USING DEEP TILLAGE TO IMPROVE YIELDS FROM DRYLAND SOYBEANS: AN ECONOMIC ANALYSIS

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Abstract. Research has shown that deep tillage improves yields of dryland soybeans. However, there are increased production costs associated with deep tillage. To examine the economic effects of deep tillage, statistical, breakeven, and sensitivity analyses were performed using yield data from University of Arkansas agronomic experiments conducted from 1995 to 1997. It was hypothesized that the deep tillage treatments result in increased net returns. This was true for the clay soils at Keiser. However, results at Pine Tree were inconsistent, and it was concluded that the least expensive treatment should be used to maximize net returns on silt loam soils.

INTRODUCTION

Deep tillage has been shown to increase yields of dryland soybeans. In a study by Wesley, Smith, and Spurlock (1993), deep tillage under dryland conditions resulted in an average yield increase of 47% when compared to yields from conventional tillage under dryland conditions. This yield effect is associated with increased water intake and profile storage. However, since deep tillage implies an additional expense for the producer, it is necessary to perform an economic analysis to determine the feasibility of such practices. In addition, further study is needed to determine if deep tillage will consistently give such results. As irrigation for soybeans is often not an option for producers, it is necessary to examine methods of increasing net returns from dryland soybean production.

MATERIALS AND METHODS

Deep tillage studies were begun in the fall of 1994 at the University of Arkansas' Northeast Research and Extension Center (NEREC) at Keiser, Arkansas, and the Pine Tree Branch Experiment Station near Colt, Arkansas. Tillage treatments were: (1) conventional shallow tillage twice in late winter or early spring to prepare a seed bed, (2) deep chiseling in fall to a depth of circa 6 inches when the soil was dry, (3) subsoiling in planting direction in fall when soil was dry with hyperbolic subsoiler to a depth of circa 14 to 18 inches, (4) same as treatment number 3 but at a 45 degree angle to planting direction, (5) same as treatment number 3 but performed in late winter or early spring when soil was wet. Treatments were arranged in a randomized complete block design with 8 to 10 replications. Alleys between plots were 29.5 ft wide to give ample room for tillage implements to take the ground prior to entering the plot and to keep machinery out of adjacent plots when leaving the plot and turning. Plots were 49.2 ft by 12.5 ft rectangles except for the 45 degree treatment which was 49.2 ft by 37.4 ft to allow for turning on the sides without trafficking adjacent plots.

The early soybean production system (ESPS) was used since it results in late summer or early fall harvest dates (Heatherley, 1999). This early harvest is necessary so that deep tillage can be done in dry soil before the fall rains. After the tillage treatments were done, no additional tillage treatments were performed until late winter or early spring when normal seed-bed preparation activities occur. Seed-bed preparation consisted of two passes with a field cultivator to loosen the soil, smooth the ground, and apply and incorporate herbicides where appropriate. Other cultural practices were commensurate with Arkansas Cooperative Extension Service recommendations.

Soybean yield (adjusted to 13% moisture) was calculated from strips harvested from the center of each plot. Yield data were analyzed statistically using the General Linear Models (GLM) procedure in the Statistical Analysis System (SAS).

Economic analyses are based on enterprise budgets generated by the Mississippi State Budget Generator (MSBG). An enterprise budget was generated for each year for each tillage treatment, year, and location combination utilized in the study. Due to the number of replications in the experiment, MSBG was used to calculate only direct and fixed expenses, while net returns were calculated using a spreadsheet. A five year (1993 - 1997) average of the statewide soybean price of $6.72/bu was used to calculate gross receipts. Price data were taken from various issues of the *Arkansas Agricultural Statistics* (Arkansas Agricultural Statistics Service, 1996, 1997, 1998). This average price was used to eliminate any market effects due to years with abnormally high or low prices. The input prices included in the version of MSBG issued by the Arkansas Cooperative Extension Service for 1997 were used for the field operations.

For budgeting purposes, all treatments utilized a machinery complement consisting of a 29.58 ft field cultivator pulled by a 200 hp tractor, a 20 ft grain drill pulled by a 145 hp tractor, a 47 ft broadcast sprayer pulled by a 145 hp tractor, a 1000 gallon water tank pulled by a 3/4 ton pickup, an 8 ft furrow ditcher pulled by a 145 hp tractor, and a 20 ft soybean combine. Fall and spring subsoiled treatments also utilized a 12 ft, seven shank subsoiler. Deep chiseled plots used a 17 ft chisel plow, and paratill treatments utilized a 15 ft, six shank paratill implement. All deep tillage implements were drawn by 225 hp tractors.

The GLM procedure in SAS was used to determine the significance of the various treatments used in the agronomic experiment. A model using tillage treatment, replication, year, year by replication interaction, and tillage treatment by year interaction as explanatory variables was used to analyze the dependent variables, which were yields, and net returns above total expenses (see Table 1). Duncan's Multiple Range Test was used to rank the various production systems by determining least significant differences across treatments.

Breakeven and sensitivity analyses were conducted in order to gain a broader perspective of the economic implications of the various tillage, planting, and herbicide combinations. Breakeven analysis was conducted for prices and yields above both direct and total expenses, while sensitivity analysis was conducted using soybean prices which were 10% and 25% higher and lower than the five year average price of $6.72/bu.

RESULTS AND DISCUSSION

Statistical analysis (Table 1) showed that at Keiser, year and tillage treatment were statistically significant at the .01 level, while replication and the replication by year interaction were significant at the .05 level. The year by tillage treatment interaction was not statistically significant. Based on this analysis, year and tillage treatment were the main causes of yield effects. Since this was a designed experiment, the significance of replication was expected and is therefore ignored.

Statistical analysis for yields at Pine Tree showed that replication, year, and the replication by year interaction were all significant at the .01 level. Again, replication was expected to be significant and is ignored. Tillage treatment was significant at the .10 level, while the year by treatment interaction was not statistically significant.

Statistical analysis for net returns above total expenses at Keiser showed replication to be statistically insignificant, while year was significant at the .01 level. The year by replication interaction was significant at only the .10 level. Tillage treatment was significant at the .05 level, but the year by treatment interaction was again not statistically significant.

The same analysis for Pine Tree showed replication, year, and the year by replication interaction to be significant at the .01 level. Tillage treatment was only significant at the .10 level for net returns above total costs. The tillage treatment by year interaction was also not statistically significant for net returns at the Pine Tree location.

Yields at the Keiser location were considerably higher than those at the Pine Tree location, as can be seen in Table 2. Duncan's Multiple Range Test showed that only 1995 was significantly different among years at Keiser, while significant differences between tillage treatments were somewhat more complex. All three years were significantly different at Pine Tree, and only spring subsoiling and chisel plowing were significantly different from each other. All Duncan groupings are shown in Table 2.

Given the higher yields at Keiser, net returns were consistently higher at that location. Duncan results for net returns above direct expenses and net returns above total expenses were identical to those for yields. Net returns above direct expenses and net returns above total expenses are shown in Tables 3 and 4, respectively.

Sensitivity analysis (Table 5) showed net returns above total costs to be highly sensitive to changes in price. At Keiser, a 10% change in soybean price resulted in a 14 - 19% change in net returns above total costs, depending on year and tillage treatment. A 25% change in price resulted in 35 - 49% change in net returns above total costs, depending on year and tillage treatment. The results for Pine Tree were far more erratic. There, a 10% change in price resulted in a 11- 470% change in net returns above total costs, depending on year and tillage treatment, while a 25% change in price resulted in a 28 - 1178% change in net returns above total costs. This is attributable to the yield differentials between locations, since cost structures are similar for both Pine Tree and Keiser. Direct and total expenses are shown in Tables 6 and 7, respectively.

Fall deep tillage (subsoil dry) at Keiser had the lowest breakeven prices (Table 8) above direct costs in 1995 and 1996, while conventional tillage had the lowest in 1997. Breakeven prices above total costs were lowest for conventional tillage in 1995 and 1997, and for fall deep tillage (subsoil dry) in 1996. Results show that breakeven prices above direct and total expenses are higher for the

Pine Tree location than for the Keiser location. This can again be attributed to the lower yields at Pine Tree. Breakeven prices above both direct and total expenses at Pine Tree were lowest for fall deep tillage (subsoil dry) in 1995, for conventional tillage in 1996, and for deep chiseling in 1997. Breakeven yields, however, were similar for both locations, due to the similar cost structures. Breakeven yields are shown in Table 9. In all cases conventional tillage consistently had the lowest breakeven yields above direct and total expenses.

Given that fall deep tillage gave the highest yields and net returns in two out of three years at Keiser, and that yields and net returns from fall deep tillage are significantly different from yields and net returns of other treatments, it may be concluded that it is a viable practice under heavy soil conditions such as are found at Keiser. However, at Pine Tree, there are inconsistent results across years and treatments, and only deep chisel plowing and spring deep tillage (subsoil wet) are not significantly different from one another. Therefore, one may conclude that the least expensive treatment should be used to maximize net returns on silt loam soils such as those found at Pine Tree. This would be consistent with the findings of other studies that determined that deep tillage increases yields by eliminating mechanical impedances to root growth, which facilitates moisture uptake (Wesley and Smith, 1991; Wesley, Smith, and Spurlock, 1993).

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Table 1: Statistical Analysis of Yields and Net Returns at Pine Tree and Keiser, 1995 - 1997

Section I: Pine Tree		Yield Model	Net Returns Above Total Costs Model	
Model	F Value	Pr > F	F Value	Pr > F
EDF = 89	7.22	0.0001	6.05	0.0001
Variables	F Value	Pr > F	F Value	Pr > F
Replication	6.05	0.0001	3.59	0.0007
Year	71.90	0.0001	65.20	0.0001
Year X Replication	2.50	0.0040	2.29	0.0083
Treatment	2.24	0.0896	2.35	0.0779
Year X Treatment	1.70	0.1310	1.25	0.2873
Section II: Keiser		Yield Model	**Net Returns Above Total Costs Model**	
Model	F Value	Pr > F	F Value	Pr > F
EDF = 104	7.18	0.0001	3.44	0.0001
Variables	F Value	Pr > F	F Value	Pr > F
Replication	2.32	0.0190	1.56	0.1361
Year	89.45	0.0001	35.72	0.0001
Year X Replication	1.72	0.0508	1.52	0.0996
Treatment	9.29	0.0001	2.78	0.0446
Year X Treatment	1.44	0.2060	1.24	0.2932

Note: EDF = Error Degrees of freedom Pr>F=Probability of F value

Table 2: Yield (Bu/acre)* at Pine Tree and Keiser, 1995 - 1997

	Conventional Tillage	Deep Chisel	Subsoil Dry	Subsoil Wet
Pine Tree	(a, b)	(a)	(a, b)	(b)
1995 (b)	15.77	15.78	19.50	13.59
1996 (c)	11.42	12.03	10.66	11.58
1997 (a)	24.15	27.26	24.29	23.50
Keiser	(b, c)	(c)	(a)	(a, b)
1995 (b)	35.39	35.02	39.96	37.82
1996 (a)	47.55	47.93	59.44	49.76
1997 (a)	53.09	45.42	52.20	53.34

* Letters in parentheses represent results from Duncan's Multiple Range Test. Years and treatments with the same letter are not significantly different.

Table 3: Net Returns above Direct Costs ($/acre) at PineTree and Keiser, 1995 - 1997

Pine Tree	Conventional Tillage	Deep Chisel	Subsoil Dry	Subsoil Wet
1995	38.41	34.66	54.37	14.98
1996	(2.79)	(4.02)	(17.06)	(10.55)
1997	87.82	104.83	79.58	74.62
Keiser				
1995	155.38	149.05	176.92	162.91
1996	245.66	242.91	316.47	251.73
1997	274.71	219.46	259.70	267.66

Table 4: Net Returns above Total Costs ($/acre) at Pine Tree and Keiser, 1995 - 1997

Pine Tree	Conventional Treatment	Deep Chisel	Subsoil Dry	Subsoil Wet
1995	4.59	(2.25)	12.87	(26.52)
1996	(42.42)	(47.93)	(64.36)	(57.85)
1997	55.73	69.66	39.82	34.86
Keiser				
1995	131.12	121.70	144.98	130.97
1996	221.13	214.10	284.27	219.53
1997	243.81	185.82	221.47	229.43

Table 5: Price Sensitivity Analysis for Pine Tree and Keiser, 1995 - 1997

	% change in net returns above total costs at prices 10% higher and lower than average			
Pine Tree	Conventional Tillage	Deep Chisel	Subsoil Dry	Subsoil Wet
1995	±30	±470	±99	±134
1996	±18	±17	±11	±13
1997	±29	±26	±41	±45
Keiser				
1995	±18	±19	±18	±19
1996	±14	±15	±14	±15
1997	±15	±16	±16	±16
	% change in net returns above total costs at prices 25% higher and lower than average			
Pine Tree	Conventional Tillage	Deep Chisel	Subsoil Dry	Subsoil Wet
1995	±577	±1178	±255	±86
1996	±45	±42	±28	±34
1997	±73	±66	±102	±113
Keiser				
1995	±45	±48	±46	±49
1996	±36	±38	±35	±38
1997	±37	±41	±40	±39

Table 6: Direct Expenses ($/acre) at Pine Tree and Keiser, 1995 - 1997.

Pine Tree	Conventional Tillage	Deep Chisel	Subsoil Dry	Subsoil Wet
1995	67.53	71.38	76.68	76.36
1996	79.55	84.89	88.70	88.39
1997	74.48	78.33	83.62	83.31
Keiser				
1995	82.44	86.29	91.59	91.27
1996	73.85	79.17	83.00	82.68
1997	82.08	85.79	91.08	90.77

Table 7: Total Expenses ($/acre) at Pine Tree and Keiser, 1995 - 1997.

Pine Tree	Conventional Tillage	Deep Chisel	Subsoil Dry	Subsoil Wet
1995	101.35	108.29	118.18	117.86
1996	119.18	128.80	136.00	135.69
1997	106.57	113.50	123.38	123.07
Keiser				
1995	106.70	113.64	123.53	123.21
1996	98.38	107.98	115.20	114.88
1997	112.98	119.43	129.31	129.0

Table 8: Breakeven Prices for Pine Tree and Keiser, 1995 - 1997.

	Above direct expenses ($/bu)				Above total expenses ($/bu)			
Pine Tree	Conventional Tillage	Deep Chisel	Subsoil Dry	Subsoil Wet	Conventional Tillage	Deep Chisel	Subsoil Dry	Subsoil Wet
1995	4.28	4.52	3.93	5.62	6.43	6.86	6.06	8.67
1996	6.97	7.06	8.32	7.63	10.44	10.71	12.76	11.72
1997	3.08	2.87	3.44	3.55	4.41	4.16	5.08	5.24
Keiser								
1995	2.33	2.46	2.29	2.41	3.01	3.25	3.09	3.26
1996	1.55	1.65	1.40	1.66	2.07	2.25	1.94	2.31
1997	1.55	1.89	1.74	1.70	2.13	2.63	2.48	2.42

Table 9: Breakeven Yields for Pine Tree and Keiser, 1995 - 1997

	Above direct expenses (bu/acre)				Above total expenses (bu/acre)			
Pine Tree	Conventional Tillage	Deep Chisel	Subsoil Dry	Subsoil Wet	Conventional Tillage	Deep Chisel	Subsoil Dry	Subsoil Wet
1995	10.05	10.62	11.41	11.36	15.08	16.11	17.59	17.54
1996	11.84	12.63	13.20	13.15	17.74	19.17	20.24	20.19
1997	11.08	11.66	12.44	12.40	15.86	16.89	18.36	18.31
Keiser								
1995	12.27	12.84	13.63	13.58	15.88	16.91	18.38	18.33
1996	10.99	11.78	12.35	12.30	14.64	16.07	17.14	17.10
1997	12.21	12.77	13.55	13.51	16.81	17.77	19.24	19.20