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Warm-Season Legume Cover Cropping in the Delta

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Introduction:

We established an on-farm trial in the Sacramento-San Joaquin Delta region to evaluate warm-season, annual legume cover cropping between winter small grain forage crops. Cover cropping is a management practice identified by the Healthy Soils Program of the California Department of Food and Agriculture as having the potential to improve soil health, sequester carbon, and reduce greenhouse gas emissions. Cover cropping, however, is not a typical practice in the annual crop rotations of the region, and summer cover cropping is particularly rare. The Delta is a unique agricultural region with unique environmental challenges. Some soils in the region are subsided due to oxidation of organic matter, and some soils suffer from salinity, having limited ability to leach salts due to low permeability soils and shallow groundwater. We evaluated the potential for summer cover cropping with a legume to improve soil tilth at a time of year when the soil might otherwise be fallowed and dry with no soil cover.

Methods:

The trial took place from 2018 to 2020 over 4.5 acres of a commercial field. We compared an irrigated summer cover crop treatment (CC) to a dry, fallow soil (No CC), assessing soil health properties, greenhouse gas emissions, and winter small grain forage yield. Plot size was approximately 0.75 acres, with three replicates in a randomized complete block design. The soil type across the trial was a Valdez silt loam.

A cowpea cover crop (*Vigna unguiculata* cv. 'Red Ripper') was inoculated with Rhizobium and drill-seeded at 7-in row spacing. The cover crop was planted in late spring or summer of each year (Tab. 1). Irrigation was only applied to the cover crop plots, which imposed differences in soil moisture between the two treatments. We managed the trial in this way because we surmised that irrigating the No CC plots would result in weed growth, and that weed biomass could confound the results. In the first year, planting occurred after a flood/furrow pre-irrigation, and one additional irrigation was applied approximately one month later. Due to the slope of the field, however, water infiltration was uneven. In the second and third years, planting occurred into dry soil, and the cover crop was irrigated up with sprinklers. In 2020, we estimated that five inches of irrigation was applied to the cover crop, using surface water with moderately low salinity (seasonal EC_w of 0.5 dS/m).

We evaluated cover crop and cash crop parameters across the three years. Cowpea stand was evaluated approximately two weeks after planting by counting the number of plants in six replicate 11-ft^2 (1-m^2) quadrats in each of the three cover crop plots. Just prior to termination, we also evaluated cover crop biomass across six replicate 11-ft^2 quadrats per plot. Biomass was separated into cultivated cowpea, volunteer small grains, and weeds. These were dried and weighed separately, and each component was analyzed for total carbon (C) and nitrogen (N). Triticale forage yield was assessed in June 2019 and May 2020 by sampling two replicate 11-ft^2 quadrats per plot. Data were analyzed by ANOVA with means separated by Student's t ($\alpha = 0.05$) test.

Table 1. Agronomic practices during the three-year study.

Year	Pre-Season Soil Sampling Date	Cover Crop Planting Date	End-of-Season Soil and Biomass Sampling Date	Cowpea Seeding Rate (lb/ac)	Irrigation Method
2018	July 2nd	July 30th	October 23rd	51	Furrow/Flood
2019	June 6th	July 15th	September 13th	56	Sprinkler
2020	May 14th	May 29th	July 29th	50	Sprinkler

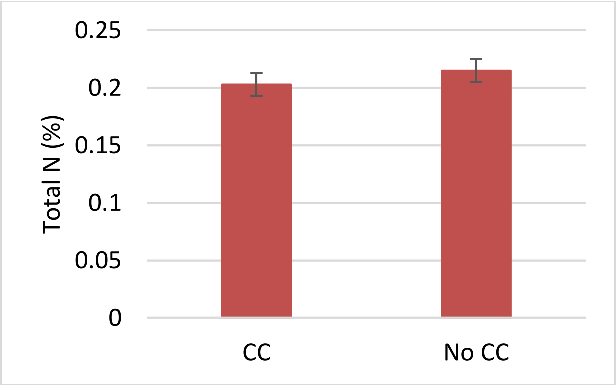
Baseline soil samples were collected for the entire experimental area on July 2, 2018, following wheat harvest but prior to tillage. Annual soil sampling was conducted immediately prior to cover crop termination in each year. Soil was sampled from 0-6, 6-12, 12-24, and 24-36 inch depths, and six to ten subsamples were aggregated by depth for each plot. We evaluated bulk density, salinity (electrical conductivity of the soil saturated paste, EC_e), pH, and total N and total C (by combustion method). Additionally, we soil sampled prior to cover crop planting in 2019 and 2020 (i.e. following small grain forage harvest but prior to tillage operations). We analyzed those samples for EC_e, pH, bulk density, and soil moisture only. In-situ water infiltration rates were measured at the conclusion of the project (i.e. prior to 2020 cover crop termination). Data were analyzed by ANOVA with means separated by Student's t ($\alpha = 0.05$) test, or by Tukey's range test where interactions in the data were significant.

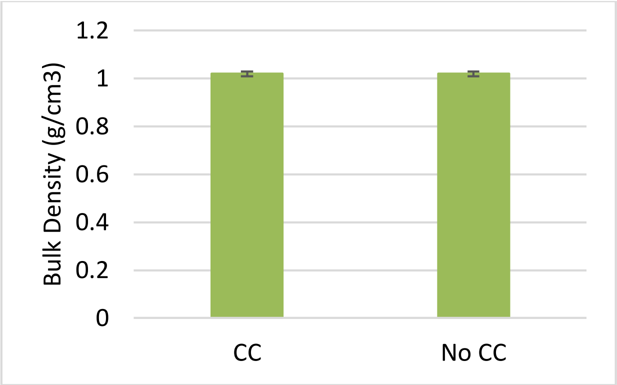
This project also included monthly greenhouse gas (GHG) sampling and soil testing for particulate organic carbon (POX-C), which is the fraction of soil organic matter that is readily available as an energy source for soil microorganisms. This report does not discuss the results of the GHG monitoring or POX-C analysis.

Results and Discussion:

Soil properties:

After three years of cover cropping, we did not observe improvements in total N or bulk density from cover cropping, and for total C, there was a statistical interaction between the treatment and block effects (Fig. 1). The statistical interaction suggests that there was an inherent characteristic to the soil, like texture, that had more of an impact on total C than the cover cropping treatment. When we impose these data onto the plot map, we observe that the plots on the western half of the trial trended toward higher total C than the plots on the eastern half of the trial. It is not altogether surprising that we did not observe differences between treatments for these properties because these properties often take many years to change with management.





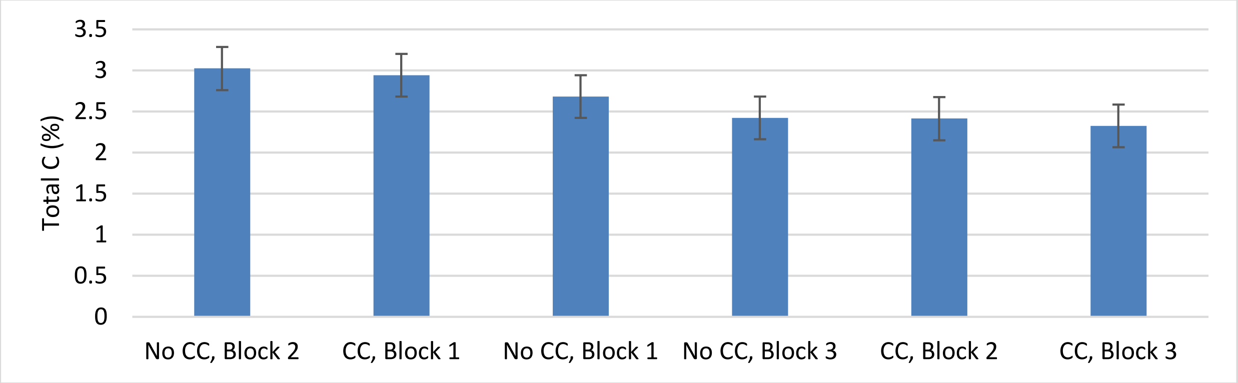


Figure 1. There were no differences in total N (P=0.2354) or bulk density (0.8463) between CC and No CC treatments. There was a statistical interation between treatment and block for total C (P=0.0001). The error bars represent the standard errors.

We observed differences in parameters that are influenced by soil-water status. After three years of cover cropping, we observed better water infiltration in the CC plots (Fig. 2). Cover crop roots likely contributed to better soil structure and water conductance. The grower observed differences in subsequently-planted small grains, with seedlings in the CC plots emerging about five days earlier than seedlings in the No CC plots. Furthermore, in June 2020, after triticale forage harvest and tillage operations that were uniformly performed over the entire field, there was a visible difference between CC and No CC plots (Fig. 2).

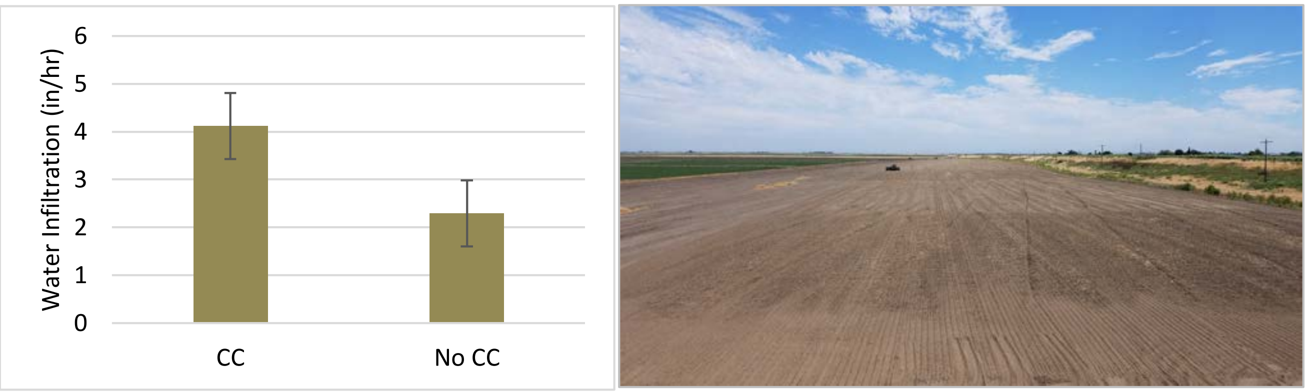


Figure 2. Three years of cover cropping improved water infiltration (P=0.0198) compared to the standard dry fallow. The error bars represent the standard errors. The photo illustrates how there were visible differences between treatments in soil physical characteristics, even after triticale forage harvest and uniform tillage operations. No CC soil was a fine powder (bottom of the photo); whereas, CC soil was observed to have better aggregation.

We also observed differences between treatments for salinity and pH (Fig. 3). After three years of cover cropping, there was lower salinity in the CC plots. The data over time illustrate that winter rainfall was never sufficient to leach salts that had accumulated in the No CC plots and that irrigating a summer cover crop could help to stave off salt accumulation. For pH, there was a statistical interaction between the treatment and block effects, but the trend was for the CC plots to have a higher (i.e. less acidic) pH than the No CC plots.

These results suggest that cover cropping can improve certain soil characteristics, particularly those related to soil-water status, on a relatively short timeframe. Changes in nutrients and C storage, however, are less likely to be observed following short-term changes in management.

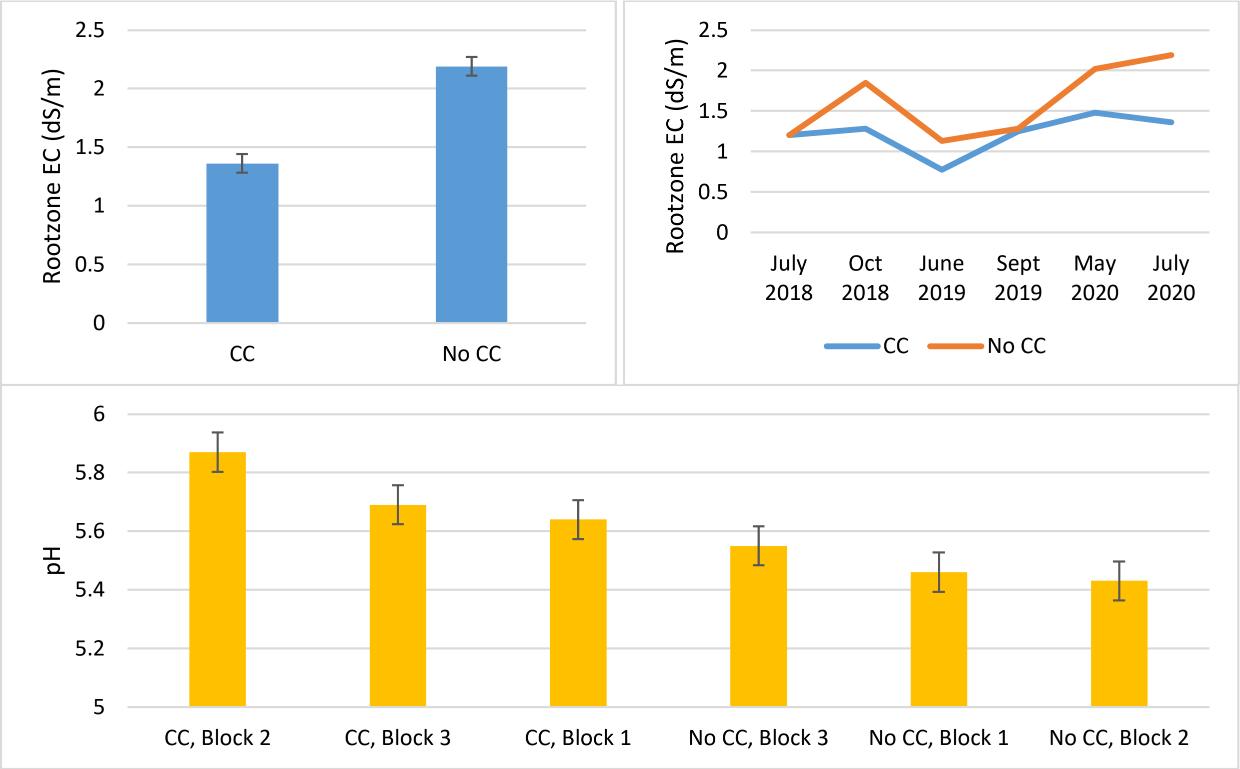


Figure 3. Three years of cover cropping reduced salinity compared to the standard dry fallow (P=0.0004). Over the course of the study, root zone EC increased for both treatments, but it increased more for the No CC plots. For pH, there was a statistical interaction between the treatment and block effects (P<0.0001). The error bars represent the standard errors.

Cover crop stand:

Cover crop composition varied over the course of the study and was likely impacted by changes in management (i.e. planting and irrigation methods). In 2020, the grower had a new seed drill which may have planted more accurately to the desired seeding rate. The stand count range across replicates was narrower in 2020 compared to 2018 and 2019 (Tab. 2).

Table 2. Cowpea stand counts at two weeks after planting.

Year	**Stand Count Range (plants/m^2)**	**Stand Count Average (plants/ac)**
2018	16-43	125264
2019	16-79	182693
2020	29-52	151473

While cowpea was the only seed planted, the stand was a mix of cowpea, volunteer wheat/triticale, and weeds (Fig. 4). We decided not to manage the volunteers or weeds with tillage or herbicides. Both add biomass to the soil, which is an objective of the Healthy Soils Program. In 2018 and 2020, biomass was largely composed of volunteer small grains; the weeds predominated in 2019. While overall biomass was less in 2020, we also observed lower weed pressure. Additionally, most weeds had not yet produced seed. Competition from the volunteers and weeds may have impeded the cowpea stand, so future studies could investigate how managing volunteers and weeds impacts legume stand and soil nitrogen from nitrogen fixation.

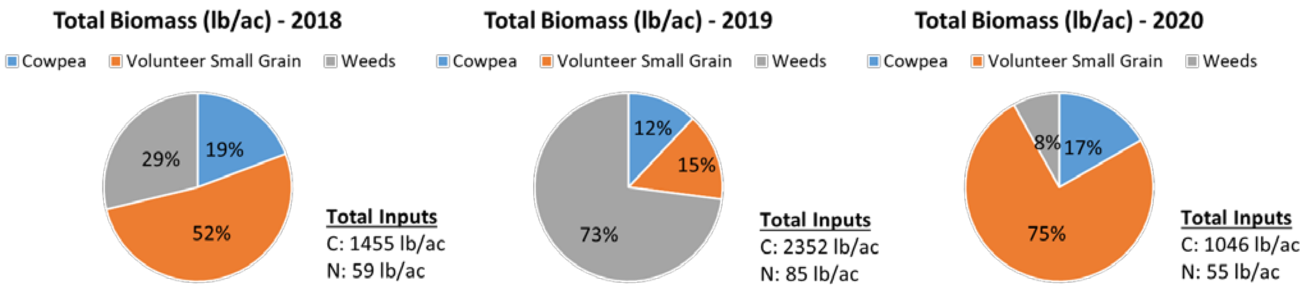


Figure 4. Proportion of cowpeas, volunteer small grains, and weeds in total cover crop biomass (dry weight), and total C and N inputs from the cover crop.

Triticale forage yield:

Despite certain soil health benefits, cover cropping did not improve triticale forage yield. The No CC treatment yielded higher than the CC treatment across both years (Fig. 5). The CC plots yielded below the two-year field average of 5.5 tons per acre, and the No CC treatment yielded above the field average yield. Given the improved soil-water, pH, and salinity conditions in the CC treatment, the yield result is difficult to explain. While this result may present an obstacle for growers who are considering cover cropping, other studies have shown cover cropping to improve cash crop yields. This trial was likely too short to deliver that response, and future studies should examine cash crop yield with long-term cover cropping.

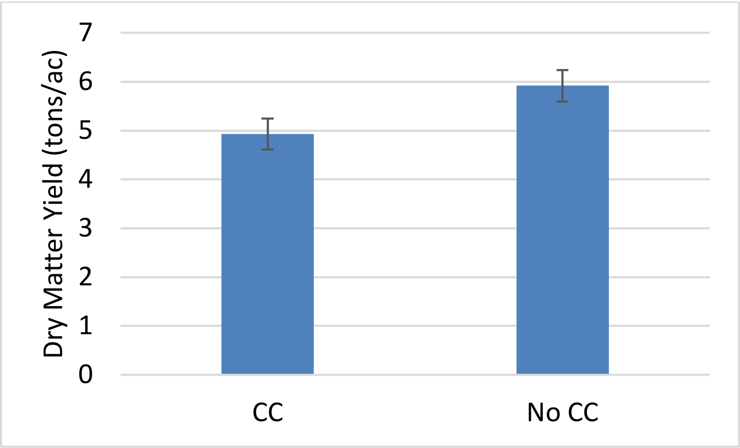


Figure 7. Triticale forage yield as tons of dry matter per acre. The No CC treatment yielded higher than the CC treatments across both years (P=0.0059).

Summary:

In summary, cover cropping, particularly in the warm-season, is not a typical management practice in the annual crop rotations of the Delta region. In our three-year study, cover cropping had no effect on total N, bulk density, and total C, but it improved soil properties like water infiltration, salinity, and pH. Cowpea stand establishment and volunteer grain and weed competition were the biggest challenges to growing a summer cover crop at this site, and triticale forage (i.e. cash crop) yield did not improve as a result of cover cropping. Despite these challenges, the grower observed better soil aggregation and subsequent triticale seedling emergence in areas of the field where the cover crop had grown. We learned that sprinkler irrigation, compared to furrow, and earlier planting and termination, like in 2020, improved overall manageability of the cover crop. Overall, the potential benefits of cover-cropping may not be realized in the first few cover crop cycles, which could hinder long-term adoption. Results may also depend on the cover crop biomass obtained and other site-specific factors. While scientific studies have demonstrated soil health and cash crop yield improvements with cover cropping, longer-term studies are needed in California to demonstrate whether these benefits can be realized.

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