SOUTHEAST PURDUE AGRICULTURAL CENTER (SEPAC)

Soil drainage and crop yields:

Insights from long-term SEPAC study

Eileen Kladivko
Agronomy Department
Purdue University
West Lafayette, Indiana

Long-term drainage experiment insights on crop yield, cover crop growth, soil improvement, water flow, and chemical transport in southeastern Indiana: Part 1 of 3-part series.

Drainage pays!

This is Part 1 (of 3) of a study detailing key findings of a 35-year project conducted at the Southeast Purdue Agricultural Center (SEPAC) in Butlerville, Indiana, six miles east of North Vernon in Jennings County.

Part 1 (AY-397-W) focuses on cash crop establishment and yield as affected by drain spacing. Key conclusions:

- **Drainage improved timeliness of fieldwork by 1 to 15 days**
- **Drainage improved corn yields by 24 bu/A over the 35-year study, but did not change soybean yields**

Part 2 (AY-398-W) discusses the effects of drainage on cover crop growth and the effectiveness of other conservation practices on improving crop growth and soil properties.

Part 3 (AY-399-W) discusses drain spacing effects on the amount of water and nitrate-nitrogen leaving the field in drainflow and the effects of cover crops on those losses.

Although these results are specific to this study on the Clermont silt loam soil at SEPAC, most of the findings are more generally applicable across other poorly drained soils, although the specific values will vary with soil and climate.

Parts 1, 2, 3 and the executive summary (AY-396-W) can be downloaded for free at Purdue Extension Education Store. https://www.edustore.purdue.edu/

Naturally poorly-drained soils present many challenges for crop production. Subsurface "tile" drainage is a common water management practice for naturally poorly-drained soils throughout Indiana and much of the Midwest.

At the Southeast Purdue Agricultural Center (SEPAC), we have conducted long-term studies on tile drainage on a Clermont silt loam (now sometimes called Cobbsfork), typical of the soils in southeastern Indiana and similar to soils stretching from southwestern Ohio to eastern Kansas. Prior to this research, the Clermont was typically drained only with surface drainage consisting of land-leveling and shallow surface drains. This approach required frequent maintenance of the shallow drains due to the poor soil structure of the high silt, low organic matter soil. Subsurface drainage had not been used due to concerns about silt accumulation clogging the tiles and slow water flow through the poorly structured soil. With the advent of plastic perforated drainage "tiles" in the 1970s, farmers in the region requested an evaluation of these modern technologies for drainage of the Clermont. With funding from the state of Indiana and a new research farm in southeastern Indiana, long-term drainage research studies were begun in 1983.

The original goals of the SEPAC drainage studies were to evaluate 1) subsurface drain spacings on drain flow and corn growth and yield, and 2) combinations of agronomic management practices and drainage on soil physical properties and corn growth and yield. Additional objectives were added over the years, especially related to movement of agricultural chemicals (nitrate-N and pesticides) through the soil into the drainage waters. The drainage systems were installed during February-March 1983, during unusually warm and dry weather (Photos 1, 2). The first experimental measurements and crop growth studies were begun in 1984.

SEPAC drainage research site

- Drainage installed at four spacings to research spacing effect on yield.
- 5m, 10m, 20m, 40 m
- (16 ft, 33 ft, 66 ft, 132 ft)
- 2.5-3 ft depth
- 4-inch plastic drain tube, no sock or filter

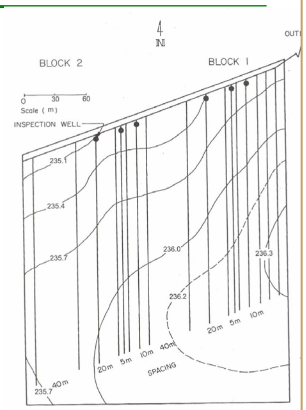

Figure 1. SEPAC drainage spacing field layout.

Photo 1. Drainage field installations

Photo 2. Lateral drain installation, exiting into culvert for measurement

The drain spacing experiment consisted of three drain spacings plus an "undrained control", replicated twice in the field (see Fig. 1). Drains were installed at spacings of 5, 10, and 20 m (16, 33, and 66 ft), with the undrained control being at a spacing of 40 m (133 ft). Due to the very slow permeability of the Clermont soil, the 40 m spacing was considered to be a good proxy for "undrained" conditions (see Photo 3). Lateral drains were 4-inch diameter perforated plastic drain tubes, with no sock or filter, installed at a 0.4% grade at a depth of 2.5-3 ft. The installation depth kept the tiles above the depth of the restricting layer (fragipan) which was generally at 3.5-4 ft. deep. The drain grade was steeper than usual; the contractor suggested it as a way to keep the tiles from silting in. Observations later in the study showed that the drains, in general, collected only a small amount of sediment in the corrugations and otherwise stayed clean and flowing.

Drainage improved timeliness of fieldwork by 1 to 15 days

One reason to install subsurface drains is to gain more timely access to fields in the spring. During the first 10 years of the drain spacing experiment, each of the four drain spacings (including the "undrained" control) were tilled and planted according to when the soil was "suitable" for primary tillage with a chisel plow. The farm superintendent made the assessment of when the soil had dried sufficiently to allow chiseling to occur without damage to the soil and to provide good seedbed preparation. For each spacing, chiseling was done one day; the next day a secondary tillage pass (field cultivator or disk) was done, and then the corn was planted.

If a spacing was "ready," it would be tilled and planted; the other spacings would be re-evaluated the next day and so on until all were planted. If rain occurred, planting of the wider spacings could be delayed even longer.

Table 1 shows the planting dates of the 5-m spacing and the delay for the 10-m and 20-m spacings and the undrained control, during the first 10 years (1984-1993) of continuous corn. During that span, only three times was the planting date for the narrowest spacing later than the latest optimum May 10th date. This reflects the drier-than-normal spring weather during much of the early part of the study. In addition, only twice was the undrained control significantly delayed from the 5-m spacing. Planting delays of 11 and 15 days occurred in 1984 and 1989, respectively, due to rains occurring between the planting of the 5-m spacing and the readiness of the undrained control.

The approximately two-week planting date advantage in two of the 10 years could be a greater benefit to more typical farming operations than it was in our study. Most farmers have multiple fields and larger fields than our 15-acre experimental field. In our study, the research farm staff was on site, and this experiment was a priority. Thus, the staff was able to assess each plot and perform tillage and planting as soon as each spacing was ready.

Drainage improved corn yields but not soybean yields

Crop yield is, of course, a prime reason why farmers invest in subsurface drainage systems. Corn yields during the first 10 years and on average over those 10 years are shown in Fig. 2. Yields varied from year to year.

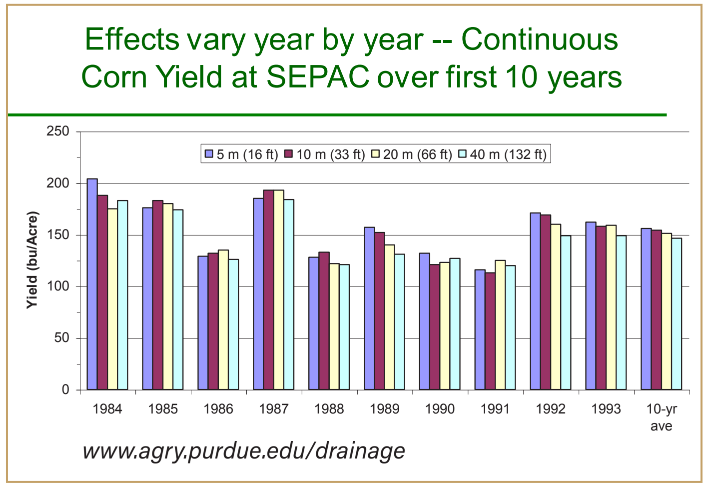

Figure 2. Corn yields during the first 10 yrs and the average of the 10 yrs, as affected by drain spacing at SEPAC.

The highest yields sometimes occurred in the narrowest spacing and other years in the intermediate spacings. The undrained control had the lowest yield in 7 of the 10 years. The lower yields in the undrained control in 1989 were partly due to the delayed planting date, but in most years the effect was due to the wetter conditions after planting and not to delayed planting date. On average over the 10 years, the yields were 157, 155, 152, and 147 bushels per acre for the 5-, 10-, 20-, and 40-m plots, respectively.

Although yield differences were not as great in those early years as initially expected, for several reasons we expect farmers will see greater yield benefits from subsurface drainage. First, as discussed earlier, subsurface drainage resulted in earlier field operations, and that benefit would likely be larger for a more typical farm operation. Second, our field has relatively good surface drainage and slightly more slope (but still less than 1%) than typical fields with Clermont soils. Typical fields with less slope often have poorer surface drainage and therefore suffer from ponding and flooding that may "drown out" the crop. Subsurface drainage can minimize ponding and flooding. In another part of our field (separate from the drain spacing study), with a higher frequency of surface ponding, the undrained

Table 1. Timeliness of planting at SEPAC during first 10 years of experiment. Plots were chisel-plowed when "ready" and planted the next day. Note 3 years of 10 with planting dates after May 10 for all plots, and 2 years of 10 with greater than 10-day delay between 5m and undrained control plots. For fields larger than our 15-acre site and with less ideal surface drainage, the timeliness benefit would likely be much greater.

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
5 m planted-->	My 21	Ap 22	Ap 30	Ap 28	My 02	My 18	My 29	My 01	My 05	My 10
10 m delay-->	+0	+0	+0	+0	+0	+0	+1	+0	+0	+0
20 m delay-->	+4	+0	+0	+1	+0	+1	+2	+1	+0	+1
40 m delay-->	+11	+2	+0	+2	+3	+15	+3	+2	+3	+1

block was drowned out and replanted three times in one year, producing no yield at all, which of course accentuates the benefits of subsurface drainage (Photo 4). Because all plots (both drained and undrained) in our drain spacing study have relatively little surface ponding, we would expect greater benefits to yield in fields where surface ponding occurs and could be reduced by subsurface drainage.

Drainage also affected the grain moisture content at harvest in this field. All plots were harvested on the same date. On average over the 10 years, the 5-m spacing was two points drier in grain moisture than the undrained control (21% vs. 23%), which would reduce grain drying costs for the drained vs. undrained treatments.

Crop yields during 1994-2018 showed much greater benefit of drainage than in the first 10 years. This is likely due in part to generally wetter conditions for the latter 25-yr period. It may also reflect further maturation of the drainage system with time. The field management was changed from continuous corn with chisel tillage, to a corn-soybean rotation with no-till and with cover crops in some years, so it is also possible that the modified field management accentuated the benefits of drainage on corn yield. It should be noted that all plots were planted on the same date after the first 10 years, so timeliness benefits were no longer being assessed once we made the switch to no-till.

Corn yields from 2007-2017 are shown in Fig. 3. In some years (2007, 2011) there was little difference in yield across all three spacings and the undrained control. But in many years there was a significant yield reduction in the undrained control compared to the three drain spacings, reflecting in part the wetter years compared to earlier in the study. Clearly a 40-50+ bu/A yield benefit of any of the drain spacings, compared to the undrained control, would be a significant benefit to farmers. During

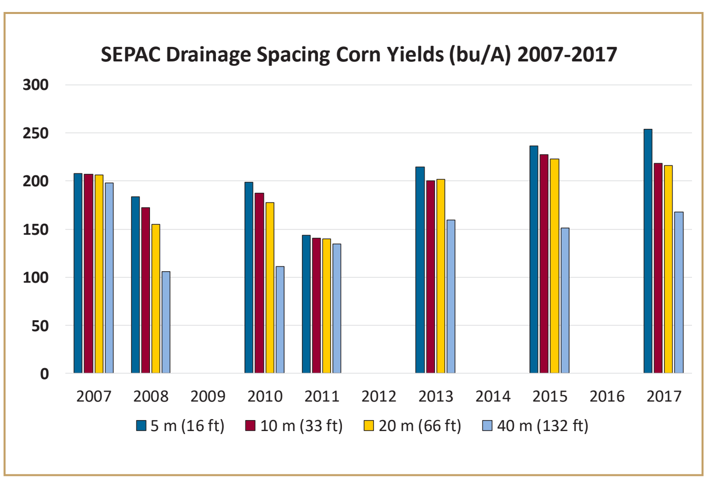

Figure 3. Corn yields from 2007-2017.

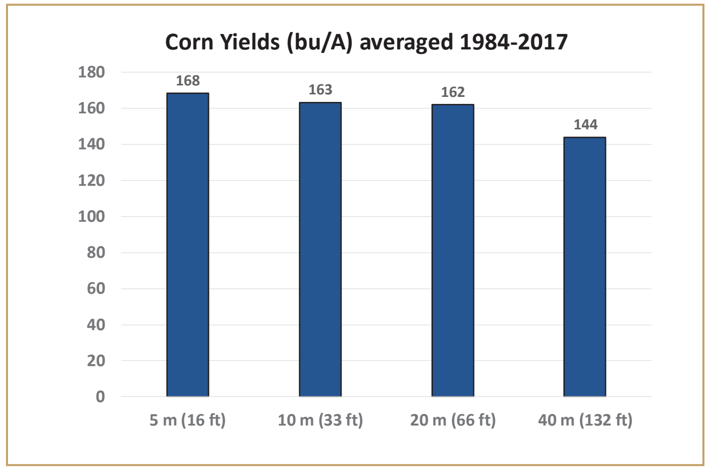

Figure 4. Corn yields averaged over all corn years of the 1984-2017 time period showed relatively little difference in corn yields among the 5-, 10-, and 20-m drain spacings, but a 24 bu/A reduction in the undrained control compared to the narrowest drain spacing.

2017 there was an additional timing disadvantage to the undrained control, in that the first planting on May 16th did not establish well and needed to be replanted 2 weeks later, on June 2nd (Photo 5). Thus the lower yield was due in part to excess wetness after planting and in part to delayed planting date compared to the drained plots.

Corn yields averaged over all corn years of the 1984-2017 time period showed relatively little difference in corn yields among the 5-, 10-, and 20-m drain spacings, but a 24 bu/A reduction in the undrained control compared to the narrowest drain spacing (Fig. 4). This is much greater than the 10 bu/A disadvantage found during the first 10 years of the study. The later time periods were wetter than the early part of the study, and the benefit of drainage was much more pronounced than in the early time periods.

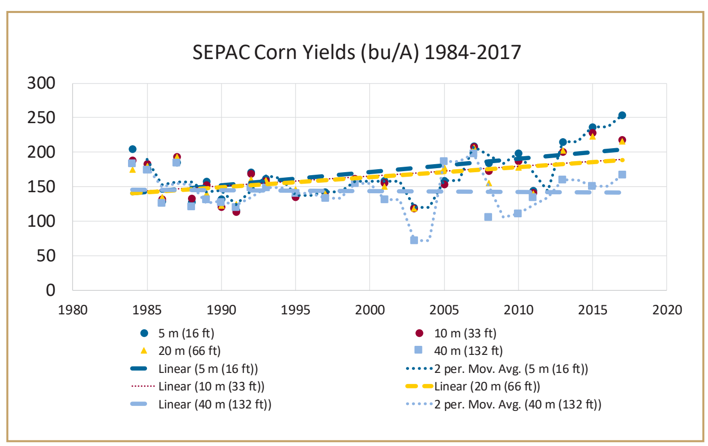

Figure 5. When looking at the corn yield trend over time, from the first to most recent corn year, the trends for the three drain spacings are similar to general corn yield trends reflecting improvements in genetics and other practices, while the undrained control has remained flat or even decreased slightly.

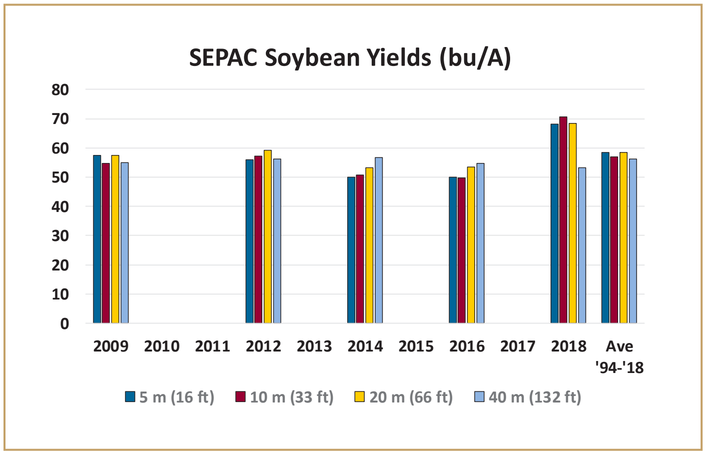

Figure 6. Soybean yields on this field have generally not been affected by drainage.

Photo 3. Aerial image of drainage field, with drain lines superimposed on the image. The lighter-colored soil over the drainlines clearly shows the impact of the drains on drying the soil faster than where drains are not present. Note the darker areas in the right-hand side of the field, correspond to the undrained control (compare to Fig. 1 for field design).

Photo 4. Lack of corn stubble in foreground on undrained block, compared to corn stubble in background on drained block, illustrates the extremes of benefits of subsurface drainage on fields with areas of ponding. This was the agronomic treatment experiment (discussed in publication 2 of the 3-part series), seen in the left side of Photo 3.

Photo 5. The undrained control plot (center of picture heading up toward trees) on 6/12/17, has no corn stand from original planting date of 5/16/17, whereas drained plots to right and left had sufficient stand from the original planting.

When looking at the corn yield trend over time, from the first to most recent corn year (Fig. 5), the trends for the three drain spacings are similar to general corn yield trends reflecting improvements in genetics and other practices, while the undrained control has remained flat or even decreased slightly. Although there is large variation around the trendline, the 5-m spacing had an average yield increase of 1.9 bu/A per year from 1984 to 2017, whereas the undrained control had an average yield loss of 0.1 bu/A per year. This illustrates that to capture the benefits of improved genetics and other technologies, an adequate drainage system is a necessary first step on a naturally poorly drained soil.

Soybean yields on this field have generally not been affected by drainage (Fig. 6). Although some years, such as 2018, showed a large disadvantage for the undrained control, other years, such as 2014, have shown a slight benefit for the undrained control. On average for the soybean years during 1994 to 2018, there are no significant differences in soybean yields among the four drain spacings, and yields averaged 57 bu/A.

Drainage is a long-term investment

Installation of tile drainage is a long-term investment in a field. Drainage flow paths seem to develop over time, at least for the first several years after installation. Crop yield effects vary from year to year, based on the weather, so some years drainage will not have any effect on yields. Other conservation practices also take time to improve soil health, and the effects of drainage on these improvements will likely become more evident with time. But the long-term improvement in cash crop yields, cover crop growth, and effectiveness of other conservation practices make the installation of tile drains on naturally poorly drained soils a good investment in the long-term productivity of a field.

Acknowledgements

The author wishes to thank the many people who have worked on this project over the years, including the SEPAC farm crew, graduate students and post-docs, faculty colleagues, and NRCS colleagues. This project was supported in part by the Purdue Agricultural Research Programs, and USDA National Institute of Food and Agriculture, Hatch project 87887.