	5	Variable	Variable	20	0
2002		Corn	Pioneer 37M81	Variable	Variable	5	Variable	Variable	15	5
2002		Sunflowers	Triumph 545A	0	0	5	0	0	15	5
2002		Wheat	Stanton	Variable	Variable	5	Variable	Variable	20	0
2003	05/21/03	Corn	Pioneer K06							
2003	06/28/03	Sunflowers	???							
2003		Wheat	Stanton	Variable	Variable	5	Variable	Variable	20	0
2004		Corn	Triumph 9066 Roundup Ready	Variable	Variable	5	Variable	Variable	15	5
2004		Sunflowers	Triumph 765 (confection type)	0	0	5	0	0	15	5
2004	09/17/04	Wheat	Yumar	3	54	0	50	50	15	5

Table 3. Littleton/Englewood biosolids used at the Byers Research site, 1999-2004.

Parameter	1999 Wheat	2000 Corn, Sunflowers	2001 Corn, Sunflowers	2001 Wheat	2003 Corn, sunflowers	2003 Wheat	2004 Wheat
Total solids, g kg^{-1}	217	---	210	220	254	192	197
pH	7.6	7.8	8.4	8.1	8.5	8.2	8.8
EC, dS m^{-1}	6.2	11.2	10.6	8.7	7.6	7.4	4.5
Organic N, g kg^{-1}	50	47	58	39	54	46	43
NH_4-N, g kg^{-1}	12	7	14	16	9	13	14
NO_3-N, g kg^{-1}	0.023	0.068	0.020	0.021	0.027	0.016	0.010
K, g kg^{-1}	5.1	2.6	1.6	1.9	2.2	2.6	2.1
P, g kg^{-1}	29	18	34	32	26	28	29
Al, g kg^{-1}	28	18	15	18	14	15	17
Fe, g kg^{-1}	31	22	34	33	23	24	20
Cu, mg kg^{-1}	560	820	650	750	596	689	696
Zn, mg kg^{-1}	410	543	710	770	506	629	676
Ni, mg kg^{-1}	22	6	11	9	11	12	16
Mo, mg kg^{-1}	19	22	36	17	21	34	21
Cd, mg kg^{-1}	6.2	2.6	1.6	1.5	1.5	2.2	4.2
Cr, mg kg^{-1}	44	17	17	13	9	14	18
Pb, mg kg^{-1}	43	17	16	18	15	21	26
As, mg kg^{-1}	5.5	2.6	1.4	3.8	1.4	1.6	0.5
Se, mg kg^{-1}	20	16	7	6	17	1	3
Hg, mg kg^{-1}	3.4	0.5	2.6	2.0	1.1	0.4	0.9
Ag, mg kg^{-1}	---	---	---	---	15	7	0.5
Ba, mg kg^{-1}	---	---	---	---	---	---	533
Be, mg kg^{-1}	---	---	---	---	---	---	0.05
Mn, mg kg^{-1}	---	---	---	---	---	---	239

Table 4. Soil characteristics for the sunflower rotation (SFWWC) at the Byers research site for 2003. ***Highlighted parameters*** are significant at the 10% probability level.

Parameter, units	Depth, inches	Nitrogen	Biosolids	Probability level
AB-DTPA P, mg kg^{-1}	0-2	37.0	30.4	0.358
	2-4	8.9	5.5	0.269
	4-8	3.2	2.9	0.422
	8-12	4.3	1.8	0.273
AB-DTPA Zn, mg kg^{-1}	0-2	1.1	0.5	0.230
	2-4	0.2	0.1	0.237
	4-8	0.1	0.1	0.160
	8-12	0.1	0.1	0.471
AB-DTPA Cu, mg kg^{-1}	0-2	5.3	3.2	0.299
	2-4	2.5	2.2	0.202
	4-8	3.0	3.9	0.239
	8-12	2.6	2.8	0.181
ECe, dS m^{-1}	***0-2***	***0.41***	***0.50***	***0.019***
	2-4	0.63	0.77	0.226
	4-8	***0.55***	***0.81***	***0.049***
	8-12	***0.41***	***0.80***	***0.029***
NO_3-N, mg kg^{-1}	0-2	8.1	7.9	0.295
	2-4	5.7	18.5	0.397
	4-8	***9.7***	***23.2***	***0.060***
	8-12	4.8	26.8	0.108
	12-24	3.6	25.0	0.222
	24-36	7.4	3.8	0.584
	36-48	***4.3***	***2.6***	***0.027***
	48-60	0.9	0.9	0.229
	60-72	0.4	0.4	0.705

Figure 1. Grain yields for 2003 dryland-wheat-rotation harvests comparing Littleton/Englewood biosolids to commercial fertilizer. In the statistical, $LSD_{0.10}$ represents the least significant difference at the 10% probability level and NS indicates non-significant differences.

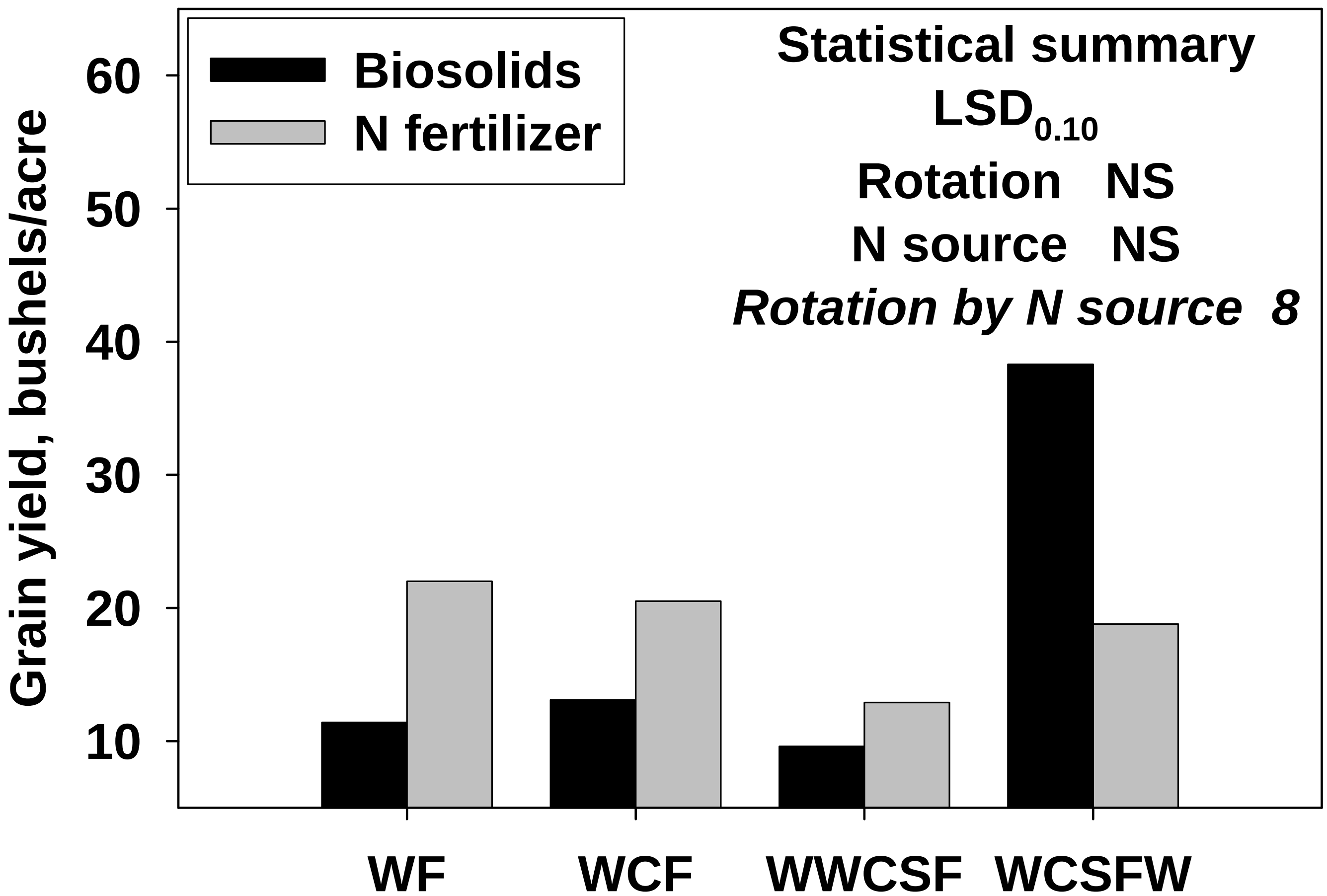


Figure 2. Grain protein concentrations for 2003 dryland-wheat-rotation harvests comparing Littleton/Englewood biosolids to commercial fertilizer. In the statistical, $LSD_{0.10}$ represents the least significant difference at the 10% probability level and NS indicates non-significant differences.

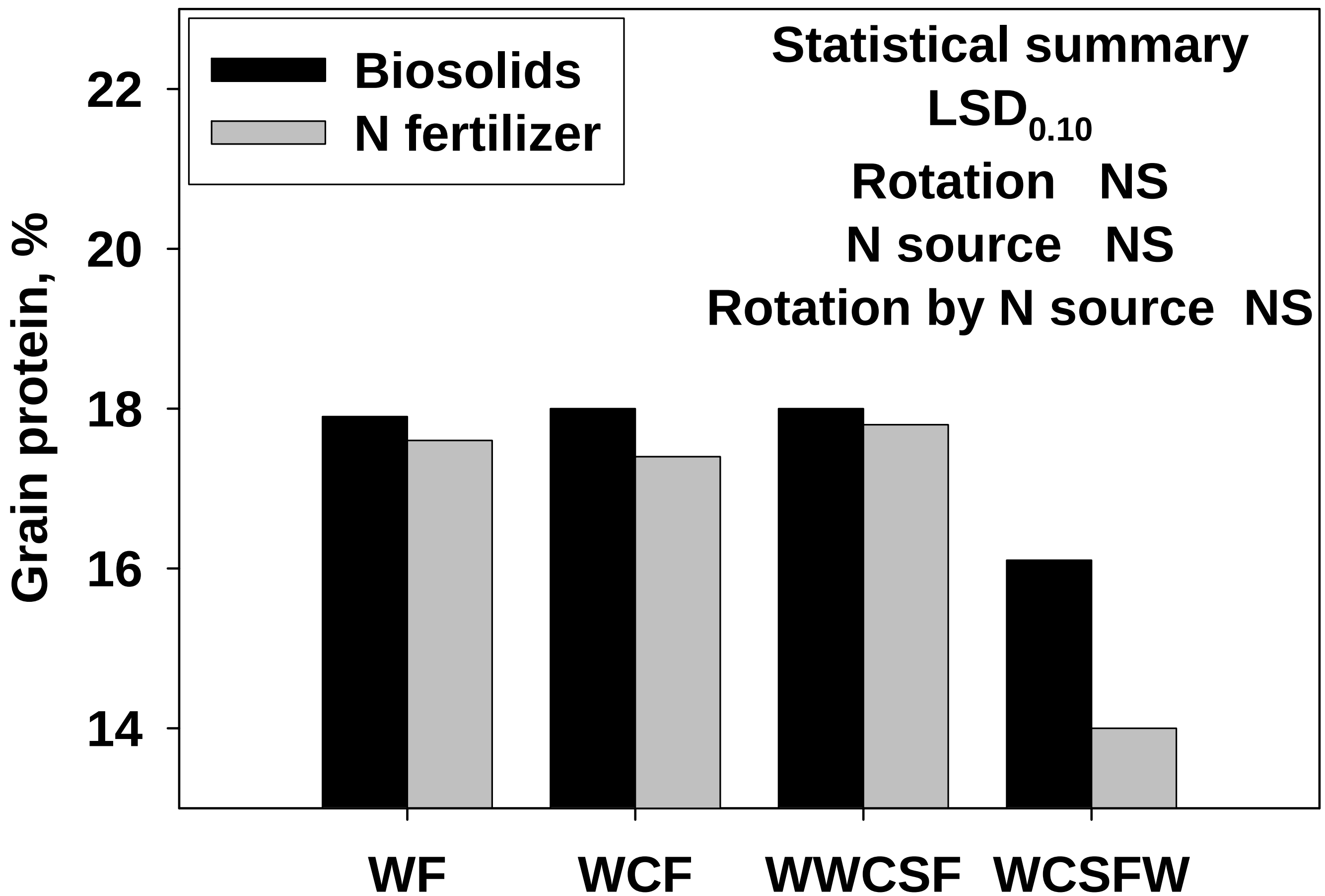


Figure 3. Grain P concentrations for 2003 dryland-wheat-rotation harvests comparing Littleton/Englewood biosolids to commercial fertilizer. In the statistical, $LSD_{0.10}$ represents the least significant difference at the 10% probability level and NS indicates non-significant differences.

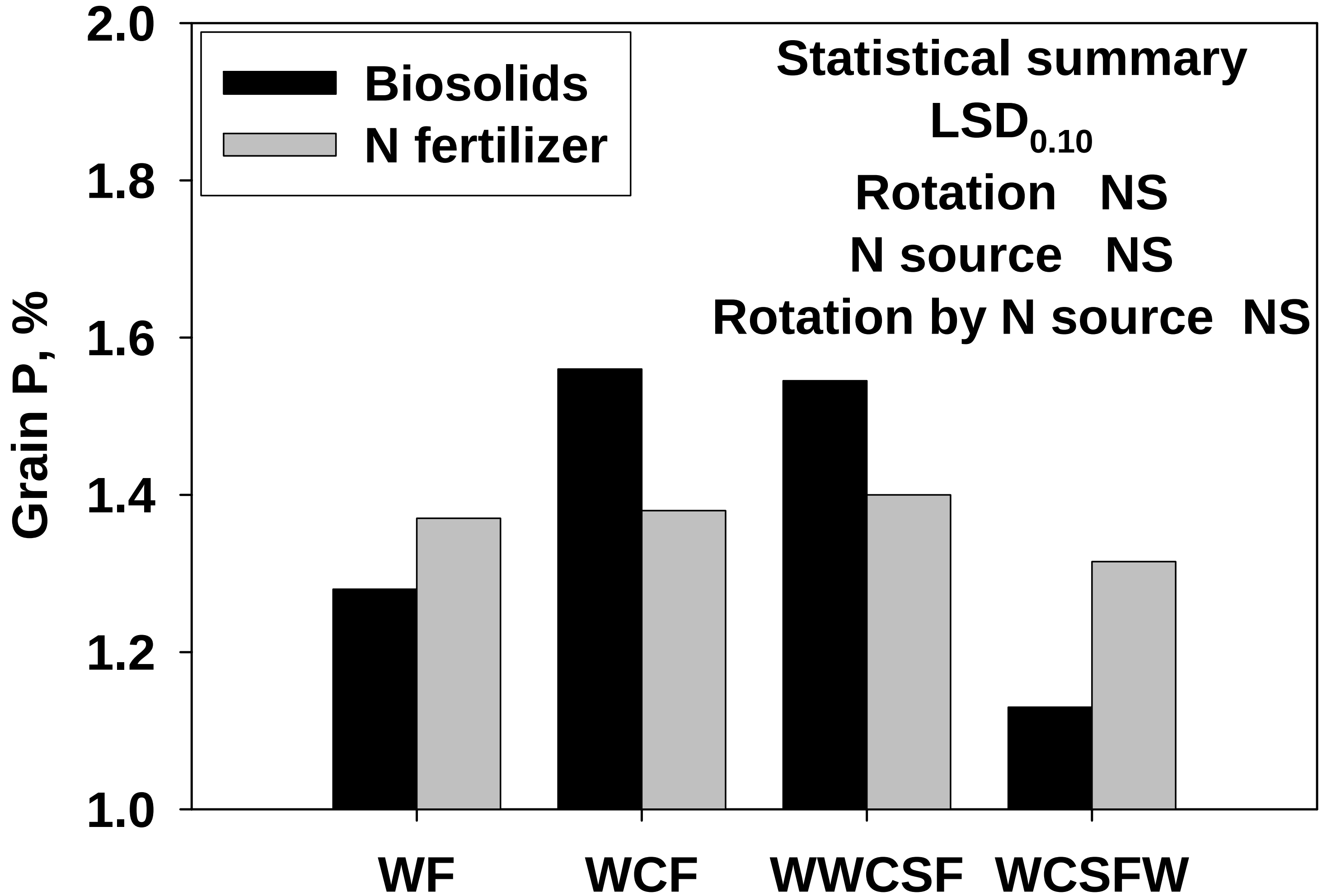


Figure 4. Grain Zn concentrations for 2003 dryland-wheat-rotation harvests comparing Littleton/Englewood biosolids to commercial fertilizer. In the statistical, $LSD_{0.10}$ represents the least significant difference at the 10% probability level and NS indicates non-significant differences.

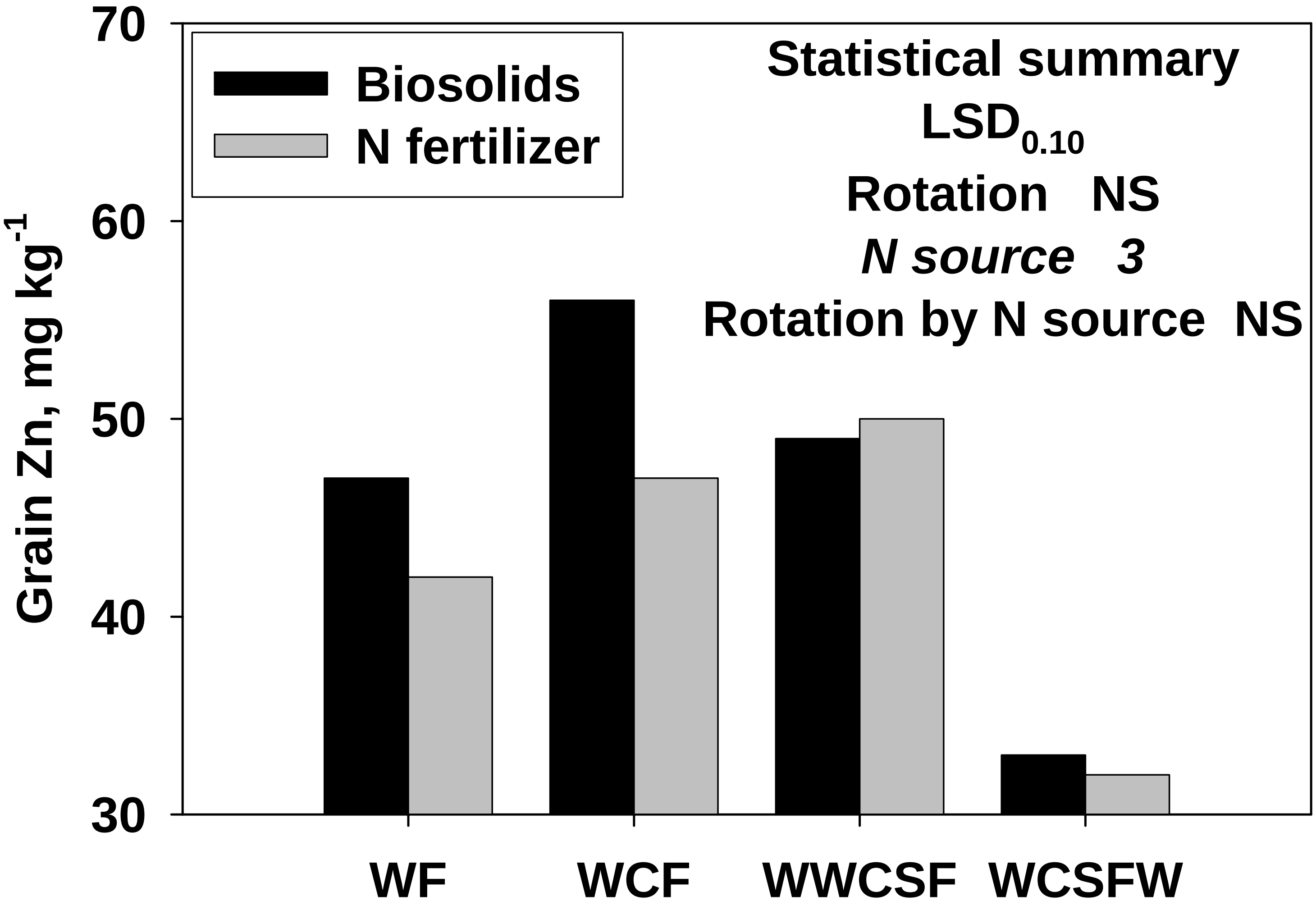


Figure 5. Grain Cu concentrations for 2003 dryland-wheat-rotation harvests comparing Littleton/Englewood biosolids to commercial fertilizer. In the statistical, $LSD_{0.10}$ represents the least significant difference at the 10% probability level and NS indicates non-significant differences.

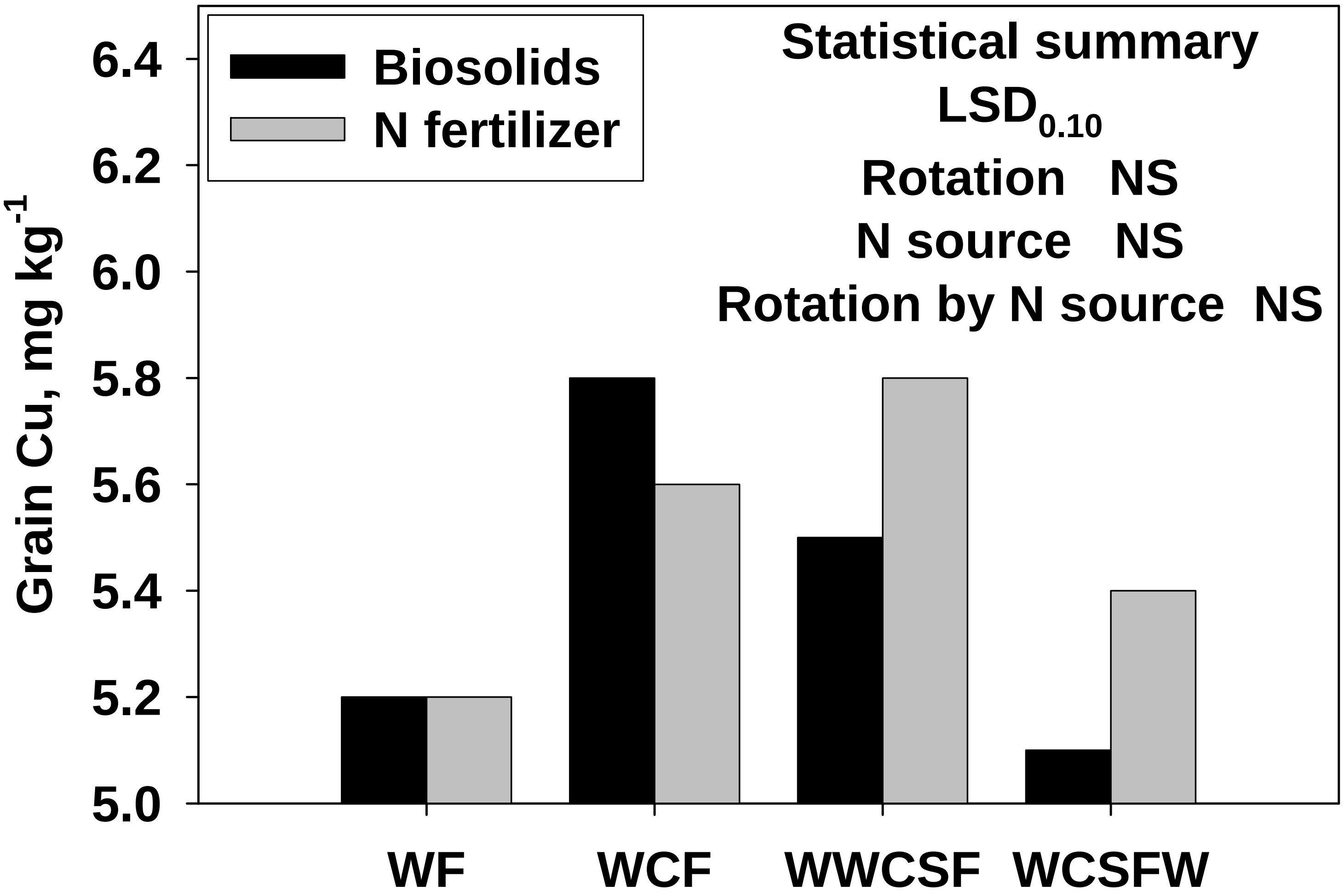
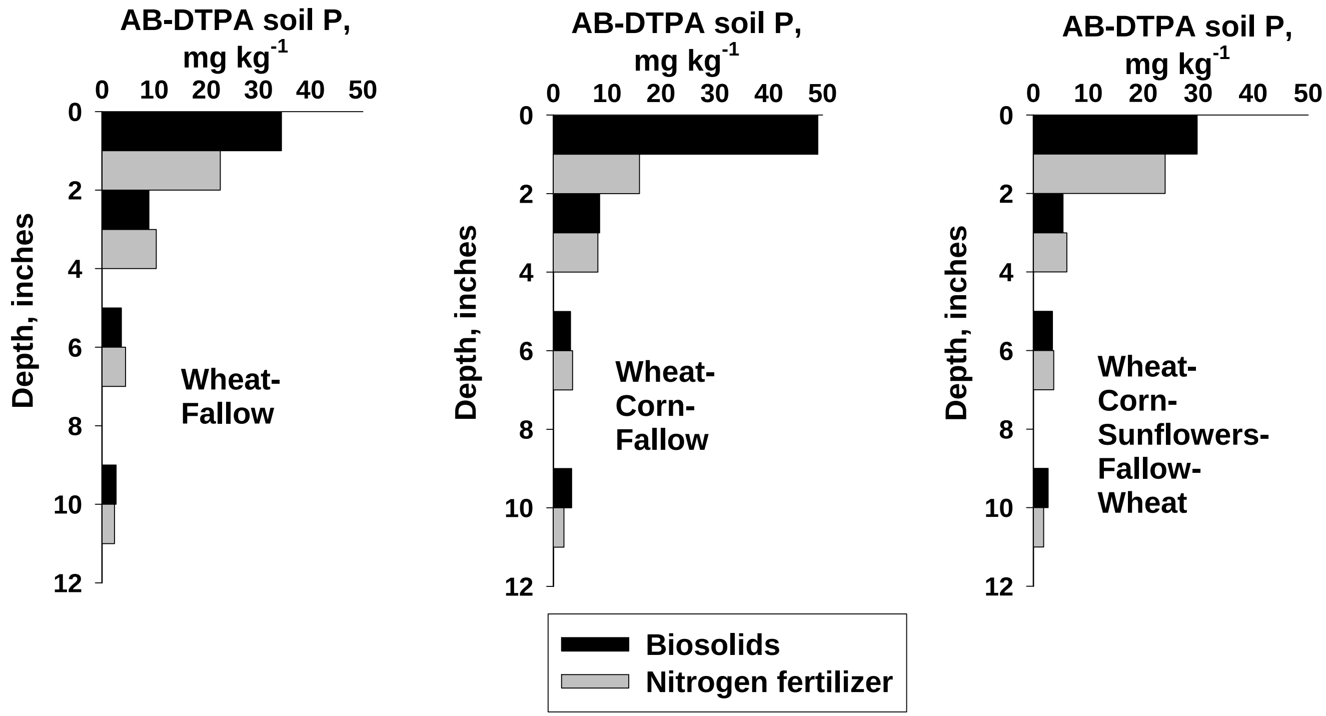


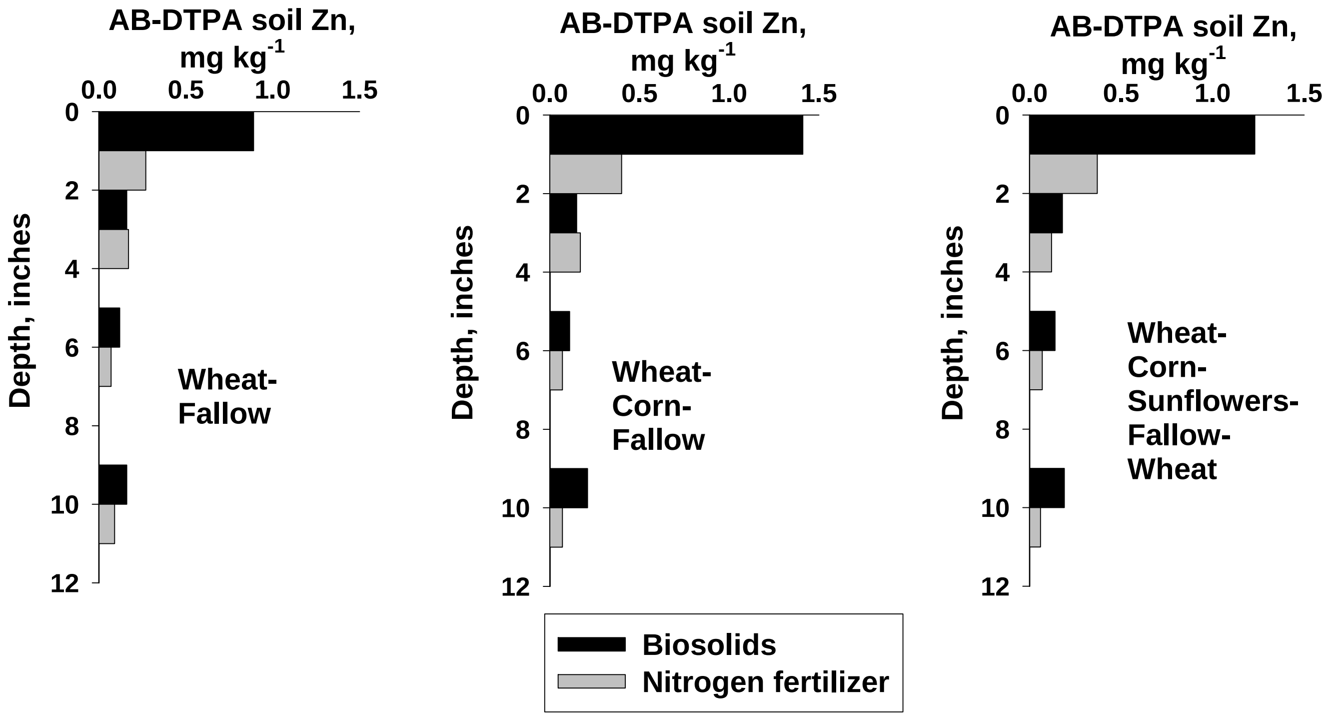
Figure 6. Soil AB-DTPA-extractable P concentration following 2003 dryland-wheat-rotation harvests comparing Littleton/Englewood biosolids to commercial N fertilizer. In the statistical summary, $LSD_{0.10}$ represents the least significant difference at the 10% probability level and NS indicates non-significant differences.



Statistical summary by soil depth:

0-2 inches	2-4 inches	4-8 inches	8-12 inches
$LSD_{0.10}$	$LSD_{0.10}$	$LSD_{0.10}$	$LSD_{0.10}$
Rotations NS	Rotations NS	Rotations NS	Rotations NS
Treatment 5.4	*Treatment 0.6*	Treatment NS	Treatment NS
Rot. X Treat. 31.1	Rot. X Treat. NS	Rot. X Treat. NS	Rot. X Treat. NS

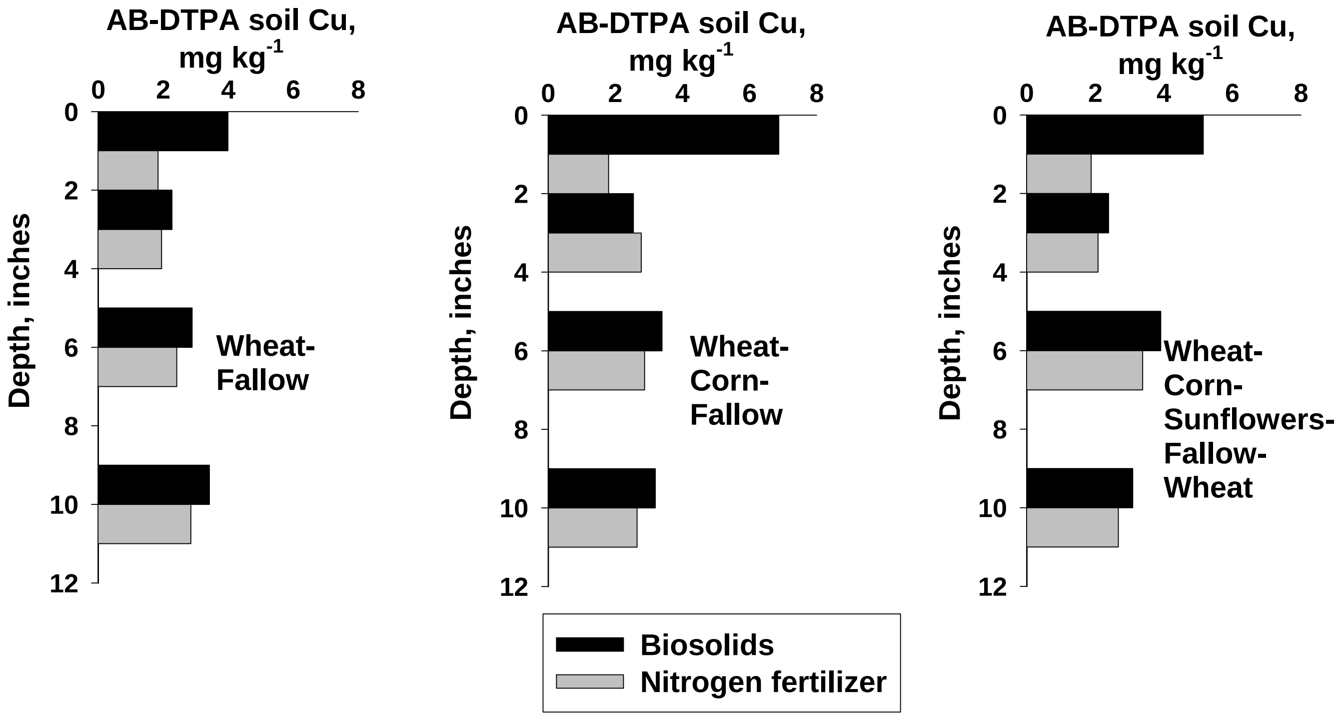
Figure 7. Soil AB-DTPA-extractable Zn concentration following 2003 dryland-wheat-rotation harvests comparing Littleton/Englewood biosolids to commercial N fertilizer. In the statistical summary, $LSD_{0.10}$ represents the least significant difference at the 10% probability level and NS indicates non-significant differences.



Statistical summary by soil depth:

0-2 inches	2-4 inches	4-8 inches	8-12 inches
$LSD_{0.10}$	$LSD_{0.10}$	$LSD_{0.10}$	$LSD_{0.10}$
Rotations NS	Rotations NS	Rotations NS	Rotations NS
Treatment 0.25	Treatment NS	*Treatment 0.04*	*Treatment 0.08*
Rot. X Treat. NS	Rot. X Treat. NS	Rot. X Treat. NS	Rot. X Treat. NS

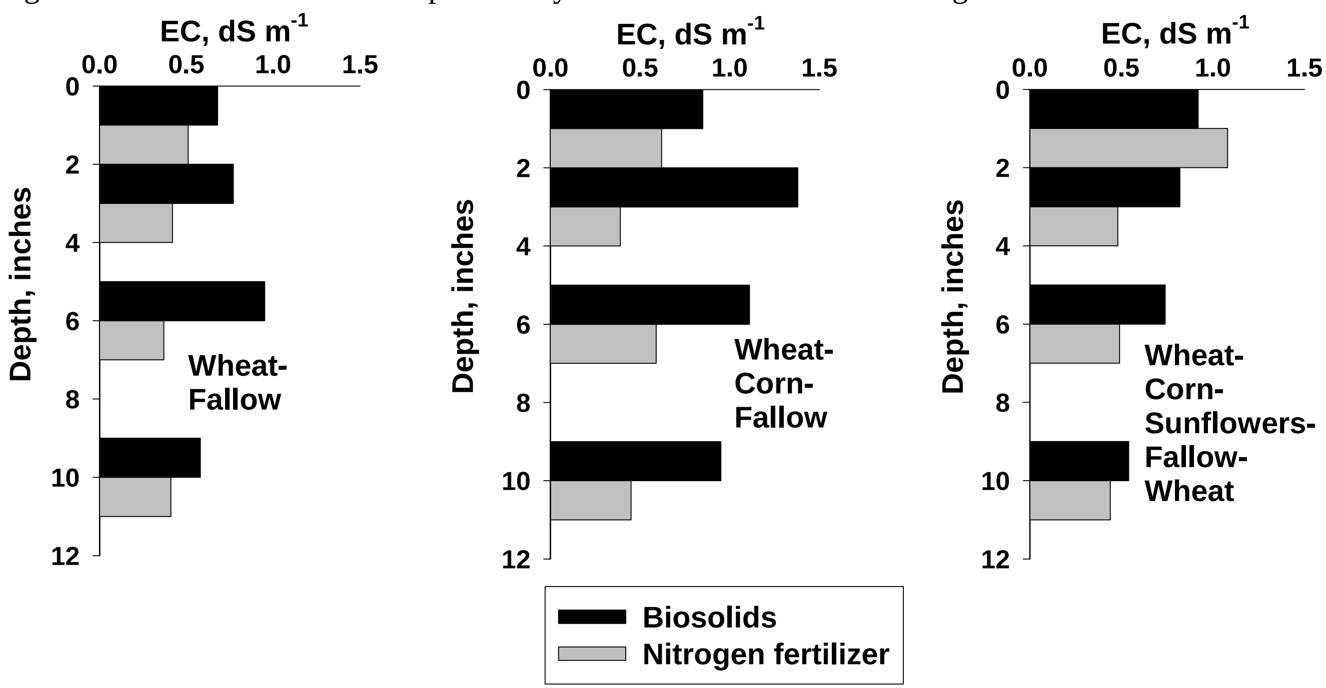
Figure 8. Soil AB-DTPA-extractable Cu concentration following 2003 dryland-wheat-rotation harvests comparing Littleton/Englewood biosolids to commercial N fertilizer. In the statistical summary, $LSD_{0.10}$ represents the least significant difference at the 10% probability level and NS indicates non-significant differences.



Statistical summary by soil depth:

0-2 inches	2-4 inches	4-8 inches	8-12 inches
$LSD_{0.10}$	$LSD_{0.10}$	$LSD_{0.10}$	$LSD_{0.10}$
Rotations NS	Rotations NS	Rotations NS	Rotations NS
Treatment 1.73	Treatment NS	Treatment NS	Treatment NS
Rot. X Treat. NS	Rot. X Treat. NS	Rot. X Treat. NS	Rot. X Treat. NS

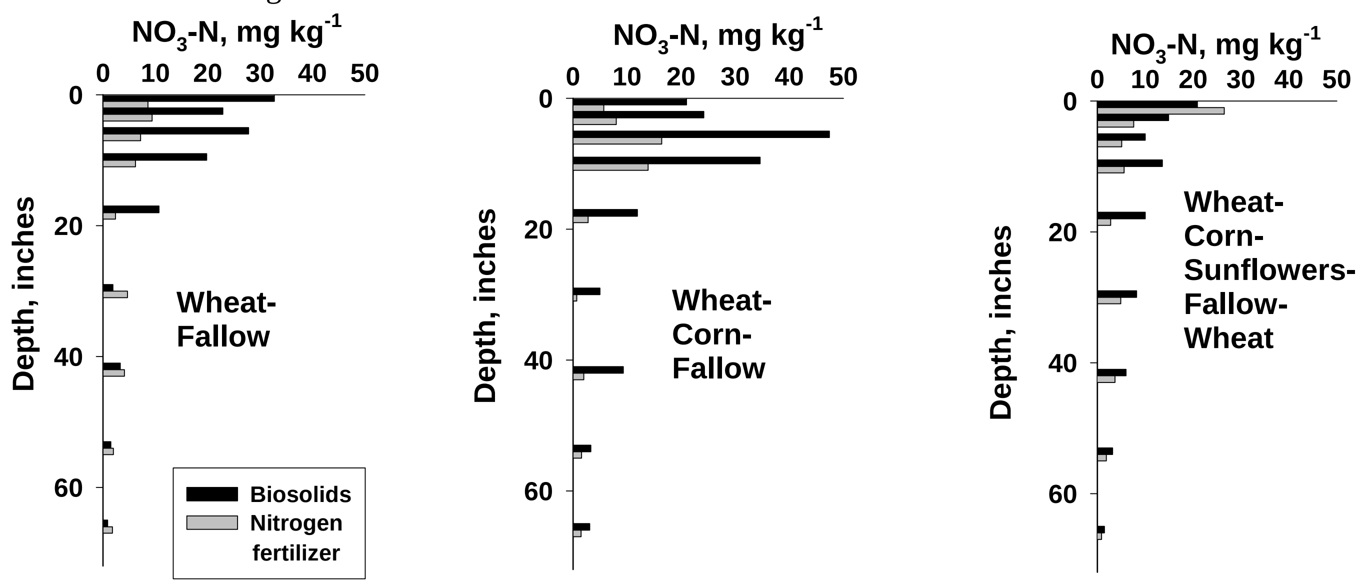
Figure 9. Soil saturated paste extract electrical conductivity (EC) following 2003 dryland-wheat-rotation harvests comparing Littleton/Englewood biosolids to commercial N fertilizer. In the statistical summary, $LSD_{0.10}$ represents the least significant difference at the 10% probability level and NS indicates non-significant differences.



Statistical summary by soil depth:

0-2 inches	2-4 inches	4-8 inches	8-12 inches
$LSD_{0.10}$	$LSD_{0.10}$	$LSD_{0.10}$	$LSD_{0.10}$
Rotations NS	*Rotations 0.25*	*Rotations 0.18*	Rotations NS
Treatment NS	*Treatment 0.19*	*Treatment 0.39*	Treatment NS
Rot. X Treat. NS	*Rot. X Treat. 0.37*	Rot. X Treat. NS	Rot. X Treat. NS

Figure 10. Soil NO_3^- following 2003 dryland-wheat-rotation harvests comparing Littleton/Englewood biosolids to commercial N fertilizer. In the statistical summary, $LSD_{0.10}$ represents the least significant difference at the 10% probability level and NS indicates non-significant differences.



Statistical summary by soil depth:

0-2 inches
$LSD_{0.10}$
Rotations NS
Treatment NS
Rot. X Treat. NS

2-4 inches
$LSD_{0.10}$
Rotations NS
Treatment 4.2
Rot. X Treat. NS

4-8 inches
$LSD_{0.10}$
Rotations NS
Treatment 10.6
Rot. X Treat. NS

8-12 inches
$LSD_{0.10}$
Rotations NS
Treatment 12.3
Rot. X Treat. NS

12-24 inches
$LSD_{0.10}$
Rotations NS
Treatment 8.5
Rot. X Treat. NS

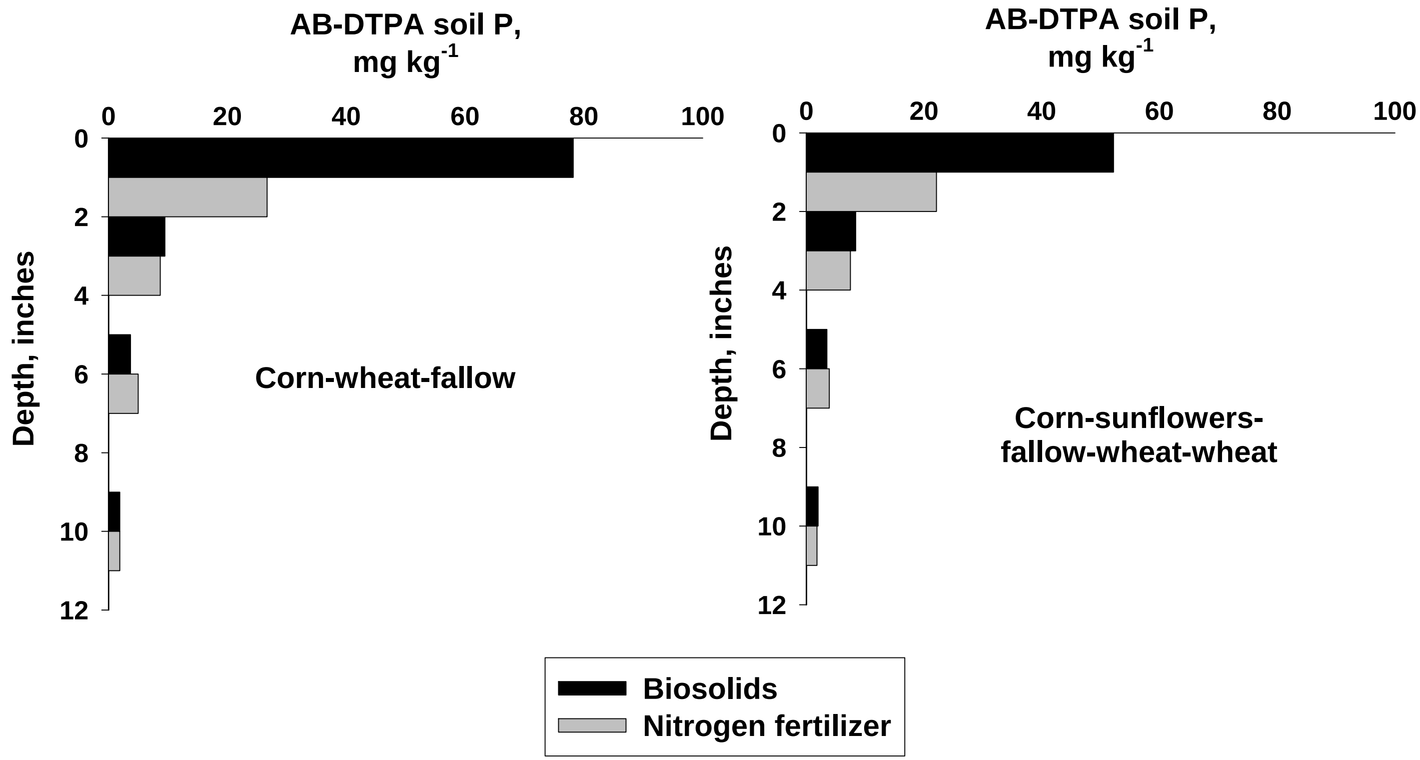
24-36 inches
$LSD_{0.10}$
Rotations NS
Treatment NS
Rot. X Treat. NS

36-48 inches
$LSD_{0.10}$
Rotations NS
Treatment NS
Rot. X Treat. NS

48-60 inches
$LSD_{0.10}$
Rotations NS
Treatment NS
Rot. X Treat. NS

60-72 inches
$LSD_{0.10}$
Rotations NS
Treatment NS
Rot. X Treat. NS

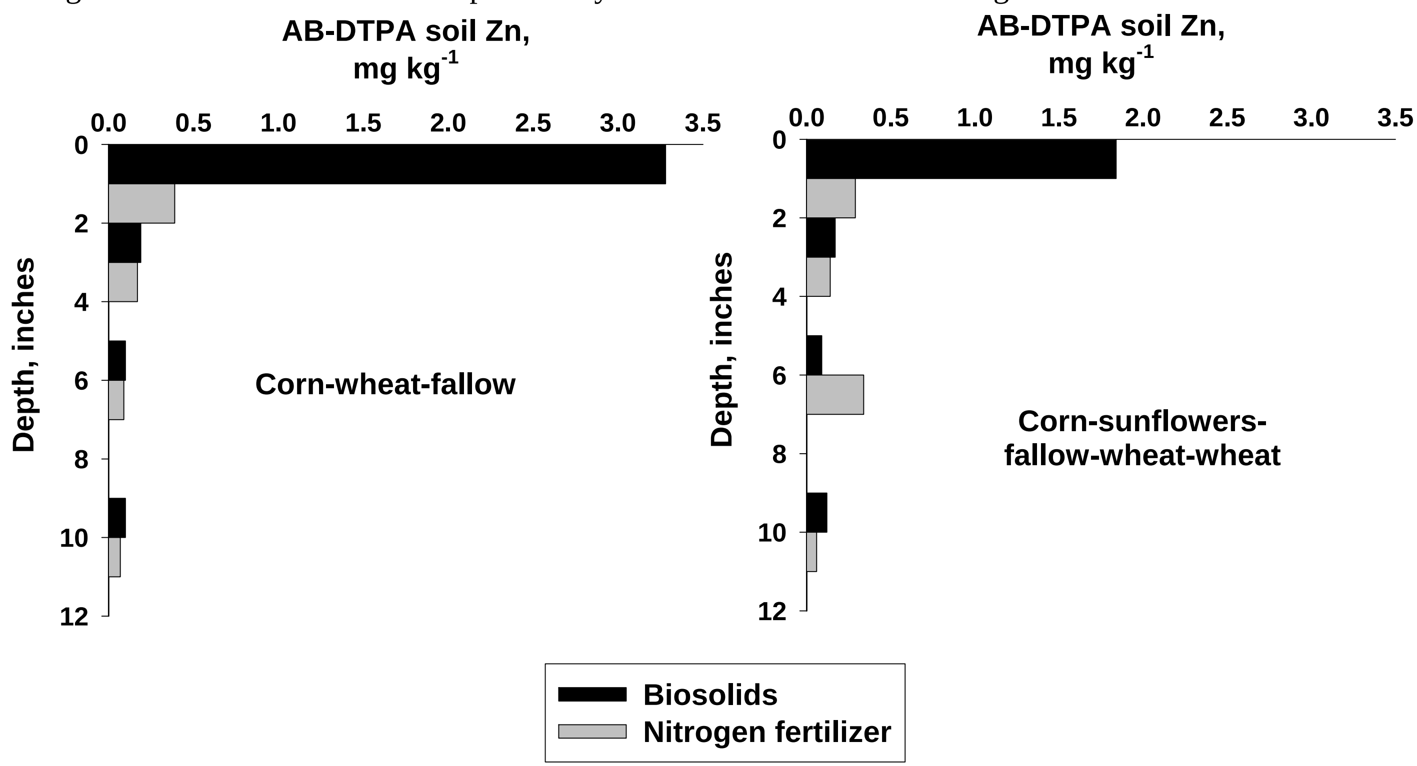
Figure 11. Soil AB-DTPA-extractable P concentration following 2003 dryland-corn-rotation harvests comparing Littleton/Englewood biosolids to commercial N fertilizer. In the statistical summary, $LSD_{0.10}$ represents the least significant difference at the 10% probability level and NS indicates non-significant differences.



Statistical summary by soil depth:

<u>0-2 inches</u>	<u>2-4 inches</u>	<u>4-8 inches</u>	<u>8-12 inches</u>
$LSD_{0.10}$	**$LSD_{0.10}$**	**$LSD_{0.10}$**	**$LSD_{0.10}$**
Rotations NS	**Rotations NS**	**Rotations NS**	**Rotations NS**
Treatment 35.4	**Treatment NS**	**Treatment NS**	**Treatment NS**
Rot. X Treat. NS	**Rot. X Treat. NS**	**Rot. X Treat. NS**	**Rot. X Treat. NS**

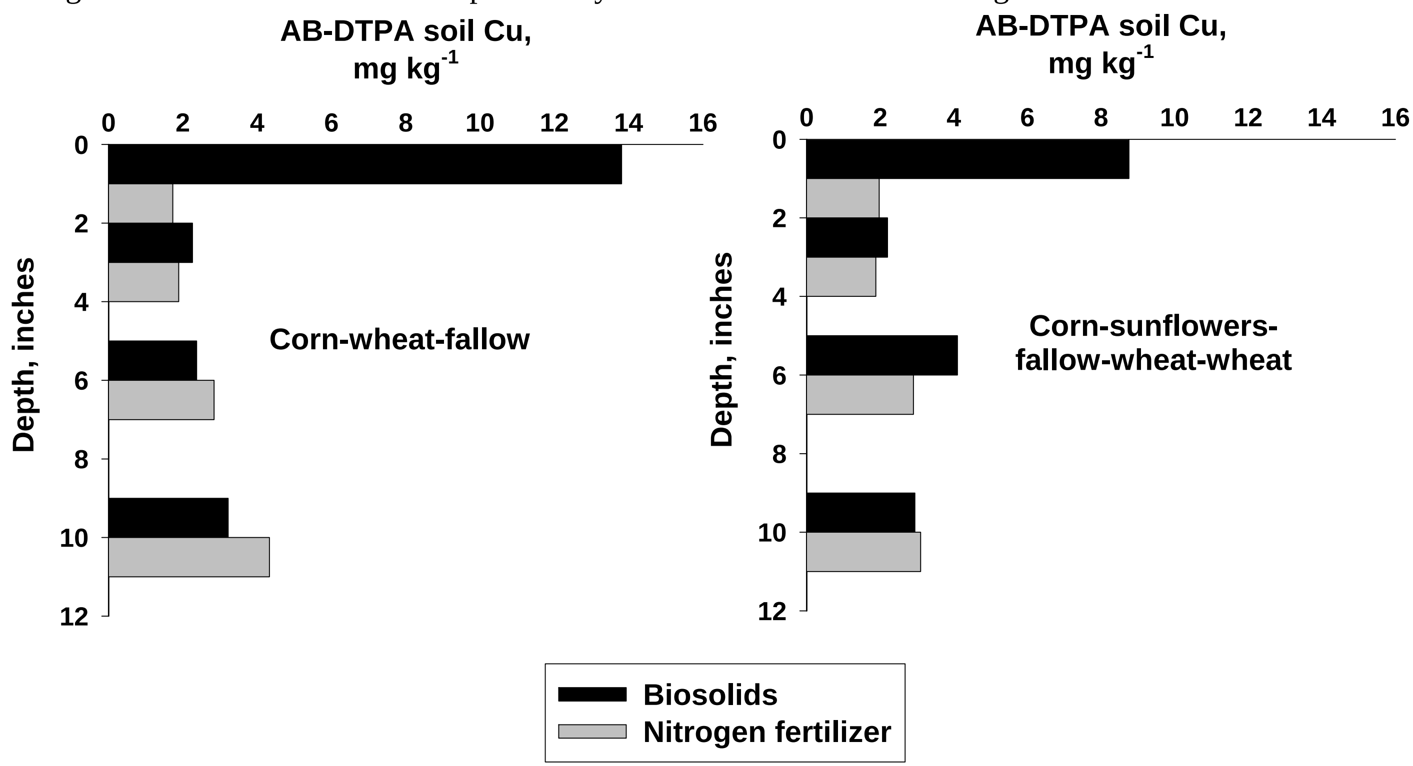
Figure 12. Soil AB-DTPA-extractable Zn concentration following 2003 dryland-corn-rotation harvests comparing Littleton/Englewood biosolids to commercial N fertilizer. In the statistical summary, $LSD_{0.10}$ represents the least significant difference at the 10% probability level and NS indicates non-significant differences.



Statistical summary by soil depth:

0-2 inches	2-4 inches	4-8 inches	8-12 inches
$LSD_{0.10}$	$LSD_{0.10}$	$LSD_{0.10}$	$LSD_{0.10}$
Rotations NS	Rotations NS	Rotations NS	Rotations NS
Treatment NS	Treatment NS	Treatment NS	Treatment NS
Rot. X Treat. NS	Rot. X Treat. NS	Rot. X Treat. NS	Rot. X Treat. NS

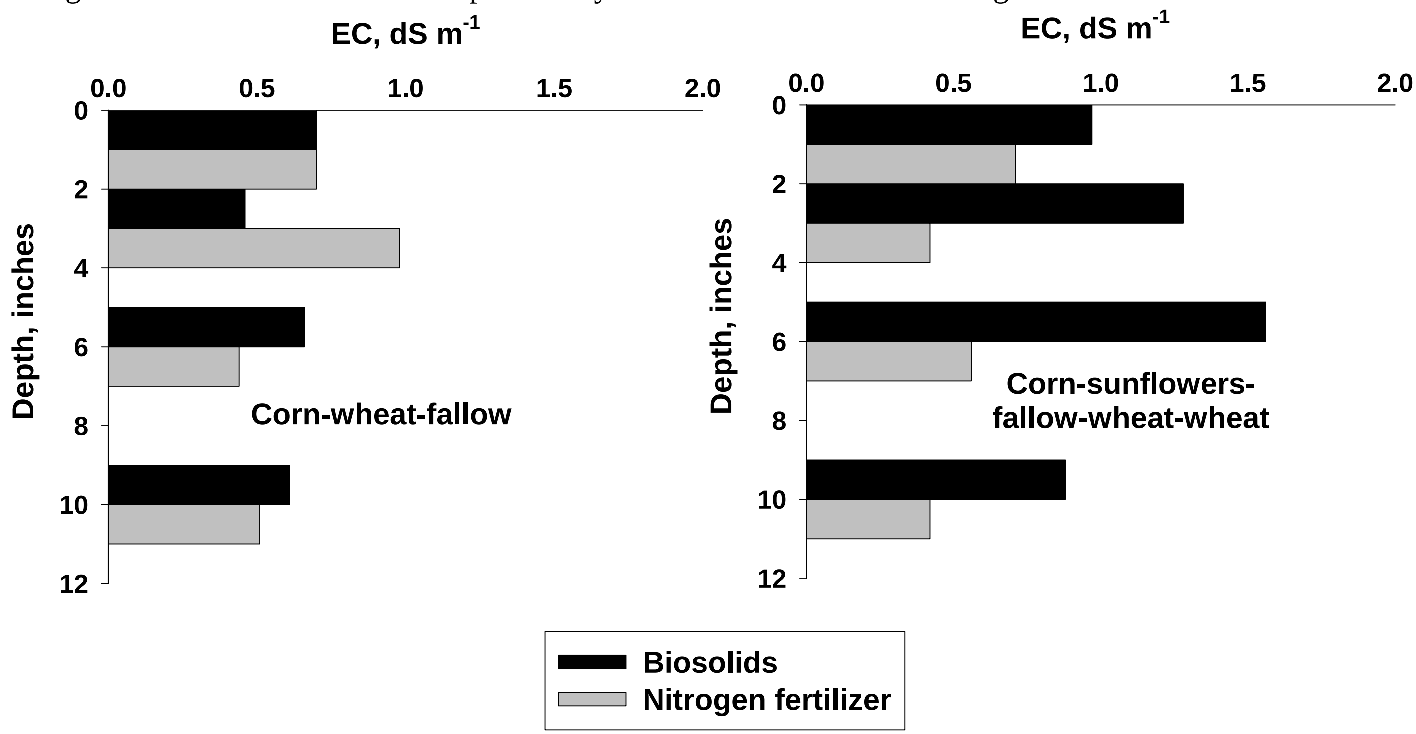
Figure 13. Soil AB-DTPA-extractable Cu concentration following 2003 dryland-corn-rotation harvests comparing Littleton/Englewood biosolids to commercial N fertilizer. In the statistical summary, $LSD_{0.10}$ represents the least significant difference at the 10% probability level and NS indicates non-significant differences.



Statistical summary by soil depth:

0-2 inches	2-4 inches	4-8 inches	8-12 inches
$LSD_{0.10}$	$LSD_{0.10}$	$LSD_{0.10}$	$LSD_{0.10}$
Rotations NS	Rotations NS	*Rotations 0.10*	Rotations NS
Treatment NS	Treatment NS	Treatment NS	*Treatment 0.44*
Rot. X Treat. NS	Rot. X Treat. NS	Rot. X Treat. NS	*Rot. X Treat. 0.62*

Figure 14. Soil saturated paste extract electrical conductivity (EC) following 2003 dryland-corn-rotation harvests comparing Littleton/Englewood biosolids to commercial N fertilizer. In the statistical summary, $LSD_{0.10}$ represents the least significant difference at the 10% probability level and NS indicates non-significant differences.



Statistical summary by soil depth:

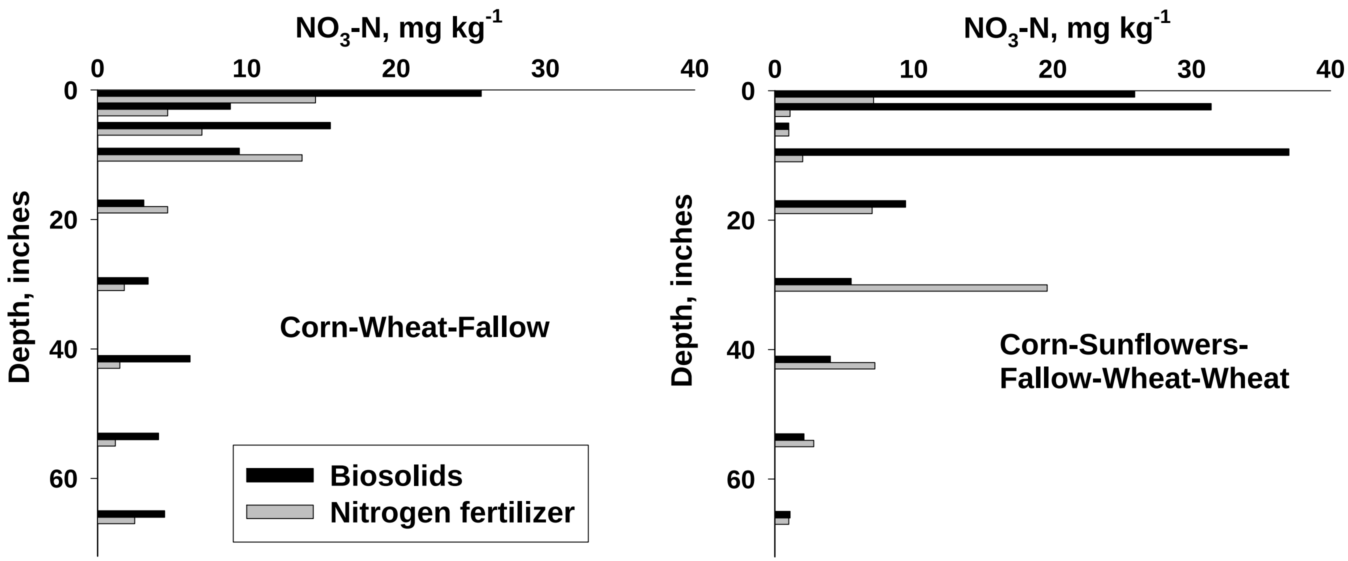
0-2 inches
$LSD_{0.10}$
Rotations NS
Treatment 0.06
Rot. X Treat. 0.09

2-4 inches
$LSD_{0.10}$
Rotations NS
Treatment NS
Rot. X Treat. 0.38

4-8 inches
$LSD_{0.10}$
Rotations 0.17
Treatment 0.11
Rot. X Treat. 0.16

8-12 inches
$LSD_{0.10}$
Rotations NS
Treatment 0.25
Rot. X Treat. NS

Figure 15. Soil NO_3^- following 2003 dryland-corn-rotation harvests comparing Littleton/Englewood biosolids to commercial N fertilizer. In the statistical summary, $LSD_{0.10}$ represents the least significant difference at the 10% probability level and NS indicates non-significant differences.



Statistical summary by soil depth:

0-2 inches
$LSD_{0.10}$
Rotations 1.4
Treatment NS
Rot. X Treat. NS

2-4 inches
$LSD_{0.10}$
Rotations NS
Treatment 16.9
Rot. X Treat. NS

4-8 inches
$LSD_{0.10}$
Rotations NS
Treatment NS
Rot. X Treat. NS

8-12 inches
$LSD_{0.10}$
Rotations NS
Treatment 2.2
Rot. X Treat. 3.1

12-24 inches
$LSD_{0.10}$
Rotations 2.2
Treatment NS
Rot. X Treat. NS

24-36 inches
$LSD_{0.10}$
Rotations 1.8
Treatment NS
Rot. X Treat. NS

36-48 inches
$LSD_{0.10}$
Rotations NS
Treatment NS
Rot. X Treat. NS

48-60 inches
$LSD_{0.10}$
Rotations NS
Treatment NS
Rot. X Treat. NS

60-72 inches
$LSD_{0.10}$
Rotations NS
Treatment NS
Rot. X Treat. NS