9-1980

Soybean-Wheat Cropping Systems: Evaluation of Planting Methods, Varieties, Row Spacings, and Weed Control

University of Tennessee Agricultural Experiment Station

Charles R. Graves

Tom McCutchen

Larry S. Jeffery

Joseph R. Overton

See next page for additional authors

Authors
University of Tennessee Agricultural Experiment Station, Charles R. Graves, Tom McCutchen, Larry S. Jeffery, Joseph R. Overton, and Robert M. Hayes

Bulletin 597
September 1980

Soybean-Wheat Cropping Systems: Evaluation of Planting Methods, Varieties, Row Spacings, and Weed Control

Charles R. Graves
Tom McCutchen
Larry S. Jeffery
Joseph R. Overton
Robert M. Hayes

The University of Tennessee
Agricultural Experiment Station
D. M. Gossett, Dean
Knoxville

SUMMARY

Several methods of growing soybeans in single crop and double cropping systems with wheat were evaluated at Milan from 1964 through 1979. In the early years soybean yields in mulch planting and no-till systems were low due to inadequate planting equipment and poor weed control.

Five soybean varieties were evaluated in a single crop and double cropping system with wheat.

Several soybean varieties were evaluated at Milan for no-till planting after wheat harvest in rows spaced 40, 20, and 10 inches apart.

Soybeans were evaluated by double cropping with wheat when they were surface seeded in green wheat with a cyclone seeder (airplane simulation), drilled in green wheat with a Tye drill or no-till planter, no-till after wheat harvest, and planted in a conventional seedbed after wheat harvest compared with single crop soybeans. Several herbicides and herbicide combinations were evaluated for weed control under no-till double cropping of soybeans following wheat. The effect of row spacing on weed control was also evaluated.

CONCLUSIONS

Using all data for comparing single cropped soybeans vs double cropped soybeans, the yields were reduced 19% by double cropping. The wheat yields obtained more than offset the yield reduction from soybeans, thus making double cropping of soybeans and wheat appear to have economic advantages over single cropping soybeans.

Essex and Forrest (maturity group V) were the two leading varieties evaluated in a single cropping or double cropping system with wheat. The lowest soybean yield in no-till following wheat was obtained when Lee 68 or Lee 74 (maturity group VI) was used. No-till soybeans following wheat should be grown in narrow rows for maximum yields. Rows of 20 inches usually give better weed control.

Seeding soybeans in green wheat by airplane should be attempted only when adequate soil moisture is available. This cropping system was the most risky system studied. Seeding soybeans in green wheat with a Tye drill or no-till planter shows promise with slight reduction in wheat yields.

Under no-till double cropping of soybeans following wheat in Tennessee, a weed control mixture of alachlor (Lasso) 2 pounds per acre (lb./A) + linuron (Lorox) 0.75 lb./A + paraquat) 0.5 lb./A + surfactant consistently gave good to excellent control of annual grasses and common ragweed. When 1.5 lb./A of glyphosate (Roundup) was substituted for paraquat in this mixture, excellent weed control was obtained.

The mixture of metolachlor with either linuron (Lorox) or metribuzin (Sencor) + paraquat (Paraquat) + surfactant gave excellent weed control and compared favorably with the three-way mixtures. Dinoseb (Pre-emerge) or linuron, or dinoseb + naptalam (Alanap) gave adequate and erratic weed control.

A system of no-till double cropping of soybeans and wheat requires skillful management and careful planning for consistent success. Adequate soil moisture and weed control are the keys to success of a double cropping system. In planning a double cropping system, such factors as weed population, kind of weeds, water supplying capacity of the soils, and proper planting equipment are a few of the factors that must be considered. Double cropping of wheat and soybeans requires a higher level of management to accomplish than a single cropping system, but under suitable conditions this may be more profitable than the single cropping system.

CONTENTS

Soybean-Wheat Cropping Systems: Evaluation of Planting Methods, Varieties, Row Spacings, and Weed Control

by Charles R. Graves, Tom McCutchen, Larry Jeffery
Joseph R. Overton and Robert M. Hayes*

INTRODUCTION

Research was conducted at the Milan Experiment Station from 1964 through 1979 on several methods of growing soybeans in single crop and double cropping systems with wheat. Wheat was chosen for these experiments because it is the most widely grown small grain in West Tennessee.

Double cropping of soybeans and wheat was standard practice on many farms in West Tennessee, but little research information was available when these studies were started in 1964. In addition to the cropping system studied, soybeans after wheat (no-till) was studied in detail to compare varieties, row spacings, and methods of weed control. In conjunction with the replicated experiments, soybeans were grown single crop and double crop (no-till) following wheat on Production fields at Milan from 1971 through 1979.

Production practices on these fields changed as better varieties, herbicides, fertility practices, and planting and harvesting equipment were developed. The best practices from experiments were adapted to the production of soybeans and wheat on these larger acreages. In 1971 most tests were conducted in 40 inch rows for soybeans regardless of when they were planted. In the latter years most of these double cropping production fields were planted in 20 inch rows. This

*Associate Professor, Department of Plant and Soil Science (Knoxville); Superintendent, Milan Experiment Station (Milan); and Associate Professor (Knoxville); Associate Professor (Jackson); and Associate Professor (Jackson); Department of Plant and Soil Science, respectively.

is only one of the production changes that has been adapted in the latter years. In the early years, the research emphasis was on methods of growing soybeans in single cropping systems and in later years when better planters and more effective herbicides were developed, the emphasis shifted to no-till following wheat in a double cropping situation. The early work of tillage methods of growing soybeans single crop and double crop with wheat (no-till) was not included in this report due to problems encountered with inadequate no-till planters and the lack of good herbicides for adequate weed control.

The process of finding the best cropping system for growing soybeans and wheat for maximum economic returns is a never-ending process because newer and better varieties of both crops are being developed along with constant change and development of better herbicides, planting and harvesting equipment, fertilizer practices, shifts in energy cost, and the importance of soil erosion control. This bulletin is a summary of experiments at Milan Experiment Station from 1964 through 1979 that have contributed to a better understanding of growing soybeans in single and double cropping systems.

Results of Soybeans Grown as a Single Crop and Double Crop (no-till) at Milan in Production Fields From 1971 Through 1979

At Milan, from 1971 through 1979, 325 acres of double crop (no-till) soybeans and 823 acres of single crop beans were grown. The double cropped soybeans yielded 32 bushels per acre and the single crop soybeans yielded 36 bushels per acre. The single cropped soybeans produced 11% more than when grown under double cropped no-till conditions.

SECTION I

Soybean Variety – Wheat Double Cropping

A soybean variety-cropping system study was started in the spring of 1973 to compare soybean varieties of varying maturities in a single cropping system and in a double cropping system following wheat. Kent, Lee 68, Dare, Essex, and Forrest soybean varieties were seeded on May 25 in the single crop treatment in a conventional seedbed and the same varieties were seeded June 22 to simulate a double cropping situation. Lasso at 2 pounds active ingredient per acre (AI/acre) was used in 1973 and 1974 as a preemerge herbicide and the soybeans were cultivated as needed. In 1975 and 1976 Dyanap (1.5 lb. dinoseb + 3 lb. naptalam active ingredient) was used.

The soybeans were fertilized with 0-40-40 pounds per acre prior to seeding. The plot size was four rows 60 feet long and 40 inches between rows. The seeding rate was 12 seed per foot of row. The treatments were randomized in a complete block design with four replications. Arthur 71 wheat was seeded for the first time in the fall of 1973 after each soybean variety had been harvested. One treatment consisted of wheat being grown as a single crop which was planted at an early recommended planting date. The wheat was fertilized at the time of seeding each year with a mixed fertilizer at the rate of 30-60-60 pounds per acre and topdressed in the spring with 30 pounds of nitrogen. Arthur replaced Arthur 71 in the test in 1975 and Lee 74 replaced Lee 68. The test started in 1973 and was conducted in the same area on a Loring silt loam for 3 years.

The soil test results for Dec. 16, 1974 were: pH 6.2, P (M) and K (H). A similar test using the same varieties was seeded in a new area on a Loring silt loam in 1975 and 1976. The soil test results on Dec. 16, 1974 was: pH 6.1, P (H) and K (H). Results from the two areas are reported for 1975.

Results and Discussion

In the 3-year study (1973-75), Essex, Forrest, and Lee 68 yields were not significantly reduced from double cropping as shown in Table 1. Dare and Kent yields were reduced 8 bushels per acre from

Table 1. Five soybean varieties evaluated in a single cropping and double cropping system with wheat at Milan from 1973 through 1975 on a Loring silt loam

Soybean variety	Cropping[1] system	3 yr. avg. 1973-1975	1975	1974	1973
			Bushels per acre		
Essex	Single	47a	39ab	50a	51a
Essex	Double	43ab	39ab	38bc	51a
Forrest	Single	41b	35abc	42b	46ab
Forrest	Double	42b	39ab	39bc	50ab
Dare	Single	43ab	36abc	42b	50ab
Dare	Double	35c	29c	32c	43bc
Kent	Single	41b	44a	41b	39c
Kent	Double	33c	20d	36bc	44abc
Lee 68[2]	Single	37c	28cd	36bc	46ab
Lee 68	Double	35c	31bc	31c	44b
Single Crop avg.		41.8			
Double Crop avg.		37.6			

[1]Single crop—soybeans grown alone.
Double crop—soybeans grown following wheat.

[2]Evaluated as Lee 74 in 1975.

[3]Values in individual columns followed by the same letter are not significantly different at the .05 level of probability.

Table 2. Wheat yields of Arthur 71 grown alone and after soybeans at Milan in 1974 and 1975

Wheat grown after soybeans or wheat		Avg.	1975	1974
Variety	Crop		Bushels per acre	
Forrest	Soybeans	43	41	45a
Essex	Soybeans	41	40	42ab
Dare	Soybeans	39	39	40ab
Lee 68[1]	Soybeans	39	39	39ab
Kent	Soybeans	37	36	38b
Arthur 71	Wheat	26	35	16c
L.S.D. (.05)			N.S.	
			Date seeded	
			1974	1973
Forrest			Nov. 3	Oct. 24
Essex			Nov. 3	Oct. 24
Dare			Nov. 3	Oct. 24
Lee 68[1]			Nov. 3	Nov. 2
Kent			Nov. 3	Oct. 17
Arthur 71 (wheat)			Nov. 3	Sept. 18

[1] 1975 evaluated Lee 74.

double cropping with wheat. The average soybean yield reduction for double cropping with wheat was 4.2 bushels per acre. The wheat yield for wheat grown alone in 1974 was very low due to Barley Yellow Dwarf Virus (BYDV). This treatment was seeded on Sept. 18, 1973 and was attacked by aphids which spread the BYDV disease. When the wheat was seeded after soybean harvest, no disease problem from BYDV was noticed. In 1975 there were no significant differences among wheat yields. The reason for this was because all wheat plots were seeded on Nov. 3 due to the wet fall. The average wheat yield following soybeans was 40 bushels per acre (1974-75). The average soybean yield following wheat was 38 bushels per acre (1973-75) and the average single crop soybean yield (1973-74) was 42 bushels per acre. The soybean yields for the double cropping treatments were high in 1973 and 1974 due to good moisture during the growing season.

Table 3. Five soybean varieties evaluated in a single cropping and double cropping system with wheat at Milan in 1975 and 1976 on a Loring silt loam

Soybean variety	Cropping[1] system	2 yr. avg. 1975-1976	1976	1975
			Bushels per acre	
Forrest	Single	48a[2]	39a	57a
Forrest	Double	35cd	23b	47de
Essex	Single	46ab	36a	57a
Essex	Double	35cd	24b	46de
Dare	Single	44ab	33a	54ab
Dare	Double	31d	20b	43e
Lee 74	Single	44ab	34a	54abc
Lee 74	Double	35cd	21b	49cd
Kent	Single	41bc	32a	50cbd
Kent	Double	29d	16b	42e
Single Crop Avg.		44.7		
Double Crop Avg.		33.0		

[1]Single crop—soybeans grown alone.
Double crop—soybeans grown following wheat

[2]Values in individual columns followed by the same letter are not significantly different at the .05 level of probability.

In the 2-year study on a new location all five soybeans varieties produced lower yields following wheat. The average yield (Table 3) for single cropped soybeans was almost 45 bushels per acre and 33 bushels per acre for the beans following wheat. No yields of wheat were reported for this test because the wheat was planted late and all plots were winter killed.

SECTION II

Soybean Varieties Grown No-Till After Wheat in 40-, 20-, and 10-Inch Rows

Pickett, York, Essex, Dare, and Forrest were grown no-till after wheat in rows spaced 20 and 40 inches apart from 1974 through 1976 (Table 4).

Table 4. Five soybean varieties evaluated under no-till conditions in 40- and 20-inch rows at Milan following wheat from 1974 through 1976

	40" spacing				20" spacing			
Variety	**Avg.**	**1976**	**1975**	**1974**	**Avg.**	**1976**	**1975**	**1974**
	Bushels per acre							
Essex	26	18	20	39	32	20	30	44
York	24	15	21	37	28	18	27	38
Dare	23	17	18	34	28	23	23	36
Pickett 71	22	19	17	30	27	22	26	32
Forrest	21	14	16	34	27	21	23	36

	Average across spacing			
Variety	**Avg.**	**1976**	**1975**	**1974**
	Bushels per acre			
Essex	29	19	25	42
York	26	17	24	38
Dare	25	20	20	35
Pickett 71	24	21	22	31
Forrest	24	17	19	35
L.S.D. (.05)	–	N.S.	N.S.	2.7

Spacing between rows	Average across varieties			
	Avg.	**1976**	**1975**	**1974**
inches	Bushels per acre			
40	23	17	18	35
20	28	21	26	38
L.S.D. (.05)	–	2.6	3.5	3.2

Essex, Forrest, Pickett 71, and Centennial were evaluated under no-till conditions following wheat in 10- and 20-inch rows from 1977 through 1979.

All experiments were conducted on Loring or Memphis silt loam with a pH of 6.3 to 6.7. Soil tests were medium to high for P and high for K. The wheat was fertilized in the fall with a mixed fertilizer of 30-60-60 pounds per acre each year except for 1974 when 90 pounds per acre of P_20_5 was used when the soil tested medium in this element. The wheat was topdressed with nitrogen in the spring at rates ranging from 30 to 60 pounds of N per acre.

The weed control consisted of alachlor 2.0 pounds + linuron .75 pounds + paraquat .5 pounds AI/A + surfactant as a preemerge application. Metolachlor was used in 1979 in the place of alachlor. Bentazon was used as needed for cocklebur control in July and August.

The soybeans were seeded as soon after wheat harvest as possible. The planting dates for the 5 years ranged from June 8 in 1977 to June 26 in 1978.

Results and Discussion

A positive response to close row spacing was obtained each year when 40-inch spacing was compared with 20-inch spacing (Table 4). When 20-inch spacing was compared to 10-inch spacing, a significant response to closer row spacing was obtained only 1 out of the 3 years (Table 5). There was no variety X spacing interaction any year and no significant differences among the five varieties evaluated in 40- and 20-inch spacing in 1975 and 1976 (Table 4). Essex produced the highest average yield (1974-76) and also the highest average yield when grown in 20- and 10-inch row spacing. In 1977 under severe drought conditions Forrest and Essex produced 7 and 8 bushels per acre respectively. Centennial grew better and produced the highest yields under these severe drought conditions. Essex and Forrest were the leading varieties in yield in 1978 and 1979.

Table 5. Four soybean varieties evaluated under no-till condition at Milan in 20- and 10-inch rows following wheat from 1977 through 1979

	20" spacing				10" spacing			
Variety	Avg.	1979	1978	1977	Avg.	1979	1978	1977
	Bushels per acre							
Essex	26	37	26	6	29	42	36	10
Forrest	23	30	34	5	25	35	32	8
Centennial	22	30	22	14	25	31	25	19
Pickett 71	20	28	25	7	25	30	28	17

	Average across spacing			
Variety	Avg.	1979	1978	1977
	Bushels per acre			
Essex	29	40	36	8
Forrest	24	33	32	7
Centennial	23	30	23	16
Pickett 71	22	29	26	12
L.S.D. (.05)	–	6.7	2.6	4.7

Spacing between rows	Average across varieties			
	Avg.	1979	1978	1977
inches	Bushels per acre			
10	26	34	30	14
20	23	31	29	8
L.S.D. (.05)	–	2.7	N.S.	4.9

Summary

Five soybean varieties were evaluated for no-till planting after wheat harvest in rows spaced 40 and 20 inches apart from 1974 through 1976. The average response of all varieties to the closer row spacings was 5 bushels per acre. A significant response to the closer row spacing was obtained each year.

Four soybean varieties were evaluated from 1977 through 1979 in 20- and 10-inch spacing under no-till conditions following wheat. The average response to the 10-inch spacing over the 20-inch spacing was 2.8 bushels per acre. A significant response was obtained 2 out of 3 years to the closer row spacing of 10 inches. There was no variety x spacing interaction any year. Of the three varieties evaluated for the 6-year period, Essex produced the highest average yield. Essex produced the highest yield in 4 out of the 6 years.

These data show that soybeans respond to close row spacing when planted in a no-till double cropping system following wheat. Essex performed well except under severe drought conditions. However, no variety performed well under severe drought.

Table 6. Management practices used from 1974 through 1979 when soybean varieties were evaluated at Milan under no-till conditions following wheat in 40-, 20-, and 10-inch row spacing[1]

Year	Date seeded soybeans	Spacing between rows in inches			pH	Soil test		Fertilization of wheat crop		Soil type
		40	20	10		P	K	Seeding	Topdressing	
		-----Seed/ft of row------							--Lb. of N--	
1974	June 21	12	8	–	6.3	(M)	(H)	30-90-60	32	Loring S.L.
1975	June 23	12	8	–	6.8	35(H)	190(M)	0-40-60	60	Loring S.L.
1976	June 22			–	6.1	17(M)	270(H)	30-60-60	57	Loring S.L.
1977	June 8	–	9	9	6.2	21(M)	270(H)	30-60-60	60	Memphis S.L.
1978	June 26	–	9	6	6.7	40(H)	300(H)	30-60-60	46	Memphis S.L.
1979	June 16	–	10	6	6.0	16(M)	230(H)	30-60-60	67	Loring S.L.

[1] Preemerge weed control each year was Lasso 2.0 pounds + Lorox .75 pounds + Paraquat .5 pound AI/A + Surf. Dual was used instead of Lasso in 1979. Basagran 1.0 pound AI/A was used in 1979, 1977, and twice in 1976 to control cocklebur.

SECTION III

Double Cropping Systems Using Soybeans or Grain Sorghum and Wheat

In 1979, Tennessee farmers double cropped about 100,000 acres of wheat and soybeans. Many of these soybeans were seeded in wheat stubble. However, a few acres were seeded by airplane in green wheat 3 to 4 weeks before harvest.

In a no-till wheat-soybean double cropping system, soybeans are usually seeded the second or third week of June in wheat stubble. Date of planting studies have shown that yields are reduced when soybeans are planted after June 1. Therefore, any practice that would permit earlier planting of soybeans in a double-cropping system should generally result in higher yields. Also, any method of seeding soybeans in a double-cropping system that would reduce the production cost and at the same time increase soybean yields is surely needed.

At Milan and Springfield in 1976 soybean and grain sorghum yields were compared when soybeans or grain sorghum were seeded in green wheat (airplane treatment), wheat stubble (no-till), conventional seedbed after wheat harvest, and a check treatment consisting of each crop in a single cropping system. The experimental design was a randomized complete block with six replications. The data from each crop were analyzed separately.

At Milan in 1976 the airplane treatment was simulated by seeding with a cyclone seeder on May 12 in green Arthur wheat 4 weeks before harvest. The no-till wheat stubble and conventional seedbed treatments were planted on June 14 in 20-inch rows. The single crop treatments of both soybean and grain sorghum were seeded in 20-inch rows on May 21 and soybeans replanted on June 14 due to poor stand. The 20-inch row spacing was chosen for the studies because previous work has shown that late-planted beans under no-till conditions respond to narrow rows.

In addition to these treatments at Milan in 1976, an adjacent area of 12 acres was seeded by airplane with 2 bushels per acre of Essex soybeans in green wheat on May 12 or 4 weeks before harvest. Arthur wheat was used at both locations in 1976 and at Springfield in 1977. At Milan, Coker 747 was grown the second year. Essex was grown each year at both locations. McNair 546BR grain sorghum was used at Milan both years, and Funk G-516BR was used at Springfield in 1976.

At Milan in 1977, two new seeding methods were added to the experiment. The first method consisted of seeding soybeans and grain sorghum in wheat stubble on June 3 after wheat had been cut by hand on June 1 at 32% moisture and placed in a windrow and harvested with a combine on June 3. This method will be referred to as the swath method. The second method involved drilling soybeans and grain sorghum in green wheat was harvested on June 7 (at 15% moisture) and the soybean and grain sorghum no-till treatments were seeded on June 8. No new treatments were added in 1978 but a killed wheat (no-till) treatment was added in 1979. Bedford and Essex were evaluated in 1978 and Essex was evaluated in 1979.

Seeding Rates

The simulated airplane seeding of soybeans in green wheat was made with a cyclone seeder at the rate of 2 bushels per acre in 1976 and 3 bushels per acre in 1977, 1978, and 1979; 1.5 bushels of soybeans were used in the drilled plots in 1978 and 1979. All other soybean treatments were seeded at the rate of 1 bushel per acre.

Fertilization

The soil type at Milan in 1976 was Grenada-Loring silt loam in 1977, 1978 a Memphis silt loam, and in 1979 Loring silt loam. All soils had a pH of about 6.5 with P and K testing high. The soil type at Springfield in 1976 was Bewleyville and Sango silt loams and a Dickson silt loam in 1977. Fertilizer was applied to the wheat and grain sorghum but no fertilizer was added to the soybean crop.

At Milan the wheat was fertilized with 300 pounds of 10-20-20 per acre each year and was topdressed with 125 to 146 pounds of 46% urea in February. The wheat at Springfield was fertilized with 30 pounds of N in the fall and 30 pounds of N as a topdressing in the spring. P and K were applied according to soil tests each year. The grain sorghum received 60 pounds of N as a sidedressing at both locations.

Chemical Weed Control

Soybeans or grain sorghum seeded in green wheat before harvest received no weed control. Soybeans seeded in wheat stubble (no-till) received linuron (Lorox) 0.75 pound + alachlor (Lasso) 2 pounds + Paraquat (Paraquat) 0.5 pound AI/A + surfactant 0.5% by volume. Soybeans seeded in conventional seedbed were treated in 1976 and 1977 with linuron 0.75 pound + alachlor 2 pounds active ingredient per acre. In 1978 the conventional seedbed treatments received Lasso 2 pounds AI/A and in 1979 the conventional single crop treatment received Lasso 2 pounds AI/A and the conventional after wheat received Dual + Lorox. The grain sorghum seeded in wheat stubble (no-till) receive 2.0 pounds of propazine (Milogard) + paraquat (Paraquat) 0.5 pound AI/A + surfactant 0.5% by volume. The grain sorghum seeded in a conventional seedbed received only Propazine

(2 pounds AI/A). All chemical weed control treatments were applied preemergence.

Results and Discussion

In 1976 at Milan, the highest soybean yield was obtained from the soybeans seeded in green wheat (simulated airplane seeding) before harvest (39 bu/acre) (Table 9). A 12-acre field seeded by airplane at Milan produced an average yield of 46 bushels per acre. This field had been in cotton for 6 years; therefore the wheat had very little weed competition and highly fertile conditions existed. If the same field is used for airplane seeding more than 1 year, a weed problem may be encountered. The no-till treatment was next in yield at 36 bushels per acre. The conventional single crop seedbed treatment which was replanted on June 14 yielded the same as the conventional seedbed treatment on June 14 after wheat harvest, 27 bushels per acre.

At Milan, grain sorghum produced its highest yield when grown as a single crop in a conventional seedbed. The lowest grain sorghum yield was obtained from the simulated airplane treatment. At Highland Rim Experiment Station at Springfield in 1976, the grain sorghum seeded in green wheat before harvest was a complete failure. Grain sorghum planted in no-till after wheat harvest produced only 8 bushels per acre and the conventional seedbed after wheat harvest treatment produced only 18 bushels per acre. A yield of 108 bushels per acre was obtained when planted on May 15 in a conventional seedbed, single cropping situation. In 1977 at Springfield, grain sorghum was not evaluated due to its poor performance in 1976.

In 1976 and 1977 at Springfield, the highest soybean yield was obtained from the single crop treatment (Tables 8 and 11). The conventional seedbed treatment seeded after wheat harvest was a failure due to poor stand. This poor stand was due to a thick soil crust caused by a heavy rain immediately after planting. Also, some washing occurred resulting in the seed being covered too deeply. Soybeans planted in wheat stubble produced 17 and 16 bushels per acre in 1976 and 1977, respectively.

In 1977 at Springfield and Milan, the soybeans seeded in green wheat (simulating airplane seeding) failed completely (Tables 10 and 11). At Milan in 1977, a 6-acre field was seeded on April 25 with 3 bushels per acre and reseeded on May 6 with 2 bushels per acre, and both were failures. The same field was planted with no-till soybeans on July 5 in 20-inch rows and produced 24 bushels per acre.

These failures in 1977 were due to dry weather at seeding time and several days later. The swath and drilled treatments at Milan also produced low soybean yields due to severe dry weather.

Swathing of wheat shows promise as being an effective way of getting the soybeans planted a few days earlier. In 1977, the wheat

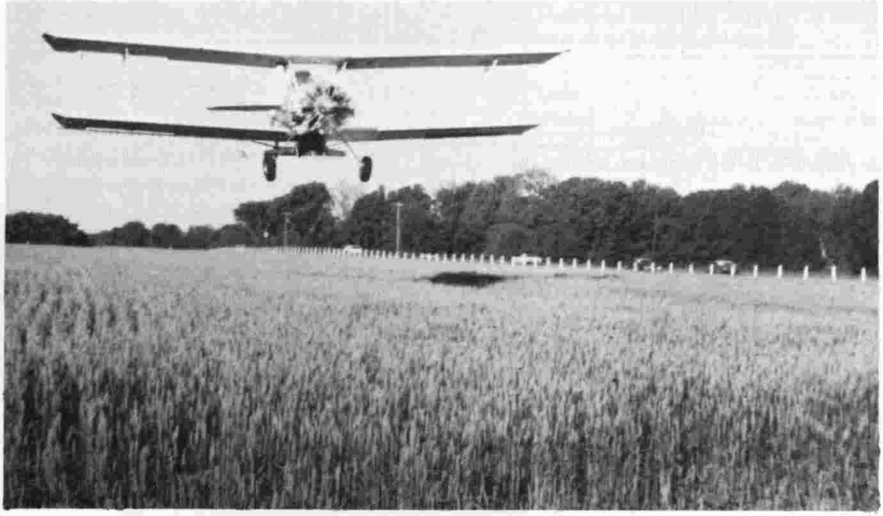

Figure 1. Airplane seeding soybeans in green wheat at Milan.

le 7. Yields of soybeans seeded in green wheat by airplane at Milan from 1975 through 1978

Year	Acres	Yield
		Bu./A
1975 Simulated	1	32.6
1976 Airplane	12	46.0
1977[1] Airplane	6	0
1978 Airplane	5	0

[1]Seeded twice—poor stand – planted no-till following wheat harvest.

Table 8. Yields of Essex soybeans and Funk G-516BR grain sorghum grown in a double-cropping system with wheat at Springfield in 1976[1]

Treatments	Date seeded	Crop	
		Soybeans	Grain sorghum
Soybeans or Grain Sorghum Seeded in:		---- Bushels per acre ----	
1. Green wheat-airplane simulation	April 22	17	0
2. Wheat stubble (no-till)	June 28	17	8
3. Conventional seedbed after wheat harvest[2]	June 28	0	18
4. Single Crop (Soybeans or grain sorghum)	May 15	35	108
L.S.D. (.05)		4.0	13.0
C.V.%		13.5	22.6

[1]Bewleyville and Sango silt loams (0% to 2% slopes).

[2]Planted with a no-till planter and a poor stand was obtained due to planting too deep in loose soil. Also a heavy rain occurred after planting which resulted in a heavy crust forming over the seed.

Table 9. Yields of Essex soybeans and McNair 546BR grain sorghum grown in a double-cropping system with wheat at Milan in 1976[1]

Treatments	Date seeded	Crop	
		Soybeans	Grain sorghum
Soybeans or Grain Sorghum Seeded in:		---- Bushels per acre ----	
1. Green wheat-airplane simulation	May 12	39	42
2. Wheat stubble (no-till)	June 14	36	90
3. Conventional seedbed after wheat harvest	June 14	27	98
4. Single crop (soybeans or grain sorghum) May 21 Soybean replanted on June 14	June 14	26	114
L.S.D. (.05)		9.1	16.5
C.V.%		23.3	15.6

[1]Loring silt loam (2% to 5% slopes).

Table 10. Yields of Essex soybeans and McNair 546BR grain sorghum grown in a double-cropping system with wheat at Milan in 1977[1]

Treatments	Date seeded	Crop	
		Soybeans	Grain sorghum
Soybeans or Grain Sorghum Seeded in:		---- Bushels per acre ----	
1. Green wheat-airplane simulation	May 11	0	0
2. Wheat stubble (no-till)	June 8	7	15
3. Conventional seedbed after wheat harvest	June 8	4	10
4. Single Crop (Soybeans)	May 12	56	72
5. Wheat stubble after swathed (windrowed)	June 3	8	10
6. Drilled in green wheat before heading	April 26	6	0
L.S.D. (.05)		5.0	10.5
C.V.%		25.0	33.0

[1]Memphis silt loam (2% to 5% slopes).

Table 11. Yields of Essex soybeans grown in a double-cropping system with wheat at Springfield in 1977[1]

Treatments	Date seeded	Yield
Soybeans Seeded in:		**Bu./A**
1. Green wheat-airplane simulation	May 17	0
2. Wheat stubble (no-till)	June 2	16
3. Conventional seedbed after wheat harvest	June 2	21
4. Single Crop (Soybeans)	May 17	24
L.S.D. (.05)		3.5
C.V.%		13.6

[1]Dickson silt loam (2% to 5% slopes).

Figure 2. Left, soybeans seeded in green wheat with a cyclone seeder (airplane simulation); and right, soybeans seeded in wheat stubble no-till at Milan in 1978.

yields were reduced from swathing at 32% moisture, but this was probably due to the swathing by hand and some grain might have been lost. Where the soybeans were drilled in the green wheat, only slight wheat yield reductions occurred.

In 1978 Bedford and Essex were evaluated (Table 12). The two varieties performed similarly except Bedford produced a low yield following wheat (no-till). This low yield was due to a poor stand. The airplane simulation treatment yields were low for both varieties with Essex producing only 14 bushels per acre. Essex yield in 1978 was reduced 5 bushels per acre (no-till) following wheat when compared to single cropped soybeans planted on May 16. This was a yield reduction of 13%. In 1979 the airplane simulation soybean yield was the lowest with soybeans seeded in killed wheat the highest (Table 13). In 1979

Table 12. Yields of Essex and Bedford soybeans grown in a double-cropping system with wheat at Milan in 1978[1]

Treatments	Date seeded	Variety		Avg.
		Essex	Bedford	
Soybeans Seeded in:		--------- Bushels per acre -------		
1. Single crop (soybeans)	May 16	39	29	34
2. Conventional seedbed after wheat harvest	June 22	37	30	33
3. Wheat stubble (16% moisture) no-till	June 13	35	34	35
4. Wheat stubble (no-till)	June 22	34	22*	28
5. Drilled in green wheat before heading	May 2	28	31	29
6. Green wheat-airplane simulation	May 8	14	24	19
L.S.D. (.05)		6.8	5.5	–
C.V.%		18.4	16.3	–

*Poor stand

[1] Memphis silt loam (2% to 5% slopes).

Table 13. Yields of Essex soybeans grown in a double-cropping system with wheat at Milan in 1979[1]

Treatments	Date seeded	Yield
Soybeans Seeded in:		**Bu./A**
1. Killed wheat (no-till)	May 11	48
2. Drilled in green wheat before heading	May 7	46
3. Wheat stubble (no-till)	June 15	44
4. Single crop (soybeans)	May 11	44
5. Wheat stubble (high moisture) no-till	June 15	41
6. Conventional seedbed after wheat harvest	June 15	41
7. Green wheat-airplane simulation	May 11	36
L.S.D. (.05)		6.5
C.V.%		12.9

[1] Loring silt loam (2% to 5% slopes).

no yield reduction was obtained from planting no-till following wheat and drilling in green wheat before harvest when compared to single cropped soybeans. The wheat yields were only reduced about 3 bushels per acre by drilling in green wheat before harvest. Using a 3-year average, the single crop soybean yields were about 19 bushels more than no-till, drilled, or conventional seedbed after wheat harvest treatments. Using a 2-year average (1978-79), the single crop yields were only 2 or 3 bushels more than these three treatments.

Summary and Conclusion

Grain sorghum, soybeans, and wheat were evaluated in a double cropping system at Springfield and Milan in 1976, 1977, and soybeans only at Milan in 1978 and 1979. At Milan and Springfield, grain sorghum performed best when grown as a single crop in a conventional seedbed. The procedure of seeding soybeans with a cyclone seeder (airplane simulation) in green wheat before harvest was a complete failure two out of six times. For the practice of seeding soybeans in green wheat by airplane to be successful, soil moisture must be adequate at seeding time and several days later, and the wheat field be relatively free of weeds. In 1978 moisture was adequate but the temperature was too low for good germination. If this practice is continued on the same field for more than 1 year, a severe weed problem may result. None of the double cropping practices was successful in 1977 due to dry weather. Soybean no-till following wheat and drilling in green wheat was successful when moisture was adequate in 1978 and 1979. Wheat yields were only slightly reduced from drilling in green wheat.

Using a 3-year average (1977-79), the soybean yields were reduced from following wheat (no-till) by 39%. However, when the 1978-79 data were considered, a yield reduction of only 4.9% was obtained. There was little difference among yields when soybean yields grown in wheat stubble (no-till), in a conventional seedbed after wheat harvest, or drilled in green wheat were compared. However, when soybeans were seeded in green wheat (airplane simulation), the yield was reduced severely.

Examples of cost and return budgets are presented in the appendix. These budgets, which were prepared by Estel H. Hudson, Extension Professor of Agricultural Economics, stationed at Jackson, are presented as a guide and will vary depending on the price and yield of wheat or soybeans and will change over time as other expenses change. These budgets can be used to calculate the net return from a cropping system when the proper yield for that system is used in the calculations.

Figure 3. Soybeans seeded in 20 inch rows with a Tye drill in green wheat at Milan in 1978.

Table 14. Soybean yields of Essex grown at Milan in five cropping systems from 1977 through 1979

Treatment	3 yr. Avg. (1977-79)	2 yr. Avg. (1978-79)	1977	1978	1979
Soybeans Seeded in:	Bushels per acre				
1. Single crop (soybeans)	46	41	56	39	44
2. Wheat stubble (no-till)	28	39	7	34	44
3. Conventional seedbed after wheat harvest	27	39	4	37	41
4. Drilled in green wheat before heading	26	37	6	28	46
5. Green wheat-airplane simulation	17	25	0	14	36

SECTION IV

Weed Control in Double-Cropped No-Tilled Soybeans Planted in Wheat Stubble

Farmers and agricultural researchers are continually searching for more efficient methods to increase crop production and to maximize net profits. Two methods which have received considerable interest are double cropping and reduced tillage, for example minimum tillage and no tillage.

The objectives of these studies were to evaluate several herbicides and herbicide combinations for better weed control in no-tillage soybeans planted into non-tilled wheat stubble and to evaluate the effects of row spacing on weed control.

Materials and Methods

Experiments were conducted at the Knoxville Plant Science Farm and the Milan Experiment Station from 1970 to 1978. The soil types, planting dates, herbicide application dates, plot size, cultivars, etc., are shown in Table 15. Natural weed infestations were used in all cases. The common name, the commercial name, and the chemical name for each herbicide tested are included in Table 16. Herbicides were applied broadcast with sprayers designed specifically for small plot weed control experiments. Spray volume was 20 to 40 gallons per acre and sprayer pressure was 30 to 40 pounds per square inch. A surfactant was included with each herbicide mixture on a 0.5% volume basis. None of the plots treated with a herbicide received any type of mechanical cultivation. At Milan, soybeans were planted with an Allis Chalmers[1] no-till planter filled with a fluted coulter and at Knoxville with a conventional International Harvester[1] planter.

Either a weed-free or a weedy check, or both, was included in each experiment. Each week-free check was hand-hoed two or three times during the season. The weeds in the weedy check were allowed to compete with the crop for the entire season. Also a mechanically tilled weed-free check was included at Knoxville in 1970. These plots were disked two or three times to prepare a conventional seedbed several days before planting and then were maintained in a weed-free condition after planting by cultivating and hand-hoeing three times during the season. The plot areas were fertilized as needed according to soil test.

[1] Mention of a specific brand does not constitute an endorsement of an implement by the University of Tennessee to the exclusion of other suitable implements.

Table 15. Conditions existing for experiments conducted from 1970 to 1978

	Knoxville		Milan					
	1970	1972	1971	1972	1974	1975	1976	1978
Soil type ▶	**Sequatchie Fine Sandy Loam**	**Sequatchie Fine Sandy Loam**	**Calloway Silt Loam**	**Grenada Silt Loam**	**Memphis-Lexington-Collins Silt**	**Collins-Lexington Silt Loam**	**Henry Silt Loam**	**Grenada Silt Loam**
Planting date	July 1	June 14	June 18	June 17	June 19	June 20	June 21	June 30
Herbicide Application date	July 1	June 18	June 18	June 17 June 22	June 20	June 21	June 21	June 30
Cultivar	**Lee**	**Lee 68**	**Dare**	**Pickett**	**Dare**	**Dare**	**Forrest**	**Bedford**
Plot size (ft.)	10 x 30	13.3 x 25	13.3 x 50	13.3 x 30	13.3 x 60	13.3 x 60	13.3 x 60	6.7 x 30
gpa	20	20	36	40	40	40	40	20
psi	30	30	40	30	40	40	40	30
Row width (inches)	20 & 40	20 & 40	40	20 & 40	20	20	20	20

Table 16. Common name, commercial name, and chemical name for herbicides used in this study

Common Name	Commercial Name	Chemical name
Alachlor	Lasso	2-chloro-2', 6'-diethyl-N-(methoxymethyl) acetanilide
Dinoseb[1]	Premerge	2-sec-butyl-4, 6-dinitrophenol
Glyphosate	Roundup	N-(phosphonomethyl) glycine
Linuron	Lorox	3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea
Metolachlor	Dual	2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl) acetamide
Metribuzin	Sencor/Lexone	4-amino-6-tert-butyl-3-(methylthio)-as-triazin-5(4H)-one
Naptalam[1]	Alanap	N-1-naphthylphthalamic acid
Oryzalin	Surflan	3,5-dinitro-N^4,N^4-dipropylsulfanilamide
Paraquat	Paraquat	1,1'-dimethyl-4,4'-bipyridinium ion

[1] A commercial mixture of dinoseb plus naptalam used was "Dyanap."

Two row spacings (20- and 40-inch) were included as main plot variables at Knoxville in 1970 and 1972 and at Milan in 1972. These experiments were arranged in a split plot design with weed control treatments as subplots. All other experiments were arranged in a randomized complete block design. All experiments were replicated three times.

Visual ratings on the basis of percent weed control were made on each experiment. In this rating scale, about 90% is considered as excellent, 75 to 90% as good, 60 to 75% as fair, and 60% or less as poor. Less than 75% is not usually acceptable and above 90% is most desirable.

Results and Discussion

Row spacing had little effect on weed control in 1970, but in 1972 at both Knoxville and Milan better weed control occurred in the 20-inch row spacing than in the 40-inch row spacing (Table 17). The degree of weed control was a combination effect between row spacing and herbicide treatment. Herbicide treatments varied from location to location and year to year; therefore, they will be discussed on an individual basis.

Slightly larger yields were obtained from 20-inch rows than from the 40-inch rows in the weed-free checks and noticeably larger yields were obtained from the 20-inch rows of the weedy checks (Table 19). Yield differences in term of bushels per acre due to row spacing were even greater where some herbicides were used. Soybean yields from the mechanically tilled check (maintained weed free) in 1970 were almost equal to the no-tilled weed-free check (Table 19).

Alachlor + Paraquat + Surfactant. This treatment provided fair to good control of annual grasses in 1970 at Knoxville, excellent control in 1971 at Milan, and at both locations in 1972 under the 20-inch row spacing (Table 17). Control of common ragweed was excellent at both Knoxville and Milan in 1972. Paraquat killed both annual grasses and broadleaf weeds which were growing in the wheat stubble at the time of herbicide application. Paraquat has no residual soil activity. Alachlor provided some residual preemergence activity on annual grasses germinating after planting but had little activity on most broadleaf weeds.

Alachlor + Linuron + Paraquat + Surfactant. This combination of herbicides provides paraquat for contact kill of existing vegetation, alachlor for preemergence and residual control of most annual grasses, and linuron for preemergence and residual control of many broadleaf weeds. In most cases this treatment gave excellent initial control of annual grasses and most broadleaf weeds (Tables 17, 18, 20). In some cases annual grasses (Table 17) became established later in the season but did not reduce yield.

Alachlor + Linuron + Glyphosate + Surfactant. This mixture of herbicides, in which glyphosate was substituted for paraquat, was compared directly to the alachlor + linuron + paraquat treatment for 4 years (Table 20). Plants manifest symptoms of paraquat injury within a few hours after application whereas symptoms of glyphosate injury may not be noticeable until a week or more after application. Glyphosate, being translocated, will kill many perennial weeds, while

Table 17. Control of annual grasses in no-till double-cropped soybeans planted in 20" and 40" rows at Milan and Knoxville, TN, 1970-1972

		Annual grass[2] response, % control											
		1970				1971		1972					
		Knoxville				Milan		Knoxville		Milan			
	Rate	20"		40"		40"		20"	40"	20"		40"	
Treatment[1]	Lb./A, A.I.	8/27	11/5	8/27	11/5	7/9	8/13	7/19	7/19	7/10	7/24	7/10	7/24
Alachlor + Paraquat + Surfactant	2.0 + 0.5	70	47	78	43	98	47	93	82	92	53	72	3
Alachlor + Linuron +Paraquat + Surfactant	2.0+0.5+0.5	–	–	–	–	99	58	98	98	98	82	98	60
Dinoseb + Surfactant	3.0	37	35	52	50	81	41	85	57	–	–	–	–
Dinoseb + Naptalam + Surfactant	1.5 + 3.0	–	–	–	–	89	57	78	27	7	3	7	0
Linuron + Surfactant	0.75	57	58	45	55	93	61	93	40	23	7	23	0
Linuron + Paraquat + Surfactant	0.75+0.5	93	66	90	63	97	57	97	94	88	0	95	0
Weed Free Check	– –	100	98	100	95	100	100						
Weedy Check	– –	0	0	0	0	0	0	0	0	0	0	0	0

[1]Surfactant X-77 was included with each herbicide treatment at the rate of 0.5% on a volume basis.

[2]Predominant annual grasses were large crabgrass and goosegrass at Knoxville and large crabgrass at Milan

Table 18. Control of common ragweed in no-till, double-cropped soybeans, at Knoxville and Milan, TN 1972

Treatment[1]	Rate lb./A A.I.	% control of ragweed					
		Knoxville		Milan			
		20"	40"	20"		40"	
				7/10	7/24	7/10	7/24
Alachlor + Paraquat + Surfactant	2.0 + 0.5	99	82	92	82	98	93
Alachlor + Linuron + Paraquat + Surfactant	2.0 + 0.5 + 0.5	99	100	98	97	100	98
Dinoseb + Surfactant	3.0	87	77	–	–	–	–
Dinoseb + Naptalam + Surfactant	1.5 + 3.0	87	64	60	0	65	32
Linuron + Surfactant	0.75	98	94	100	90	98	93
Linuron + Paraquat + Surfactant	0.75 + 0.5	100	97	93	93	100	92
Weedy Check	---------	0	0	0	0	0	0

[1]Surfactant X-77 was included with each herbicide treatment at the rate of 0.5% on a volume basis.

Table 19. Yields of no-till soybeans, planted in wheat stubble st Knoxville and Milan, Tennessee, 1970-1972

		Soybeans, yield, bu./A						
		1970		1971	1972			
		Knoxville		Milan	Knoxville		Milan	
Treatment[1]	Rate Lb./A, A.I.	20"	40"	40"	20"	40"	20"	40"
Alachlor + Paraquat + Surfactant	2.0 + 0.5	33.1	31.8	23.4	21.5	14.2	25.7	17.1
Alachlor + Linuron + Paraquat + Surfactant	2.0 + 5 + 0.5	––	––	25.0	19.6	18.2	32.9	25.2
Dinoseb + Surfactant	3.0	26.5	25.5	––	24.3	18.9	––	––
Dinoseb + Naptalam + Surfactant	1.5 + 3.0	––	––	24.5	18.5	8.4	9.3	4.1
Linuron + Surfactant	0.75	27.3	19.6	25.6	22.9	9.0	15.9	11.7
Linuron + Paraquat + Surfactant	0.75 + 0.5	27.3	20.7	22.0	21.8	26.2	28.6	18.4
Weed Free Check	–––––––	27.2	25.2	21.3			27.7	24.5
Weedy Check	–––––––	21.1	12.7	9.6	15.3	10.9	15.5	7.8

[1]Surfactant X-77 was included with each herbicide treatment at the rate of 0.5% on a volume basis.

paraquat, a contact herbicide, will kill top growth but it is not translocated in underground reproductive tissue and regrowth will occur. Control of annual grasses, pigweed, and ragweed was better in 1973 (Table 20), when glyphosate was used; however, in 1976, (Table 20) the degree of pigweed control was reversed. Regardless of year, weed control with either mixture was (commercially) acceptable.

Alachlor + Metribuzin + Paraquat + Surfactant. In 1976 and 1978, metribuzin was substituted for linuron (Table 20) to control annual broadleaf weeds. Control of annual grasses, common ragweed, and pigweed was excellent. No soybean injury was noted and yield from this treatment was the highest in the experiment.

Alachlor + Metribuzin + Glyphosate + Surfactant. Control of annual grasses in 1974 and 1976 (Table 20) was excellent, control of pigweed and common ragweed in 1976 was complete, and control of broadleaf weeds in 1978 was excellent.

Dinoseb + Surfactant. Dinoseb was included in several experiments from 1970 to 1972 (Table 17, 18, 19). Control of annual grasses at Knoxville was poor in 1970, and only good in 1971. Dinoseb has insufficient residual effect to prevent reinfestation of annual grass within a few weeks after herbicide application. Control of ragweed was good at Knoxville in 1972. When compared to the previously mentioned treatments, weed control was insufficient to continue testing this treatment.

Dinoseb + Naptalam + Surfactant. This mixture is available commercially under the trade name of Dyanap, Klean-Krop, or Ancrack. Control of annual grasses was good at Knoxville in 1972 and at Milan in 1971. Annual grass control at Milan in 1972 was very poor (Table 17). Control of commom ragweed was fair to good depending on location (Table 18). This combination did not compare favorably with the three-way combinations discussed previously.

Linuron + Surfactant. This herbicide was included in four experiments at either Knoxville or Milan from 1970 to 1972. Control of annual grasses was poor to excellent depending on location and year (Table 17). Herbicide activity was influenced by the amount of rainfall received after herbicide application. In 1971, 0.27 inches of rainfall was received at Milan 1 day after spray application and another 1.14 inches over a 4-day period within the first 10 days after application. Control of annual grasses was excellent. In 1972 a trace of rain was recorded 4 days after application, another trace 9 days after application, 1.38 inches 10 days after application, and then an

Table 20. Control of annual grasses, redroot pigweed, and common ragweed in no-till soybeans planted in wheat stubble at Milan, Tennessee, 1973, 74, 76, 78

Treatment[1]	Rate lb./A A.I.	% control: Annual Grasses 1973	Annual Grasses 1974	Annual Grasses 1976	Annual Grasses 1978	Pigweed 1973	Pigweed 1976	Ragweed 1972	Ragweed 1976	Broadleaf weeds 1978
Alachlor[2] + Linuron[3] + Glyphosate[4]	2.0[2] + 0.75[2] + 1.5	83	93	96	95	96	87	98	100	96
Alachlor[2] + Linuron[3] + Paraquat + Surfactant	2.0 + 0.75 + 0.5	70	95	97	96	93	100	86	100	94
Alachlor[2] + Metribuzin + Glyphosate[4]	2.0 + 0.5 + 1.5	–	97	92	91	–	100	–	100	93
Alachlor[2] + Metribuzin + Paraquat + Surfactant	2.0 + 0.5 + 0.5	–	–	97	95	–	100	–	100	93
Metolachlor + Linuron[3] + Paraquat + Surfactant	2.0 + 0.75[3] + 0.5	–	–	99	96	–	100	–	100	96
Metolachlor + Metribuzin + Paraquat + Surfactant	2.0 + 0.5 + 0.5	–	–	99	92	–	100	–	100	92
Oryzalin + Linuron[3] + Paraquat + Surfactant	1.0 + 0.75[3] + 0.5	–	–	99	96	–	100	–	100	95
Oryzalin + Metribuzin + Paraquat + Surfactant	1.0 + 0.5 + 0.5	–	–	99	95	–	100	–	100	95
Weedy Check	–––––––	0	0	0	0	0	0	0	0	0

[1]Surfactant X-77, was added to all herbicide mixtures which included paraquat.

[2]Alachlor rate was 2.5 lb./A in 1978.

[3]Linuron rate was 1.0 lb./A in 1978

[4]Glyphosate rate was 2.0 lb./A in 1978

additional 5.39 inches fell over the next 10-day period. Control of annual grasses was very poor. First it was too dry and the herbicide probably was deactivated on the soil surface and then any remaining active herbicide was diluted in the soil profile by the leaching activity of the heavy rains. In 1972 when adequate rainfall occurred in Knoxville within 2 days after application, annual grass control was excellent. In 1970 rainfall was very sparse and grass control was only fair. Control of ragweed at Knoxville and Milan in 1972 was excellent (Table 18). The ragweed was probably growing in the wheat stubble at the time the linuron was applied. Linuron plus surfactant had good postemergence activity on broadleaf weeds. Postemergence activity does not depend on rainfall; therefore, ragweed control in 1972 was excellent despite the dry conditions at Milan.

Linuron + Paraquat + Surfactant. Adding paraquat to linuron plus surfactant increased the control of annual grasses (Table 3). This would indicate better control of grasses already established in wheat stubble at the time of herbicide application since paraquat had little or no preemergence activity. Ragweed control was about the same as it was without the addition of paraquat. This combination had little effect on soybean vigor and soybean yield was in proportion to weed control obtained (Tables 17, 18, 19).

Metolachlor + Linuron + Paraquat + Surfactant. This combination was included in 1976 and 1978 (Table 20). Metolachlor was substituted for, and compared to alachlor for the control of annual grasses. Control of annual grasses, pigweed, ragweed, and annual broadleaf weeds was excellent. No crop injury or yield reduction was noted.

Metolachlor + Metribuzin + Paraquat + Surfactant. In this tank mixture, paraquat was included for initial contact kill, metolachlor for control of annual grasses, and metribuzin for control of annual broadleaf weeds. The mixture was included in the experiments conducted at Milan in 1976 and 1978 (Table 20). Control of annual grasses and broadleaf weeds was excellent in both years. Control was slightly less in 1978 with this mixture than when linuron was included instead of metribuzin.

Oryzalin + Linuron + Paraquat + Surfactant. In this mixture oryzalin is included for controlling annual grasses and should be compared with either alachlor or metolachlor. Control of annual grasses was excellent in both 1976 and 1978 (Table 20). It compared very favorably with alachlor and metolachlor. The mixture gave excellent control of broadleafed weeds. Oryzalin caused some soybean vigor reduction in 1976 and possibly reduced yield (Table 21). This did not occur in 1978. If crop injury is to be prevented, the amount of soil covering the seed after planting seems to be more critical when oryzalin is used than when either alachlor or metolachlor is used.

Oryzalin + Metribuzin + Paraquat + Surfactant. This mixture also gave excellent control of annual grasses and broadleaf weeds in both 1976 and 1978. Crop injury also occurred in 1976 and some occurred in 1978. Yield was reduced in 1976 but not in 1978 (Table 21).

Summary

Under the conditions existing in Tennessee, alachlor (2 lb./A) + linuron (0.75 lb./A) + paraquat (.05 lb./A) + surfactant (0.5% v/v) consistently gave good to excellent control of annual grasses and common ragweed. Although not tested as long, the mixture of alachlor (2 lb./A) + linuron (0.75 lb./A) + glyphosate (1.5 lb./A) also gave excellent weed control. This mixture was slightly superior in some cases, and will provide greater potential in areas where perennial weeds are a problem. The substitution of metribuzin for linuron in these mixtures is a definite possibility since weed control with it was excellent in each case tested. The mixture of either metolachlor (2.0 lb./A) + Linuron (0.75) + paraquat (0.5 lb./A) + surfactant or metolachlor (2.0 lb./A) + metribuzin (0.5 lb./A) + paraquat (0.5 lb./A) + surfactant gave excellent control of weeds in the 2 years tested. When oryzalin was substituted for either metolachlor or alachlor in the mixtures, weed control was excellent but a greater probability of soybean injury exists. Linuron (0.75 lb./A) + paraquat (0.5 lb./A) + surfactant gave excellent weed control and compared favorably with the three-way mixtures. Dinoseb, dinoseb + naptalam, and linuron gave inadequate and erratic weed control.

In some experiments, better weed control was obtained when soybeans were planted in 20-inch rows than in 40-inch rows.

Acknowledgments

The authors express their appreciation to Chevron Chemical Company, Ciba-Geigy Corporation, Dow Chemical, E. I. duPont deNemours and Co., Elanco Products Company, Mobay Chemical Corporation, Monsanto Company, and Uniroyal Chemical for supplying the herbicides used in this study and for grants-in-aid which provide partial support to the weed control project. The authors also express their appreciation to the various graduate students who have helped in collecting and analyzing data and to all who have helped conduct these experiments.

Table 21. Vigor reduction and yield of no-till, stubble-planted soybeans after applying various herbicides, Milan, Tennessee, 1973, 74, 76, 78

Treatment[1]	Rate lb./A A.i.	Vigor reduction				Yield, bu./A[2]		
		1973	1974	1976	1978	1973	1976	1978
Alachlor[3] + Linuron[4] + Glyphosate[5]	2.0[2] + 0.75[2] + 1.5	0	0	2	0	29.2	15.3	22.2
Alachlor[3] + Linuron[4] + Paraquat + Surfactant	2.0 + 0.75 + 0.5	0	0	7	3	39.4	15.2	24.0
Alachlor[3] + Metribuzin + Glyphosate[5]	2.0 + 0.5 + 1.5	–	0	0	2	––	15.1	24.8
Alachlor[3] + Metribuzin + Paraquat + Surfactant	2.0 + 0.5 + 0.5	0		0	2	––	20.1	27.3
Metolachlor + Linuron[4] + Paraquat + Surfactant	2.0 + 0.75[3] + 0.5	–		0	2	––	23.1	24.3
Metolachlor + Metribuzin + Paraquat + Surfactant	2.0 + 0.5 + 0.5	–		0	3	––	20.0	27.7
Oryzalin + Linuron[4] + Paraquat + Surfactant	1.0 + 0.75[3] + 0.5	–		20	3	––	9.1	29.8
Oryzalin + Metribuzin + Paraquat + Surfactant	1.0 + 0.5 + 0.5	–		22	10	––	10.7	29.8
Weedy Check	–––––––	–		0	0	16.5	10.7	––
					LSD .05		5.4	

[1]Surfactant X-77, was added to all herbicide mixtures which included paraquat.

[2]Soybeans were not harvested in 1974.

[3]Alachlor rate was 2.5 lb./A in 1978.

[4]Linuron rate was 1.0 lb./A in 1978.

[5]Glyphosate rate was 2.0 lb./A in 1978.

APPENDIX

SOYBEANS

Soybeans Aerial Seeded In Green Wheat
Estimated Returns and Expenses Per Acre

Item	Description	Unit	Quantity	Price (Dollars)	Amount (Dollars)
Revenue	**Beans**	**Bu.**	**20**	**$ 6.50**	**$130.00**
Expenses					
a. **Variable**					
Seed	Broadcast	bu.	3	8.25	24.75
Inoculation	Rhizobium japonicum	pkg.	.33	.45	.15
Fertilizer	P_2O_5	lb.	.40	.25	10.00
	K_2O	lb.	.40	.12	4.80
Lime	3T every 4 yrs.	Ton	.75	10.50	7.88
Weed control					
Over-Top	Basagran	pt.	1.5	7.81	11.42
Round-up	Rope wick				1.50
Flying-on	$2 per acre plus $1 per bu.	Ac.	1	5.00	5.00
Truck	2 Ton	hr.	.37	8.00	2.64
Tractor	100 HP	hr.	.38	7.58	2.88
Combine	13.5' SP	hr.	.33	17.25	5.69
			Total variable costs		76.71
b. **Fixed**					
Tractor	100 HP	hr.	.38	$ 4.71	$ 1.56
Truck	2 Ton	hr.	.33	3.78	1.25
Combine	13.5' SP	hr.	.33	25.71	8.48
			Total fixed expenses		$ 11.29
		Total variable and fixed expenses			$ 88.00
	Net Return to land, labor, capital, and management				$ 42.00

Labor distribution

	JA	SO	ND
Spray	.08		
Rope wick (2x)	.30		
Harvest and Haul		.5	.32
Total	.38	.5	.32

WHEAT (Drilled)

Estimated Returns and Expenses per Acre

Item	Description	Unit	Quantity	Price (Dollars)	Amount (Dollars)
Revenue					
Wheat	**Grain**	**Bu.**	**40**	**$ 3.75**	**$150.00**
Expenses					
a. Variable					
Seed		bu.	1.25	8.75	10.94
Fertilizer	N	lb.	75	.23	17.25
	P_2O_5	lb.	50	.25	12.50
	K_2O	lb.	30	.12	3.60
Lime		Ton	.4	10.50	4.20
Tractor	100 HP	hr.	.8	7.58	6.06
Combine	13.5 SP	hr.	.33	17.25	5.69
Truck	2 ton	hr.	.33	8.00	2.64
Other machinery					.75
			Total variable expenses		$ 63.63
b. Fixed					
Tractor	100 HP	hr.	.8	4.11	3.29
Truck	2 ton	hr.	.33	3.78	1.25
Combine	13.5' SP	hr.	.33	25.71	8.48
Other machinery					2.16
			Total fixed expenses		$ 15.18
			Total variable and fixed expenses		$ 78.81
			Net Return to land, labor, capital, and management		$ 71.19

Labor distribution

	JF	MA	MJ	JA	SO	ND
Top dress	.2					
Spread fert.					.2	
Disc					.25	
Drill					.25	
Combine and haul			.8			
Total	.2		.8		.7	

SOYBEANS

Soybeans In Green Wheat (Killed)
No-Till – 20" Rows
Estimated Returns and Expenses per Acre

Item	Description	Unit	Quantity	Price (Dollars)	Amount (Dollars)
Revenue	**Beans**	**Bu.**	**28**	**$ 6.50**	**$182.00**
Expenses					
a. Variable					
Cover crop	Wheat disc-in				17.12
Seed	6-8 plants/ft.	lb.	60	.15	9.00
Inoculation	Rhizobium japonicum	pkg.	.33	.45	.15
Fertilizer	P_2O_5	lb.	40	.25	10.00
	K_2O	lb.	40	.12	4.80
Lime	3 T. every 4 yrs.	Ton	.75	10.50	7.88
Weed control					
Pre-plant	Paraquart[1] +	pt.	2.0	4.70	9.40
	Lorox +	lb.	1.5	4.26	6.39
	Lasso +	qt.	2.25	3.87	8.71
	Surfactant X-77				.30
Post-emerge	Basagran	pt.	1.5	7.81	11.72
Tractor	100 HP	hr.	.4	7.58	3.03
Sod planter	4 Row	hr.	.3	4.46	1.34
Sprayer	20 ft.	hr.	.1	.60	.06
Combine	13.5' SP	hr.	.33	17.25	5.69
Truck	2 Ton	hr.	.33	8.00	2.64
			Total variable expenses		$ 98.23
b. Fixed					
Tractor	100 HP	hr.	.4	4.11	1.64
Sod planter	4 row	hr.	.3	9.56	2.96
Sprayer	20 ft.	hr.	.1	1.76	.18
Combine	13.5' SP	hr.	.33	25.71	8.48
Truck	2 Ton	hr.	.33	3.78	1.25
			Total fixed expenses		$ 14.51
			Total variable and fixed expenses		$112.74
			Net Return to land, labor, capital, and management		$ 69.26

Labor distribution

	MJ	SO	ND
Plant	.4		
Spray	.1		
Combine and haul		.5	.32
Total	.5	.5	.32

[1]If planted in heavy grass sod, increase paraquat to 1 quart; could also use Sencor instead of Lorox, or Dual instead of Lasso or Lexone in place of Sencor.

SOYBEANS

Soybeans Drilled In Green Wheat
20" Rows
Estimated Returns and Expenses per Acre

	Item	Description	Unit	Quantity	Price (Dollars)	Amount (Dollars)
	Revenue	**Beans**	**Bu.**	**28**	**$ 6.50**	**$182.00**
	Expenses					
a.	**Variable**					
	Seed	2½ – 3 plants per ft. of row	lb.	90	.15	13.50
	Inoculation	Rhizobium japonicum	pkg.	.33	.45	.15
		P_2O_5	lb.	40	.25	10.00
		K_2O_5	lb.	40	.12	4.80
	Lime	3 ton every 4 yrs.	Ton	.75	10.50	7.88
	Weed control					
	Round-up	Wick-bar	Ac.	1.0		1.50
	Over-top	Basagran	pt.	1.5	7.81	11.72
	Tractor	100 HP	hr.	.6	7.58	4.55
	Truck	2 ton	hr.	.33	8.00	2.64
	Combine	13.5' SP	hr.	.33	17.25	5.69
	Machinery	Drill 13'	hr.	.25	2.50	.63
					Total variable costs	$ 63.09
b.	**Fixed**					
	Tractor	100 HP	hr.	.6	4.11	2.47
	Truck	2 ton	hr.	.33	3.78	1.25
	Combine	13.5' SP	hr.	.33	25.71	8.48
	Machinery	Drill 13'	hr.	.25	6.25	1.56
					Total fixed expenses	$ 13.76
					Total variable and fixed expenses	$ 76.85
					Net Return to land, labor, capital, and management	$105.15

Labor distribution

	MJ	JA	SO	ND
Drill	.3			
Spray		.08		
Rope wick		.30		
Combine and haul			.50	.32
Total	.3	.38	.50	.32

SOYBEANS

No-Till – 20" Rows
Estimated Returns and Expenses per Acre

Item	Description	Unit	Quantity	Price (Dollars)	Amount (Dollars)
Revenue	**Beans**	**bu.**	**28**	**$ 6.50**	**$182.00**
Expenses					
a. Variable					
Seed	608 plants/ft.	lb.	60	.15	9.00
Inoculation	Rhizobium japonicum	pkg.	.33	.45	.15
Fertilizer	P_2O_5	lb.	40	.25	10.00
	K_2O	lb.	40	.12	4.80
Lime	3 T. every 4 yrs.	Ton	.75	10.50	7.88
Weed control					
Pre-plant	Paraquat[1] +	pt.	1.0	4.70	4.70
	Lorox +	lb.	1.5	4.26	6.39
	Lasso +	qt.	2.25	3.87	8.71
	Surfactant X-77				.30
Post-emerge	Basagran	pt.	1.5	7.81	11.72
Tractor	100 HP	hr.	.4	7.58	3.03
Sod planter	4 row	hr.	.3	4.46	1.34
Sprayer	20 ft.	hr.	.1	.60	.06
Combine	13.5' SP	hr.	.33	17.25	5.69
Truck	2 ton	hr.	.33	8.00	2.64
			Total variable expenses		$ 76.41
b. Fixed					
Tractor	100 HP	hr.	.4	4.11	1.64
Sod planter	4 row	hr.	.3	9.56	2.96
Sprayer	20 ft.	hr.	.1	1.76	.18
Combine	13.5' SP	hr.	.33	25.71	8.48
Truck	2 ton	hr.	.33	3.78	1.25
			Total fixed expenses		$ 14.51
			Total variable and fixed expenses		$ 90.92
		Net return to land, labor, capital, and management			$ 91.08

Labor distribution

	MJ	SO	ND
Plant	.4		
Spray	.1		
Combine and haul		.5	.32
Total	.5	.5	.32

[1] If planted in heavy grass sod, increase paraquat to 1 quart; could also use Sencor instead of Lorox, or Dual instead of Lasso or Lexone in place of Sencor.

Revised 1-80
Prepared by Estel H. Hudson, Ag. Economics

SOYBEANS

Estimated Returns and Expenses per Acre

Item	**Description**	**Unit**	**Quantity**	**Price (Dollars)**	**Amount (Dollars)**
Revenue					
Soybeans	**Beans**	**bu.**	**28**	**$ 6.50**	**$182.00**
Expenses					
a. Variable					
Seed	8-10 plants/ft.	lb.	40	$ .17	$ 6.80
Inoculation	Rhizobium japonicum	pkg.	.33	.45	.15
Fertilizer	P_2O_5	lb.	40	.25	10.00
	K_2O	lb.	40	.12	4.80
Lime	3 tons every 4 yrs.	ton	.75	10.50	7.88
Weed control					
Pre-plant	Treflan 4 lb./gal.	pt.	1.5	3.50	5.25
Pre-emerge	Sencor	pt.	.75	8.70	6.52
Post-emerge	Basagran	pt.	1.5	7.81	11.72
Tractor	100 PTO-HP	hr.	1.39	7.58	9.78
Truck	2 ton	hr.	.33	8.00	2.64
Combine	13.5' SP	hr.	.33	17.25	5.69
Other machinery					4.55
			Total variable expenses		$ 75.78
b. Fixed					
Tractor	100 PTO-HP	hr.	1.39	$ 4.11	$ 5.71
Truck	2 ton	hr.	.33	3.78	1.25
Combine	13.5' SP	hr.	.33	25.71	8.48
Other machinery					6.92
			Total fixed expenses		$ 22.36
			Total variable and fixed expenses		$ 98.14
			Net Return to land, labor, capital, and management		$ 83.86

Revised 1-80
Prepared by Estel H. Hudson, Ag. Economics

SOYBEANS – (Prepared Seedbed)

Drilled In 7' Rows
Estimated Returns and Expenses per Acre

	Item	Description	Unit	Quantity	Price (Dollars)	Amount (Dollars)
	Revenue	**Beans**	**bu.**	**28**	**$ 6.50**	**$182.00**
	Expenses					
a.	**Variable**					
	Seed	2½-3 plants per ft. of row	lb.	60	$ .15	$ 9.00
	Inoculation	Rhizobium japonicum	pkg.	.33	.45	.15
	Fertilizer	P_2O_5	lb.	40	.25	10.00
		K_2O	lb.	40	.12	4.80
	Lime	3 ton every 4 yrs.	ton	.75	10.50	7.88
	Weed control					
	Pre-plant	Treflan 4 lb./gal.	pt.	1.5	3.50	5.25
	Pre-emerge	Lorox	lb.	1.5	4.26	6.39
	Over-top	Basagran	pt.	1.5	7.81	11.72
	Tractor	100 HP	hr.	1.42	7.58	10.76
	Truck	2 ton	hr.	.33	8.00	2.64
	Combine	13.5' SP	hr.	.33	17.25	5.69
	Other machinery					$ 1.85
					Total variable costs	$ 76.13
b.	**Fixed**					
	Tractor	100 HP	hr.	1.42	4.11	5.84
	Truck	2 ton	hr.	.33	3.78	1.25
	Combine	13.5' SP	hr.	.33	25.71	8.48
	Other machinery					3.74
					Total fixed expenses	$ 19.31
					Total variable and fixed expenses	$ 95.44
					Net Return to land, labor, capital, and management	$ 86.56

Labor distribution

	MA	MJ	JA	SO	ND
Chisel or plow	.35				
Disc		.25			
Disc		.25			
Do-all		.25			
Drill		.37			
Spray		.08			
Combine + haul				.50	.32
Total	.35	1.20		.50	.32

Revised 1-80
Prepared by Estel H. Hudson, Ag. Economics

(2.2M/1-81)