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Economic risk, returns and input use under ridge and conventional tillage in the northern Corn Belt, USA

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Abstract

Ridge tillage (RT) has been proposed as an economically viable conservation tillage alternative for row crop production; however the long-term economic viability of RT in the northern Corn Belt of the USA is largely unknown. Economic returns, risk and input use were compared for RT and conventional tillage (CT) in a corn (*Zea mays* L.) and soybean (*Glycine max* (L.) Merr.) rotation with high, medium and low nitrogen treatments. The analysis was based on 10 years of experimental data from Brookings, SD on a Barnes clay loam (US soil taxonomy: fine-loamy, mixed, superactive, frigid Calcic Hapludoll; FAO classification: Chernozem). Economic returns were significantly higher at the highest nitrogen treatment levels. Highest average net returns to land and management were $ 78 per hectare for RT at the high nitrogen treatment level (RT-H) followed by $ 59 per hectare for CT at the high nitrogen treatment level (CT-H). Risk, measured as the standard deviation of net returns, was the lowest for CT at the medium nitrogen treatment level (CT-M) followed by RT-H and CT-H. However, net returns were substantially lower under CT-M at $ 32 per hectare. Average yields and average operating costs were not significantly different for RT-H and CT-H. Reduced equipment operating costs for CT-H were offset by increased herbicide costs for RT-H. Equipment ownership costs were significantly lower for RT-H than CT-H. There were no significant differences in fertilizer use for RT and CT. Pesticide use was significantly higher for RT-H than CT-H. Fuel use was 18–22% lower and labor use was 24–27% lower for RT-H than CT-H. Despite continued low adoption rates for RT in the northern Corn Belt, our analysis shows that RT is an economically viable alternative to CT.
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Keywords: Corn; Soybean; Economics; Tillage

1. Introduction

Ridge tillage (RT) has been proposed as a compromise between conventional tillage (CT) and no-tillage systems. Behn (1985) indicated that planting on ridges provides the benefits of no-tillage such as erosion control, and time and fuel savings without the problems of no-tillage such as delayed planting, poor stand establishment and weed control.

Despite claims that RT can be an economical system for row crop production (Exner, 1996), adoption of RT has been low. RT represents only 1.1% of planted

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cropland acres in the United States, and this percentage has remained steady since 1990. In the midwest, RT represents only 1.2% of planted cropland acres (Conservation Tillage Information Center, 2000).

Previous economic comparisons of RT and CT indicate mixed results. Smolik et al. (1995) showed RT produced lower net returns than CT for a corn–soybean–spring wheat (*Triticum* spp.) rotation in South Dakota. Similarly, Chase and Duffy (1991) indicated that RT produced lower net returns than moldboard plow tillage and chisel plow tillage for a continuous corn rotation and a corn–soybean rotation in Iowa. Jolly et al. (1983), showed RT generally produced lower net returns than moldboard plow and chisel plow tillage systems for a corn–soybean rotation in Iowa. In each of these studies differences in net returns were largely due to reduced crop yields under RT.

On the other hand Weersink et al. (1992) showed that RT produced higher net returns than no-till, chisel plow and moldboard plow tillage for a corn–soybean rotation in southern Ontario. Similarly, Doster et al. (1983) showed RT produced higher net returns than fall plow, fall chisel, spring plow, spring chisel, and no-till systems for a corn–soybean rotation in Indiana. In both of these studies yields were maintained or increased and costs decreased under RT.

Our objectives were to compare economic risks and returns, and input use for three nitrogen treatment levels in an RT and a CT system.

2. Materials and methods

2.1. Experimental design and management

Data for this study were obtained from experiments conducted at the Eastern South Dakota Soil and Water Research Farm located near Brookings, SD (Pikul et al., 2001). The experiments were carried out in the beginning in 1990 on Barnes clay loam soils (US soil taxonomy: fine-loamy, mixed, superactive, frigid Calcic Hapludoll; FAO classification: Chernozem) with nearly level topography. The experimental design was a randomized complete block with split plot treatments and three replications. Main plots were tillage treatments, sub-plots were nitrogen (N) treatments. Corn was grown in rotation with soybean and each crop was present each year in each treatment. Plots were 30 m long and 30 m wide.

Typical crop production practices for each treatment are listed in Table 1. Pikul et al. (2001) provide further details on agronomic and soil related features of this study. Primary tillage since 1990 on the CT plots has been with a moldboard or chisel plow in the fall of the year except in 1995 and 1996 when wet weather conditions precluded fall tillage. Primary tillage since 1996 has been with a chisel plow. Seedbeds for corn and soybean under CT were prepared in spring using a tandem disk and field cultivator. CT plots were cultivated twice during the growing season for weed control. The only tillage on RT plots has been

Table 1
Typical crop production practices[a]

Tillage/crop	Crop production practices
CT	
Corn	Fall chisel plow, disk, field cultivate, plant with starter fertilizer and insecticide, spray pre-emergence herbicide, cultivate, spray post-emergence herbicide, broadcast nitrogen fertilizer, cultivate, harvest, chop stalks
Soybean	Fall chisel plow, disk, field cultivate, plant with starter fertilizer, spray pre-emergence herbicide, cultivate, spray post-emergence herbicide, cultivate, harvest
RT	
Corn	Ridge plant with starter fertilizer and insecticide, spray pre-emergence herbicide, ridge cultivate, spray post-emergence herbicide, broadcast nitrogen fertilizer, ridge cultivate, harvest, chop stalks
Soybean	Ridge plant with starter fertilizer, spray pre-emergence herbicide, ridge cultivate, spray post-emergence herbicide, ridge cultivate, harvest

[a] Actual crop production practices varied from year to year. Prior to 1996 primary tillage under CT was moldboard plow for H, alternated between moldboard plow and chisel plow for M, and was chisel plow for L. Also, prior to 1996, herbicide and insecticide was applied to M plots only when weed or insect counts indicated potential economic loss, L plots received no insecticide and received only post-emergence herbicides when weed counts indicated potential economic loss. L plots received no nitrogen fertilizer.

Table 2
Fertilizer and pesticide inputs

Crop/nitrogen treatment	Years	Starter fertilizer[a]	Nitrogen fertilizer[b]	Herbicide[c]	Insecticide[c]
Corn					
H	1990–1996	111 kg/ha 13–14–11	8.5 Mg/ha yield goal	Prophylactic	Prophylactic
	1996–1999	112 kg/ha 14–16–11	8.5 Mg/ha yield goal	Prophylactic	None
M	1990–1996	53 kg/ha 13–14–11	5.3 Mg/ha yield goal	Threshold	Threshold
	1996–1999	112 kg/ha 7–16–11	5.3 Mg/ha yield goal	Prophylactic	None
L	1990–1996	None	None	Threshold	None
	1996–1999	111 kg/ha 0–16–11	None	Prophylactic	None
Soybeans					
H	1990–1996	111 kg/ha 13–14–11	Starter only	Prophylactic	Prophylactic
	1996–1999	112 kg/ha 14–16–11	Starter only	Prophylactic	None
M	1990–1996	53 kg/ha 13–14–11	Starter only	Threshold	Threshold
	1996–1999	112 kg/ha 7–16–11	Starter only	Prophylactic	None
L	1990–1996	None	None	Threshold	None
	1996–1999	111 kg/ha 0–16–11	None	Prophylactic	None

[a] Rates applied at planting (elemental N–P–K).
[b] Nitrogen fertilizer was applied to corn based on soil nitrate tests for the specified yield goal.
[c] Prophylactic pesticide applications indicate routine applications regardless of weed or pest populations. Threshold applications indicate applications based on weed or insect counts. Quantities and types of pesticides varied from year to year.

two row cultivations per year for both corn and soybean crops.

Fertilizer and pesticide inputs are listed in Table 2. High (H) and medium (M) N treatments (split plots) for corn were determined according to yield goals of 8.5 Mg grain/ha for H and 5.3 Mg grain/ha for M. The low N (L) treatment plots received no applied N fertilizer. Soybean plots received only starter fertilizer. Nitrogen fertilizer prescription (NP) for each tillage and N treatment for corn was calculated based on total soil nitrate (TSN) as (Gerwing and Gelderman, 1996):

$$NP = 0.022YG - TSN.$$

Starter fertilizer was applied at seeding to both corn and soybean. Starting in 1996, H, M and L plots for both corn and soybean received 112 kg/ha of starter fertilizer as 14–16–11, 7–16–11 and 0–16–11 (elemental N–P–K), respectively. Prior to 1996, H and M plots for both corn and soybeans received 111 and 53 kg/ha, respectively, of 13–14–11 (elemental N–P–K). Low (L) N plots received no starter fertilizer prior to 1996. Prior to spring field work in 1996 all plots received an application of triple super phosphate providing 89 kg/ha of elemental P.

Prior to 1996 H, M and L were termed management inputs levels for both tillage treatments. Primary tillage on CT plots varied with input level. Primary tillage on H was fall moldboard plow, on M alternated between fall moldboard plow and fall chisel plow, and on L was fall chisel plow. High (H) N plots received prophylactic herbicide and insecticide treatments, M plots received herbicide and insecticide only when weed or insect counts indicated potential economic loss, L plots received no insecticide and only post-emergence herbicide when weed counts indicated potential economic loss. Riedell et al. (1998) provides further details on experimental conditions prior to 1996. Beginning in 1996, all N treatments within a tillage system have received the same herbicide treatments. No insecticides have been applied since 1996.

2.2. *Economics*

Annual crop budgets were constructed using the USDA-Natural Resources Conservation Service (NRCS) Cost and Returns Estimator (CARE) for each treatment based on the actual tillage operations and inputs used that year. Operating costs include machinery repairs, fuel, labor, seed, fertilizer, herbicides, insecticides, crop drying costs, and interest on operating capital. Operating cost estimates in CARE are based on American Society of Agricultural Engineers (2000) procedures. These procedures also provided estimates for fuel and labor use. Labor estimates are for labor directly associated with field operations, and do not include such things as time spent in management activities, equipment repairs, and crop scouting.

No land costs were included since land costs are constant across treatments. Equipment ownership costs were calculated outside CARE following American Agricultural Economics Association (1998) standards. A farm size of 223 ha of cropland was assumed in selecting equipment size and estimating equipment ownership costs. This represents a typical farm size for the area. Several implements were used only in the early years of the study. A moldboard plow was used on the CT-H and CT-M plots through 1995, a rotary hoe was used on the CT-L and RT-L plots through 1994, and a chisel plow was used in 1992 on the RT plots to knock down the ridges. Ownership costs for each implement were included through their last year of use. Fig. 1 shows the decrease in equipment ownership costs as use of individual implements was discontinued.

All costs are calculated using current (2000) prices. Equipment prices and costs are based on information from Lazarus (2000). Input prices and crop prices are from South Dakota Agricultural Statistics Service (2000). A corn price of \$ 90.56 Mg^{-1} and a soybean price of \$ 220.13 Mg^{-1} were used for estimating returns. These prices are the average of the 1990–1999 marketing year average prices for South Dakota adjusted to 1999 dollars. The wage rate for labor is \$ 9.50 h^{-1}.

All data were subjected to analysis of variance using SAS GLM with LSD for means separation of main effects where more than two means were involved and LSMEANS PDIFF for means separation of interaction effects (SAS, 1988).

3. Results and discussion

3.1. Economic returns

A summary of crop yields, production costs and returns is given in Table 3. Gross returns are crop yield times crop price. Gross margin denotes returns over operating costs and is calculated as gross returns minus operating costs. Net returns are the returns to land and management and are calculated as gross margin minus equipment ownership costs.

Nitrogen treatments within tillage systems had a significant effect on operating costs and returns for both corn and soybeans. Average yields for both corn and soybeans were significantly higher at higher N treatment levels. Yield differences for both corn and soybeans were generally greater prior to 1996, when

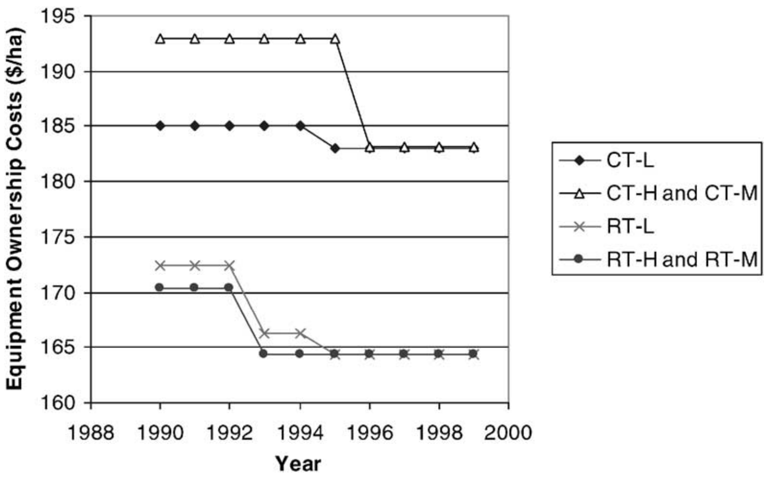

Fig. 1. Equipment ownership costs per hectare for CT and RT at high (H), medium (M) and low (L) N treatment levels.

Table 3
Crop yields, production costs and returns to land and management for corn and soybeans under CT and RT 1990–1999

Data	Tillage and N treatment level[a]					
	CT-H	CT-M	CT-L	RT-H	RT-M	RT-L
Yield (kg/ha/year)						
Corn	7714 a[b]	6890 b	4671 c	7697 a	6338 b	4536 d
Soybean	2354 a	2008 b	1732 d	2279 a	1882 c	1797 cd
Gross returns ($/ha/year)[c]						
Corn	698.63 a	623.99 b	423.06 c	697.04 a	573.95 b	410.75 d
Soybean	518.27 a	442.04 b	381.30 d	501.60 a	414.29 c	395.60 cd
Rotation average	608.45 a	533.02 b	402.18 d	599.32 a	494.12 c	403.17 d
Operating costs ($/ha/year)						
Corn	432.26 a	360.05 b	273.61 d	426.49 a	341.13 c	267.76 d
Soybean	288.44 a	263.32 b	222.77 c	284.24 a	257.61 b	234.18 c
Rotation average	360.35 a	311.69 b	248.19 d	355.37 a	299.37 c	250.97 d
Ownership costs ($/ha/year)						
Corn	206.54 a	206.66 a	197.46 b	183.90 c	183.95 c	181.17 d
Soybean	171.54 a	171.37 a	170.64 a	148.43 c	148.36 c	153.09 b
Rotation average	189.04 a	189.02 a	184.05 b	166.17 c	166.16 c	167.13 c
Gross margin ($/ha/year)[d]						
Corn	266.37 a	263.94 a	149.45 c	270.55 a	232.83 b	142.99 c
Soybean	229.83 a	178.72 b	158.54 c	217.36 a	156.68 c	161.42 bc
Rotation average	248.10 a	221.33 b	153.99 d	243.96 a	194.75 c	152.21 d
Net returns ($/ha/year)[e]						
Corn	59.83 b	57.27 b	−48.01 c	86.65 a	48.87 b	−38.18 c
Soybean	58.29 a	7.35 b	−12.10 c	68.92 a	8.32 b	8.33 b
Rotation average	59.06 b	32.31 c	−30.06 d	77.79 a	28.60 c	−14.93 d

[a] CT-H: conventional tillage high N treatment level, CT-M: conventional tillage medium N treatment level, CT-L: conventional tillage low N treatment level, RT-H: ridge tillage high N treatment level, RT-M: ridge tillage medium N treatment level, RT-L: ridge tillage low N treatment level.
[b] Means within rows joined by the same letter are not significantly different ($P = 0.05$).
[c] Gross returns calculated as (crop yield) × (crop price).
[d] Gross margin calculated as (gross returns) − (operating costs).
[e] Net returns calculated as (gross margin) − (ownership costs).

pest and tillage treatments differed with N treatment levels. However, since 1996, both corn and soybean yields also showed significant increases with N treatment levels. Phosphorus and K applications have been held constant across N treatment levels since 1986, which indicated a soybean yield response to starter N fertilizer and a corn yield response to total starter and side-dress N fertilizer applications. Operating costs were also significantly higher at higher N treatment levels. However, the increased operating costs were more than offset by the additional revenue generated by better yields, so average gross margin and average net returns were significantly higher at higher N treatment levels.

Results indicated no statistical difference in yields or gross returns between CT-H and RT-H. Operating costs also showed no difference, implying that the higher fuel and labor costs associated with CT were counterbalanced by higher herbicide costs associated with RT. Since gross returns and operating costs for CT-H and RT-H were not significantly different, gross margins were also not significantly different. Ownership costs were $ 22.87 h^{-1} higher for CT-H than for RT-H. This reflects the added equipment needs of CT (moldboard plow, chisel plow, disk and field cultivator) compared to RT (RT planter and RT cultivator). This analysis also assumes that a producer switching from CT to RT would have enough confidence in the system that they

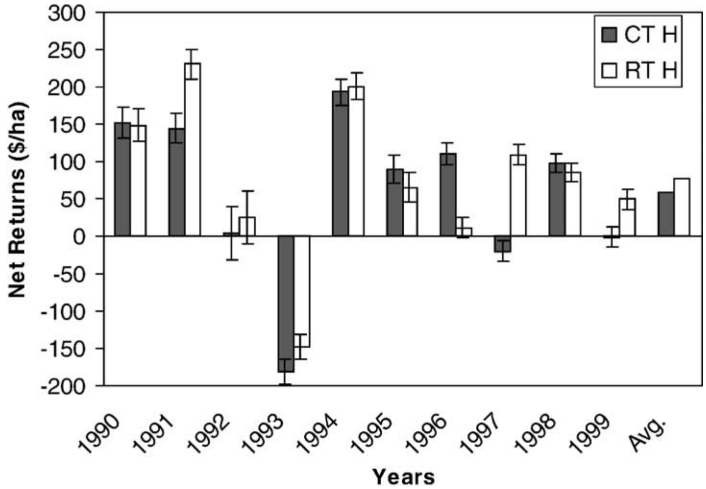

Fig. 2. Annual net returns per hectare with standard errors for CT and RT at a high N treatment levels.

would sell unneeded equipment rather than keep it. Due to the higher equipment ownership costs under CT, rotation average net returns were $ 18.73 per hectare higher for RT-H than for CT-H (Table 3).

3.2. Risk

There was considerable variability in net returns from year to year. Fig. 2 shows the annual net returns for CT-H and RT-H. Very low net returns occurred for both tillage systems in 1993 because of poor yields due to extremely wet conditions. Net returns for RT-H were significantly higher than for CT-H in 3 out of the 10 years: 1991, 1997, and 1999. Net returns for CT-H were significantly higher in 1 out of the 10 years: 1996. It is generally believed that most producers are risk averse. All things being equal, they prefer less risk to more risk.

One measure of risk is the standard deviation of net returns. Fig. 3 shows the relationship between average net returns and the associated standard deviation of net returns (risk) for each tillage system and N treatment combination. Risk averse producers should prefer systems with higher average returns and lower standard deviations (upward and to the left on the graph). For the RT systems average net returns increased and risk decreased as the N level increased, indicating that

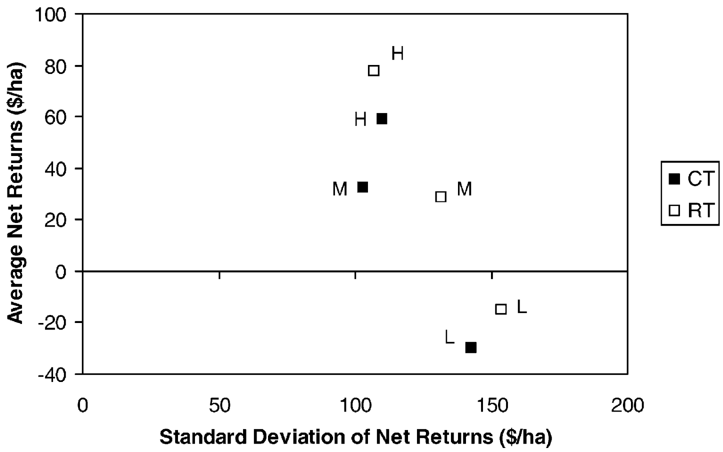

Fig. 3. Mean and standard deviation of net returns per hectare for CT and RT at high (H), medium (M) and low (L) N treatment levels.

risk averse producers should always prefer higher N treatment levels to lower levels. With CT average net returns increased with N treatment levels and risk decreased from L to M, but increased from M to H. A producer who is willing to give up $ 26.74 per hectare in average net returns for a $ 7.32 per hectare decrease in the standard deviation in net returns may prefer the M N level to the H.

The RT-H treatment produced the highest average net returns overall and did so at lower risk than the next best net return, CT-H. A risk averse producer faced with these two options should prefer RT-H to CT-H. Risk preference is a matter of degree and it is not inconceivable that a producer may choose CT-M, with lower risk and lower average net return, over RT-H. A producer willing to give up to $ 45.48 per hectare in average net returns for a $ 4.30 reduction in the standard deviation of net returns may prefer CT-M to RT-H.

3.3. Labor, fuel and chemical use

Labor, fuel and chemical input use are important factors in the feasibility of cropping systems. They may also be the indicators of the sustainability of alternative systems. In this study P and K fertilizer applications were constant at each N level across tillage systems from 1990 through 1995. From 1996 through 1999, P and K application rates were constant across all N treatments and tillage systems. As a result, there were no differences in average P and K application rates between tillage systems at a given N level, although the average rates declined as N treatment level declined (data not shown).

Nitrogen fertilizer was applied to each sub-plot based on soil tests and yield goals, so average application rates could potentially vary by tillage for a given N treatment. Average N application rates are shown in Table 4. As expected, N application rates decreased significantly as the treatment level goes from H to M to L, with either CT or RT. However there were no significant differences in application rates between tillage systems at a given treatment level, indicating that RT required no more N fertilizer than CT.

Pesticide applications (insecticide plus herbicide) varied with input level from 1990 to 1995. Since 1996 pesticide applications have been constant across N treatments, but do vary by tillage system. Table 4 shows the average pesticide expenditures for each treatment. Pesticide expenditures decreased significantly as N treatment levels decreased. Pesticide expenditures were significantly higher for RT-H than CT-H as herbicide was substituted for tillage for weed control. Lighthall (1996) noted that RT systems have the potential to reduce herbicide use since they are well suited to banding over the row with cultivation used for weed control over the middle of the row. Post-emergence herbicides were not banded in this study, so this potential savings was not realized.

There were more tillage operations under CT than RT. This affects both fuel and labor use for each system. Table 4 shows the fuel use for each tillage and N treatment. Fuel use was 10–13 l/ha less under RT than CT, an 18–22% reduction. Fuel use did not vary significantly with N treatments under RT. With CT, fuel use declined with N treatment levels mainly reflecting the differences in tillage between input levels in 1990 through 1995, when moldboard plow

Table 4
Rotation average input use for corn and soybeans grown under CT and RT 1990–1999

Tillage and input level	N fertilizer applied (kg/ha/yr)	Pesticide expenditure ($/ha/yr)	Diesel fuel use (l/ha/yr)	Labor use (h/ha/yr)
Conventional				
High	69.2 a[a]	114.40 b	58.1 a	2.83 a
Medium	37.5 b	95.05 c	56.5 b	2.75 b
Low	0.0 c	74.51 d	54.1 c	2.61 c
Ridge				
High	69.8 a	126.65 a	45.1 d	2.08 d
Medium	37.1 b	100.70 c	44.8 d	2.06 d
Low	0.0 c	89.33 c	44.2 d	1.99 d

[a] Means within columns joined by the same letter are not significantly different ($P = 0.05$).

was used on H plots, moldboard plow and chisel plow were alternated on M plots, and chisel plow was used on L plots. Similarly, Table 4 shows labor use for each tillage and N treatment. Labor use was 0.62–0.75 h/ha less under RT than CT, a 24–27% reduction. Labor use did not vary significantly with N treatment under RT but it did decline with N treatment levels under CT. This decreased use of labor in CT across treatments is again primarily due to differences in tillage from 1990 through 1995. The labor savings under RT indicates that a producer might be able to farm more acres than under CT. However, this depends on whether the labor savings occur at times when labor is a limiting factor.

4. Conclusions

Despite continued low adoption rates for RT in the northern Corn Belt, our analysis shows that RT was an economically viable alternative to CT. At high N treatment levels, RT had higher net returns and lower economic risk than CT. The difference in net returns was due to increased equipment ownership costs under CT. Yields and operating costs were not significantly different between tillage systems.

There was no significant difference in fertilizer use between tillage systems. Pesticide use was significantly higher under RT than under CT; however fuel and labor use were significantly lower.

In general net returns were higher when N was used more intensively. Yield improvements more than made up for increased operating costs at higher N treatment levels for both CT and RT, indicating the importance of maintaining soil fertility and controlling pests with either tillage system.

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