Interaction of Tillage System and Irrigation Amount on Peanut Performance in the Southeastern U.S.

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ABSTRACT

A five-year study to investigate the potential interaction of conservation tillage with reduced irrigation amounts was conducted near Dawson, GA on peanut (*Arachis hypogaea* L.). Conventional tillage was compared to two conservation tillage programs (wide-strip and narrow-strip tillage) under four irrigation levels (100, 66, 33, and 0% of a recommended amount). Peanut yield did not exhibit a tillage by irrigation interaction as expected, although the main effects of irrigation and tillage were each significant by year due to weather variations. Peanut yield in narrow-strip tillage or wide-strip tillage were individually superior to conventional tillage in three seasons out of five, however only in one year did both conservation tillage systems outperform the conventional system. No detrimental effects on yields could be attributed to conservation tillage. Peanut quality and digging loss were dependent on the tillage by year effect as well as the main effect of irrigation. Irrigation increased total sound mature kernels (TSMK) 2% versus non-irrigated (0% irrigation level); tillage was not significant each year of the study but increased TSMK 2% in three of five years. Digging losses were greater in plots with increased yield potential such as those receiving irrigation. Net economic returns revealed a moderate trend towards sustained profitability under reduced irrigation levels through narrow-strip tillage and to a lesser extent, wide-strip tillage. Under conventional tillage systems, returns decreased with decreasing amounts of irrigation applied.

Key Words: *Arachis hypogaea* L., conservation tillage, strip tillage, supplemental irrigation, peanut quality.

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Crop production in the southeastern region of the Coastal Plain of the United States is generally water-limiting. The highly-weathered soil systems present water management challenges because they tend to be drought-prone and are susceptible to compaction and erosion. To complicate this, rainfall is poorly distributed, and producers commonly utilize supplemental irrigation to sustain crops during extended dry periods. A major problem facing producers in the region is maintaining crop yield, while maximizing current water resources through efficient water use. Lamb *et al.* (1997, 2004, 2007) reported significant increases in yield, quality, net returns, and a reduction in aflatoxin contamination for peanuts produced under irrigation compared to dryland peanut production systems. These findings illustrate the importance of irrigation and demonstrate the potential negative impacts future water restrictions may have on growers in the region. Interstate litigation regarding water rights has focused much attention on agricultural water use in the Southeast in recent years. Moratoria on agricultural withdrawal permits in certain watersheds and voluntary auctioning of agricultural water rights have occurred in Georgia, thus limiting the future expansion of irrigated acreage unless alternative methods of irrigation are adopted or current production practices become more efficient.

Conservation tillage production systems for peanut have been researched extensively for the last 30 years. Studies have evaluated conservation tillage practices in all production regions in the U.S., on many of the major soil series, and across the four market types of peanut (runner, virginia, spanish, and valencia). In summary, five studies have given conservation tillage a clear advantage in either yield, improved quality, or net economic returns (Brandenburg *et al.* 1998; Hartzog and Adams, 1989; Hurt *et al.*, 2006; Marois and Wright, 2003; Tubbs and Gallaher, 2005). Seven studies, four of which were conducted with the virginia market type, favored conventional, high intensity tillage practices that could not be considered conservation tillage (Colvin *et al.*, 1988; Grichar and Boswell, 1987; Jordan *et al.*, 2001; Jordan *et al.*, 2003; Minton *et al.*, 1991; Wright and Porter, 1991a; Wright and Porter, 1995). Not surprisingly, seven other studies showed no differences in conservation tillage systems versus conventional tillage (Chapin *et al.*, 2001; Colvin and Brecke, 1988; Grichar, 2006; Grichar and Smith, 1992; Grichar and Smith, 1992; Johnson *et al.*, 2001; Wiatrak *et al.*, 2004). In fact, a comparison of the sources named above indeed shows the same authors with studies that support conservation tillage, give it no clear advantage, or even oppose conservation tillage for peanut. Hartzog and Adams (1989) summarized their own field studies indicating reduced tillage increased yield at 3 sites, decreased yield at 5 sites, and had no effect at 9 sites; indeed an accurate summary of nearly 30 years of conservation tillage research by themselves and many others.

Clearly conservation tillage peanut has a fit in the production schemes of many producers. While not always increasing yield, the benefit through changes in insects populations (Olson *et al.*, 2006), weed species shift and pressure (Johnson *et al.*, 2001; Price *et al.*, 2007), and reduced disease pressures (Monfort *et al.*, 2004; Wright and Porter, 1991b) illustrates that producers will seek conservation systems to fill specific needs in their cropping systems. This is evident in adoption rates of conservation tillage which stands around 30% (J. Beasley, personnel communication) in the SE U.S. A linkage to increased water use efficiency could increase adoption of conservation tillage in peanut, but perhaps more importantly provide non-irrigated growers a risk mitigation tool not previously considered.

Surface residue management coupled with conservation tillage is a viable management tool for producers. The positive impact of conservation tillage, strip-tillage in particular, on infiltration, runoff and soil quality has been well-researched in several crops (Bosch *et al.*, 2005; Lascano *et al.*, 1994; Potter *et al.*, 1995; Truman *et al.*, 2007). It is also suspected that conservation tillage increases the amount of plant available water, thus increasing the efficiency of rainfall or irrigation (Sullivan *et al.*, 2007). As illustrated previously, conservation tillage systems for peanut have been successful, although not always increasing yield when compared with conventional tillage systems. To satisfy this gap in information a long-term field study was designed with the following goal: to quantify the effect of reduced irrigation amounts within conservation and conventional tillage peanut production systems and, ultimately, to understand if reductions in irrigation water may necessitate a shift to conservation tillage systems for sustainable peanut production.

Materials and Methods

Site description. An experimental site was established on a Greenville fine sandy loam (fine, kaolinitic, thermic Rhodic Kandiudults) at the Hooks-Hanner Environmental Resource Center, near Dawson, GA in the fall of 2001. The soil had a sand, silt, and clay composition of 70, 16, and 14%, respectively, with pH maintained near 6.5 with lime applications as needed. The site was fallow the previous 5 yr with an occasional disking or mowing to limit weed growth. The research site was under the care of the USDA-ARS National Peanut Research Laboratory though owned by the state of Georgia.

Tillage systems. Three tillage systems were compared under 4 irrigation amounts. Overhead irrigation, the most common form of irrigation, was utilized thus plot sizes were larger than typical research-sized plots to accommodate sprinkler overlap and variablity. This facilitated the need for a split block treatment arrangement with irrigation serving as block and tillage and replication as the split plots. The following three tillage systems were implemented on 6-row by 36.5 m plots: conventional tillage, wide-strip conservation tillage, and narrow-strip conservation tillage. Conventional tillage (CT) occurred in the autumn of each year and consisted of multiple diskings, subsoiling (year one only) and moldboard plowing, field cultivation, and bed formation (183 cm) prior to planting. Wide-strip conservation tillage (WST) consisted of a single-pass tillage operation with an implement consisting of a coulter ahead of a subsoil shank, followed by two sets of fluted coulters ahead of a rolling basket and a drag chain assembly (Rip/Strip Gen I, Kelley Mfg. Corp. P.O. Drawer 1467, Tifton, GA 31793). The resulting area tilled was approximately 45 cm wide directly over the row with no further disturbance of the soil except by planting and peanut harvesting operations. Narrow-strip conservation tillage (NST) consisted of the same coulter and subsoil shank implement used for WST, but with only two parallel press wheels to firm the disturbed area trailing behind. This resulted in a tilled area approximately 31 cm wide over the row with no further disturbance of the soil except by planting and peanut harvesting operations. Both WST and NST tillage operations were performed two to three weeks prior to planting each season, dependent on weather and soil conditions. A wheat (*Triticum aestivum* L.) or rye (*Secale cereal* L.) cover crop, depending on seed availability, was drill-seeded each fall at a rate of 85 kg ha^{-1} on conservation tillage plots (WST and NST) only.

Table 1. Total rainfall received and supplemental irrigation applied to the 2002–2006 peanut crops at the Hooks-Hanner Environmental Research Center, Dawson, GA[a].

Source	2002	2003	2004	2005	2006
			mm		
Rainfall	610	707	713	582	296
Irrigation[b]	213	45	178	117	236
Total water	823	752	891	699	532

[a]30-yr average rainfall = 630 mm (Data provided by Georgia Automated Environmental Monitoring Network; http://www.georgiaweather.net).

[b]Irrigation amounts are those in the 100% irrigation level.

Cover crop seed were locally obtained from non-certified sources. This cover crop was terminated approximately four weeks prior to planting of each crop species using the herbicides paraquat or glyphosate. A unique aspect of this study was the fact that plot integrity with regard to tillage was maintained throughout the duration of the study.

Irrigation. The three tillage systems were replicated three times each under one of four decreasing irrigation levels: 100%, 66%, 33%, and 0% of a recommended amount. Irrigation recommendations were provided through the use of irrigation scheduling tools such as plant evapotranspiration (ET) measurements (2002) and Irrigator Pro® (USDA National Peanut Research Laboratory, Dawson, GA), an irrigation decision support system that uses soil temperature and plant growth stage (2003–2006). Irrigation levels were implemented using a lateral move overhead sprinkler irrigation system with three spans, each span nozzled for the appropriate reduction in volume as described above. The nonirrigated area lay just beyond the third span of the lateral. All plots received irrigation at the same time, based on the 100% recommendation level; thus if the 100% called for 2.5 cm of irrigation, each irrigation treatment received its respective percentage of irrigation down to 0 cm for the 0% or non-irrigated treatment. Table 1 describes rainfall and irrigation amounts over the course of this study.

General agronomic practices. The study was established in triplicate with each of the following three crops present each year and in rotation: peanut (*Arachis hypogea* L. var. 'Georgia Green'), (Branch, 1996) followed by cotton (*Gossypium hirsutum* L.), followed by corn (*Zea mays* L.). Peanut only was planted in a twin row pattern, with the center of each twin row spaced 91 cm apart (approximately 20 cm between twin rows). Best management practices for peanut were followed with regard to seeding rates, fertility, pest management, and harvest timings. Plot size was large enough to facilitate management based on plot need; for peanut there was no difference in management within a given year between plots. This was not the case for corn (fertilizer, planting populations) and cotton (vegetative growth management). Given the longevity of this study, peanut management varied from year to year with respect to herbicides applied and fungicide programs utilized due to availability, weather, and pest conditions. Peanut was always managed for optimum yield and quality.

Data collection. After inversion at peak maturity, vines were cured in the field to an acceptable threshing moisture (15–20%) and threshed with a 2-row peanut combine. The center two rows by 30.5 m were machine harvested to determine yield. Harvested pods were sampled for moisture and forced-air dried to 10% moisture levels for storage and grading. Dried pods were weighed on a plot basis and a 2.5 kg sample randomly removed for grade analysis. Peanut grades per plot were analyzed in-house 2002–2004 and sub-contracted to Federal State Inspection Service (Dawson, GA) following standard published protocol to derive total sound mature kernels (TSMK), sound splits (SS), other kernels (OK), loose shelled kernels (LSK), damaged kernels (DK), and foreign material (FM) (USDA, 1997). Within 2 weeks of harvest, a harvest loss analysis was conducted on each plot. Threshed vines were removed from a 0.5 m^2 area near the center of the plot. Soil was excavated to a 6 cm depth and sieved to isolate any pods remaining in the soil. Pods were visually characterized as diseased (not harvestable) or sound (harvestable) pods. Sound pods were collected and weighed. Assuming uniform threshing these harvest loss data are presented as digging losses on a kg ha^{-1} basis. Other data collected but not included in this discussion were: soilborne and foliar disease evaluations at digging, post-harvest aflatoxin analysis, numerous soil moisture sensors, and a complete shelling evaluation.

Economic analyses. Net economic returns were calculated using standard enterprise budgets (UGA, 2006) with the following adjustments: variable cost of irrigation, \$1.04 cm^{-1} ha^{-1}; irrigated land rent, \$247 ha^{-1}; dryland rent, \$123.50 ha^{-1}; cost (variable plus fixed costs) of machinery and fuel for conventional tillage, \$207.00 ha^{-1}; cost of machinery and fuel for strip tillage (both WST and NST), \$70.25 ha^{-1}. Prices were based on yearly marketing loan value as reported by USDA (NASS, 2006). Variable inputs such as fungicide and herbicide that differed by year were accounted for and also included in enterprise budgets.

Table 2. Analysis of variance results for the effects of year, tillage, irrigation, and their interactions.

Effect	Yield	Grade	Net return	Digging loss
Year (Y)	< .0001	< .0001	< .0001	< .0001
Tillage (T)	0.1793	0.0008	< .0001	0.2020
Y × T	0.0129	0.0495	0.0020	0.0137
Irrigation (I)	< .0001	0.0003	0.8221	< .0001
Y × I	< .0001	0.3572	< .0001	0.1057
I × T	0.1579	0.4307	0.0767	0.1287
Y × I × T	0.7224	0.3416	0.8620	0.7114

Statistical analyses. The focus on this study was overall sustainability of conservation tillage systems thus yield, grade (quality), digging losses, and net economic returns were selected for analyses. Data for those parameters were subjected to Mixed Models analysis (SAS v6.1, SAS Institute, Cary, NC) with both tillage and irrigation held as fixed effects while year was designated a random effect. Effects were considered significant at P = 0.05. Orthogonal contrasts were performed to enable multiple comparison within the tillage variable. Fisher's Protected LSD was used as a means test when appropriate.

Results and Discussion

Interestingly, ANOVA did not show an interaction of tillage system and irrigation amount at the pre-selected P=0.05 level of significance. Net economic return did show a significant interaction at P=0.10. Given the complexity of the interaction and the five-year term of the project, this level will be discussed for this particular interaction in addition to the standard analyses described previously. All measured responses showed a significant year by tillage interaction. Both yield and net returns showed strongly significant response ($p<.0001$) to the interaction of year by irrigation.

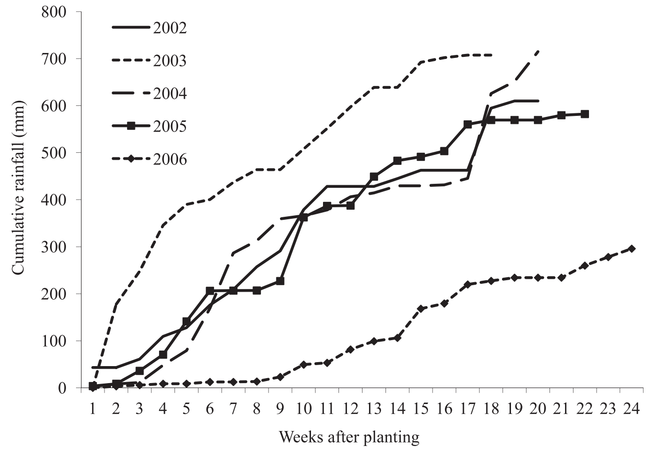

Fig. 1. Cumulative rainfall distribution for the 2002–2006 cropping seasons at the Hooks-Hanner Environmental Research Center, Dawson, GA. Data provided by the Georgia Automated Environmental Monitoring Network (http://www.georgiaweather.net).

Both peanut grade and digging loss showed main effect responses to irrigation with no interactions.

Peanut yield. Peanut response to tillage by year is described in Table 3. Overall, peanut yields at this site were above the Georgia state-wide average with the exception of 2005. During the 2005 growing season, a water drainage issue developed near the peanut plots that depressed yields for the entire growing season (Table 2). Excessive rains during weeks 9–11 resulted in considerable flooding of the plot site that persisted through week 14 (Figure 1). Plots recovered and were harvested but detrimental effects on yield were realized during this critical flowering and pod development stage. Contrasts between tillage treatments revealed that only during one season (2004), were differences shown between the conservation tillage systems (both WST and NST) and the conventional tillage system. Narrow-strip tillage or wide-strip tillage were individually superior to conventional tillage in three seasons out of five, however not always in the

Table 3. Mean peanut yield and tillage treatment contrasts by year as influenced by tillage practices.

Tillage system	2002	2003	2004	2005	2006
	kg ha^{-1}				
Conventional	3650	4270	3740	2900	3430
Wide-strip	3020	3880	4410	3230	4000
Narrow-strip	3750	4230	4290	3490	3120
	P > F				
Contrast[a]					
Conventional vs. strip[b]	0.1536	0.2670	0.0435	0.1685	0.7124
Wide-strip vs. narrow-strip	0.0021	0.1136	0.6682	0.5543	<.0001
Wide-strip vs. conventional	0.0104	0.0943	0.0052	0.0046	0.0149
Narrow-strip vs. conventional	0.7970	0.8979	0.0427	0.0314	0.0920

[a]Contrasts considered significant if $P \leq 0.05$.
[b]Strip tillage in this contrast is either wide-strip or narrow-strip tillage.

Table 4. Yearly effect of irrigation level on peanut yield and net economic returns 2002–2006[a].

Irrigation level	2002		2003		2004		2005		2006	
	Yield	Net return	Yield	Net return	Yield	Net return	Yield	Net return	Yield	Net return
	kg ha^{-1}	*\$ ha^{-1}*	*kg ha^{-1}*	*\$ ha^{-1}*	*kg ha^{-1}*	*\$ ha^{-1}*	*kg ha^{-1}*	*\$ ha^{-1}*	*kg ha^{-1}*	*\$ ha^{-1}*
0%	3480 c	5.00 b	4120 a	398.00 a	4150 b	363.00 a	3310 b	201.00 a	2670 c	−24.00 c
33%	4760 b	351.00 a	4150 a	277.00 ab	4230 ab	237.00 b	3720 a	204.00 a	3200 bc	95.00 b
66%	5330 a	481.00 a	3870 ab	147.00 c	4520 ab	323.00 ab	3710 a	169.00 a	4510 a	275.00 a
100%	5400 a	388.00 a	4100 a	234.00 b	4640 a	334.00 a	2600 c	−93.00 b	3680 b	251.00 a

[a]Means within a column followed by the same lowercase letter are not significantly different as tested by Fisher's Protected LSD (P=0.05).

same season and with no clear pattern. In two of five years differences between the two strip tillage systems were demonstrated; in 2002, NST out-yielded WST by 730 kg ha^{-1} while in 2006 WST outperformed NST by 880 kg ha^{-1}. This agrees with several of the previously cited researchers who gave no clear advantage to either conservation tillage or conventional tillage systems (Chapin *et al*., 2001; Colvin and Brecke, 1988; Johnson *et al*., 2001; Wiatrak *et al*., 2004).

Irrigation was a significant effect in each year except 2003 (Table 4). Rainfall received during the 2003 cropping season was above average, especially early in the growing season (Figure 1). Only two irrigation events totaling 45 mm were applied to the crop in 2003 (Table 1). Peanut yield across all three tillage systems for 2003 averaged 4060 kg ha^{-1}. Of the remaining years of the study, highest yield was obtained at the 100% irrigation level during 2002 and 2004 Table 4). During both of these years, the 66% was not different than the 100%. Both 2002 and 2004 were years with both adequate and well-timed rainfall (Figure 1). The 2005 growing season saw excessive rain during a two-week period and yields averaged across irrigation treatments reflect such. Not surprisingly, lower irrigation amounts (33 and 66%) showed highest yields as compared to the fully irrigated 100% level. Few conclusions can be derived from this exceptional season. During the abnormally dry 2006 growing season, the 66% level of irrigation gave highest yield with the 33 and 100% levels showing no distinction. On a composite basis, irrigation resulted in higher yields in three of five growing seasons. In all five years of this study, the 66% level was equal to the highest yielding plot, suggesting that irrigation amounts for peanut warrant further investigation.

Net economic returns. Conventional tillage had the lowest net return in four of the five seasons evaluated (Table 5). In 2004 and 2005, both strip tillage systems had greater net return than the conventional tillage. Few differences exist among the strip tillage treatments, with only 2002 showing an economic advantage to NST over WST. NST had a higher incidence of greater economic return versus conventional tillage than WST. Interestingly, years 2002, 2004, and 2005 had very similar rainfall patterns and total amounts and in those years NST demonstrated greatest value. In both of the outlying weather years, 2003 and 2006, no tillage system showed a clear benefit economically speaking.

Net returns did not match the pattern of yield with respect to irrigation levels (Table 4). In 2003, 2004, and 2005, the 0% or non-irrigated treatment was the highest return or statistically equivalent to the highest net return. This was not surprising

Table 5. Mean net economic return and tillage treatment contrasts by year as influenced by tillage practices.

Tillage system	2002	2003	2004	2005	2006
			\$ ha^{-1}		
Conventional	49.00	349.00	82.00	22.00	254.00
Wide-strip	−51.00	477.00	529.00	248.00	302.00
Narrow-strip	252.00	501.00	477.00	221.0	288.00
			P > F		
Contrast[a]					
Conventional vs. strip[b]	0.6973	0.3560	0.0059	<.0001	0.5429
Wide-strip vs. narrow-strip	0.0345	0.1141	0.6676	0.7164	0.6123
Wide-strip vs. conventional	0.5225	0.9566	0.0087	0.0004	0.2167
Narrow-strip vs. conventional	0.0051	0.1237	0.0149	0.0027	0.4862

[a]Contrasts considered significant if $P \leq 0.05$.
[b]Strip tillage in this contrast is either wide-strip or narrow-strip tillage.

Table 6. Interaction of tillage and irrigation on net economic return for peanut, 2002–2006.

Irrigation amount[a]	Tillage system[b]		
	CT	WST	NST
	$ ha^{-1}		
0%	3.00 Cb	225.00 Ba	249.00 Ba
33%	92.00 Bc	201.00 Bb	402.00 Aa
66%	247.00 Ab	452.00 Aa	465.00 Aa
100%	265.00 Ab	450.00 Aa	418.00 Aa

[a]Means within an irrigation level (rows) followed by the same lowercase letter are not significant according to Fisher's Protected LSD at P=0.05.

[b]Means within a tillage system (columns) followed by the same uppercase letter are not significant according to Fisher's Protected LSD at P=0.05.

given that large differences in yield between treatments were not observed over the course of this study. In 2002, any level of irrigation resulted in greater economic return versus the 0% level. Similarly, the 66 and 100% levels were superior to the 0 and 33% irrigation levels during 2006. Irrigation, as used in this study, could not be prescribed independently due to physical limitations of equipment. Yield data suggests that perhaps excess water is being applied, thus the lack of response in net returns were realized. The ability to pinpoint water applications, even at reduced levels, should maximize both yield and economic return.

The interaction of tillage and irrigation was only evident for economic return and then only at P=0.10 (Table 6). Strip tillage in the form of either WST or NST had higher net returns at all irrigation levels. Although yield was not always greater within a given tillage system (Table 3), the decrease in production costs caused this increase in net returns. Within the CT and WST tillage systems, net returns increased with increasing amounts of irrigation as expected. However, NST showed equal net returns at all irrigation levels versus the 0% or non-irrigated. This suggests that narrow-strip tillage could be used as a strategy under water-limiting situations to maintain net return on a peanut crop. This argument is strengthened by the fact that this data set represents five years, but three differing weather patterns that may occur in the Southeastern peanut production area: wet (2003), adequate (2002, 2004, 2005), and dry (2006).

Peanut grade. Peanut grade, as represented by TSMK, showed a tillage interaction by year and an irrigation main effect. Peanut grades were acceptable during the first three years of the study but slightly lower during 2005 and 2006 (Table 7). The same excessively wet conditions that negatively impacted yield in 2005 could have depressed grades, as well as the drought conditions seen the following year in 2006. In 2003, TSMK was significantly higher for NST versus CT, however WST did not differ from CT. Strip tillage in either the wide or narrow system had higher grades of 2.1% and 3.1% in 2004 and 2005, respectively as compared to the conventional tillage plots. Tillage did not influence grade in 2002 nor in 2006. No differences in peanut grade were detected between the two strip tillage systems. Peanut grade also exhibited a main effect of irrigation level (Table 8). TSMK increased 2.4% from the 0% irrigation up to the 100% irrigation level. No differences were detected among the irrigated treatments and both the 33% and 100% had greater TSMK than the 0% treatment.

Digging loss. Potential yield lost in the digging/inversion process showed a tillage interaction by year. Digging losses overall were above average at this location (Table 7). In years 2002, 2004, and 2005 digging losses were equal among tillage treatments and averaged 15, 12, and 13% of harvested yield, respectively. Those years in which digging losses represented a lower overall percentage of harvested yield were the same years that showed differences among tillage treatments. In

Table 7. Yearly effect of tillage on peanut grade and digging losses 2002–2006.

	2002		2003		2004		2005		2006	
Tillage	TSMK[ab]	Digging loss	TSMK	Digging loss	TSMK	Digging loss	TSMK	Digging loss	TSMK	Digging loss
	%	kg ha^{-1}	%	kg ha^{-1}	%	kg ha^{-1}	%	kg ha^{-1}	%	kg ha^{-1}
CT	74.9 a	540 a	72.3 b	486 a	71.8 b	463 a	66.7 b	387 a	70.3 a	157 a
WST	74.8 a	516 a	72.8 ab	438 b	74.1 a	495 a	70.0 a	401 a	71.2 a	425 b
NST	75.3 a	562 a	73.5 a	445 b	73.9 a	500 a	69.8 a	485 a	71.0 a	224 a

[a]Abbreviations: CT, conventional tillage; NST, Narrow-strip tillage; TSMK, total sound mature kernels; WST, wide-strip tillage.

[b]Means within a column followed by the same lowercase letter are not significantly different as tested by Fisher's Protected LSD (P=0.05).

Table 8. Peanut grade and digging loss by irrigation treatment.

Irrigation treatment	TSMK[a]	Digging loss
	%	*kg ha^{-1}*
0%	72.1 b	81 b
33%	74.5 a	155 ab
66%	73.6 ab	372 ab
100%	74.5 a	410 a

[a]Abbreviations: TSMK, total sound mature kernels.

[b]Means within a column followed by the same lowercase letter are not significantly different as tested by Fisher's Protected LSD (P=0.05)

2003, losses within either of the strip tillage systems were lower than CT. In 2006, the year with the least amount of total digging loss, CT and NST had equal losses and both were significantly lower than WST. As with grade, digging loss analysis was strongly influenced by the main effect of irrigation (Table 8). Digging losses increased 5-fold going from 0% irrigation up to 100% irrigation, presumably due to the increase in yield. Extremely dry conditions that can occur at harvest time and would particularly influence the 0% treatment were not manifest during this study period. All irrigation levels showed greater digging loss than the 0% non-irrigated treatment.

Summary

This five-year study comparing conventional tillage with two forms of strip tillage was subjected to three distinct rainfall/weather patterns. Accordingly, high variability in yield, grade, and economic returns was realized. As reported by other researchers, conservation tillage in the form of wide-strip and narrow-strip tillage was equal to or sometimes greater in yield and economic returns than conventional tillage practices. No negative effect due to tillage can be concluded. A primary goal of this project was to establish a linkage between irrigation amount and conservation tillage. Given the wide variability in weather conditions and the resulting yield variation, that link was only suggested when viewed in light of economic returns. Preliminary results show a moderate trend toward strip tillage, particularly narrow-strip tillage, for sustained economic returns at lower irrigation levels. More research is needed to confirm this linkage.

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