

Technical Report 19-9



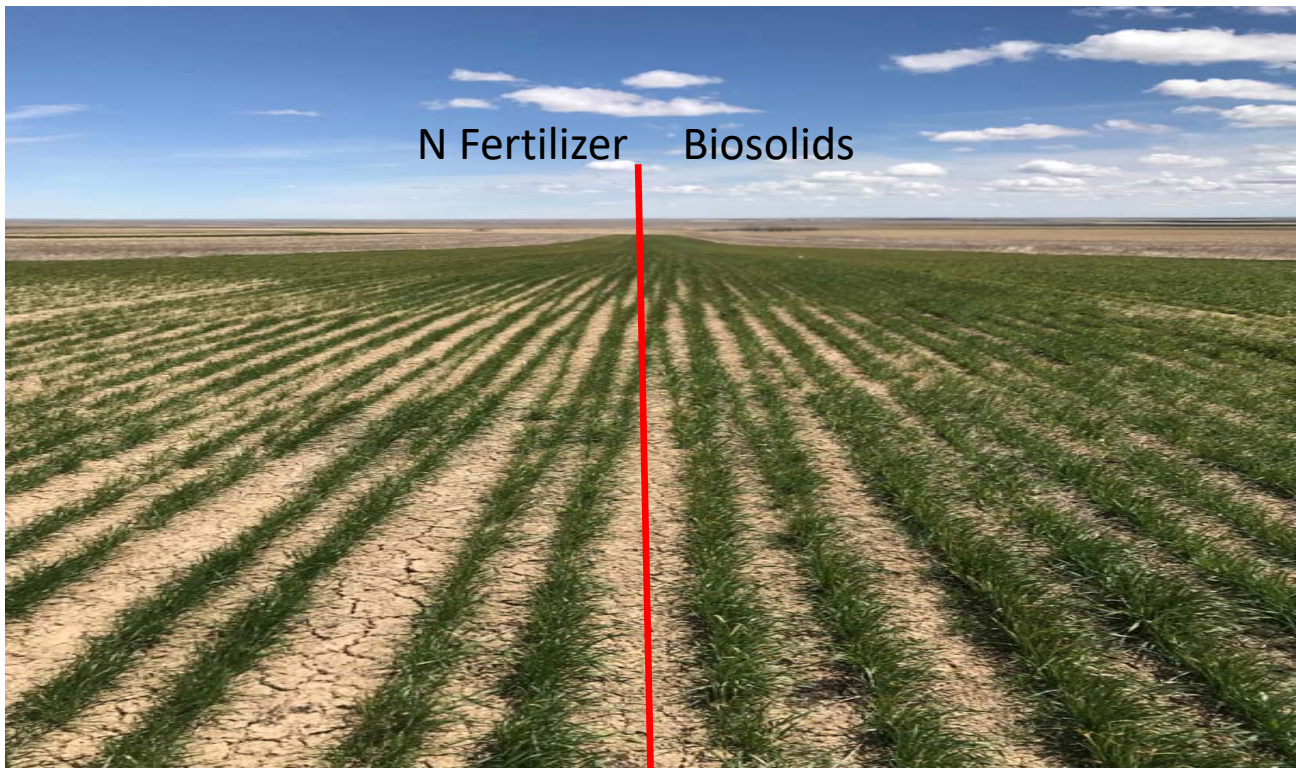
Agricultural Experiment Station

College of
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Soil and Crop Sciences

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Biosolids or Inorganic Fertilizer Applications Affect Wheat Grain and Soil in Dryland Cropping Rotations: 2017-2018



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Cover photo of winter wheat, April 2018 (Jim Ippolito)

INTRODUCTION

A long-term biosolids land application site was established in 1999 near Byers, Colorado, with support from the South Platte Water Renewal Partners (SPWRP). This site has supported practical, never-performed-before research focused on true production agricultural practices and the effects of biosolids or inorganic fertilizer application to dryland crops grown in Eastern Colorado. No-till and minimum tillage management is increasing in popularity in eastern Colorado because it improves water conservation and allows more intensive cropping. Biosolids application could enhance the benefits of no-till or minimum tillage by working in concert with crop residues to maintain or enhance crop yields and grain nutrient content, without negatively affecting environmental quality. Thus, continued, long-term biosolids applications could provide production and economic advantages, along with building agroecosystems that could be more resilient in the face of ever-changing and erratic climatic conditions. More producers in eastern Colorado (and elsewhere under similar climatic conditions and agroecosystem practices) could eventually use biosolids as an integral part of a conservation program, along with enhancing soil quality/soil health to improve agroecosystem resiliency.

Historically, dryland cropping systems in eastern Colorado have utilized a wheat-fallow rotation. However, based on work by former Colorado State University cropping systems experts (Drs. Gary Peterson and Dwayne Westfall, both retired), it appears that adding another crop in the rotation may benefit producers by raising two crops out of three years versus raising one crop out of two years. Thus, the long-term study objectives are to understand:

1. If biosolids can play an integral role in wheat-fallow and wheat-corn-fallow dryland agroecosystems.

2. If increasing biosolids application from once every two years to twice every three years is a feasible management alternative.
3. The effects of biosolids application at an agronomic rate compared to commercial inorganic fertilizer in two cropping systems on winter wheat grain and soil accumulation of plant nutrients and trace elements limited by the Colorado Department of Public Health and Environment biosolids application regulations.

MATERIALS AND METHODS

The project began in 1999 at a dryland agroecosystem site west of Byers, Colorado (39° 45'47"N 103°47'50"W) utilizing wheat-fallow (WF), wheat-corn-fallow (WCF), and wheat-wheat-corn-sunflower-fallow (WWCSF) dryland cropping rotations. Due to crop failures with the WWCSF rotation, beginning in fall 2005 we replaced this rotation with either WF or WCF rotations. We now use four blocks (replications) of each treatment arranged in a split-plot design. The main plots consist of the cropping rotations (e.g., WF or WCF). Each main plot is split to accommodate biosolids application on half the plot and commercial fertilizer addition on the other half. All phases of each rotation are present each year to allow assessment of all soil and crop responses each year. This requires a total of 20 main plots and 40 split plots (4 replications, 5 cropping rotations, biosolids/fertilizer treatment splits). Each main plot is 0.5 miles long by 100 feet wide. Each biosolids/fertilizer split is therefore 50 feet wide.

Biosolids (supplied by the SPWRP) surface-application (i.e., no incorporation) recommendations were based on soil NO₃-N concentration and soil organic matter content to a depth of 2 feet, determined prior to application; our past research suggested that 1 ton SPWRP biosolids = approximately 16 lbs N/ac. The above information was used to determine the

biosolids-N needs of either dryland wheat or corn (e.g., the agronomic rate). A similar approach was taken agronomic N fertilizer applications, with other inorganic fertilizers applied based on cooperating producer input. In some years, residual soil N suggested that no biosolids or inorganic fertilizers were required. For dryland winter wheat or dryland corn, biosolids and inorganic fertilizers were applied either in September 2017 or May 2018, respectively. Table 1 illustrates the biosolids or inorganic fertilizer applications and timing, for individual crops and varieties, since project inception in 1999.

For purposes of this report, following wheat harvest from within the WF or WCF rotations, we determined yields (by harvesting each entire plot), grain protein content, and grain total P, Cd, Cr, Cu, Fe, Mo, Ni, Pb, and Zn concentrations (using a concentrated nitric acid + peroxide digestion). We determined plant-available soil P, Cd, Cr, Cu, Fe, Mo, Ni, Pb, and Zn (using an AB-DTPA extraction), and NO₃-N concentrations (using a 2M potassium chloride extraction) in the 0-2, 2-4, 4-6, and 6-12 inch depths, and soil NO₃-N in the 12-24, 24-36, 36-48, 48-60, and 60-72 inch depths.

RESULTS AND DISCUSSION

Winter Wheat Grain Characteristics

Wheat grain yields averaged 62 bushels acre⁻¹ (Table 2). There were no significant differences between grain yields for the wheat-fallow (WF) and wheat-corn-fallow (WCF) rotations, between biosolids or N fertilizer, or the interaction between nutrient source and rotation. Wheat grain protein averaged 16.0% in 2017-18, with the WCF rotation producing a greater grain protein content as compared to the WF rotation. Regardless, a protein premium might have been paid for this grain from any portion of the field. Biosolids application also produced similar wheat grain nutrient concentrations

as compared to inorganic fertilizer. This suggests that biosolids act similarly to inorganic fertilizers that producers would utilize to produce winter wheat in Colorado.

Soil Characteristics:

Figures A through I illustrate changes in soil P, Cd, Cr, Cu, Fe, Ni, Pb, Zn, and NO₃-N concentrations due to biosolids or fertilizer application, or due to cropping rotation, with depth. Biosolids application caused a slight but significant increase in plant-available soil Cu in the 4-6-inch depth as compared to commercial fertilizer; nutrient source did not affect any other elements within any other depth. There were also no differences in plant-available soil elements between WF and WCF for any soil depth, except for NO₃-N in the 2-4-inch depth. These results corroborate the findings within wheat grain, that biosolids act relatively similarly to inorganic fertilizer application in terms their effect on general soil characteristics.

These findings were different from last year's findings for N, P, Cu, and Zn, where differences were evident in the 0 to 2 inch soil depth due to 1) biosolids being surface applied with no incorporation, and 2) biosolids typically containing appreciable quantities of N, P, Cu, and Zn. Biosolids typically contain relatively elevated Cu and Zn concentrations due to municipality infrastructure (e.g., Cu piping and Zn solder). It is important to note that biosolids Cu and Zn concentrations have never been above EPA regulatory limits for these biosolids over the course of this study. Overall, biosolids supports dryland winter wheat yields comparable to inorganic fertilizer applications, with this finding supported over the past 19 study years.

Table 1. Biosolids and fertilizer applications and crop varieties used at the Byers research site, 1999-2018.

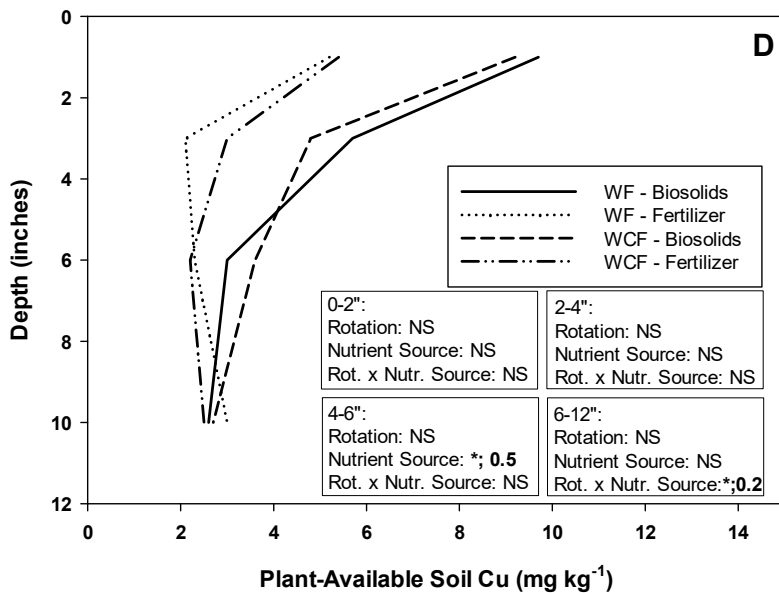
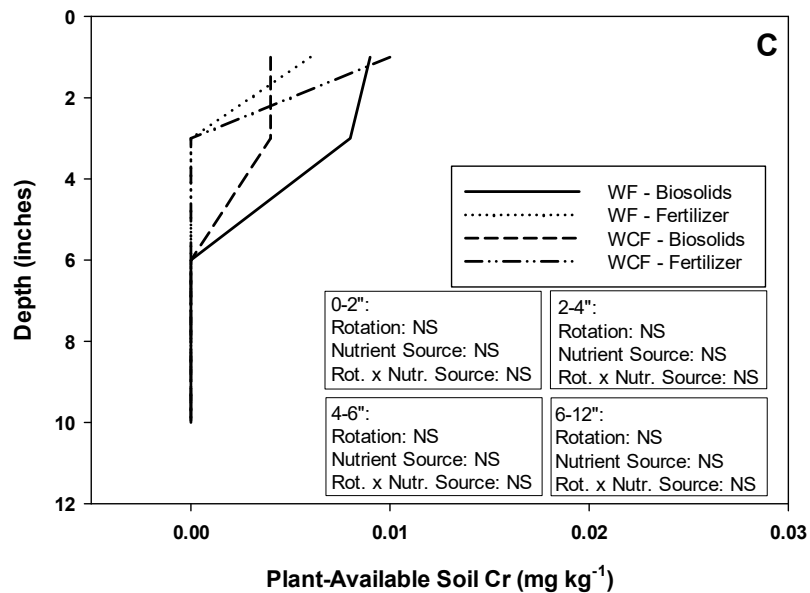
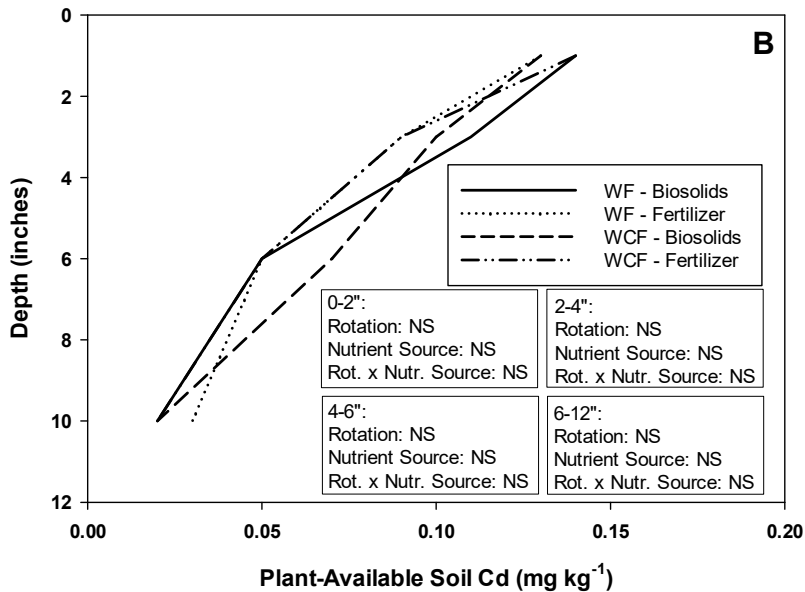
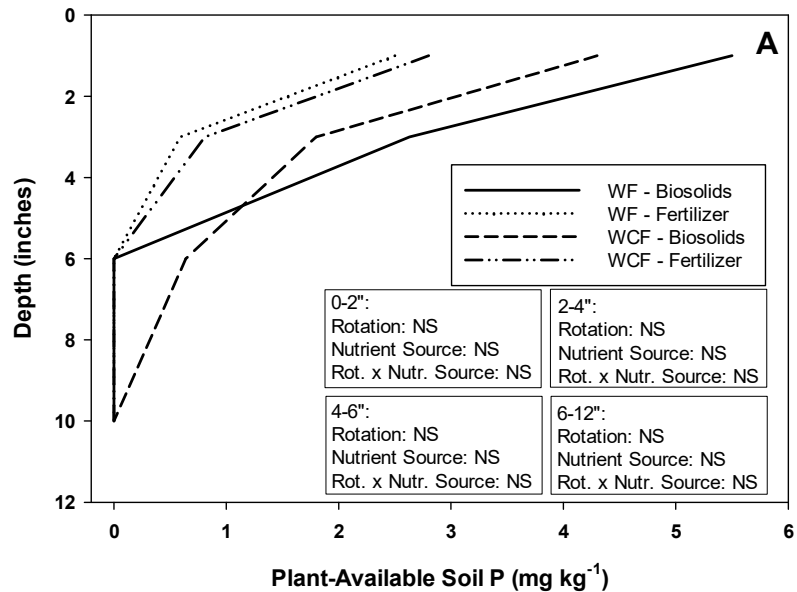
Year Planted	Date Planted	Crop	Variety	Biosolids Biosolids tons/acre	Treatment Bio/N equiv. lbs	Nitrogen N lbs/acre with seed	Fertilizer N lbs/acre after planting	Treatment Total N lbs/acre	P ₂ O ₅ lbs/acre	Zn lbs/acre
1999	Early Oct.	Wheat	Halt	2.4	38.4	5	40	45	20	0
2000	May	Corn	Pioneer 3752	4	64	5	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	Unknown							
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
2005	05/10/05	Corn	Pioneer J99	4	72	0	75	75	15	5
2006	Sept.	Wheat	Yumar	0	0	0	0	0	0	0
2007	May	Corn	Pioneer J99	0	0	0	0	0	0	0
2007	Sept.	Wheat	Yumar	0	0	0	0	0	0	0
2008	May	Corn	Pioneer J99	0	0	0	0	0	0	0

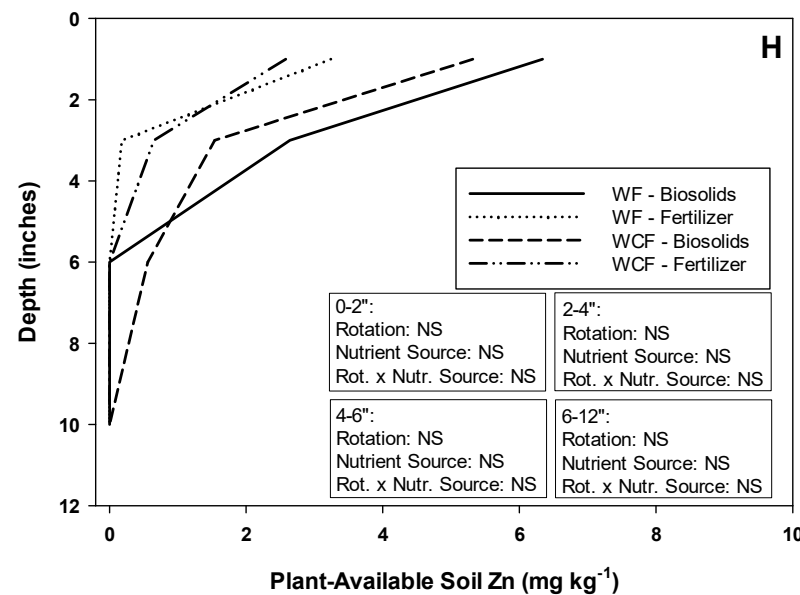
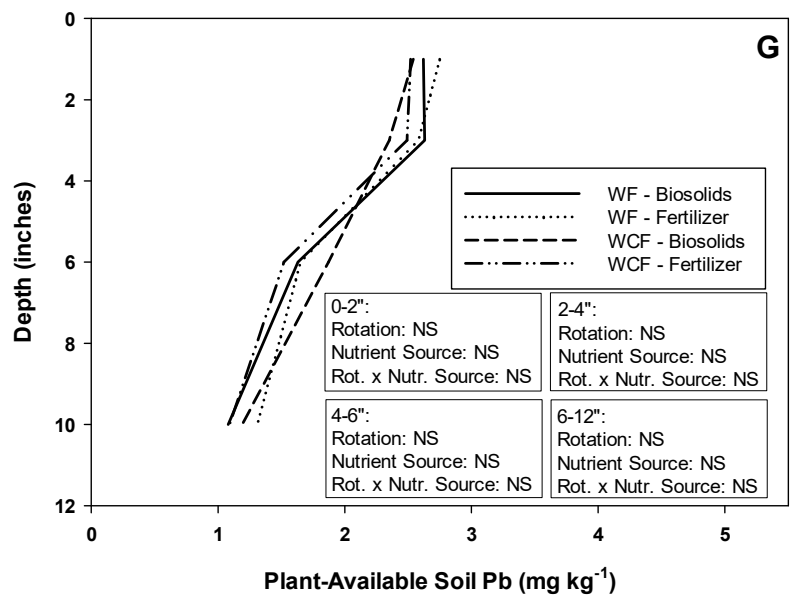
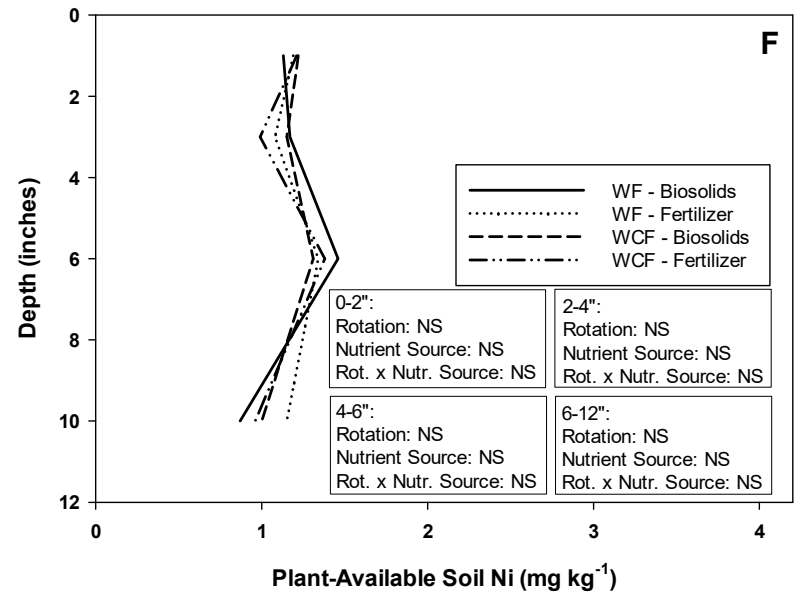
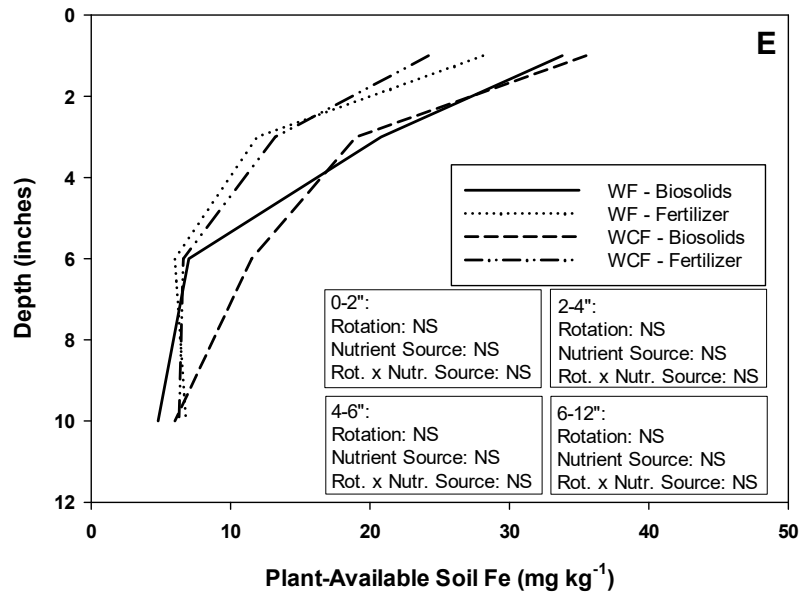
2008	Sept.	Wheat	Yumar	0	0	0	0	0	0	0
2009	May	Corn	Pioneer J99	0	0	0	0	0	0	0
2009	Sept.	Wheat	Yumar	0	0	0	0	0	0	0
2010	May	Corn	Pioneer J99	0	0	0	0	0	0	0
2010	Sept.	Wheat	Yumar	0	0	0	0	0	0	0
2011	May	Corn	Pioneer J99	0	0	0	0	0	0	0
2011	Sept.	Wheat	Snowmass	2	32	5	30	35	20	0
2012	May	Corn	Triumph 9958	2	32	5	30	35	20	0
2012	Sept.	Wheat	Snowmass	2	32	5	30	35	20	0
2013	May	Corn	Triumph 9958	2	32	5	30	35	15	5
2013	Sept.	Wheat	Byrd	2	32	5	30	35	20	0
2014	May	Corn	Triumph 9811	2	32	5	30	35	15	5
2014	Sept.	Wheat	Byrd	2	32	5	30	35	20	0
2015	May	Corn	Triumph 9811	2	32	5	30	35	15	5
2015	Sept.	Wheat	Snowmass	2	32	0	45	45	0	0
2016	May	Corn	Pioneer 0157	0	0	0	50	50	0	0
2016	Sept.	Wheat	Snowmass	2	32	0	45	45	0	0
2017	May	Corn	Pioneer 0157	0	0	0	50	50	0	0
2017	Sept.	Wheat	Snowmass	2	32	0	45	45	0	0
2018	May	Corn	Pioneer 9697	0	0	0	50	50	0	0

Table 2. Mean wheat grain characteristics for the 2017-2018 harvest from within wheat-fallow or wheat-corn-fallow rotations treated with agronomic rates of either biosolids or inorganic N fertilizer (and other inorganic fertilizers; see Table 1) at the Byers research site.

Rotation [†]	Nutrient source	Grain Yield	Protein	P	Cd	Cr	Cu	Fe	Mo	Ni	Pb	Zn
		bu ac ⁻¹	%	g kg ⁻¹	----- mg kg ⁻¹ -----							
WF	Biosolids	63.0	15.6	3.4	BD*	BD	4.4	34	0.53	0.73	BD	28.2
	N	56.7	15.3	3.4	BD	BD	4.2	34	0.44	0.52	BD	24.5
WCF	Biosolids	62.2	16.6	3.7	BD	BD	4.7	40	0.55	0.65	BD	30.0
	N	64.2	16.4	3.5	BD	BD	4.6	36	0.65	0.54	BD	27.5
WF	Mean Over	59.8	15.5	3.4	BD	BD	4.3	34	0.49	0.62	BD	26.4
WCF	Nutri.	63.2		3.6			4.7	38	0.60	0.60		28.8
	Source		16.6		BD	BD					BD	
Mean over	Biosolids	62.6	16.2	3.5			4.5	37	0.54	0.69		29.3
Rotation	N	61.0	16.0	3.4			4.5	35	0.56	0.53		26.2
Analyses of		P>F	P>F	P>F			P>F	P>F	P>F	P>F		P>F
Variance												
Rotation		0.6886	0.0955	0.5132			0.5589	0.2447	0.1441	0.6365		0.3591
Nutrient		0.8920	0.4349				0.6226	0.3448	0.7465	0.1764		0.3808
Source				0.5494								
Rotation X		0.6900	0.6444	0.9541					0.8285	0.7703		0.8522
Nutrient							0.6857	0.9941				
Source												
		LSD _{0.10} [‡]	LSD _{0.10}	LSD _{0.10}			LSD _{0.10}	LSD _{0.10}	LSD _{0.10}	LSD _{0.10}		LSD _{0.10}
Rotation		NS [‡]	0.04	NS			NS	NS	NS [‡]	NS		NS [‡]
Nutrient		NS	NS	NS			NS	NS	NS	NS		NS
Source												
Rotation X		NS	NS	NS			NS	NS	NS	NS		NS
Nutrient												
Source												

[†] WF = wheat-fallow and WCF = wheat-corn-fallow. [‡] LSD = least significant difference at a probability of 90%. [‡] NS = not significant. * BD = Below detection.





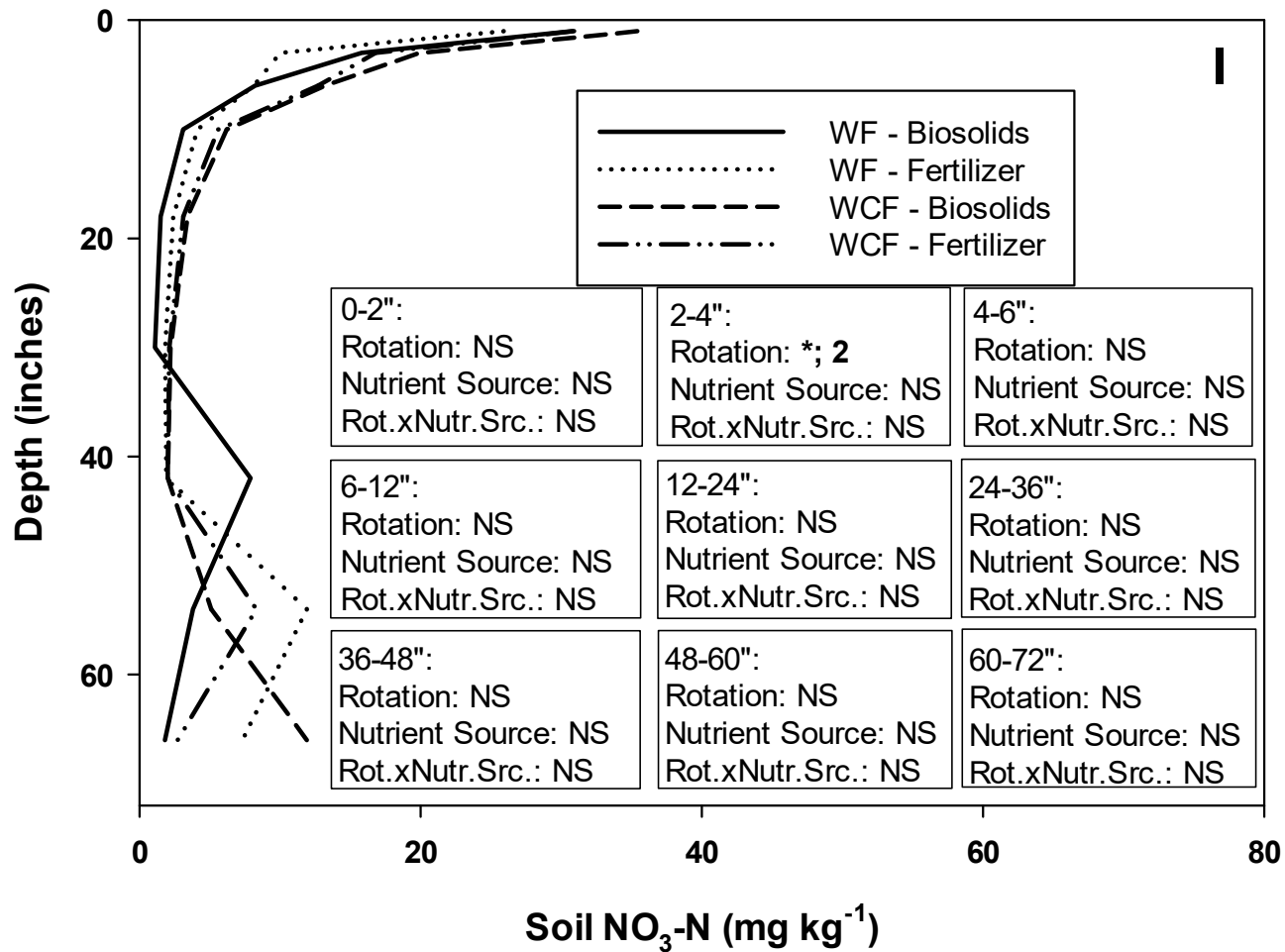


Figure 1. Plant-available soil A) phosphorus, B) cadmium, C) chromium, D) copper, E) iron, F) nickel, G) lead, H) zinc, and I) nitrate-nitrogen concentrations with depth after wheat harvest, 2018.