Rodale Institute
Final Project Report
Project Title: Effect of Sioux Preshrunk Coreva on Cotton Plant Growth and Soil Characteristics
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Introduction

Sioux Preshrunk Coreva (SPC) is the world's first compostable stretch denim fabric. It is a fabric utilized to manufacture cotton-based clothing; a technology patented by Candiani Denim that uses elastic yarns obtained from natural rubber in place of synthetic yarns. In the process of fabric and clothing production, a percentage of textiles is wasted. This waste can include fabric scraps from cutting, leftover fabrics from the rolls, sampling yardage, damaged fabrics, clothing samples, unsold garments, and second-hand clothing waste. Sioux preshrunk Coreva fabric waste can be processed and utilized in agriculture as a soil amendment to enhance soil chemical and physical characteristics, along with minimizing the environmental footprint of the production process. Previous research on SPC determined 98% disintegration within 12 weeks of composting process and the compost obtained from the disintegration test in presence of the sample of SPC has not determined an inhibiting effect on either the germination or growth of potted plants analyzed at different compost concentrations. This replicated field trial was conducted to evaluate the effect of SPC as a soil amendment on soil health properties and cotton plant growth in southern California.

Materials and Methods

A field experiment was conducted at the Rodale Institute California Organic Center in Camarillo, in a coastal environment of southern California.
The experiment was set up as a split-plot design with 4 replicas and 2 treatments: I) SPC incorporated into the soil at a rate of 90 g/m^2 and II) C or untreated control. SPC chemical analysis is reported in table 1 and figure 1. Each plot was 10 m long and 4.87 m wide consisting of six planting rows with three rows hand sown (Direct seed), and three rows transplanted with seedlings grown in a controlled environment for 15 days (Trans). Cotton seeds and seedlings (Blue Seed cultivar) were planted with an in-row spacing of 7.7 cm and between-row spacing of 91.5 cm resulting in 143,500 plants/hectare. All plots were irrigated using a drip irrigation system and received 25.4 mm water/acre/week for 11 weeks (1 inch water/ acre /week). At 160 DAS (days after seeding or transplanting) plants were topped and the distal part of the plant above the last white flower was removed to limit vegetative growth.
Before study initiation, soil samples were taken to determine soil background properties. Soil has a clay loam texture with 38.4% clay, 38.4 % silt, and 23.1 % sand (with 0% fine sand and 23.1 % coarse sand). Chemical analysis showed a balanced nutrient concentration with high concentration of zinc (Z), iron (Fe), Magnesium (Mg), and Manganese (Mn). Soil CEC was balanced. Soil pH

was 7.7 and C/ N ratio was 7.7. Microbially active carbon was measured, which reflects how much of the organic carbon pool was acted upon by the microbes as soil respiration, and it had a value between 40 and 80%, indicating a balance of fertility and organic carbon to support microbial biomass.

Weather data for the experimental site were recorded 2 km from the site at CIMIS station #152 (https://cimis.water.ca.gov/) (Table 2).

At cotton flowering (56 DAS) and harvest (180 DAS) soil samples (0-20 cm depth) were taken from all plots to determine the effect of SCP application on soil properties. The results of soil chemical analyses are shown in Table 3. The field Solvita respirometry assays were also performed as an indicator of soil biological activities.

At week 11, three soil samples were collected from each replica of the treated areas to visually evaluate the decomposition of SCP. The core samples were scored on a scale from 1 to 5 with 1 as not decomposed, 2 as minimal decomposition, 3 as medium decomposition, 4 as highly decomposed, 5 as not visible.

Soil volumetric water content was measured in 0-15cm depth using a TDR soil moisture probe (Acclima, Inc., Meridian, ID) on days 1, 3, and 7 after each irrigation event at 1, 3, 5, 7, 9, 11 weeks after study initiation.

Foliar nutrient status in cotton was assessed by collecting the most recent fully expanded leaf (three nodes from the top of the plants) at flowering and beginning of maturity (140 DAS). Ten leaves per plot were sampled at each sampling and mixed for analysis.

Plants were harvested and processed at 180 DAS. At harvest, plants were cut at ground level and plant count per square meter, main stem plants' height, node counts, node above white flower (NAWF), and number and type of fruit were recorded. A square was defined as being present when the leaf that subtended the square had unfolded. Fruit was defined as green bolls from the day of anthesis and as open bolls once two sutures had split. Lint weight, seed weight, and seed count were recorded and final yield, and yield components (final boll seed and boll weight and lint percentage) were calculated. At 90, 120, and 150 DAS plant height and node count of seedlings or directly sowed cotton plants in soil treated with SPC and untreated were determined.

Yield and harvest parameters variance were assessed through one-way ANOVA with Student-Newman-Keuls mean test using CoSTAT software (CoHort software, Monterey, CA, USA).

Results

Soil chemical and biological properties

Soil macro and micronutrients mineral concentrations such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), sulfur (S), and copper (Cu) were present at a sufficient level to support plant growth in control and SPC treated soil. High concentrations of zinc (Z), iron (Fe), Magnesium (Mg), and Manganese (Mn) were found in control and SPC-treated samples, as seen for the baseline dataset. Organic matter content was low, and N organic content was adequate in all the blocks. Soil was characterized by a 7.8 C/N ratio and pH of 7.7. Although no differences were found between treatments, differences in soil mineral concentrations were observed between the two sampling dates with a higher concentration of most nutrients observed at flowering compared to harvest (Tab. 3).

Soil treated with SPC had significantly higher respiration compared to untreated control at the cotton flowering stage, but the difference was not significant at harvest. Application of SCP did not change soil chemical characteristics (Fig. 2, 3, and 4).

SPC decomposition
At week 11 soil samples were collected to visually evaluate the decomposition process. The average score was 4.5, suggesting that the SPC was near the end of the decomposition process (Tab. 4, fig. 5 and 6).

Soil Moisture dynamic
Volumetric soil water content was different between treatments at 24, 28, 38, 42, 50, 52, and 56 DAS with a significantly higher soil moisture content in the SPC-treated soil. The effect on soil water retention of SPC was found after 3 weeks after sowing and continued until week 7, at weeks 9 and 11 no differences were found (Fig.7).

Nutrient concentration in cotton plants
Leaf tissues of plants in SPC-treated plots had a higher concentration of P and Zn at flowering however this difference was not observed at harvest (Fig. 8).

Cotton growth and yield
At 90, 120, and 150 DAS plant height and node count of transplanted or directly sown cotton plants were measured in all plots. No statistically significant differences were found between treatments for these parameters (Tab. 5). At harvest, plant height, node count, internode length, green boll count, node above white flower, green boll weight, open bolls count, and squares count did not differ between treatments. Transplanted cotton had a greater final boll count compared to directly sown plants irrespective of the soil amendment treatment. The final boll count from directly sown plants was 239 in control plots compared to 235 in SPC-treated plots. On average, transplanted plants produced 337 boll/m^2 in control plots vs. 349 in SPC-treated plots (Tab. 6). Fruit analysis revealed similarities between control and SPC-treated plants. No statistical differences were found for lint weight, open boll seed weight, open boll total weight, lint fraction, and seed weight. Yet, seed counts were significantly higher in the control plants compared to SPC-treated plants (Tab. 7).

Discussion
SPC band application at 900 kg/ha did not influence soil chemical characteristics in this one-year study. Soil respiration was higher in SPC-treated plots at flowering (no significant difference was detected at harvest), which may indicate that SPC application did not have a detrimental effect on soil microorganisms. This would require further investigation to be validated. SPC application slightly affected soil moisture retention between weeks 3 and 7 post-application. Soil moisture was significantly higher in the soil with SPC three days after the irrigation event in week 3, and again after 1, 3, and 7 days after the irrigation event in weeks 5 and 7. No significant difference was observed between SCP-treated soil and control plots after week 9, most likely because the majority of SPC was degraded by this time in the soil.

The increased moisture retention in response to SPC application can be attributed to the structure of SPC and the creation of new air space. SPC also prevented water from faster percolation to the deeper layer of the soil. SPC might have facilitated moisture dispersion by allowing water to move laterally more readily from its point of application.

SPC biodegradability was evaluated at week 11 and only minimal traces of SPC were found in the core samples, indicating that the microbially active community was able to decompose the fabric within 11 weeks from the date of the material incorporation.

Leaf mineral analysis indicated higher concentrations of P and Zn in plants grown on soil treated with SPC. Cotton fibers are comprised of 88%–97% of cellulose therefore the increased microbial activity might be due most likely to cellulolytic microorganisms. Some of these bacteria are common inhabitants of the soil and they secrete antibiotics, hydrolases, and other bacteriolytic compounds that can affect other microorganisms and therefore nutrient cycles and plant availability. P and Zn availability to plants depends upon physicochemical properties of soil, activity of plant roots and microflora in rhizosphere and other non-edaphic factors. In this experiment, the degradation of SCP might have resulted in stimulation of P and Zn releasing/promoting microbes and bacteria.

Highlights

In conclusion, this one-year study revealed:

- SPC did not impact soil chemical characteristics but increased soil respiration at flowering.
- SPC application did not influence cotton growth, yield, and nutrient uptake except for P and Zn at flowering.
- Soil treated with SPC showed similar or greater volumetric moisture content compared to non-treated control throughout the study. This can be useful when implementing deficit irrigation systems in dry regions.
- SPC was almost completely decomposed in 65 days after incorporation in the soil.

Recommendations

- Repeat the study for at least two more years to obtain more reliable data
- Test SPC application at higher rates and various methods such as broadcasting and incorporating should be tested
- Add SPC to compost piles as a C-source or use as bedding material and apply to the soil in combination with manure and animal waste

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List of Tables and Figures:

Tab. 1. Chemical composition analysis of moisture-free (Analysis Dry) and as received (Analysis as is basis) Sioux Preshrunk Coreva (SPC) cotton utilized in the experiment.
Fig. 1. Close picture of SPC.

Paramether	Analysis Dry		As is Basis Lbs/ Ton
Organic N	0.33	%	6.3
Ammonium N	0.01	%	0.2
Nitrate N	0.00	%	0.0
Total N	0.35	%	6.5
Total C	45.13	%	796.7
Total C:N	128.90	Ratio	
Phosphorus	0.09	%	1.7
Potassium	0.34	%	6.3
Sulfur	0.14	%	2.6
Calcium	0.24	%	4.5
Magnesium	0.11	%	2.0
Sodium	0.22	%	4.2
Sodium Adsorption	9.42	Ratio	0.0
Zinc	16.20	ppm	0.0
Iron	170.60	ppm	0.0
Manganese	9.30	ppm	0.0
Copper	12.10	ppm	0.0
Boron	4.20	ppm	0.0
Soluble Salts	14.41	mmho/cm	17.3
pH	6.00		
Moisture	6.05	%	
Dry Matter	93.95	%	

Tab. 2. Monthly precipitation, maximum, minimum and average air temperature, maximum, minimum and average relative humidity, average dew point, average soil temperature and GDD (Growing Degree Days at min. 15.5 C) collected at CIMIS station n° 152 in Camarillo, CA from May 1st, 2022, to October 31st, 2022.

Month Year	Total Precip (mm)	Avg Max Air Temp (°C)	Avg Min Air Temp (°C)	Avg Air Temp (°C)	Avg Max Rel Hum (%)	Avg Min Rel Hum (%)	Avg Rel Hum (%)	Avg Dew Point (°C)	Avg Soil Temp (°C)	GDD (°C)
May-22	0.2	21.3	9.5	15.4	97	55	75	10.6	17.7	59.28
Jun-22	30.9	24.5	12.7	18.3	99	58	79	14.5	20.8	113.31
Jul-22	55.4	24.7	14.3	18.9	99	61	80	15.5	22.1	133.3
Aug-22	61.1	26.7	14.3	20	99	55	76	15.7	21.4	170.51
Sep-22	50.6	28.3	15.6	21.5	98	52	74	16.7	21.1	151.16
Oct-22	27.6	24.3	12.4	17.7	95	54	75	12.8	17.7	121.63
	225.8	25.0	13.1	18.6	97.8	55.8	76.5	14.3	20.1	749.19

Tab. 3. Soil macro and micronutrient concentration at cotton flowering and at harvest stage in soil treated with Sioux Preshrunk Coreva (SPC) and untreated (control).

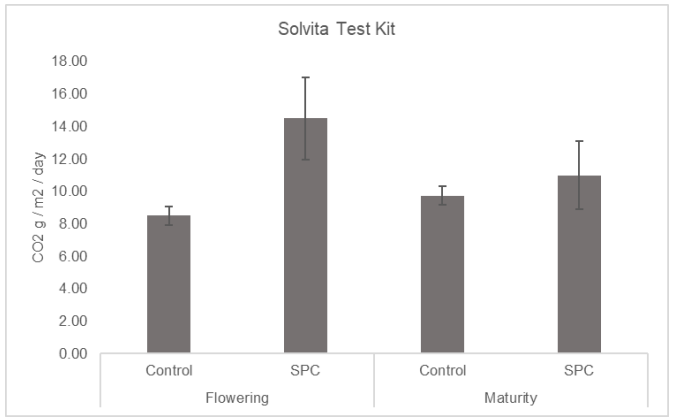
		O.M.		N		P		K		Ca		S		Mg	
		%		%		ppm		ppm		ppm		ppm		ppm	
Time	Trt	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Flowering	Control	2.03	0.15	1.75	0	31.18	11.76	250.25	32.26	1851.25	90.28	107.60	13.83	393.00	31.29
	SPC	2.10	0.24	1.87	0.09	34.20	13.91	265.75	41.02	1800.75	106.16	93.65	20.06	387.75	22.16
Harvest	Control	2.75	0.79	1.34	0.05	17.18	1.64	330.00	45.84	1951.50	65.65	121.13	28.87	469.00	34.94
	SPC	3.30	0.74	1.28	0.05	15.98	1.08	318.50	44.10	1963.75	112.89	108.43	43.59	474.75	12.76

		Zn		Fe		Mn		Cu		Na		CEC	
		ppm		ppm		ppm		ppm		ppm		me/100g	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Flowering	Control	2.33	0.22	12.30	2.55	6.55	0.53	1.26	0.07	127.75	8.92	13.73	0.76
	SPC	2.03	0.10	12.78	1.77	7.15	1.34	1.28	0.10	118.75	7.93	13.45	0.70
Harvest	Control	2.02	0.14	7.98	1.08	4.53	0.54	0.93	0.10	166.25	11.95	15.23	0.74
	SPC	1.68	0.09	8.78	1.48	4.18	1.23	0.97	0.06	166.25	25.90	15.33	0.52

		Organic C		Organic N		Organic C:N		NH4		NO3		Microbially Active Carbon	
		ppm		ppm		Ratio		ppm		ppm		%	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Flowering	Control	128.25	13.45	17.48	2.15	7.35	0.40	0.90	0.14	23.97	7.81	37.45	13.29
	SPC	133.25	4.11	18.65	1.50	7.15	0.39	1.13	0.17	30.17	9.72	43.78	21.01
Harvest	Control	155.00	11.69	13.43	2.23	11.70	1.19	2.98	1.30	11.14	2.18	61.80	22.70
	SPC	144.75	9.03	12.75	1.29	11.43	0.74	1.53	0.59	10.62	3.09	78.98	15.15

1 ppm = 1 mg/Kg
S.D. Standard Deviation

Fig. 2 Soil respiration in g CO^2/ m^2 / day evaluated with the Solvita Field Test.
Fig. 3 Comparison of soil mixed with SPC (S) and control soil.
Fig. 4 Color coded scale for samples' results interpretation.



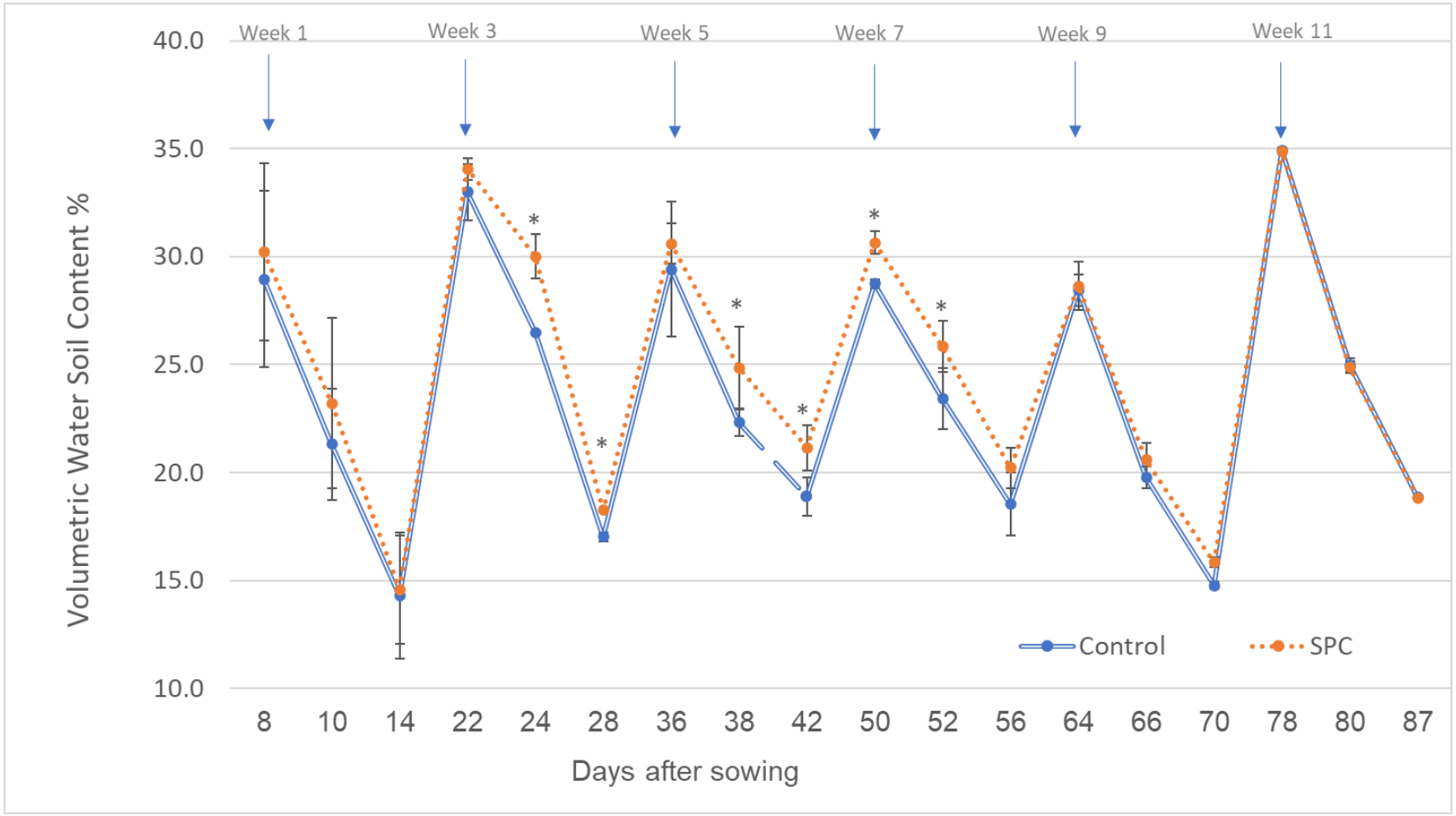
Vertical lines represent the standard deviation
Color code values:
Color 0 – 1.0 Blue Gray (0.6 - 0.8 g CO^2/ m^2 / day): extremely low activity. Very depleted soil.
Color 1.0 - 2.5 Gray-Green (0.8 - 2.9 g CO^2/ m^2 / day): low activity. Limited biological activity with low carbon levels.
Color 2.5 - 3.5 Green (2.9 – 7 g CO^2/ m^2 / day) medium-low activity. Medium active -accumulating carbon.
Color 3.5 - 4.0 Green-Yellow (7 – 11 g CO^2/ m^2 / day) ideal activity. Active microbes with carbon supply.
Color 4.0 - 5.0 Yellow (11 – 26 g CO^2/ m^2 / day) high activity. Very active biologically.

Tab 5. Visual evaluation of SCP decomposition progress in the soil at 77 DAS.
Fig. 6. Soil core sample scored 4 in the decomposition rate, the arrow indicates the presence of SCP.
Fig. 7. A section of the core sample.

Rep	Decomposition rate
Rep 1	4
Rep 1	5
Rep 1	5
Rep 2	5
Rep 2	4
Rep 2	4
Rep 3	4
Rep 3	5
Rep 3	4
Rep 4	5
Rep 4	5
Rep 4	5
Mean	4.6

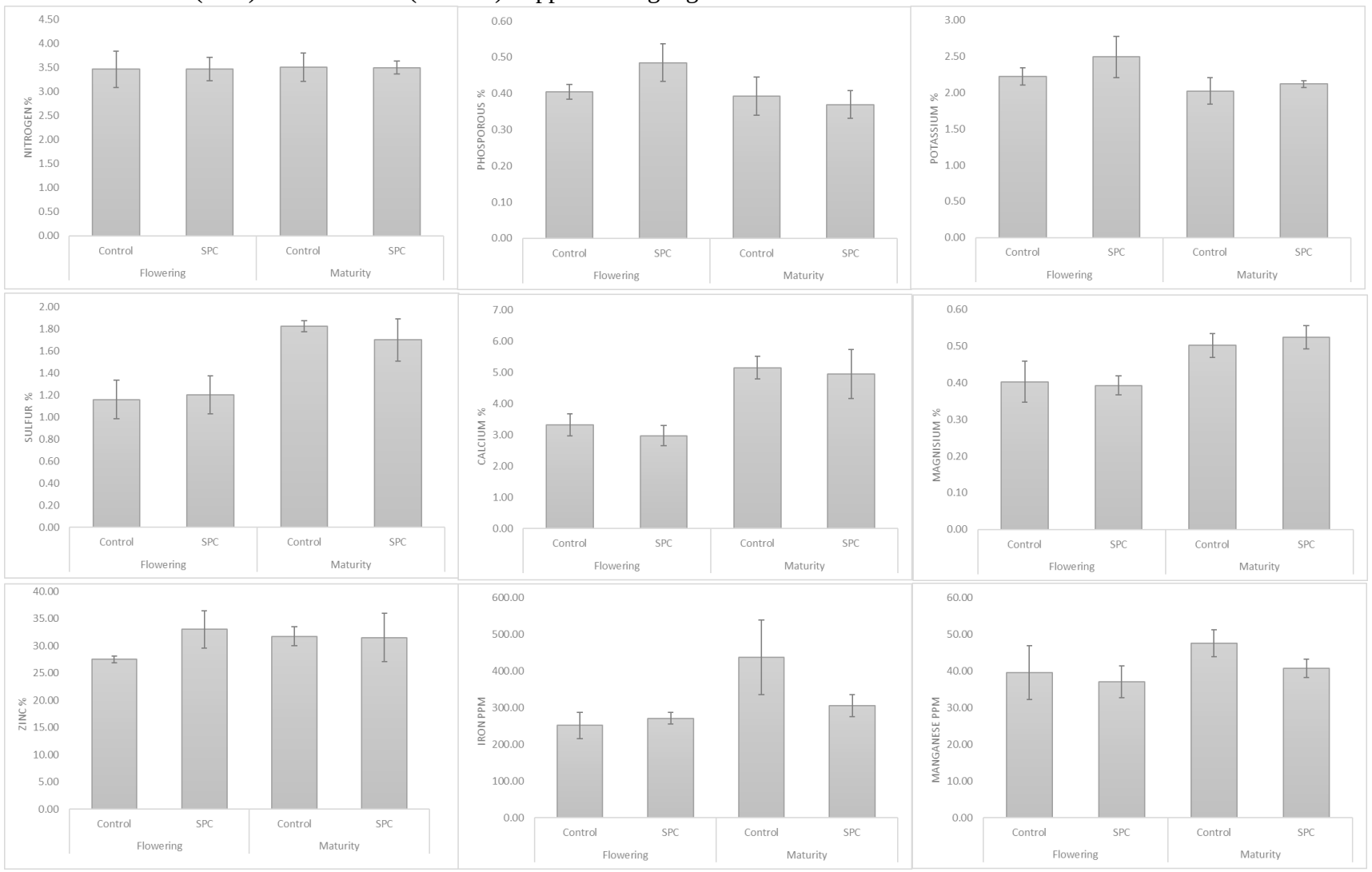
5	Not visible
4	Highly decomposed
3	Medium decomposition
2	Minimal decomposition
1	Not decomposed

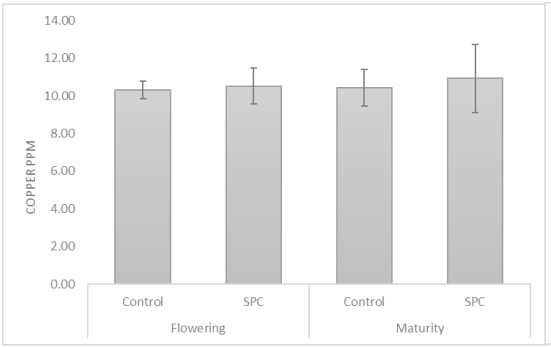
Fig. 7. Volumetric soil moisture content (%) in cotton field from 8 to 90 DAS in soil treated with Sioux Preshrunk Coreva (SPC) and untreated (control). Bars on columns represent standard deviation.

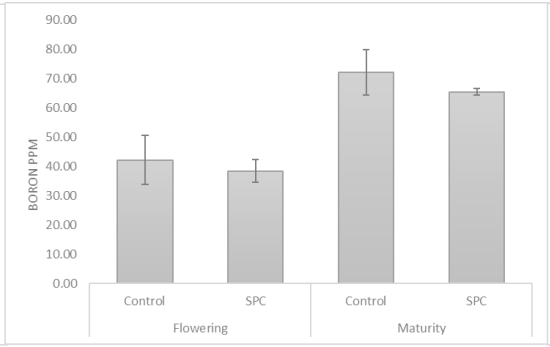


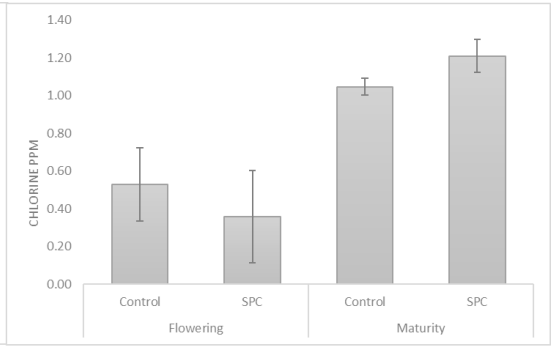
'*' significant for $p < 0.05$
Arrows indicate irrigation events,
Vertical lines represent the standard deviation.

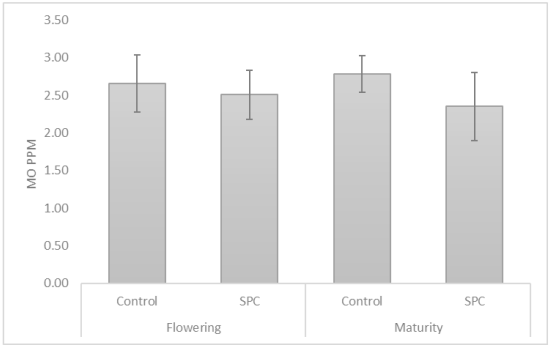
Fig. 8. Foliar macro and micronutrient concentration at bloom and beginning of maturity in cotton grown on soil treated with Sioux Preshrunk Coreva (SPC) and untreated (Control). 1 ppm = 1 mg/Kg.











Vertical lines represent standard deviation.

Tab.5 Plant height and nodes count of seedlings (Transplants) or direct sowed (Direct Seed) cotton plants at 90, 120 and 150 DAS (a) in soil treated with Sioux Preshrunk Coreva (SPC) and untreated (Control).

DAS	Trt	Plant Height Direct Seed cm		Plant Height Transp cm		Node Counts Direct Seed n°		Node Counts Transp n°	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
90	Control	88.6	10.3	87.9	25.4	9.4	0.8	9.4	0.9
	SPC	83.5	9.7	98.4	10.2	9.5	0.5	9.4	0.7
	Significance								
	LSD (0.05)	8.50		16.38		0.57		0.67	
		n.s.		n.s.		n.s.		n.s.	
120	Control	109.9	5.8	119.6	8.4	15.4	0.7	16.3	0.6
	SPC	110.5	6.7	123.5	11.5	23.9	0.0	16.7	1.1
	Significance								
	LSD (0.05)	5.32		8.52		17.36		0.74	
		n.s.		n.s.		n.s.		n.s.	
150	Control	161.2	3.9	163.1	6.4	23.6	0.9	24.2	1.2
	SPC	161.2	3.4	162.0	5.7	23.6	1.0	24.3	1.1
	Significance			ns		ns		ns	
	LSD (0.05)	5.21		5.61		0.98		1.1	
		n.s.		n.s.		n.s.		n.s.	

n.s., *, **, *** Nonsignificant or significant at p _ 0.05, 0.01 or 0.001, respectively. Letters represent mean separation comparison (Student-Newman-Keuls test). S.D. Standard Deviation

Tab. 6. Cotton plants count, height, nodes count, internode length, green bolls count, green boll weight, open bolls count, squares count and bolls per sq meter at harvest of transplanted (Transplants) or direct sowed (Direct seed) cotton plants in soil treated with Sioux Preshrunk Coreva (SPC) and untreated (Control).

		Plant count		Plant height		Nodes count		Internode length		NAWF		Green boll count		Green boll weight		Open bolls count		Squares count		Fruit count		Final boll count		
		n° / m2		cm		n°		cm		n°		n°		g		n°		n°		n°/plant		n° / m2		
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean		S.D.
Control	Seeds	10.0	3.2	163.0	12.0	21.4	4.4	7.9	1.7	2.3	1.1	17.9	5.6	23.0	3.0	4.5	2.3	1.5	1.7	23.9	8.2	239.2	b	82.3
	Trans	13.3	2.8	169.0	9.0	21.2	3.7	8.3	1.7	2.7	1.1	18.9	5.0	22.8	1.5	5.2	1.7	1.2	1.2	25.3	6.6	336.8	a	87.9
SPC	Seeds	9.7	4.5	172.5	14.4	22.4	3.9	7.9	1.7	2.5	0.9	18.4	3.5	21.9	1.3	5.4	2.2	0.5	0.7	24.3	5.3	235.3	b	50.8
	Trans	12.4	5.0	169.6	9.7	21.4	3.5	8.1	1.6	2.8	1.0	20.5	4.2	23.1	2.7	6.0	2.4	1.6	1.6	28.1	5.9	348.8	a	73.6
Significance																								
LSD (0.05)		3.3		9.45		3.19		1.30		0.84		3.82		1.84		1.77		1.11		5.42		61.70		
		n.s.		n.s.		n.s.		n.s.		n.s.		n.s.		n.s.		n.s.		n.s.		n.s.		*		

n.s., *, **, *** Nonsignificant or significant at p _ 0.05, 0.01 or 0.001, respectively. Letters represent mean separation comparison (Student-Newman-Keuls test). S.D. Standard Deviation

Tab. 7. Open boll lint weight, open boll seed weight, total boll weight, lint %, seed weight and count at harvest of transplanted (Transplants) or direct sowed (Direct seed) cotton plants in soil treated with Sioux Preshrunk Coreva (SPC) and untreated (Control).

		Lint weight		Open ball seed weight		Open boll tot weight		Lint fraction		Seeds count			Seeds weight	
		g		g		cm		%		n°			g	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.		Mean	S.D.
Control	Seeds	3.97	0.87	5.10	0.43	9.07	0.91	43.34	6.24	40.07	1.94	ab	0.13	0.01
	Trans	4.12	1.01	5.22	0.48	9.34	1.18	43.70	5.24	40.61	3.02	a	0.13	0.01
SPC	Seeds	4.50	1.13	5.03	0.44	9.53	1.16	46.66	6.30	38.93	1.82	b	0.13	0.01
	Trans	4.01	1.25	5.12	0.39	9.13	1.38	43.03	7.41	39.39	1.73	ab	0.13	0.01
Significance														
LSD (0.05)		0.56		0.23		0.61		3.36		1.16			0.01	
		n.s.		n.s.		n.s.		n.s.		*			n.s.	

n.s., *, **, *** Nonsignificant or significant at p _ 0.05, 0.01 or 0.001, respectively. Letters represent mean separation comparison (Student-Newman-Keuls test). S.D. Standard Deviation