Project title: Using Sudangrass and Sorghum-Sudangrass hybrids as cover crops following leafy greens to mitigate water and soil related issues in the Imperial and Salinas Valleys.

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Abstract

Trials were conducted in the Salinas and Pajaro Valleys to evaluate using warm season adapted cover crops planted in the fall to limit biomass growth during the winter while providing water quality benefits such as reducing runoff, increasing rainfall infiltration, and scavenging residual soil nitrate. Cold weather during the winter greatly slowed or set back growth of sudangrass and sorghum sudangrass cover crops thereby limiting dry matter yield to 1 to 2 tons per acre. Nitrogen uptake of these cover crops ranged from 45 to 135 lbs N per acre and the C:N ratio of the tissue was ~15 near maturity, which is sufficiently high to minimize the rate of N mineralization after soil incorporation. The cover crops could be easily terminated and incorporated into the soil using a mulcher in early spring. At the Salinas Valley trial, which had a soil type susceptible to crusting and more than a 5% slope, sudangrass and sorghum sudangrass reduced storm runoff by 70% and increased recharge from rainfall by more than 20% during the season. Additionally, these cover crop species reduced sediment loss by as much as 94% compared to plots left bare fallow. No significant volume of runoff was measured at the PajaroValley site which had less than a 2% slope and where the soil was a well-aggregated silt loam.

Objectives

The overall goal of this project was to develop information on the efficacy of winter grown sudangrass and sorghum-sudangrass hybrid cover crops on N leaching losses, stormwater runoff, and infiltration of winter rain in vegetable fields in the Salinas Valley. Specific objectives were

a. To evaluate of growth and biomass accumulation of sudangrass and sorghum-sudangrass hybrid cover crops planted in the late summer/early fall following leafy greens.
b. To evaluate N uptake of the sudangrass and sorghum-sudangrass planted in the fall and left in place during the winter.

c. To evaluate soil moisture, rainfall infiltration, runoff, and salinity and nitrate distribution in the soil profile under cover crop and bare soil treatments during the winter fallow period.

Procedures:

Cover crop trials were established in the Pajaro and Salinas Valleys in September and October of 2023 (Table 1). The Pajaro Valley site (Site 1) was located near San Juan Rd. between Aromas and Pajaro CA. The soil type was a Mocho silt loam on < 2% slope. The Salinas Valley site (Site 2) was located near Arroyo Seco Rd., west of Soledad CA. The soil type was an Arroyo Seco gravelly loam on > 5% slope. Before planting both fields were tilled and listed with 40-inch-wide beds for planting lettuce crops in the spring of 2024. Cover crop treatments established at each site were bare-fallow, sudangrass (*cv.* piper), and sorghum-sudangrass hybrid (*cv.* sweet and honey). The experimental design was a randomized complete block, with 2 replications at site 1 and 4 replications at site 2. Plots measured 13.3 ft wide × field length (Table 1). The cover crops were planted with a grain drill on the top, side, and furrow between beds. Seeding rates are presented in Table 1. Sprinklers were used to germinate the cover crops using 2.6 to 3.7 inches of water (Table 1). Applied water was measured using a flowmeter (Seametric AG3000) positioned on the submain. After emergence of the cover crop, sprinklers were removed from the field and no additional irrigation water was applied. An application of the herbicide Bromoxinil (Buctril/Maestro) was applied to kill emerged broadleaf weeds approximately 30 to 45 days after planting .

Air temperature was monitored at each site in one of the cover-cropped plots and in a bare fallow plot. Rainfall was recorded at 30-minute intervals using a tipping bucket rain gauge with a 10-inch diameter and a datalogger.

Flumes were installed at the lower end of each plot to monitor runoff volume during storm events. Stilling wells and float mechanisms connected to the flumes allowed water height in the flumes to be recorded at 2-minute intervals using a datalogger. A standard curve provided by the flume manufacturer was used to convert runoff height to flow rate. The datalogger also activated peristaltic pumps at 5-minute intervals when flow was detected in the flumes so that runoff could be sampled into collection buckets. Runoff samples were analyzed for pH, EC, and turbidity at the UCCE Monterey laboratory. Samples were further analyzed for NO_3-N, total N, PO_4-P total P, and total suspended solids (TSS) at the UC Davis Analytical laboratory. Seasonal sediment loss from the plots was estimated by multiplying the concentration of TSS by the total volume of runoff measured with the flumes for each storm event.
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At each site, hydroprobe PVC access tubes were installed at 2 locations within each plot. Measurements of volumetric soil moisture were made with the hydroprobe to a 4 ft depth at 2-to-3-week intervals during the trial.

Soil from each plot was periodically sampled to a 3-foot depth for analysis of soil mineral N and salinity. Soil nitrate was evaluated using the quick nitrate test using the reflectoquant analyzer Samples were also extracted with 2N KCl for analysis of mineral N at the UC Davis analytical laboratory. Soil samples were air dried for salinity analysis.

Aboveground biomass was measured in the cover crop treatments at 3 to 4 dates during the fall and winter. A sample of the biomass was oven dried at 60 °C to determine the moisture content and then sent to the UC Davis analytical laboratory for determination of N and C content.

Growth of the lettuce crops planted in the spring and summer after the winter cover crop treatments were evaluated by: 1. Comparing plant populations among treatments, and 2. Measuring the above ground biomass at maturity. These measurements were completed at site 1 at the time of submitting the final report but was not possible to finish for site 2 as the crop was still a few weeks away from harvest.

Results and Discussion:

Above ground biomass

The cover crops accumulated different amounts of dry matter for sites 1 and 2 (Tables 2 and 3). Above ground dry biomass for sudangrass and sorghum-sudangrass reached a maximum of 2.2 and 1.9 tons/acre, respectively, ~ 100 days after planting (DAP) at site 1 (Table 2). A decline in dry matter biomass occurred by 152 days. At site 2 both cover crop treatments accumulated less than 1 ton/acre of dry matter by 161 DAP (Table 3).

Several factors may have contributed to the difference in biomass yield between sites. Because site 1 was closest to the ocean, the minimum daily temperatures tended to be higher than at site 2 which was located inland near Soledad. Also, the frequency and duration of freezing temperatures was less at site 1 than at site 2 (Figs. 1 and 2). In addition, soil moisture was less during the first months of establishment at site 2 compared to site 1, which was on silt loam soil with a high-water holding capacity. Finally, the cover crops were planted deeper than recommended (> 1 inch) at site 2, which delayed emergence.

Nitrogen uptake and carbon accumulation

Nitrogen update by the cover crops was greater than 100 lbs N/acre by 100 DAP at site 1 (Table 2), and around 50 lbs N/acre by 161 DAP at site 2 (Table 3). Carbon to nitrogen ratios (C:N) reached a maximum of 15 at 150 DAP for both sites. A C:N ratio of 15 would presumably mineralize N slowly after soil incorporation. Hence the combined effect of the cover crops taking up residual soil N in the late fall, before the arrival of winter rainstorms, and slowly releasing N after spring incorporation could potentially minimize losses of nitrate-N over the winter months.

Storm runoff volume

Total seasonal rainfall (Figs. 3 and 4) was greater at site 1 (~17 inches) compared to site 2 (~10 inches), which was further south and in the rain shadow of the San Lucio mountains. However, minimal runoff was measured at site 1, and only detected in the bare plots. In contrast, runoff was measured in all plots at site 2, which had a soil type susceptible to crusting and significant slope. Most runoff events at site 2 occurred in late January and early February during the most

frequent and intense storm events (Fig. 4). During this period 50% of the rainfall infiltrated in the bare plots and 85% in the cover cropped plots (Fig. 5). Over the entire winter season, which included less intense storm events, 76% of the rainfall infiltrated in the bare plots and 93% in the cover cropped plots (Fig. 6).

Nutrient and sediment loss in runoff

Storm runoff sampled from the cover cropped plots had significantly lower concentrations of total N, total P, suspended sediments (total suspended solids), and turbidity than the bare plots (Table 4). Seasonal loss of sediment from the bare plots averaged more than 3500 lbs/acre Seasonal loss of sediment in the sudangrass and sorghum-sudangrass cover crops was 98% and 96% less, respectively, compared to the bare (no cover crop plots) (Fig. 7). The significant reduction in sediment loss under the cover cropped plots resulted from the combined effect of less runoff volume and less suspended sediments in the runoff compared to the bare plots.

Soil Nitrate and salinity

Soil N status to a 3 ft depth was compared among treatments at site 2 over the fall and winter months, where cover crops accumulated 45 to 55 lbs N/acre. There was not sufficient replication of the treatments to make a similar comparison at site 1. In the fall (10/17/23) soil N status was similar among the three treatments at site 2 (Fig. 8). By the second week of January (1/11/24) less N was measured in the top foot of the soil profile in the cover crop treatments than the bare treatment. It is unclear if this reduction was caused by the cover crops taking up nitrogen or from more leaching. The second and third foot of depth had similar concentrations of N among cover crop and bare treatments. After the heaviest rains occurred during the early February soil N levels in the second- and third-foot depths were less in the cover cropped treatments than the bare treatment, suggesting that extra water which infiltrated in the cover crop treatments may have resulted in more leached nitrate. Analysis of how salinity changed in the soil profile in each treatment over winter may help confirm if leaching was greater under the cover crop treatments compared to the bare treatment. However, more funding will be needed to complete the salinity analyses. We anticipate finishing this task during the second year of the project.

Effects of cover crop treatments on lettuce growth

The cover cropped plots at site 1 were terminated by incorporating with a tractor driven mulcher on April 4, 2024. The field was later planted with a romaine crop on 80-inch beds in early May 2024. Yield was evaluated on 7/16/24 a few days before commercial harvest. Untrimmed head weight was higher in the cover crop treatments than the bare treatment (Table 5). Marketable and diseased plant numbers were similar among treatments. Biomass and estimated marketable yield were about 20% greater in the cover cropped plots compared to the bare plots. This result may be an artifact of insufficient replication (n = 2) rather than a significant effect of the cover crops. However, these results provide some assurance that the sudangrass and sorghum-sudangrass cover crops have no negative carry over effects on the growth of the following lettuce crops. Further evaluation of the effect of these cover crops on lettuce growth is continuing at site 2.

Conclusions

Trials were conducted to evaluate using warm season adapted cover crop species planted in the fall to limit biomass growth during the winter while providing water quality benefits such as reducing runoff, increasing rainfall infiltration, and taking up residual soil nitrate. Cold weather greatly slowed or set back growth of both sudangrass and sorghum sudangrass thereby limiting dry matter yield to 1 to 2 tons per acre. Nitrogen uptake of these cover crops ranged from 45 to 135 lbs N per acre and the C:N ratio of the tissue was ~15 near maturity. The cover crops could be easily terminated and incorporated into the soil using a mulcher in early spring. The trials showed that in fields susceptible to runoff and erosion due to soil type and/or slope, sudangrass and sorghum sudangrass can greatly reduce storm runoff and increase recharge from rainfall. Additionally, these cover crop species showed potential to significantly reduce sediment loss during storm events.

Table 1. Details of cover crop field trials at sites 1 and 2.

Site variable	Site 1	Site 2
Soil type	Mocho silt loam	Arroyo Seco gravelly loam
Slope	< 2%	> 5%
Plot length	465 ft	1053 ft
Plot width	13.33 ft	13.33 ft
bed width	40 inches	40 inches
treatment replications (n)	2	4
cover crop seeding date	9/27/2024	10/4/2024
seeding rate (Sudangrass)	70 lbs/acre	65 lbs/acre
seeding rate (Sorghum sudangrass)	91 lbs/acre	79 lbs/acre
germination water volume	3.7 in	2.6 in

Table 2. Aboveground biomass, and N and C content of cover crop treatments at site 1 at multiple dates after planting.

Treatment	Dry aboveground biomass yield	N content	C content	N uptake	Carbon accumulation	C:N ratio
	tons/acre	%	%	----- lbs/acre -------		
	----------	29 DAP (10/26/23)	----------			
Sudangrass	0.31	5.2	43.7	32.3	273	8
Sorghum-sudangrass	0.27	4.3	43.8	23.5	239	10
	----------	47 DAP (11/20/23)	----------			
Sudangrass	0.96	3.9	42.7	74.0	819	11
Sorghum-sudangrass	1.10	3.3	42.5	73.7	935	13
	----------	99 DAP (1/11/24)	----------			
Sudangrass	2.24	3.0	41.6	134.9	1863	14
Sorghum-sudangrass	1.86	3.0	41.4	110.7	1541	14
	----------	152 DAP (2/26/24)	----------			
Sudangrass	1.73	2.9	41.7	99.5	1442	14
Sorghum-sudangrass	1.82	2.6	41.0	93.6	1493	16

Table 3. Aboveground biomass, and N and C content of cover crop treatments at site 2 at multiple dates after planting.

Treatment	dry biomass yield (t/ac)	N content	C content	N uptake	Carbon	C:N ratio
	tons/acre	%	%	------ lbs/acre -----		
	---------- 57 DAP (11/30/23) ----------					
Sudangrass	0.28	4.2	43.8	23.2	243	11
Sorghum-sudangrass	0.21	4.4	44.0	19.0	188	10
	---------- 97 DAP (1/9/24) ----------					
Sudangrass	0.53	3.8	43.4	39.1	455	12
Sorghum-sudangrass	0.35	4.1	43.5	28.1	301	11
	---------- 161 DAP (3/13/24)----------					
Sudangrass	0.96	2.9	43.1	55.8	826	15
Sorghum-sudangrass	0.80	2.8	43.7	45.5	699	15

Table 4. Chemistry of runoff collected from cover crop treatments (2/2/24 – 2/21/24). Average of 4 sampling dates (2/2, 2/5, 2/8, 2/21/24).

Treatment	EC	pH	Total N	NO_3-N	P (Total)	PO_4-P (Sol P)	Turbidity	Total Suspended Solids
	dS/m		---------- mg/L ----------				NTU	mg/L
Bare fallow	0.11	7.68	6.45	0.93	12.38	0.92	8633	7311
Sudangrass	0.09	7.17	2.96	0.65	2.50	0.90	1209	706
Sorghum-sudangrass	0.07	7.20	3.58	0.56	3.92	0.93	2445	1673

Table 5. Romaine lettuce plant weight, plant population, biomass yield, and estimated marketable yield following winter cover crop treatments at site 1.

		Plant population at harvest					
Treatment	Average plant wt (untrimmed)	Total	Diseased	Marketable	Diseased	Biomass yield	Estimated marketable yield
	lb/plant	---- plants per 100 ft of bed ------			%	----- lbs/acre ----	
Bare fallow	1.54	516	46	470	9.0	47217	33052
Sorghum-sudangrass	1.73	540	37	503	6.9	56861	39803
Sudangrass	1.82	515	40	475	7.7	56464	39525

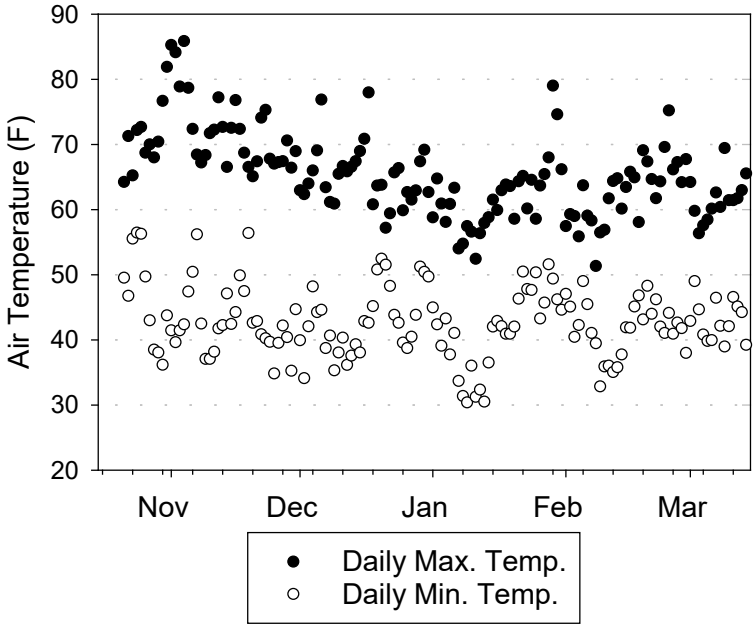

Figure 1. Maximum and minimum air temperature at site 1.

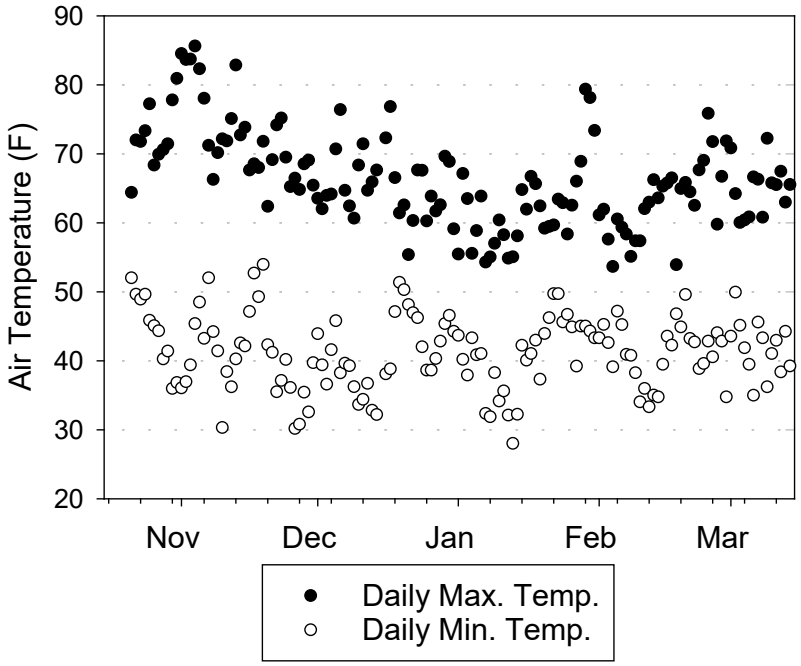

Figure 2. Maximum and minimum air temperature at site 2.

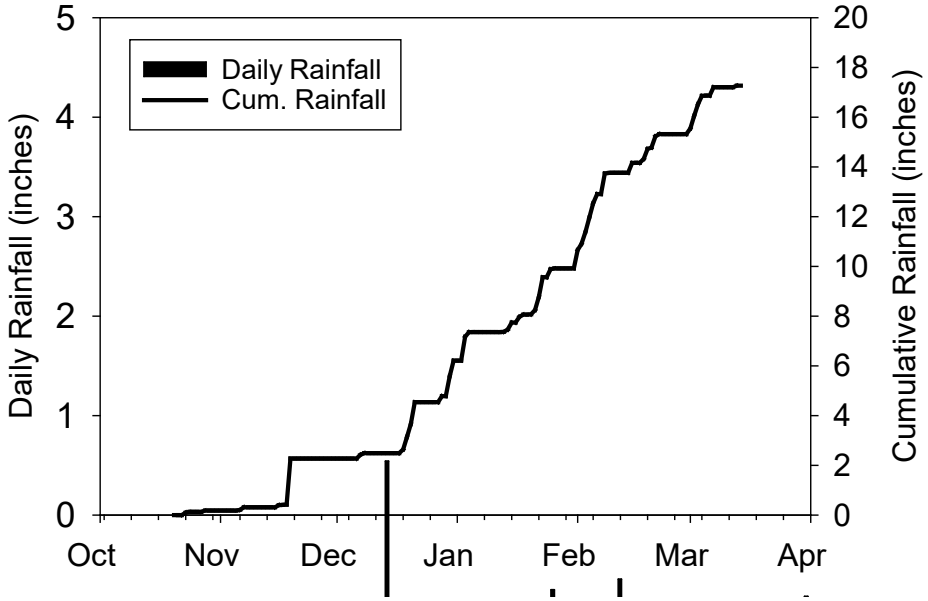

Figure 3. Daily and cumulative rainfall at site 1.

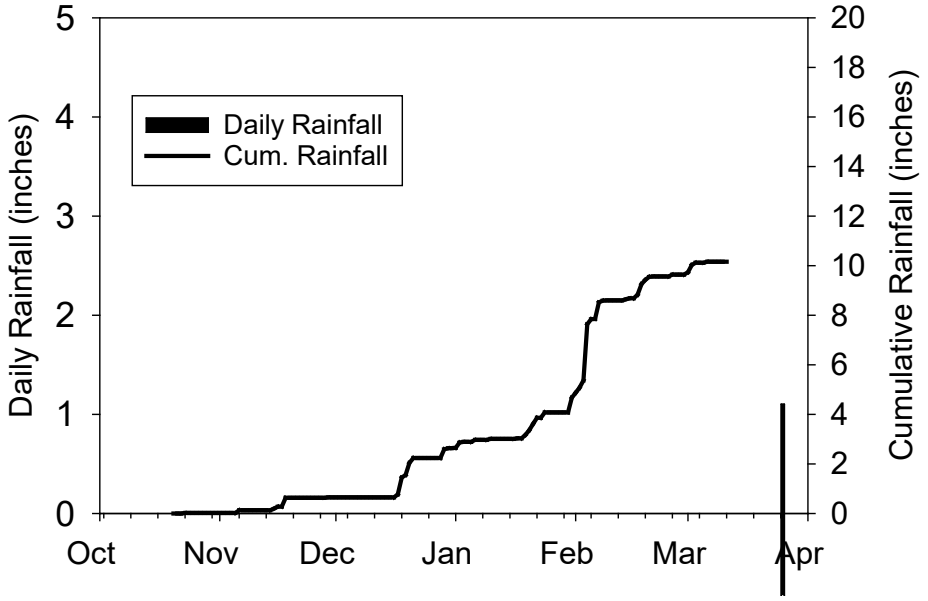

Figure 4. Daily and cumulative rainfall at site 2.

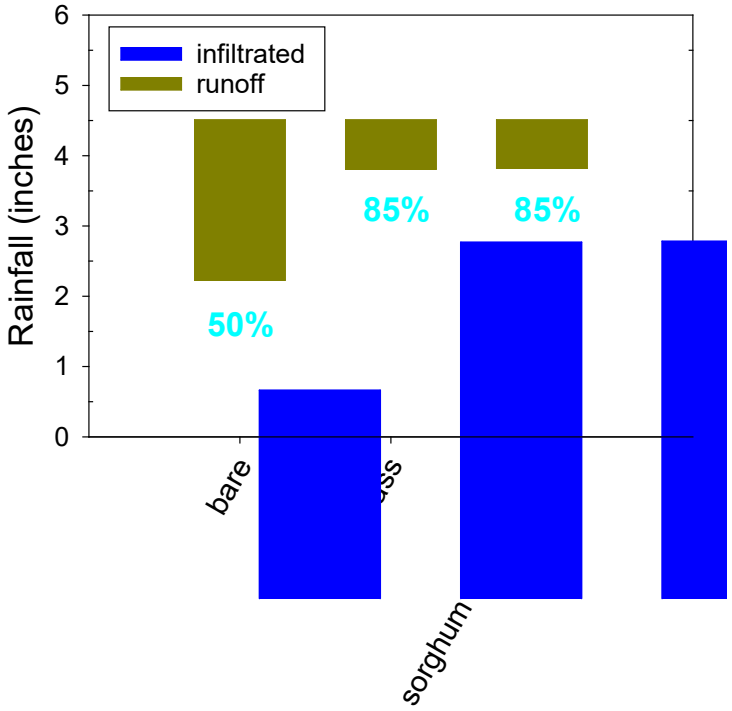

Figure 5. Rainfall volume infiltrated and lost as runoff in the cover crop and bare treatments at site 2 during late January and early February 2024.

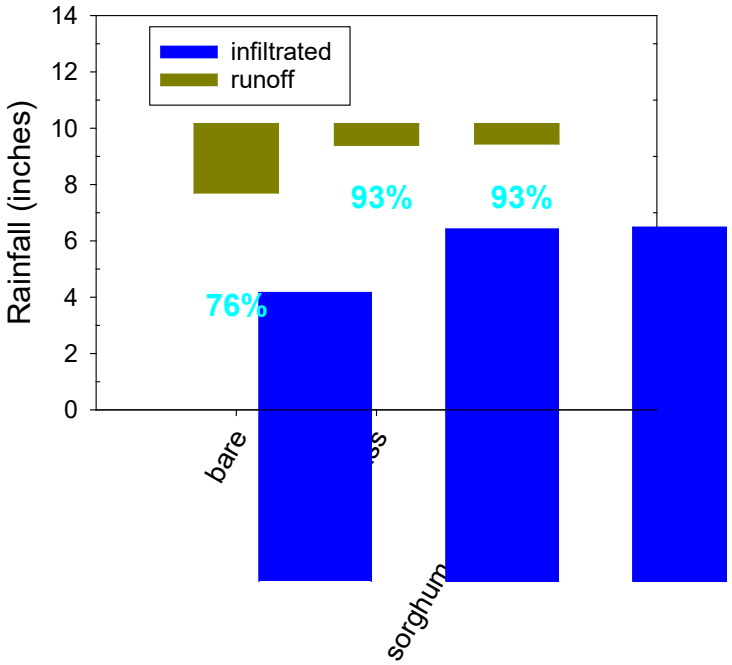

Figure 6. Rainfall volume infiltrated and lost as runoff in the cover crop and bare treatments during the 2023-24 winter season at site 2.

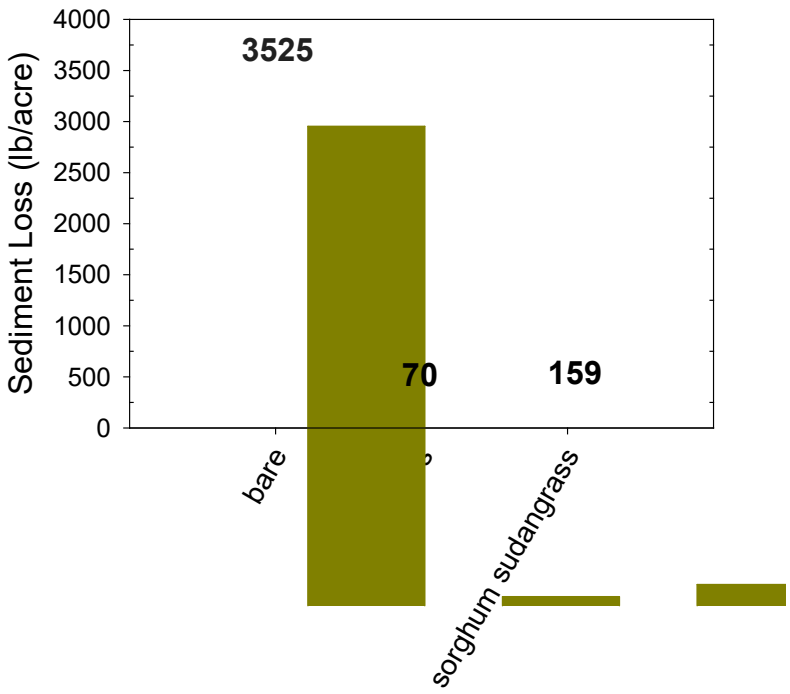

Figure 7. Sediment loss of cover crop and bare treatments at site 2 during the 2023-24 winter season.

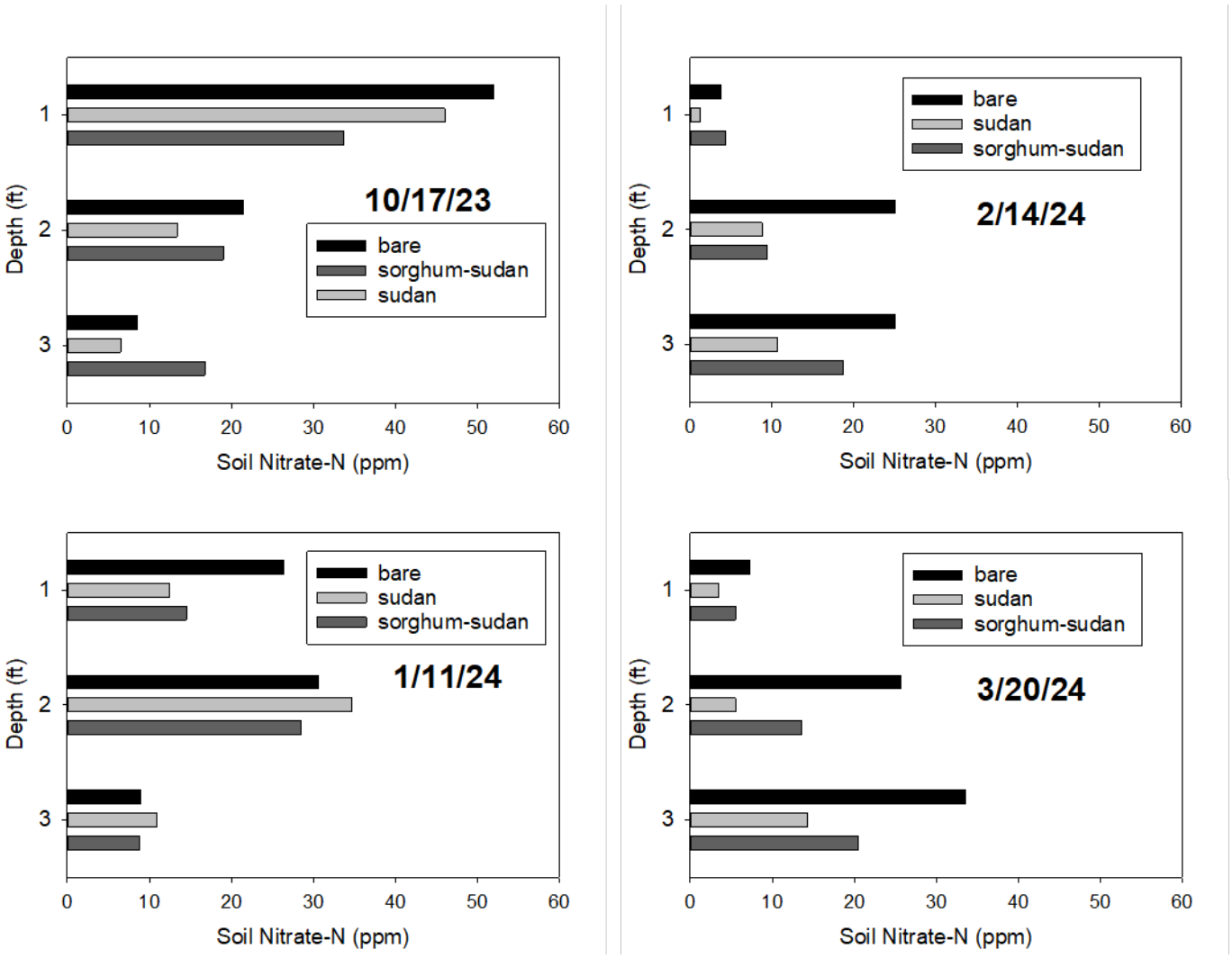

Figure 8. Nitrate concentration in the soil profile at site 2 during the 2023-24 winter season.