MISSISSIPPI SOYBEAN PROMOTION BOARD
PROJECT 25-2017 (YEAR 7)
2017 FINAL REPORT

Project Title: Corn and Soybean Crop Residue Management Impact on Soil Quality, Soybean Yield, and Returns

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BACKGROUND AND OBJECTIVES

Soil organic matter and soil biology (microbial communities' population, diversity, and biomass) are key components of soil quality. High quality properly functioning regulates water infiltration into and runoff from soil; sustains plant and associated animal life; filters potential pollutants; and recycles nutrients including the major crop nutrients.

Soil structure encompasses inherent and dynamic soil qualities (aggregate stability, organic matter). Parent material, climate, age, and landscape position are large factors in soil structure. The dynamic physical, chemical and biological factors that give soil the structure are ultimately responsible for cropping conditions and can be influenced by management. Larger soil aggregates are more stable and improve water infiltration, water holding properties, aeration, fertility, and reduce erosion potential. Tillage in crop production can decrease the soil's aggregate stability, and organic matter content.

Little information is available in Mississippi regarding cropping systems and tillage effects on soil quality, ground residue cover, and yield. Since soil quality changes occur at a slow rate, long-term (2012-2016) studies were conducted on silt loam soils at two locations. The studies were conducted in a soybean/corn rotation (established in 2011) using controlled traffic systems (all wheel traffic in the row middles).

The objectives were to evaluate corn crop residue management (burn corn residue vs. no-burn) and tillage systems [[1) [Reduced Till (reshaped old bed when spring bed heights were less than 3 to 4 inches—Verona October 2013 and March 2015 and 2017, and Stoneville November 2013, February 2015, and March 2016 and 2017)], 2) Bed-roller, 3) in-row-subsoil-bed-roller (TerraTill® Bigham Ag, Lubbock, TX one-pass operation), and 4) Disk (2x) + TerraTill]] in irrigated (Stoneville) and non-irrigated (Verona) environments effect on 1) soil quality (soil organic matter, aggregate stability, water holding capacity, respiration and microbial biomass), 2) soybean growth and yield, 3) crop residue yield and nutrient content (N, P, Ca, Mg and K), and 4) returns above total specified expenses for each tillage system.

Soil P and K levels were maintained at high soil test levels. All tillage treatments were applied in the fall of each year, except Stoneville where 2014, 2015, and 2016 soil conditions delayed fall tillage applications until February 2015 and March 2016 and 2017, respectively. Irrigation timing at Stoneville was based on visual observation and rainfall events. Each row middle was furrowed out and watered through roll-out plastic polypipe from a surface water source.

REPORT OF PROGRESS/ACTIVITY

Objective 1

Verona (non-irrigated). The six-year (2012-2017) rainfall data indicated that below the 25-year (1987-2010) monthly average occurred during the growing seasons April-June 2012, June, July and August 2013, May and August 2014, June 2015, April-July 2016, and April, May, July, and August of 2017 (Table 1). Departures from the monthly mean maximum air temperature were quite variable, ranging from -3 to +7º F during the early growing season (April - June) (Table 1). Late season (July and August) temperatures generally ranged from +2 to -6º F below the 25-year (1981-2011) mean maximum monthly air temperature.
Crop residue management indicated burning corn crop residue resulted in reduced spring ground cover (winter vegetation and old crop residue), bed height, and yield. The six-year (2012-2017) average indicated Reduced Till and TerraTill (least intensive tillage systems) had more ground cover where the corn crop residue was not burned. All of the tillage systems' spring bed heights were greater where corn crop residue had not been burned (Table 6). Year 2013 was the only year where not burning corn residue in the fall of 2012 resulted in greater yield in 2013 than burning the residue (data not shown). The six-year average yields indicated TerraTill yield of 74.3 bu/acre was greater than the other tillage systems (Figure 1).

Stoneville (irrigated). The six-year (2012-2017) maximum monthly mean temperatures for April ranged from 0 to +8º F above the 25-year (1987-2011) monthly average, while May, June, July, and August temperatures ranged from -5 to +3º F above the 25-year mean (Table 2). Rainfall was highly variable during the growing season, ranging from 18% for May 2012 to 399% for August 2017 of the 25-year monthly average. There was no crop residue management or crop residue management by tillage interaction for all factors evaluated, except spring ground cover in 2012 and tillage. In 2012, no-burn had greater ground cover than burning corn crop residue (data not shown). The six-year average spring ground cover was greater for Reduced Till and TerraTill than Bed-roller and Disk (2x) + TerraTill (Table 8). The six-year average spring bed height for the Bed-roller was greater than for the other tillage systems (Table 8). Tillage systems six-year average yields ranged from 61.1 to 62.6 bu/acre and were not different (Figure 1).

Soil Quality. Since soil quality measured variables varied widely from year to year, the results are for the final year 2017. Since residue management—i.e. burning vs no burning—also had no effect, the discussion is limited to tillage treatments. The effects of tillage on soil properties, especially microbial-related properties, can accrue over time as depicted in Figs. 3-8 and Table 10. The degree of soil disturbance by tillage practices from least to most were Reduced Till, TerraTill, Bed-roller, and Disk (2x) + TerraTill.

There was little to no change in soil organic matter (% OM) between 2012 and 2017 for the Stoneville location (data not shown). The 2017 data indicated tillage did not dramatically influence soil organic matter (Figs. 3 and 4). The Verona % OM from 2012 (0.84%) to 2017 increased with all tillage systems and the % OM was greater in the least intensive tillage systems (Reduced Till and TerraTill) (Fig. 3). The 2017 results indicated a cumulative effect on the quality of soil organic matter and the microbial communities of crop residue decomposers. The higher quality substrate (crop residue and organic matter) in soils under less intensive tillage resulted in greater microbial activity (Figs. 5 and 6) and a greater mass of microbial organisms utilizing the substrate [Verona, Reduced Till and TerraTill (Fig. 7)] and to a lesser extent at Stoneville, [Reduced Till (Fig. 8)]. The cumulative benefits from less intensive tillage are based on the Simpson diversity index which takes into account the number of microbial species present and their relative abundances, where a higher value indicates greater microbial diversity (Table 10). From 2013 to 2015 the least intense tillage practices (Reduced Till and TerraTill) had greater soil microbial diversity than the more intensive tillage (Bed-roller and Disk (2x) + TerraTill).

Tillage effects on soil physical properties for 2017 indicated there were no differences in bulk density and moisture content at field capacity (Tables 11 and 12). These values did not significantly change from those measured at initiation of the project in 2012 (data not shown). We believe this is due to compaction of soils prior to the beginning of the field trials. For example, bulk density values were high for Stoneville and extremely high at Verona (Tables 11 and 12).

Not surprisingly, the moisture contents reflect bulk density values. On the other hand, aggregate stability, which is a determination of the percentage of soil aggregates able to withstand disintegration by agitation in water, was influenced differently by the tillage systems (Tables 11 and 12). The stability of aggregates is mainly determined by quantity and nature of organic compounds involved in binding soil particles together. The sources of these binding agents are by-products of decomposition of soil organic matter and crop residues and secretions by microorganisms. The higher percentages of stable aggregates for the least intensive tillage practices (Tables 11 and 12) are consistent with increase in substrate quality (Figs. 5 and 6), greater microbial biomass (Figs. 7 and 8), and more microbial diversity (Table 10).

No differences due to tillage for other soil chemical properties (Tables 13 and 14) were observed in 2017. These are consistent with observations made in 2012 (data not shown).

Objective 2

There was no crop residue management effect or crop residue management by tillage systems interaction for crop residue yields at both locations. The six year (2012-2017) crop residue tillage average yields at Verona ranged from 2.35 to 2.54 ton/acre (Table 7) and the nutrient contents were similar (Table 15). The N content ranged from 30 to 37 lb N/acre; 6.6 to 7.2 lb P/acre; and 37.8 to 44.1 lb K/acre. The Stoneville six-year tillage soybean crop residue yield averages ranged from 2.10 to 2.38 tons/acre with the Reduced Till yield of 2.38 ton/acre being greater than TerraTill and Disk (2x) + TerraTill (Table 9). The six-year average residue biomass nutrient content analysis also indicated little or no differences among tillage systems (Table 16). The nutrient content ranged from 24 to 31 lb N/acre; 5.2 to 6.5 lb P/acre; and 45 to 53 lb K/acre.

Objective 3

The returns above total specified tillage costs were based on the six-year (2012-2016) averages for total specified tillage treatment costs (MSU Budget Generator); USDA (Greenwood, MS) market price ($11.02/bu) for the week of soybean plot harvest; and the tillage treatment yields. The economic analysis for both locations indicated there was no crop residue management, crop residue management by tillage systems or year by tillage systems interactions for net returns above total specified tillage costs. The six-year total specified tillage costs for Verona ranged from $2.40/acre for Reduced Till to $35.89/acre for Disk (2x) + TerraTill at Verona (Table 7) and $9.80 for Reduced Till and $43.33/acre for the Disk (2x) + TerraTill at Stoneville (Table 9). In the non-irrigated environment (Verona), TerraTill net returns above tillage cost of $801/acre was greater than Reduced Till and the Disk (2x) + TerraTill and numerically greater than Bed-roller $770/acre (Figure 2). Stoneville returns ranged from $600 to $626/acre with no differences between tillage systems (Figure 2). However, Reduced Till numerically had greater returns than the other tillage systems.

Impacts and Benefits to Mississippi Soybean Producers

With the exception of spring ground cover (old crop residue and winter vegetation) and bed height, burning corn crop residue had no influence on soil quality, yield and returns above tillage system total specified cost. Not burning crop residue however, enhanced spring ground cover and bed height. Good ground cover reduces soil erosion potential. In addition, crop residues contain fertilizer nutrients and are a carbon source essential for soil microbes to utilize in improving soil quality i.e. soil health. The less intensive conservation tillage systems "Reduced Till" (irrigated environment) and "TerraTill" (non-irrigated environment) had a positive effect on soil quality, yield and returns. In contrast, the most intensive tillage system Disk (2x) + TerraTill had a negative effect on soil quality and returns; and had higher populations of the *Proteobacteria* which destroy soil organic matter. The positive effects of these conservation tillage systems on aggregate stability are evidence that improvement in soil structure can be expected. This creates the potential for better soil internal drainage with wet conditions and better moisture retention under dry conditions. Our findings indicate the potential for continued improvement in soil quality from conservation tillage practices.

In the non-irrigated environment, TerraTill, which had soil quality factors similar to Reduced Till, maximized yield and net returns. Other studies (non-irrigated) we have done, indicate in-row subsoiling (TerraTill) every other year is adequate for maximizing yield and returns. Neither subsoiling nor disking are necessary for the Mississippi Delta irrigated environment. However, additional research with Reduced Till and in-row-subsoiling (TerraTill) needs to be done with soil moisture sensors in an irrigated environment to determine whether the number of irrigations can be reduced with subsoiling. These results agreed with research by Pringle et.al. (2003) in cotton.

End Products

2014

<u>Grower Meetings (Poster Presentations)</u>

- Buehring, N.W., M.P. Harrison, A.R. Taylor, L.L. Falconer, M.W. Ebelhar, W. Kingery and S. Shanmugam. Corn-crop residue management impact on soybean grain yield and crop residue yield and nutrient content. North Mississippi Research and Extension Row Crops Field Day, Verona, MS. August 7, 2014.

- Harrison, M.P., N.W. Buehring, A.R. Taylor, M.W. Ebelhar, L.L. Falconer, W. Kingery and S.G. Shanmugam. Soybean yield and net return response to corn crop residue management. North Mississippi Producer Advisory Council meeting, Verona, MS. February 18, 2015.

2015

<u>Professional Meetings</u>

- Ebelhar, M.W., N.W. Buehring and W.L. Kingery. 2015. Crop residue management and tillage interactions for soybean/corn rotation. Southern Branch ASA meeting, Southern Association of Agricultural Scientist Meeting, Atlanta, GA. February 1-4, 2015.

- Buehring, Normie, Billy Kingery, Shankar Shanmugam, Wayne Ebelhar, Mark Harrison and Andy Taylor. 2018. Crop residue management and tillage systems' impact on yield and soil quality. Southern Branch American Society of Agronomy meeting, Jacksonville, FL. February 4-6, 2015.

- Shanmugam, S.G, M.W. Ebelhar, M.S. Cox, J.L. Oldham and W.L. Kingery. 2015. Impact of tillage and residue management on soil microbial biodiversity under soybean-corn rotation. Annual Meeting of the American Society of Agronomy, Minneapolis, MN. November 15-18, 2015.

- Taylor, A.R., N.W. Buehring, M.P. Harrison, L.L. Falconer, M.W. Ebelhar, W.L. Kingery and S.G. Shanmugam. 2015. Crop residue management and tillage system effect on bed height, ground cover, corn grain yield and net returns in a soybean/corn rotation. American Society Agronomy Meeting, Minneapolis, MN. November 15-18, 2015.

- Harrison, M.P., N.W. Buehring, A.R. Taylor, M.W. Ebelhar, L.L. Falconer, W.L. Kingery and S.G. Shanmugam. 2015. Soybean yield and net returns response to corn crop residue management and tillage systems in a corn/soybean rotation. American Society Agronomy Meeting, Minneapolis, MN. November 15-18, 2015.

Grower Meetings (Poster Presentations)

- Harrison, M.P., N.W. Buehring, A.R. Taylor, M.W. Ebelhar, L.L. Falconer, W. Kingery and S.G. Shanmugam. Soybean yield and net return response to corn crop residue management. North Mississippi Producer Advisory Council meeting, Verona, MS. February 18, 2015.

2016.

Journal Publications

- Shanmugam, S.G., N.W. Buehring, M.W. Ebelhar, M.S. Cox, J.L. Oldham, D.G. Peterson and W.L. Kingery. 2016. Short-term effects of tillage treatments on soil microbial biodiversity under soybean-corn rotation. International Journal of Agriculture and Environmental Research 2: 1277-1303.

Professional Meetings

- Falconer, L.L., N.W. Buehring and M.W. Ebelhar. 2016. Economic analysis of corn and soybean crop residue management and tillage strategies in Mississippi. Southern Agricultural Economic Association 2016 Annual Meeting, San Antonio, TX. February 6-9, 2016.

- Ebelhar, M., and N.W. Buehring. 2016. Effect of residue management and tillage on corn and soybean yields in rotations. In annual meeting abstracts [CD] ASA-CSSA and SSSA, Phoenix, AZ. November 7, 2016.
- Shanmugam, S.G., N.W. Buehring, M.W. Ebelhar, M.S. Cox, J.L. Oldham and W.L. Kingery. 2016. Long term impact of tillage and crop rotation management on soil microbial biodiversity and soil health. In annual meeting abstracts [CD] ASA, CSSA and SSSA, Phoenix, AZ. November 7, 2016.

Grower Meetings (Poster Presentations)

- Harrison, M.P., N.W. Buehring, A.R. Taylor, M.W. Ebelhar, L.L. Falconer, W.L. Kingery and S.G. Shanmugam. 2016. Soybean yield and net returns response to corn crop residue management and tillage systems in a corn/soybean rotation. North Mississippi Research and Extension Center Producer Advisory Council Meeting, Verona, MS. February 18, 2016.

- Taylor, A.R., M.P. Harrison, N.W. Buehring, M.W. Ebelhar, L.L. Falconer, W.L. Kingery, and S.G. Shanmugam. Crop residue management and tillage systems effect on bed height, ground cover, corn grain yield and net returns. 2016. North Mississippi Research and Extension Center Producer Advisory Council Meeting, Verona, MS. February 18, 2016.

2017

Grower Meetings (Poster Presentations)

- Taylor, A. R., N. W. Buehring, M. P. Harrison, L. L. Falconer, M. W. Ebelhar, W. L. Kingery, and S. G. Shanmugam. Long-term corn grain yield and net returns response to crop residue management and tillage system in a soybean/corn rotation. North Mississippi Producer Advisory Council Meeting, Verona, MS. February 19, 2017.

- Harrison, M. P., N. W. Buehring, A. R. Taylor, M. W. Ebelhar, L. L. Falconer, W. L. Kingery, and S. G. Shanmugam. Long-term soybean yield and net returns response to corn crop residue management and tillage systems in a corn/soybean rotation. North Mississippi Producer Advisory Council Meeting, Verona, MS. February 19, 2017.

- Buehring, Normie, William Kingery, Mark Harrison, Andy Taylor and Shankar Shanmugam. Soil quality factors as influenced by crop residue management and tillage systems with soybean in a corn-soybean rotation system. North Mississippi Producer Advisory Council Meeting, Verona, MS. February 19, 2017.

- Harrison, Mark, Normie Buehring, William Kingery, Andy Taylor, and Shankar Shanmugam. Soil quality factors as influenced by crop residue management and tillage systems with corn in a corn-soybean rotation system. North Mississippi Producer Advisory Council Meeting, Verona, MS. February 19, 2017.

2018

Professional Meetings

- Buehring, Normie. Long-term conservation tillage influence on soil quality, yield and returns. The 21st Annual National Conservation Systems Cotton and Rice Conference, Memphis, TN. February 10-12, 2018.

- Buehring, Normie, Billy Kingery, Mark Shankar Shanmugam, Wayne Ebelhar, Mark Harrison, and Andy Taylor. 2018. Crop residue management and tillage systems impact on yield and soil quality. Southern Branch American Society of Agronomy meeting, Jacksonville, FL. February 4-6, 2018.

- Ebelhar, M.W. and N.W. Buehring. 2018. Tillage and Residue Management in Mississippi Delta Corn and Soybean Yields. Southern Branch American Society of Agronomy meeting, Jacksonville, FL. February 4-6, 2018.

Grower Meetings (Poster Presentations)

- Harrison, M.P., N.W. Buehring, A.R. Taylor, M.W. Ebelhar, L.L. Falconer, W.L. Kingery, and S.G. Shanmugam. 2018. Long-term corn crop residue management and tillage systems in a corn/soybean rotation impact on soybean yield and returns. North Mississippi Producer Advisory Council meeting, Verona, MS. February 15, 2018.

- Taylor, A.R., M.P. Harrison, N.W. Buehring, M.W. Ebelhar, L.L. Falconer, W.L. Kingery and S.G. Shanmugam. 2018. Corn grain yield and net returns response to long-term crop residue management and tillage system in a soybean/corn rotation. North Mississippi Producer Advisory Council meeting, Verona, MS. February 15, 2018.

- Taylor, Andy, Normie Buehring, William Kingery, Mark Harrison, and Shankar Shanmugam. Soil health factors as influenced by crop residue management and tillage systems with soybean in a corn-soybean rotation system. North Mississippi Producer Advisory Council meeting, Verona, MS. February 15, 2018.

- Mark Harrison, Normie Buehring, William Kingery, Andy Taylor, and Shankar Shanmugam. Crop residue management tillage systems' impact on soil health with corn in a corn-soybean rotation system. North Mississippi Producer Advisory Council meeting, Verona, MS. February 15, 2018.

Table 1. The 2012-2017 monthly maximum mean air temperature departures and monthly rainfall percentage comparison to the 25 year (1982-2011) monthly mean, Verona, MS.

	Maximum Mean Air Temperature (ºF)				
Year	April	May	June	July	August
1987-2011 Mean	**74**	**82**	**88**	**92**	**92**
	Mean Departure (ºF)				
2012	+2	+4	+3	+1	-3
2013	-2	-3	+1	-4	-2
2014	-1	-2	-2	-6	-3
2015	+1	+1	0	+1	-3
2016	+1	-1	+4	+2	+1
2017	+7	0	-2	+1	-2
	Rainfall (in)				
1987-2011 Mean	**4.96**	**5.53**	**4.73**	**4.56**	**3.84**
	% Mean				
2012	52	55	35	134	106
2013	102	100	65	35	48
2014	145	76	217	125	42
2015	154	120	53	142	192
2016	88	16	59	21	105
2017	78	86	126	56	130

Table 2. The 2012-2017 monthly maximum mean air temperature departures and monthly rainfall percentage comparison to the 25 year (1987-2011) monthly mean, Stoneville, MS.

			Maximum Mean Air Temperature (ºF)		
Year	April	May	June	July	August
1987-2011 Mean	**72**	**84**	**90**	**92**	**92**
			Mean Departure (ºF)		
2012	+6	+3	+1	+1	+1
2013	0	-5	-3	-5	+1
2014	+1	-3	-1	-4	-2
2015	+4	-1	+1	+1	0
2016	+5	-1	+1	+1	0
2017	+8	-3	-4	0	-3
			Rainfall (in)		
1987-2011 Mean	**5.12**	**4.94**	**3.23**	**3.83**	**2.69**
			% Mean		
2012	82	18	198	119	159
2013	129	115	113	50	74
2014	192	126	178	122	113
2015	124	141	80	83	27
2016	84	67	157	170	204
2017	129	99	235	113	399

Table 3. Fertilizer and lime applications on a Marietta loam soil, 2011-2017, Verona, MS.

Fertilizer[1]	2011	2012	2013	2014	2015	2016	2017
				Lb/acre			
Lime	0	3600	0	0	0	0	0
P_2O_5	52	0	0	184	200	150	200
K_2O	52	120	150	240	200	150	200
N (corn)[2]	200	200	200	250	250	250	250
Magnesium (36% Mg)	0	0	15	0	0	0	0
Sulfur[3]	0	26	0	0	0	0	0
Zinc (6.5% Zn) (corn)	0	0	0	2 qt	2 qt	2 qt	2 qt

[1]All P_2O_5, K_2O, lime and magnesium were applied in the fall. All N, sulfur and zinc were applied during growing season.
[2]Applied as 32% urea-nitrate solution with a colter-knife application system side-dress with application at 1 to 2 leaf corn and at V4-V5 corn growth stage.
[3]Applied as ammonium sulfate.

Table 4. Fall tillage operation dates, soybean variety, seeding rate and planting dates, 2011-2017, on a Marietta loam soil, Verona, MS.

---------- Tillage ----------			Seeding	
Year	Date	Variety	Rate/A	Planting Date
2011	October 27	Pioneer 94Y90	137,000	May 11
2012	November 1	Pioneer 94Y90	137,000	April 25
2013	October 21	Pioneer 49T80R	137,000	May 2
2014	October 28	Pioneer 49T80R	137,000	May 5
2015	October 20	Pioneer 49T80R	137,000	May 6
2016	----	Pioneer 49T80R	137,000	May 11
2017	March 24	Delta Grow 4790R2Y	137,000	April 19

Table 5. Fall tillage operation dates, soybean variety seeding rates, planting dates and number of furrow irrigations on a Bosket fine sandy loam and Dubbs silt loam soils, 2011-2017, Stoneville, MS.

Year	---------- Tillage ---------- Date	Variety	Seeding Rate/A	Planting Date	# irrigations
2011	January 5	Pioneer 94Y70	150,000	May 11	----
2012	November 26	Pioneer 94Y71	150,000	April 13	5
2013	November 25	HALO 465	150,000	May 9	7
2014	----	Pioneer 45T77L	150,000	May 5	0[1]
2015	February 11	Pioneer 48T67L	150,000	June 6	2
2016	March 8	HBK 4653LL	150,000	April 29	2
2017	March 24	Credenz 4748LL	150,000	April 21	2

[1]No irrigations were needed due to above normal rainfall and below normal temperatures.

Table 6. Spring ground cover as influenced by crop residue management and tillage, averaged over years (2012-2016), Verona, MS.

	----- % ground cover -----		------------- Bed Height (in) -------------		
Tillage	Burn	No-burn	Burn	No-burn	Mean
Reduced Till	20 B[1]ab[2]	96 Aa	3.1 B[1]c[2]	3.8 Ad	3.5 d
Bed-roller	32 Aa	23 Ac	6.4 Ba	6.7 Aa	6.6 a
TerraTill	11 Bab	36 Ab	5.2 Bb	5.6 Ab	5.4 b
Disk (2x) + TerraTill	3 Ab	4 Ad	3.3 Bc	4.4 Ac	3.9 c

[1]Within tillage treatment across crop residue management systems, numbers with the same uppercase letters are not significantly different according to Fisher's Protected LSD (P=0.05).
[2]Within a column, numbers with the same lowercase letters are not significantly different according to Fisher's Protected LSD (P=0.05).

Table 7. Six-year (2012-2017)One hundred seed weight, soybean crop residue yield, grain yield, tillage cost and net returns above tillage costs, as influenced by tillage system, averaged over crop residue management and years, Verona, MS.

Tillage	Yield bu/acre	100 seed wt. gram	Tillage Cost $/acre	Returns[1] $/acre	Residue T/acre
Reduced Till	68.5 c[2]	15.13 ab	2.40	753 b	2.35 a
Bed-roller	70.6 b	15.48 a	7.49	770 ab	2.37 a
TerraTill	74.3 a	15.39 a	17.43	801 a	2.54 a
Disk (2x) + TerraTill	71.7 b	14.94 b	35.89	754 b	2.48 a

[1]Net returns above tillage costs.
[2]Within a column, numbers with the same lowercase letters are not significantly different according to Fisher's Protected LSD (P=0.05).

Table 8. Spring ground cover and spring bed heights as influenced by tillage system, averaged over years (2012-2016) and crop residue management system, Stoneville, MS.

Tillage	% ground cover	Bed height (in)
Reduced Till	72 a[1]	2.4 b
Bed-roller	38 c	4.5 a
TerraTill	57 b	2.3 b
Disk (2x) + TerraTill	43 c	1.6 c

[1]Within a column, numbers with same lowercase letters are not significantly different according to Fisher's Protected LSD (P=0.05).

Table 9. Six-year (2012-2017) average soybean one hundred seed weight, crop residue yield, grain yield, tillage costs and net returns above tillage costs, averaged over years and crop residue management, Stoneville, MS.

Tillage	Yield bu/acre	100 seed wt. gram	Tillage Cost $/acre	Returns[1] $/acre	Crop Residue Ton/acre
Reduced Till	62.6 a[2]	13.92 a	9.80	626 a	2.38 a
Bed-roller	61.1 a	13.87 a	13.66	619 a	2.26 ab
TerraTill	62.1 a	13.92 a	24.89	610 a	2.10 b
Disk (2x) + TerraTill	63.4 a	14.06 a	43.33	600 a	2.15 b

[1]Net returns above tillage costs.
[2]Within a column, numbers followed by the same lowercase letters are not significantly different according to Fisher's Protected LSD (P=0.05).

Table 10. The Simpson diversity index of bacteria across tillage treatment plots as influenced by tillage system, averaged over crop residue management, Verona and Stoneville, MS. (2013-2015).

	Verona				**Stoneville**			
Year	**Reduced Till**	**Bed-roller**	**Disk (2x) + TerraTill**	**TerraTill**	**Reduced Till**	**Bed-roller**	**Disk (2x) + TerraTill**	**TerraTill**
2013	205 a[1]	134 b	125 b	189 ab	211 a	129 b	142 ab	192 a
2014	211 a	142 b	126 b	210 a	223 a	144 b	139 b	189 a
2015	216 a	141 b	136 b	217 a	234 a	139 b	151 b	202 a

[1]Means within rows followed by the same letter are not significantly different according to Fisher's Protected LSD (P=0.05)

Table 11. Soybean soil physical properties in 2017, as influenced by tillage system, averaged over crop residue management, Verona, MS.

Tillage	% Aggregate Stability	Bulk Density g/cm^3	Moisture content at field capacity (%)
Reduced Till	35 a[1]	1.84 a	16.2 a
Bed-roller	23 b	1.79 a	16.1 a
Disk (2x) + TerraTill	26 b	1.88 a	14.3 a
TerraTill	30 ab	1.83 a	15.5 a

[1]Numbers within a column with the same lowercase letters are not significant according to Fisher's Protected LSD (P=0.05).

Table12. Soybean soil physical properties in 2017, as influenced by tillage system, averaged over crop residue management, Stoneville, MS.

Tillage	% Aggregate Stability	Bulk Density g/cm^3	Moisture content at field capacity (%)
Reduced Till	39 a[1]	1.53 a	19.8 a
Bed-roller	23 b	1.64 a	19.2 a
Disk (2x) + TerraTill	26 b	1.54 a	20.6 a
TerraTill	29 b	1.58 a	20.8 a

[1]Numbers within a column with the same lowercase letters are not significant according to Fisher's Protected LSD (P=0.05).

Table 13. Soybean soil chemical properties in 2017, as influenced by tillage system, averaged over crop residue management, Verona, MS.

Tillage	pH	P	K	Zn
		lbs/acre		
Reduced Till	6.3 a[1]	137 a	313 ab	4.0 a
Bed-roller	6.5 a	157 a	282 ab	5.3 a
Disk (2x) +TerraTill	6.3 a	147 a	280 b	4.2 a
TerraTill	6.3 a	156 a	363 a	5.7 a

[1]Numbers within a column with the same lowercase letters are not significant according to Fisher's Protected LSD (P=0.05).

Table 14. Soybean soil chemical properties in 2017, as influenced by tillage system, averaged over crop residue management, Stoneville, MS.

Tillage	pH	P	K	Zn
		lbs/acre		
Reduced Till	5.7 a[1]	78 a	411 a	3.0 a
Bed-roller	6.1 a	76 a	291 a	2.9 a
Disk (2x) + TerraTill	5.9 a	83 a	421 a	3.4 a
TerraTill	5.9 a	75 a	315 a	3.0 a

[1]Numbers within a column with the same lowercase letters are not significant according to Fisher's Protected LSD (P=0.05).

Table 15. Influence of tillage system on residue nutrient removal, as influenced by tillage system, averaged over years (2012-2017) and crop residue management system, Verona, MS.

Tillage system	N	P	K	Ca	Mg
	lbs/acre of residue biomass				
Reduced Till	33 a[1]	6.6 a	37.8 b	75 b	13 a
Bed-roller	35 a	7.2 a	39.6 ab	81 ab	14 a
Disk (2X) + TerraTill	37 a	7.1 a	39.8 ab	86 a	14 a
TerraTill	30 a	7.2 a	44.1 a	85 ab	15 a

[1]Numbers in a column followed by the same letter are not significantly different according to Fisher's Protected LSD (P=0.05)

Table 16. Influence of tillage system on residue nutrient removal, as influenced by tillage system, averaged over years (2012-2017) and crop residue management system, Stoneville, MS.

Tillage system	N	P	K	Ca	Mg
	lbs/acre of residue biomass				
Reduced Till	31 a[1]	6.5 a	50 ab	48 a	14 a
Bed-roller	28 ab	5.7 ab	53 a	47 a	14 a
Disk (2X) + TerraTill	24 b	5.2 b	45 b	42 a	13 a
TerraTill	28 a	5.8 ab	49 ab	43 a	13 a

[1]Numbers in a column followed by the same letter are not significantly different according to Fisher's Protected LSD (P=0.05)

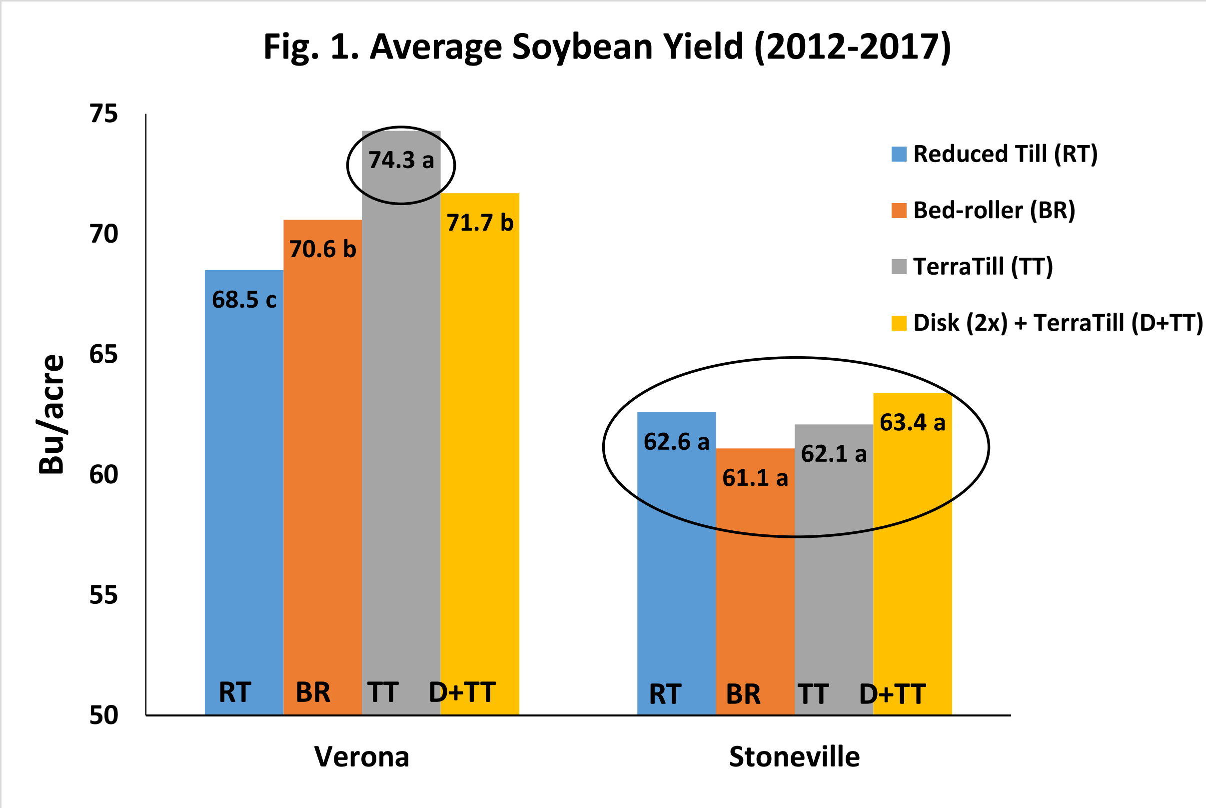
Fig. 1. Average Soybean Yield (2012-2017)
Bu/acre
75
70
65
60
55
50
68.5 c
70.6 b
74.3 a
71.7 b
62.6 a
61.1 a
62.1 a
63.4 a
RT
BR
TT
D+TT
RT
BR
TT
D+TT
Verona
Stoneville
Reduced Till (RT)
Bed-roller (BR)
TerraTill (TT)
Disk (2x) + TerraTill (D+TT)

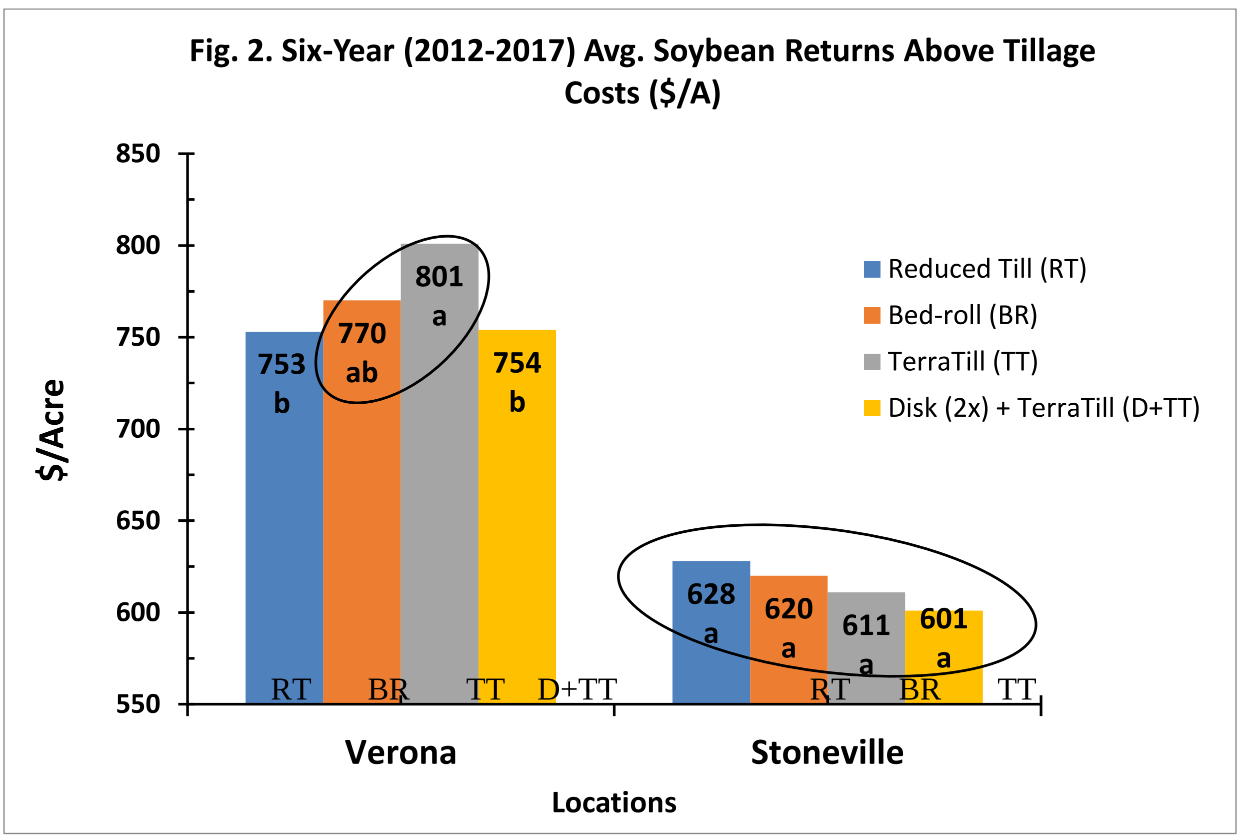
Fig. 2. Six-Year (2012-2017) Avg. Soybean Returns Above Tillage Costs ($/A)
$/Acre
850
800
750
700
650
600
550
753 b
770 ab
801 a
754 b
628 a
620 a
611 a
601 a
RT
BR
TT
D+TT
RT
BR
TT
Verona
Stoneville
Locations
Reduced Till (RT)
Bed-roll (BR)
TerraTill (TT)
Disk (2x) + TerraTill (D+TT)

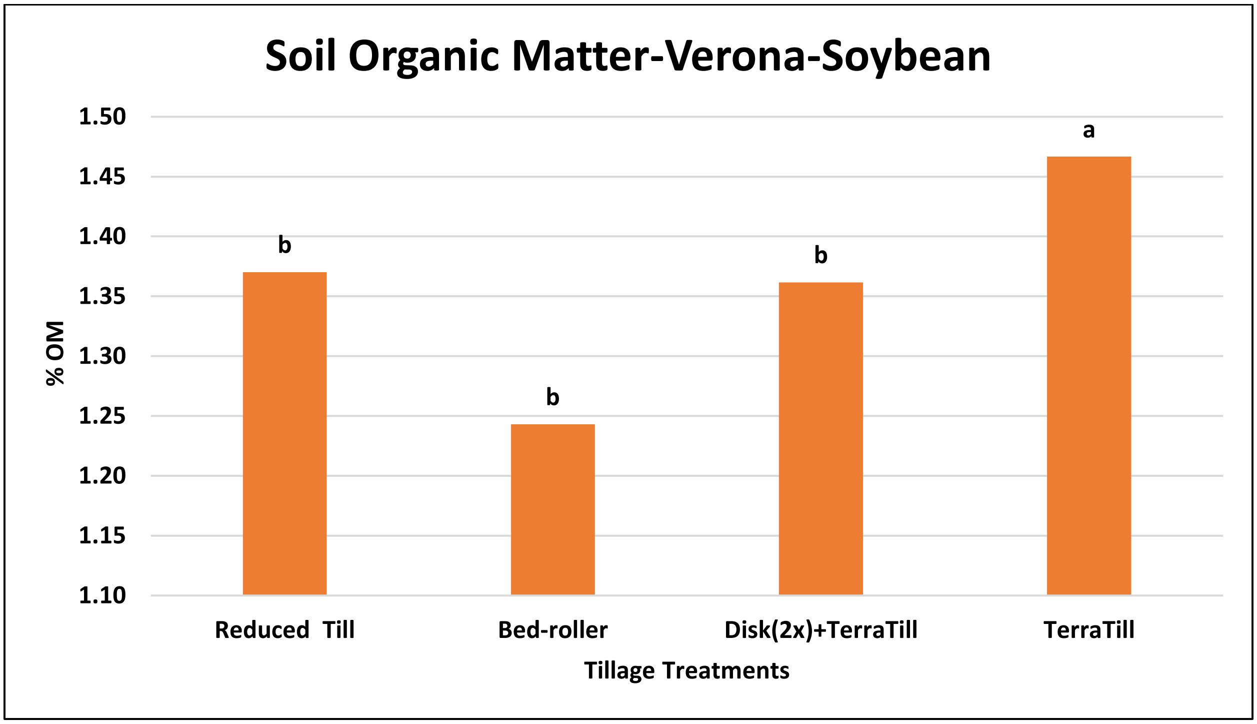

Fig 3: Soybean soil organic matter analysis in 2017, Verona, MS.
Bar graphs labelled with the same lowercase letters are not significantly different according to Fisher's Protected LSD (P=0.05)

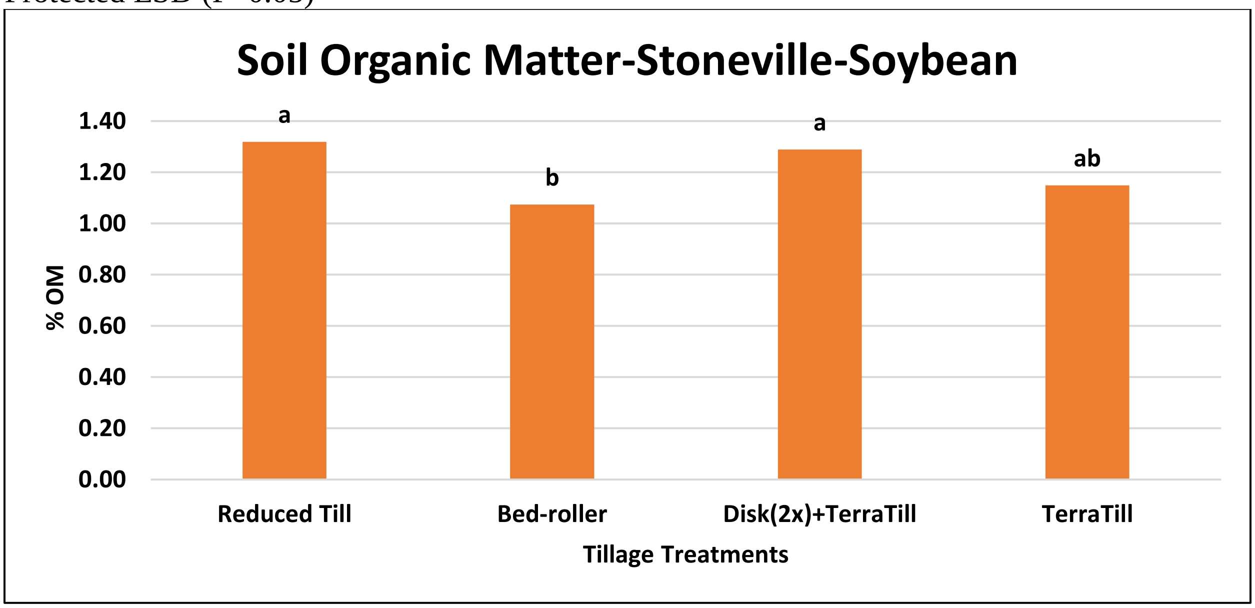

Fig 4: Soybean soil organic matter analysis in 2017, Stoneville, MS.
Bar graphs labeled with the same lowercase letters are not significantly different according to Fisher's Protected LSD (P=0.05)

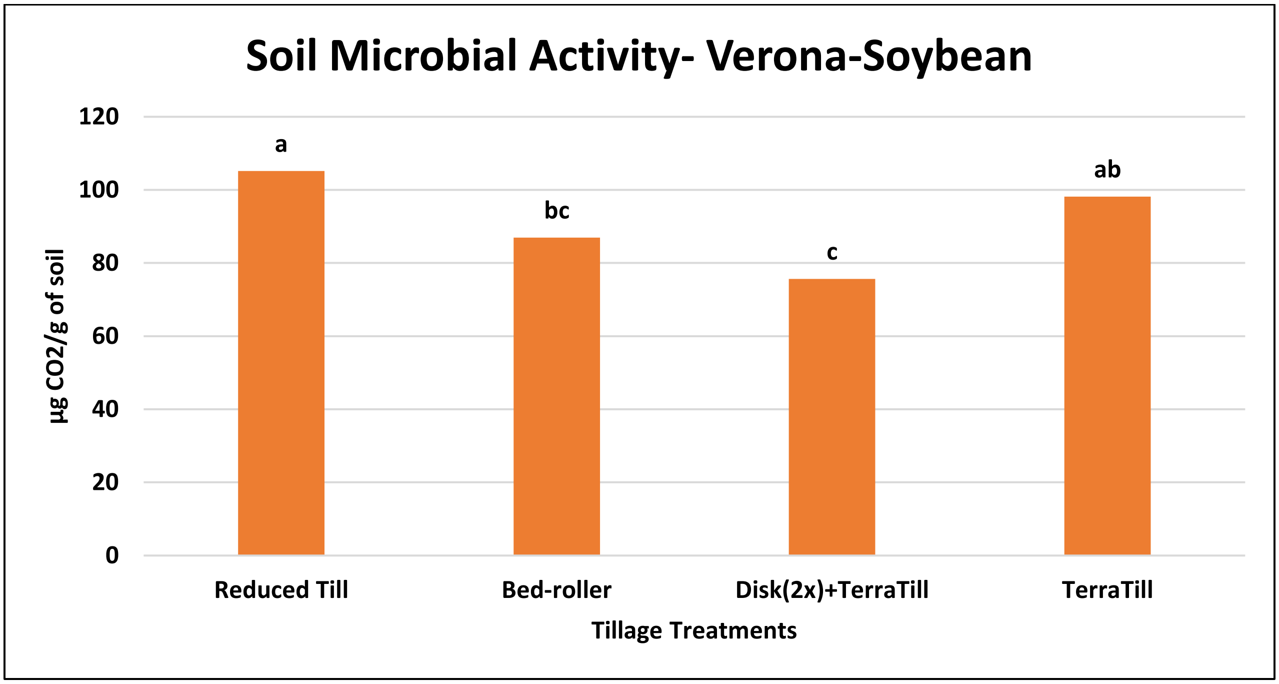

Fig 5: Soybean soil microbial activity in 2017, Verona, MS
Bar graphs labeled with the same lowercase letters are not significantly different according to Fisher's Protected LSD (P=0.05)

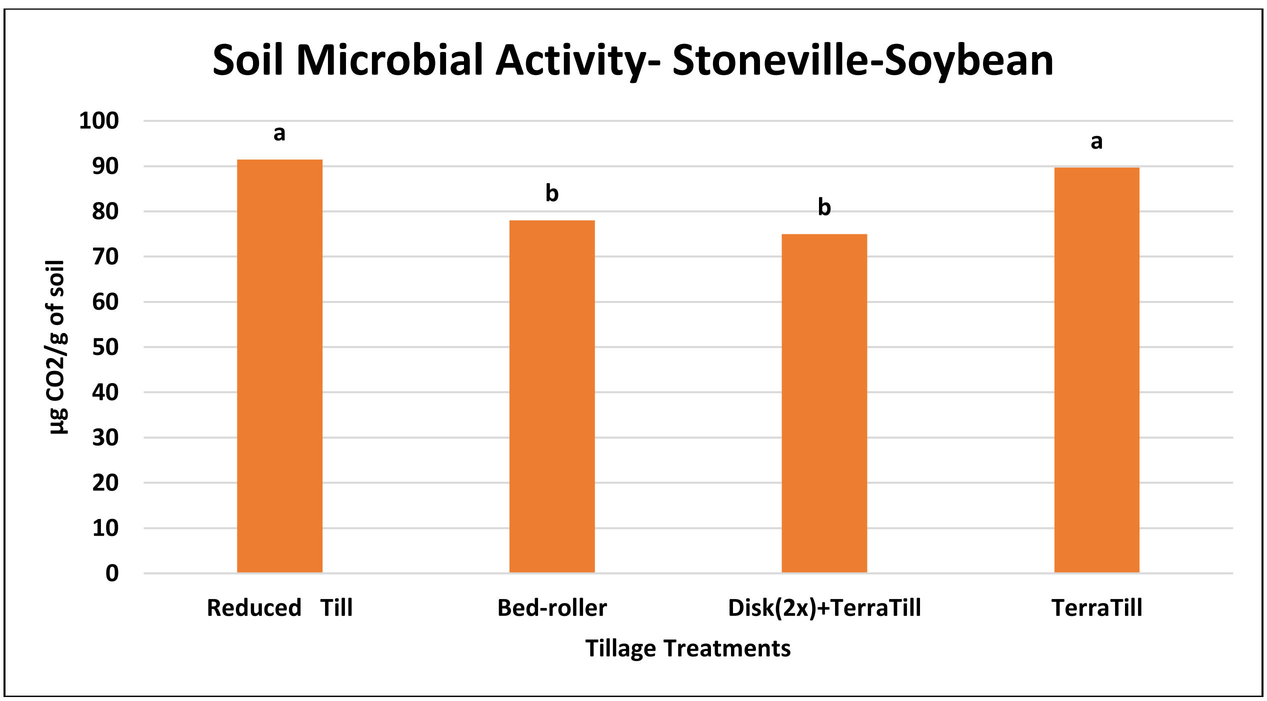

Fig 6: Soybean soil microbial activity in 2017, Stoneville, MS
Bar graphs labeled with the same lowercase letters are not significantly different according to Fisher's Protected LSD (P=0.05)

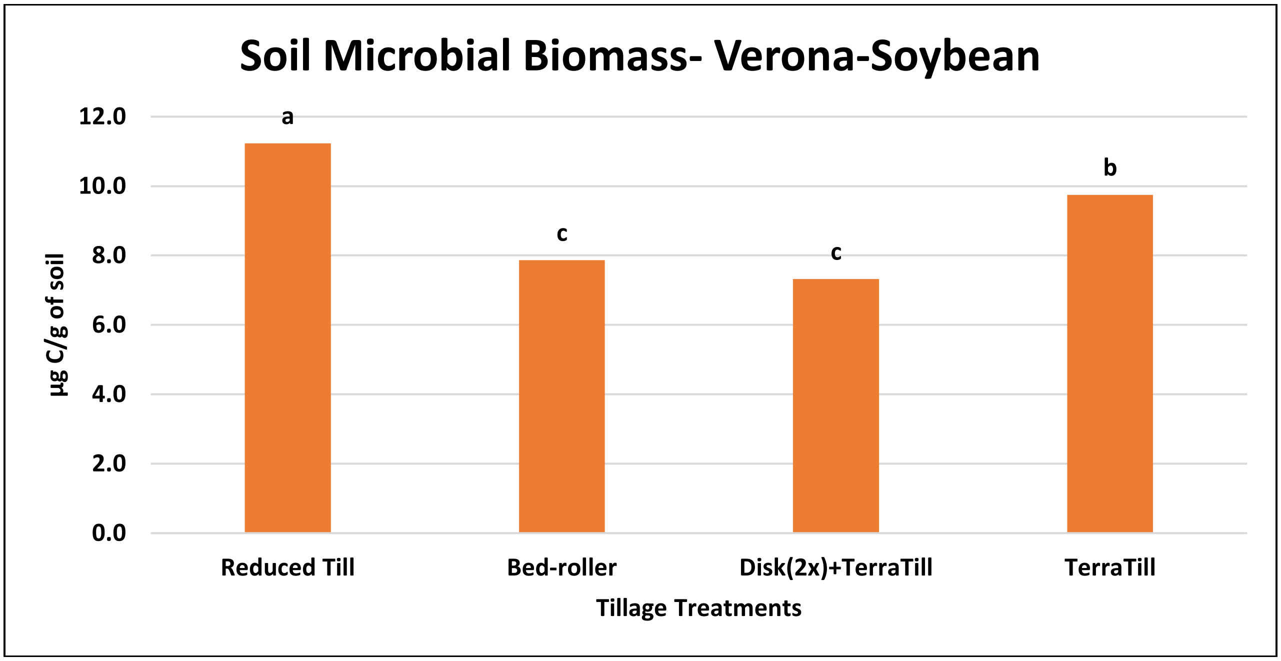

Fig 7: Soybean soil microbial biomass in 2017, Verona, MS
Bar graphs labeled with the same lowercase letters are not significantly different according to Fisher's Protected LSD (P=0.05)

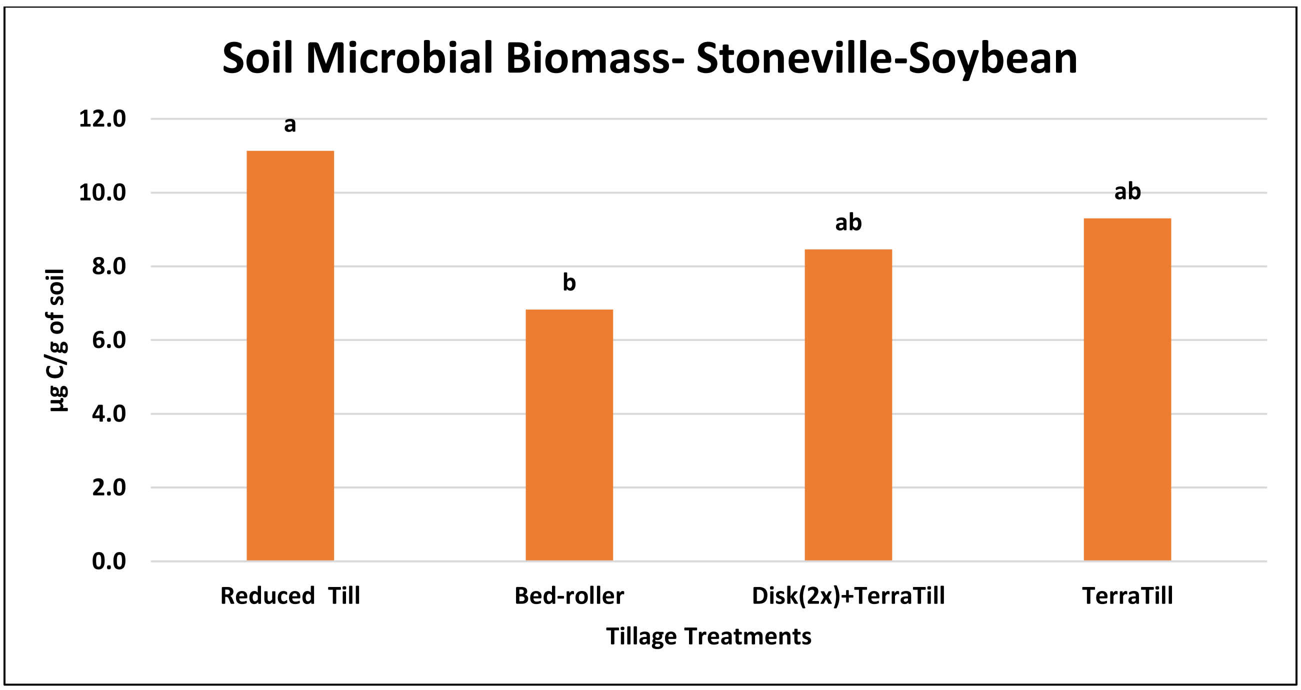

Fig 8: Soybean soil microbial biomass in 2017, Stoneville, MS
Bar graphs labeled with the same lowercase letters are not significantly different according to Fisher's Protected LSD (P=0.05)