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Dryland No-Tillage Winter Wheat Response to Planter Type

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Crop planting becomes increasingly difficult as surface residue amounts increase, as with conservation tillage. Planters for such conditions are available, but costly. With relatively low residue amounts, as for winter wheat (*Triticum aestivum* L.) and grain sorghum [*Sorghum bicolor* (L.) Moench.] grown in rotation on dryland, it was hypothesized that drills used under conventional tillage conditions could satisfactorily plant wheat into no-tillage sorghum residues. Objectives of this study were to test this hypothesis. The information would show whether different planting equipment is needed when switching to a conservation tillage system. Drills were John Deere 8200 (Deere and Co., Moline, IL) with single-disk, Graham-Hoeme PD-160 (United Farm Tools, Oelwein, IA) and Fabco M-10 (Fabco Ltd., Swift Current, SK, Canada) with double-disk, and International 7100 (J. I. Case, Racine, WI) with hoe openers. No drill provided 1.5 in. (target depth) of seed coverage; it was least (0.75 in.) with the John Deere, which moved more soil from the seed row than other drills. The number of seedlings emerged was not affected by drill types. Mean yields with the John Deere (2000 lb/acre grain; 4200 lb/acre residue) were lower than with other drills (2410 to 2670 lb/acre grain; 4900 lb/acre for residue). Differences in seed coverage depth and soil removal from the drill row possibly caused the yield differences. A suitable drill should be used for planting wheat under conservation tillage, but using a heavy-weight drill, as the Fabco, is not warranted when grain sorghum residues on dryland are similar to the amounts present under the conditions of this study (4900 lb/acre).

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Proper seed placement in soil is critical for successful production of any crop. For rapid and uniform germination and seedling establishment, seed must be uniformly placed in contact with moist soil. Proper placement usually is possible with a variety of planters where crop residues are incorporated by tillage. Proper placement becomes increasingly difficult as surface residue amounts increase, as with conservation tillage, especially no-tillage, for which crop residues are retained on the surface (Allen, 1988; Allen et al., 1984; Pollard, 1977).

Randomly-oriented surface residues of a crop such as winter wheat may interfere with seed placement under no-tillage because the residues are difficult to cut, especially when moist. Under such conditions, coulters or disk-openers push residues into the soil, thus enveloping the seed, preventing good seed-moist soil contact, and causing poor germination. In other cases, seed is not placed at the proper depth. When wheat residue levels were 3570 lb/acre (4000 kg/ha) on Pullman clay loam (fine, mixed, thermic Torrertic Paleustoll), sorghum was planted with little difficulty with planters having disk or shovel openers when the residues were dry and brittle. When moist, the residues clogged a shovel-opener drill (Allen et al., 1984).

Abbreviation: HI, harvest index.

Corn (*Zea mays* L.), sorghum, sunflower (*Helianthus annuus* L.), and winter wheat were successfully planted with double-disk-opener planters or drills where wheat residue amounts were up to 8930 lb/acre (10 000 kg/ha) in other no-tillage studies on Pullman soil (Allen et al., 1975, 1976; Musick et al., 1975, 1977; Unger, 1981, 1984, 1986; Unger and Wiese, 1979). Planters used in these studies were developed primarily for operation under clean tillage and low-residue conditions. The row crops (corn, sorghum, and sunflower) usually were planted between wheat drill rows, which minimized interference due to surface residues.

Even though crops were successfully planted under some conditions by using equipment designed for clean tillage or low-residue conditions, farmers often have given the lack of suitable equipment for planting under high-residue conditions as a reason for not adopting conservation tillage (Allen, 1988). To overcome this objection, manufacturers in recent decades have developed planters and drills for high-residue conditions. However, farmers still have not adopted conservation tillage in many cases because of the high cost of changing from presently owned planting equipment to specialized, more costly no-tillage equipment.

Most farmers using a winter wheat-grain sorghum rotation have a planter for sorghum and a drill for wheat. For the above studies, sorghum was successfully planted into wheat residues using a variety of older types of planters and drills. To keep production costs low, many farmers prefer to use equipment they already own to also plant their wheat.

Low amounts of grain sorghum residues usually remain on the surface at wheat planting time in a dryland winter wheat-grain sorghum rotation. Hence, it was hypothesized that type of drill would not affect no-tillage wheat establishment and yields enough to warrant purchase of a new, specialized drill. This study tested this hypothesis by comparing the establishment and grain yields of no-tillage wheat using some conventional and specialized drills in a dryland wheat-sorghum rotation. If yields are not affected by drill type, then farmers having similar drills could adopt no-tillage planting of wheat into sorghum residues without lowering their income. If yields are affected,the data should provide a basis for evaluating the financial benefits to be gained by switching to a drill that performs better under the conditions encountered.

MATERIALS AND METHODS

A field study was conducted from 1989 to 1992 on Pullman clay loam with 0.3% slope at the USDA-ARS Conservation and Production Research Laboratory, Bushland, TX. The fields had been used for a dryland no-tillage wheat-grain sorghum rotation for at least 7 yr. A different, but adjacent, field was used for each wheat crop. A 300- by 330-d fallow period occurred from sorghum harvest until wheat planting. The fields were not tilled during the fallow period.

The drills were manufactured by John Deere[1], Graham-Hoeme, Fabco, and International (Table 1). The John Deere, Graham-Hoeme, and International are considered conventional drills and are widely used for planting wheat in the region. The Fabco is a specialized drill designed for planting under high-residue conditions. Plantings with the different drills were replicated three times in the experiment that had a randomized block design. Plots were at least 26 ft (8 m) wide (depending on drill width) and 79 ft (24 m) long.

Table 1. Drill specifications.

	Drill type†			
Specification	John Deere	Graham-Hoeme	Fabco	International
Model	8200	PD-160	M-10	7100
Width, ft	13.1	13.5	10.0	13.5
Weight, lb	1920	2500	3400	3600
Openers, type	Single disk	Double disk	Double disk	Narrow hoe point
Number	16	16	12	14
Spacing, in.	10	10	10	12
Down force per opener, lb	NG‡	Up to 88	NG	Up to 176
Metering type	Fluted/double run	Fluted cup	Notched wheel	Fluted-roll cups

† Drill manufacturers: John Deere, Deere & Co., Moline, IL; Graham-Hoeme, United Farm Tools, Oelwein, IA; Fabco, Fabco LTD., Swift Current, SK, Canada; International, J. I. Case Co., Racine, WI.
‡ NG = Not given.

During fallow after the sorghum crop, chlorsulfuron was applied at 0.5 oz a.i./acre (3.5 mg/m) to control weeds. Glyphosate was applied at 8 oz a.i./acre (60 mg/m) for additional weed control when needed. Also, if needed, 2,4-D was applied to wheat plots for growing-season weed control.

"Scout 66" wheat was planted on 9 Sept. 1989, 20 Sept. 1990, and 11 Sept. 1991. Drills were set to plant wheat at a 35-lb/acre (39 kg/ha) rate, which is a typical rate for dryland wheat in the U.S. southern Great Plains. Germination was 92% and number of seed per ounce was 990 for seed planted for the 1991–1992 crop. The 35-lb/acre planting rate with 92% germination provided about 12 viable seed/sq ft. Differences in seed size and germination percentage undoubtedly caused differences in the numbers of viable seed in other years.

The target opener penetration depth was at least 1.5 in. (3.8 cm) to achieve a 1.5-in. (3.8 cm) seed coverage depth. Tractor speed at planting was between 4.0 and 4.5 mi/hr (6.4 and 7.2 km/hr). Wheat planting direction was perpendicular to rows for the previous sorghum crop. This arrangement avoided drill rows being at the same position as sorghum rows, which previously caused seedling establishment problems under similar conditions. Wheat harvest dates were 12 June 1990, 27 June 1991, and 30 June 1992.

Determinations made were (i) weight and percentage cover due to sorghum residues, (ii) opener penetration depth (based on depth of seed placement below the original soil surface measured at 10 positions per plot), (iii) seed coverage depth (based on firmed soil above the seed measured at 10 positions per plot), (iv) emerged seedlings (number per square foot, counted at five 3.3-ft-long [1.0-m] drill row sections per plot), (v) tillers at harvest (number per square foot, based on number of grain-bearing and barren stems from two 10.76 sq ft [1.0-sq m] areas per plot), (vi) grain yield (machine harvest of a 15.0-ft-wide [4.6-m] swath for the entire plot length), (vii) harvest index (from hand-harvested samples, and (viii) residue yield. Sorghum residue weight at planting was determined for the field area (not individual

[1] Mention of a trade name or product does not constitute a recommendation, endorsement, or exclusion for use by the USDA, nor does it imply registration under FIFRA as amended.

plots) and surface cover was calculated using the corn coefficient for the equation of Gregory (1982). (Corn and grain sorghum have similar characteristics and a coefficient for sorghum was not available.) Wheat from a measured area in each plot (15.0 ft wide and 79 ft long) was machine-harvested to obtain grain yields. Harvest index (HI) was determined by clipping entire plants near the soil surface from two 10.76-sq ft (1-sq m) areas in each plot, air drying the samples, weighing the entire sample, threshing and weighing the grain, and calculating the portion of the total plant weight that was grain. Residue yields were calculated from the machine-harvested grain yields and HI. Grain and residue yields are reported at 10% moisture content.

Precipitation was measured near the plot area. Soil water content was determined gravimetrically to a 6.0-ft (1.8-m) depth by 1.0-ft (0.3-m) increments at planting and harvest of the 1989–1990 and 1990–1991 crops in field areas adjacent to the study areas. Determinations were not made for individual plots. Soil water content inadvertently was not determined for a 1991–1992 crop.

Sorghum residue weight, percentage residue cover, and soil water content data were not analyzed statistically. Other data were analyzed by the General Linear Models (GLM) procedure (SAS, 1989). When mean differences were statistically significant at the 0.05 level of probability, means were separated by the least significant difference test (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Precipitation and Soil Water Content

Rain for the 30 d before planting was greatest for the 1989–1990 crop and least for the 1990–1991 crop (Table 2). Rain totaled at least 0.71 in. (18 mm) 3 to 10 d before planting in all years, which provided favorable water contents in the upper 1.0 ft (0.3 m) of soil at planting (Table 2). Even though rain amounts differed before planting the 1989–1990 and 1990–1991 crops, water contents in the upper 1.0 ft of soil were similar at planting. Planting was 9 d after a 1.89-in. (48-mm) rain in 1989 and 3 d after a 0.75-in. (19.mm) rain in 1990. Undoubtedly, evaporation losses were greater during the longer period between rain and planting in 1989 than in 1990. Although not determined, rain late in the 30 d before planting in 1991 should have provided soil water contents similar to those in other years. To the 6.0-ft (1.8-m) depth, total water content at planting was 1.14 in. (29 mm) greater in 1989 than in 1990.

Harvest-time water contents reflected differences in rain amounts late in the growing season. For the 1989–1990 crop, rains totaled only 1.38 in. (35 mm) after 1 April, and the surface soil dried to below the −15 bar (−1.5 MPa) matric potential (permanent wilting point) by harvest time. In contrast, the surface soil contained some plant-available water at harvest of the 1990–1991 crop because of late-season rains. Even more water undoubtedly was present at harvest of the 1991–1992 crop because more rain occurred late in the growing season than for other crops.

Growing-season precipitation was greatest for the 1991–1992 crop and least for 1989–1990 crop. Long-term average precipitation (1939–1991) varied for the different growing seasons because of different planting and harvesting dates (Table 2). Precipitation was about 52% of the long-term average for 1989–1990, 111% for 1990–1991, and 152% for 1991–1992. Differences in growing-season precipitation distribution contributed to the yield differences among years, which are discussed in a subsequent section.

Table 2. Precipitation and soil water contents related to winter wheat crops, 1989–1992, Bushland, TX.

Period or month	Crop year 1989–1990	1990–1991	1991–1992
	in.		
Precipitation			
0 to 30 d before planting	4.06	0.87	2.60
September, after planting	0	1.85	0.31
October	0.16	0.35	0.94
November	0	0.75	0.91
December	0.47	0.28	2.76
January	1.10	1.38	0.79
February	1.06	0	0.51
March	1.02	0.47	1.50
April	0.67	0.31	1.02
May	0.71	2.68	3.07
June, until harvesting	0	3.50	7.24
Growing season total	5.19	11.57	19.05
Growing season average (1939–1991)†	9.84	10.43	12.56
Plant available soil water content—			
At planting, 0- to 1.0-ft depth	1.50	1.42	–‡
At harvest, 0- to 1.0-ft depth	−0.39	0.98	--
At planting, 0- to 6.0-ft depth	8.78	7.64	--
At harvest, 0- to 6.0-ft depth	1.46	3.23	--

† Based on unpublished lab records, Bushland, TX.
‡ Not determined.

Wheat Establishment

Sorghum residues remaining on the surface at wheat planting were 4200 lb/acre (4700 kg/ha) in 1989, 4910 lb/acre (5500 kg/ha) in 1990, and 3660 lb/acre (4100 kg/ha) in 1991. Based on the relationship between residue weight and cover (Gregory, 1982), the residues provided 85, 89, and 91% surface cover in the respective years. The relationship assumes a uniform distribution of residues flat on the surface. It was noted, however, that the sorghum residues generally were concentrated on or near sorghum rows, with areas of bare soil between rows. Also, some sorghum residues (stalks) were still standing at wheat planting time. The uneven residue distribution did not appear to interfere with drill performance in this study.

Opener penetration depths did not differ among years, but differed due to drill type (Table 3). Penetration was least for the Graham-Hoeme and greatest for the International. The target penetration depth (1.5 in., 3.8 cm) was not achieved with the Graham-Hoeme in any year. Differences in penetration depths resulted from drill weight and opener type. The John Deere was lightest and the Fabco was heaviest of the disk-opener drills (Table 1). However, penetration depth did not uniformly increase with increases in drill weight. Instead, the lighter John Deere with single-disk openers had better penetration than the heavier Graham-Hoeme with double-disk openers. The lighter disk-opener drills (John Deere and Graham-Hoeme) had some difficulty cutting surface residues and penetrating the relatively firm no-tillage soil. The Fabco was heavy enough to achieve deeper penetration. Hoe openers on the International under-

Table 3. Winter wheat establishment and yield factors as affected by crop year and drill type, Bushland, TX, 1989 to 1992.

Crop year	JD	GH	Fabco	INT	Mean
	Drill type†				
	Opener penetration depth‡, in.				
1989–1990	1.5	1.2	1.7	1.7	1.5
1990–1991	1.5	1.1	2.0	2.1	1.7
1991–1992	1.6	1.2	1.7	2.3	1.7
Mean	1.5	1.2	1.8	2.0	
LSD§ (0.05 level): Year (Y) = NS¶, Drill type (D) = 0.2, Y × D = NS					
	Seed coverage depth#, in.				
1989–1990	0.8	1.0	1.0	0.8	0.9
1990–1991	0.7	1.0	1.2	0.9	1.0
1991–1992	0.7	1.1	0.7	1.3	1.0
Mean	0.7	1.0	1.0	1.0	
LSD (0.05 level): Year (Y) = NS, Drill type (D) = 0.2, Y × D = 0.4					
	Emerged seedlings, no./sq ft.				
1989–1990	7	9	11	13	10
1990–1991	16	17	16	16	16
1991–1992	11	11	11	12	11
Mean	11	12	13	14	
LSD (0.05 level): Year (Y) = 2, Drill type (D) = NS, Y × D = NS					
	Tillers at harvest, no./sq ft				
1989–1990	52	52	55	64	58
1990–1991	48	48	51	56	51
1991–1992	90	85	86	92	88
Mean	63	62	64	71	
LSD (0.05 level): Year (Y) = 12, Drill type (D) = 6, Y × D = NS					
	Grain yield, lb/acre				
1989–1990	1740	2460	2840	2380	2360
1990–1991	1740	1800	2020	1880	1860
1991–1992	2520	2970	3160	2970	2910
Mean	2000	2410	2670	2410	
LSD (0.05 level): Year (Y) = 420, Drill type (D) = 410, Y × D = NS					
	Harvest index				
1989–1990	0.35	0.36	0.38	0.37	0.36
1990–1991	0.38	0.39	0.41	0.39	0.39
1991–1992	0.28	0.28	0.30	0.28	0.28
Mean	0.33	0.34	0.36	0.35	
LSD§ (0.05 level): Year (Y) = 0.03, Drill type (D) = NS, Y × D = NS					
	Residue yield, lb/acre				
1989–1990	3200	4300	4600	4200	4100
1990–1991	2800	2800	2900	2900	2900
1991–1992	6600	7700	7300	7700	7300
Mean	4200	4900	4900	4900	
LSD (0.05 level): Year (Y) = 200, Drill type (D) = 200, Y × D = NS					

† Drill types: JD = John Deere 8200; GH = Graham-Hoeme PD-160; Fabco = Fabco M-10; INT = International 7100.
‡ Depth of penetration below the level of the original soil surface.
§ Protected least significant difference.
¶ Not significant
# Thickness of soil cover over seed.

cut the surface residues and penetration depth was not affected.

Seed coverage depths differed among treatments and the year × drill type interaction effect was significant (Table 3). The target coverage depth of 1.5 in. (3.8 cm) was not achieved with any drill because it was difficult to move the relatively firm no-tillage soil over the seed ahead of the press wheels. Coverage was least (0.7 in.) for the John Deere, which had single-disk openers that moved too much soil from the drill row. Mean coverage depths were identical with other drills. The year × drill type interaction effect was significant because coverage was similar for all drills in 1989–1990, the Fabco resulted in greater coverage than the John Deere in 1990–1991, and the Graham-Hoeme resulted in greater coverage than the John Deere and the International resulted in greater coverage than the John Deere and Fabco in 1991–1992. In addition, coverage was greater in 1990–1991 than in 1991–1992 with the Fabco and greater in 1991–1992 than in 1989–1990 and 1990–1991 with the International. These differences probably were caused by differences in soil water content and in amount and distribution of surface residues.

The number of seedlings emerged was greater in 1990–1991 than in other years (Table 3). Differences due to drill type were not significant.

The mean number of tillers at harvest was similar for the 1989–1990 and 1990–1991 crops, but was greater in 1991–1992 than in other years. This difference is attributed to the greater amount and better distribution of growing-season precipitation for the 1991–1992 crop (Table 2). The mean number of tillers was significantly lower with the John Deere, Graham-Hoeme, and Fabco than with the International. Greater tillering with the International possibly resulted from the greater opener penetration, which may have placed seed in a soil environment more conducive to tiller development or tiller survival during winter.

Grain and Residue Yields

Grain yields differed due to years and drill types (Table 3). Yields were greatest in 1991–1992 when precipitation was greatest and generally well distributed (Table 2). Greater yield in 1989–1990 when precipitation was lowest than in 1990–1991 when precipitation was greater is attributed to greater soil water content at planting and greater use of that water by the 1989–1990 crop (Table 2). In addition, some precipitation for the 1990–1991 crop (in late-May and June) occurred too late to affect grain yields. Late-winter and early-spring (February–April) precipitation was 2.76 in. (70 mm) for the 1989–1990 crop and 0.79 in. (20 mm) for the 1990–1991 crop, which contributed to the yield differences.

Mean grain yield was lower with the John Deere than with the other drills. For the John Deere, mean opener penetration depth was intermediate and mean numbers of seedlings emerged and tillers at harvest were similar to those with the Graham-Hoeme and International (Table 3). The only measured factor that was significantly different with the John Deere than with all other drills was mean seed coverage depth. It was less with the John Deere, which, according to Paulsen (1987), could have resulted in greater soil drying, poorer seed germination and seedling establishment, and greater plant lodging. Because the number of seedlings emerged was not affected and lodging was not noted, the reason for lower yields with the John Deere is not known.

The results indicate that the Graham-Hoeme, Fabco, and International drills were suitable for planting wheat into the sorghum residues under the conditions of this study. The results also indicate that a special heavy-weight drill such as the Fabco is not needed when planting wheat in a soil that has been in no-tillage for at least 7 yr. Yields were greater with drills having double-disk or hoe openers than with a drill having single-disk openers. This indicates that farmers who have a single-disk-opener drill may need to replace it with a more suitable drill if they adopt a conservation tillage system. Of course, factors such as yield differences, acres being farmed, drill replacement cost, and grain prices must be considered in making a decision whether to obtain a different type of drill.

Mean HIs were greater in 1989–1990 and 1990–1991 when grain yields were lower than in 1991–1992 when grain yields were greatest (Table 3). Howell (1990) obtained a high correlation between grain yield and total plant dry matter yield for wheat produced under various conditions at Bushland, TX, indicating that HI was not greatly affected, for example, by water supply at different times during the growing season. Musick and Porter (1990), however, indicated that HI was sensitive to postanthesis water deficits. Based on the greater amount and better distribution of precipitation in 1991–1992 than in other crop years (Table 2), the reason for the lower HI in 1991–1992 is not clear. A possibility is that post-planting precipitation in the fall (October–December) enhanced vegetative growth to a greater extent for the 1991–1992 crop than for other crops. Although precipitation was greater in the spring for the 1991–1992 crop, a water deficit at a critical stage may have resulted in the lower HI for that crop. The HI was not affected by drill type or the year × drill type interaction.

Residue yields were greatest in 1991–1992 when precipitation amounts and distribution were most favorable and least in 1990–1991 when precipitation was intermediate. As for grain yields, greater residue yields with lower total precipitation for the 1989–1990 than the 1990–1991 crop resulted from greater late-winter and early-spring precipitation (February–April) for the 1989–1990 crop. Precipitation for those periods totaled 2.76 in. (70 mm) for the 1989–1990 crop and 0.79 in. (20 mm) for the 1990–1991 crop. As for mean grain yield, mean residue yield was lower with the John Deere than with the other drills. The reason for the low yield with the John Deere is not known because only seed coverage depth was significantly different (lower) with the John Deere than with all other drills (Table 3).

CONCLUSIONS

Four drills (one with single disk, two with double disk, and one with hoe openers) were compared for wheat establishment, and grain and residue yields under dryland no-tillage conditions. The following conclusions are based on results of this 3-yr study:

1. Wheat establishment based on the number of seedlings emerged was not affected by drill type. Some-what deeper opener penetration with the Fabco and International could result in more consistent seed placement in wetter soil, which could be an advantage when surface soil water contents are low at planting time.
2. Mean grain and residue yields were lower with the John Deere (single-disk opener) than with other drills (double-disk or hoe openers), possibly because the single-disk opener moved more soil from the planting zone and, therefore, resulted in a lower seed coverage depth.
3. A suitable drill should be used for planting wheat under conservation tillage, but using a heavy-weight drill, such as the Fabco, is not warranted when grain sorghum residues on dryland are similar to amounts present under conditions of this study (4900 lb/acre; 5500 kg/ha maximum). Yield differences expected, acres farmed, drill replacement cost, and grain prices must be considered when making a decision whether to obtain a different drill.

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What was the effect of drill type on wheat grain yield?

Average grain yield was less (410 to 670 lb/acre) with the single-disk-opener drill than with other drills for which the differences in yield were not significant.

Should farmers invest in a heavy-weight drill when adopting a conservation tillage system for dryland winter wheat?

Results of this study suggest that farmers having conventional drills with double-disk or hoe openers need not invest in a heavy-weight drill. Farmers having a single-disk-opener drill should evaluate the economics of switching to a different drill. Factors to consider in all cases include grain yield increase expected, grain price, acres to be planted, and drill cost.