Comparison of Trenchless Drain Plow and Trench Methods of Drainage Installation

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ABSTRACT

THE performance of two methods of subsurface drain installation (corrugated plastic drain pipes installed with a trencher, and a trenchless drain plow) was evaluated using five years of field data on water table heights and crop yields. Two subsurface drains, each installed with a different method, were monitored from 1980 to 1984 to compare the effect of methods of drain installation on water table heights. Subsurface drains installed with a chain trencher had lower water table heights throughout the crop growing season in comparison to the water table heights in areas drained by the plow method. Based on these water table measurements, subsurface drains installed with a chain trencher appeared to remove more drainage water from the soil than did subsurface drains installed with a plow.

Data collected on corn and soybean yields from the various tillage experiments, drained by two methods of drain installation were compared. Plots drained by trenched drains yielded more than plots drained by plowed drains but differences were not statistically significant at 95% level.

INTRODUCTION

Artificial drainage is necessary to increase the productivity and versatility of many of the world's soils. Subsurface drainage systems were first installed on a large scale in the temperate zones of the world, especially North America, Europe, and the Soviet Union (Ziglstra and van Someren, 1980); but in recent decades, drainage techniques have also been applied in arid and semiarid zones in combination with irrigated agriculture. Donnan (1977) indicates that the demand for subsurface drainage is increasing rapidly worldwide. Drainage practices have added more than 12.1 million ha to the tillable area of the Midwest of the United States and increased production on another 16.2 million ha (Palmer, 1975). With today's agricultural investments in fertilizer, chemicals, seeds, etc., subsurface water management has almost become a necessity.

Drainage contractors use two main methods for the installation of subsurface drains. One method is the trench method, in which an open ditch of proper depth is dug with a high speed chain or wheel trencher and the drain pipe is laid on the floor of the trench. The second method is a trenchless drain plow (plow-in) method, whereby a tunnel is made in the ground by a plow at a prescribed depth without soil excavation, and the tubing is placed in the tunnel. The plow blade is designed to lift and split the soil as it moves forward. The tubing is fed in behind the plow blade and the soil falls back around the pipe. Whatever installation method is used, the pipe must be well bedded so that alignment and grade can be maintained and external loads supported without deformation of the pipe (Spoor and Fry, 1983).

The installation of subsurface drains in agricultural areas with a plow has received wide acceptance in many parts of the world (Eggelsman, 1979; Fouss, 1982; Geohring et al., 1980; Naarding, 1979; and Olesen, 1979). Drain installation with a plow has been accepted as an effective, rapid, and economical method of installing drains in the United States. Reeve (1978) reported that the speed of installation and low machine maintenance costs were the two factors mainly responsible for the change from trenching to plow-in drainage.

One of the questions that has concerned subsurface drain installation contractors and farmers is the effectiveness of a plastic drain installed with a trencher compared with one installed with a drain plow. Some concerns have been expressed about the quality of drain plow installations, particularly tubing stretch, soil distruption, compaction, effect of stones, drain grade, and drainage system efficiency (Spoor and Fry, 1983; Olesen, 1979; and Geohring et al., 1980). Several authors presented comparisons of the performance of two methods of drain installation (Boels, 1979; Eggelsman, 1979; Olesen, 1979; and Naarding, 1979). Boels (1979) indicated that there is no clear understanding of the influence of installation errors on the functioning of the drainage system, but found that plow installations require a high draft force and may cause soil deformation or compaction when drains are installed at deep depth. Spoor and Fry (1983) identified two types of soil disturbance that can occur simultaneously with the trenchless plow, upward failure and lateral deformation. Upward failure induces soil loosening, whereas lateral deformation can, in certain circumstances, lead to an increase in soil density and reduction in the size of the larger soil pores. Spoor and Godwin (1978) did not find evidence of compaction within the immediate vicinity of the drain installed with a plow, but observed soil disturbance patterns similar to the one created by rigid chisel tines and mole plows.

A limited number of field studies have been reported to compare the performance of drainage systems installed using trenching and plow methods; the results

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are not conclusive. Naarding (1979) and Olesen (1979) reported poorer drain performance and higher water tables after plow installations on finer textured soils, whereas Eggelsman (1979) observed the opposite. The differences in performance were related to different soil conditions near the pipe. Spoor and Fry (1983) suggest that trenchless drainage installation techniques can be used with confidence over a wide range of soil conditions, provided that care is taken, and, in some cases, modifications made to the installation technique. A few serious seepage impedance problems could arise following plow or trencher installation with the development of impeding layers alongside the pipe, reducing the drainage efficiency. Vittetoe and Garner (1978) have presented the results of field evaluation of the flow performance of 209 subsurface drainage systems installed by the trench and plow methods. They concluded that the systems installed by the plow method are discharging lower drainage flow volumes, than systems installed by the trench method which preponderantly exhibit good flow performance.

A long-term field study was started at Iowa State University's Northeast Research Center, Nashua, Iowa, in the fall of 1979 to compare the field performance of subsurface drains installed with a chain trencher and a trenchless drain plow. The objective of this paper is to report the results of this study and to examine the effects of the methods of drain installation on water table heights and crop production.

FIELD EXPERIMENTS

The experimental site for this drainage study was located at the Iowa State University's Northeast Research Center, Nashua, Floyd County, IA. Fig. 1 shows the topographic features of the experiment site. The study site is on a predominantly Kenyon loam soil in the Kenyon-Floyd-Clyde Soil Association. Kenyon soils are gently sloping. These soils are moderately well drained, with a thick dark loamy surface layer and a high available water holding capacity.

A HOES* trenchless drain plow (TITAN 623 model with 228 mm flat blade) and 152 mm tubing guide box) and a HOES* chain trencher (GIGANT 685 model with a 290 mm chain width and 254 mm tubing box) were used to install 102 mm diameter corrugated plastic tubing in the experimental area in the fall of 1979 as a part of a larger drainage project on the research farm. The average depth of drains was 1.2 m. All drains were installed without prewrapped envelope materials around the corrugated plastic pipe. At the time of installation, soil moisture content at 1.2 m depth was near or above field capacity.

The drain lines in the experimental area were spaced 24 m (80 ft) apart and arranged in one group of three drain lines installed using the trencher method of drain installation and another group of three drain lines installed using the plow method of drain installation. Fig. 1 also shows the detailed experimental layout of the drains installed with the plow and trench methods. This arrangement of drain layout allowed water table measurements to be made relative to the middle drain line in each case, to allow measurements between drain lines of similar installation, and to permit better isolation of the drain installation methods. The middle drain line in each treatment was selected for extensive monitoring during the growing season (April through November) to compare the response of the water table to the methods of installation. Eighteen observation wells (16 mm diameter, 1.5 m long plastic pipe with open end and perforated sides) were installed in three groups on both sides of the middle drains at distances of 3, 6, and 12 m from the middle drains. Well locations are shown in Fig. 1. The observation wells were installed to a depth of 120 cm below the ground surface. A hand probe was used to measure the water levels in the observation wells.

Data on water table heights were collected once a week from April 1 through November 30 for 5 years (1980-1984) except for the months of April and May of 1981 when water tables were measured three times a week. Most other data on weather, soils, and crops needed for this study were collected at the experimental site.

Long-term tillage treatment plots were established in areas completely drained with either the trench or plow methods. These plots were used to conduct long term crop rotation studies. The data on crop yields from these plots were also used to examine the effects of the methods of drain installation on crop production. The size of tillage plots were 9 m wide by 18 m long. Tillage plots and crop rotation treatments were established in a randomized complete block in areas drained exclusively with the same method of drain installation. The data on crop yields were taken from the middle 3.9 m width of each plot. Three tillage treatments used in this study were replicated twice.

RESULTS AND DISCUSSION

The field data on water table elevations at middrain spacing were used to compare the drainage performance of two systems. Measured water table depths at middrain spacing for the two methods of drain installation, for the years 1980, 1982, 1983, and 1984 are plotted in Fig. 2. Water table depths were measured in three sets of observation wells at distances of 3, 6, and 12 m from the middle drains (as shown in Fig. 1) for each drainage system. Fig. 2 shows the average of three water table

*Trade name is included for the benefit of the readers and does not imply endorsement or preferential treatment of the product by Iowa State University or the USDA to the exclusions of others that may be suitable.

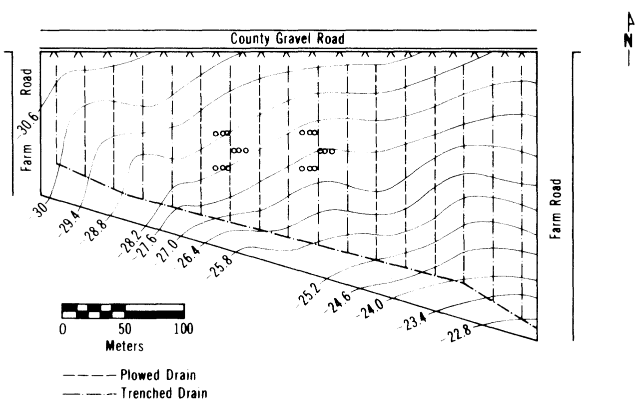

Fig. 1—Topographic map of the experimental site, and layout of the subsurface drainage systems at the Northeast Research Center, Nashua, Iowa. The contour lines are given in meters.

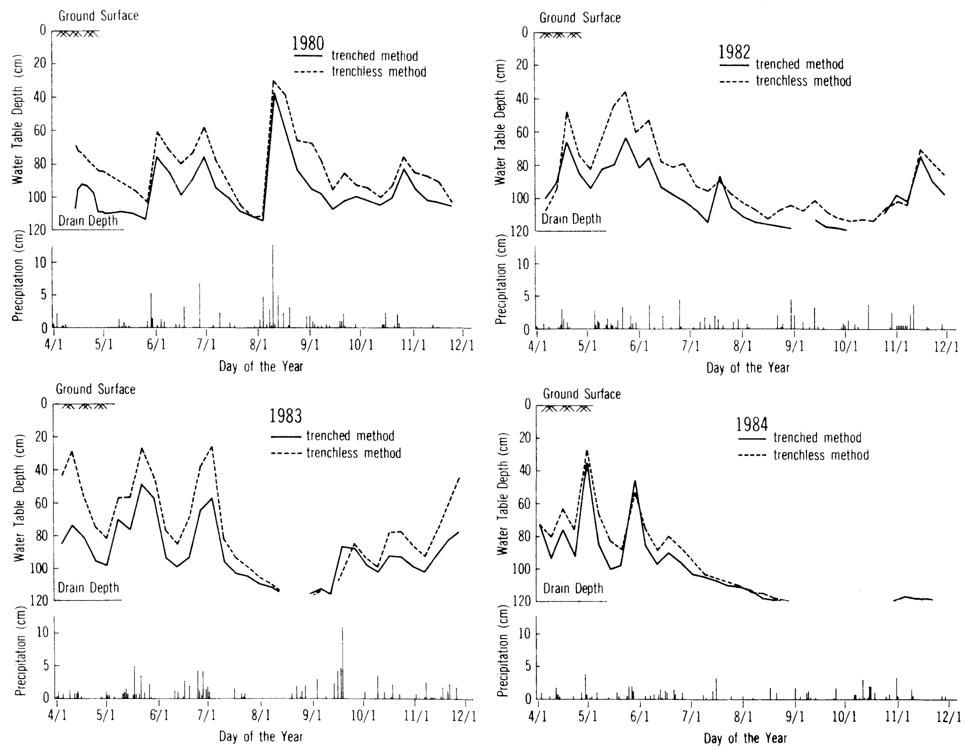

Fig. 2—Observed water table depths in areas drained by the plowed (trenchless) and trenched methods of subsurface drainage, and rainfall for four growing seasons (1980, 1982, 1983, and 1984).

readings taken from observation wells at 12 m distance from drains. From this figure, it is clear that both drainage systems (installed with a trencher and plow) have similar patterns of response to rainfall and are quite effective in lowering the water tables of the respective areas within a reasonable time.

Fig. 2 shows that the drainage system installed by a plow tended to maintain consistently higher water elevations in the field area in comparison with the drainage system installed with a chain trencher. These data suggest that the drainage systems installed with the plow method are discharging subsurface drainage water at a slower rate than the drainage systems installed by the trench method under similar soil and topographic conditions. This observation is in agreement with field evaluations (of the performance of drains installed by the plow and trench method) made by Vittetoe and Garner (1978) for data collected on flow performance of 209 subsurface drainage systems in the Lower Rio Grande Valley of Texas. Olesen (1979) reported similar findings under Danish soil conditions. His results indicate that differences between drain installation methods have been reduced with time and that the drainage efficiency (drain flow per unit of water table height) of the plow method was about 80% of chain trenching at the end of the 5 year study period. The data in Fig. 2 show no sign of a reduction in the gap between the water table elevations for the two drainage treatments five years after drain installation. The gap between the data for the two treatments appears to be less in 1984 than in the other years.

Table 1 gives the monthly averages of water table heights after the installation of both drainage systems. According to Table 1, the plowed system of drainage maintained a water table height of 5 to 17 cm higher than the trenched system of drainage. A maximum difference of 55 cm in water table height was observed between the two systems of drainage (Fig. 2). Table 1 shows that the differences between the water table heights of the two drainage systems are larger for the months of April through June and are somewhat smaller for the months of July through November. Average monthly data given in Table 1 indicate that differences between the water table heights of the trenched and plow drainage systems

TABLE 1. AVERAGE WATER TABLE HEIGHTS* (ABOVE THE DRAIN) IN cm FOR THE PLOWED AND TRENCHED METHOD OF SUBSURFACE DRAINAGE FOR VARIOUS MONTHS OF FIVE GROWING SEASONS (1980-1984)

MONTH	1980		1981		1982		1983		1984		5 yr average†	
	Plow	Trench	Plow	Trench	Plow	Trench	Plow	Trench	Plow	Trench	Plow	Trench
April	42.6	20.4	42.3	34.7	39.5	34.7	69.4	36.3	56.3	46.0	50.5a	34.4a
May	27.0	9.3	52.7	35.9	63.6	40.3	66.6	49.8	47.7	38.2	51.5a	34.7b
June	50.9	35.1	53.5	36.6	49.7	30.1	52.5	32.1	37.7	28.2	48.9a	32.4a
July	23.2	16.0	24.9	13.7	26.2	17.8	44.7	29.5	15.8	12.9	26.9a	18.0b
August	58.3	45.9	29.2	24.0	13.2	4.7	6.4	5.3	3.3	2.1	22.0a	16.4b
September	35.9	19.5	15.9	9.0	12.9	2.9	13.2	19.2	0.0	0.0	17.4a	10.1b
October	29.2	22.4	7.3	1.3	8.2	2.9	33.2	23.6	0.0	0.0	15.6a	10.0b
November	25.4	18.6	7.6	2.2	32.4	28.0	51.2	31.5	0.6	1.5	23.5a	16.4b

*Each value is an average of three measurements at the midpoints between two similar subsurface drains (either plowed or trenched). These values are the averages of the data for all observation days in the month.

†Within this column, means of the same month followed by the same letter are not different at the 95% level.

have not been reduced after five years of drain installations. Further, the values in Table 1 do not show a long term trend to indicate a reduction in this difference with time. But both methods appear to be giving adequate drainage. The water table is less than 30 cm from the surface for only a couple of days each year and the water table is more than 50 cm below the surface most of the time. The apparently slower drainage of the area drained by the drain laying plow could even be considered to be providing a small sub-irrigation, or water conservation benefit.

Some of the European experiences (Naarding, 1979; Olesen, 1979; Spoor and Fry, 1983; and Eggelsman, 1979) suggest that the soil moisture conditions at the time of drain installation are important. Experimental data (Olesen, 1979) show that, if soil is relatively dry at drain depth at installation time, equivalent drainage can be obtained with the plow system in a moraine loam soil. If the plow drainage method is used when the soil is wet to drain depth, however, a lower drainage performance is expected. At high soil moisture contents, the plow blade presses the soil sideways and compacts it. After passage of the blade the furrow closes but exhibits a decrease in the hydraulic conductivity of the soil near the furrow. Spoor and Fry (1983) have shown that local conductivity reductions beneath and to the side of the pipe drains may be one of the major causes of inferior performance of drains installed with the drain plow.

A comparison was made between the water table heights maintained in the field areas by the two drain installation methods by calculating the standard error and the average deviation (Kanwar et al., 1984). Table 2 gives the calculated values of two statistical parameters for the five years of field data. Statistically, the average deviation and the standard error are indicators of quantitative dispersion between the water table heights maintained in the experimental plots by drain pipes laid using a trencher and drain plow.

The average deviation between the two water table heights varies from about 5 to 15 cm, and the standard error varies from 7 to 19 cm. Statistically, Table 2 shows that on the basis of five years of data on water table heights, the plowed system of drainage is likely to give on the average, a dispersion of 11 to 14 cm in the water table heights more than the trenched system of drainage.

The five years of data on water table heights, was subjected to linear regression analysis. Fig. 3 gives a relationship between the water table heights for drainage systems installed by the trench and plow method. As can be seen from Fig. 3, data points are scattered around the line of best fit, but the correlation of field data is high, with a correlation coefficient (R) of 0.93. The

TABLE 2. AVERAGE DEVIATION AND STANDARD ERROR BETWEEN OBSERVED WATER TABLE HEIGHTS FOR 5 YEARS OF DATA FOR TWO DRAINAGE SYSTEMS, THE TRENCHED AND PLOW METHODS OF DRAIN INSTALLATION

Year	Number of observations	Average deviation, cm	Standard error, cm
1980	39	14.3	16.3
1981	35	10.3	11.6
1982	35	11.8	13.9
1983	35	15.0	18.8
1984	35	4.9	7.5
1980-1984	179	11.3	14.2

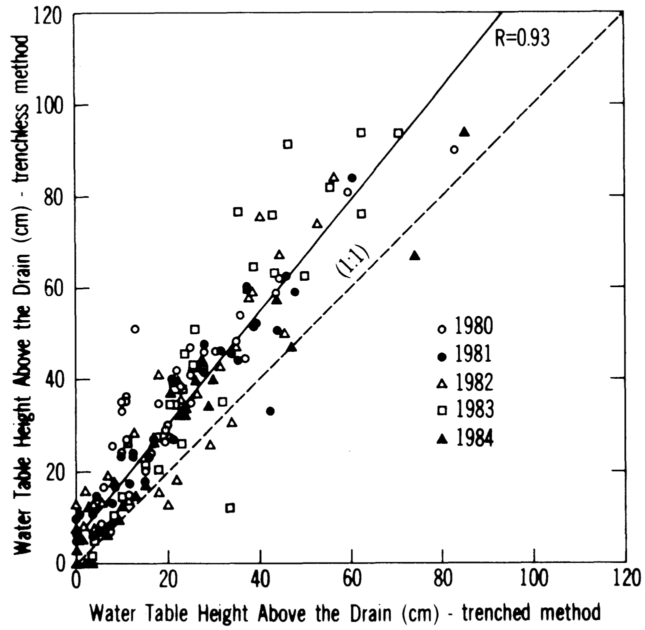

Fig. 3—Relationship between the observed water tables heights under two subsurface drainage systems (trench and trenchless) for Kenyon-loam soils.

relationship between the two water heights can be described by a linear regression model for the data given in Fig. 3. The equation for the regression solid straight line shown in Fig. 3 is given below:

$$(WTH)_{plowed\ method} = 5.82 + 1.22\ (WTH)_{trench\ method}$$

where WTH is the water table height above the drain at midpoint in cm. The slope of the regression line shown in Fig. 3 is 1.22. If two methods of drain installation would have similar performance, the slope of this regression line would have been close to 1:1. The regression line with a slope of 1.22 was compared statistically with a 1:1 straight line, and two straight lines were found significantly different at the 0.05 level as determined by t - and F - tests. These lines show that the differences in rate of water table lowering between two methods of drain installation do exist and should be considered in making decisions.

Fig. 4 shows the water table data as a function of the distance from the drain line for various times of the year during the study period (1980-1984) for the two methods of drain installation. Each point shown in this figure is an average of three readings, with sets of readings obtained from both sides of the tile lines. The data shown in Fig. 4 indicate the water table elevations in areas drained by a trenchless drain plow method at 3, 6, and 12 m from the drain stay approximately at the same elevation and show a large decline in water table elevation as the water table approaches the drain level for the years 1980-82. Areas drained by the trenched method of drainage show lower water tables and steady decline of the water table height as the water table approached the level of the drain during the same period (1980-82). This indicates that the trench backfill remains permeable for several years following installation. Under such conditions, the trench effectively functions as a ditch. In a ditch, the extreme convergence of flow lines as compared to a pipe drain eliminates high head loss near

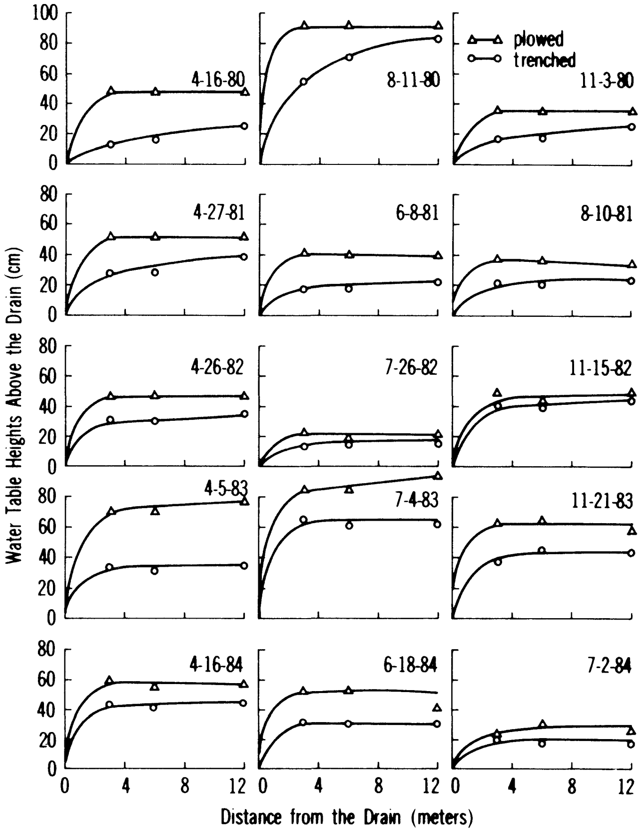

Fig. 4—Water table heights for trench and plow drainage as a function of distance from the ditch for various times.

the drain. With less resistance, the quantity of flow is increased and more water is removed giving a flatter slope to the free water surface.

Table 3 provides the summary of the crop production history in the experimental area where water table heights were monitored along with the details of the tillage systems and crop rotations in the area. Tillage and crop rotation treatments were replicated twice and Table 3 gives the means of the observations from the two replicates of crop yields for five years (1980-1984) within tillage and drain installation. The crop yield data in Table 3 indicate a lower corn yield for the plow drainage method, especially for the no-till tillage treatment where early spring drainage is important fo early plant growth and vigor. Soybean yields are consistantly lower for plowed installations across all tillage treatments. An analysis of variance, in which three tillage systems were compared to two drain installation methods, demonstrated that there is no significant difference in corn and soybean yields due to drain installation methods.

Table 4 gives the average corn yields for four years (1981-84) as a function of three tillage systems (no-till, chisel plow, and conventional tillage) and methods of drain installation in another area of the field where water tables were not monitored. These data indicate that the trenched method of drain installation gave higher corn yields. The data given in Table 4 are shown to support some of the observations made in the plots represented in Table 3.

TABLE 4. CORN YIELDS IN kg/ha AS A FUNCTION OF THE TILLAGE SYSTEM AND METHOD OF DRAIN INSTALLATION (from Don Timmons, Soil Scientist, USDA-ARS, Ames, Iowa)

Year	Conventional tillage		Chisel plow		No-till	
	Trench	Plow	Trench	Plow	Trench	Plow
1981	(9363)	(8825)	(9969)	(9969)	(9681)	(7619)
1982	(7438)	(6713)	(6844)	(6544)	(5975)	(4725)
1983	(5381)	(4438)	(4156)	(4069)	(3063)	(3281)
1984	(5850)	(5700)	(4488)	(4619)	(3813)	(4188)
Avg.	(7008)	(6419)	(6363)	(5939)	(5633)	(4953)

CONCLUSIONS

Two subsurface drainage systems were installed at 1.2 m depth in Kenyon loam soil in Iowa, one with a chain trencher and another with a trenchless drain plow. Water table measurements for the 5-year period (1980-1984) showed that the area drained by the trenchless drain plow method exhibited higher water table heights most of the time, compared with the area drained by the trenched method. Statistical analyses of the water table data for the two drainage systems indicated that the average deviation and standard error ranged from 5 to 15 cm and 7 to 19 cm, respectively. The data on crop yields showed that the trenched system of drainage resulted in higher average yields of corn and soybeans as compared with the plowed method of drainage but they were not significantly different (95) for the 5-year period. The factors affecting the performance of trenchless drainage are not clearly revealed by this research, but other studies have shown that the performance of the trenchless drain plow installations may be associated with a smearing and compaction by

TABLE 3. CROP YIELDS AS A FUNCTION OF TWO METHODS OF SUBSURFACE DRAIN INSTALLATION (PLOW AND TRENCH DRAIN) AND THREE TILLAGE SYSTEMS

YEAR	CROP	CROP YIELDS, kg/ha					
		Tillage 1*		Tillage 2†		Tillage ‡	
		Plow	Trench	Plow	Trench	Plow	Trench
1980	Corn	(8416)	(8679)	(7879)	(8332)	(8723)	(8316)
1981	Soybeans	(1489)	(1704)	(1091)	(1235)	(1315)	(1479)
1982	Corn	(8357)	(8910)	(8276)	(9360)	(9844)	(9285)
1983	Soybeans	(3050)	(3071)	(2587)	(3577)	(2774)	(3145)
1984	Corn	(8866)	(8858)	(9330)	(9539)	(9896)	(10292)
Avg	Corn §	(8546)a	(8816)a	(8495)a	(9077)a	(9488)a	(9297)a
	Soybeans	(2270)a	(2386)a	(1839)a	(2406)a	(2045)a	(2312)a

*No-till corn, no-till soybean rotation.
†No-till corn, plow soybean rotation.
‡Plow corn, plow soybean rotation.
§Within this row, means followed by the same letter under each tillage system are not different at 95% level.

the plow action. Significant compaction may influence the hydraulic conductivity of the soil and water flow through the soil to the drain. Several other factors such as sharpness of plow edge, lift design of cutting edge and the front soil lifting plane on plow boot, trench width, soil plasticity, and soil moisture conditions at drain depth during installation could also affect the performance of plow methods of drain installation.

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