MISSISSIPPI SOYBEAN PROMOTION BOARD
PROJECT NO. 02-2015 (YEAR 3)
2015 Final Report

Title: Evaluation of soybean plant response to tillage system

PI: Dr. Ernie Flint*, Area Agronomist, Mississippi State University Extension Service ernestf@ext.msstate.edu, 662-289-5431
Dr. Glover Triplett, Prof. Emeritus, Department of Plant and Soil Sciences, Mississippi State University, GTriplett@PSS.MsState.edu

ABSTRACT

The purpose of this study was to evaluate the value of tillage in soybean production in Central Mississippi. This was accomplished by introducing tilled areas into otherwise undisturbed soil environments.

For this study two locations were selected: one was designated as short-term no-tillage where tillage was done on a routine basis every 2 to 3 years in the fall following the harvest. A second location, designated as long-term no-tillage, had not been tilled in almost 20 years. During the first 2 years of the proposed 3-year study, yields were similar for tilled and no-tilled areas of the two trials. Thus, the cost of tillage and supporting factors would not have been justified at either location. The no-tillage system was more profitable simply as the result of cost savings.

During the third and final year of the study in 2015, the no-tillage treatment produced almost 20% more yield of soybeans than the tilled treatment. The only factor differing between the two treatments was that the tilled treatment was disturbed by one pass with a standard chisel implement at a depth of approximately 8-9 inches. This single tillage operation resulted in decreased yield from an average of 59 bushels/acre to 37 bushels/acre in a four- replication trial.

A third location at which soybeans were to be drilled into existing sod was prepared in similar fashion as the other two sites. An unexpected occurrence at this site was the profuse emergence of weeds, primarily pigweed, in the tilled plots. Because of the uncertainty of the impact of this early competition, the site was not used further in the study. However, the level of weed emergence demonstrated the potential effect of tillage on the development of weeds in sites where large amounts of dormant seed are present. The physical movement of weed seed to the soil surface along with the introduction of light following tillage triggered germination and emergence of weeds, primarily pigweed.

MATERIALS AND METHODS

Locations

Location one. Locations were selected on the farms of two cooperating growers for use in this study. One of the farms had not received tillage for more than 20 years except for the purpose of localized repair or improvement of drainage. The farm had been managed by one of the earliest adopters of no-tillage crop production in Mississippi. The farm has since changed owners, but the present owner has continued the management system of the previous farmer.

The soil on this farm near Madden in Leake County, MS is the Rosebloom/Arkabutla association described as fine, silty, mixed, active, acid, thermic, Fluvaquentic Endoaquepts. This field is in an area that has in the past been prone to short term flooding; however, significant drainage improvements through the years makes it now unlikely to be flooded. It has been recognized as one of the most productive farms in the locality due in large part to the owner's adoption of conservation tillage practices.

A randomized complete block design was utilized with four replications and two treatments per replication. Treatments were Tilled and No-Till. In the first 2 years of the study, the tilled plots were prepared with a small tractor-mounted rotary tiller with two passes over plots 10 by 20 feet to a depth of approximately 6-8 inches. In the third and final year of the study, the tilled plots were prepared by one pass with a standard chisel plow run at a depth of 7-9 inches.

No significant soil crusting following the tillage operation was noted at either location, and seedlings emerged normally within a week all 3 years. Stand counts were made at the first trifoliate stage. Subsequent measurements of height, chlorophyll index, stomatal conductivity, and yield were conducted. In the final year of the study, the long term no-tillage location was not used due to late planting, poor emergence of seedlings, and extended drought.

Location two. The second location in Madison County near Canton, MS utilized the same experimental design as that in Leake County. The Madison County site was chosen as the short-term no-till site for its recent history in which the soil had been tilled in the fall within the last 2 years, and was planted to corn 2 years prior to this work and to soybeans the year prior to this work.

The soil at this location was Calloway silt loam (fine-silty, mixed, active, thermic Aquic Fraglossudalfs). From the designation as a "fragi-udalf" one might expect that periodic deep tillage may be beneficial for the purpose of keeping the fragipan from impeding root penetration and water infiltration; however, no indication of this was noted from the results of the study.

Measurements

Stomatal Conductivity. These measurements were performed to estimate the availability of water to plants in the tilled and no-till soil. The instrument utilized was a Decagon Model SC-1leaf porometer from Decagon Devices in Pullman, WA. The unit of measurement was mmol/m^2/sec, which can be considered as an index of water loss from plants as transpiration. The amount of water loss can then be used to infer the availability of water to plants as a

function of the existing soil/plant relationship. Rather than attempting to evaluate the individual effects of infiltration, soil organic activity, mycorrhizal colonization, and myriad other factors, this measurement suggested the end result of all these factors combined as a system.

Chlorophyll index. This measurement was used to compare plant activity as expressed by the level of photosynthesis being carried on within the cells of plant leaves. These determinations were done with an Apogee CCM-200 Chlorophyll Content Meter. The measurement was done on all plants within the study in as short a time period as possible on clear days as a way of avoiding the effect of variations in sunlight. As with stomatal conductivity, this index provides a snapshot of plant health and level of photosynthesis supporting growth and reproduction.

Measurement of both stomatal conductivity and chlorophyll index were made in a short time period on clear days to avoid the effect of variations in sunlight.

Seed yield. Yield was determined by hand-harvesting a five-foot-long strip of row from each plot. The plants were cut at the soil line and removed from the field to complete drying, after which the seeds were separated with a plot thresher and weighed to determine yields.

RESULTS AND DISCUSSION

Stand Establishment. The long term no-till location near Madden, MS in Leake County showed no apparent difference in stand from counts that were done 5 weeks after planting in 2013; however, there were more surviving plants in the no-tillage plots than in the tilled plots in 2014.

Table 1. Stand counts in the long-term no-till site in Leake County near Madden, MS.

	Tilled	No-Till
2013 Plants Per Acre	133,575	132,433
2014 Plants Per Acre	118,200	130,020
2015 data not taken due to poor field conditions and drought.		
Average	125,888	131,226

In the short term no-till location on the Murphy Farm in Madison County near Canton, MS, there was a 13% greater plant population in the tilled plots at 5 weeks after planting in 2013, but there was no difference in 2014 and 2015. The argument proposed by some that there is a consistent difference between tilled and no-till treatments with regard to stand establishment is not supported by this study.

Table 2. Stand counts in short-term no-till site in Madison County near Canton, MS in 2013.

	Tilled	No-Till
Plants per acre 2013	96,570	85,550
Plants per acre 2014	82,880	82,880
Plants per acre 2015	135,250	135,000
Average	104,900	101,143

Plant Height. Overall mean height of soybean plants in the long-term no-till area in Leake County showed no real advantage for the no-tillage. These plants were suppressed in growth by a well-justified application of a combined fomesafen plus metolochlor product (Prefix) due to areas of heavy morninglory infestation after emergence in 2013. This application caused considerable leaf damage to plants, and likely led to reduced height. In 2014, the preplant burndown application of glyphosate plus metribuzin was more effective, thus enabling the grower to use glyphosate alone for a single postemergence treatment. Data were not taken at the long term site in 2015 due to very late planting, poor emergence, and extended drought.

Table 3. Plant height (inches) at long-term no-till site.

	Tilled	No-Till
Treatment Mean 2013 at V6	6.4	6.5
Treatment Mean 2013 at R3	32.2	33.6
Treatment Mean 2014 at V6	13.0	12.5
Treatment Mean 2014 at R3	30.0	30.0
Treatment Mean 2014 at R6	37.5	36.8

Plants in the short term no-till site showed little difference in height for the first 2 years of the study, but in the third and final year, plants in the no-till areas were taller at R6. During the first two years the area received sufficient rainfall to avoid the stress that was experienced in the third year. In 2015, drought likely resulted in the no-tillage areas producing taller plants than the tilled areas. Also, some of the differences from one year to the next were likely due to different varieties being planting across years.

Table 4. Plant height (in.) at the short-term no-till site in Madison Co.

	Tilled	No-Till
Treatment Mean 2013 at V7	9.8	9.9
Treatment Mean 2013 at R3	35.5	34.5
Treatment Mean 2014 at V6	15.5	15.3
Treatment Mean 2014 at R3	29.8	26.5
Treatment Mean 2014 at R6	30.3	28.6
Treatment Mean 2015 at R6	38.2	44.7*

Stomatal Conductance. Measurements of stomatal conductance on plants in the long-term no-till area in Leake County during a dry period in early July 2013 showed that plants in no-till soil were transpiring more water than plants in the tilled soil treatment. This suggests that plants in this particular no-till soil environment were able to extract more water from the soil at the time this measurement was made. The overall mean of measurements of this parameter in the 2 years this area was utilized suggest that plants were able to access more water in the no-tillage treatment. Transpiration rate was more than 17% greater in the no-till treatment at the long-term site.

Table 5. Stomatal conductivity readings at the long-term no-till location in Leake County.

	Tilled	No-Till
Treatment Mean 2013 at R2	559.4	733.9
Treatment Mean 2013 at R5	1239.9	1296.0
Treatment Mean 2014 at R4	237.3	351.4
Treatment Mean 2014 at R6	188.5	230.1
2015 data not taken due to poor emergence and drought		
Overall Mean	556.1	652.9

Measurements of stomatal conductance on treatments in the short-term no-till area in Madison County also showed generally higher levels of transpiration in the no-till plots, again suggesting that more water was available to plants in undisturbed soil. The overall total index of porometer readings was almost 9% greater for plants in no-till areas at the short-term site.

Table 6. Stomatal conductivity readings at the short-term no-till location in Madison County.

	Tilled	No-Till
Treatment Mean 2013 at R3	765.7	771.6
Treatment Mean 2013 at R4	1176.2	1326.2
Treatment Mean 2014 at R5	870.2	914.1
Treatment Mean 2014 at R6	986.0	1131.9
Treatment Mean 2015 at R6	1164.0	1253.0
Overall Total (Index)	4962.0	5396.6

An observation from the stomatal conductivity was that during periods of drought stress these readings were higher for plants growing in no-till soil compared to plants growing in tilled soil. However, when there was abundant soil moisture there was little if any difference. A general conclusion from this is that plants in no-till soil can tolerate periods of drought better than those in tilled soil. This is likely due to the ability of undisturbed soil to retain more water, combined with the association of plant roots with higher levels of organic activity such as mycorrhizal fungi. The two trial locations are very different in that the long-term site in Leake County was a loamy sand and the short term site in Madison County was a silt loam.

There was very little difference in final yield during the first 2 years of the study when rainfall was adequate compared to the third year of the study; however, in the final year the area

experienced abundant to excessive rainfall during the spring which was followed by an extended drought. The combined effects of suppressed root development during the early wet period and then having the crop subjected to an extended and extreme drought produced the result of suppressed yield in the tilled treatment.

Chlorophyll Index. Chlorophyll index (CI) of soybean plants was measured using an Apogee Model CCM-200 chlorophyll meter. Results of measurements made at different stages of growth at the trial locations are shown below.

CI at the long-term site was slightly during reproductive development in 2013 and 2014. CI of soybean plants in the short-term no-till location in Madison County was generally higher for no-till plants than for plants in the tilled plots across years. Thus, the relationship of chlorophyll index (CI) and tillage practice was similar for the short and long term no-tillage systems, with both locations trending to a higher CI in the no-till treatments.

Table 7. Chlorophyll index at the long-term no-till location in Leake County.

	Tilled	No-Till
Treatment Mean at R2 (2013)	20.2	22.8
Treatment Mean at V6 (2014)	23.6	23.3
Treatment Mean at R6 (2014)	21.2	24.2

2015 data not taken due to poor emergence and drought.

Table 8. Chlorophyll index at the short-term no-till location in Madison County.

	Tilled	No-Till
Treatment Mean at V6 (2013)	14.1	16.7
Treatment Mean at R3 (2014)	24.7	27.9
Treatment Mean at R6 (2014)	31.6	32.9
Treatment Mean at R3 (2015	18.5	25.0
Treatment Mean at R6 (2015)	29.0	30.8

Seed Size. Seed size was determined by counting and weighting four replicates of 100 seed from each location for seed produced from the treatments in 2013 and 2014. Results are shown below.

Table 9. Relationship of tillage treatment and seed size in 2013 and 2014. Results expressed in grams per 100 seed.

	Tilled	No Till
Long Term Site 2013	13.4	13.5
Short Term Site 2013	13.8	14.6
Long Term Site 2014	12.1	11.6
Short Term Site 2014	15.2	15.3
Short Term Site 2015	9.3	11.4

In 2013 and 2014, seed size differences between tilled and no-till treatments were not pronounced. In 2015, the drought year, the no-till treatment produced the larger seed.

This underscores that plants in no-till soil can produce equally as well as those in tilled soil, but it also suggests that in drought years plants in no-till fields may perform better than plants in tilled fields as far as seed size is concerned.

These results indicate the most benefit to be gained from no-tillage systems is that of improved water relations during years of reduced rainfall. This is a tremendous advantage in areas where irrigation is not practical.

Yield. Average seed yields from both tillage treatments in both the long-term and short-term studies were nearly identical in both 2013 and 2014 (Tables 10 and 11). In the second year, reduced rainfall resulted in very low yield at the long-term location, apparently due to the very sandy nature of the soil (Table 11). In 2015, yield from the no-till treatment in the short-term study was over 20 bu/acre greater than yield from the tilled treatment. This suggests that the stale soil environment was much more supportive of high soybean yield at this location in a drought year.

Table 10. Yields achieved in 2013 by tilled and no-till soybeans in long-term and short-term no-till soil environments.

	Tilled Soil	No-Till Soil	% Difference
Long Term No-Till	38.9 Bu/Ac	38.5 Bu/Ac	1%
Short Term No-Till	46.2 Bu/Ac	46.9 Bu/Ac	1.5%

Table 11. Yields achieved in 2014 by tilled and no-till soybeans in long-term and short-term no-till soil environments.

	Tilled Soil	No-Till Soil	% Difference
Long Term No-Till	28.2 Bu/Ac	28.4 Bu/Ac	0.071%
Short Term No-Till	62.2 Bu/Ac	62.3 Bu/Ac	0.016%

Table 12. Yields achieved in 2015 by tilled and no-till soybeans in short term no-till soil environment.

	Tilled Soil	No-till Soil	% Difference
Short Term No-till	37.6 Bu/Ac	59.3 Bu/Ac	57.7%

Economic Considerations. When this study was proposed, there was some expectation (hypothetical) that there might be some apparent difference in yield between the treatments. However, yields achieved in the first two years the study were nearly identical from the tilled and no-till treatments. The economic analysis was therefore fairly simple and straightforward. Since yields for the two treatments were similar, and with all inputs the same, net return for the treatments should then only differ by the amount of the cost of tillage.

The 2014 Soybean Planning Budget produced by the Department of Agricultural Economics at Mississippi State University shows total specified cost projection for soybeans grown in a conventional tillage system to be $253.51 per acre, and for soybeans in a no-tillage system the corresponding cost is projected to be $219.00 per acre. These numbers then suggest an increased return of $34.51 per acre for the no-till treatment.

Additional savings and value can be expected through reduction in the loss of nutrients and soil from the fields in the no-till system. The savings derived from the no-tillage system in this comparison are equivalent to an approximate three bushel yield difference given soybean prices in the $10 to $12 per bushel range.

In the third and final year of the study in 2015, the hypothesized advantage for a no-tillage system was realized as no-tillage treatments produced 57.7 percent more yield than the tilled treatment as the result of drought stress that reduced yields dramatically in the tilled treatment.

Other Observations

Mulch Cover. This photo demonstrates the effect of tillage on mulch cover following a previous year of corn without incorporation of stalks and one year of no-till soybeans. This strip was tilled as an extra plot for data collection, but showed its value in evaluating the effect of tillage on mulch cover. This photo was taken on the short term no-till location at the Murphy farm near Canton, MS. Smaller tilled plots within the replicated trial showed similar sparse cover.

Figure 1. Photo showing sparse mulch cover in fall 2013 following one year of soybeans grown in tilled plot. The field was in no-till corn in 2012. This field was at the short term no-till site in Madison County.

Maturation. Tilled areas in the short term no-till location in Madison County showed earlier senescence than areas that had not been tilled. The following photo that was taken at the site would suggest that a difference in maturation approaching one maturity stage might be expected in the maturation of soybeans at that site. Although a complete explanation for this is not offered, a possible one might be that areas that had not been tilled were able to supply more water to the crop during the final stages of maturation, thereby delaying leaf senescence.

Figure 2. Photo taken in 2013 at the short term no-till site in Madison County as the crop nears maturity. Outlined area is one of the tilled plots. Another tilled plot can be seen in the upper right portion of the photo.

Influence of tillage on weed emergence. The location at Louisville demonstrated the weed control aspect of tillage in that the plots that were tilled had explosive emergence of pigweed, mostly spiny amaranth and some Palmer. The grower sprayed the area with glyphosate shortly after this photo was taken, removing them from the stand since resistance has not developed in the area so far. Soybeans were at the V7 to V8 stage of development. It is shown in black and white since the pigweeds are more apparent without the color which was similar for soybeans and pigweeds. This is one of the six tilled plots at this location.

Figure 3. Black and white photo of one of the 2013 plots near Louisville, MS showing extremely high level of weed emergence in one of the tilled plots in a field of sod planted soybeans.

The following photo shows Dr. Glover Triplett standing at the corner of the same plot as in the picture above. An apparent difference in height between the pigweeds and the soybeans can be seen in this photo. Pigweeds emerged in other parts of the field as well, but at a much lower population than in the tilled plots.

Figure 4. Color photo of the same 2013 tilled plot in sod planted soybeans as in Figure 3, but from a different angle.

These photos provide visual evidence that soil disturbance was closely linked to emergence of pigweed seed from the seed bank in this soil. The introduction of sunlight, providing the trigger for germination of weed seed, was a major factor in this reaction. A likely reason for the high level of seed in this soil is that the area had been utilized as a feeding area for cattle in recent years.

Weed reaction was the only use made of this area since these beans were drilled, making other measurements subject to microenvironment within the canopy. For the purposes of this work, soybeans planted in rows are needed for good results. The grower's yield on this farm ranged from 55 to over 80 bushels/acre depending on location.

Additional Comments. Because of the dramatic change in response to tillage during the third and final year of this study, I am including a summary of data from this final year (2015) in support of the difference in yield that was seen. These data are presented in the following table.

Table 13. Summary of data from 2015, the final year of the study, showing dramatic yield difference in favor of the no-tillage system.

Influence of Tillage on Soybeans Under Low Rainfall Conditions in 2015: From tillage trial on Murphy Farm near Canton, MS.

Tillage System	No. Seed Per Plant	Seed Per Pod	Seed Wt. per Plant (100K/Ac.	Yield per Acre	Porometer at R6 (mmol/cm2/sec)	Chlorophyll Index at R3	Height at R6	No. Nodes at R6	Stem Dia. (inch)	Seed Wt. g/100 seed
No Tillage	142	2.45	16.15g	59.3 Bu./Ac.	1164	25.0	44 in.	17	0.32	11.4
Tilled Soil 1 pass chisel	110	2.22	10.25g	37.6 Bu./Ac.	1253	18.5	38 in.	17	0.29	9.3
Percent Change From Tilled	+29%	+10.3%	+57.6%	+57.7%	-0.07%	+35.2%	+15.8%	0	+10.3%	+22.6%

E. Flint

Conclusions. This study has confirmed that no-tillage soybean production is feasible for dryland production systems in the rolling hill country of central Mississippi where irrigation is not widely practiced or feasible. Some of the advantages for the no-tillage system are as follows:

1. Reduction of soil loss
2. Conservation of moisture and nutrients
3. Increased soil organic matter
4. More seed per plant
5. Increased number of seed per pod
6. Improved chlorophyll index and by inference increased photosynthesis
7. Improved height and stem diameter
8. Larger individual seeds
9. Reduced emergence of weeds since fewer weed seed are brought to the surface by tillage
10. Reduced production cost
11. Higher final yield
12. The main factor in the difference between tilled and no-tillage systems is the availability of water to the crop.

Final Statement. I would like to thank the Mississippi Soybean Production Board for their support for this work. I have tried to be conservative in the use of funds that were provided, and I feel the results can be used to make a definitive statement to growers that the reduced tillage/conservation tillage/no-tillage techniques which have been used in recent years are well worth developing and using in long-term practice on farms of this region. I believe this is especially true in areas where irrigation is not available to growers.