The Use and Effects of Controlled Traffic Farming

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ORIGIN OF PAPER

The Use and Effects of Controlled Traffic Farming is a project which was conducted from April to December 2006 by Jacob Bolson, an undergraduate agricultural engineering student in the Department of Agricultural and Biosystems Engineering at Iowa State University. The project was supervised by Dr. Amy Kaleita, Assistant Professor of Agricultural and Biosystems Engineering. Data collection took place near Waterloo, Iowa, United States, at the Mitchell Farm. Funding for the project was provided by the Practical Farmers of Iowa—Iowa State University College of Agricultural On-Farm Research and Demonstration Program.

CONTROLLED TRAFFIC FARMING

What is controlled traffic farming (CTF)? CTF is an agricultural production method in which the same wheel tracks are used by all field operations, to the extent possible. The implementation of Global Positioning Systems (GPS) in agriculture has taken a significant role in the adaptation of CTF methods by the use of machines equipped with high-accuracy autosteer. With high-accuracy autosteer, farmers are able to see consistent repeatability from year to year and between different fields. Thus, it becomes increasingly possible to operate equipment in permanent, well-defined, and precise tracks.

Potential benefits of CTF are numerous. Because compaction is limited to the tracks, overall infiltration of water into the soil is increased. Improvements in soil structure also mean that drainage is improved, allowing an early warm-up of the soil in the spring. Furthermore, the improved seedbed conditions result in more even germination. As a result, overall yields from CTF can be 5-23% higher than fields with non-CTF practices, despite the unplanted wheel tracks, which generally account for approximately 16% of the total field area. Other benefits include decreased soil erosion, higher organic matter retention due to decreased tillage, and increased moisture retention. CTF can also reduce operating costs in addition to increasing yields. Fuel usage can be lowered, due to higher tractive efficiency, as well as the lower energy requirements for tillage. Also, with less need for intensive tillage, lighter tractors can be used.

CTF does have disadvantages. Equipment investment can be quite intense or very minimal, depending on the current status of the operation. Implement widths must be of equal width or multiples of each other in order for CTF to work. If the implement widths are not set up this way, following permanent, well-defined tracks is not feasible. In addition to implement widths, machines need to be equipped with high-accuracy, GPS powered autosteer. Without high-accuracy autosteer, GPS error can lead to vehicle travel outside of the specified wheel tracks. With the vehicle traveling outside of the wheel tracks, the purpose of CTF is defeated. Implement drift is also something which can cause issues in CTF. Tow-behind implements tend to drift more than integral (3-point hitch) mounted implements. Depending on the level of implement drift, an implement such as a strip-till bar or planter can drift into a wheel track.

Management becomes more intensive with a CTF operation. There is no more "just drive into the field." Records need to be kept on the location of the wheel tracks through an in-field marker and/or electronic storage via GPS coordinates. These records must be very strict so that consistent wheel track usage can be kept constant. If these records are not accurate, GPS error will only magnify any problems may occur.

Rutting is also a problem which can develop over time. As the wheel tracks get repeated use and the crop bed soil structure improves, the height of the wheel tracks can become lower that the adjacent crop bed. At time of heavy rainfall, this height difference can lead to the wheel tracks acting as waterways. This can lead to erosion problems on the wheel tracks.

OBJECTIVE

Controlled traffic is an agricultural production tool whose effects are largely unknown in a Midwestern United States environment. The objective of this research project was to collect water infiltration, soil resistance, and
crop yield data for a Midwestern United States farm utilizing controlled traffic as a tool in their agricultural production and then provide that data to agricultural producers interested in controlled traffic.

THE MITCHELL FARM

The CTF system used by the Mitchell Farm is based on 30 foot (9 meter) implement widths and 120 inch (3 meter) wheel track width. The general cropping procedure on the Mitchell Farm consists of a corn and soybean rotation. Corn in planted in 30 inch rows and soybeans are planted in 15 inch rows. The Mitchells combine, tractors, and sprayer are fitted with RTK-powered autosteer. The fertilizer cart for the strip till bar, as well as the corn planter and soybean air seeder, are fitted with RTK-powered implement guidance. Tire size information for the tractors and combine is provided in Table 1.

Table 1. Machinery tire sizes

Vehicle	Front tire size	Rear tire size
CaseIH MX270 Tractor	600/70 R30	710/70 R42
John Deere 8530 Tractor	600/70 R30	710/70 R42
CaseIH AFX8010 Combine	900/60 R32	600/65 R28

MATERIALS AND METHODS

Site description

The water infiltration and soil resistance data collection site consisted of soils which were generally of the silty clay loam type. The CTF field was in its third growing season of controlled traffic at the time of data collection. The production history of the non-CTF field was unknown.

Water infiltration

Infiltration is defined as the process of water entry into the soil, collected in units of depth per unit of time. The data in this project was collected in units of millimeters per hour ($^{mm}/_{hour}$). Infiltration can be influenced by a number of factors that often occur at the soil surface or within the soil, such as physical soil characteristics, soil surface cover, and soil water content. Increased levels of soil resistance (compaction), a physical soil characteristic, can result in greatly reduced infiltration rates.

Two types of infiltrometers were considered for collecting water infiltration data: single-ring (Figure 1) and double-ring (Figure 2). In comparing the two models, the single-ring model has a distinct size and weight advantage. The single-ring model permits rapid, unsupervised measurement of infiltration through an automated data collection system. However, the data from a single-ring model can be influenced easier by factors causing an abnormal increase in infiltration rate, such as plant roots and wormholes. A double-ring infiltrometer is not as easily influenced by these factors because the infiltration data is collected over a larger area. Despite the potential for abnormal infiltration rates, it was decided to use the single-ring model because of its size advantage (Figure 3).

Soil resistance

A Jornada impact penetrometer was chosen to capture soil resistance data because it provides results independent of the user when developing a soil resistance profile. There are two key issues with standard "push-type" penetrometers. First, "push-type" penetrometers do not give a resistance profile; they only give maximum soil resistance. Second, the soil resistance value which is displayed by the penetrometer is a function of how the probe is pressed into the ground. A Jornada impact penetrometer solves both of these problems by developing a 24 inch resistance profile and providing consistent results. The impact penetrometer works by dropping a 2 kilogram weight from a set height on to a striker plate. The striker plate hits are counted for every 2 inches of soil penetration. This data is then used to map the resistance profile. The 2 inch soil penetration value can be changed to meet user preference. Figure 3 provides a visual description of the Jornada impact penetrometer with Figure 4 showing an example of soil resistance data collection.

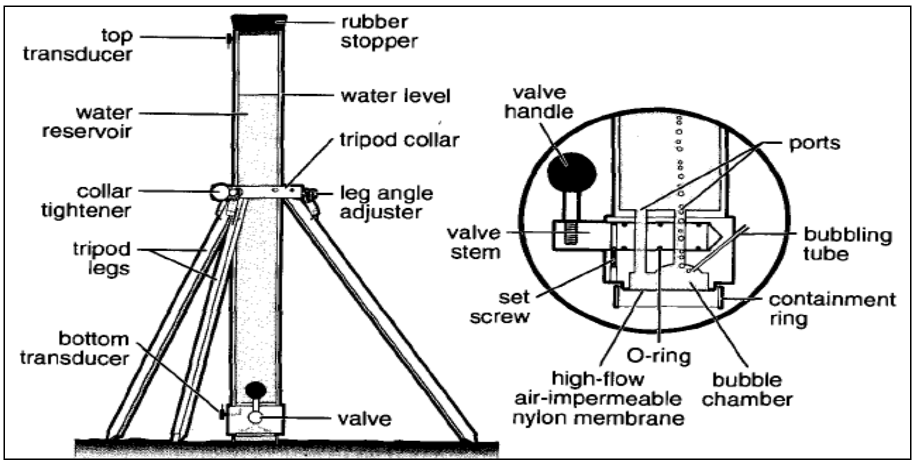

Figure 1. Schematic diagram of the single-ring infiltrometer (*(image courtesy of Fangmeier, et al.)*

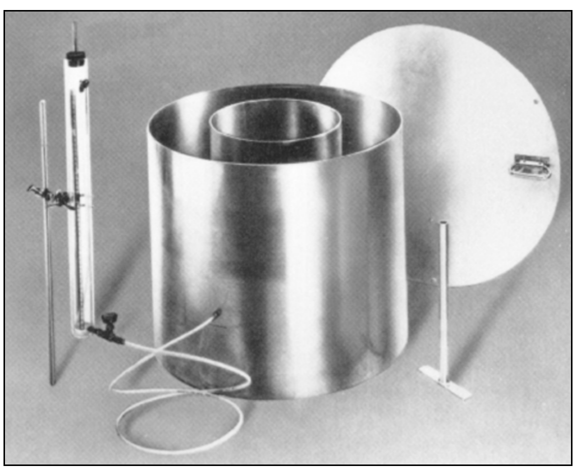

Figure 2. Double-ring infiltrometer *(image courtesy of www.rickly.com)*

Figure 3. Water infiltration data collection

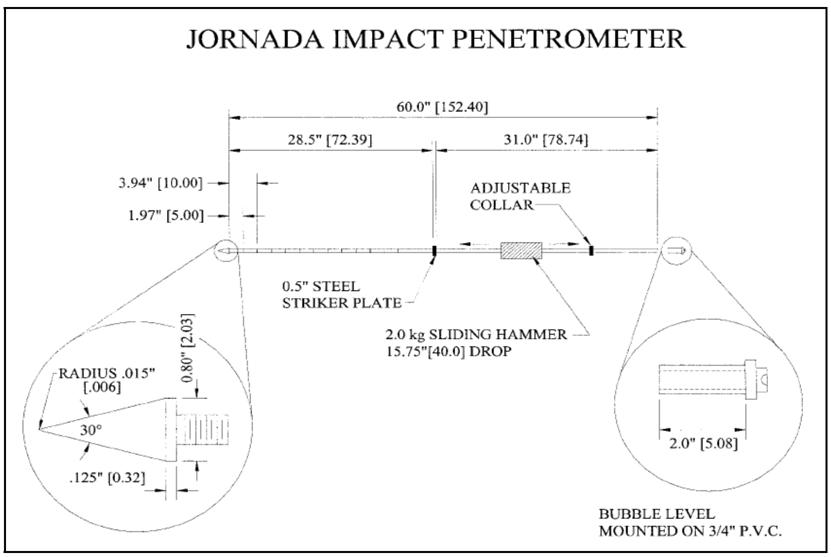

Figure 4. Jornada impact penetrometer

Figure 5. Soil resistance data collection

Crop yield

In order to collect crop yield data, a partnership was formed with Robert Recker of Cedar Valley Innovation, LLC. Crop yield data was collected in a row-by-row manner using equipment provided by Mr. Recker (Figure 6). It was decided to collect crop yield data in this manner so that row-by-row yield comparisons could be made, something which is not possible when collecting data from multiple rows at once. The crop yield data from each crop row was calculated using a yield monitor and then adjusted accordingly using data from a weigh wagon. All corn row lengths were approximately ½ mile.

RESULTS AND DISCUSSION

Water infiltration

Table 2 provides a list of basic water infiltration rates referenced to various soil types. The rates linked with each soil type are theoretical rates based on assumed soil properties. Data was successfully collected from only CTF transect 1 instead of all four transects and 25 of the 26 non-CTF points (non-CTF transect 1 plus non-CTF transect 2). Figures 7 and 8 provide the data collected in these two environments with Table 3 providing a summary of the data. It was expected that once the results from the infiltration data collection were compiled, there would be a substantial difference between the CTF wheel track, CTF crop bed, and non-CTF rates. However, the data proved to be inconclusive.

Figure 6. Crop yield data collection

Table 2: Basic water infiltration rates

Soil type	Basic infiltration rate ($^{mm}/_{hour}$)
Sand	Less than 30
Sandy loam	20 to 30
Loam	10 to 20
Clay loam	5 to 10
Clay	1 to 5

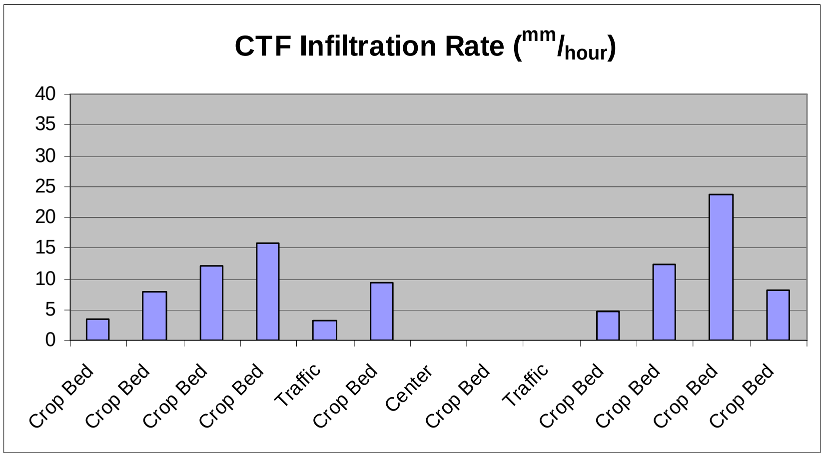

Figure 7. CTF transect 1 infiltration rate

Table 3: Infiltration data summary

Environment	Average infiltration rate ($^{mm}/_{hr}$)	Standard deviation ($^{mm}/_{hr}$)
CTF wheel track	4.4	6.2
CTF crop bed	19.3	19.1
Non-CTF	21.6	26.5

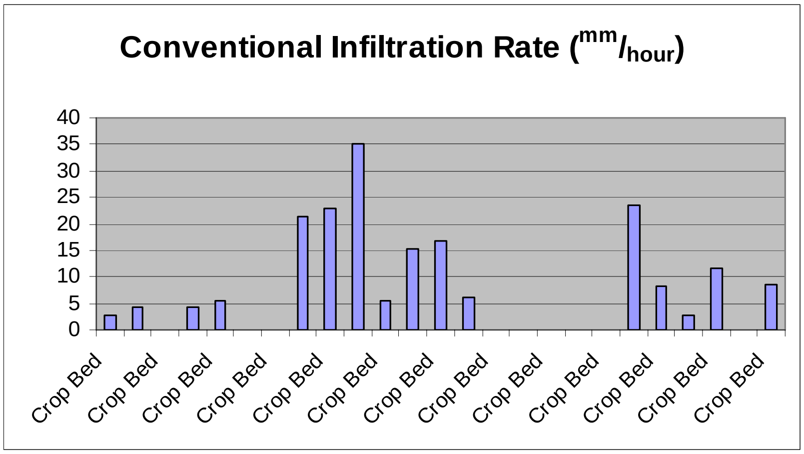

Figure 8. Non-CTF infiltration rate (transects 1 and 2)

Soil resistance

Stating that a specific soil resistance level inhibits crop root development is difficult because soil resistance is a function of many factors: soil texture, moisture content, bulk density, etc. Appendix Figures 19, 20, 21, and 22 provide the soil resistance data captured at four CTF transects with Appendix Figures 23 and 24 providing resistance data for two conventional (non-CTF) transects. The CTF soil resistance data points were collected in 30 inch increments across each transect with the data point naming schematic originating at the center of the transect. The naming schematic was defined as follows, using 1/W/3 as an example:

- Transect number (1)
- Data collection location: west of transect center or east of transect center (west)
- Distance from transect center in 30 inch increments (3 x 30 = 90 inches from center).

The conventional data was also collected in 30 inch increments across the two transects but the data point naming schematic originated at the outer edge of the transects.
The resistance levels are per two inches of soil depth. As expected, the soil resistance in the wheel tracks of the CTF transects was significantly higher than the crop beds. A key observation to note is that the wheel track compaction penetrates to a depth of approximately 8 to 10 inches. Before data collection took place, it was expected that this compaction would reach to greater depths. Another key observation is the soil resistance levels from the two non-CTF transects; there were data measurement points within the conventional transects which had soil resistance levels higher than wheel tracks in the CTF transects. This shows the harm which random wheel traffic in a field can do, resulting in crops growing in areas of high soil resistance. Figure 9 provides a summary of all soil resistance data. The aforementioned note about soil resistance becoming relatively uniform after 8 to 10 inches is shown clearly by this graph.

Crop yield

When collecting the crop yield data, the purpose was not to compare actual yields but consider yield trends. CTF yield data are provided in Figures 10 and 11 with conventional yield data provided in Figure 12. The yield data in Figure 10 is from 12 rows of broadacre corn with the data in Figure 12 from 12 rows of strip intercrop corn. Strip intercropping is a cropping procedure in which strips of corn and soybeans are alternated across a field: 12 corn rows, 12 soybean rows, 12 corn rows, 12 soybean rows, etc. This procedure is used to increase corn yields by capitalizing on the increased sunlight usage by the outer rows.

As shown by the CTF crop yield data in Figure 10, there is noticeable yield variability from row-to-row. In a conventional cropping practice, this variability can come from a variety of factors: planter problems, fertilizer application problems, compaction, etc. By utilizing a CTF cropping procedure, compaction can virtually be eliminated from the list of possible problems leading to yield reduction. A conventional cropping procedure does not allow this elimination, no matter the tillage practice. This is supported by the soil resistance data discussed earlier in which there were levels of conventional soil resistance higher than the CTF wheel track resistance. Figure 11 shows less row-to-row variability, resulting in an overall increase in total yield. Also, the yield increase of the outer 4 rows shows the benefit of strip intercropping. Figure 12 shows another excellent example of noticeable row-to-row yield variability over 32 total rows, two passes of a 16 row planter. Again, this exemplifies the need to reduce the number of factors which can cause yield reduction, which is an advantage of CTF.

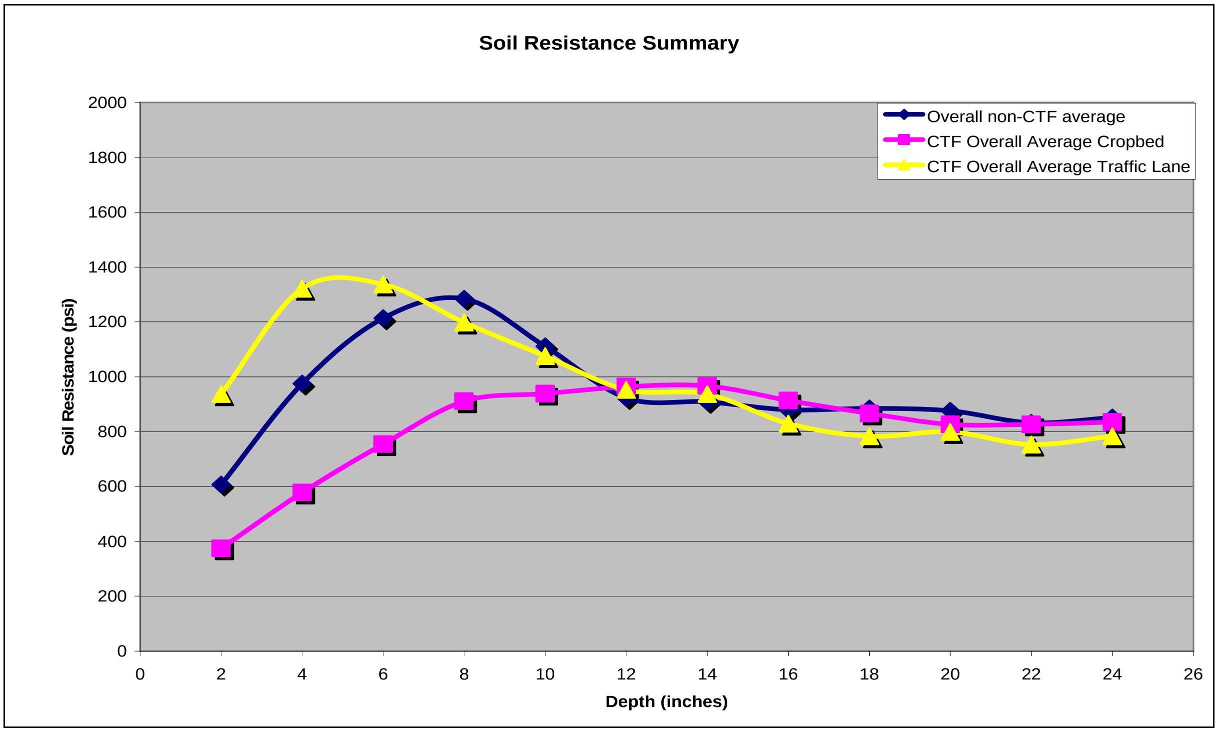

Figure 9. Soil resistance summary

Additional observations

Besides the water infiltration, soil resistance, and crop yield, other general observations were made. First, it is difficult to quantify some of the benefits of CTF. For example, on July 1 a walk was taken around the fields in which the water infiltration and soil resistance data were collected. Figures 13 and 14 provide images taken on that day. The left side of Figure 15 is a CTF wheel track and the right side is a crop bed. On July 1, there had been no precipitation for many weeks and the soil appeared to be very dry. As expected, the non-CTF soil was hard and crusty; its condition resembling that of a CTF wheel track. However, even though the soil was very dry, the CTF soil was still soft and had no surface layer, which the non-CTF did. The overall health of the CTF soil appeared to be substantially better.

CTF DISADVANTAGES

There are four key disadvantages of CTF:

- Cost
- Management
- Row spacing
- Wheel track rutting

The initial cost of CTF can be large. Initially, capital may need to be invested in equipment so that implement widths are equal or in odd multiples of each other. Also, an investment in high-accuracy auto-steer may need to take place as CTF is nearly impossible without auto-steer. In additional to financial investment, CTF does require an external level of management. The locations of the permanent wheel tracks must be recorded and logistics for crop harvest must be carefully planned.

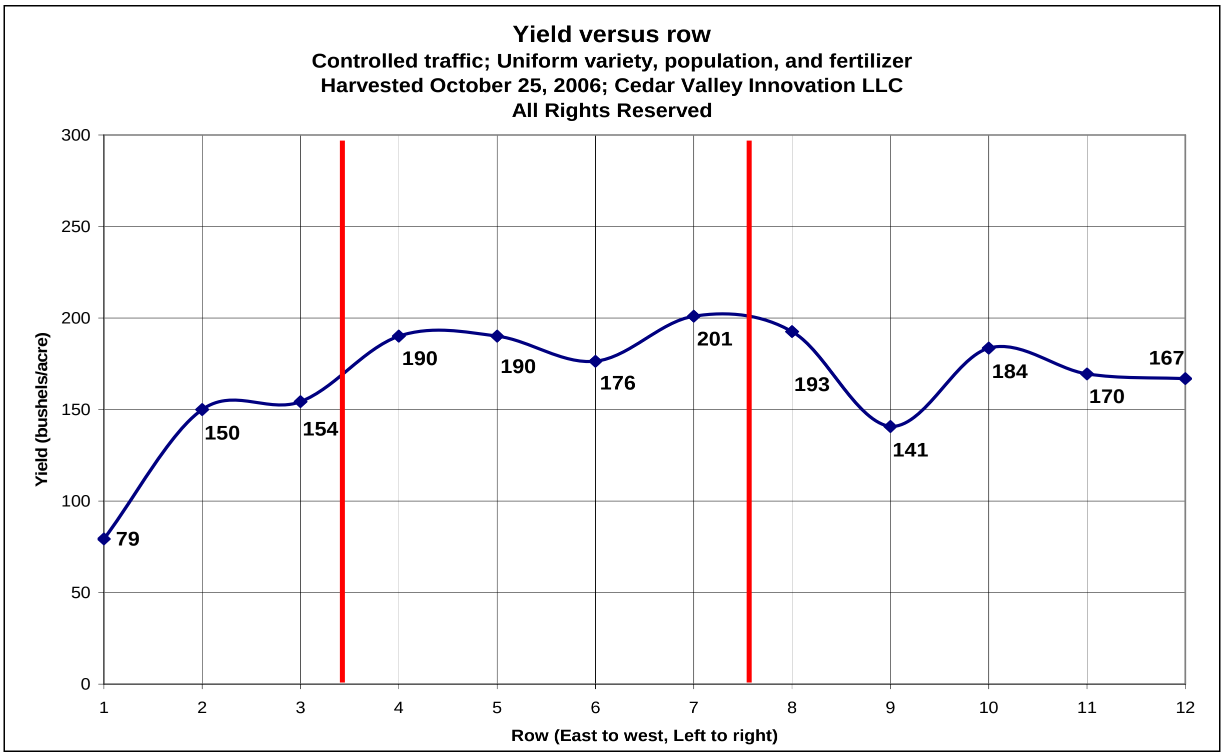

Figure 10. Yield versus row; controlled traffic; uniform variety, population, and fertilizer (Red lines denote traffic lanes)

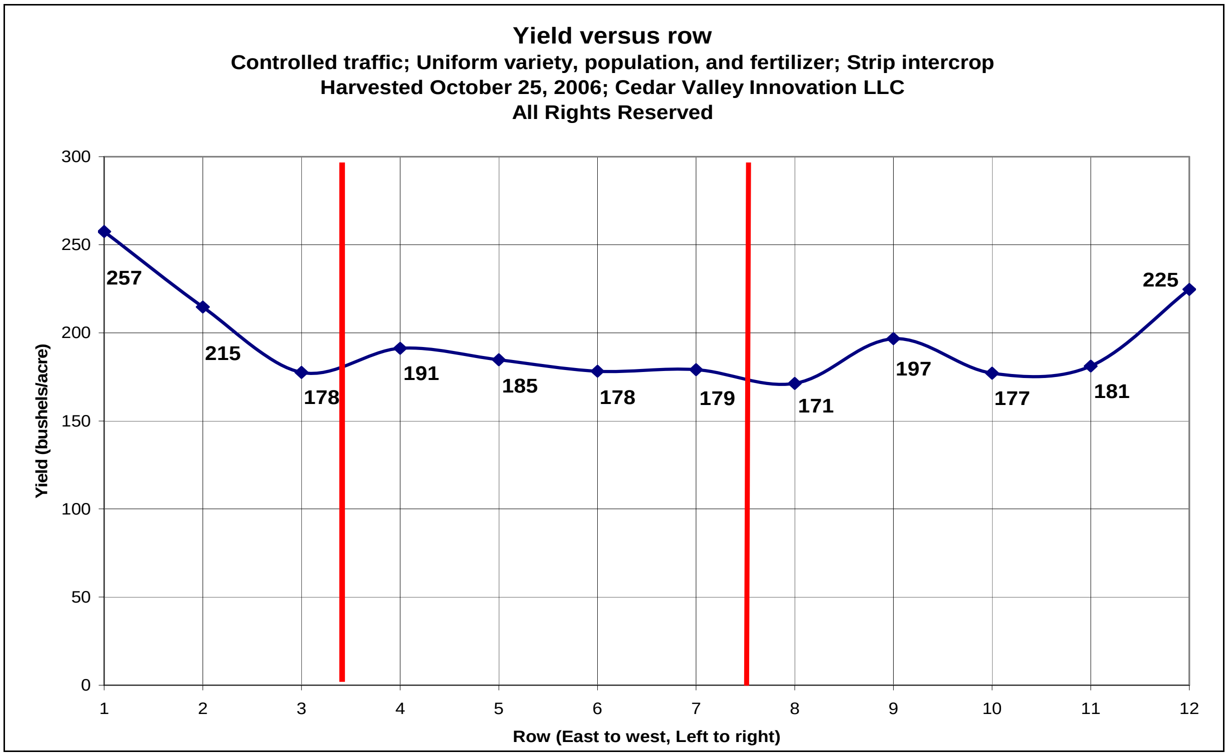

Figure 11. Yield versus row; Controlled traffic; Uniform variety, population, and fertilizer; strip intercrop (Red lines denote traffic lanes)

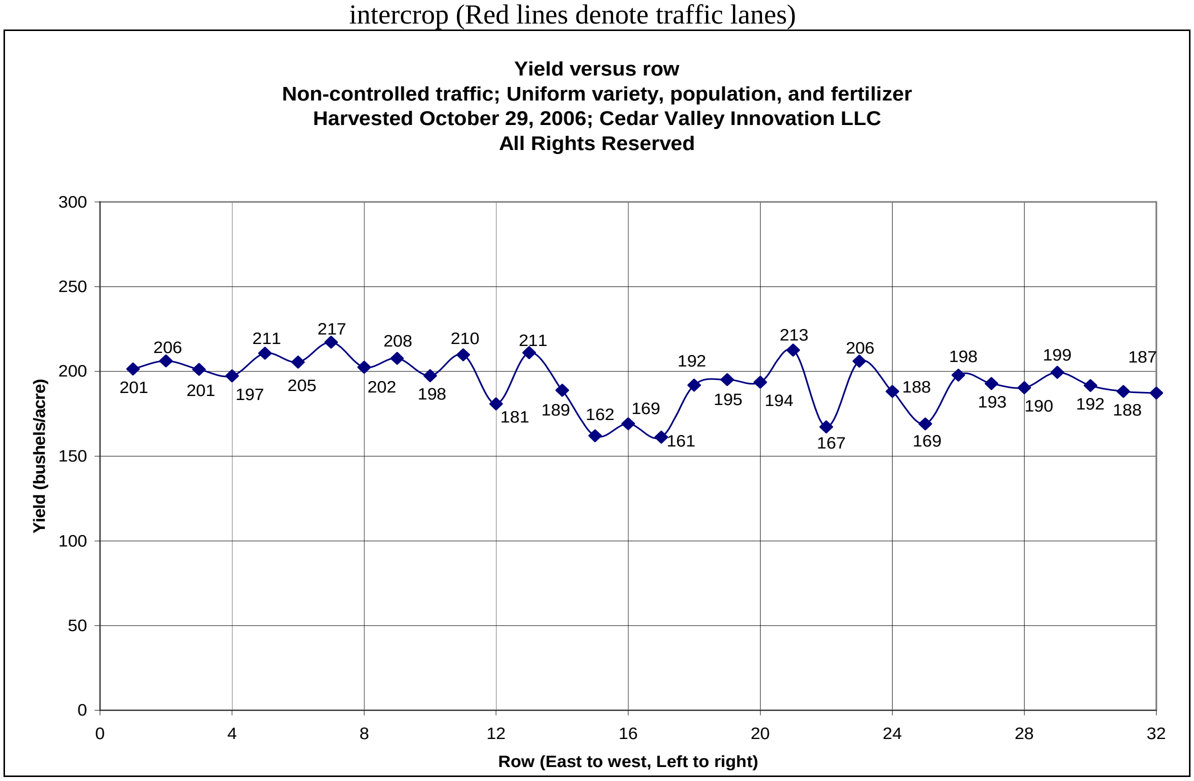

Figure 12. Yield versus row; non-controlled traffic; uniform variety, population, and fertilizer

Figure 13. July 1, 2006 CTF soil surface

Crop row spacing must be carefully considered in a CTF environment. In a corn and soybean rotation, many times the crops use the same row spacing. This creates a challenge in a CTF cropping procedure because the end result will be trying to grow one crop in the same location as the previous year's crop. This problem has been addressed on the Mitchell Farm by utilizing a 15 inch soybean row spacing, which places the soybean rows 7.5 inches on either side of the previous year's corn row. However, in a system which requires the use of equal row spacing between different crops, a strong solution to the crop overlap problem has not emerged.

Figure 14. July 1, 2006 non-CTF soil surface

Figure 15. Wheel track height (left) versus crop bed height (right)

Wheel track erosion is also an issue with CTF. Over time, the height of the wheel tracks can becomes lower than the surrounding crop beds. As of June 2006, this height difference was approximately 2 inches across the Mitchell Farm (Figure 15). In times of heavy rainfall, these wheel tracks can act like waterways and because of their high levels of compaction, water infiltration is low and therefore, erosion can take place. There are isolated locations on the Mitchell Farm where wheel track erosion had led to the wheel track-crop bed height difference up to 4 inches. Currently, there is not any equipment on the market specifically for addressing the height difference. However, there are producers who have developed their own tools as well as thought being given towards adapting equipment engineered for filling in pivots left by center-pivot irrigation systems. An example of one of these tools is shown in Figure 16.

Figure 16. Bigham Brothers pivot track disc filler (image courtesy of *http://www.bighambrothers.com/trackfiller.htm*)

INTERNATIONAL CTF

Popularity of CTF in Australia is very strong and widespread with popularity in the United Kingdom continually increasing. The Australian Controlled Traffic Farming Association is an excellent resource for general and Australian-specific CTF information: http://www.actfa.net/. CTF Solutions is also an excellent Australian-specific CTF resource: http://www.ctfsolutions.com.au/.

Controlled Traffic Farming, Ltd. is a company in the United Kingdom which serves as a general and United Kingdom-specific CTF information source: http://www.controlledtrafficfarming.com/. From November 18 to 24, 2007, CTF in the United Kingdom was experienced first-hand courtesy of Tim Chamen, proprietor of Controlled Traffic Farming, Ltd. Figures 17 and 18 show a tractor set up for CTF and a CTF field, respectively.

CONCLUSION

Controlled traffic farming (CTF) is an agricultural production method which, when compared to non-CTF, produced more consistent row-to-row crop yields and lower levels of soil resistance (to a depth of 8 to 10 inches). Water infiltration between the two production environments produced an inconclusive comparison. CTF does have disadvantages such as cost and wheel track rutting

FURTHER RESEARCH

Further research should concentrate on continuing collection of water infiltration, soil resistance, and crop yield data. Research should also explore methods of utilizing CTF in an environment where year-to-year crops use identical row spacing. Horizontal compaction from the wheel tracks should also be researched to determine its effects on crop rows adjacent to the tracks.

ACKNOWLEDGEMENTS

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Figure 17. Tractor configured for 3 meter (120 inch) CTF

Figure 18. CTF field in the United Kingdom

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