Alternative Arkansas Rotations and Tillage Practices

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ABSTRACT

The objective of this study was to provide agronomic, nematode, and economic analysis of alternative production rotation systems for soybean *(Glycine max*) on an Arkansas silt loam. Monocropped soybean and soybean double-cropped with wheat *(Triticum aestivum*) was included as well as grain sorghum *(Sorghum bicolor)* under dryland conditions in order to reduce soybean cyst nematode *(Heterodera glycines)* populations. A total of seven crop rotations and 11 treatments that included alternative tillage conditions and wheat stubble management practices were analyzed using data from experiments conducted from 1980 to 1984 at the Arkansas Cotton Branch Experiment Station on a Loring-Calloway-Henry silt loam. Although crop rotation was effective for nematode suppression, yields for double-cropped soybeans were comparable to soybean yields under monocropped, continuous management practices. Economic results indicated that average net returns of %137/a were highest for the continuous double-cropped wheat-soybean production management systems which combine the conventional tillage method with burning of wheat stubble. For the conditions analyzed and level of soybean cyst nematode present, this research provides evidence that control of the soybean cyst nematode through rotation practices that utilize grain sorghum is not economically efficient where continuous double-cropped wheat-soybeans systems can be incorporated.

INTRODUCTION

Crop rotation has been recognized for years as a primary strategy for the effective control of soilbome diseases. With the removal of dibromochloropropene, usually the most cost-effective nematicide in soybean *(Glycine max* [L.] Merr.) production, the use of resistant soybean cultivars, coupled with crop rotation, is seemingly the only remaining control strategy for the cyst nematode *(Heterodera gIycines* Ichinohe). Previous research has indicated that non-host crops for one year in the rotation dramatically decreased the nematode population (Slack et al., 1981; Dabney et al., 1988). Research conducted in Kentucky indicated that the combination of no-till and leaving wheat *(Triticum aestivum* L.) straw generally suppressed nematode populations (Hershman and Bachi, 1995), whereas Alabama evidence shows little effect (Edwards et al., 1988). In the Mississippi Delta and Loessial Terraces regions of Arkansas, several million acres of loess-derived soils are very low in organic matter and are subject to severe cyst nematode problems.

In these regions, nonirrigated silt loam soil not cropped to cotton *(Gossypium hirsutum* L.) is almost exclusively cropped to continuous soybean or double-cropped wheat-soybean. The wheat residue usually is burned. This practice of wheat straw burning has been perceived by agronomists as an undesirable practice on soils with very low organic matter (<0.8%) for as long as it has been practiced. The objective of this study was to examine the profit potential of alternative soybean production rotation systems on an Arkansas silt loam within a multidisciplinary (agronomic, pathologic, and economic) framework.

MATERIALS AND METHODS

As a multidisciplinary study, several methodological aspects are discussed. Procedures for the agronomic component, nematode assay, and economic analysis are presented.

Agronomic Component

Experiments were conducted from 1980 to 1984 at the Arkansas Cotton Branch Experiment Station on a Loring-Calloway-Henry silt loam. The initial soil test values were 6.2for soil pH with 0.6% organic matter and 64 lb P/a and 170 lb K/a.

The study included seven rotational cropping systems composed of continuous soybean (monocropped),wheat-soybean double-cropped, and five biennial rotations of which two were single crops per year and the remaining three were double-crop systems. The exact cropping sequences are shown in Table 1.

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Also defined in Table 1 are various cropping-system designations. Additional cultural practices were imposed on selected crop rotations. The continuous soybean and wheat-soybean double-crop systems were grown under both conventional tillage and no-till methods. The wheat-soybean double-crop system also had residue management treatments in that the wheat stover was either burned or left on the surface. This plan resulted in a total of four double-cropped wheat-soybean production systems and two continuous soybean systems.

A total of 11 crop production systems were arranged in a randomized complete block design with three replications. Individual production *system* plots were 13.7 ft wide x 100 ft long. Grain sorghum and soybean were planted on 38 in. rows with a conventional planter (John Deere 7000®) equipped for no-till by using cutting coulters, double disk openers, cast iron press wheels and heavy down pressure springs while the wheat was sown in 7.5-in. rows with a Crust Buster no-till drill. Wheat residue was burned in all cases where the crop production system is not otherwise specified.

The study area was planted to soybean in the summer of 1980. The study began with wheat planted that fall and summer crops in the spring of 1981. Yields were determined by harvesting the two middle rows in each plot for both grain sorghum *(Sorghum bicolor* [L.] Moench) and soybean and a 60-in.-wide swath in the middle of the wheat plots. Grain yields were adjusted to 14.0, 13.0, and 13.0% moisture for grain sorghum, soybean, and wheat, respectively. The specific features of each production system were commensurate with commercial production practices used in the area.

Nematode Assay

Every plot was sampled each fall for soybean cyst nematode population density determinations. Soil samples from the 0 to 4 in. depth were taken from the seedling row with a soil probe to generate 20 samples per plot. Second-stage juveniles of *H. glycines* were extracted (Southey, 1986), counted, and analyzed statistically using a square root transformation

Economic Analysis

Economic analysis was conducted using enterprise budgeting techniques. Budgets were compiled on each cropping *system* annually by using the Mississippi State Budget Generator computer program (Spurlock, 1992). In order to remove the effects of market fluctuations and focus upon production economic issues, *crop* prices were based on a 10-yr average (1985-1994) for each crop (Anon., 1995). These prices were $5.92/bu for soybeans, 03.12/bu for wheat, and $1.95bu for grain sorghum. Recent data were used to reflect current conditions. Total income was calculated by multiplying yield and average crop price. Direct expenses were calculated using the average prices paid for seed, chemicals, fertilizer, custom work, labor, repairs, maintenance, fuel, and interest on operating capital. Input requirements were those actually used for seed chemicals, fertilizer, etc., with standard American Society of Agricultural Engineers (ASAE) machinery *costs* calculations for the remainder using recent ASAE coefficients. Recent input prices for Arkansas (Anon., 1994) were also used. Fixed expenses include depreciation, insurance, property taxes, and interest on capital invested associated with tractors, combines, and other field equipment. Total expenses included both the direct and fixed expenses. Net returns are considered the difference between total income and total expenses. Average net returns are calculated over the 4-yr period. Gross income, total expenses, and net returns for the double-crop rotations include the total income, expenses, and returns for both crops produced in each system. No charge was issued for land, risk, overhead labor, other overhead, crop insurance, real estate taxes, or management.

RESULTS AND DISCUSSION

Although economic considerations are a primary motivation of production management decision-making, knowledge of the underlying production processes is crucial to the realization of economic objectives. Consequently, results are presented, in turn for three components that affect performance: agronomic, pathologic (nematode), and economic.

Agronomic

Grain yields for the study generally follow expectations for the crops and cultivars used in the study area without irrigation (Table 2). These particular crop rotations were selected for the alternation of host crop for the management of soilborne plant pathogens, a weed spectrum easily controlled by available herbicides, and economic potential. Other production practices were included to reduce mechanical inputs (no-till) or to retain crop residue.

Nematode

The nematode analyses indicated that leaving wheat residue or burning it did not significantly influence the associated nematode population which averaged 700 and 509 juveniles per pt of soil for wheat residue burned or unburned, respectively. This reduction in nematodes from leaving wheat straw, while not significant, tends to agree with that reported by Hershman and Bachi (1995).

Crop rotations used in this study were of two types: 1) those recommended for nematode suppression that contain a year of non-host crop and 2) those not recommended for nematode suppression that contain host crops planted every year. Rotations were, therefore, classed according to these two schemes. The crop rotation x year interaction was highly significant (P=0.01) and is shown graphically in Figure 1. Essentially, in the fall following a year of non-host crop, the nematode populations were suppressed to a very low level as compared to rotations containing a host crop every year. This finding illustrates the effectiveness of crop rotation for nematode suppression.

The tillage effect on nematode populations was found to be highly significant (P=0.01) and to be independent of crop rotation and year. The data are presented only for continuous single and double-crop soybean (Figure 1). Both rotations had host plants seeded each year. However, the no-till resulted in substantially fewer nematodes than the tilled systems. The no-till production system suppressed the nematodes as well as non-host crop rotation. This result suggests that no-till could well be considered as an alternative to crop rotation for nematode suppression. However, on some sods, the reduction in nematode population density made during a no-till crop may not be sufficient to prevent damage the next year if a susceptible cultivar is planted.

Economic

As expected, net returns varied across years and treatments (Table 3). Over the entire 4 yr of the study, average net returns/a ranged from a high of $136.99 for conventionally produced double-cropped wheat-soybean to a low of $39.44 for no-till continuous soybean (Table 4). Of the crop rotation systems, the wheat-soybean continuous double-cropped systems regardless of tillage practice and stubble management, produced the largest net returns. The least favorable of these four was for soybean no-tilled into wheat residue. At the time of this study the technology was not available to make this treatment yield as it should (Keisling et al., 1994). Therefore, the net returns reported for continuous double-cropped wheat-soybean with wheat residue left and *soybean* no-tilled into the wheat straw will be lower than what can be currently expected.

The next most profitable systems were continuous double-cropped wheat-soybean-monocropped soybean, monocropped grain sorghum-soybean, and double-cropped wheat-grain sorghum-monocropped soybean. These crops were about two-thirds as profitable as the most profitable system. The least profitable rotation was continuous no-till soybean. Net returns for wheat-summer fallow-monocropped soybean were the next lowest. Net returns for the least profitable continuous no-till soybeans were less than one third of the net returns achieved by the most profitable group.

In order to expand the potential for application of the research results to a more diverse set of conditions and address the limitation of the study related to the yield data used, sensitivity analysis was conducted. Specifically, given the wide range of production management abilities, soil potential, and different resources and conditions, yields understandably varied dramatically. This variation in yield obviously has a substantial impact on the net returns that a producer receives. Furthermore, yields have been impacted by changes in technology, cultivar availability, and management information. Consequently, average net returns for selected treatments are calculated under a range of soybean yields and other crop yields. The yield sensitivity analysis focused upon four treatments: conventional, continuous GS/S; conventional, continuous soybeans: no-till continuous soybeans; and conventional continuous, doublecropped wheat-soybeans with burned wheat stubble. In all cases, soybean yields were varied in 10-bu increments from 10 to 40 bu/a. Grain sorghum yield was varied in 10-bu increments from 60 to 80 bu/a and wheat yield was varied in 10-bu increments from 30 to 50 bu/a. The results are presented in Table 5. Notably, all double-cropped wheat-soybean yield levels examined still earned positive net returns and, with a 60 bu/a sorghum yield exception on the GS/S rotation, all 20 bu/a soybean yield levels were sufficient to result in positive net returns for the remaining treatments and yield levels considered.

CONCLUSIONS

In conclusion, the results of the study emphasize the advantage of conducting research within a multidisciplinary framework, given the complicated environment which faces farm managers in their production management decisionmaking. While inclusion of grain sorghum in the rotation was effective in reducing soybean cyst nematode populations, the agronomic production function was such that soybean yields under continuous double-cropped wheat-soybean production practices were comparable to continuous monocropped soybeans. Furthermore, the additional net returns achieved from wheat complemented the continuous double-cropped wheat-soybean production strategy enough to compensate for the lower soybean yields compared to the grain sorghum rotations.

Although control of soybean cyst nematode is essential to good production management, one should consider the economic impact of switching to less profitable enterprises.

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Table 1. Cropping Sequences and Seedbed Preparation for Eleven Crop Production Systems from 1981 to 1984

			Year							
		Wheat	1980	1981		1982		1983		1984
Crop Rotation'	Tillage'	Stubble Mgmt.	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
GS/S	Conv.			**GS**		S		GS		S
S/S	Conv.			S		S		S		**S**
S/S	No-till			S		S		S		**S**
W-F/S	Conv.	Bum	W			S	W			S
W-GS/S	Conv.	Bum	W	GS		S	W	GS		S
W-GS/W-S	No-till	Bum	W	**GS**	W	S	W	GS	W	S
W-S/S	Conv.	Bum	W	S		S	W	S		S
W-SiW-S	Conv.	Bum	W	S	W	S	W	S	W	S
W-S/W-S	No-Till	Burn	W	S	W	S	W	S	W	S
W-S/W-S	Conv.	Leave	W	S	W	S	W	S	W	S
W-S/W-S	No-till	Leave	W	S	W	S	W	S	W	S

'Yearly cropping rotations are divided by '/' and individual crops harvested same year are divided by '-', crops are shown as 'GS' for grain **sorghum,** 'S' for soybean, 'W' for wheat, **and** 'F' for fallow.
[1]Mgmt refers to management (**Burn** indicates wheat stubble is burned, Leave indicates the stubble is left unburned on the surface).

Table 2. Grain Yield for the Eleven Crop Sequences

Crop Rotation’	Tillage	Wheat Stubble Mgmt.‡	Crop	Year 1981	1982	1983	1984	Avg.
				bu/a				
GS/S	Conv.	---	GS	86.0‘	---	107.1	---	96.6
GS/S	Conv.	---	S	---	40.8	---	36.8	38.8
S/S	Conv.	---	S	28.7	31.2	17.1	35.4	28.1
S/S	No-Till	---	S	34.6	20.2	10.7	31.2	24.2
W-FIS	Conv.	Burn	W	34.0	---	38.6	---	36.3
W-FIS	Conv.	Bum	S	---	34.7	---	34.6	34.6
W-GSIS	Conv.	Bum	W	34.0	---	40.6	---	37.3
W-GSIS	Conv.	Burn	GS	62.3	---	62.3	---	62.3
W-GSIS	Conv.	Bum	S	---	36.7	---	36.9	36.8
W-GS-IW-S	No-Till	Bum	W	34.0	28.0	40.1	32.3	33.6
W-GSIW-S	No-Till	Burn	GS	36.0	---	35.5	---	35.8
W-GSIW-S	No-Till	Burn	S	---	28.7	---	33.9	31.3
W-S/S	Conv.	Burn	W	34.0	---	40.1	---	37.1
W-S/S	Conv.	Burn	S	27.1	32.1	16.4	39.0	28.8
W-S/W-S	Conv.	Burn	W	34.0	34.7	37.6	42.1	37.1
W-S/W-S	Conv.	Burn	S	34.6	30.3	19.4	33.9	29.5
W-S/W-S	No-Till	Burn	W	34.0	32.0	38.6	43.9	37.1
W-S/W-S	No-Till	Burn	S	35.3	31.2	19.0	35.4	30.2
W-S/W-S	Conv.	Leave	W	34.0	31.4	35.1	34.1	33.8
W-S/W-S	Conv.	Leave	S	33.1	31.0	16.8	36.5	29.4
W-S/W-S	No-Till	Leave	W	34.0	34.0	37.1	23.7	32.2
W-S/W-S	No-Till	Leave	S	39.5	29.4	19.0	26.6	28.6

† Yearly cropping rotations *are* divided by '/' and individual crops harvested same year divided by '-', crops *are* shown as ‘GS’ for grain sorghum, ‘S’ for soybean, ‘W’ for wheat and 'F' for fallow.

‡Mgmt refers to management (Bum indicates wheat stubble is burned, Leave indicates the stubble is left on the surface).

’Measured plots yields of 16 bu/a were based on experiment station average on 300 a. Small plots of early grain sorghum were heavily damaged by birds.

Table 3. Total Income (TINC), total Expenses (TEXP) and Net Returns Above Expenses (NRET) for the Eleven Crop Systems

			1981			1982		
Crop Rotation'	Tillage	Wheat Stubble Mgmt.[‡]	TINC	TEXP	NRET	TINC	TEXP	NRET
GS/S	Conv.	---	167.70	114.41	53.29	241.71	129.22	112.49
S/S	Conv.	---	170.08	71.20	98.88	184.88	131.98	52.91
S/S	No-Till	---	204.83	81.85	122.98	119.58	125.83	-6.24
W-FIS	Conv.	Bum	106.08	71.64	34.44	205.25	128.29	76.96
W-GSIS	Conv.	Bum	227.62	173.13	54.49	217.26	128.60	88.66
W-GSN-S	No-Till	Burn	176.22	149.00	27.22	257.44	178.98	78.46
w-SIS	Conv.	Burn	266.69	141.48	125.21	193.58	127.99	65.59
W-S/W-S	Conv.	Burn	310.73	140.48	170.25	287.46	166.76	120.70
W-SN-S	No-Till	Burn	314.88	152.23	162.65	284.37	170.40	113.97
w-SN-s	Conv.	Leave	302.03	162.87	164.14	281.76	167.81	113.95
W-SN-S	No-Till	Leave	339.92	157.94	181.98	280.04	179.76	100.29
GIS	Conv.	---	208.90	117.60	91.30	217.86	128.61	89.24
S/S	Conv.	---	101.23	69.44	31.79	209.57	128.40	81.17
SIS	No-Till	---	63.34	80.72	-17.37	184.41	126.03	58.38
W-F/S	Conv.	Burn	120.43	72.34	48.09	204.83	128.28	76.55
W-GSIS	Conv.	Burn	248.22	174.16	74.06	218.45	128.63	89.82
W-GSN-S	No-Till	Bum	194.40	149.88	44.51	301.37	172.49	128.88
W-S/S	Conv.	Bum	222.20	140.81	81.39	230.70	128.94	101.76
W-SN-S	Conv.	Bum	232.25	138.76	93 .50	331.96	168.46	163.49
W-SN-S	No-Till	Bum	233.09	150.49	82.60	346.71	172.89	173.82
W-SN-S	Conv.	Leave	210.76	136.96	73.79	322.56	169.05	153.51
W-S/W-S	No-Till	Leave	228.32	155.32	72.99	231 24	169.79	61.45

'Yearly cropping rotations are divided by '/' and individual crops harvested same year are divided by '-', crops are shown as 'GS' for grain sorghum, 'S' **for** soybean, 'W' for wheat and 'F' for fallow.

[‡]Mgmt refers to management (Bum indicates wheat stubble is burned, Leave indicates the stubble is left unburned on the surface.

Table 4. Averages for Total **Income (TINC),** Total **Expenses (TEXP)** and **Net Returns** Above **Expenses (NRET)** for **the Eleven Crop Systems**

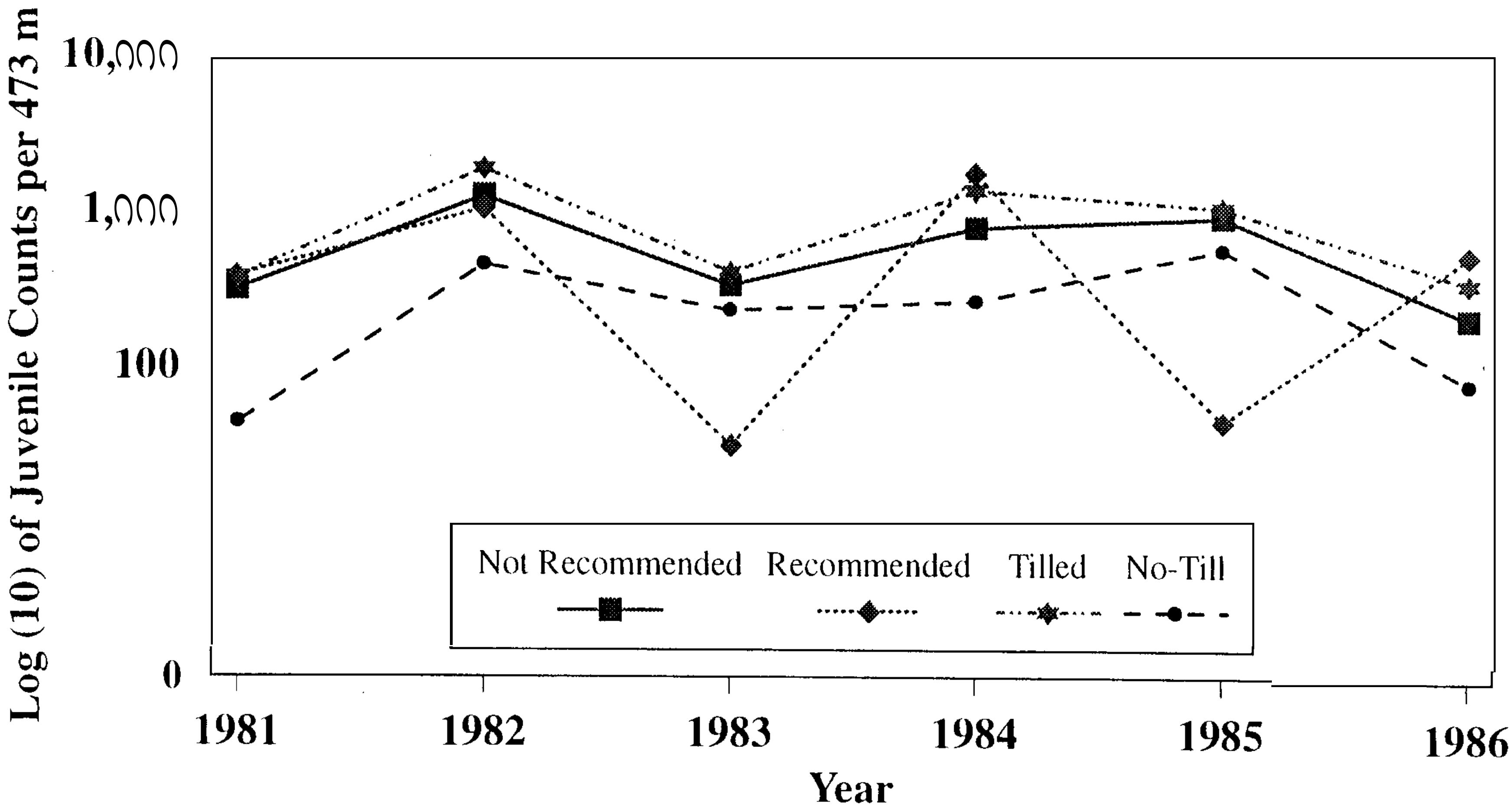
			Average of 1981 through 1984		
Crop Rotation'	Tillage	Wheat Stubble Mgmt.‡	TINC	TEXP	NRET
GS/S	Conv.	---	209.04	122.46	86.58
S/S	Conv.	---	166.44	100.26	66.19
S/S	No-till	_-	143.04	103.61	39.44
W-F/S	Conv.	Bum	159.15	100.14	59.01
W-GS/S	Conv.	Bum	227.89	151.13	76.76
W-GS/W-S	No-till	Burn	232.36	162.59	69.77
W-S/S	Conv.	Burn	228.29	134.81	93.49
W-S/W-S	Conv.	Burn	290.60	153.62	136.99
W-S/W-S	No-till	Burn	294.76	161.50	133.26
W-S/W-S	Conv.	Leave	279.28	159.17	126.35
W-S/W-S	No-till	Leave	269.88	165.70	104.18

'Yearly cropping rotations are divided by '/' and individual crops harvested same year are divided by '-', crops are shown as 'GS' for grain sorghum, 'S' for soybean, 'W for wheat and 'F' for fallow.
‡Mgmt refers to management (Bum indicates wheat stubble is bumed, Leave indicates the stubble is left unburned on the surface).

Table 5. Average Net Returns' ($/a) Sensitivity Analysis of Yield Effects for Selected Treatments

		Nonsoybean		Soybean Yield			
Rotation'	Tillage	Crop	Yield	10	20	30	40
GSlS	Conv.	*GS*	60	-29.42	-0.58	28.27	57.11
GSlS	Conv.	*GS*	70	-20.43	8.42	37.27	66.11
GSlS	Conv.	*GS*	80	-11.43	17.42	46.26	75.10
S/S	Conv.	NA	NA	-39.37	18.32	76.01	133.70
S/S	No-till	NA	NA	-41.29	16.41	74.10	131.78
W/S‡	Conv.	W	30	3.24	60.93	118.62	176.31
W/S‡	Conv.	W	40	32.89	90.58	148.26	205.95
W/S‡	Conv.	W	50	62.53	120.22	177.91	235.60

'Yearly cropping rotations are divided by '/' and individual crops harvested same year are divided by '-', crops are shown as 'GS' for grain sorghum, 'S' for soybean, ' W for wheat and 'F' for fallow.
‡The wheat stubble was burned.



Note Recommended includes grain sorghum in 81, 83 and 85.
Not recommended excludes grain sorghum.