Supplemental Information

Table S1. Field activities for each study year including timing of planting, sampling, installation of equipment, cover crop termination, and sorghum harvest.

Year 1 (2016–17)		Year 2 (2017–18)	
16 Sep, 2016	Pre-treatment soil cores	*19 Sep, 2017*	Pre-treatment soil cores
16 Oct, 2016	Fertilize, then plant cover crops	*22 Sep, 2017*	Fertilize, then plant cover crops
24 Oct, 2016	Install lysimeters and sample soils	*28 Sep, 2017*	Install lysimeters and TDR's
Mid December	Radish winter-kill event	*27 Oct, 2017*	Sample soils
20 Dec, 2016	Sample soils and harvest cover crop biomass samples	*19 Dec, 2017*	Sample soils and harvest cover crop biomass samples
14 Feb, 2016	Install TDRs	*Mid January*	Radish winter-kill event
30 Mar, 2017	Sample soils and harvest cover crop biomass samples	*4 Apr, 2018*	Sample soils and harvest cover crop biomass samples
24 May, 2017	Sample soils and harvest cover crop biomass samples	*5 Jun, 2018*	Sample soils and harvest cover crop biomass samples
5 Jun, 2017	Terminated cover crops	*10 Jun, 2018*	Terminated cover crops
15 Jun, 2017	Plant sorghum	*25 Jun, 2018*	Plant sorghum
4 Sep, 2017	Harvest sorghum biomass; Sample soils	*2 Oct, 2018*	Harvest sorghum biomass; Sample soils

Table S2. (LEFT) Cover crop biomass, biomass N and mineral soil N in the spring-summer (collection date 24 May 2017) and estimated N leaching from spring-summer (21 Mar - 24 May 2017) for each cover crop treatment and fall N level. (RIGHT) Sorghum biomass, sorghum biomass N, and mineral soil N at sorghum harvest (collection date 4 Sep 2017) for each cover crop treatment and fall N level.

		Spring-Summer				*Sorghum harvest*		
Fall N level	**Cover crop treatment**	**Cover crop biomass**†	**Cover crop biomass N**†	**Mineral Soil N**†	**N leaching (estimated)** ‡	**Sorghum biomass**¶	**Sorghum biomass N**¶	**Mineral Soil N**¶
		Mg ha^{-1}	*kg-N ha^{-1}*	*kg-N ha^{-1}*	*kg-N ha^{-1}*	*Mg ha^{-1}*	*kg-N ha^{-1}*	*kg-N ha^{-1}*
High	No cover crop	-	-	85.1 (16.0)	16.1 (9.3)	12.7 (0.7)	135.1 (11.0)	79.4 (7.8)
	Radish	-	-	27.6 (12.4)	13.7 (10.7)	12.6 (0.3)	91.1 (2.8)	75.6 (10.8)
	Rye	9.9 (1.1)	73.8 (12.0)	30.4 (14.8)	1.2 (1.1)	10.8 (0.5)	73.5 (7.2)	79.5 (6.4)
	Triticale	8.8 (1.1)	73.9 (5.7)	17.6 (7.3)	2.0 (0.3)	9.1 (0.8)	55.1 (2.7)	89.7 (20.1)
	Radish+rye	5.6 (0.6)	49.3 (7.0)	41.2 (19.1)	-	10.4 (0.7)	65.5 (6.3)	78.5 (13.2)
	Radish+triticale	6.4 (0.9)	63.7 (9.1)	26.7 (10.0)	-	9.0 (0.5)	63.4 (7.1)	-
Mid-	No cover crop	-	-	56.4 (6.0)	-	12.7 (0.9)	93.3 (13.2)	74.2 (4.9)
	Radish	-	-	29.8 (6.6)	-	11.5 (0.2)	75.8 (3.4)	-
	Rye	9.8 (0.6)	48.8 (3.9)	19.7 (5.6)	-	6.8 (0.5)	42.7 (4.2)	-
	Triticale	10.2 (0.8)	61.7 (7.9)	-	-	8.3 (0.5)	51.9 (1.1)	-
	Radish+rye	6.8 (0.4)	39.5 (2.5)	-	-	7.2 (0.5)	47.9 (4.6)	-
	Radish+triticale	5.4 (0.3)	40.9 (2.3)	-	-	8.2 (1.3)	49.9 (8.1)	-
Low	No cover crop	-	-	43.0 (13.7)	-	12.4 (0.5)	23.1 (11.5)	69.0 (8.0)
	Radish	-	-	26.4 (6.4)	-	11.2 (0.6)	68.0 (4.7)	-
	Rye	7.7 (1.0)	38.0 (6.1)	25.0 (7.7)	-	7.1 (0.2)	44.4 (2.7)	-
	Triticale	7.2 (0.9)	40.4 (4.2)	-	-	8.2 (0.6)	47.2 (3.5)	-
	Radish+rye	4.7 (1.0)	22.3 (4.7)	-	-	7.7 (0.5)	46.0 (2.3)	-
	Radish+triticale	5.1 (0.6)	34.8 (5.8)	-	-	8.0 (0.7)	56.2 (9.8)	-

† Spring-Summer = 24 May 2017
‡ Spring-Summer = 21 Mar - 24 May 2017
¶ Sorghum harvest = 4 Sep 2017

Table S3. (LEFT) Cover crop biomass, biomass N and mineral soil N in the spring-summer (collection date 5 Jun 2018) and estimated N leaching from spring-summer (21 Mar - 5 Jun 2018) for each cover crop treatment and fall N level. (RIGHT) Sorghum biomass, sorghum biomass N, and mineral soil N at sorghum harvest (collection date 2 Oct 2017) for each cover crop treatment and fall N level.

		Spring-Summer				*Sorghum harvest*		
Fall N level	**Cover crop treatment**	**Cover crop biomass**†	**Cover crop biomass N**†	**Mineral Soil N**†	**N leaching (estimated)** ‡	**Sorghum biomass**¶	**Sorghum biomass N**¶	**Mineral Soil N**¶
		Mg ha^{-1}	*kg-N ha^{-1}*	*kg-N ha^{-1}*	*kg-N ha^{-1}*	*Mg ha^{-1}*	*kg-N ha^{-1}*	
High	No cover crop	-	-	81.3 (19.0)	16.8 (4.0)	5.6 (0.2)	41.4 (2.3)	40.0 (8.9)
	Radish	-	-	71.7 (20.8)	2.9 (1.4)	5.5 (0.3)	39.6 (3.6)	34.2 (16.3)
	Rye	10.0 (0.4)	83.5 (4.4)	68.9 (9.1)	0.2 (0.2)	4.3 (0.3)	33.2 (2.1)	36.7 (7.6)
	Triticale	10.7 (1.0)	110.4 (14.5)	57.9 (5.7)	0.0 (0.0)	4.7 (0.2)	34.4 (1.5)	55.7 (17.6)
	Radish+rye	7.7 (0.3)	64.4 (4.9)	60.6 (17.1)	-	4.5 (0.2)	32.7 (1.7)	56.4 (13.6)
Mid-	No cover crop	-	-	59.2 (14.4)	-	5.5 (0.8)	42.1 (10.7)	41.3 (9.3)
	Radish	-	-	59.5 (11.1)	-	6.0 (1.0)	44.9 (11.7)	-
	Rye	7.2 (0.6)	53.7 (9.6)	66.1 (16.2)	-	4.5 (0.3)	31.3 (4.0)	-
	Triticale	8.0 (1.4)	68.7 (13.9)	61.6 (12.2)	-	4.1 (0.5)	26.5 (4.0)	-
	Radish+rye	2.8 (0.4)	18.6 (3.5)	74.5 (10.1)	-	4.7 (0.3)	32.1 (3.8)	-
Low	No cover crop	-	-	54.8 (18.8)	-	5.3 (0.6)	38.6 (8.6)	33.1 (3.6)
	Radish	-	-	56.5 (20.6)	-	5.0 (0.3)	32.7 (2.0)	-
	Rye	5.3 (0.5)	37.3 (4.2)	56.2 (19.0)	-	4.2 (0.3)	27.2 (2.6)	-
	Triticale	5.9 (0.8)	47.9 (7.1)	61.1 (22.2)	-	4.6 (0.5)	30.3 (5.6)	-
	Radish+rye	1.9 (0.3)	14.1 (2.1)	76.2 (23.0)	-	4.2 (0.3)	29.2 (2.0)	-

† Spring-Summer = 5 Jun 2018
‡ Spring-Summer = 21 Mar - 5 Jun 2018
¶ Sorghum harvest = 2 Oct 2018

Table S4. Analysis of variance model output for soil solution NO_3^--N concentration by cover crop treatment and season (fall-winter, winter-spring, spring-summer). These data were Box-Cox transformed (Box and Cox, 1964) for analysis using a lambda value of 0.2 and 0.1 in year 1 and year 2, respectively.

Year 1			
Effect	df	F value	P>F
Cover crop	3	15.92	<0.001
Season	1	64.73	<0.001
Cover crop:Season	3	6.56	<0.001
Year 2			
Effect	df	F value	P>F
Cover crop	3	60.80	<0.001
Season	2	246.80	<0.001
Cover crop:Season	6	79.16	<0.001

Table S5. Analysis of variance model output for mean soil solution NO_3^--N concentration by cover crop treatment over the entire cover crop growing season. These data were Box-Cox transformed (Box and Cox, 1964) for analysis using a lambda value of 0.2 and 0.1 in year 1 and year 2, respectively.

Year 1			
Effect	df	F value	P>F
Cover crop	3	11.89	<0.001
Year 2			
Effect	df	F value	P>F
Cover crop	3	55.95	<0.001

Table S6. Analysis of variance model output for estimated NO_3^--N leaching losses by cover crop treatment and season (fall-winter, winter-spring, spring-summer). These data were Box-Cox transformed (Box and Cox, 1964) for analysis using a lambda value of 0.2 for both study years.

Year 1			
Effect	df	F value	P>F
Cover crop	3	2.80	0.11 (n.s.)
Season	1	0.71	0.43 (n.s.)
Cover crop:Season	3	0.12	0.94 (n.s.)
Year 2			
Effect	df	F value	P>F
Cover crop	3	35.16	<0.001
Seaon	2	18.61	<0.001
Cover crop:Season	6	9.5	<0.001

Table S7. Analysis of variance model output for estimated NO_3^--N leaching losses by cover crop treatment and fall N level over the entire cover crop growing season. These data were Box-Cox transformed (Box and Cox, 1964) for analysis using a lambda value of 0.1 and 0.9 in year 1 and year 2, respectively.

Year 1			
Effect	df	F value	P>F
Cover crop	3	1.24	0.41 (n.s.)
Year 2			
Effect	df	F value	P>F
Cover crop	3	56.35	<0.001

Table S8. Analysis of variance model output for cover crop biomass (Mg ha^{-1}) by cover crop treatment and fall N level. These data were Box-Cox transformed (Box and Cox, 1964) for analysis using a lambda value of -0.3, 0.9, 2.0 in high, mid, and low fall N level in year 1. Year 2 data were Box-Cox transformed (Box and Cox, 1964) for analysis using a lambda value of -0.1, -0.1, -0.9 in high, mid, and low fall N level, respectively.

		Fall-Winter (Year 1)		
Fall N level	Effect	df	F value	P>F
High	Cover crop	4	1.47	0.27 (n.s.)
Mid	Cover crop	4	0.83	0.53 (n.s.)
Low	Cover crop	4	4.11	0.03
		Fall-Winter (Year 2)		
Fall N level	Effect	df	F value	P>F
High	Cover crop	3	10.75	0.001
Mid	Cover crop	3	10.44	0.001
Low	Cover crop	3	9.26	0.002

Table S9. Analysis of variance model output for cover crop biomass N (kg-N ha^{-1}) by cover crop treatment and fall N level. These data were Box-Cox transformed (Box and Cox, 1964) for analysis using a lambda value of -0.2, 0.7, 2.0 in high, mid, and low fall N level in year 1, respectively. Year 2 data were Box-Cox transformed (Box and Cox, 1964) for analysis using a lambda value of 0.8, 0.7, -0.9 in high, mid, and low fall N level, respectively.

		Fall-Winter (Year 1)		
Fall N level	Effect	df	F value	P>F
High	Cover crop	4	2.51	0.10 (n.s.)
Mid	Cover crop	4	1.91	0.11 (n.s.)
Low	Cover crop	4	13.78	<0.001
		Fall-Winter (Year 2)		
Fall N level	Effect	df	F value	P>F
High	Cover crop	3	13.35	0.001
Mid	Cover crop	3	24.52	<0.001
Low	Cover crop	3	7.34	0.003

Table S10. Analysis of variance model output for mineral soil N (kg-N ha^{-1}) by cover crop treatment in the high fall N level for year 1 and by cover crop treatment and fall N level in year 2. These data were Box-Cox transformed (Box and Cox, 1964) for analysis using a lambda value of 1.8 and 1.0 in year 1 and year 2, respectively.

Fall-Winter (Year 1)			
Effect	df	F value	P>F
Cover crop	3	2.29	0.15
Fall-Winter (Year 2)			
Effect	df	F value	P>F
Cover crop	4	9.42	0.001
Fall N	2	6.89	0.028
Cover crop:Fall N	8	4.09	0.005
Block	3	41.54	<0.001
Error A	6	8.27	<0.001
Error B	12	4.06	0.002
Error C	20	-	-

Table S11. Analysis of variance model output for cover crop biomass (Mg ha^{-1}) by cover crop treatment and fall N level. These data were Box-Cox transformed (Box and Cox, 1964) for analysis using a lambda value of 0.4 and -0.4 in year 1 and year 2, respectively.

Winter-Spring (Year 1)			
Effect	df	F value	P>F
Cover crop	3	17.09	<0.001
Fall N	2	11.46	0.01
Cover crop:Fall N	6	3.87	0.01
Block	3	2.67	0.08 (n.s.)
Error A	6	2.50	0.06 (n.s.)
Error B	9	2.37	0.01
Error C	18	-	-
Winter-Spring (Year 2)			
Effect	df	F value	P>F
Cover crop	2	44.77	<0.001
Fall N	2	67.71	<0.001
Cover crop:Fall N	4	21.39	<0.001
Block	3	2.37	0.11 (n.s.)
Error A	6	2.58	0.04
Error B	6	2.00	0.11 (n.s.)
Error C	22	-	-

Table S12. Analysis of variance model output for cover crop biomass N (kg-N ha^{-1}) by cover crop treatment and fall N level. These data were Box-Cox transformed (Box and Cox, 1964) for analysis using a lambda value of 0.4 in year 1. Year 2 data were Box-Cox transformed (Box and Cox, 1964) for analysis using a lambda value of -0.6, -0.4, -1.7 in high, mid, and low fall N level, respectively.

		Winter-Spring (Year 1)		
Fall N level	Effect	df	F value	P>F
-	Cover crop	3	5.28	0.02
	Fall N	2	13.78	0.01
	Cover crop:Fall N	6	4.59	0.01
	Block	3	3.69	0.03
	Error A	6	2.20	0.09 (n.s.)
	Error B	9	2.72	0.03
	Error C	18	-	-
		Winter-Spring (Year 2)		
Fall N level	Effect	df	F value	
High	Cover crop	2	4.86	0.03
Mid	Cover crop	2	20.18	<0.001
Low	Cover crop	2	79.50	<0.001

Table S13. Analysis of variance model output for mineral soil N (kg-N ha^{-1}) by cover crop treatment and fall N level. These data were Box-Cox transformed (Box and Cox, 1964) for analysis using a lambda value of 0.4 the in high fall N level in year 1. Year 2 data were Box-Cox transformed (Box and Cox, 1964) for analysis using a lambda value of -0.5, 0.3, 0.5 in high, mid, and low fall N level, respectively.

		Winter-Spring (Year 1)		
Fall N level	Effect	df	F value	P>F
High	Cover crop	3	9.98	0.001
		Winter-Spring (Year 2)		
	Effect	df	F value	P>F
High	Cover crop	4	5.29	0.01
Mid	Cover crop	4	2.69	0.08 (n.s.)
Low	Cover crop	4	0.46	0.76 (n.s.)

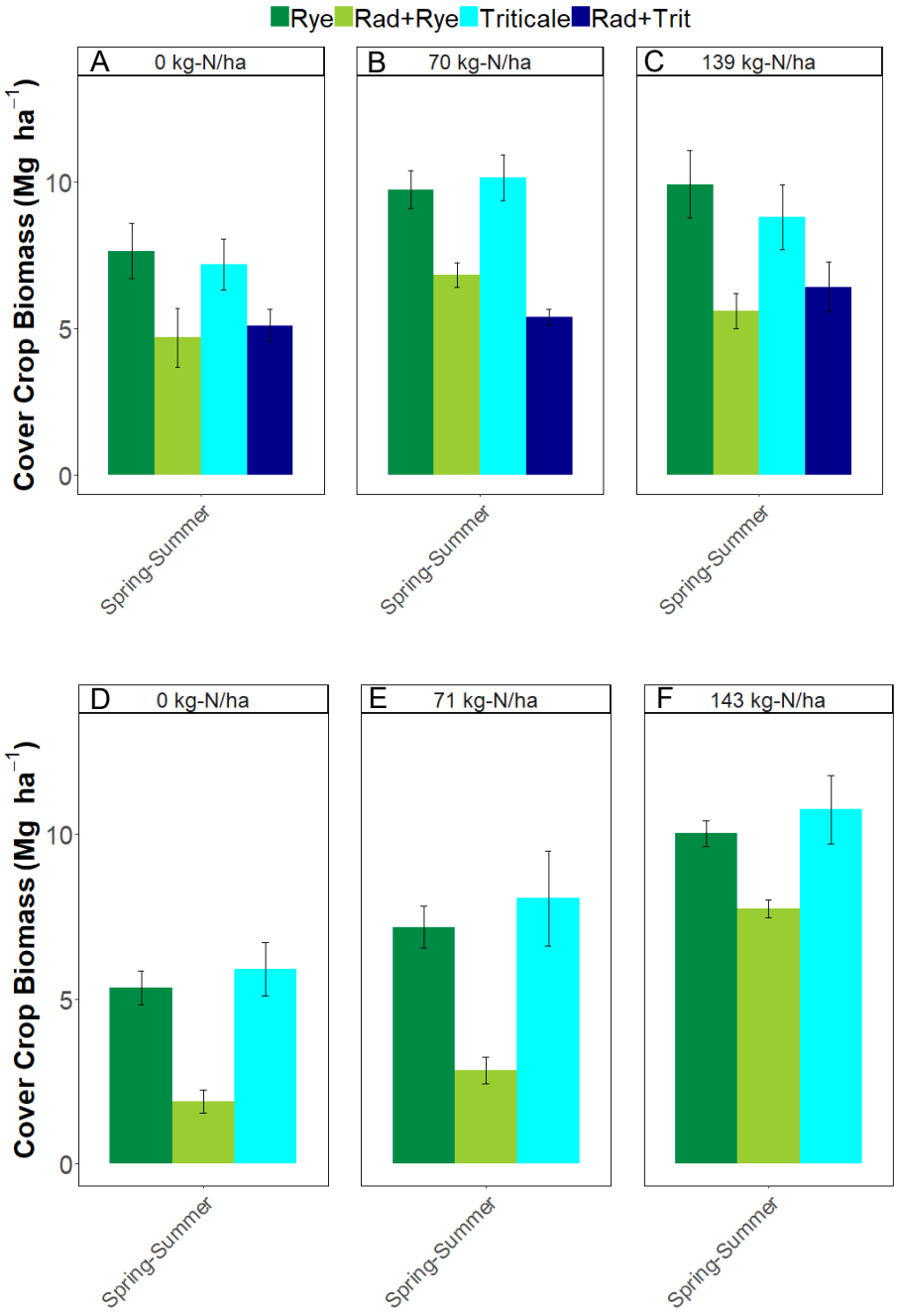

Figure S1. Cover crop biomass (Mg ha^{-1}) in (A-C) year 1 and (D-F) year 2 in the (A, D) low, (B, E) mid, and (C, F) high residual N levels. Cover crop treatments include rye (dark green), radish+rye (light green), triticale (cyan), and radish+triticale (dark blue). Vertical bars represent the standard error of the mean.

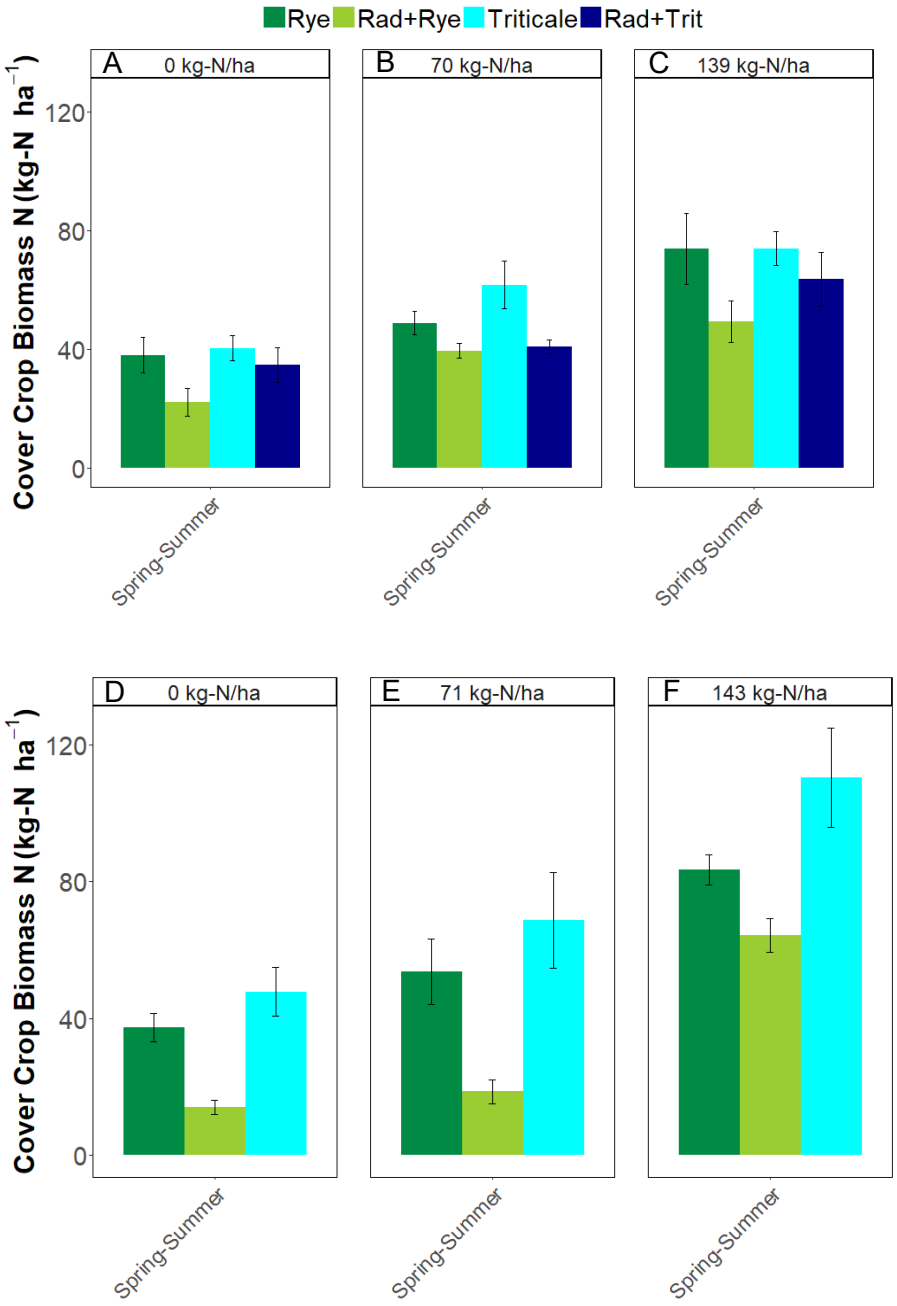

Figure S2. Cover crop biomass N (kg ha^{-1}) by treatment in (A-C) year 1 and (D-F) year 2 in the (A, D) low, (B, E) mid, and (C, F) high residual N levels. Cover crop treatments include rye (dark green), radish+rye (light green), triticale (cyan), and radish+triticale (dark blue). Vertical bars represent the standard error of the mean.

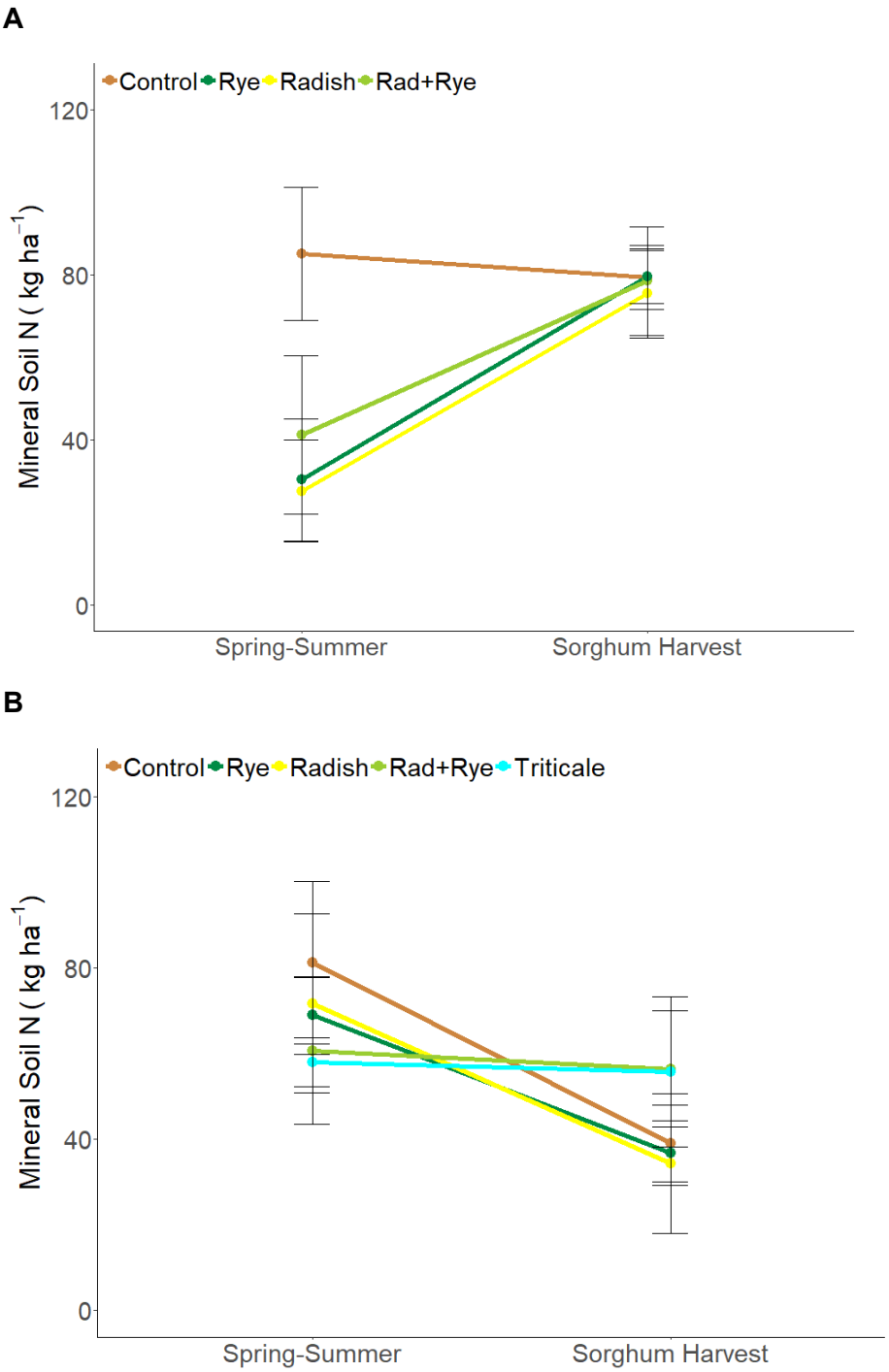

Figure S3. Mineral soil N (kg-N ha^{-1}) from 0-60 cm collected in (A) year 1 and (B) year 2 in the high fall N treatment only. In year 1, spring-summer was 24 May 2017 and sorghum harvest was 4 Sep 2017. In year 2, spring-summer was 5 Jun 2018 and sorghum harvest was 2 Oct 2018. Cover crop treatments include control (brown), rye (dark green), radish (yellow), radish+rye (light green), and triticale (cyan). Vertical bars represent the standard error of the mean.

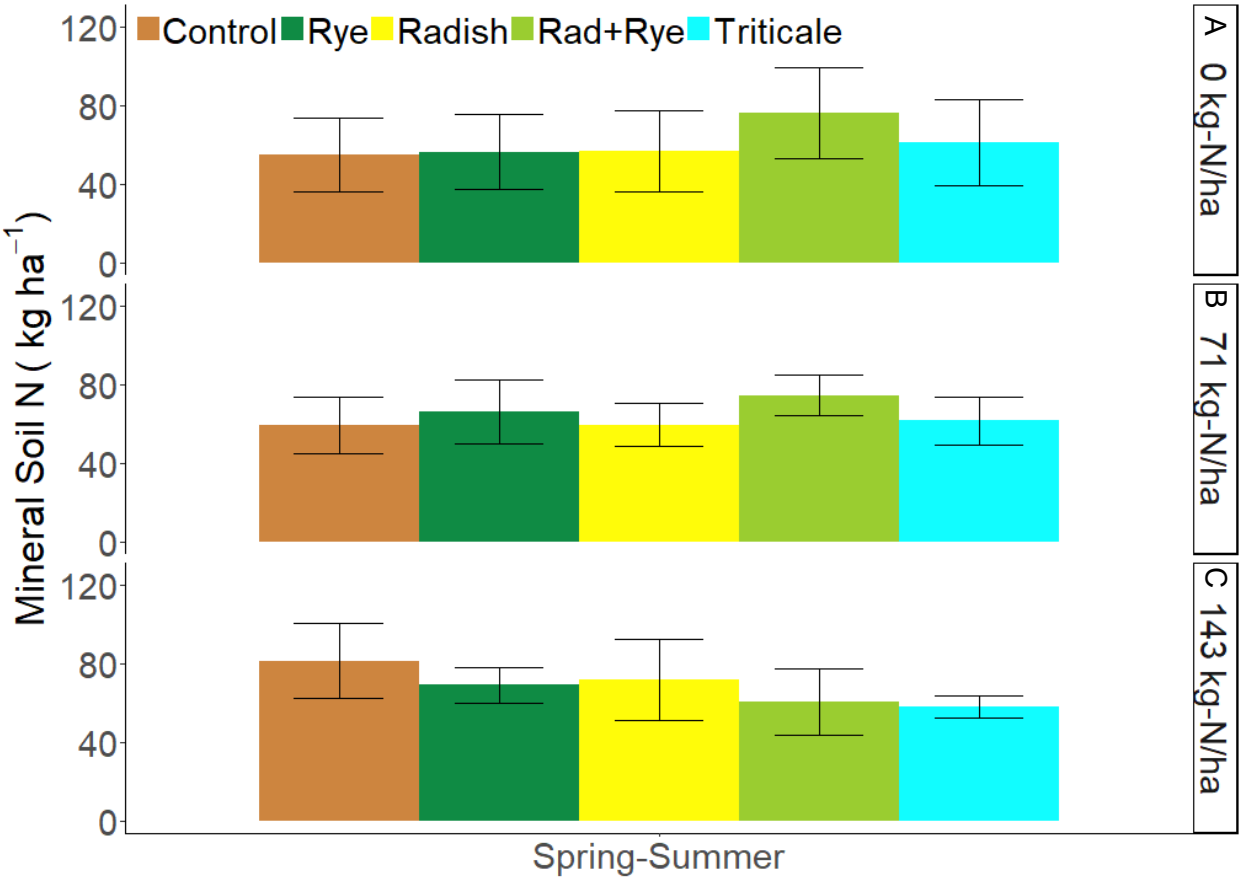

Figure S4. Mineral soil N (kg-N ha^{-1}) from 0-60 cm in the low (A), mid (B), and high (C) fall N levels on 5 Jun 2018 in year 2. Cover crop treatments include control (brown), rye (dark green), radish (yellow), radish+rye (light green), and triticale (cyan). Vertical bars represent the standard error of the mean.

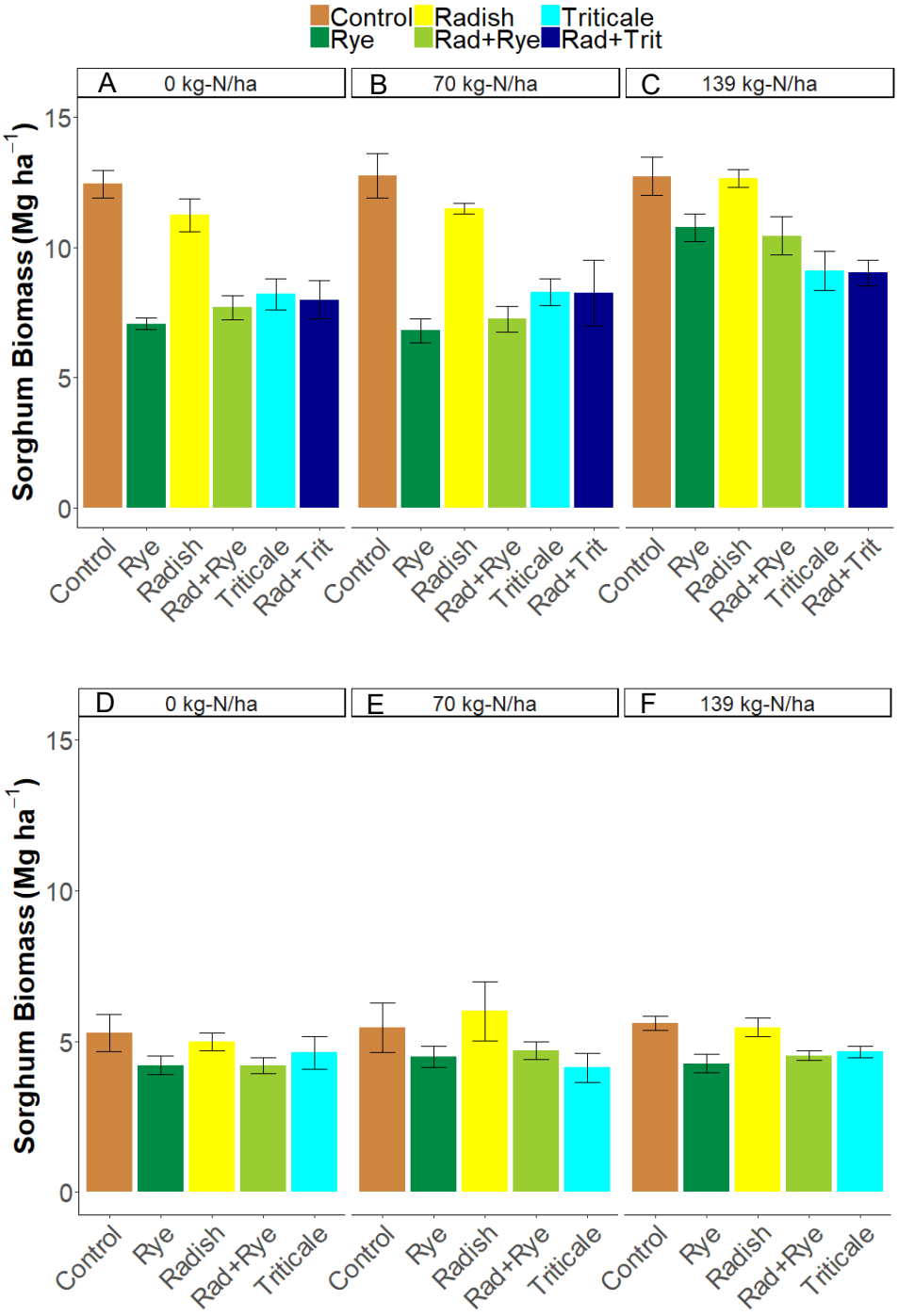

Figure S5. Sorghum aboveground biomass (Mg ha^{-1}) in (A-C) year 1 and (D-F) year 2 by (A, D) low, (B, E) mid, and (C, F) high residual N levels. Cover crop treatments include: control (brown), rye (dark green), radish (yellow), radish+rye (light green), and triticale (cyan). Black bars are the standard error of the mean.

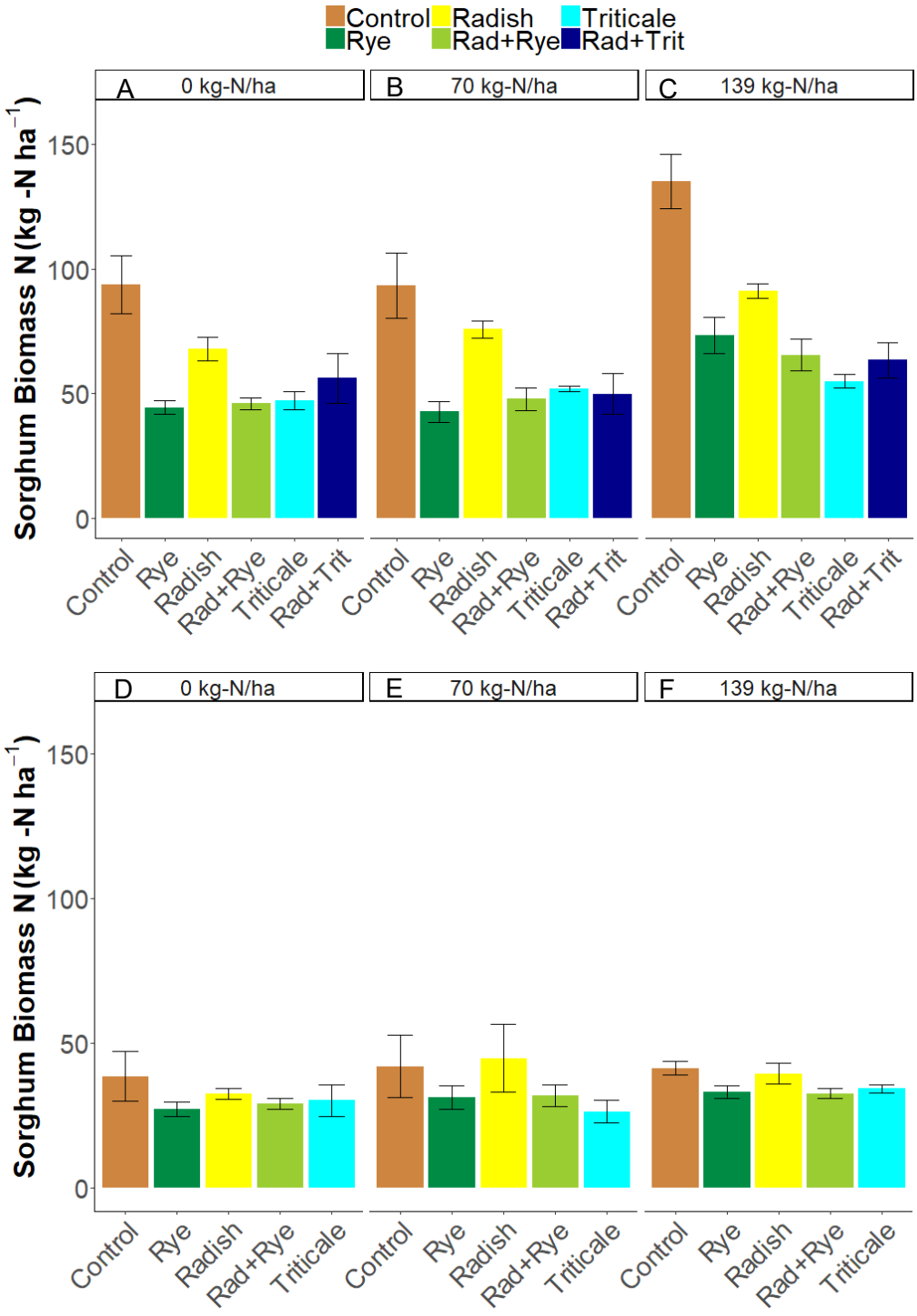

Figure S6. Sorghum biomass N (kg-N ha^{-1}) in (A-C) year 1 and (D-F) year 2 by (A, D) low, (B, E) mid, and (C, F) high residual N levels. Cover crop treatments include: control (brown), rye (dark green), radish (gold), radish+rye (light green), triticale (cyan), and radish+triticale (dark blue). Black bars are the standard error of the mean.

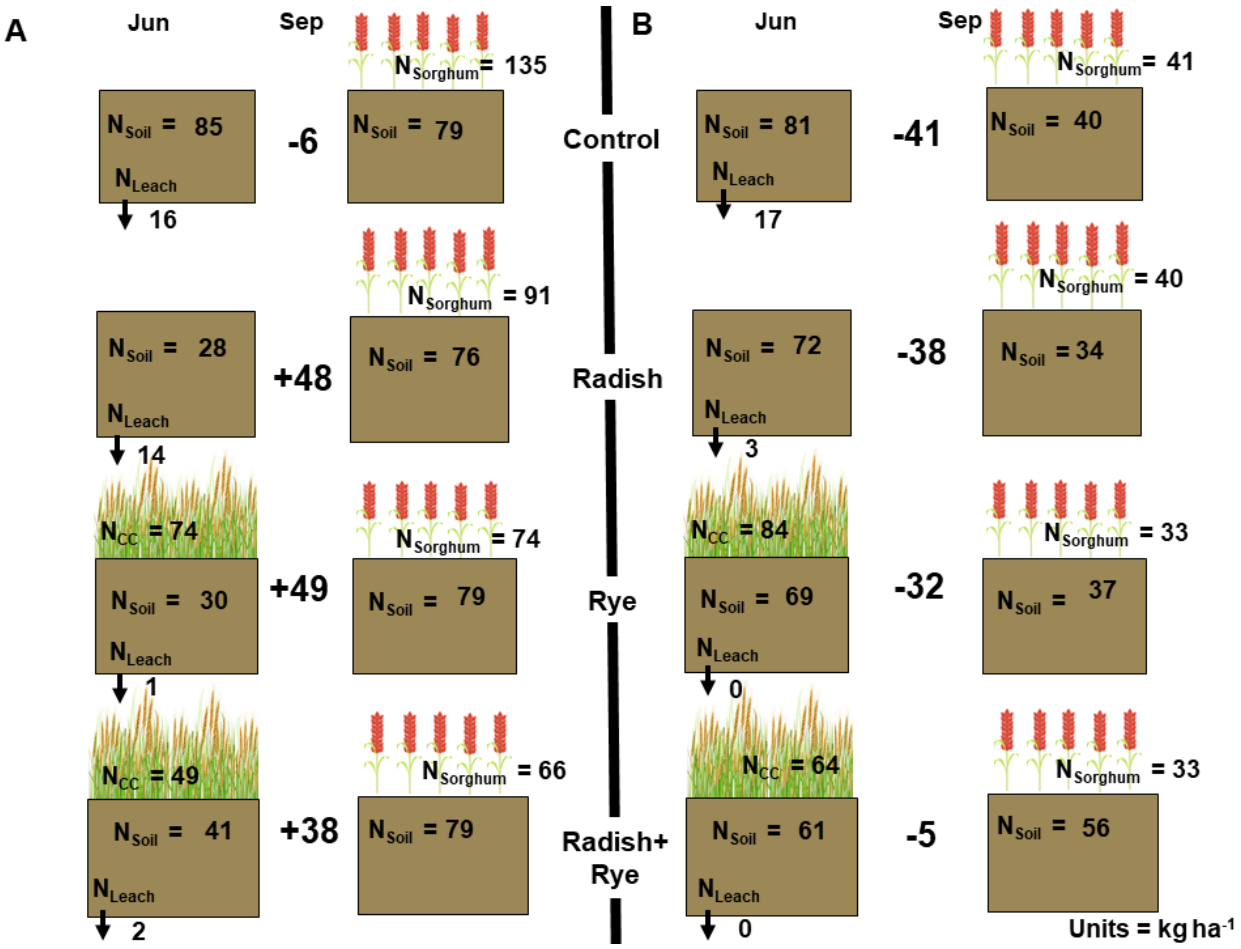

Figure S7. Mineral N, cover crop biomass N, and estimated N leaching by cover crop treatment on 24 May and 4 Sep 2017 in year 1 (A) and on 5 Jun and 2 Oct in year 2 (B). All values are reported in kg ha^{-1}. Where N_{soil} is the mineral soil N, N_{cc} is the cover crop biomass N, N_{Leach} is the N leaching losses, and $N_{Sorghum}$ is the sorghum biomass N. In year 1 N leaching losses are from 21 Mar - 24 May 2017 and from 21 Mar - 5 Jun 2018 in year 2.

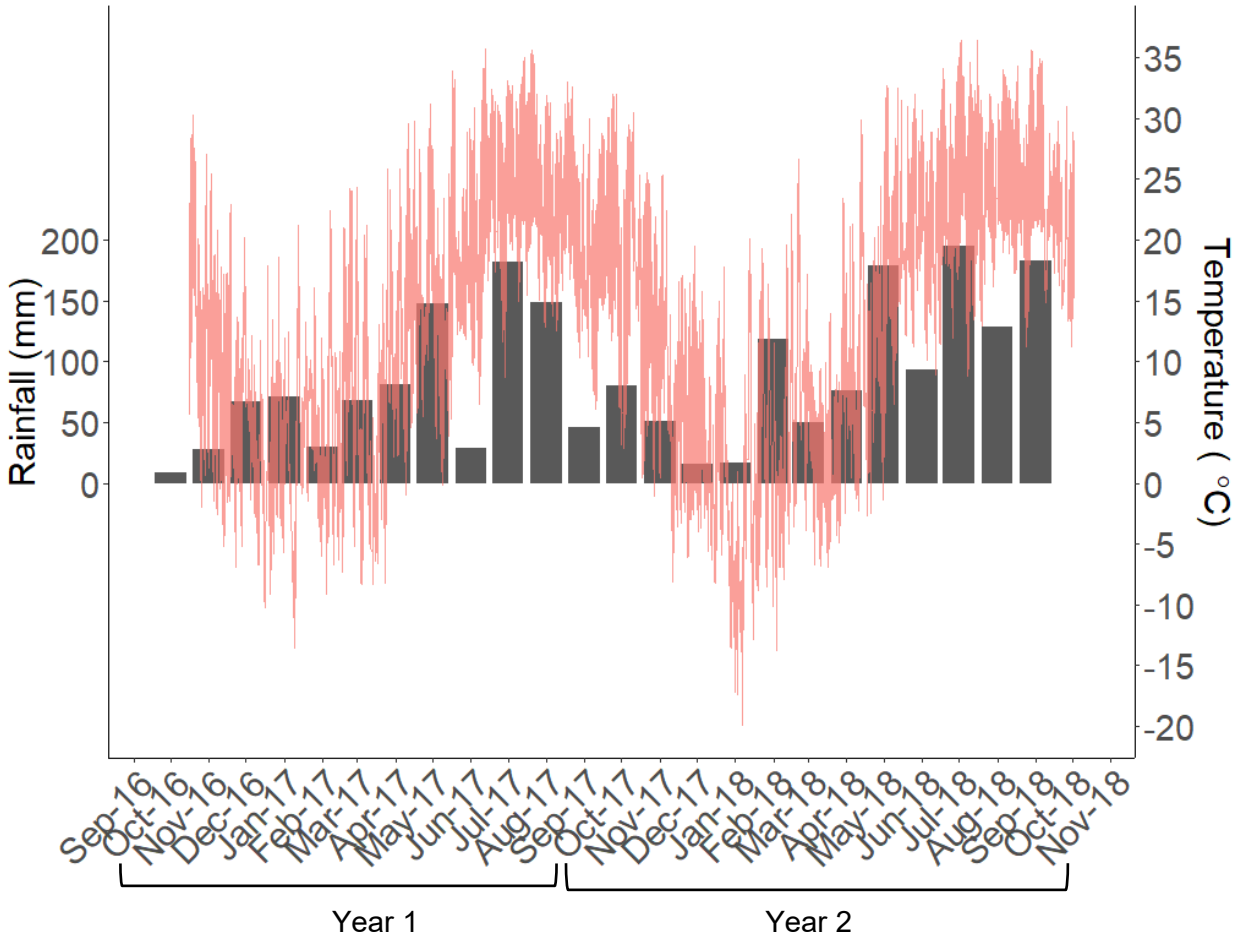

Figure S8. Rainfall (mm; gray bars) and temperature (°C; red lines) from cover crop planting to sorghum harvest for both study years. These data were collected from a nearby (1.2 km) meteorological tower (USDA-ARS, 2019).