Tillage, Weed Control Methods and Row Spacing Affect Soil Properties and Yield of Grain Sorghum and Soybean

U.R. Bishnoi and D. Mays

Department of Plant and Soil Sciences, Alabama A&M University, Normal AL 35762. USA.

Corresponding author's e-mail: ubishnoi@aamu.edu

ABSTRACT

In the southeast, soybean and grain sorghum are important crops, and there is a need to determine the effects of tillage, weed control methods, and row spacing on soil properties and yield of these crops. The objectives of this research were to determine the effects of three weed control methods (none, cultivation, and herbicides) and three row spacings (45, 60, and 90 cm) on no-till (NT), planted grain sorghum (after wheat and clover), conventionally planted soybeans and no-till in wheat stubble for two growing seasons. NT planted soybeans produced 3102 kg ha^{-1}, 2911 kg ha^{-1} and 2216 kg ha^{-1} seed with herbicide, mechanical, and no weed control system, respectively. In conventionally prepared seedbeds, use of herbicides and cultivation produced almost equal seed yield (3898 kg ha^{-1} and 3954 kg ha^{-1}), which was significantly higher than no weed control (3151 kg ha^{-1}) plots. Soybean in narrow (45 cm) rows (3997 kg ha^{-1}) consistently out-yielded the wider, 60 cm (3130 kg ha^{-1}) and 90 cm (2490 kg ha^{-1}), rows. Results averaged across years showed that conventionally planted soybean produced higher yields (3668 kg ha^{-1}) than NT planted soybeans (2743 kg ha^{-1}). The weed infestation was significantly less in narrow rows (45 cm) than in wider row (60 and 90 cm) plots. Similar results were observed in the case of grain sorghum. Soil moisture content, organic matter content, total soil nitrogen, and disease ratings of bacterial blight in soybeans were higher in NT than in conventional plots.

KEYWORDS

No-till, cover crops, double-cropping, herbicides.

INTRODUCTION

Pre-plant tillage has traditionally been performed to prepare the seed bed, incorporate the fertilizer, and control weeds. No-till (NT) planting systems have enhanced double cropping production systems of soybean (*Glycine max* (L.) Merr.) and grain sorghum (*Sorghum bicolor* (L.) Moench) following wheat (*Triticum aestivum* L.) or clover. However, NT planting has sometimes resulted in poor crop stands in comparison with conventional tillage (CT). The low germination rates in NT stands are due to excessive crop debris, which causes poor soil-seed contact, greater weed infestation, and higher disease incidence (Wright *et al.*, 1984; Vasilas *et al.*, 1988). Weed problems have been minimized by judicious use of pre- and post-emergent herbicides. Crabtree and Rupp (1980) reported lower soybean yields due to poor stands with NT in comparison with CT systems, whereas Edwards *et al.* (1988) observed that soybean yields under NT were higher than those from CT owing to the advantage conferred by the moisture-conserving mulch in a NT system.

While studying the influence of row spacing on cowpea, Herbert and Baggerman (1983) found that seed yield was higher in wide rows and it increased with increasing plant densities within rows. Witt (1984) studied the effects of herbicides on weeds in NT systems and concluded that weed problems can be reduced when either tillage or herbicides are used for weed control. Sufficient information is not available on grain sorghum, soybean, and soil property responses to integrated cultural practices such as row spacing and weed control methods in NT and CT systems. Therefore, this research was undertaken to determine the effects of tillage systems, row spacing, and weed control methods on grain sorghum and soybean yields and soil properties after soybeans.

MATERIALS AND METHODS

The experiments were conducted for two crop-growing seasons on a Decatur silty clay loam (Rhodic Paleudult) soil with a pH of 6.3. The two tillage systems used in the study were: (1) CT with fall plowing, spring disking, and harrowing and (2) NT after wheat and clover harvested as forage. The row spacings were 45, 60 and 90 cm, and the methods of post-plant weed control were the use of herbicide, hoeing, and no weed control. The experimental design was a split-split plot with five replications using tillage systems as main plots, which were randomly as-

IN E. van Santen (ed.) 2002. Making Conservation Tillage Conventional: Building a Future on 25 Years of Research. Proc. of 25th Annual Southern Conservation Tillage Conference for Sustainable Agriculture. Auburn, AL 24-26 June 2002. Special Report no. 1. Alabama Agric. Expt. Stn. and Auburn University, AL 36849. USA.

signed within each replication. Row spacings were randomly arranged within each main plot as subplots, and weed control methods were sub-subplots and were randomized within subplots. Each subplot was comprised of four rows 7.5 m long and 1.8 m, 2.4 m, and 3.6 m wide for the 45 cm, 60 cm and 90 cm row spacings, respectively.

Soybean cv. "Essex" and grain sorghum cv. Funk-G-1516 BR were planted in mid May at the recommended seeding rates with an Allis-Chambers™ NT planter. Fifteen days before planting, glyphosate (N- (phosphonomethyl) glycerin) was sprayed in all NT plots at the rate of 0.6 kg a.i. ha^{-1} to kill existing weeds. Acifluorfen 5-[2-chloro-4-(trifluoromethyl)phenoxy]-2-nitrobenzoic acid was sprayed at 25 and 45 days after planting (DAP) on the chemical control plots in both CT and NT areas at the rate of 2.24 kg a.i. ha^{-1} using a Solo™ knapsack sprayer (Solo, Germany). A surfactant, Surf-Ac 820 (Drexel Chemical Co., Memphis, TN) was added to the glyphosate and acifluorfen spray solutions at the rate of 0.5%. Mechanical post-plant weed control was performed by hand hoeing on the same day that acifluorfen was applied. In sorghum, atrazine at 1.4 kg a.i. ha^{-1} was applied at the 6 leaf stage. Soybean plant population was determined 40 DAP by counting plants in a 2 m section of the row in each plot selected at random. The total number of weeds in an area of 1 m^2 selected at random in each plot was also counted at 40 DAP in soybeans, but at crop maturity in grain sorghum. In both planting systems, the incidence of bacterial blight of soybean (BBS) caused by *Pseudomonas syringae* pv *glycinea* (Coerper) was evaluated at full pod (R4) growth stage and recorded. To determine gravimetric soil moisture content, soil samples were collected from the 0-15 cm depth at growth stages V5, R2, R4, and R8 (Fehr and Caviness, 1977) from each plot. Soil samples were collected at harvest (R8) to determine organic matter (OM) and nitrogen (N) content using the techniques of Walkley and Black (1934) and Bremner and Mulvaney (1982), respectively. Soybeans were combine-harvested from each plot at harvestable maturity of the crops. The seeds were cleaned and the yields were recorded in kg ha^{-1} at 12% moisture. Data were subjected to an analysis of variance procedure appropriate for a split-split plot design using a data processing package of the Statistical Analysis Systems Institute (SAS, 1982). The differences between treatment means were separated by use of Tukey's test.

RESULTS AND DISCUSSION

Tillage system

A lower plant population of soybeans (221,754 plants ha^{-1}) was observed in NT plots in comparison with the CT (335,439 plants ha^{-1}), as shown in Table 1. The greater plant population in conventional plots probably occurred because of better soil-seed contact. Wright *et al.* (1984) and Vasilas *et al.* (1988) observed a similar difference in plants' density owing to shallow planting of seeds and the presence of crop residues in NT plots which hindered good soil-seed contact. Use of glyphosate as a pre-plant herbicide was more effective in controlling weeds in NT than in CT, which showed that weeds could be effectively controlled in a NT system.

Disease rating (DR) and infestation (DI) of BBS were significantly higher in NT than in the CT system. Similarly, average soil moisture content, soil organic matter, and total nitrogen were higher in NT than in CT at the 0-15 cm depth (Table 1). The beneficial effects of NT on soil moisture can

Table 1. Tillage effects on plant population, weed population, bacterial blight rating, soil properties and soybean seed test weight.

Response variable	No-till following wheat (NTW)	Conventional tillage (CT)	$LSD_{0.04}$
Plant population, 1000 plants ha^{-1}	222	335	4
Weed population, weed m^{-2}	19.8	23.9	3.9
Bacterial blight rating†	8.8	6.8	0.8
Soil moisture content, %‡	16.8	15.6	0.4
Soil organic matter at harvest, %	2.31	1.46	0.84
Total soil nitrogen at harvest, %	0.14	0.12	0.01
Hundred seed weight, g	12.2	14.3	0.8

†Disease rating from 0 = no infection to 9 = 90% disease and defoliation.

‡Means averaged over three periods (during V5, R2, and R8)

Table 2. Weed population and soybean yields under different row spacings, weed control method and tillage systems

	No-till (NT)			Conventional till (CT)		
Treatments	Weed population	Seed yield		Weed population	Seed yield	
	1988	1987	1988	1988	1987	1988
	weeds m^{-2}	------kg ha^{-1}------		weeds m^{-2}	------kg ha^{-1}------	
Row spacing, cm						
45	17.6 b†	3463 a	3306 a	18.8 c	4736 a	4483 a
60	20.2 a	2593 b	2593 b	22.9 b	3216 b	3836 b
90	21.7 a	2379 c	1844 c	30.1 a	2645 c	3091 c
Weed control method						
Hoeing	15.4 b	2930 b	2913 b	10.3 b	3789 a	4159 a
Herbicide	13.1 b	3119 a	3086 a	8.8 b	3512 b	3512 b
No control	30.9 a	2406 c	2026 c	52.7 a	334 b	2967 b

† Means within a column followed by the same letter do not differ significantly at $P = 0.05$ according to Tukey's studentized range test.

be attributed to the mulching effect of wheat stubble and killed weeds, which reduced runoff and evaporation. Soil organic matter, even with CT, was higher than usual for the region because the experimental site had been under sod for many years before this experiment was conducted. Organic matter and soil N could be expected to be somewhat higher with NT, as reported by Culley *et al.* (1987), who found that organic C and soil moisture were both higher under NT than under CT. The relatively large difference in OM between NT and CT in this experiment may have been owing to poor mixing of the organic duff layer with the soil when the sampling was done.

Tillage systems significantly influenced soybean yields in both years (Table 2). A similar yield trend was also observed in grain sorghum (Table 3). The difference in yields probably occurred primarily because NT had a lower plant population than CT. The plant population of 221,754 plants ha^{-1} with NT was significantly less than that recommended as a base population for predicting yield losses due to stand reduction (308,600 plants ha^{-1}; National Crop Insurance Association, 1985). Torri *et al.* (1987) reported that no yield reduction occurs during vegetative growth stages if a plant population of at least 308,600 plants ha^{-1} is maintained. Second, the higher incidence of BBS and lower seed weight in NT likely had negative effects on yields. Results averaged across years showed that conventionally planted soybeans produced a significantly higher yield (3668 kg ha^{-1}) than no-till planted soybeans. In grain sorghum, the significant increase in yield from no-till after clover and after wheat over conventional tillage was probably due to higher soil moisture content in no-till plots as well as due to the soil nitrogen fixed by clover. With no-till after wheat and clover, no significant yield differences were observed between chemical and mechanical methods of weed control; however, the herbicide controlled weeds more effectively than hoeing.

Row spacing

Decreasing the row width significantly reduced weed populations in both tillage systems (Table 2 and 3) because of increased competition from a higher density of crop plants. Similar effects on weed population of increased crop resulting from better soybean root distribution and more rapid shading of the ground have been reported by Burnside and Moomaw (1977) and Murdock *et al.* (1986). Freed *et al.* (1987) also observed that if weeds are controlled for the first 4-5 weeks after planting in narrow rows, the soybean canopy suppresses late emerging weeds. The yield from the

Table 3. Effects of tillage, row spacing and method of weed control on weed population and yield of grain sorghum.

	Conventional till (CT)		No-till after wheat (NTW)		No-till after clover (NTC)	
Main effect	Weed infestation†	Grain yield	Weed infestation	Grain yield	Weed infestation	Grain yield
	----- % -----	-- lbs $acre^{-1}$ --	----- % -----	-- lbs $acre^{-1}$ --	----- % -----	-- lbs $acre^{-1}$ --
Row spacing						
18 in	43.8 b‡	4375 a	47.7	5031 a	87.7 a	5713 a
24 in	66.2 a	3696 b	50 a	4619 b	51.1 b	4407 b
36 in	63.3 a	3301 c	54.5 a	3562 c	48.3 b	3635 c
$LSD_{0.05}$	5.5	164.5	9.8	259.6	31.1	126.4
CV%	11.3	17	18.9	19.3	19.3	12.5
Weed control methods						
None	100	3696 b	100 a	4267 b	100 a	4532 b
Mechanical	46.5 b	4090 a	44.6 b	3445 ab	5.8 b	4569 b
Chemical	26.9 c	4052 a	7.7 c	4506 a	2.3 c	4769 a
$LSD_{0.05}$	6	138.1	9.4	220.5	26.3	190.8
CV%	13.7	16.7	14.4	15.9	15.6	14.7

†Weed percentageare in comparison to check as 100%.

‡Means within a column and variables followed by the same letter are not significantly different (P = 0.05) by Duncan's multiple range test .

45 cm row spacing was significantly higher than those from the 60 and 90 cm rows for all planting systems (Table 2 and 3). In both crops, a significant increase in yields from the 45 cm row was probably owing to suppression of weeds and better utilization of light, water, and nutrients because of rapid shading of the soil with the dense canopy and the greater number of plants per unit area. Similar yield results in soybeans have been reported by Parker *et al.* (1981). Although a significant tillage system x row spacing interaction affected both the seed yield and weed population (Table 4 and 5), it accounted for 0.4% and 1%, respectively, of the total variance.

Weed Control Method

The average weed population in plots treated with herbicide was markedly lower than that in plots with no control but was not significantly different from that in the hoeing treatment in both planting systems (Table 2 and 3). These results concur with those reported by Burnside and Moomaw (1977). Acifluorfen provided variable control of broadleaf and grass weeds, being very effective when applied at an early stage of growth. In NT, herbicide treatment consistently produced the highest grain sorghum as well as soybean yield. The lowest yields were obtained from the plots with no weed control, because of weed competition in both crops. A row spacing x weed control interaction was not significant for seed yield (Table 4 and 5). However, the tillage systems x weed control and tillage systems x row spacing x weed control interactions were found to be significant for the seed yields, but they only accounted for less than 3% of the total variance and were deemed to be unimportant for further testing.

Table 4. Analysis of variance mean squares for soybean seed yield and weed population.

Source	d.f.	Seed yield	Weed population
Tillage system (T)	1	22930929 **	304 *
Error A	3	28589	27
Row spacing (R)	2	12455060 **	359 **
T ´ R	2	131721 *	87 **
Error B	12	9762	3
Weed control (W)	2	10063362 **	7173 **
T ´ W	2	161626 *	1401 **
R ´ W	4	78195	47 **
T ´ R ´W	4	226448 **	35 **
Error C	36	37588	6

*, ** Effect significant at *P* = 0.05 and *P* = 0.01, respectively.

Table 5. Analysis of variance for each sorghum planting system for weed infestation, grain yield and protein percentage.

		Conventional (CT)			NT after wheat			NT after clover		
Source	d.f.	Weed pop.	Grain yield	% protein	Weed pop.	Grain yield	% protein	Weed pop.	Grain yield	% protein
Replicate	4	NS	NS	NS	NS	NS	NS	NS	NS	NS
Row Spacing (S)	2	**	**	**	**	**	**	**	**	**
R x S	8	NS	NS	NS	NS	NS	NS	NS	NS	NS
Weed Control (W)	2	**	**	**	**	**	**	**	**	**
R x S x W	4	**	**	NS	**	**	NS	NS	**	NS

*, ** Effect significant at *P* = 0.05 and *P* = 0.01, respectively.

CONCLUSIONS

The results of this research indicate that with proper weed control and other management inputs, growers can improve soybean and grain sorghum yield and reduce the cost of weed control by planting in narrow rows. Although yields with NT were lower, the land preparation costs were less and soil moisture as well as total soil nitrogen levels were higher. The loss in soybean seed yield can be minimized with adequate plant stands, which can be achieved with planter modification to achieve good soil-seed contact. Grain sorghum planted no-till after clover and wheat produced more grain than in the conventional tillage

LITERATURE CITED

Bremner, J.M. and C.S Mulvaney. 1982. *IN* A.L. Page, R.H. Miller, and D. R. Keeney (eds.), Methods of Soil Analysis. Nitrogen-Total. Part 2, 2nd edn. Publ. No. 9, American Society of Agronomy, Madison, pp. 595-622.

Burnside, O. C. and R.S. Moomaw. 1977. Control of weeds in narrow-row soybeans. Agron .J., 69:793-796.

Crabtree, R.J., and R.N. Rupp. 1980. Double and monocropped wheat and soybeans under different tillage and row spacings. Agron. J., 72:445-448.

Culley, J.L.B., W.E. Lanson, and G.W Randall. 1987. Physical properties of a Typic Haplaquall under conventional tillage and no-tillage. Soil Sci. Soc. Am. J., 51:1587-1592.

Edwards, J.H., D.L. Thurlow, and J.T. Eason. 1988. Influence of tillage and crop rotation on yields of corn, soybean and wheat. Agron. J., 80:76-80.

Fehr, W.R., and C.E. Caviness. 1977. Stages of soybean development. Iowa Coop. Ext. Serv. Spec. Rep. 80, pp. 12.

Freed, B.E., E.S. Oplinger, and D.D. Butler. 1987. Velvet leaf control for solid-seeded soybean in three corn residual management systems. Agron. J., 79:119-123.

Herbert, S.J., and F.D. Baggerman. 1983. Cowpeas response to row width, density and irrigation. Agron. J., 75:982-986.

Merdock, E.C., P.A. Banks, and J.E. Toler. 1986. Shade development effects on pitted morning glory (*Ipomea lacunosa*) interference with soybeans (*Glycine max*). Weed Sci., 34:711-717.

National Crop Insurance Association, 1985. Soybean loss instructions. NCIA Review 6302, National Crop Insurance Association, Colorado Springs, CO, pp. 61-64.

Parker, M.B., W.H. Marchant, and B.J. Mullins, Jr. 1981. Date of planting and row spacing effects on four soybean cultivars. Agron. J., 73:759-762.

Statistical Analysis Systems Institute, 1982. SAS Users Guide: Statistics. SAS Institute Inc., Cary, NC. pp. 119-137.

Torri, K., B.L. Vasilas, S.G. Garmer, and C.A. Smyth. 1987. Growth and yield response of solid-seeded soybean to early season stand reduction. Agron. J., 79:555-558.

Vasilas, B.L., R.W. Esgar, W.M. Walker, R.H. Beck, and M.J. Mainz. 1988. Soybean response to potassium fertility under four tillage systems. Agron. J., 80:5-8.

Walkley, A., and J.A. Black. 1934. An examination of the Defjaroff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. J. 37:29-38.

Witt, W.W. 1984. Response of weeds and herbicides under no-till conditions. pp. 152-170. *IN* R.E. Philips and S.H. Philips (eds.), No-tillage Agriculture. Principles and Practices. Van Nostrand Reinhold, New York.

Wright, D.L., F.M. Shokes, and R.K. Sprenkel. 1984. Planting method and plant population influence on soybeans. Agron. J. 76:921-924.