EFFECT OF TILLAGE METHOD, TILLAGE TIMING, AND NITROGEN FERTILIZER APPLICATION RATE ON SUGARBEET PRODUCTION: YEAR 1 SUMMARY

David D. Tarkalson, Dave L. Bjorneberg, Amber Moore, Brent Beutler

ABSTRACT

The sugarbeet industry in Idaho is primarily interested in strip tillage due to the potential savings in tillage costs. This study was conducted to evaluate the use of strip tillage in Idaho compared to conventional tillage practices. The effect of tillage method (strip tillage, moldboard plow system, and chisel plow system), tillage time (fall and spring), and N application rate (0, 50, 100, 150, 200 lbs applied N/acre) on sugarbeet production factors were investigated in Kimberly, ID starting in 2008 on a Portnuef silt loam. In 2008, the residual soil nitrate (NO_3-N) and ammonium (NH_4-N) were the same for all tillage method and timing treatments (mean = 118 lbs N/acre). There were no differences in total yield (tons/acre) and estimated recoverable sugar (ERS, lbs/acre) between fall and spring tillage times. Total yield and ERS was statistically the same in the strip tillage and moldboard plow treatments across all N application rates and total N supplies (fertilizer N application + initial soil N supply). Total yield and ERS in the chisel plow treatment was the same as the other two tillage methods at all N supplies except for the highest N supply (chisel plow < strip tillage). The difference was due to a significant decrease in root population at the highest N supply level compared to the strip tillage and moldboard plow treatments. The economically optimum N rate/supply (EONR, fertilizer N + residual soil NO_3-N and NH_4-N) for the strip tillage treatment at N prices of 0.43, 0.65, 0.87, and 1.08 $/lb N were 202, 189, 181, and 174 lbs N/acre, respectively. The range of yields over the EONR range was small, 34.8 to 34.3 tons/acre. The N requirement per ton of beets ranged from 5.8 to 5.1. This range was much lower than the N requirement range of 7 to 8 lbs N/ton commonly being recommended and used in the industry in Idaho. Year one data suggests that sugarbeet production under strip tillage compares well with conventional tillage practices. ***This report is a summary of year one results. Interpretation of this data should be done with caution. Results and conclusions could change when data from multiple years is pooled and analyzed.***

RATIONALE AND OBJECTIVES

Strip tillage is a practice that creates a residue free and tilled zone, approximately 6 to 15 inches wide and 6 to 8 inches deep. The remaining area is not tilled and the residue from the previous crop remains on the soil surface. Strip tillage also allows for the deep banding of fertilizers. The use of strip tillage and other conservation tillage practices are common in many areas of the Corn Belt to conserve soil and water through residue management and reduce tillage costs. However, in the Pacific Northwest these tillage practices are less common. Limited research has been conducted on the use of strip tillage in sugarbeet production. Preliminary research results from the USDA-ARS in Sidney, Montana have indicated some potential production advantages for sugarbeets

---

Presented at the Snake River Sugarbeet Conference on January 9, 2009.

grown under strip tillage compared to conventional tillage (Evans et al., 2008). Various potential advantages of using strip tillage in sugarbeet production (fuel savings, labor savings, residue protection, etc…) warrant the need for research to evaluate the practice in southern Idaho. The objectives of this study were to compare strip tillage to conventional tillage practices, and evaluate the response of sugarbeet grown under strip tillage to N supply.

MATERIALS AND METHODS

The treatments included tillage time (spring and fall), tillage method (strip tillage [Twin Diamond Industries, LLC Strip Cat], moldboard plow system, and chisel plow system), and nitrogen fertilizer application rate (0, 50, 100, 150, and 200 lbs N/acre). The tillage method systems descriptions are shown in Table 1. The treatments were arranged in a split split plot design with three replications. Tillage time was the main plot, tillage method was the subplot and, nitrogen fertilizer application rate was the sub-subplot. Each plot was 8 ft wide (8-22 inch rows) and 40 ft long.

Prior to fertilizer application and planting three soil cores were taken from the 0-12 inch and 12-24 inch depth in each tillage time/tillage method strip combination on April 21, 2008. The three cores for each strip were then bulked by depth. The soil samples were analyzed for nitrate-N (NO_3-N) and ammonium-N (NH_4-N) after extraction in 2M KCl and analysis on a Flow Injection Analyzer, sodium bicarbonate extractable P (Olsen et al., 1954), and exchangeable K. The data were used to determine the initial soil N supply as well as to guide fertilizer application rates.

Nitrogen and P fertilizer applications were on April 25, 2008. Urea-ammonium nitrate (32-0-0) was used as the N source. One quart of Agrotain was added to 600 lbs of UAN to reduce ammonia (NH_3) volatilization after application of N prior to first irrigation. Nitrogen fertilizer was surface applied in 6 inch bands over each row. Based on the soil test P analysis, 170 lbs P_2O_5/acre was surface banded above each row as fertilizer grade liquid phosphoric acid over the entire study area according to Amalgamated Sugar Inc. fertilizer nutrient recommendations.

Sugarbeet (Beta Seed 25RR05) was planted on April 25, 2008 after fertilizer application at a seeding rate of 51,800 plants/acre. On April 29, 2008 plots were irrigated with a solid set irrigation system with 0.6 inches of water to move UAN into soil and reduce potential for NH_3 volatilization. The study area was irrigated approximately two times a week after emergence to harvest to match the estimated crop water requirement based on Agrimet data and soil water measurements.

To control weeds Roundup PowerMAX was applied on May 27, June 5, and July 17, 2008 at a rate of 22 oz/acre.

Whole plant tops were harvested on October 21, 2008 from 5-ft sections of 2 rows in each plot. The samples were dried at 149° F, ground to pass through a 2 mm sieve, and analyzed for total N by combusting a 25 mg sample using a FlashEA1112 CNH analyzer (CE, Elantech, Lakewood, NJ).

Following topping of the entire study area on October 23, 2008, harvest areas of 30 ft by four rows were marked in each plot. Root counts were obtained in the entire harvest area from each plot. Root harvest was on October 23 and 24, 2008. Total root weight (determination of total yield) from the harvest area in each plot was obtained using a load cell-scale on the plot harvester. From each plot three 8-root samples were obtained and bagged. Two of the samples were sent to the Amalgamated Sugar Inc. tare lab for analysis of percent sugar, nitrate, and conductivity. From this data and total root yield, estimated recoverable sugar/acre (ERS) was determined. The third 8-root sample was ground, dried at 200° F, and analyzed for total N by combusting a 25 mg sample using the FlashEA1112 CNH analyzer.

Total yield (tons/acre), percent sugar, ERS (lbs/acre), root population at harvest, top biomass dry matter (lbs/acre), and N uptake (lbs/acre) were plotted versus N supply (fertilizer N application rate and fertilizer N application rate + residual NO_3-N and NH_4-N). For the strip tillage treatment, a response function (exponential rise to a maximum model) was fitted to the total yield versus N supply data.

(1) Exponential rise to a maximum model (modified Mitscherlich equation):

Yield (tons/acre) = $a + b\,(1 - e^{-cN})$

a = yield without N application

b = maximum yield increase from applying N (change in yield at the maximum N rate)

c = curvature parameter

N = N application rate (lbs N/acre)

The economically optimum N rate/supply (EONR, lbs N/acre) was calculated based on the fitted function for a range of N fertilizer prices. The EONR was the N rate at which the net return from N application or total N supply (RTN) was maximized. The RTN was calculated for every 1 lb increment increase in N up to the highest N rate (1…200 lbs N/acre).

(2) RTN = (Yield_{+N} × Gross Return) – (Yield_{-N} × Gross Return) – (Fertilizer N Amount × N Price)

Gross return was calculated from a base return of $40/ton at 17.4% sugar. The base return was adjusted to the gross return ± $0.30 for every ± 0.1% sugar. The estimated % sugar at each N application rate was calculated based on a fitted function (sigmoidal model) for the % sugar versus N application rate data.

(3) Sigmoidal 3 parameter model:

% Sugar = $a / (1 + e^{(-(x-x0)/b)})$

a = % sugar without N application

x = N rate

x0 and b = fixed parameters

Nitrogen prices used were \$0.43, \$0.65, \$0.87, and \$1.08/lbs N. These prices were based urea costs of 400, 600, 800, and 1000 \$/ton.

RESULTS AND DISCUSSION

Pre-study soil NO_3-N and NH_4-N

There were not differences in soil NO_3-N + NH_4-N (soil N supply) between tillage time/tillage method treatments. The average soil N in the 0-24 inch depth was 94 lbs N/acre. Due to observed soil water depletion in the 24-36 inch soil depth, it was likely root penetration to this depth accessed available soil N. Therefore, a conservative soil N supply of 24 lbs N/acre was estimated at the 24-36 inch depth. The total soil N supply for the 0-36 inch depth was approximately 118 lbs N/acre.

Total Yield

There were no differences in total yield (tons/acre) between the spring and fall tillage time treatments. Therefore, for each tillage method treatment, the yields for spring and fall treatments were averaged at each N supply level. The relationship of total yield versus N supply level (N application rate and soil N supply + N application rate) for each tillage method treatment is shown in Figure 1. There were no differences in total yield between tillage method treatments at the 0, 50, 100, and 150 lbs of fertilizer N/acre. At the highest N supply the total yield of the chisel plow treatment was significantly less than with strip tillage. This difference was likely due to reduced root populations in the chisel plow treatment at the highest N supply (see results and discussion under Harvest Root Population below). Over all tillage method and N supply treatments, the mean total yield was 31.4 tons/acre. In year one, strip tillage had total yields at least equal to the moldboard plow system.

Percent Sugar and Brei Nitrate

For each N supply level the percent sugar and brei nitrate was averaged over tillage time and tillage method treatments. Percent sugar was the same for all N rates up to 150 lbs of applied N/acre (ave = 17.8 %), but significantly decreased at the highest N supply (Figure 2). Brei nitrate concentration was the same for all N rates up to 150 lbs of applied N/acre (ave = 64 ppm), but significantly increased at the highest N supply (Figure 2). Even at the highest N supply the brei nitrate never reached the critical concentration of 250 ppm. The relationship between percent sugar and brei nitrate seen in Figure 2 is similar to that shown in other studies.

Estimated Recoverable Sugar

There were no differences in ERS (lbs/acre) between the spring and fall tillage time treatments. Therefore, for each tillage method treatment, the yields for spring and fall treatments were averaged at each N supply level. The relationship of ERS versus N application rate and total N supply for each tillage method treatment is shown in Figure 3. There were no differences in ERS at the 0, 50, 100, and 150 lbs of fertilizer N/acre. At the highest N supply the ERS in the chisel plow treatment was significantly less than with strip tillage. This difference is likely due to reduced root populations in the chisel plow treatment at the highest N supply (See results and discussion under Harvest Root Population below). Over all tillage method and N supply treatments, the mean ERS was

9,600 lbs/acre. In year one, strip tillage had ERS at least equal to the moldboard plow system.

Harvest Root Population

Figure 4 shows the root populations at harvest at the N application rates for the tillage method treatments (averaged over spring and fall tillage time treatments). Root populations decreased as N application rate increased in the chisel plow and moldboard plow treatments. The root populations were the statistically the same for all N application rates in the strip tillage treatment. The rate of decrease in plant population was greatest in the chisel plow treatment compared to the moldboard plow treatment. The range of populations in the chisel plow treatment over all N application rates was 40,900-22,600 roots/acre. The range of populations in the moldboard plow treatment over all N application rates was 42,500-32,500 roots/acre. The average population in the strip tillage treatment was 37,500 roots/acre. The population at the highest N rate in the moldboard plow treatment was similar to the strip tillage treatment average. The population at the highest N rate in the chisel plow treatment, however, was 9,900 and 14,900 roots/acre less than the population at the highest N rate in moldboard plow and the average population in strip tillage treatments, respectively. It appears that there is an N rate effect on population in the chisel plow and moldboard plow treatments. It is not clear why this affect was not seen in the strip tillage treatment since the N application and planting methods were the same for all treatments. Data obtained in future years of this study will hopefully elucidate the results from year one. At the highest N rate, it appears that the decrease in plant population in the chisel plow treatment caused the yield and ERS to be less then the other two tillage method treatments.

Plant Top Biomass and Nitrogen Uptake

Top biomass and N uptake increased as N supply increased (Figure 5 and 6). N uptake of roots varied very little over N supply levels. Excess N above the amount needed to maximize yield and profits is stored in the sugarbeet tops. At the EONR (total N in soil = 202 lbs N/acre; N price = \$0.43) in the strip tillage treatment, the roots and tops removed 79 and 89 lbs N/acre, respectively. At the highest N supply level (total N in soil = 318 lbs N/acre) in the strip tillage treatment, the roots and tops removed 81 and 136 lbs N/acre, respectively. At the EONR (N price = \$0.43) in the strip tillage treatment, the roots removed approximately 50% of the total soil N supply at harvest.

Nitrogen Requirements

The EONR (fertilizer N + soil N) decreased from 202 lbs N/acre to 174 lbs N/acre as N price increased from \$0.43 to \$1.08 for the strip tillage study (Figure 7). The total yield, however only ranged from 34.8 to 34.3 tons/acre over this EONR range. The range of sugarbeet N requirement (lbs N/ton) ranged from 5.8 to 5.1. This range was much lower than the N requirement range of 7 to 8 lbs N/ton commonly being recommended and used in the industry in Idaho.

REFERENCES

Evans, B., B. Iversen, and B. Stevens. 2008. Strip tillage on sprinkler irrigated sugarbeets. Status Report, February 2008. USDA-ARS, Northern Plains Agricultural Research Laboratory Agricultural Systems Research Unit. Sidney, MT.

Olson, R.A., M.B. Rhodes, and A.F. Dreier. 1954. Available phosphorus status of Nebraska soils in relation to series classification, time of sampling and method of measurement. Agron. J. 46:175-180.

Table 1. Tillage method and tillage timing treatment descriptions.

Tillage Method Designation	Tillage Time Designation	Fall Activity	Spring Activity
Strip Tillage	Fall	Strip Tillage	---
Strip Tillage	Spring	---	Strip Tillage
Moldboard Plow	Fall	Moldboard Plow Roller Harrow Bed	---
Moldboard Plow	Spring	---	Moldboard Plow Roller Harrow Bed
Chisel Plow	Fall	Offset Disk Chisel Plow Tandem Disk Bed	---
Chisel Plow	Spring	Offset Disk	Chisel Plow Tandem Disk Bed

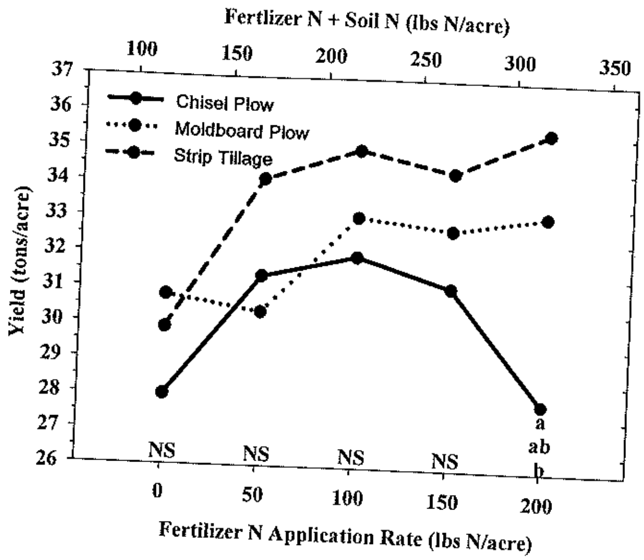


Figure 1. Total yield versus N supply for each tillage method treatment. Within each N supply level, tillage methods with the same letter are not significantly different. NS = not significant

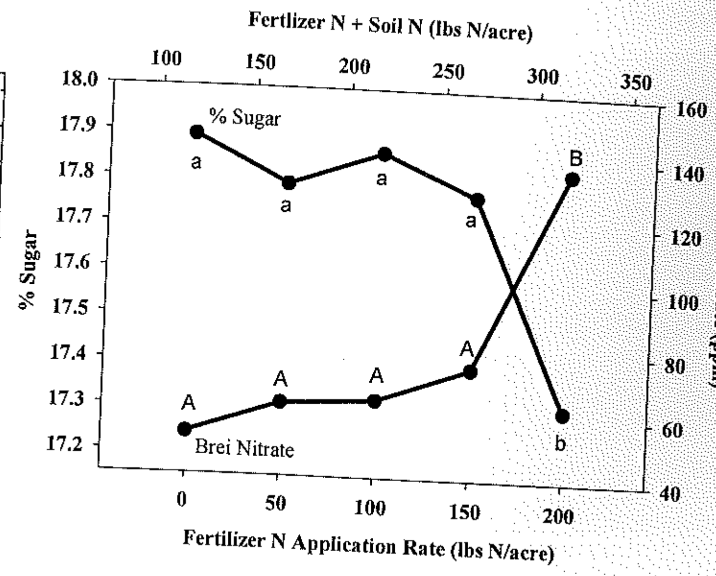


Figure 2. Percent sugar and brei nitrate versus N supply. Within each N supply level and measurement (% sugar and brei nitrate), N supplies with the same letter are not significantly different. NS = not significant. Each point is averaged across tillage time and method treatments.

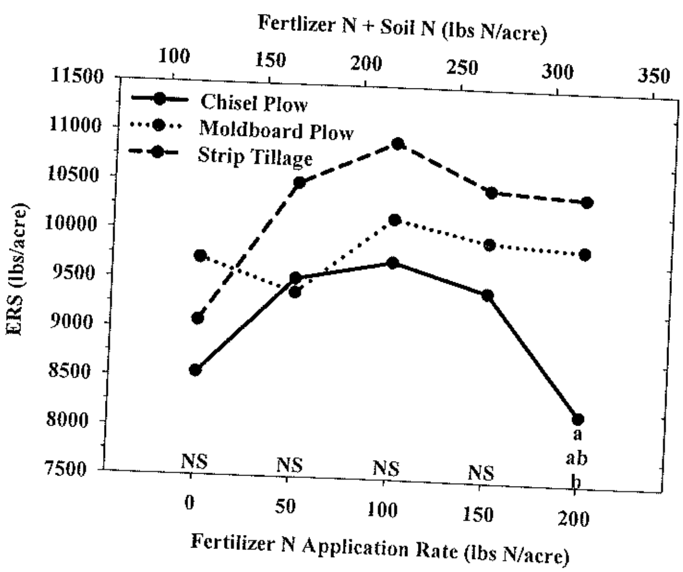


Figure 3. Estimated recoverable sugar (ERS) versus N supply for each tillage method treatment. Within each N supply level, tillage methods with the same letter are not significantly different. NS = not significant

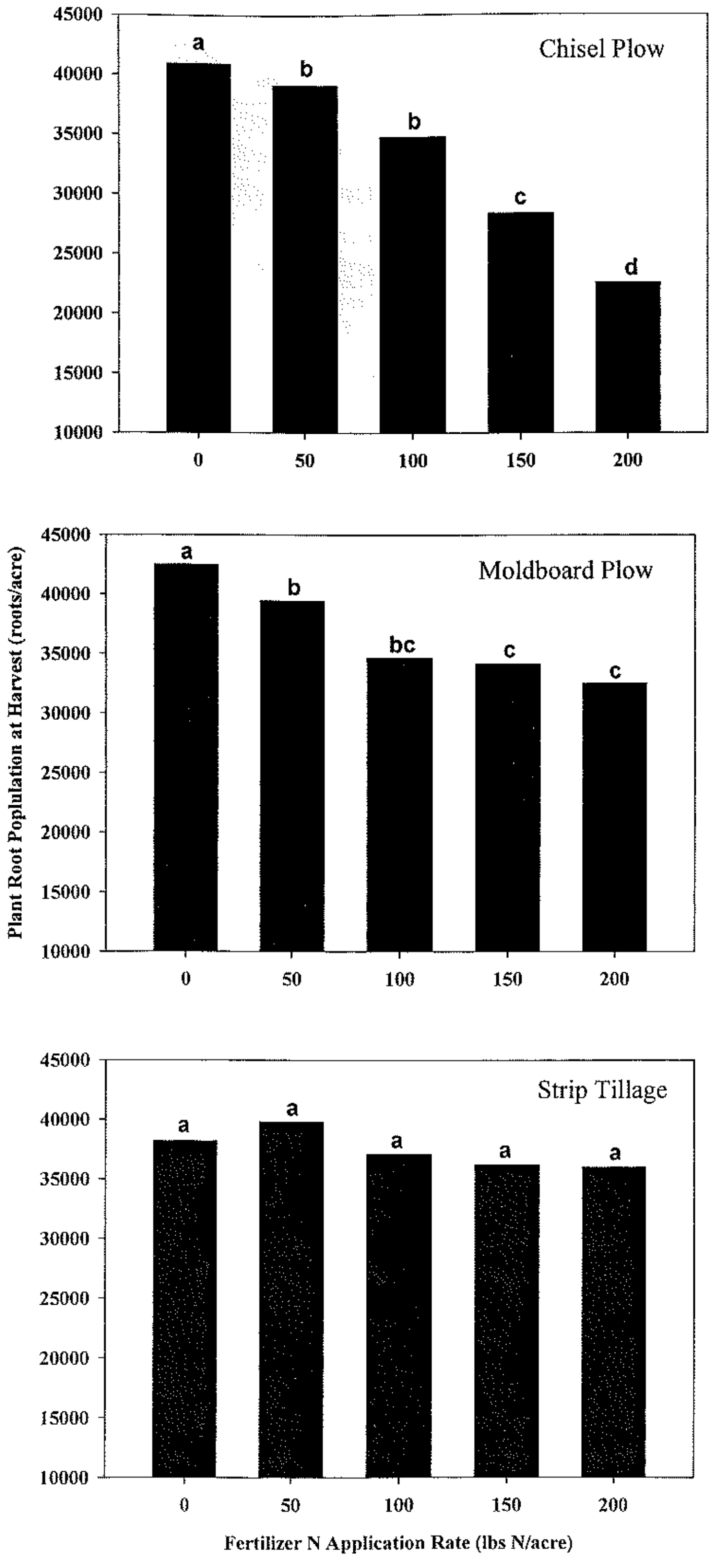


Figure 4. Root populations at harvest for tillage method treatments. Values are averaged over tillage time and three replications. Within each tillage method treatment, columns with the same letter are not significantly different at the 0.05 probability level.

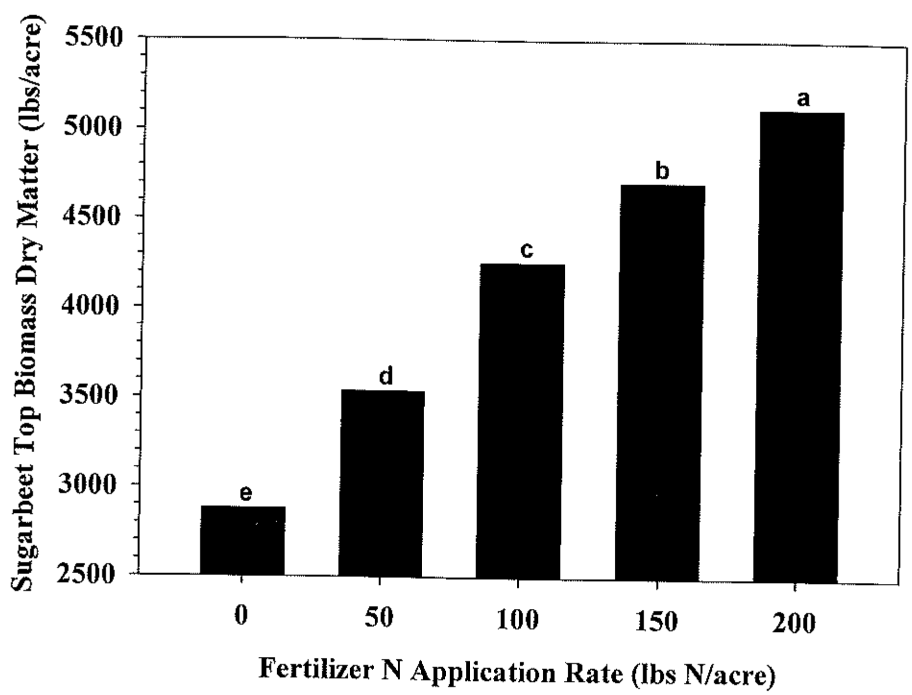


Figure 5. Top biomass dry matter versus fertilizer N application rate. Columns with the same letter are nor significantly different at the 0.05 probability level.

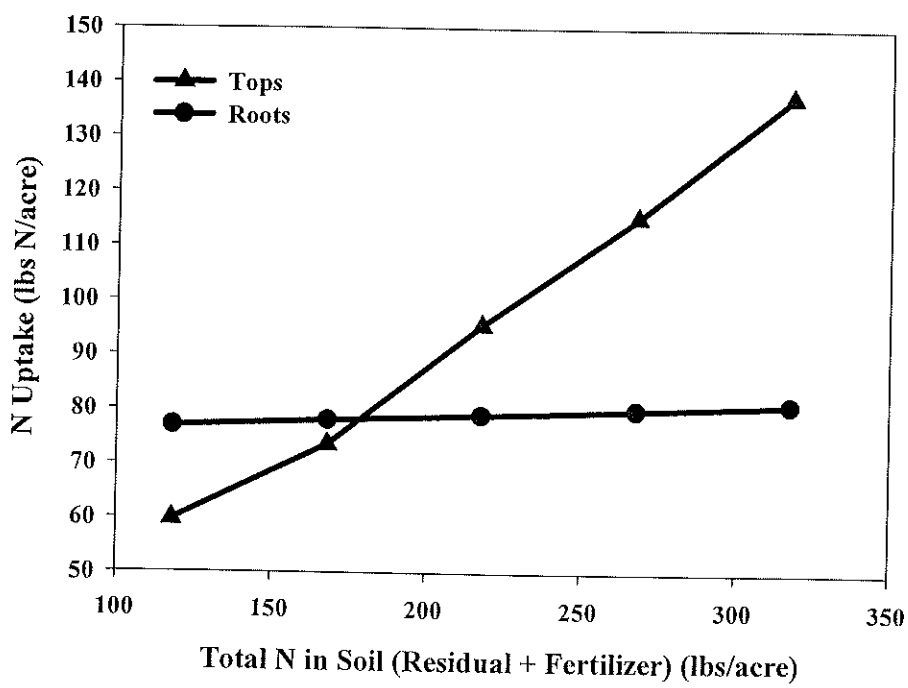
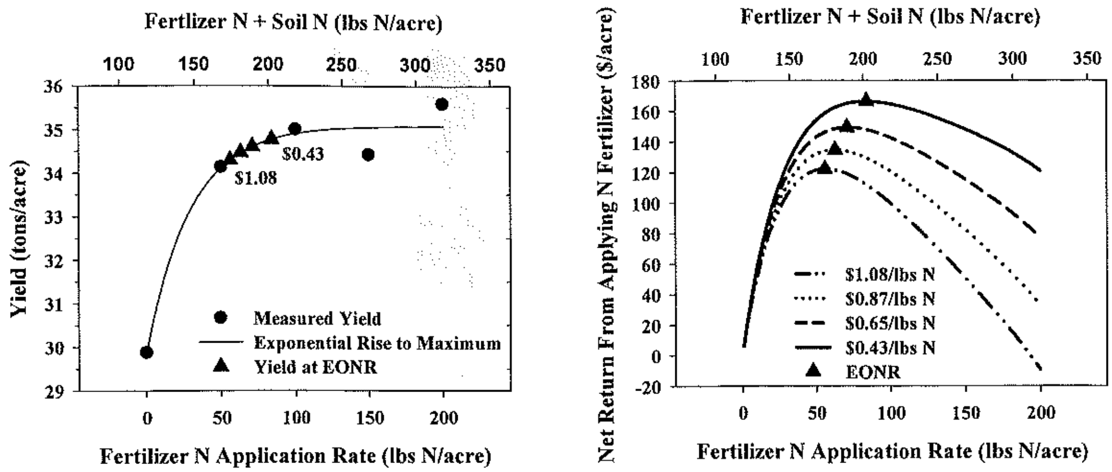


Figure 6. Top and root N uptake versus total N supply in soil.



N Fertilizer Price ($/lb N)	EONR-ferilizer (lbs/acre)	EONR-total supply (lbs/acre)	Yield at EONR (tons/acre)	N Req. At EONR (lbs N/ton)
0.43	84	202	34.8	5.8
0.65	71	189	34.6	5.5
0.87	63	181	34.5	5.2
1.08	56	174	34.3	5.1

Figure 7. Yield response of sugarbeet for strip-tillage treatment to N supply in 2008; fit of the exponential rise to a maximum response function; and the EONR, yield at the EONR, and N requirement at the EONR derived for different N prices.