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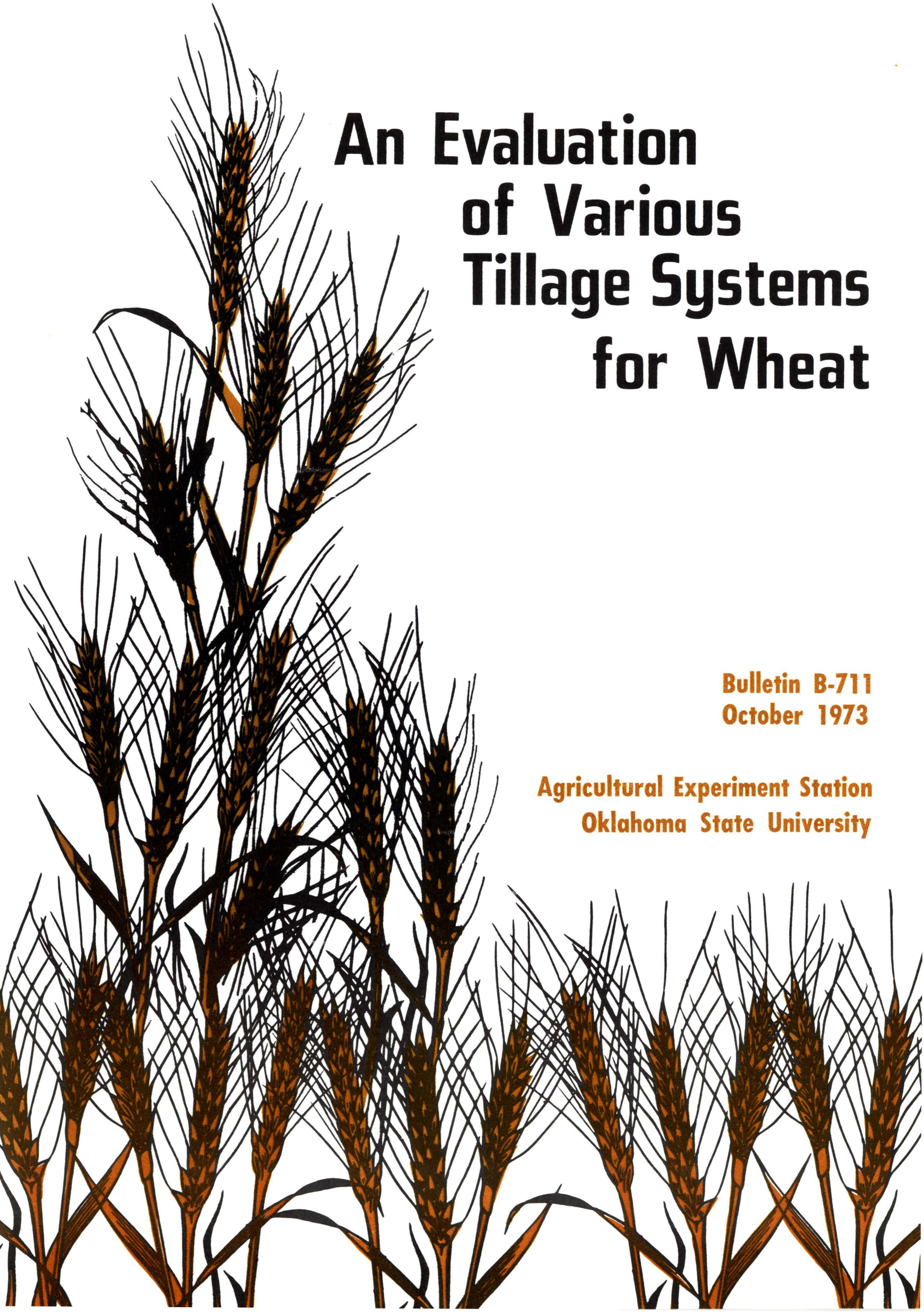

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An Evaluation of Various Tillage Systems for Wheat

J. M. Davidson and P. W. Santelmann[1]
Agronomy Department

Food and fiber requirements in the United States continue to rise, but higher grower operational expenses demand that these production increases be achieved more economically than in the past. As a result of these two pressures, new tillage systems requiring less mechanical energy are being developed and evaluated throughout the United States.

Recently, several new tillage systems for row crops have been introduced. These methods, frequently referred to as "minimum tillage", involve less traffic over the soil. Consequently, they reduce both time and cost of seedbed preparation to the grower, and may also improve and preserve soil physical properties beneficial to plant growth.

The term minimum tillage has been used to describe several types of tillage systems. Agricultural engineers have used the term to describe a plow and plant (9) system with no other intermediate cultivations used in seedbed preparation. The same term, however, has been used to describe procedures where herbicides were used for weed control and fewer than normal mechanical soil tillages were performed. "No tillage" has been used to describe those systems where no soil disturbance occurs at any time (10). No tillage has worked in some regions for row crops, but its suitability for small grains in the Great Plains has not been established.

A tillage system for wheat must accomplish the following: (1) control weeds between the harvest to plowing period, (2) prevent wind and water erosion, (3) conserve soil water and enhance water infiltration and (4) be economical.

The conservation of soil-water during the harvest to planting period represents a serious problem in the Great Plains. Water storage efficiencies (change in soil-water content during the fallow period divided

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[1] Associate Professor and Professor, respectively, Department of Agronomy, Oklahoma State University.

by total rainfall during the fallow period) of 26 percent or less (7) have been reported for fallow wheat land in this region. The use of stubble mulch tillage (which maintains wheat stubble on the surface) has increased the efficiency to 34 percent (3) for similar climatic and fallow procedures. Army et al. and Wicks et al. (14) have reported higher-soil-water contents in the top 6 cm of soil where herbicides were used for weed control as compared to adjacent experimental plots where conventional tillage procedures were employed.

Changes in soil physical conditions under minimum or no tillage systems have not been studied extensively. Tanchandropongs and Davidson (12) have shown that aggregate stability, organic matter content and bulk density were significantly better in the top 12 inches of soil after 11 years of stubble mulching in wheat, compared to conventional plow or clean tillage procedures. However, these same authors show yield reductions on treatments possessing what are frequently considered better soil physical conditions. Rao et al. (9) observed better soil physical conditions under minimum tillage practices as well as equal or superior corn yields. The minimum tillage system was significantly influenced by soil texture with the coarser textured soils being better suited to the minimum tillage practice.

This study was initiated in order to determine what changes in soil-physical conditions and soil-water storage occur under various tillage systems for continuous wheat. Soil physical conditions, soil-water content at specific periods of the year and wheat yield were all measured and evaluated. Also, visual observations concerning weed control in the various wheat tillage systems were made.

Experimental Procedure

This study was conducted on the Wheatland Conservation Experimental Station, Cherokee, Oklahoma. The station was closed at the end of the 1969 harvest. The soil is a Grant silt loam with a surface slope of 2 percent. Each treatment was replicated three times in a randomized block design, using 35 x 100 ft. plots.

The treatments were initiated in the fall of 1965 and consisted of the following practices during the harvest to planting period:

01 Clean tillage — moldboard plow immediately after harvest and cultivate as needed for weed control.

02 Stubble mulch — use large sweep (3 foot wide blade) immediately after harvest and as needed for weed control.

03 Check — allow weeds to grow.

04 Close mow — mow weeds as needed to prevent rank growth.

05 Chemical — use 1 lb/A of paraquat (1,1'-dimethyl-4,4' bipyridinium ion) as needed for weed control.

06 Chemical (pre and contact) — apply 4 lb/A of propachlor (2-chloro-N-isopropyl-acetanilide) immediately after harvest and paraquat thereafter as needed for weed control.

07 Mechanical plus chemical — use large sweep immediately after harvest and 1 lb/A paraquat as needed for additional weed control.

The exact procedures and dates of activity are given in the appendix for each treatment. All treatments were planted in October of each year with Kaw wheat, and fertilized with 20 lb of N per acre and 20 lb of P_2O_5 per acre. A topdressing of 20 lb of N per acre was made during the spring of 1966, but was increased to 40 lb per acre during the last three years of the study. A field cultivator or springtooth harrow was used in treatment 01 for weed control. Treatment 01 was plowed 6-9 inches deep and the sweep treatments (02 and 07) were never set deeper than 3 inches.

Grain yields from each plot within the study were obtained by harvesting an 8 by 92-foot strip with a standard 8-foot combine. The amount of dry residue (straw) remaining on the soil surface in May was determined by sampling two random 9 ft square areas in each plot. Soil-water content was measured using a neutron meter. Soil-water content measurements were obtained from 6, 12, 24, 36, and 48 inches. One neutron access tube was located in the center of each plot (total of 21 tubes).

Disturbed and undisturbed soil samples were collected after the 1969 harvest at two random locations within each plot. Soil depths sampled were 0-3, 3-6, 6-9, 9-12, 12-15, and 15-18 inches. The soil-water content at sampling was uniform across the experimental area. No tillage operations had been performed prior to sampling.

Undisturbed 3 by 3 inch soil cores were taken at each 3-inch soil increment to 15-inches. A steel cylindrical sampler equipped with a driving assembly and cutting edge similar to that described by Van Doren and Kingebiel (4) was used to obtain the soil cores. Each core was trimmed to size in the field and placed in a paraffin-coated cardboard container for transit to the laboratory. All cores were oven dried at 105 C, weighed, and the soil bulk density was calculated. Disturbed samples for aggregate stability and organic matter determinations were collected at the same locations and time in 3-inch increments to 18-inches.

The amount of organic matter in each sample was measured using the modified Schollenberger procedure (5). A 0.5 g sample of 20 mesh air-dried soil was treated with 0.4 N $K_2Cr_5O_7$ and concentrated sulfuric acid added and heated to 165 C. Excess dichromate was back titrated with ferrous ammonium sulfate to a red end point and this value converted to percent organic matter. Undecomposed surface residue was not included in these samples.

Samples of the disturbed soil were air-dried at room temperature and sieved through an 8 mm screen. Aggregates or clods larger than 8 mm were pulled apart until their sub-units were small enough to pass through the 8 mm screen. Water stable aggregate analyses were made using the wet-sieve method described by Kemper and Chepil (6).

For aggregate stability measurements, a 30 g sample of aggregates less than 8 mm but larger than 2 mm was wet under vacuum in a desiccator with de-aired water. The saturated aggregate sample was then transferred to a nest of sieves that oscillated up and down in a water bath for 15 minutes at 40 cycle/minute. The nest of sieves consisted of a 2 mm over a 0.25 mm sieve. After the 15 minute oscillation period, the over-dry weight of the soil material on each sieve was measured and recorded as percent of over-dry soil added. The percent water present in the 30 g sample was determined by oven-drying a separate representative soil sample.

The field experiment was a randomized complete block design. An analysis of variance was conducted for each set of measurements and the Duncan Multiple Range Test was used to determine the significant difference between treatments at the 5 percent level.

The number of cultivations and chemical treatments for weed control between harvest and planting for the various tillage systems during each year of the study is given in Table 1 of the Appendix. The study area has been stubble mulched prior to initiating the study on October, 1965.

Table 1. Percent Organic Matter

	Depth (Inches)					
Treatment	**0-3**	**3-6**	**6-9**	**9-12**	**12-15**	**15-18**
01	1.11	1.11	1.07	0.94	0.86	0.78
02	1.33	1.27	1.12	1.01	0.92	0.83
03	1.42	1.27	1.17	0.96	0.83	0.77
04	1.26	1.20	1.24	1.06	0.92	0.86
05	1.50	1.35	1.37	1.27	1.21	1.03
06	1.33	1.17	1.16	1.12	0.95	0.90
07	1.27	1.08	1.14	0.96	0.83	0.71
Ave.	1.32	1.21	1.18	1.05	0.93	0.84

Results and Discussion

The average organic matter content at each soil depth for the seven treatments is given in Table 1. There was no significant difference in organic matter content at any soil depth owing to treatment at the end of the study. A normal decrease in organic matter content with soil depth was observed in each treatment. The clean tilled or plowed treatment (01) shows a lower organic matter content in the top 0-3 inches of soil than the other treatments, but owing to sample variability the difference was not significant. These values are somewhat less than those reported by Tanchandrphongs and Davidson (12) for the same soil series, but are typical for the area. Owing to the large variability between replications and the short duration of the study, the lack of a significant difference between treatments was not unexpected.

The average soil bulk density distribution in the top 15 inches of each treatment by 3 inch increments is given in Table 2. There was no significant difference in bulk density owing to treatment in the top 9 inches of the profile. The difference between treatments 01 (plow) and 04 (close mow) at the 9-12 inch depth is difficult to justify and probably has no physical significance. However, the significant difference noted between treatments 01 and 02 (sweep or stubble mulch) suggests that compaction may be occurring below the plow depth. The amount of compaction is not clear in that the tillage system for treatments 02 and 07 (sweep and chemical) are similar, but yet they do not agree based on bulk density values. The result of Tanchandrphongs and Davidson (12) clearly illustrated compaction below the plow depth (9-12 inches) when compared to stubble mulching (sweep). Again the short duration of the study makes it difficult to separate small changes in soil physical properties owing to the tillage system imposed.

Table 2. Soil Bulk Density

	Soil Depth (Inches)				
Treatment	0-3	3-6	6-9	9-12	12-15
01	1.46	1.51	1.55	1.47 a*	1.42 a*
02	1.45	1.54	1.48	1.39 ab	1.28 c
03	1.50	1.52	1.54	1.40 ab	1.39 a
04	1.51	1.55	1.50	1.33 b	1.33 abc
05	1.45	1.48	1.48	1.36 ab	1.30 bc
06	1.46	1.51	1.51	1.43 ab	1.32 abc
07	1.45	1.51	1.55	1.38 ab	1.37 abc
Average	1.47	1.52	1.52	1.39	1.34

*Any numbers followed by the same letter in any column are not statistically significantly different.

Aggregate stability measurements were performed only on the 0-3 inch soil samples. These measurements are time consuming to make and subject to considerable error owing to sample variation and analytical procedure. It was assumed that if the aggregate stability of the surface soil was significantly changed, then soil-water infiltration, owing to soil surface stability, would also be influenced.

The average percentage of water stable aggregates in the surface soil > 2.0 mm and < 2.0 mm but greater than 0.25 mm is given in Table 3. The percentage of aggregates greater than 2.0 mm is of interest since these are indicative of changes in the macro-structure. Note that treatment 01 had the lowest percentage of large aggregates and was significantly less than all other treatments receiving no mechanical tillage (03, 04, 05, and 06). The percentage of aggregates greater than 2.0 mm in treatments receiving a minimum amount of tillage (02 and 07) were not significantly greater than in treatment 01. However, the quantity of aggregates > 2.0 mm in treatments 02 and 07 is approximately three times greater than that in treatment 01. Treatments 02 and 07 agree with one another in magnitude.

The average percentage of water stable aggregates less than 2.0 mm, but greater than 0.25 mm in each treatment was not as sensitive to tillage treatment as was the larger than 2.0 mm aggregate percentage. The only significant difference owing to treatment is that between treatments 02, 03 and 04. In general, those treatments having a high percentage of large aggregates had a lower percentage of smaller aggregates.

The amount and type of mechanical tillage appears to significantly influence the quantity of water stable aggregates greater than 2.0 mm. Wheat straw residue remaining on the surface of the chemical treatments (05 and 06) and treatments 03 and 04 (check and close mow) assists in bonding soil particles and particle groupings. The stability and

Table 3. Aggregate Stability Measurements 0-3 Inch Soil Depth

	Percent of Total Sample	
Treatment	>2.0 mm	<2.0 mm but >0.25 mm
01	8.93 a	18.0 ab
02	27.3 abc	21.9 b
03	54.9 d	10.1 a
04	41.8 bcd	10.1 a
05	46.2 cd	11.6 ab
06	32.1 bcd	14.8 ab
07	21.5 ab	20.3 ab

quantity of larger aggregates on the soil surface should, in turn, influence water conservation.

The amount of water in the top 18-inches of the soil profile in April of 1967, 68, and 69 was significantly influenced by the tillage system imposed (Table 4). Because the treatments were initiated in late 1965, no significant differences were expected or observed in April of 1966. The no tillage systems (05 and 06), in general, show more water present in the top 18 inches of soil in early spring wheat growth. Treatments 03 and 04 show similar soil water levels despite the weed growth during the 3 month fallow period. These measurements were made just prior to early spring growth.

Table 5 gives the total soil-water content in the top 54-inches of the soil profile in April of each year. Reduced tillage systems with weed control (05, 06, and 07) show more water in the profile, but the difference is not significant. Large soil-water content differences were observed in April, 1968, but owing to field variability the differences between mechanical and no-tillage treatments were not significant.

Table 4. Soil Water Content (Inches) Top 18 inches

Treatment	Date Measured			
	4/66	4/67	4/68	4/69
01	1.71 a	2.82 a	3.08 abc	3.60 a
02	2.19 a	3.42 ab	2.72 a	3.64 a
03	2.31 a	3.35 ab	3.36 abcd	3.90 ab
04	2.42 a	3.41 ab	2.77 ab	3.60 a
05	2.47 a	3.87 b	3.67 cd	4.26 b
06	2.55 a	3.52 b	3.70 cd	4.12 b
07	2.52 a	3.53 b	3.83 d	4.15 b

Table 5. Soil Water Content (Inches) Top 54 inches

Treatment	Date Measured			
	4/66	4/67	4/68	4/69
01	7.32 a	8.05 a	9.74 bc	11.9 a
02	8.63 a	9.83 a	9.30 abc	11.5 a
03	8.45 a	9.05 a	8.24 ab	11.2 a
04	7.96 a	9.08 a	7.62 a	10.2 a
05	8.39 a	9.60 a	10.21 bc	12.6 b
06	8.13 a	9.56 a	10.29 bc	12.0 a
07	9.15 a	10.57 a	11.17 c	12.0 a

The soil-water content in the top 18 inches at planting (October) is shown in Table 6. Again, owing to large sample variability, the differences between treatments were not significant. However, in all but two cases (02 in 1966 and 1968) the 05, 06, and 07 treatments had a highest water content at planting. This suggests that the reduced or no-tillage systems were able to conserve soil-water more effectively than those treatments receiving greater amounts of soil disturbance.

The results in Tables 4 and 6 agree with those presented by Army et al. (1), Simka and Wicks (11), Wicks and Simka (14), and Rao et al. (9). Less soil disturbance and more plant residue on the soil surface allows more retention of the rain that falls during the harvest to planting period. Rao et al. (9) observed higher infiltration rates, lower bulk densities, less compaction and lower soil strength in minimum tilled plots. They state that the difference between tillage systems were smaller on soils with a high clay content. The soil physical condition at the end of the study by Rao et al. (9) agrees with this study.

Wheat Yields:

The average wheat yield from each treatment from 1966 through 1969 is given in Table 7. The yield from 1966 should not be considered as representative of the imposed treatments, since the tillage systems were not imposed until shortly before planting. Treatment 01 was always significantly higher than the three chemical treatments (05, 06, and 07). The treatments that received no tillage or weed removal (03 and 04) consistently yielded below the other five systems. This was perhaps due to several factors, but competition for water and nutrients during spring wheat growth and development were probably the major reasons.

The yield reduction observed between treatments 01 and 02 has been reported in several earlier studies conducted in this area where stubble mulching and clean tillage (plow) were compared. Tanchandrphongs and Davidson (12) reported similar yield reductions for an eleven

Table 6. Soil Water Content (Inches) Top 18 inches

Treatment	Date Measured		
	10/66	10/67	10/68
01	1.96 a	3.17 c	2.73 b
02	2.82 ab	3.05 bc	2.98 b
03	1.96 a	2.46 ab	1.89 a
04	2.39 ab	2.10 a	1.76 a
05	2.67 ab	3.49 c	2.77 b
06	2.96 ab	3.64 c	2.86 b
07	3.35 b	3.54 c	3.39 b

Table 7. Wheat Yield (bu/A)

Treatment	Year 1966	1967	1968	1969
01	30.5 a	17.2 a	29.3 a	29.2 a
02	27.2 ab	12.4 b	27.8 ab	25.1 b
03	21.8 c	2.0 d	11.0 c	11.3 e
04	22.0 c	2.9 d	9.3 c	7.7 f
05	23.9 bc	9.0 c	24.2 b	16.7 d
06	23.1 c	12.4 b	23.1 b	17.1 d
07	30.0 a	13.0 b	24.8 b	20.2 c

year study. In 1967, the spring topdressing of nitrogen was increased from 20 to 40 lb of N per acre (Table 1 and Appendix) in an attempt to reduce the yield suppression. This increase in nitrogen had no measurable influence on yield. Norstadt and McCalla (8) discuss a phytotoxicity in stubble mulched soils which may account for the yield suppression. Black (2) and Whitheld and Smika (13) have shown that lower spring soil-surface temperatures that occur under stubble mulched treatments as a result of the straw residue are responsible for yield reductions. The exact cause of the yield reduction in this study has not been determined.

The quantity of straw residue on the soil surface in May of each year is given in Table 8. Note that the chemical tillage systems consistently had more straw on the surface than treatments 01 and 02. The stubble mulched treatment had residue on the surface two out of three years. These results are typical, in general, for these two treatments over a long period of time. When Table 7 and 8 are compared, the extent of yield reduction in 02 below that in the 01 treatment appears to correlate with the amount of straw on the soil surface. When the residue samples were collected, the young seedlings on the high residue plots had a yellow color. The degree of yellowing, based on visual observations, agreed with the measured quantity of residue on the soil surface. Thus, the yield reduction would appear to be related to the amount of wheat residue. Nitrogen applications did not significantly change these results and based upon the work of Whitheld and Smika (13), nitrogen would not seem to be the problem.

At planting the surface soil of the no-tilled plots were hard and difficult to penetrate with a drill. Therefore, stand establishment may be part of the problem. The bulk dnesity of the soils in this area are high, regardless of previous treatment. Thus, they present a potential root development and seedling growth problem. The physiological developments of the wheat progressed faster in treatment 01 followed by

Table 8. Straw Residue (lb/A)

Treatment	Date Sampled 5/1/67	5/22/68	5/1/69
01	–	–	–
02	1055 c	–	90 d
03	2170 ab	645 a	575 a
04	1415 cd	315 ab	120 d
05	1780 abc	320 ab	505 ab
06	2080 ab	495 ab	410 abc
07	2185 a	275 b	270 bcd

02, 07, 05, and 06. This agrees with the results concerning the loss of seedling vigor early in the spring.

Weed Control:

Control of summer annual weeds with a residual herbicide was only fairly successful. In years with good mid-summer rainfall propachlor (Ramrod-TM) provided up to 70 percent control. However, in dryer years the herbicide was ineffective.

Use of the contact herbicide paraquat to burn off existing weeds at the time of treatment was usually effective. The degree of success, however, depended on the size of the weeds when treated. Paraquat was relatively ineffective if the weeds were large. The number of treatments (Table 1, Appendix) required to maintain good weed control was too high for economical grower use at this time. However, cheaper materials may become available. Often a rain during the summer would bring on a flush of weeds. If not treated relatively soon afterward these weeds would become too big to control with chemicals. In some instances a late growth of cheat could only be burned back but not killed prior to planting wheat.

Cheat presented a serious problem in that it often occurred after planting. The problem became increasingly worse with time in the chemical plots, but was not a problem in treatment 01. Also, the weeds species occurring in the chemically treated plots changed with time, as perennial species became more prominent.

Conclusions

In spite of the equal or better soil physical condition in the minimum or no-tillage treatments, the average grain yields were lower than those from the clean or plowed treatment. The reason for the yield reduction has not been isolated, but appear to be directly related to the amount of straw residue on the surface in May.

Aggregate stability and soil-water content in the surface soil were significantly improved under reduced tillage. One tillage or soil disturbance however, may be necessary in order to reduce residue quantities on the soil surface in the spring.

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Appendix Table 1

Treatment 01:	Clean tillage
10-13-65	Topdressed 20 lb N/A
10-13-65	Planted Kaw wheat and 20 lb P_2O_5/A
2-24-66	Topdressed 20 lb N/A
6-10-66	Harvested
7-29-66	Moldboard plow 6 inches
8-26-66	Field Cultivator 3 inches
9-26-66	Field Cultivator 3 inches
10-10-66	Topdressed 20 lb N/A
10-10-66	Planted Kaw wheat + 20 lb P_2O_5/A
2-14-67	Topdressed 40 lb N/A
6-12-67	Harvested
7-7-67	Moldboard plow 6 inches
7-27-67	Field cultivator 3 inches
8-9-67	Field cultivator 3 inches
9-1-67	Springtooth
10-17-67	Topdressed 20 lb N/A
10-28-67	Planted Kaw wheat
2-10-68	Topdressed 40 lb N/A
6-20-68	Harvested
7-10-68	Sweep 3 inches (very hard)
8-26-68	Moldboard plow 6 inches
9-25-68	Springtooth
10-12-68	Topdressed 20 lb N/A
10-12-68	Springtooth
10-16-68	Planted Kaw wheat
3-5-69	Topdressed 40 lb N/A
6-25-69	Harvested

Appendix Table 1 (Cont'd.)

Treatment 02:	Stubble Mulch
10-13-65	Topdressed 20 lb N/A
10-13-65	Planted Kaw wheat + 20 lb P_2O_5/A
2-24-66	Topdressed 20 lb N/A
6-10-66	Harvested
7-29-66	Sweep 3 inches
9-9-66	Sweep 3 inches
10-10-66	Topdressed 20 lb N/A
10-10-66	Mulch treader
10-10-66	Planted Kaw wheat + lb P_2O_5/A
2-14-67	Topdressed 40 lb N/A
6-12-67	Harvested
7-6-67	Sweep 3 inches
7-28-67	Sweep 3 inches
8-14-67	Sweep 3 inches
10-17-67	Topdressed 20 lb N/A
10-28-67	Planted Kaw wheat
2-10-68	Topdressed 40 lb N/A
6-20-68	Harvested
7-10-68	Sweep 3 inches
9-7-68	Sweep 3 inches
10-12-68	Topdressed 20 lb N/A
10-16-68	Mulch treader
10-16-68	Planted Kaw wheat
3-5-69	Topdressed 40 lb N/A
6-25-69	Harvested

Treatment 03:	No weed control
10-13-65	Topdressed 20 lb N/A
10-13-65	Planted Kaw wheat + 20 lb P_2O_5/A
2-24-66	Topdressed 20 lb N/A
6-10-66	Harvested
10-10-66	Topdressed 20 lb N/A
10-10-66	Planted Kaw wheat + 20 lb P_2O_5/A
2-14-67	Topdressed 40 lb N/A
6-12-67	Harvested
10-17-67	Topdressed 20 lb N/A
10-28-67	Planted Kaw wheat
2-10-68	Topdressed 40 lb N/A
6-20-68	Harvested
10-12-68	Topdressed 20 lb N/A
10-16-68	Planted Kaw wheat
3-5-69	Topdressed 40 lb N/A
6-25-69	Harvested

Appendix Table 1 (Cont'd.)

Treatment 04:	Mow weeds
10-13-65	Topdressed 20 lb N/A
10-13-65	Planted Kaw wheat + 20 lb P_2O_5/A
2-24-66	Topdressed 20 lb N/A
6-10-66	Harvested
7-6-66	Mowed
8-21-66	Mowed
10-10-66	Topdressed 20 lb N/A
10-10-66	Mowed
10-10-66	Planted Kaw wheat + 20 lb P_2O_5/A
2-14-67	Topdressed 40 lb N/A
6-12-67	Harvested
7-6-67	Mowed
8-1-67	Mowed
10-17-67	Topdressed 20 lb N/A
10-28-67	Planted Kaw wheat
2-10-68	Topdressed 40 lb N/A
6-20-68	Harvested
7-5-68	Mowed
10-12-68	Topdressed 20 lb N/A
10-16-68	Planted Kaw wheat
3-5-69	Topdressed 40 lb N/A
6-25-69	Harvested

Treatment 05:	Chemical (contact)
10-13-65	Topdressed 20 lb N/A
10-13-65	Planted Kaw wheat + 20 lb P_2O_5/A
2-24-66	Topdressed 20 lb N/A
6-10-66	Harvested
8-4-66	1 lb/A paraquat + surfactant (1%)
9-7-66	1 lb/A paraquat + surfactant (1%)
10-10-66	Topdressed 20 lb N/A
10-10-66	Planted Kaw wheat + 20 lb P_2O_5/A
2-14-67	Topdressed 40 lb N/A
6-12-67	Harvested
7-5-67	1 lb/A paraquat + surfactant (1%)
8-2-67	1 lb/A paraquat + surfactant (1%)
8-30-67	1 lb/A parquat + surfactant (1%)
10-17-67	Topdressed 20 lb N/A
10-26-67	1 lb/A paraquat + surfactant (1%)
10-28-67	Planted Kaw wheat
2-10-68	Topdressed 40 lb N/A
6-20-68	Harvested
7-5-68	1 lb/A paraquat + surfactant (1%)
8-20-68	1 lb/A paraquat + surfactant (1%)
9-25-68	1 lb/A paraquat + surfactant (1%)
10-12-68	Topdressed 20 lb N/A
10-16-68	Planted Kaw wheat
3-5-69	Topdressed 40 lb N/A
6-25-69	Harvested

Appendix Table 1 (Cont'd.)

Treatment 06:	Chemical (Pre + Contact)
10-13-65	Topdressed 20 lb N/A
10-13-65	Planted Kaw wheat + 20 lb P_2O_5/A
2-24-66	Topdressed 20 lb N/A
6-10-66	Harvested
6-20-66	4 lb/A Ramrod (granular)
8-4-66	1 lb/A paraquat + surfactant (1%)
9-7-66	1 lb/A paraquat + surfactant (1%)
10-10-66	Topdressed 20 lb N/A
10-10-66	Planted Kaw wheat + 20 lb P_2O_5/A
2-14-67	Topdressed 40 lb N/A
6-12-67	Harvested
7-5-67	1 lb/A paraquat + surfactant (1%)
	4 lb/A Ramrod (granular)
8-2-67	1 lb/A paraquat + surfactant (1%)
8-30-67	1 lb/A paraquat + surfactant (1%)
10-17-67	Topdressed 10 lb N/A
10-26-67	1 lb/A paraquat + surfactant (1%)
10-28-67	Planted Kaw wheat
2-10-68	Topdressed 40 lb N/A
6-20-68	Harvested
7-5-68	1 lb/A paraquat + surfactant (1%)
	4 lb/A Ramrod (granular)
8-23-68	1 lb/A paraquat + surfactant (1%)
9-25-68	1 lb/A paraquat + surfactant (1%)
10-12-68	Topdressed 20 lb N/A
10-16-68	Planted Kaw wheat
3-5-69	Topdressed 40 lb N/A
6-25-69	Harvested

Treatment 07:	(Mechanical + Chemical)
10-13-65	Topdressed 20 lb N/A
10-13-65	Planted Waw wheat + 20 lb P_2O_5/A
2-24-66	Topdressed 20 lb N/A
6-10-66	Harvested
7-29-66	Sweep 3 inches
9-7-66	1 lb/A paraquat + surfactant (1%)
10-10-66	Topdressed 20 lb N/A
10-10-66	Planted Kaw wheat + 20 lb P_2O_5/A
2-14-67	Topdressed 20 lb N/A
6-12-67	Harvested
7-6-67	Sweep 3 inches
8-2-67	1 lb/A paraquat + surfactant (1%)
8-30-67	1 lb/A paraquat + surfactant (1%)
10-17-67	Topdressed 20 lb N/A
10-26-67	1 lb/A paraquat + surfactant (1%)
10-28-67	Planted Kaw wheat
2-10-68	Topdressed 40 lb N/A
6-20-68	Harvested
7-10-68	Sweep 3 icnhes
8-20-68	1 lb/A paraquat + surfactant (1%)
9-25-68	1 lb/A paraquat + surfactant (1%)
10-12-68	Topdressed 20 lb N/A
10-16-68	Planted Kaw wheat
3-5-69	Topdressed 40 lb N/A
6-25-69	Harvested