Reduced Tillage Practices for the Southwestern US Peanut Production Region

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ABSTRACT

Oklahoma growers have increased their adoption of strip tillage (strip-till) and no tillage (no-till) systems as a means of reducing production costs and conserving soil resources. An experiment was conducted over three years to study the effects of three tillage systems [(conventional till (CT), no-till (NT), and strip-till (ST)] on pod yield, peanut grade, pest pressure, and economic profitability. Insect, disease, and weed incidence were determined in each year of the study. Peanut yield and grade were determined by mechanically harvesting the plot. No consistent differences were detected between NT and CT in peanut grade or yield when tillage systems were combined across years. In addition, no consistent differences were observed in disease incidence and insect populations. Economic analysis indicated that the NT system saved \$93 ha^{-1} and generated \$179 ha^{-1} more revenue compared to the CT system. Reduced tillage practices, especially NT, seem to be a good fit for SW peanut production areas.

Key Words: peanut, tillage, no-till, conservation till.

No-till peanut (*Arachis hypogaea* L. subsp. *hypogaea* var. *hypogaea*) production practices were introduced 30 years ago, but are still regarded in many places as relatively new (Tubbs and Gallaher, 2005). Maintaining effective and economically feasible pest and weed management practices under no-till (NT) presented early challenges; however, improved pesticides and pest resistant cultivars have increased the interest in conservation tillage.

Producers have been drawn to conservation tillage for several reasons, including lower energy and fuel requirements (with the recent shocks in energy prices), reduced labor demand, and increased flexibility in crop rotation and multi-cropping. Further economic incentives for adopting conservation tillage have been provided in the farm bill legislation. Environmental benefits of conservation tillage have also been reported.

Adoption and sustained use of conservation tillage practices will occur only if economic benefits are realized by producers (Tubbs and Gallaher, 2005). Oklahoma producers have increased their adoption of strip tillage (ST) and NT systems in peanut production as a means of reducing costs and conserving soil resources, but the literature contains mixed reports on the effect of conservation tillage on disease and yield (Grichar and Boswell, 1987, Jordan *et al.*, 2003; Monfort et al, 2004). Monfort *et al.* (2004) observed that reduced tillage practices, like ST, may help with foliar disease management in peanut, especially when ST is used in combination with moderately resistant cultivars. They observed a delay in leaf spot development with reduced tillage. In North Carolina, reduced tillage decreased sclerotinia blight where considerable residue was left for ground cover prior to planting (Jordan *et al.*, 2003). Grichar and Boswell (1987) observed that no-till systems decreased peanut yield 600 to 2400 kg ha^{-1} in Texas and cited a lack of weed control and compaction as the reasons for reduced yield. The varied results suggest more research is needed to identify the soils and environments under which reduced or NT systems perform well, including measuring the impact of plant diseases. Likewise, limited data is available suggesting how insects such as spider mites, thrips, lesser cornstalk borers, and foliage feeders are affected under varying tillage regimes.

In the southwestern peanut production region, only a limited amount of information is available on the impact of plant disease, insect pressure, yield, quality, and economic returns when growing peanut in reduced tillage situations. In the early 1990's, research was conducted for three years by the Oklahoma State University (OSU) peanut team near Burneyville, OK (Sholar and Nickels, 1992). While this site had a short history of peanut production, southern blight and leaf spot became problems during the second year. There was an increase in severity of *Cercospora arachidicola* (early leaf spot) for reduced tillage systems

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compared to conventional tillage for Spanish, but not for runner peanuts. While southern blight was highest in no-till systems, levels of this disease were similar for conventional and strip-till systems. Little is known about the impact of tillage systems on other important diseases such as *Sclerotium rolfsii* (southern blight) and *Sclerotium minor* (Sclerotinia blight) in the SW.

Given the modest adoption of conservation tillage practices by peanut producers, further research is needed to provide growers with evidence of the potential benefits and/or detriments of conservation tillage and to assist Oklahoma growers in developing more economic management strategies for conventional and conservation tillage practices for peanut production. Conservation tillage can impact the producer's economic bottom line through changes in both peanut yield and production costs. The objective of this experiment was to evaluate the effectiveness of conservation tillage practices on pod yield, peanut quality and other agronomic factors and to assess the economic viability of conservation tillage in peanut.

Material and Methods

The peanut tillage study was located at the OSU Caddo County Research Station near Fort Cobb, OK (35°8′52″ N, 98°27′25″ W). The soil was classified as a Binger fine sandy loam (Fine-loamy, mixed, active, thermic Udic Rhodustalfs). Plots were initially established in the spring of 2004. Plots were arranged in a randomized complete block design with tillage as the main effect. Tillage treatments consisted of no-till (NT), strip-till (ST), and conventional till (CT). Individual plots were 22 m wide by 40 m long and were replicated four times.

In 2004, prior to plot establishment and every fall after, a winter wheat [*Triticum aestivum* (L.)] cover crop was planted in all plots. The winter wheat cover crop was chemically terminated in the NT and ST plots in early April of each year with a one-time application of glyphosate (one kg a.i. ha^{-1}), while the cover crop in the CT plots was mechanically terminated. The NT treatment was planted directly into the chemically-terminated cover. Strip-till treatment received a one-time pass with a DMI (Case-New Holland, Goodfield, IL) strip-till implement one week prior to planting. This disturbed soil in a zone 10 cm wide by 15 cm deep. The strip-till implement consisted of 61-cm diameter smooth-edge coulters at the center of each row unit, followed by a mole knife mounted on a shank. A set of berm builders and a residue conditioning basket in each row contained the tilled soil to a narrow zone and settled the surface. Conventional tillage treatments consisted of one pass with a disc to a depth of 13 cm followed by two passes with a field cultivator to a depth of five cm, resulting in no residue remaining on the soil surface. In May of each year all plots were planted using the cultivar Tamrun OL-02 (Simpson *et al.*, 2006) at a seeding rate of 100 kg seed ha^{-1}.

Best management practices were followed for peanut production (Godsey *et al.*, 2007). In late April of each year 45 kg ha^{-1} of a compound fertilizer (18%N, 46%P and 0%K) was applied to the plot area. In addition, in 2004 only, one kg of Zn ha^{-1} and 0.4 kg $ha^{-1}$of Boron was also applied. In each year, Prowl® (1 kg pendimethalin ha^{-1}) plus Glyphosate (1 kg glyphosate ha^{-1}), and crop oil was applied over the entire plot area prior to planting and following the last tillage operation of the conventionally-tilled plots. In-season weed control was similar each year and included: Gramoxone Max (0.1 kg paraquat dichloride ha^{-1}) plus surfactant (early season-late May), a mid-June application of Cadre® (0.04 kg imazapic ha^{-1}) plus Butyrac 200® (0.3 kg 4-(Dichlorophenox)butyric acid ha^{-1}) and a mid-July application of Basagran® (0.8 kg bentazon ha^{-1}). No insecticides were applied to any of the plots throughout this trial.

Fungicide treatments for peanut were applied by recommended calendar dates. Chlorothalonil (2,4,5,6-tetrachloro-1,3-benzenedicarbonitrile, Bravo WeatherStik, Syngenta Crop Protection, Greensboro, NC) was applied at a rate of 1.26 kg chlorothalonil ha^{-1}alternately with tebuconazole {alpha-[2-(4-chlorophenyl)ethyl]-alpha-(1,1-dimethylethyl)-1H-,2,4-triazole-1-ethanol} (Folicur, Bayer CropScience LP, Research Triangle Park, NC) applied at a rate of 0.20 kg tebuconazole ha^{-1}. In total, four fungicide applications were made each year.

Arthropod Monitoring and Weed Populations.

Once damage became apparent in each season, thrips (primarily *Franklinella* spp.) populations were monitored on three separate occasions in each year of the study. At each sampling, 10 quadrifoliate leaves were pulled from each plot and placed in 70% ethyl alcohol (ETOH) for transportation to the laboratory. Leaves were carefully separated and rinsed in ETOH solution and the liquid strained, using a coffee filter, for larvae and adults. In 2005, foliar damage (dieback of terminal growth) was observed and white grubs (*Phyllophaga* spp.) were identified as the causative agent. Therefore in 2006, further assessments were made and counts taken to identify differences between treatments and to account for any possible yield loss due to grubs. Grub counts were made on 28 July 2006 by sifting through three, 1 m wide by 1 m long and 10 cm in depth sections of soil within each plot.

Volunteer peanut plant and weed counts were taken shortly after planting. Volunteer peanut counts were taken using an average of five one m^2 quadrates per plot. Weed counts were taken twice. Weed assessments were made by taking a total of the number of weeds found in a 27 m^2 area within each replication. Weed assessments were made before and after herbicide application.

Disease and Nematode Evaluation.

The effects of tillage on levels of disease were evaluated prior to digging. Levels of foliar disease such as leaf spot were low in each year due to fungicide applications. Ratings for Southern Blight and Sclerotinia were assessed by counting the number of 15-cm row segments with symptoms and/or signs of disease in the middle four rows of each plot.

A composite soil sample consisting of 14 cores (1.2 cm i.d.) was collected in late July/early August of each year to a depth of 15 cm in each plot to determine root knot nematode populations (*Meloidogyne arenaria)* (Barker, 1985). Nematode genera were counted and expressed as number per 100 cm^{-3} of soil.

Economic Evaluation.

The economic returns for each tillage treatment were calculated on an average return per hectare basis using the field experiment results, which were calculated as the return (price × yield) above specified production costs. Revenue was calculated using the observed peanut yield data in each year of the field trial at the recent three-year average loan price of peanut (2004–2006), $361 per ton. Peanut prices paid to farmers in Oklahoma varied slightly during the three-year study period, ranging between $76.77 and $159.44 per ton above loan price.

Production costs were developed using crop enterprise budgets, which specifies operating and ownership costs on a per-hectare basis (Table 1). The budgeting approach required accounting for different equipment complements and a different number of tillage passes among the treatments. Conventional tillage required one pass with a disk and two passes with a field cultivator, strip tillage required one pass with a ST implement, and NT did not require any tillage since it was planted directly into the cover crop. Each tillage pass was budgeted using standard farm budget enterprise accounting techniques that itemize fuel, lube, and repair costs based on equipment size and number of passes. Fixed costs for machinery complements

Table 1. Peanut production costs across main treatment effect of tillage practice.

	Tillage Practice		
Cost Item	Conventional Till	No-Till	Strip-Till
Variable Cost ($ ha^{-1})			
Fungicide	128.58	128.58	128.58
Fertilizer	42.17	42.17	42.17
Herbicides	131.43	131.43	131.43
Insecticides	0	0	0
Seed	105.79	105.79	105.79
Machine Labor	39.32	30.84	33.67
Irrigation Labor	33.67	29.55	33.67
Fuel, Repair, and Maint.	223.61	185.69	198.33
Irr. Fuel, Repair, and Maint.	117.99	117.99	117.99
Crop Insurance	27.42	27.42	27.42
Custom Hire	91.54	91.54	91.54
Annual Operating Capital	28.25	26.73	27.32
Total Variable Cost	969.77	917.74	937.91
Fixed Costs ($ ha^{-1})			
Depreciation	227.15	209.33	232.49
Interest (mach./irrigation)	252.19	235.86	257.09
Taxes	33.36	28.41	34.84
Insurance & Shelter	17.79	15.32	18.54
Total Fixed Cost	530.49	488.91	542.96
Total Cost ($ ha^{-1})	1,500.26	1,406.65	1,480.87

were adjusted across tillage treatments by removing the disk and field cultivator from the NT and ST budgets since they were not required. It was necessary, however, to account for the strip-till implement in the ST treatment. Fixed costs were itemized for each machinery complement using standard farm enterprise budgeting techniques, which include accounting for depreciation, interest, tax, insurance, and shelter costs. Herbicide and fertilizer costs were maintained constant across tillage treatment but varied across years so they also were included in the economic return ANOVA. Remaining costs for other management practices were maintained at constant levels across the main treatment effects of tillage and were not included in the economic returns.

Plot Design and Statistical Analysis.

The statistical design was a complete randomized block with four replications of each treatment. Data were analyzed by using PROC MIXED procedure of SAS (SAS Institute, 2002) in reference to insect and disease pressure, peanut yield, grade, and economic returns. Least square means of the fixed effects were computed, and the PDIFF option of LSMEANS statement was used to display the differences among least square means for comparison. All data was tested using the Modified Levene's Test to determine if equal group variances

Table 2. Peanut yields and grades in 2004, 2005, and 2006.

Treatment	2004		2005		2006		Average	
	Yield	Grade	Yield	Grade	Yield	Grade	Yield	Grade
	kg ha^{-1}	%TSMK[†]	kg ha^{-1}	%TSMK	kg ha^{-1}	%TSMK	kg ha^{-1}	%TSMK
Strip-Till	5342 b[‡]	75 a	4222 a	74 a	2663 b	67 a	4076 b	72 a
No-Till	6671 a	77 a	4274 a	71 b	3397 a	66 a	4781 a	71 a
Conventional Till	5473 b	76 a	4457 a	73 a	3059 ab	65 a	4330 ab	71 a

[†]Percent total sound mature kernels.
[‡]Means, within columns, followed by the same letter are not significantly different (α=0.05).

existed. If data did not have equal variances, the data were adjusted using a square root transformation (Steel and Torrie, 1997), taking square root plus 0.5 ($\sqrt{x + 0.5}$) where x equals the original value. In the text all discussion is done after it is transformed back to original units.

Results and Discussion

Yields and Grades

Pod yields in 2004 were excellent, averaging 5829 kg ha^{-1} when averaged across tillage treatments. In 2004, NT peanut yields were significantly higher compared to ST and CT yields (Table 2). No-till peanut yields were 1329 and 1198 kg ha^{-1} higher than ST and CT yields, respectively. In 2005, yields once again were high resulting in an average yield of 4318 kg ha^{-1} when averaged across tillage treatments. No significant differences were observed between tillage treatments. Peanut yields in 2006 were 734 kg ha^{-1} higher in the NT tillage treatment when compared to yields from the ST treatment. No differences were observed between NT and CT. When averaged across years, NT treatments had a higher yield compared to ST. No-till yields were 705 kg ha^{-1} higher compared to ST, while no differences were detected between NT and CT treatments.

A difference in peanut grade was only detected in 2005 (Table 2), when the grade for the NT treatment was lower compared to ST and CT. No consistent differences were detected in peanut grades between tillage treatments. Our findings agree with other studies that found inconsistent effects on peanut grade (Wright and Porter, 1991; Grichar 1998).

Peanut yields tended to decrease from 2004 to 2006, probably as a result of continuous peanut production. Continuous peanut production is not a recommended practice but to realize the true benefits of tillage practices and determine the relatively long-run benefits and effects of tillage practices the same area was used. The decreased yield in strip tillage treatments in 2 out of 3 years was surprising and may be a result of planting depth problems and digging losses, although observations of plant establishment, seedling mortality or harvest losses necessary to explore this hypothesis were not made.

The lack of differences observed between NT and CT treatments in this study contradicts what others have seen in SW peanut production areas. Grichar (1998) observed a decrease in peanut yield when planting in NT compared to full tillage in 3 out of 10 yr in Texas, with weed pressure and compaction proposed as the main reasons for yield reduction. The effectiveness of weed control products has improved since that time and the soil at our study location was not prone to compaction, so this may explain the differences in observations between studies.

Insect Populations

Thrip populations varied from year to year with the highest populations being observed in 2005 (Table 3). Monitoring for adult and larval thrips resulted in no consistent differences between treatments (Table 3). Data collected for other insects such as white grubs, potato leafhoppers [*Empoasca fabae* (Harris)], three-cornered alfalfa hopper [*Spissistilus festinus* (Soy)], and various defoliating caterpillars resulted in no differences between tillage treatments (data not shown). While certain trends may appear to be evident in one given year that may relate to tillage effects on arthropods, no consistent differences seem to indicate at least a very minor impact from reduced tillage practices in peanut.

Disease

Table 4 reflects the results of counts to assess infection by Sclerotinia blight and Southern blight. No consistent differences were observed between tillage treatments. The only difference that was observed was in the ST treatment in 2005 when Southern blight had a lower incidence compare to CT. Also, there were trends for reduced levels of Sclerotinia blight for the NT treatment compared to CT and ST treatments. This is supported by Jordan *et al.* (2003), who found reduced tillage

Table 3. Total adult and larval thrips recovered from 10 quadrifoliate leaves in 2004, 2005, and 2006.

Year	Treatment	1st Week of June		2nd Week of June		3rd Week of June	
		Mean Total Larvae	Mean Total Thrips	Mean Total Larvae	Mean Total Thrips	Mean Total Larvae	Mean Total Thrips
		Mean Number of Thrips 10 Quadrifoliate Leaves					
2004							
	Strip-Till	NA†		21 a‡	25.4 a	4.7 ab	9.0 a
	No-Till			18.7 ab	24.7 ab	8.7 a	12.5 a
	Conventional Till			9.7 b	9.9 b	3.8 b	6.8 a
2005							
	Strip-Till	147.8 a	184.5 a	38.0 ab	49.0 a	9.3 a	19.0 a
	No-Till	189.0 a	219.3 a	31.8 a	45.0 ab	9.5 a	20.0 a
	Conventional Till	173.8 a	205.3 a	19.3 b	28.5 b	9.8 a	20.0 a
2006							
	Strip-Till	0.5 a	27.5 a	5.8 a	37.8 a	4.8 a	26.8 a
	No-Till	1.8 a	24.0 a	3.5 a	35.3 a	3.5 a	25.5 a
	Conventional Till	1.5 a	30.8 a	7.8 a	44.5 a	10.3 a	13.5 a

†Data for thrips was not collected for the first week of June 2004.
‡Means, within columns, followed by the same letter are not significantly different (ANOVA, LSD:P=0.05).

decreased sclerotinia blight when considerable residue was left for ground cover prior to planting in North Carolina. However, these authors also noted a great deal of variability across peanut plots due to the residue and disease pressure.

Nematodes

A fairly high number of root knot nematodes (*Meloidogyne arenaria)* were detected in 2005 (Table 5). No significant differences were observed between tillage treatments. Samples collected in 2006 did not detect any nematodes present which may be a result of the extremely high temperatures and dry weather conditions that we were experiencing during 2006. An additional nematode sampling should have been undertaken in the fall prior to harvest, to better assess treatment differences. The paucity of data obtained in this study suggest that additional research to quantify the impact of reduced till systems on pathogenic nematodes is needed.

Volunteer Peanut and Weed Populations

Reducing tillage tended to increase the number of volunteer peanut plants (Table 6). In 2006 a greater number of volunteer peanut plants were present in NT treatments compared to both ST and CT tillage treatments. The same trend was observed with weed density, where a reduction in tillage led to increased weed densities. This was especially true with weed counts before post-emerge herbicide application (data not shown). Observations made after post-emergence application indicated similar populations of weeds in 2005 and very little difference in 2006. The most common weeds in 2005 and 2006 were horsenettle (*Solanum carolinense*), yellow nutsedge (*Cyperus esculentus*), spotted spurge (*Euphorbia maculate*), and carpetweed (*Mollugo verticillatus*).

Volunteer peanuts are typically not a problem due to rotation of planting peanut only once every 2 to 4 years in a given field and an increase in volunteer peanuts from reducing tillage should not be a concern. However, if populations of volunteer peanuts were large enough to require treatment to reduce disease pressure in subsequent years of peanut production, control can be achieved with post-emergence treatments of glyphosate or glufo-

Table 4. Disease ratings for southern blight and sclerotinia blight in 2004, 2005, and 2006.

Treatment	2004		2005		2006	
	SCL†	SBL‡	SCL	SBL	SCL	SBL
	%					
Strip-Till	50.3 a§	-	2.5 a	0.7 a	18.9 a	1.7 a
No-Till	22.5 a	-	2.4 a	0.9 ab	12.8 a	2.0 a
Conventional Till	63.2 a	-	3.1 a	1.2 b	18.2 a	3.1 a

†SCL=Sclerotinia blight.
‡SBL=Southern blight.
§Means, within columns, followed by the same letter are not significantly different (ANOVA, LSD:P=0.05).

Table 5. Root-knot nematode counts for 2005 and 2006.

Treatment	2005	2006
	Number $100cc^{-1}$	
Strip-Till	104 a†	0 a
No-Till	71 a	0 a
Conventional Till	56 a	0 a

†Means, within columns, followed by the same letter are not significantly different (α=0.05).

sinate in resistant rotational crops (Corbett *et al.* 2004). The increase in weed pressure in NT systems was expected, particularly given the inability to incorporate pre-emergence herbicides. Grichar and Boswell (1987) also observed an increase in weed pressure in NT peanut production. However, it is important to note that post-emergence herbicide applications can be used to successfully control any remaining weeds, as they were in this study.

Economic Returns

Economic returns were significantly higher (P=0.05) in the NT system than either the CT or ST system (Table 7). Across all three years of the tillage study, economic returns were highest with NT, which generated an average economic return of \$495 ha^{-1}. Conventional tillage had the second highest economic returns of \$225 ha^{-1}, although there was no significant difference (P=0.05) between CT and ST, which had an economic return of \$140 ha^{-1}. The only year where this ranking did not hold (i.e. NT > CT = ST) was in 2005, when there was no statistically significant difference between any of the tillage practices (Table 7). Returns in general were low, especially in 2006, when yields were below average. Also, the loan price of peanuts was relatively low (\$361) during the time of this study which reduced economic returns.

Table 6. Weed and volunteer peanut populations in 2005 and 2006.

	Volunteer Peanut		Weeds	
Treatment	26 May 2005	12 June 2006	3 Aug 2005†	12 June 2006‡
	plants m^{-2}		weeds m^{-2}	
Strip-Till	0.11 a§	0.7 b	0.1 a	0.1 b
No-Till	0.07 ab	1.2 a	0.1 a	0.4 a
Conventional Till	0.05 b	0.2 c	0.1 a	0.1 b

†Evaluations were made on all weeds after in-season herbicide application, with the most common weed being horse nettle.

‡Evaluations were made on all weeds, with the most common occurring identified as nutsedge, spurge, and carpetweed.

§Means, within columns, followed by the same letter are not significantly different (ANOVA, LSD:P=0.05).

Table 7. Economic returns of the tillage study Caddo Research Station Ft. Cobb, OK, 2004–2006.

	2004	2005	2006	All Years
	\$ ha^{-1}			
Strip-Till	644 b†	198 a	−422 b	140 b
No-Till	1,247 a	293 a	−56 a	495 a
Conventional Till	676 b	272 a	−284 b	222 b

†Means, within columns, followed by the same letter are not significantly different (α=0.05).

The significantly higher (P=0.05) economic returns in the NT system were explained by both higher yields and lower costs. The NT system had consistently higher yields, with an average yield of 4781 kg ha^{-1} across the three year study period. Although NT yields were not significantly greater (P = 0.05) than CT, they averaged 551 kg ha^{-1} more than under CT. This translated into increased revenue of \$179 ha^{-1} compared to CT, and increased revenue of \$279 ha^{-1} over ST. Lower production costs also contributed to the higher economic returns of the NT system. Fewer tillage passes resulted in operating (i.e. variable) costs that were lowest in the NT system and highest in the CT system. Accounting for fuel, lube and labor, NT costs were \$52 ha^{-1} lower than CT and \$20 ha^{-1} lower than ST (Table 1). Fixed costs were also lower with NT than CT or ST, since less equipment was required. These savings in equipment costs resulted in fixed costs for NT being \$42 ha^{-1}, which was \$54 ha^{-1} lower than CT and ST systems (Table 1). Overall production costs savings for NT were \$94 ha^{-1} lower than CT and \$74 ha^{-1} lower than CT (Table 1). The combination of production cost savings combined with the increased revenue from higher yields resulted in the NT system generating the greatest economic return of \$495 ha^{-1} (Table 7).

Conclusion

Reduced tillage practices in the SW peanut growing region have gained in popularity. Data from this study supports the adoption of conservation tillage practices, especially NT. Peanut yields and grades were similar to the CT system, but the reduced number of tillage passes in the NT systems significantly increased net revenue compared to CT. The increased environmental benefits of reduced soil erosion with NT are also an important factor that was not evaluated in this study, but is extremely important in a large portion of the region.

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