CORN GRAIN AND ENSILAGE YIELD AND
NUTRITIVE RESPONSE TO NITROGEN
FERTILIZER AND SOIL TEST
NITRATE

By

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NOMENCLATURE

OPREC	Oklahoma Panhandle Research and Extension Center
SCARS	Southcentral Agronomy Research Station
RPN	Residual Profile Nitrate
Fert.-N	Applied Fertilizer Nitrogen
N_{max}	Nitrogen Rate at Maximum Yield
N_L	Nitrogen Rate at Lowest Predicted Response Point
GRNYLD AND ENY65	Grain and Ensilage Yield
GRNCP and ENCP	Grain and Ensilage Crude Protein
GRNTDN and ENTDN	Grain and Ensilage Total Digestible Nutrients
GRNNDF and ENNDF	Grain and Ensilage Neutral Detergent Fiber
GRNADF and GRNADF	Grain and Ensilage Acid Detergent Fiber
LR^2	Linear Coefficient of Determination
QR^2	Quadratic Coefficient of Determination

INRODUCTION

Corn (*Zea mays L.*) production in the south central USA is a function of temperature, available soil moisture, and nutrients. Even with supplemental irrigation, prevailing high daytime temperatures (> 32^0C) plus high night temperatures (> 28^0C) at critical reproductive stages can impede grain yields. In many cases a corn crop is planted and managed for grain production but harvested for ensilage due to stress conditions at critical periods of plant development. The decision to harvest a corn crop as ensilage or grain may be delayed until the R1 (silking) or R3 (blister) developmental stage. Yield potential based on prevailing environmental conditions may be more precisely assessed at these times. Management techniques such as selection of optimum plant populations and nitrogen fertilization levels may differ depending on whether the crop is to be harvested for ensilage or grain. The effects on the resulting yield and nutritive quality components of one management method verses the other becomes important to the producer.

The objectives of this study are to evaluate the grain and ensilage yields and nutritive responses of corn to nitrogen fertilizer and soil test NO_3 under a grain management system and to verify current Oklahoma nitrogen fertilizer recommendations for corn production.

II.

LITERATURE REVIEW

In the early 1900's nearly 6,000,000 acres of corn were planted in Oklahoma but by the 1950's that figure had dropped to approximately 300,000 acres (2). Lack of profitable production and limiting environmental, soil, and moisture conditions caused a shift to the central and eastern side of the state . Emphasis in this area was reflective of deeper soils and higher rainfall potential. Fertility was also added as a variable in corn research in this area with an emphasis on nitrogen fertilizer. Early work (1) with nitrogen fertilizer in Oklahoma in corn production programs indicated a nitrogen use efficiency range of 0.77 to 1.0 kg N per 62.73 kg $ha^{-1}$of corn grain yield increase with 67.2 and 100.8 kg ha^{-1} application rates. These figures agree with other states findings at this time of 0.91 kg N per 62.73 kg ha^{-1} of corn grain yield increase. However, on a total N application rate per corn grain yield goal a value of 0.5 kg N was required to produce 62.73 kg ha^{-1} of corn grain yield. Nitrogen rate recommendations went as high as 2.0 kg N in this study and were at 1.9 kg N per 62.73 kg ha^{-1} of corn grain as late as 1993 in Oklahoma. At this time, N recommendations were lowered to reflect more closely with Texas and Kansas recommendations under similar cropping situations and current N recommendations across the corn production areas of the U.S. These geographical recommendations ranged from 0.9 to 1.6 kg ha^{-1} to produce 62.73 kg $ha^{-1}$of corn grain and were verified via phone conversations with various State Extension Specialists.

Determining the maximum N rates that will produce maximum corn grain yield is a regression function. Models are applied to the data to determine which best describes the yield response to N fertilizer treatments, thus allowing a prediction of maximum N rates required to achieve maximum grain yields. In one study (3), quadratic and quadratic-plus-plateau models were compared to determine both optimum N rate and maximum grain yield associated with that rate. In this study the quadratic model predicted maximum grain yields 3-6% larger than the quadratic-plus-plateau model. The quadratic model also indicated optimal N rate requirements of 5-60% larger and reduced profit by \$.61 to \$17.12 ha^{-1} yr^{-1}. However, these reductions were associated with very site specific conditions and were not large in all cases. This study determined that the quadratic-plus-plateau model is preferable to the quadratic model for predicting N requirements for corn grain yield. Another study (4) compared square root, exponential, linear-plus-plateau, quadratic, and quadratic-plus-plateau in their ability to predict yield responses. All models fit the data equally well when evaluated by the R^2 statistic for yield response. However, the models showed marked discrepancies when predicting economic optimum N rates of fertilization. The authors concluded that the quadratic-plus-plateau model was more accurate in predicting yield responses than the quadratic model. They also noted that the R^2 statistic and the quadratic model did not give a confident evaluation or valid description of yield response when the treatment levels were 4 or less. When the treatment levels increased beyond 4, both the R^2 statistic and the quadratic model improved in comparison. Other studies utilized a smaller number of treatment levels (4-5) and found the quadratic model gave valid descriptions of the data. One study (8) evaluated 3 N treatment levels and 4 plant populations with the statistical analysis consisting of regression modeling looking at linear and quadratic responses. The analysis indicated a quadratic model best described the yield and profit response of dryland corn to N fertilizer and plant population levels. In this study a fertilizer N rate of 179 kg ha^{-1} and a plant population density of 72,500 plants ha^{-1} produced the optimum dry matter yield and profit. Multiple regression analysis was used in another study (13) to evaluate yield and quality responses to N, Phosphorus, and Plant Populations. In this study it was concluded that forage and grain yields were primarily a quadratic response to N application rate whereas Phosphorus and Plant Populations did not significantly affect yield or quality of forage. Economic optimum N rates were considered using both a quadratic and quadratic plus linear plateau analysis in yet another study (14). Both methods resulted in similar conclusions with only slightly different associated N rates for predicted maximum yield. While it is logical to assume that differences exist in the modeling approaches there are also discrepancies among the reported results as to which model is best. However, the quadratic and quadratic plus plateau models appear to be the two most utilized in terms of describing plateau yield responses.

While corn grain yield is an important component to manage, the nutritive value components are equally as important when feed quality is considered. Crude protein (CP), total digestible nutrients (TDN), acid detergent fiber (ADF), and neutral detergent fiber (NDF) are all factors that affect the value of corn grain used in animal rations. In one research study (6) relationships between grain protein concentration and N sufficiency for growth as indicated by end-of-season test for corn stalk nitrate were examined. Grain and stalk samples were collected from on-farm N response trials from 1994 to 1997 at 114 sites. Good modeling relationships were observed between grain protein concentrations and N sufficiency as indicated by the stalk test. Protein concentrations tended to increase with N sufficiency level and asymptotically reach a maximum. Analysis showed that it was not profitable to apply extra N to increase protein concentration in situations where N concentrations are already adequate to maximize yields. The relationship between grain protein concentrations and stalk NO_3^- concentrations should enable identification of economically optimal grain protein concentrations for individual corn hybrids. The results suggest individual hybrid genetics determine the protein content achievable, but the N management insures this goal is met.

Numerous studies have reported on the affects of N, water, and plant populations on corn grain yield and nutritive value but few have looked at these effects on ensilage especially in the south central USA (8). In many cases in more arid environments, corn is planted for a grain crop but harvested for a ensilage crop due to environmental stress occurring at a critical plant development period which negatively affects potential grain yield. In fact, after numerous producer visits, it was determined that many producers in Oklahoma utilize this philosophy as a possible management system. By checking their corn during ear formation and succeeding ear developmental stages producers can decide which harvest to select, grain or ensilage, through determining potential grain yield. In general, corn planted for ensilage requires a 10% -25% higher plant population to increase tonnage harvested (8). However, these plant population increases are not seen when the ensilage crop is taken from a grain management system. Therefore, the yield and nutritive value of ensilage grown under this system is important to producers. Nitrogen and S were used in one study (10) to determine the effects of these two nutrients on yield and quality of corn grown for grain and silage. Crude protein was increased by N application, but not by S. Neither N or S had an affect on ADF or NDF. The study concluded that the use of N and S should be on the basis of increased corn yield, not on improving nutritive value of the grain or ensilage. Corn grain yields were reported (12) to increase with increasing N rates but residue levels did not increase. Crude protein showed little increase in corn residues with increasing N levels. Multiple regression analysis indicated both forage and grain yields were affected by N but not by P or plant populations. Corn yields appeared to be primarily a response of N whereas a wide range of plant populations can be tolerated without significantly affecting yield or quality of ensilage produced (13). Some variability exists with these findings as another study reported (11) that high plant populations had an adverse affect on ensilage nutritive value as depression of CP was associated with high seeding rates in conjunction with lower N rates. A 1972 study (5) indicated that corn grown for ensilage under 5 N fertilizer treatments showed an increase of green and dry forage yields up to the 170 kg ha^{-1} N rate. Nitrogen fertilizer also increased the total tonnage of digestible dry matter, ear %, and dry matter digestibles with the first 57 kg ha^{-1} of N. Beyond this N rate, no response was noted. This study indicated that a plateau response was found where no additional yield or quality response was seen to added N. Heavy fertilization has been reported (11,14) to generally improve the nitrogen content of ensilage but has little other affect on nutritive value with the exception of minor CP responses. Foliar applications of N have shown similar responses (7).

The interaction between the soil and the plant is an involved and complex relationship, but one that affects the final grain or ensilage product. The processes of mineralization, nitrification, leaching, and denitrification represent both sources of addition and subtraction from the plants total pool of N. The addition of commercial N to a soil system addresses only one source of N supply that the plant can access. The process of mineralization produces plant available N in the form of both NH_4 and NO_3 from organic matter that is decaying within the soil system. This is an extremely important source of N and it differs vastly from one soil system to the next. Dr. Magdoff reported (9) 1.01 to 1.1 kg ha^{-1} d $(day)^{-1}$ in Vermont soils used in corn production without a green manure or cover crop. In soils where a green manure crop was utilized, short term mineralization was noted to be as high as 3.36 to 7.84 kg ha^{-1} d^{-1}. Under corn production he notes that some general N uptake patterns can be described. Prior to the plants entering the grand period of growth, N uptake is relatively slow. When plants enter the grand period of growth and stem elongation and new leaves appear N uptake is about 2.8 to 5.04 kg ha^{-1} d^{-1}. For high yielding corn under good environmental conditions N uptake may approach 14.5 kg ha^{-1} d^{-1}. Most Studies report a slowing of N uptake as grain fills during the reproductive stage. Some studies report a cessation of uptake during the changeover from vegetative to reproductive growth. After grain filling has finished N uptake ceases. In considering optimum N fertilization rates for maximum grain, ensilage, and nutritive yields the mineralization pool should be considered. While the purpose of this study is not to measure nor predict the mineralized N at individual site soil systems it should be noted that residual soil nitrate samples taken post harvest could be potentially partitioned into mineralized N and residual applied fertilizer N. This would somewhat affect the yield and associated N rate model predictions.

III.

MATERIALS AND METHODS

Site Description and Cultural Practices

This study was initiated in 1993 at five locations in the state of Oklahoma covering both dryland and irrigated corn production areas. The eastern dryland location was in Wagoner County on a Latonier Clay (clayey over loamy, mixed thermic, Vertic Hapludoll) while the irrigated site was in Haskell County on both a Choska Silt Loam (coarse, silty, mixed, thermic, Fluventic Hapludoll) and a Norwood Silt Loam (fine silty, mixed (calcareous), thermic, Tupic Udifuvent). Both eastern locations were on private producers farms and had to be relocated each year. When possible, corn followed corn at these sites in terms of a rotational scheme.

The southcentral locations were in Grady County at the Southcentral Agronomy Research Station, Oklahoma State University, on a Dale Silt Loam (fine, silty, mixed, thermic Pachic, Haplustoll). The fifth location was in the Panhandle of Oklahoma at the Oklahoma Panhandle Research and Extension Center, Oklahoma State University. The soil was a Richfield Clay Loam (fine, montmorillonitic, mesic, Aridic, Argiustoll). The Panhandle location was an irrigated only site typical of producer practices for this area.

Irrigation water was applied at the eastern location in conjunction with the producer's irrigation schedule (approximately 154.2 – 205.6 m^3 ha^{-1} per week starting at the V9 - V12 developmental stage). The southcentral and panhandle irrigation schedules were planned for 205.6 m^3 of water per week after the corn reached the V12 stage. Irrigation prior to this stage was on an as needed basis (approximately 102.8 - 154.2 m^3 every 10 days). Rainfall was taken into account in the irrigation scheduling. All sites utilized flood irrigation systems.

Tillage practices usually included two winter applications for destruction of corn stubble and final seed bed preparation in the early spring. Land planning and bedding were utilized at the irrigated locations with the exception of the Grady County site. Where possible, a deep tillage application was used at the beginning of the study and every other year to prevent subsoil compaction and aide in adequate root development and penetration into the soil profile.

Planting was accomplished by either a John Deere Max Emerge or 71 Flex Unit Planter, depending on location and availability of equipment. Plant populations were established from information gained from the Oklahoma Corn Performance Trials, visiting with area and county extension personnel and with the producers in a given area. Plant populations are listed in Table 1. Harvesting was accomplished using a Massey Ferguson Plot 8 Combine equipped with a two row corn head and an on board Micro-4 computerized weigh bucket system.

Weeds were chemically controlled by using either Lariet {Atrazine [6-chloro-N-ethyl-N'-(1-methylethyl)-1,3,5-triazine-2,4-diamine] + Alachlor [2-chloro-N-(2,6-diethylphenyl)-N-(methoxymethyl) acetamide]}, Bicep {Atrazine + Metolachlor [4-(dichloroacetyl)-3,4-dihydro-3-methyl-2H-1,4-benzoxazine]}, Atrazine, or a tank mix or Atrazine + Metolachlor. The Grady County and Texas County locations also had postemergence treatments of Bromoxynil (3,5-dibromo-4-hydroxybenzonitrile) and Nicosulfuron {2-[[[[(4,6-dimethoxy-2-pyrimidinyl)amino]carbonyl]amino]sulfonyl]-

N,N-dimethyl-3-pyridinecarboxamide} to control cocklebur (*Xanthium strumarium L.*) and shattercane [*Sorghum bicolor (L.) Moench*], respectively. Insecticides; Diazinon {O,O,-diethyl O-[6-methyl-2-(1-methylethyl)-4-pyrimidinyl] phosphorothioate} and Karate [alpha –cyano-3-phenoxybenzyl 3-(2-chloro-3,3,3-trifluoroprop-1-enyl)-2,2-dimethylcyclopropanecarboxylate] or Lorsban [O,O-diethyl O-(3,5,6-trichloro-2-pyridinyyl) phosphorothioate] were applied, respectively, as a preemergence treatment to address the corn rootworm (*Diabrotica sp.*) and postemergence for the corn borer (*Diatraea grandiosella*).

Treatments and Experimental Design

Treatments were rates of nitrogen application (0.0, 0.227, 0.454, and 0.681 kg N per 62.73 kg ha^{-1} of corn grain yield goal). Nitrogen fertilizer was applied by hand at all locations in the form of ammonium nitrate (NH_4NO_3). Incorporation was accomplished by mechanical tillage or by hand with a garden rake. Nitrogen fertilizer rates for each location were determined by multiplying the location yield goal (Table 1) by the nitrogen treatment rate (Table 2).

A randomized complete block design was utilized in applying fertilizer N across 16 plots at all locations. This design was used to avoid grouping of the applied fertilizer N rates in the various field site conditions where either furrow irrigation or soil gradients existed. Beyond this point the design served no purpose as applied fertilizer N was combined with resisdual soil NO_3 within each plot to form an individual plot total fertilizer N rate. Thus, sixteen total fertilizer N rates existed at each location (Tables 3-

Table 1. County Location Plant Populations and Yield Goals.

County	Plant Population ---Plants ha^{-1}---	Yield Goal --kg ha^{-1}--
Haskell (Webbers Falls, Irrigated)	65000	12546
Wagoner (Choska, Dryland)	50000	9410
Texas (OPREC, Irrigated)	72500	12546
Grady (SCARS, Irrigated)	62500	10978
Grady (SCARS, Dryland)	47500	8782

Table 2. Applied Fertilizer Nitrogen Treatment Rates and Location Application Rates Based on Grain Yield Goals.

Treat. Rate	W. Falls*	Choska	OPREC*	SCARS(I)*	SCARS(D)*
----kg----	---------------------------------------kg ha^{-1}-------------------------------------				
0.0	0.0	0.0	0.0	0.0	0.0
0.227	112.0	84.0	112.0	98.0	75.6
0.454	224.0	168.0	224.0	196.0	151.2
0.681	336.0	252.0	336.0	294.0	226.8

*, Webbers Falls, Oklahoma Panhandle Research and Extension Center, Southcentral Agronomy Research Station

7). Grady County, Haskell County, and Texas County were planted in 36.48 m * 63.84 m blocks utilizing 9.12 m * 9.12 m plot dimensions. Three such blocks were measured at the Grady County and Texas County experiment stations with two being cropped out in corn to lower and level residual soil nitrate prior to each planting year. Each year the study was placed in a new block at these sites. The Haskell and Wagoner County studies were placed in new locations each year per the producers discretion. Each study had a 9.12 m planted buffer between replications and a 3.04 – 3.65 m planted buffer between plots. The Grady County sites were planted on .912 m row spacing while the Haskell County and Texas County locations were planted on .760 m row spacing. The Wagoner County location had trial dimensions of 30.76 m * 63.84 m, plot dimensions of 7.69 m * 9.12 m and .964 m row spacing due to producer used equipment. Buffer space for this site was approximately the same as the other four locations. Plots consisted of 12, 10, or 8 rows depending on plot dimensions and available equipment.

Sampling Variables and Procedures

Composite soil samples (five subsamples) were collected from each plot at preplant (Tables 3-7) and postharvest (Table 8) from both the topsoil (0 – 152.4 mm) and subsoil (152.4 – 457.2 or 609.6 mm) to determine existing residual soil nitrate. All samples were tested for residual soil nitrate levels using the audimated cadmium reduction method.

Ensilage samples were taken from the third row of each plot. These samples were harvested by hand using machetes. A total of 2.32 or 2.79 m^2 plot area was harvested

Table 3. Residual Profile Nitrate and Applied Fertilizer Nitrogen + Residual Profile Nitrate on a Per Plot Basis at Webbers Falls, OK, Haskell County (Irrigated).

Year	1995		1996	
Plot	RPN	Fert.-N + RPN	RPN	Fert.-N + RPN
	kg ha^{-1}			
1	105.3	441.3	57.1	393.1
2	85.1	85.1	67.5	291.5
3	85.1	197.1	84.0	84.0
4	78.4	302.4	60.5	172.5
5	86.2	198.2	44.0	268.0
6	62.7	398.7	68.7	404.7
7	66.1	290.1	64.2	64.2
8	76.2	76.2	90.7	202.7
9	70.6	294.6	111.7	111.7
10	68.3	180.3	67.5	179.5
11	65.0	65.0	57.1	393.1
12	82.9	418.9	54.9	278.9
13	59.4	59.4	117.9	229.9
14	63.8	399.8	65.0	65.0
15	61.6	173.6	44.0	380.0
16	84.0	308.0	47.8	271.8

Table 4. Residual Profile Nitrate and Applied Fertilizer Nitrogen + Residual Profile Nitrate on a Per Plot Basis at Choska, OK, Wagoner County (Dryland).

Year	1994		1996	
Plot	RPN	Fert.-N + RPN	RPN	Fert.-N + RPN
	kg ha^{-1}			
1	26.9	26.9	40.7	124.7
2	41.4	209.4	49.6	49.6
3	40.3	124.3	50.7	218.7
4	25.8	277.8	67.2	319.2
5	15.7	267.7	49.6	133.6
6	16.8	16.8	64.6	232.6
7	20.2	104.2	59.0	59.0
8	40.3	208.3	78.7	330.7
9	17.9	17.9	40.3	40.3
10	17.9	185.9	33.6	117.6
11	16.8	268.8	38.1	290.1
12	17.9	101.9	33.6	201.6
13	17.9	17.9	34.7	286.7
14	15.7	99.7	42.6	210.6
15	17.9	269.9	31.0	115.0
16	20.2	188.2	31.0	31.0

Table 5. Residual Profile Nitrate and Applied Fertilizer Nitrogen + Residual Profile Nitrate on a Per Plot Basis at the Oklahoma Panhandle Research and Extension Center in Goodwell, OK, Texas County (Irrigated).

Year	1994		1995	
Plot	RPN	Fert.-N + RPN	RPN	Fert.-N + RPN
	kg ha^{-1}			
1	87.4	311.4	206.1	430.1
2	73.9	409.9	91.8	203.8
3	62.7	62.7	304.6	304.6
4	60.5	172.5	123.2	459.2
5	33.6	33.6	110.9	446.9
6	21.3	245.3	118.7	118.7
7	42.6	378.6	101.9	213.9
8	41.4	153.4	308.0	532.0
9	25.8	361.8	63.8	399.8
10	30.2	142.2	60.5	60.5
11	37.0	261.0	70.6	294.6
12	44.8	44.8	125.4	237.4
13	21.3	357.3	34.7	34.7
14	24.6	248.6	89.6	201.6
15	24.6	24.6	88.5	424.5
16	53.8	165.8	110.9	334.9

Table 5 (cont'd.). Residual Profile Nitrate and Applied Fertilizer Nitrogen + Residual Profile Nitrate on a Per Plot Basis at the Oklahoma Panhandle Research and Extension Center in Goodwell, OK, Texas County (Irrigated).

Year	1996		1997	
Plot	RPN	Fert.-N + RPN	RPN	Fert.-N + RPN
	kg ha^{-1}			
1	115.0	451.0	23.2	121.2
2	203.1	427.1	24.3	24.3
3	54.9	54.9	24.6	318.6
4	115.7	227.7	20.9	216.9
5	61.9	397.9	17.2	17.2
6	61.3	173.3	22.0	316.0
7	61.6	61.6	19.8	215.8
8	41.8	265.8	19.4	117.4
9	112.8	112.8	26.5	222.5
10	101.9	325.9	22.0	22.0
11	38.9	150.9	19.8	117.8
12	95.2	431.2	17.2	311.2
13	115.7	227.7	14.9	210.9
14	94.9	94.9	22.0	120.0
15	85.1	309.1	19.8	19.8
16	68.7	404.7	17.2	311.2

Table 6. Residual Profile Nitrate and Applied Fertilizer Nitrogen + Residual Profile Nitrate on a Per Plot Basis at the SouthCentral Agronomy Research Station in Chickasha , OK, Grady County (Irrigated).

Year	1994		1995	
Plot	RPN	Fert.-N + RPN	RPN	Fert.-N + RPN
	kg ha^{-1}			
1	22.4	120.4	39.2	137.2
2	24.6	318.6	90.7	384.7
3	28.0	28.0	48.2	244.2
4	25.8	221.8	41.4	41.4
5	23.5	219.5	37.0	37.0
6	19.0	313.0	32.5	326.5
7	19.0	19.0	31.4	129.4
8	17.9	115.9	32.5	326.5
9	19.0	313.0	42.6	336.6
10	15.7	15.7	32.5	228.5
11	17.9	213.9	32.5	130.5
12	16.8	114.8	41.4	41.4
13	16.8	16.8	41.4	237.4
14	19.0	313.0	45.9	143.9
15	25.8	221.8	38.1	38.1
16	23.5	121.5	37.0	331.0

Table 6 (cont'd.). Residual Profile Nitrate and Applied Fertilizer Nitrogen + Residual Profile Nitrate on a Per Plot Basis at the SouthCentral Agronomy Research Station in Chickasha, OK, Grady County (Irrigated).

Year	1996		1997	
Plot	RPN	Fert.-N + RPN	RPN	Fert.-N + RPN
	kg ha^{-1}			
1	50.7	50.7	23.2	121.2
2	54.1	250.1	24.3	24.3
3	51.9	149.9	24.6	318.6
4	40.0	334.0	20.9	216.9
5	43.7	337.7	17.2	17.2
6	34.7	34.7	22.0	316.0
7	44.5	240.5	19.8	215.8
8	23.2	121.2	19.4	117.4
9	48.5	146.5	26.5	222.5
10	47.4	341.4	22.0	22.0
11	48.2	244.2	19.8	117.8
12	51.5	51.5	17.2	311.2
13	--	--	14.9	210.9
14	--	--	22.0	120.0
15	--	--	19.8	19.8
16	--	--	17.2	311.2

Table 7. Residual Profile Nitrate and Applied Fertilizer Nitrogen + Residual Profile Nitrate on a Per Plot Basis at the SouthCentral Agronomy Research Station in Chickasha , OK, Grady County (Dryland).

Year	1994		1995	
Plot	RPN	Fert.-N + RPN	RPN	Fert.-N + RPN
	kg ha^{-1}			
1	14.6	165.8	45.9	45.9
2	28.0	254.8	40.3	267.1
3	19.0	94.6	31.4	107.0
4	21.3	21.3	78.4	229.6
5	20.2	247.0	39.2	114.8
6	23.5	23.5	33.6	184.8
7	19.0	94.6	35.8	35.8
8	17.9	169.1	56.0	282.8
9	23.5	23.5	62.7	289.5
10	25.8	101.4	37.0	112.6
11	35.8	262.6	35.8	187.0
12	24.6	175.8	52.6	52.6
13	15.7	166.9	41.4	192.6
14	12.3	87.9	38.1	113.7
15	19.0	19.0	33.6	260.0
16	15.7	242.5	48.2	48.2

Table 8. Post Harvest Residual Profile Nitrate by Year and Location.

Year	W. Falls*	Choska	OPREC*	SCARS(D)*	SCARS(I)*
			kg ha^{-1}		
1994	--	13.1	34.6	69.8	16.4
1995	60.4	--	165.7	23.7	19.3
1996	106.6	40.0	17.7	--	7.2
1997	--	--	87.8	--	23.3

*, Webbers Falls, Oklahoma Panhandle Research and Extension Center, Southcentral Agronomy Research Station

from each plot depending on location and production practices. The sample was weighed for plot yield then subsampled to determine dry matter percentage and nutritive values. Nutritive values analyzed for were CP, TDN, ADF, and NDF. Crude protein was determined by dry combustion analysis using a LECO instrument. Total digestible nutrients were calculated directly from ADF. Acid detergent fiber and NDF were both determined by using their respective solutions needed for the reflux procedure.

Grain harvest was taken from each plot at every location if production practices and environmental conditions made it possible for that year. A Massey Ferguson Plot 8 combine with an onboard Micro-4 computerized weigh bucket system was used to harvest grain. Some site-years were hand harvested due to incumbent weather or time restrictions on location of the combine. During the last year of the study the Micro-4 computer system failed forcing all plot grain collections to be weighed on stationary scales prior to subsampling. Location and plot harvest area was either 4.05, 6.97, 13.94, or 16.72 m^2 per plot with the exception of the Wagoner County location where, due to producer equipment needs, a harvest area of 4.05 or 17.65 m^2 was used. These combinations of harvest areas were used due to the differences between hand harvesting, harvesting excessive grain yields too large for the weigh bucket system, and normal harvest conditions * location differences. The center two or four rows of each plot were harvested, depending on location and plot size. If four rows were harvested, then two plot yield calculations were obtained and the average was taken and used as the plot yield component. If grain yield was excessive then two harvest rows were split and either two or four plot yield calculations (depending on whether two or four rows were harvested from the center of the plot) were averaged and used as the plot yield component. If grain yield was not excessive and only the center two rows were harvested then one plot yield calculation was obtained and accepted as the plot yield component. All plot grain samples at each location were caught in bags so that each plots grain sample could be subsampled for nutritive value analysis. Nutritive value components analyzed were CP, TDN, ADF, and NDF. Methods utilized for these analyses were mentioned in the ensilage discussion.

Statistical Analysis

Locations were analyzed separately due to population and yield goal management differences. Years within locations were also analyzed separately as significant differences between years existed. The only exception to this analysis statement is the Chickasha irrigated site where years 1994, 1996, and 1997 were not significantly different for grain yield and ensilage yield. Grain yield was not harvested in 1995 due to irrigation pump failure. However, ensilage yield was taken over all 4 years and this year within location analysis indicated significant differences existed between years. Therefore, to keep consistency with other location analysis and since the combined year analysis advantage was minimal this site was also treated as individual site-years. Regression analysis was then used to determine if yield and nutritive value responses were either linear or quadratic in their response to fertilizer N rates. Significance of regression model terms was determined by using a F test statistic. When the quadratic term was significant the equation ($Y = a + bX + cX^2$) was solved to determine both predicted maximum yields and associated N rates. In this equation Y = Predicted maximum yield, a = Y intercept, b = 1st degree coefficient, c = 2nd degree coefficient, and

X = Rate of nitrogen application. This calculation was accomplished by setting the first derivative of the response equation equal to zero, solving for X and then substituting the value of X back into the equation and solving for Y. The R^2 statistic was utilized whenever significance was shown for either the linear or quadratic models to indicate the amount of variation associated with the dependent yield variable that could be attributed to the independent fertilizer N variable. When the quadratic model was significant a N_{max} value (nitrogen rate at maximum yield) was indicated as the predicted fertilization rate at which maximum yield, (either grain, ensilage, or nutritional value), occurred. All statistical analysis was done using SAS program analysis system.

IV.

RESULTS AND DISCUSSION

The 1993 data will not be included in the discussion due to an initial differing analysis an experimental design approach and high initial year residual soil nitrate plot values. All references to current and former OSU N fertilizer recommendations for corn grain and ensilage yield goals will be associated with information in Table 9. This table consists of N fertilizer recommendations for corn grain and ensilage yields that were established or adapted via soil test calibration studies. These recommendations are based on yield goal projections thus reflecting a linear increase in N rate as yield goal is increased. Each yield goal projection has an associated N rate. For grain yield these two values compose a relationship that may be referred to as the nitrogen to corn grain yield goal ratio. In metric terms this ratio is defined as a determined number of kilograms of nitrogen that are needed to produce 62.73 kg ha-1 of corn grain (English units = a determined number of pounds of N that are needed to produce one bushel of corn per acre). Table 9 also reflects that in 1993 N recommendations of corn grain yield were lowered to more accurately reflect research in areas that have similar environmental conditions to Oklahoma.

Eastern Locations

Table 9. OSU Corn Grain and Ensilage Yield Goals and Associated Nitrogen Fertilizer Recommendations Per Soil Test Calibrations.

Grain --kg ha^{-1}--	Nitrogen -----kg ha^{-1}----	Ratio[†] --kg N:1 MGYU--	Ensilage --Mg ha^{-1}--	Nitrogen --kg ha^{-1}--
2508	44.8[‡] (44.8)[§]	1.12:1 (1.12:1)[¶]	11.2	50.4
3136	56.0 (61.6)	1.12:1 (1.23:1)	22.4	100.2
3763	67.2 (78.4)	1.12:1 (1.31:1)	33.6	151.2
5330	95.2 (112.0)	1.12:1 (1.32:1)	44.8	207.2
6271	123.2 (145.6)	1.23:1 (1.46:1)	56.0	268.8
7525	145.6 (190.4)	1.21:1 (1.60:1)	67.2	336.0
10034	212.8 (280.0)	1.33:1 (1.75:1)	---	---
11288	240.8 (324.8)	1.34:1 (1.80:1)	---	---
12542	268.8 (369.6)	1.34:1 (1.85:1)	---	---

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†, Ratio = Kilograms of nitrogen to produce 62.73 kg ha-1 (Metric Grain Yield Unit) of corn grain

‡, Current corn grain yield goal nitrogen fertilizer recommendations

§, Corn grain yield goal nitrogen fertilizer recommendations prior to 1993

¶, Nitrogen to corn grain yield goal ratio prior to 1993

Webbers Falls (Irrigated Site)

The Webbers Falls location study was conducted from 1994 through 1996. However, only 2 years of ensilage data and 1 year of grain data were retrieved from the Webbers Falls site due to producer oversight of the trial in 1994 and commercial harvest crew error in 1995 that compromised the grain harvest. Data results for these two years are available in Table 10. The 1995 ensilage yield data did not show a significant response to either the linear or quadratic models. This is not entirely surprising, as high residual soil NO_3 levels existed within the plots. Therefore, even the untreated check plot responded with comparable yields to the treated plots. This coupled with an environmentally good production year tends to explain the lack of response between treatments. Crude protein was the only nutritive variable to show a significant response to N fertilizer. The analysis indicated a positive linear CP response to N rate (Figure 1). The large R^2 value indicated a good relationship between CP response and N rate. The fact that CP was the only nutritive variable to respond tends to agree with the literature. In most studies CP showed small responses to increasing N while the remaining nutritive values were non responsive (6,14). The 1996 grain data indicated a significant quadratic yield and linear CP response to nitrogen. The GRNYLD response showed a plateau affect with a predicted maximum yield of 12116 kg ha^{-1} of corn grain yield associated with a 318 kg ha^{-1} of N rate (Figure 2). This is equal to 1.65 kg nitrogen to 62.73 kg ha^{-1} corn grain yield goal ratio at which point decreasing marginal returns of yield for each additional unit of N was indicated by the regression model. When comparing this site-years grain yield response data to current OSU recommendations it is somewhat but yet lower than recommendations existing prior to 1993. However, the quadratic response indicates a maximum yield point beyond which continuing to apply additional N will not increase grain yield. This would suggest that the current lower recommendations are appropriate for this location. The R^2 value indicates that two thirds of the variation associated with yield response is accounted for by N treatment rates. This indicates a good relationship between GRNYLD and N rate. The linear model responses of both grain and ensilage CP to N treatment rate (Figures 3, 4) are in agreement with the literature in terms of nutritive responses associated with N. However, the R^2 value associated with grain CP reveals that only a small amount of the variation associated with CP response can be accounted for by N treatment rates whereas the larger R^2 value associated with ensilage CP shows the opposite. This response may be somewhat related to the developmental processes within the corn plant and plant N uptake and sufficiency levels just prior to and at the point of translocation of N from the vegetative portions of the plant to the developing grain kernel. A high source to sink system would have existed at this point between the plant and the soil system. This coupled with irrigated conditions could have potentially allowed for high levels of N sufficiency within the plant thus allowing for adequate N for translocation across all treatment levels. Therefore, a weak relationship between N treatment rates and grain CP might exist. However, this is a difficult argument to support when looking at all irrigated locations data as responses of grain and ensilage CP data vary greatly and in some cases disagree with this supposition. The 1996 ensilage yield did not show a significant yield response to N rates. The lack of ensilage yield response is most likely related to high preplant levels of residual soil NO_3.

Table 10. Regression Analysis Results for Corn Grain and Ensilage Yield and Nutritive Response to Applied Fertilizer Nitrogen + Residual Profile Nitrate Nitrogen Fertilizer at Webbers Falls, Ok, Haskell County (Irrigated).

		Fert.-N + RPN			
Year	Variable	Yield Range L-H†	Model Response	Ratio or N-Rate‡	N_{max}
1995	ENY65, Mg ha^{-1}	44-71	NS§	--	---
	ENCP, g kg^{-1}	53-92	LR^2-0.75*	76-399	---
	ENTDN, g kg^{-1}	342-703	NS	--	---
	ENNDF, g kg^{-1}	420-625	NS	--	---
	ENADF, g kg^{-1}	239-371	NS	--	---
1996	GRNYLD, kg ha^{-1}	6181-13234	QR^2-0.67*	1.65:1(12116)¶	318
	GRNCP, g kg^{-1}	66-99	LR^2-0.24*	84-203	---
	GRNTDN, g kg^{-1}	860-878	NS	--	---
	GRNNDF, g kg^{-1}	61-129	NS	--	---
	GRNADF, g kg^{-1}	14-37	NS	--	---
	ENY65, Mg ha^{-1}	34-74	NS	--	---
	ENCP, g kg^{-1}	45-77	LR^2-0.62*	112-405	---
	ENTDN, g kg^{-1}	635-742	NS	--	---
	ENNDF, g kg^{-1}	364-577	NS	--	---
	ENADF, g kg^{-1}	189-327	NS	--	---

*, Significant at the 0.05 probability level

§, Non-significant at the 0.05 probability level

†, Yield range = Low Yield (L) – High Yield (H)

‡, Ratio = Kilograms of nitrogen to produce 62.73 kg ha-1 of corn grain, N-Rate = Total fertilizer nitrogen amount or range associated with yield or response results

¶, Predicted maximum yield

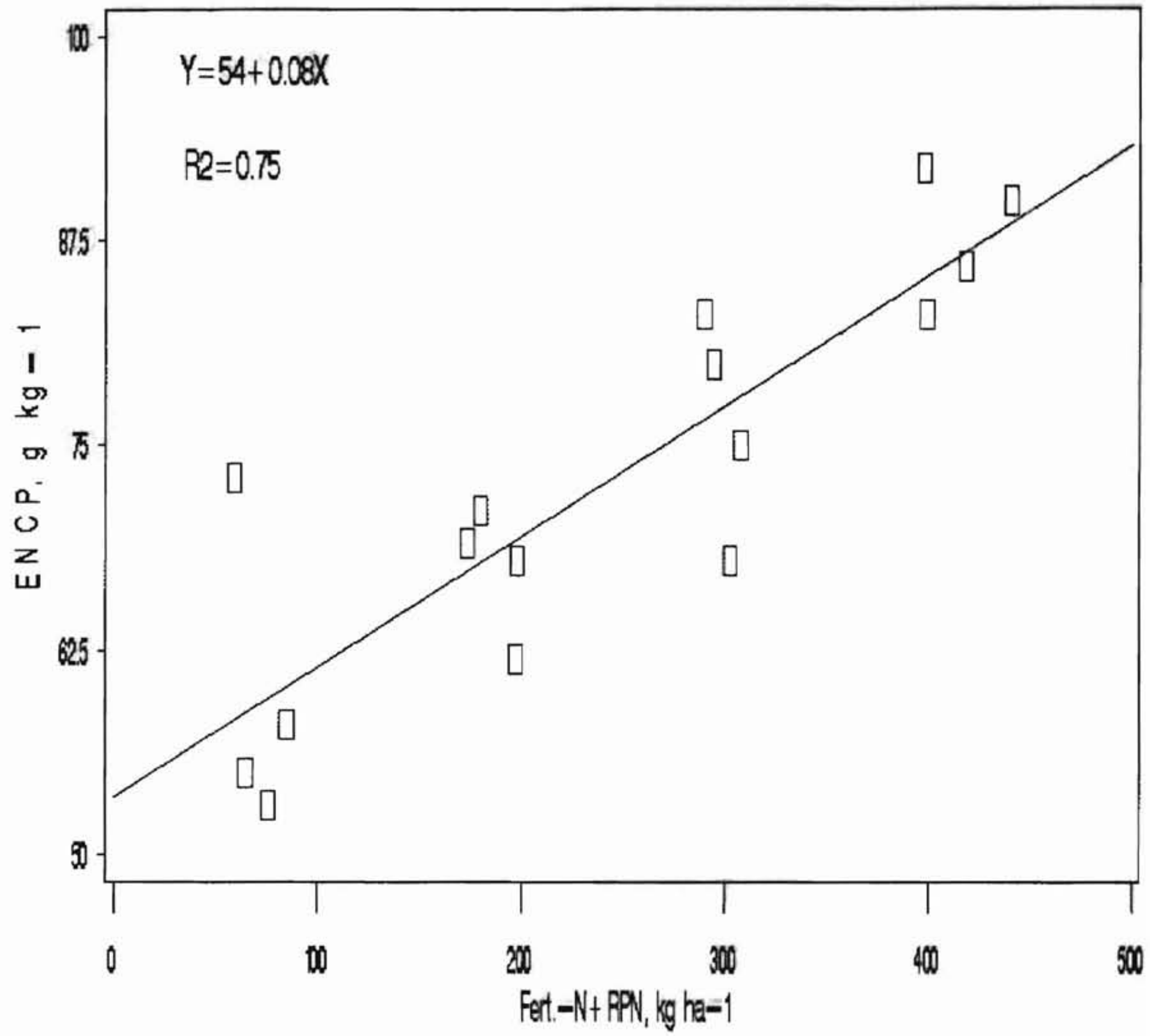

Figure 1. 1995 Webbers Falls Ensil. Crude Protein Results

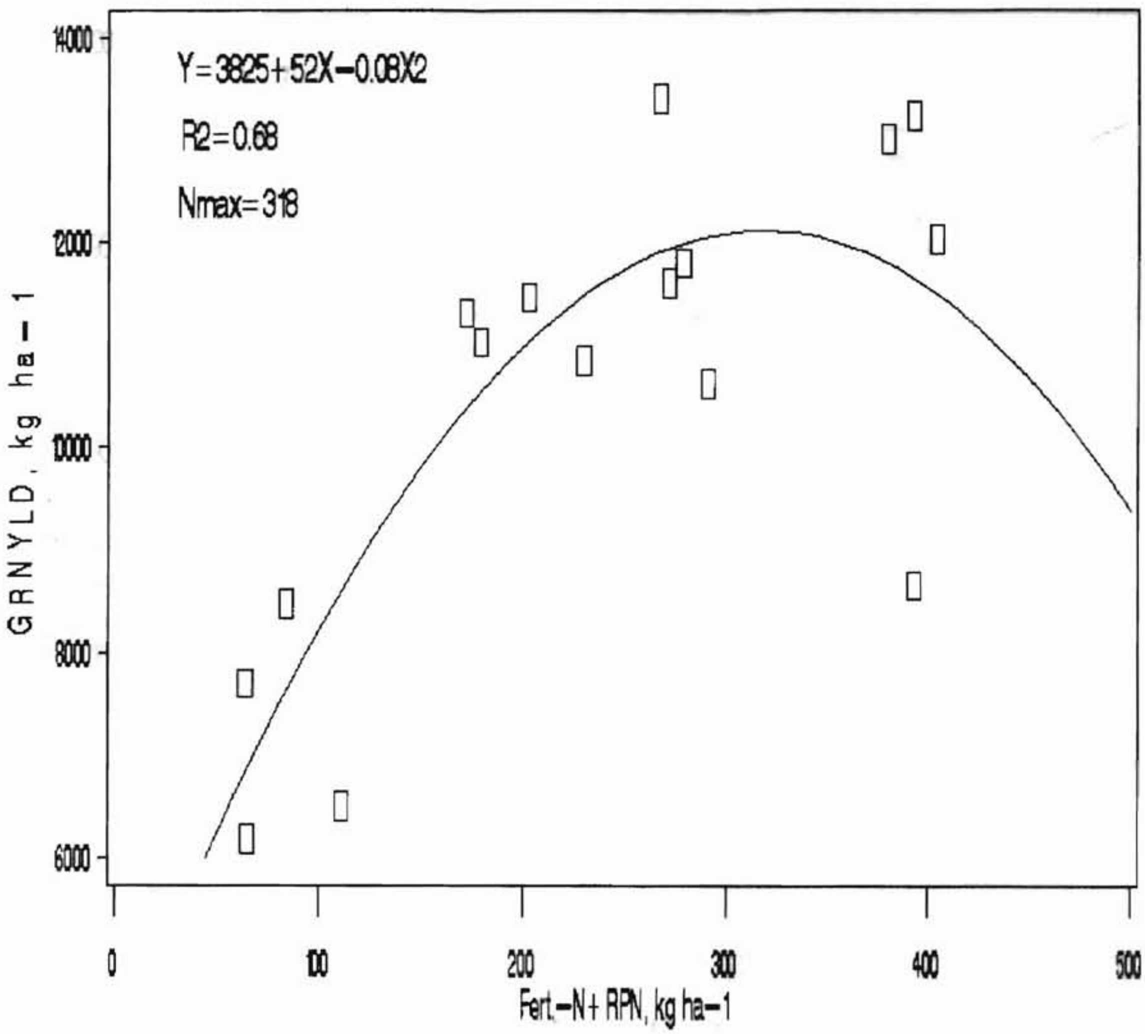

Figure 2. 1996 Webbers Falls Grain Yield Results

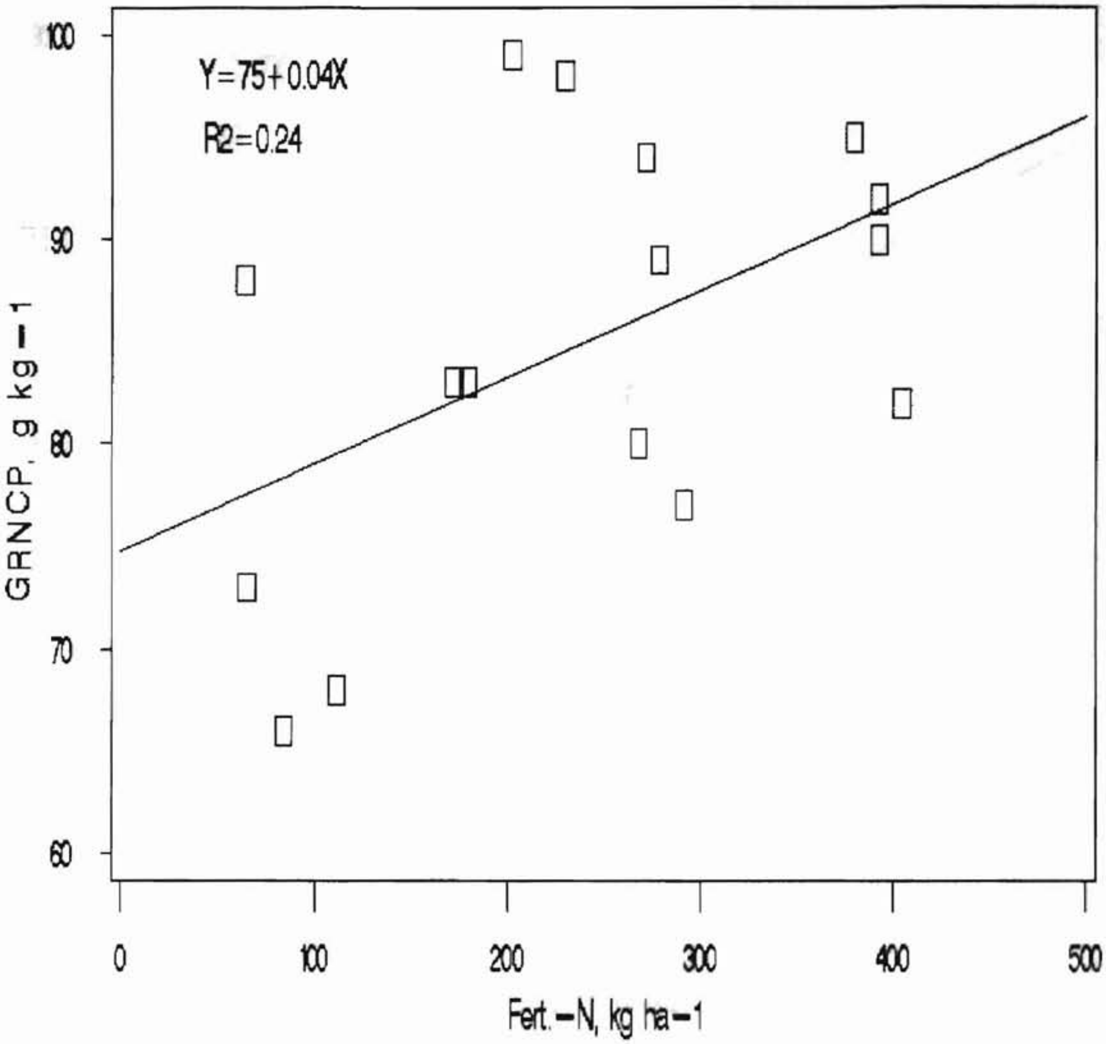

Figure 3. 1996 Webbers Falls Grain Crude Protein Results

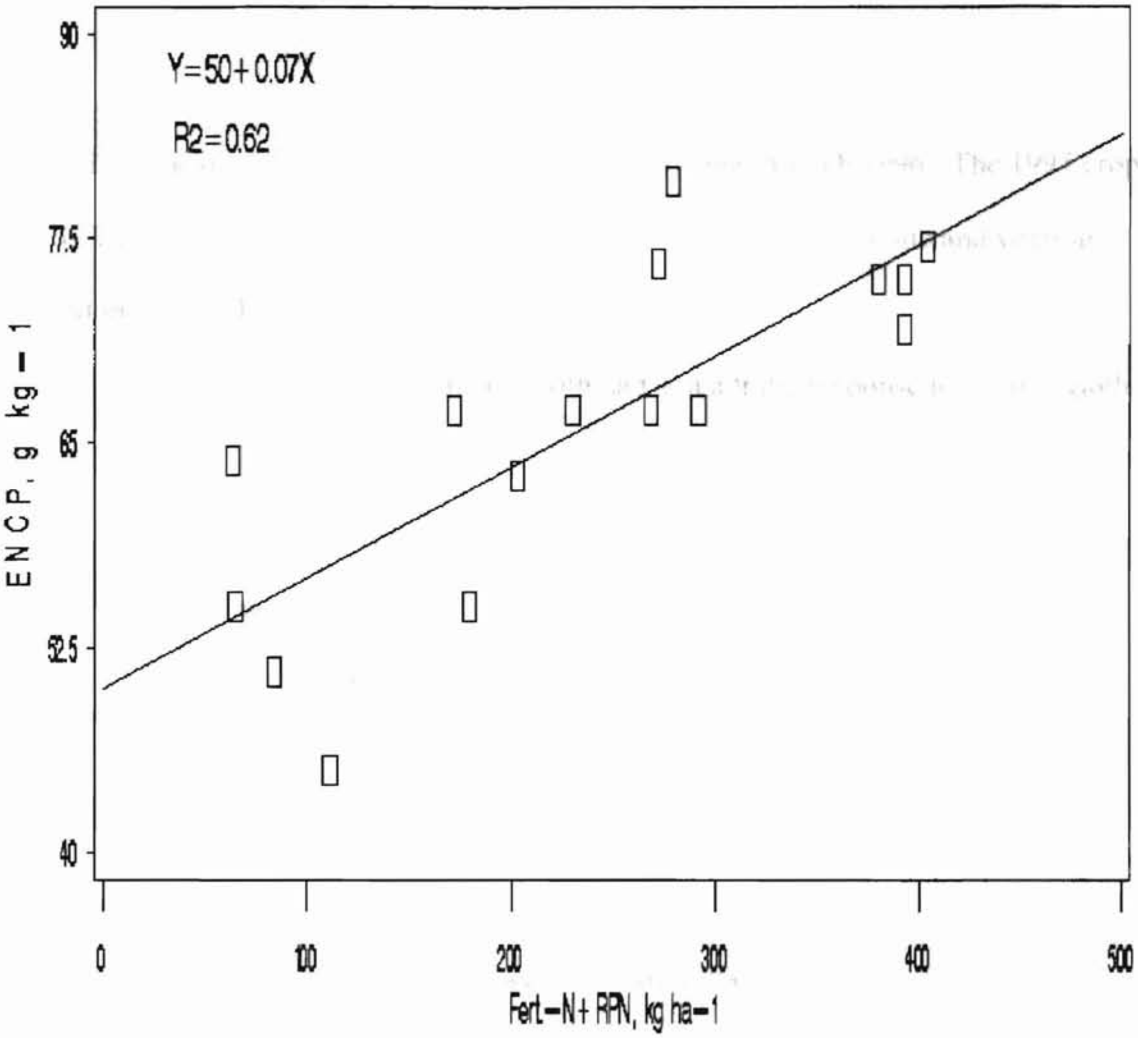

Figure 4. 1996 Webbers Falls Ensilage Crude Protein Res.

Choska (Dryland Site)

The Choska dryland site was conducted from 1994 through 1996. The 1995 crop was lost because of adverse weather conditions. Data results for this site and years are reported in Table 11.

Choska's 1994 grain yield and CP both had a quadratic response to N rate. Both also had strong R^2 values associated with the response curves. This indicates that a good relationship existed between GRNYLD and CP responses as a large portion (>80%) of the variability was accounted for by N treatment rates. The predicted maximum yield value associated with the GRNYLD response was 9545 kg ha^{-1} (Figure 5). The N_{max} value was 231 kg ha^{-1} resulting in a 1.52 kg of nitrogen to 62.73 kg ha^{-1} of corn grain yield goal ratio. This ratio is very reflective of OSU's lower nitrogen recommendations for corn grain yield. Grain CP's predicted maximum response came at 99 g kg^{-1} (Figure 6) with an associated N_{max} value of 238 kg ha^{-1}. The 1994 ensilage data analysis indicated a quadratic ENY65 response and linear CP, TDN, and ADF nutritive value responses. The plateau response of ENY65 predicted maximum yield was achieved at 54 Mg ha^{-1} with an associated N rate of 177 kg ha^{-1} (Figure 7). When compared to OSU's current N rate fertilizer recommendations this yield response was achieved with a considerably lower N rate, approximately 75 kg ha^{-1} less. Ensilage CP continued to respond to increasing N rates (Figure 8). A larger R^2 value indicates a strong relationship exists between N treatment rate and ENCP response. The TDN and ADF significant linear responses were somewhat of a surprise when compared to the literature, which in general, indicated that no response was seen to N. However, in this study various responses, depending on location, were seen. Acid detergent fiber is used as a measure of digestibility and considers that portion of the plant cell walls that are either indigestible or slowly digestible (i.e.; hemi-cellulose, lignin, cellulose). Total digestible nutrients are a mathematically derived value from ADF and address intake. The relationship between the two values is an inverse response, as ADF increases TDN decreases or vice versa. The desired response is the later scenario. In this site-year ensilage ADF decreased while TDN increased with increasing N rate (Figures 9, 10). Therefore, digestibility increased with increasing N rates. The only two variables to show a response to N treatment rates in 1996 were again ADF and TDN. However, this time it was within the grain component. In this site-year the two nutritive values had a quadratic response to N treatment rates. Acid detergent fiber's predicted maximum response was reached at 40 g kg^{-1} with an associated N_{max} value of 235 kg ha^{-1}. This value was expressed as a normal quadratic response curve whereas the TDN value, which also reflected a quadratic response to N treatment rates, had an inverted quadratic curve (Figures 11, 12). Total digestible nutrients reached its predicted maximum low point at 858 g kg^{-1} with an associated N_L value of 235 kg ha^{-1}. Upon consideration of the above discussion regarding ADF and TDN this inverse curve responses would be expected within the context of a quadratic response. In this site-year ADF increased with increasing N rates until reaching 235 kg ha^{-1} at which point it began to decrease with increasing N rates. At this same point of 235 kg ha^{-1} TDN stopped decreasing with increasing N rates and began to increase with increasing N rates. Therefore, digestibility follows this same pattern as both variables speak to fiber digestion. Again, this response was expected given the nature of the relationship between the two nutritive values. No other yield or nutritive values indicated a significant response to N treatment rates for this site-year.

Table 11. Regression Analysis Results for Corn Grain and Ensilage Yield and Nutritive Response to Applied Nitrogen Fertilizer + Residual Profile Nitrate at Choska, Ok, Wagoner County (Dryland).

		Fert.-N + RPN			
Year	Variable	Yield Range L-H†	Model Response	Ratio or N-Rate‡	N_{max}
1994	GRNYLD, kg ha^{-1}	3888-10849	QR^2-0.83*	1.36:1(9545)§	231
	GRNCP, g kg^{-1}	63-107	QR^2-0.83*	238(99)	238
	GRNTDN, g kg^{-1}	870-876	NS¶	--	---
	GRNNDF, g kg^{-1}	44-67	NS	--	---
	GRNADF, g kg^{-1}	16-25	NS	--	---
	ENY65, Mg ha^{-1}	32-57	QR^2-0.47*	177(54)	177
	ENCP, g kg^{-1}	43-77	LR^2-0.75*	18-208	---
	ENTDN, g kg^{-1}	639-708	LR^2-0.27	18-207	---
	ENNDF, g kg^{-1}	397-596	NS	--	---
	ENADF, g kg^{-1}	233-321	LR^2-0.27*	18-270	---
1996	GRNYLD, kg ha^{-1}	2711-9730	NS	--	---
	GRNCP, g kg^{-1}	84-126	NS	--	---
	GRNTDN, g kg^{-1}	856-868	QR^2-0.59*	235(858)	235(N_L)
	GRNNDF, g kg^{-1}	61-133	NS	--	---
	GRNADF, g kg^{-1}	28-46	QR^2-0.59*	235(40)	235
	ENY65, Mg ha^{-1}	12-76	NS	--	---
	ENCP, g kg^{-1}	43-90	NS	--	---
	ENTDN, g kg^{-1}	592-764	NS	--	---
	ENNDF, g kg^{-1}	336-642	NS	--	---
	ENADF, g kg^{-1}	161-381	NS	--	---

*, Significant at the 0.05 probability level

¶, Non significant at the 0.05 probability level

†, Yield range = Low Yield (L) – High Yield (H)

‡, Ratio = Kilograms of nitrogen to produce 62.73 kg ha-1 of corn grain, N-Rate = Total fertilizer nitrogen amount or range associated with yield or response results

§, Predicted maximum yield

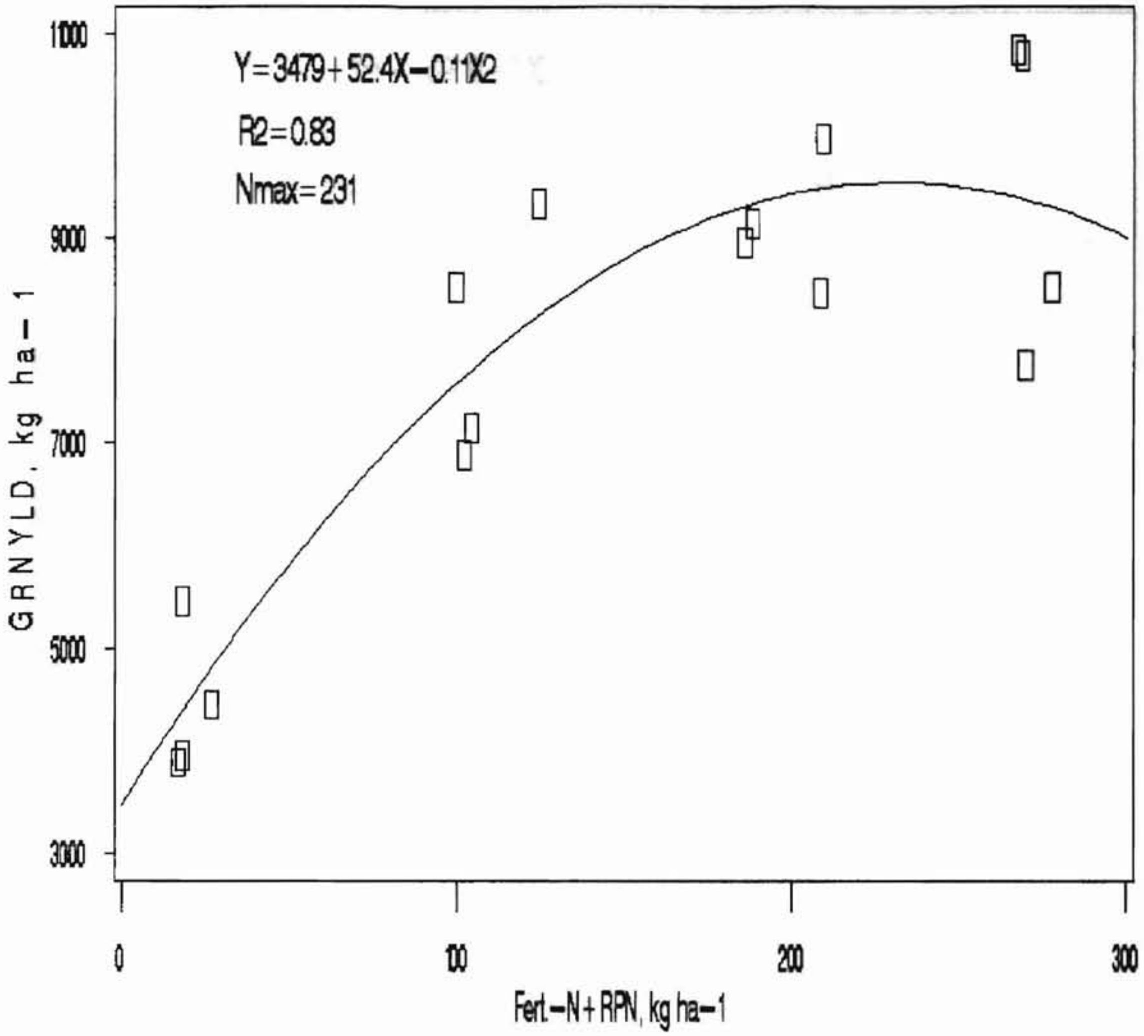

Figure 5. 1994 Choska Grain Yield Results

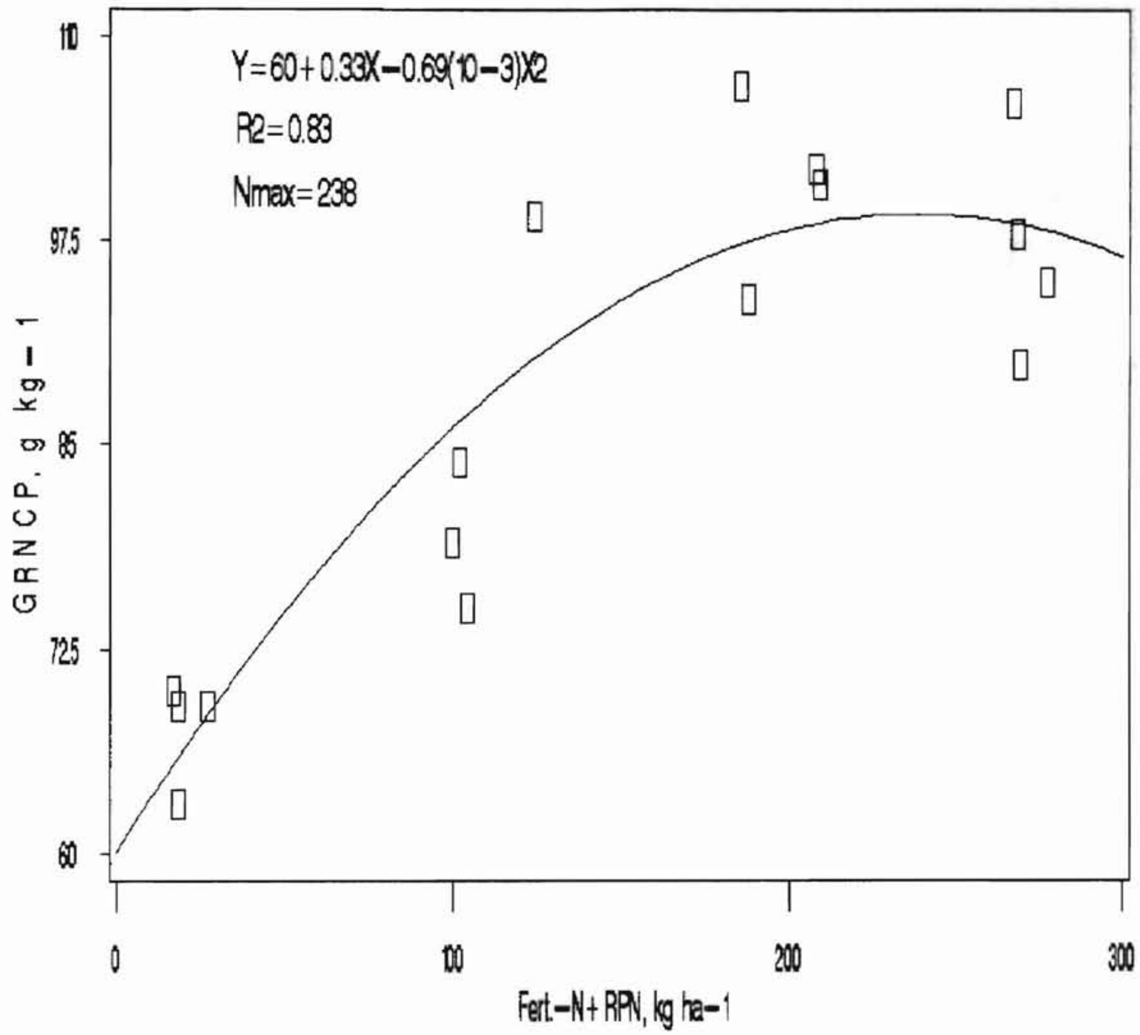

Figure 6. 1994 Choska Grain Crude Protein Results

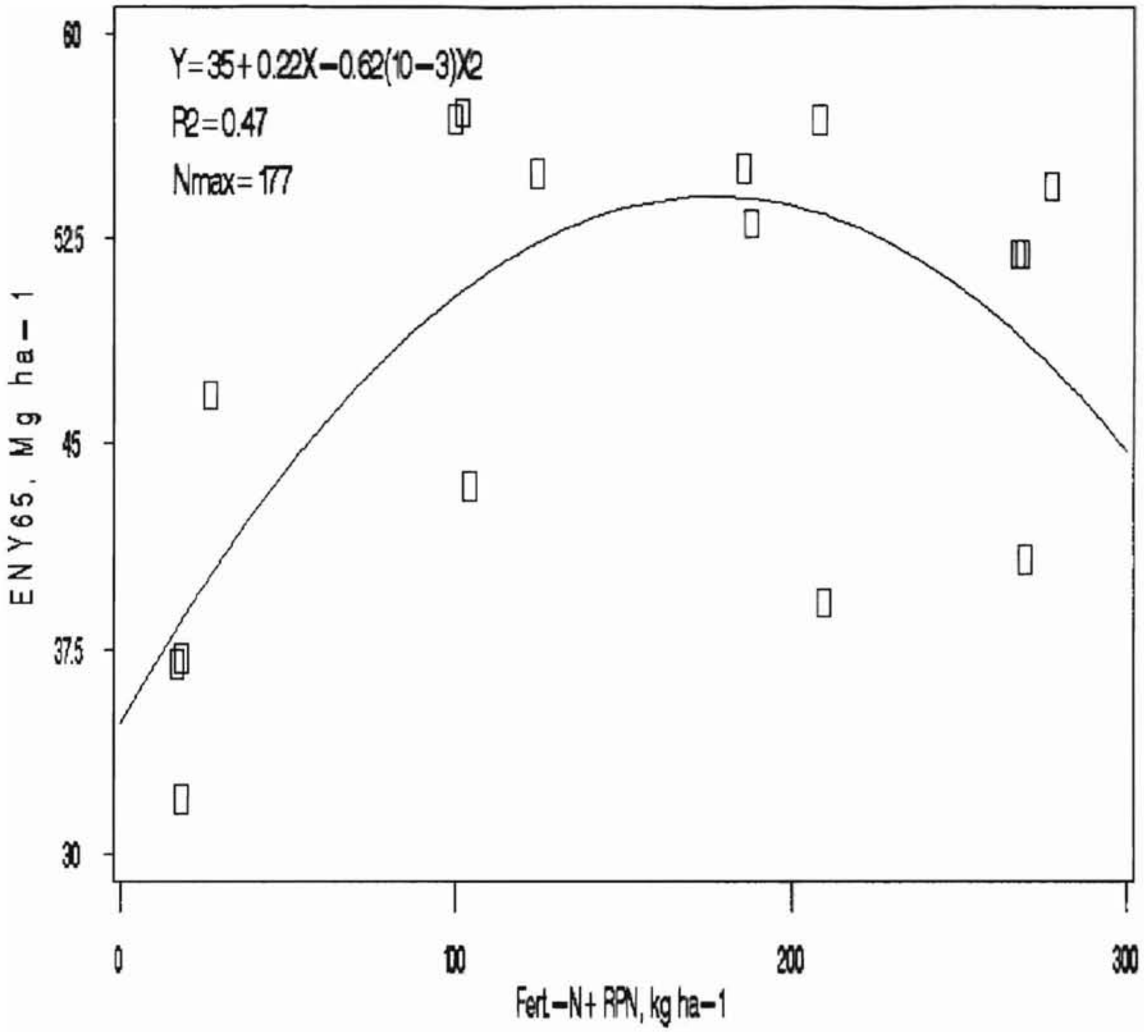

Figure 7. 1994 Choska Ensilage Yield Results

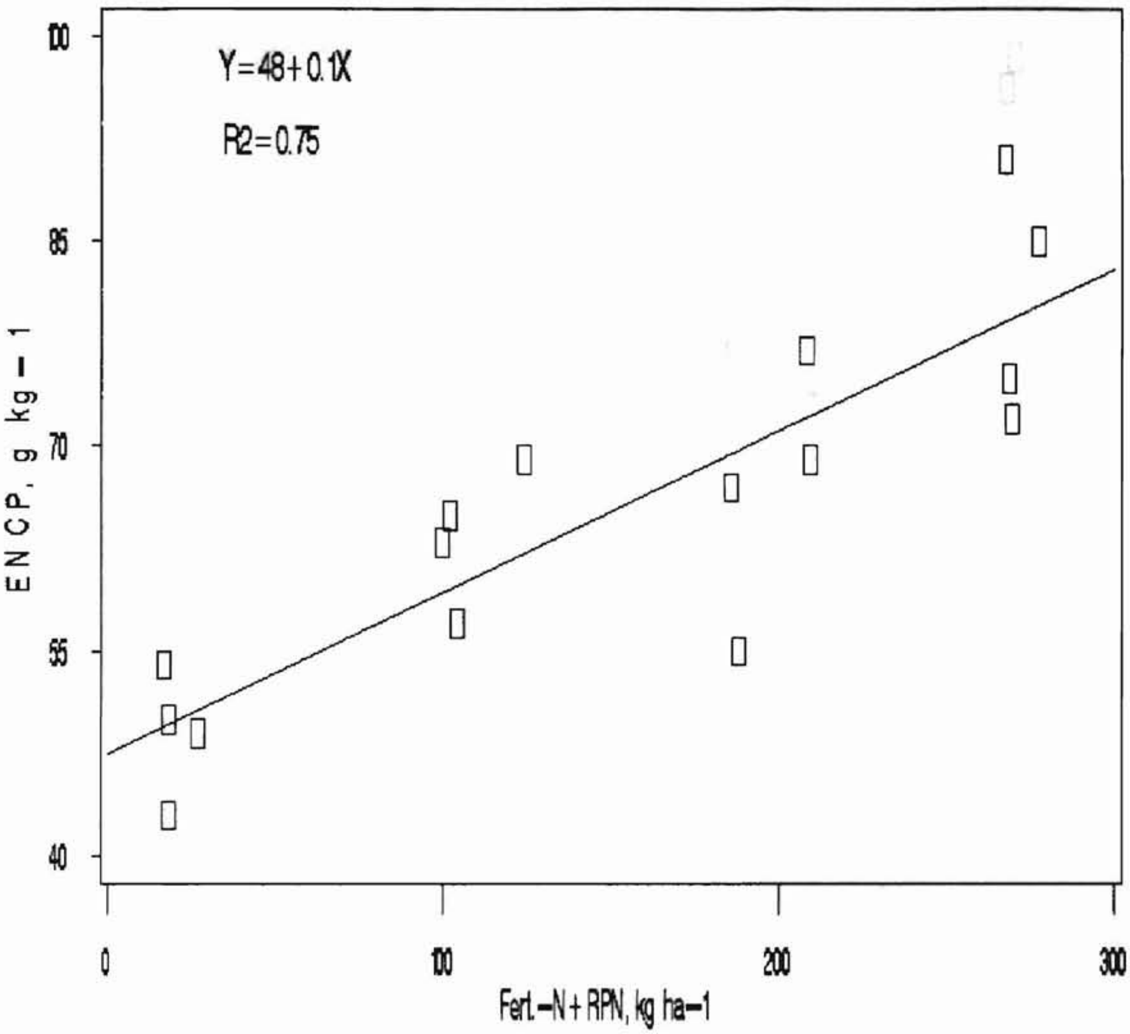

Figure 8. 1994 Choska Ensilage Crude Protein Results

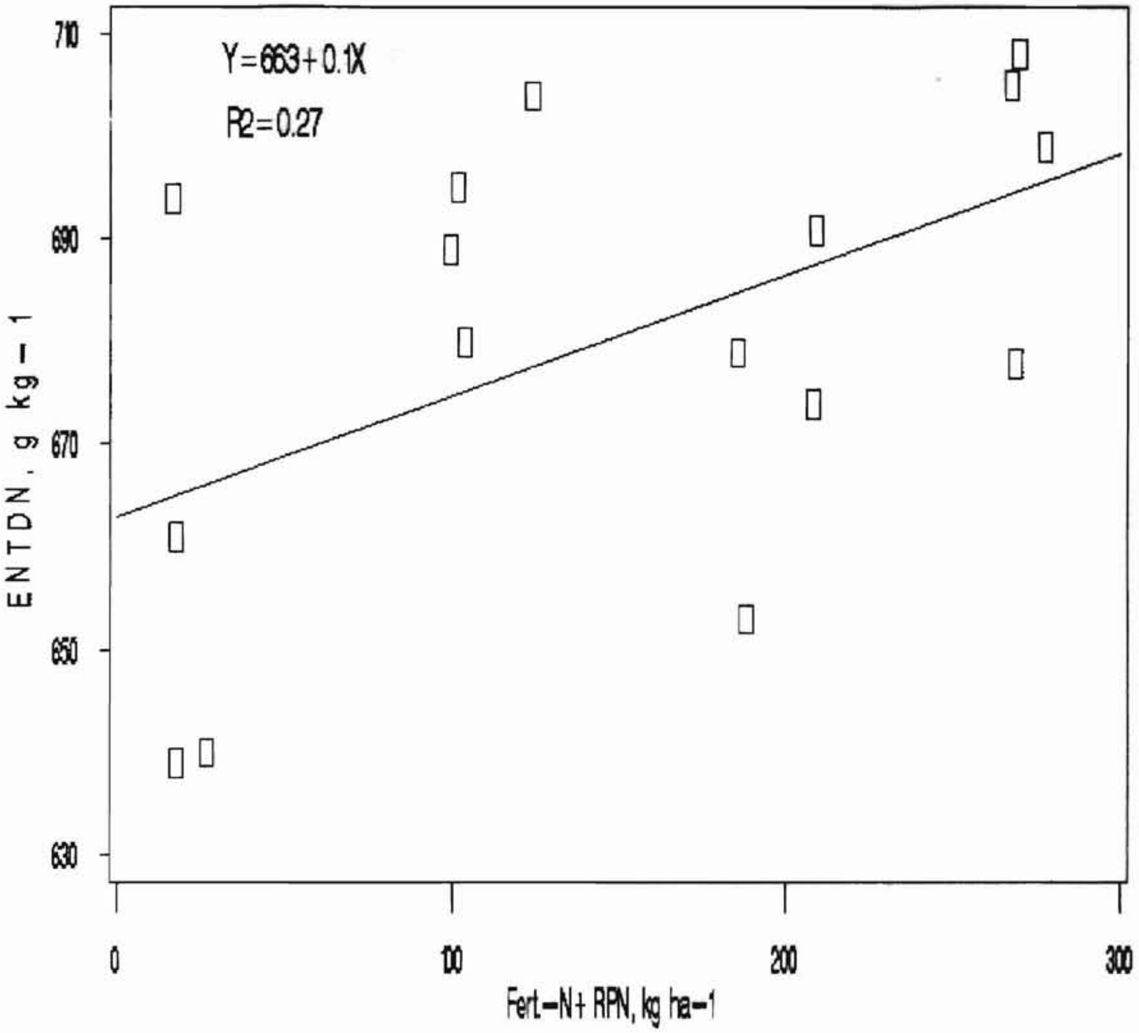

Figure 9. 1994 Choska Ensilage Total Dig. Nutrients Res.

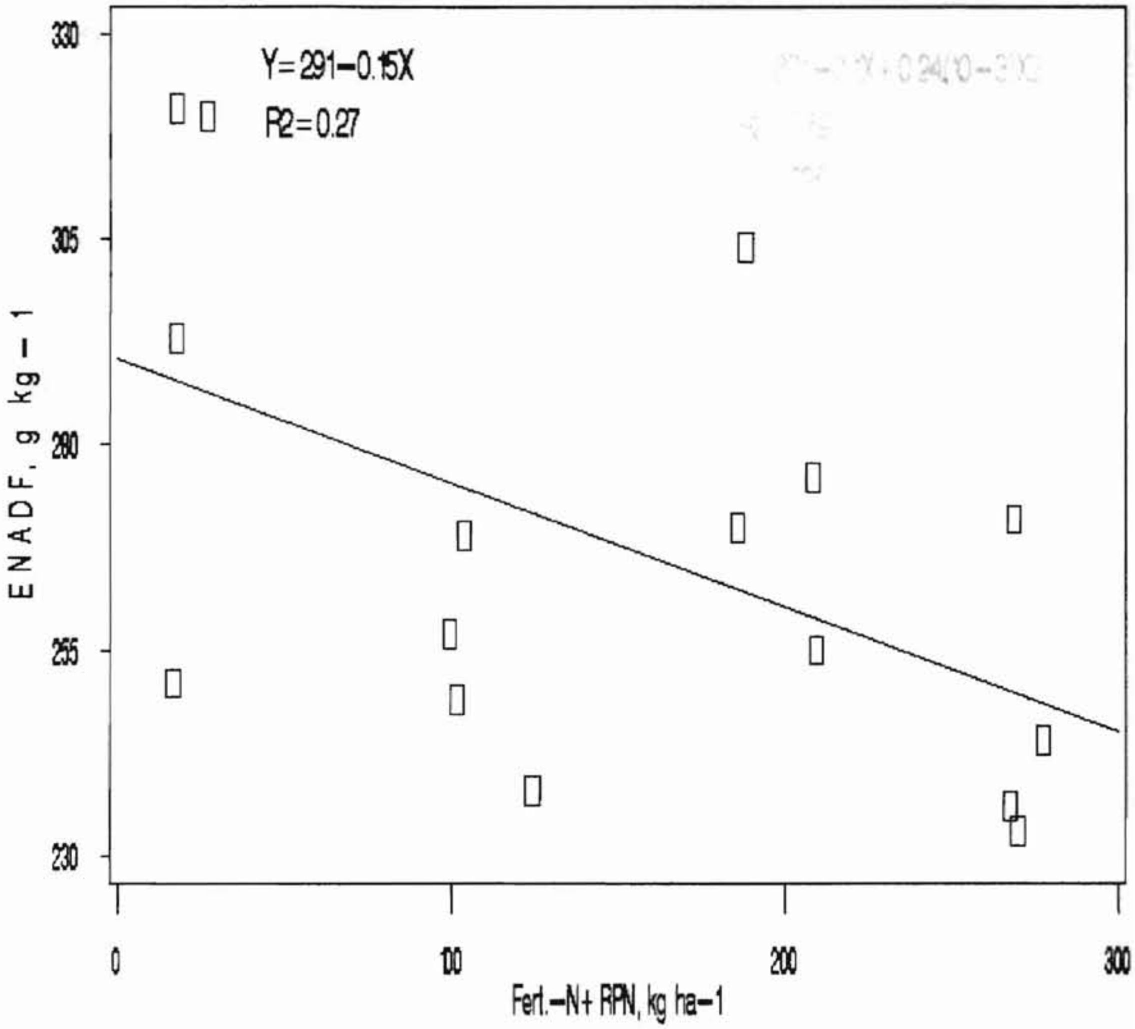

Figure 10. 1994 Choska Ensilage Acid Detergent Fiber Res.

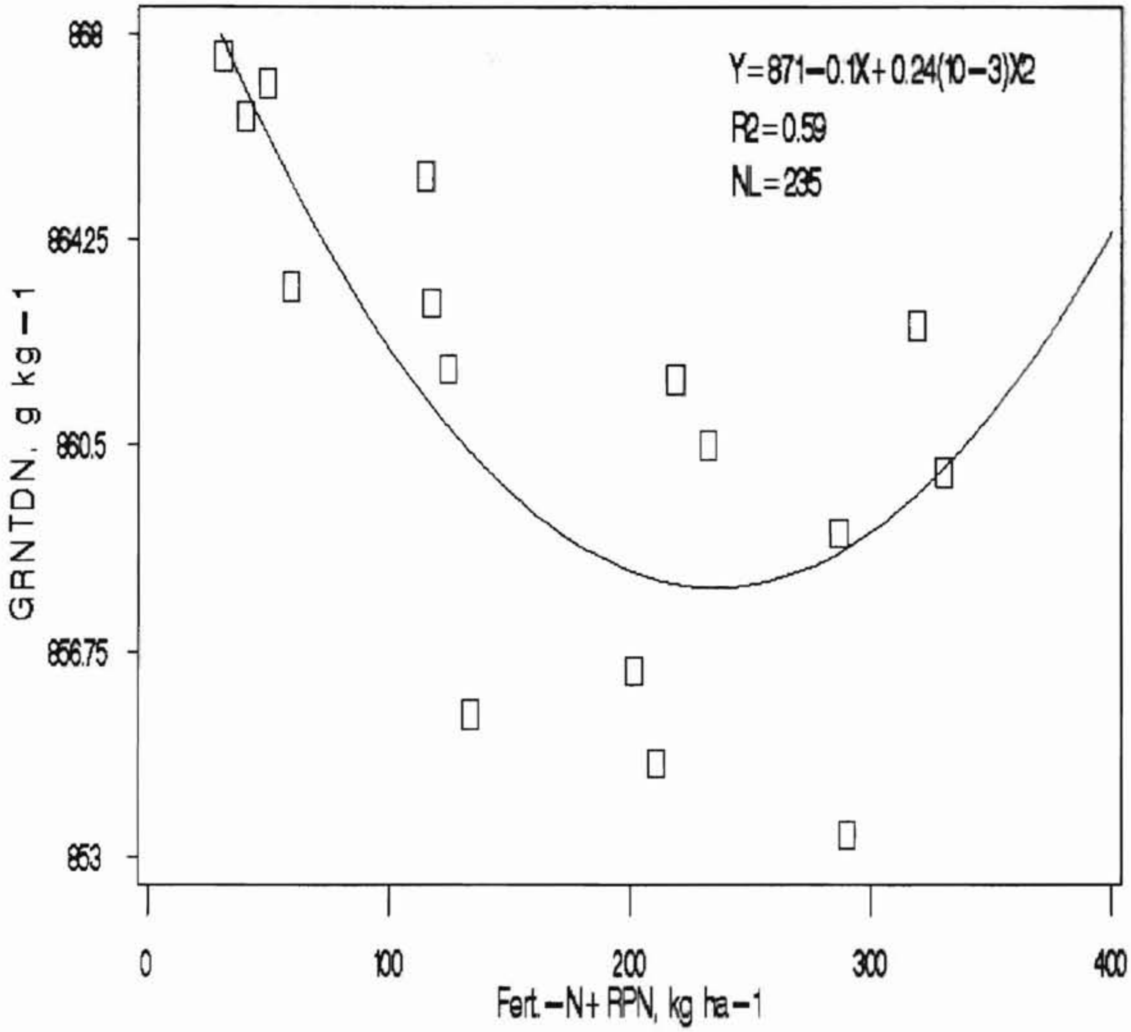

Figure 11. 1996 Choska Grain Total Digestible Nutrients Results

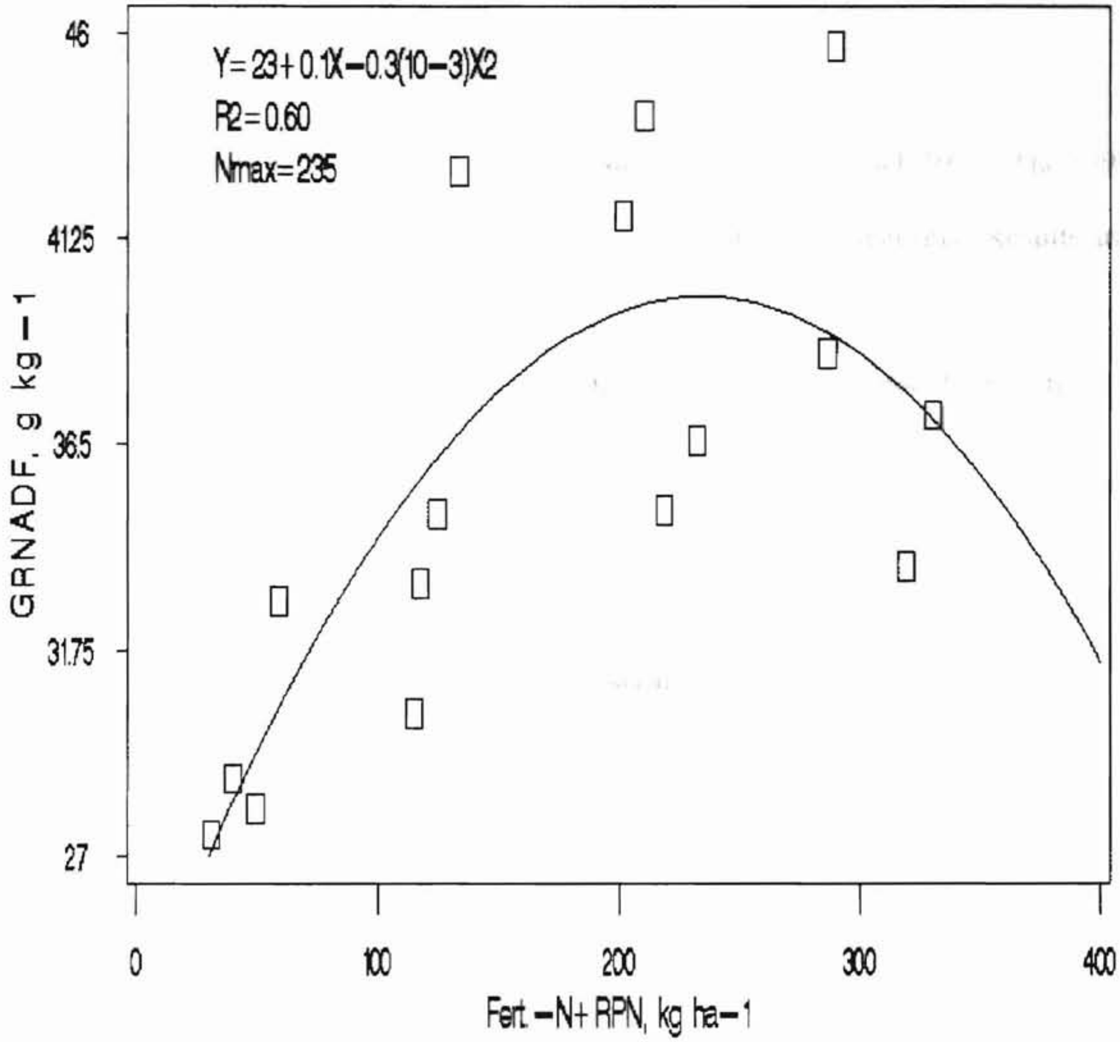

Figure 12. 1996 Choska Grain Acid Detergent Fiber Results

Panhandle Location

The panhandle location study was established from 1994 through 1997. The 1994 and 1995 crop years were restricted due to insect infestations and hailstorms. Results are reported for all years in Table 12.

The 1994 study was severely infested with European Corn Borers. Plots with greater yield potential were more severely affected with lodging and ear drop as there were more ear infestation sites. Therefore yield differences were removed for both the grain and ensilage variables. However, one nutritive variable, CP, showed a significant response to N treatment rate. A positive linear response was noted in both the grain and ensilage CP (Figures 13, 14). Associated R^2 values varied between harvest components with grain showing a lower value than ensilage. In both cases the low R^2 values indicate that other sources beyond N treatment rates were affecting variable responses. Linear responses were again noted in 1995 for this location. However, this year both grain and ensilage yield components showed positive linear responses to N treatment rates (Figure 15, 16). Grain yield and ENY65 yield components continued to increase with increasing N rates but had low R^2 values indicating weak relationships between yield increases and N treatment rates. When considering the 1995 high yield responses in relationship with associated N rates the yield responses were considerably lower than current OSU yield projections at comparable N recommendations. However this can be related to the lower yields of this year due to adverse crop conditions. The 1995 Panhandle study was severely affected by two hailstorms, one at the V9 developmental stage and the other occurring at the V12 stage. The trial was also infested with low levels of European Corn Borers that caused lodging and ear drop. Both storms and insect infestation occurred at critical periods of yield component development, thus responses to N treatment rates are most likely reflective of these occurrences. Ensilage CP also showed a positive linear response to increasing N treatment rates (Figure 17). The associated R^2 value is again lower but above the 50 percent value.

The 1996-1997 data indicated quadratic and linear responses for all grain yield and nutritive components with the exception of grain NDF in 1997. Grain yield showed a significant quadratic model response (Figure 18). A large R^2 value indicated a large portion of the variability associated with yield was accounted for by N treatment rates thus a strong relationship existed between these variables. The nitrogen to corn grain yield goal ratio of 2.03:1 was considerably higher than current OSU recommendations of 1.34:1 at this yield goal. However, with the quadratic yield response a predicted plateau yield point exists, thus increasing N rate beyond this point would not result in additional yield. This plateau response was noted at a higher rate than current recommendations. Grain CP had a positive linear response to increasing N rates (Figure 19). The associated R^2 value indicates that approximately 50% of the variability can be accounted for by the N treatment rates. Grain TDN and ADF also had linear responses to N treatment rates in 1996 and 1997. In this location TDN decreased with increasing N rate and ADF increased with increasing N rate (Figures 20, 22). The responses were similar to the 1996 Choska site where quadratic responses were noted with initial formation of the curve beginning with TDN decreases and ADF increases with increasing N rate. However, in this situation digestibility only decreased with increasing N rate whereas at the Choska location initially digestibility increased. The last grain nutritive value to show a response to N treatment rate was grain NDF (Figure 21) in 1996. This was the only site-year to indicate a NDF response. In this location NDF showed a quadratic response to N treatment rate with the predicted maximum response being 92 g kg^{-1}. The associated N_{max} value was 218 kg ha^{-1}. The R^2 value was low indicating a weak relationship between N treatment rate and NDF response. Again, when compared to literature the NDF response was not expected and indeed is not seen in other site-years. The only ensilage components to have significant responses to N treatment rates in 1996 were ENY65 and CP. Both had positive linear responses showing increasing yields as responses to increasing N rates (Figures 23, 24). The ENY65 had a low associated R^2 value indicating a weak relationship between N rate and yield. When compared to current OSU recommendations the low yield response yielded higher with 56 kg ha^{-1} less nitrogen. The 126 Mg ha^{-1} high yield response is located by itself in the data set and is most likely unrealistic. The next highest ensilage yield response is 94 Mg ha^{-1} with an associated N rate of 266 kg ha^{-1} which is more realistic when considered with the entire data set. This yield response is also higher at a comparable associated N rate than current OSU recommendations. Ensilage CP had a large R^2 value associated with it indicating a strong relationship between CP response and increasing N treatment rate. Similar variable responses were seen in the 1997 data. Grain yield again had a quadratic modeling response with a predicted maximum yield value of 15639 kg ha^{-1} of corn grain yield and an associated N_{max} value of 278 kg ha^{-1} (Figure 25). These two values give a nitrogen to corn grain yield goal ratio of 1.1 kg ha^{-1} to 62.73 kg ha^{-1} of corn grain. This ratio is lower than both current and previous recommendations. Large R^2 values indicate a strong relationship exists between yield response and N treatment rate. Grain CP, TDN, and ADF all had positive linear responses to N treatment rate (Figures 26, 27, 28). Crude protein continued to increase with increasing N rate. While not large, the associated R^2 value was similar to other site-years accounting for 50% of the variability associated with the CP response data. Grain TDN and ADF had very similar results to the 1996 data with linear responses indicating TDN would decrease as N rate increased while ADF increased as N rate increased. Likewise digestibility decreased with increasing N rate. Both variables had low R^2 values. Ensilage yield and CP (Figures 29 and 30) both had significant modeling responses to N treatment rate. Ensilage yield showed a quadratic response to N with a predicted maximum yield of 43 Mg ha^{-1} and an associated N_{max} value of 252 kg ha^{-1}. The R^2 value indicated just over 50% of the variability could be accounted for by N rate, again similar to other site-year findings. In comparison to OSU recommendations this yield response value is low in relationship to the associated N_{max} value of 252 kg ha^{-1}. Crude protein had a positive linear response to N treatment rate with an associated low R^2 value. Therefore, the total amount of variability that could be accounted for by N treatment rate was low indicating a weak relationship between these two variables.

Southcentral Locations

Chickasha (Irrigated)

The Chickasha irrigated location study was conducted from 1994 through 1997. Data from this study is reported in Table 13. The 1995 grain site-year was lost due to irrigation pump failure and replication 4 in the 1996 study was lost due to volunteer corn and cultivation error.

The 1994 GRNYLD variable showed a quadratic response to N treatment rate

Table 12. Regression Analysis Results for Corn Grain and Ensilage Yield and Nutritive Response to Applied Nitrogen Fertilizer + Residual Profile Nitrate at the Panhandle Research and Extension Center, Goodwell, Ok, Texas County (Irrigated).

		Fert.-N + RPN			
Year	Variable	Yield Range L-H†	Model Response	Ratio or N-Rate‡	N_{max}
1994	GRNYLD, kg ha^{-1}	1819-9093	NS§	--	---
	GRNCP, g kg^{-1}	68-123	LR^2-0.27*	34-379	---
	GRNTDN, g kg^{-1}	869-881	NS	--	---
	GRNNDF, g kg^{-1}	32-70	NS	--	---
	GRNADF, g kg^{-1}	11-26	NS	--	---
	ENY65, Mg ha^{-1}	18-63	NS	--	---
	ENCP, g kg^{-1}	39-81	LR^2-0.47*	25-311	---
	ENTDN, g kg^{-1}	607-707	NS	--	---
	ENNDF, g kg^{-1}	440-639	NS	--	---
	ENADF, g kg^{-1}	234-362	NS	--	---
1995	GRNYLD, kg ha^{-1}	1252-7950	LR^2-0.36*	35-459	---
	GRNCP, g kg^{-1}	68-120	NS	--	---
	GRNTDN, g kg^{-1}	870-886	NS	--	---
	GRNNDF, g kg^{-1}	32-174	NS	--	---
	GRNADF, g kg^{-1}	4-24	NS	--	---
	ENY65, Mg ha^{-1}	20-49	LR^2-0.24*	35-447	---
	ENCP, g kg^{-1}	41-92	LR^2-0.54*	35-532	---
	ENTDN, g kg^{-1}	560-691	NS	--	---
	ENNDF, g kg^{-1}	467-693	NS	--	---
	ENADF, g kg^{-1}	254-422	NS	--	---

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* Significant at the 0.05 probability level

§, Non-significant at the 0.05 probability level

†, Yield range = Low Yield (L) – High Yield (H)

‡, Ratio = Kilograms of nitrogen to produce 62.73 kg ha-1 of corn grain, N-Rate = Total fertilizer nitrogen amount or range associated with yield or response results

Table 12 (cont'd.). Regression Analysis Results for Corn Grain and Ensilage Yield and Nutritive Response to Applied Nitrogen Fertilizer + Residual Profile Nitrate at the Panhandle Research and Extension Center, Goodwell, Ok, Texas County (Irrigated).

		Fert.-N + RPN			
Year	Variable	Yield Range L-H†	Model Response	Ratio or N-Rate ‡	N_{max}
1996	GRNYLD, kg ha^{-1}	2285-12285	QR^2-0.86*	2.03:1(11111)§	403
	GRNCP, g kg^{-1}	60-99	LR^2-0.47*	151-228	---
	GRNTDN, g kg^{-1}	867-873	LR^2-0.46*	309-62	---
	GRNNDF, g kg^{-1}	72-95	QR^2-0.36*	218(92)	218
	GRNADF, g kg^{-1}	20-29	LR^2-0.46*	62-398	---
	ENY65, Mg ha^{-1}	31-126	LR^2-0.39*	95-451	---
	ENCP, g kg^{-1}	44-85	LR^2-0.73*	55-451	---
	ENTDN, g kg^{-1}	584-796	NS¶	--	---
	ENNDF, g kg^{-1}	230-606	NS	--	---
	ENADF, g kg^{-1}	120-392	NS	--	---
1997	GRNYLD, kg ha^{-1}	2055-17332	QR^2-0.81	1.1:1(15639)	278
	GRNCP, g kg^{-1}	73-129	LR^2-0.49*	139-249	---
	GRNTDN, g kg^{-1}	851-861	LR^2-0.33*	249-139	---
	GRNNDF, g kg^{-1}	66-100	NS	--	---
	GRNADF, g kg^{-1}	34-48	LR^2-0.33*	31-353	---
	ENY65, Mg ha^{-1}	10-48	QR^2-0.54*	252(43)	252
	ENCP, g kg^{-1}	41-73	LR^2-0.28*	31-360	---
	ENTDN, g kg^{-1}	513-588	NS	--	---
	ENNDF, g kg^{-1}	613-715	NS	--	---
	ENADF, g kg^{-1}	396-461	NS	--	---

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*, Significant at the 0.05 probability level

¶, Non-significant at the 0.05 probability level

†, Yield Range = Low Yield (L) – High Yield (H)

‡, Ratio = Kilograms of nitrogen to produce 62.73 kg ha^{-1} of corn grain, N-Rate = Total fertilizer nitrogen amount or range associated with yield or response results

§, Predicted maximum yield

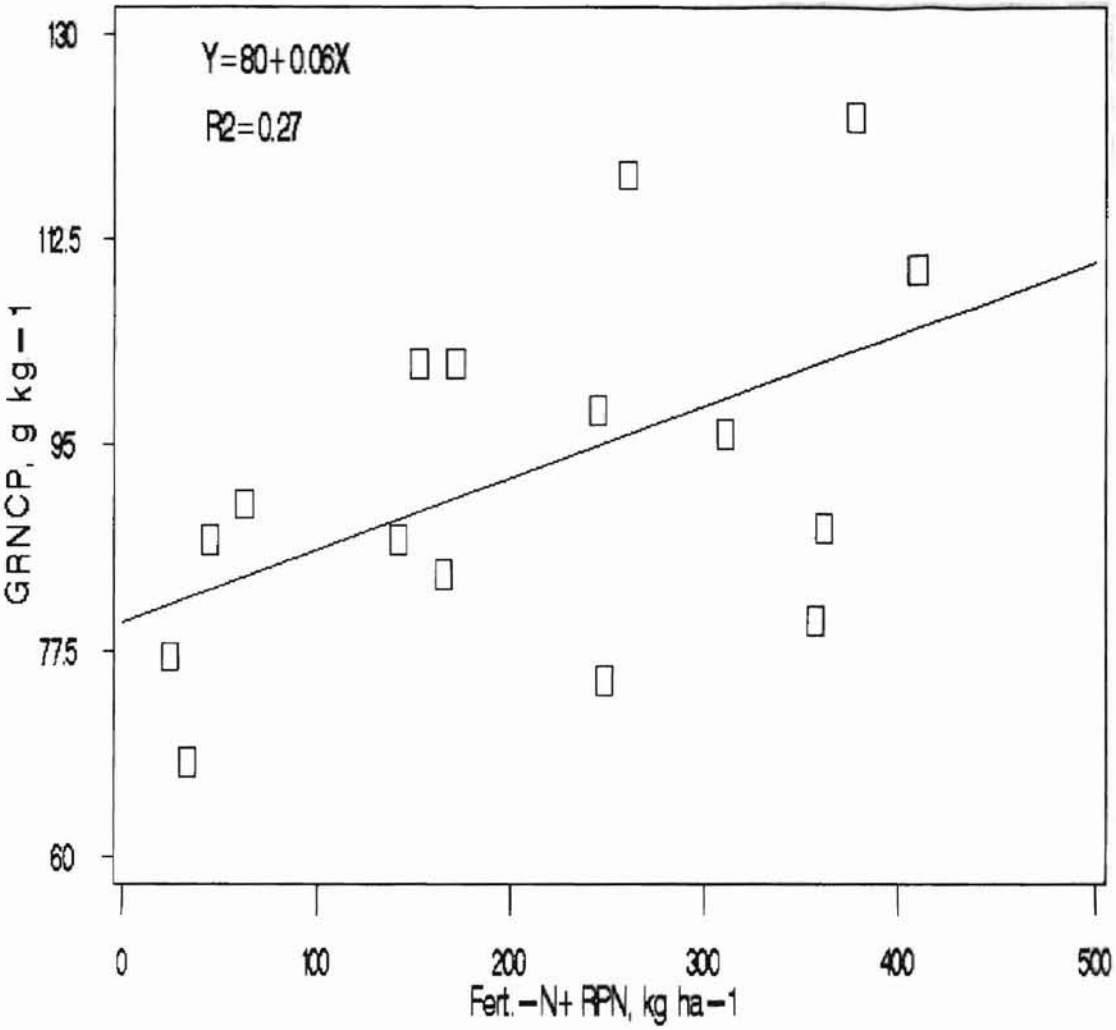

Figure 13. 1994 OPREC Grain Crude Protein Results

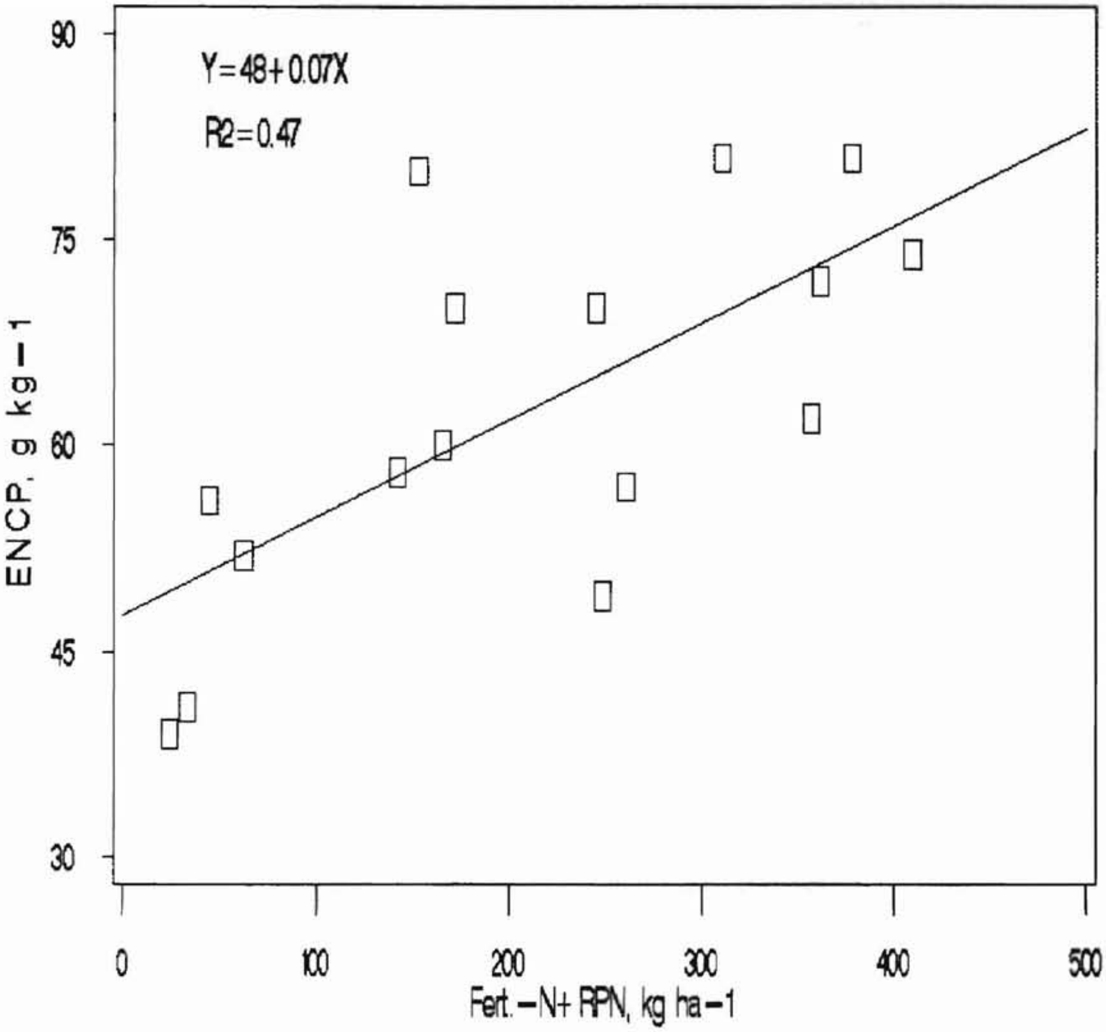

Figure 14. 1994 OPREC Ensilage Crude Protein Results

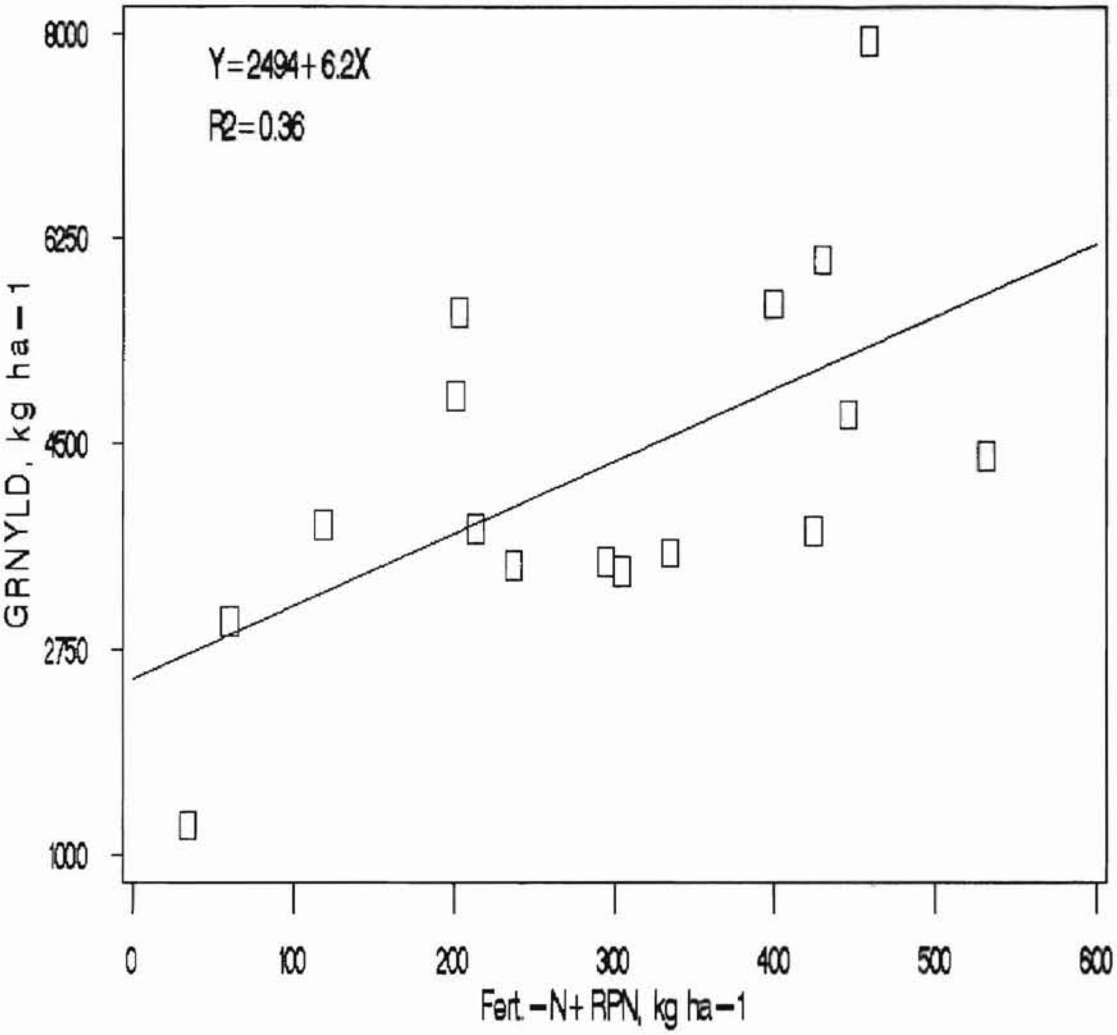

Figure 15. 1995 OPREC Grain Yield Results

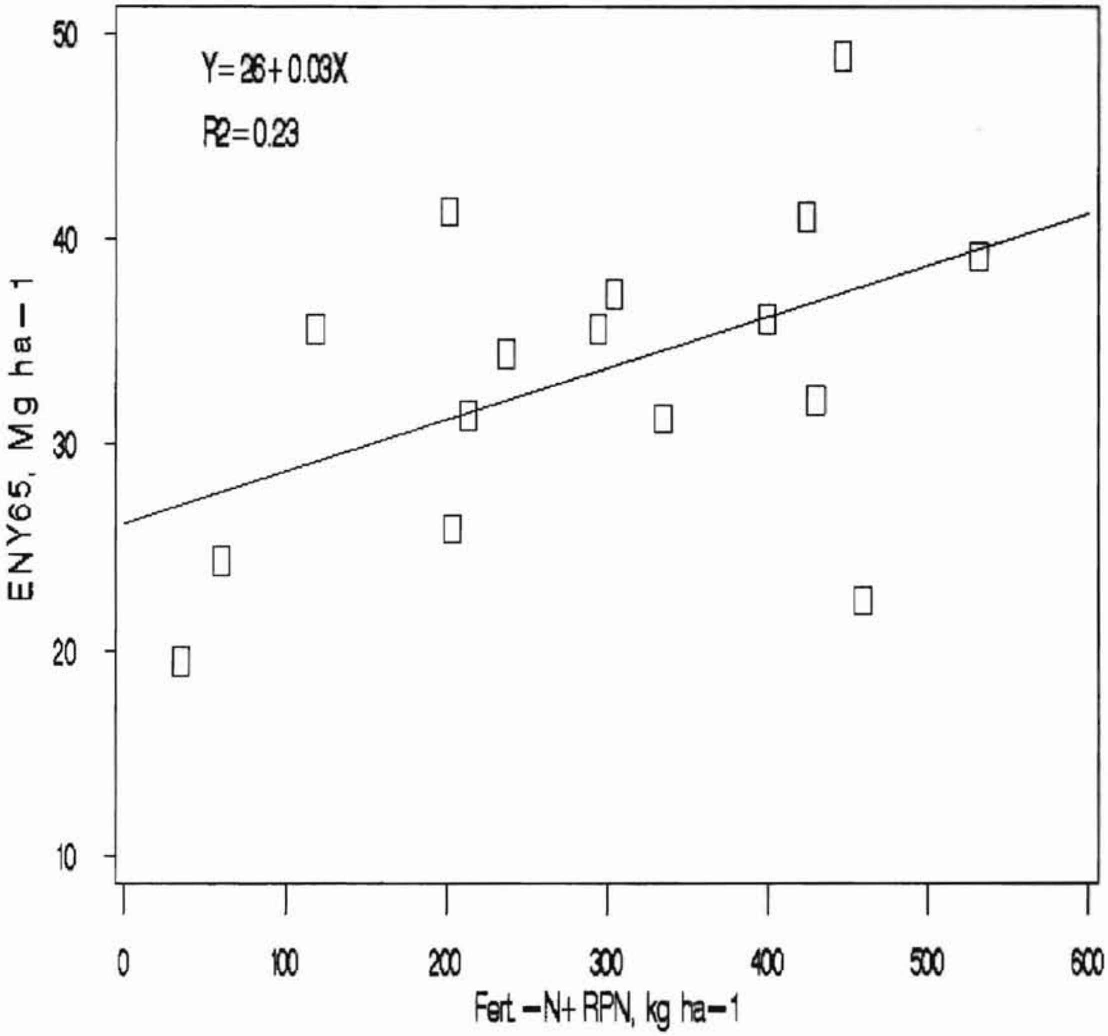

Figure 16. 1995 OPREC Ensilage Yield Results

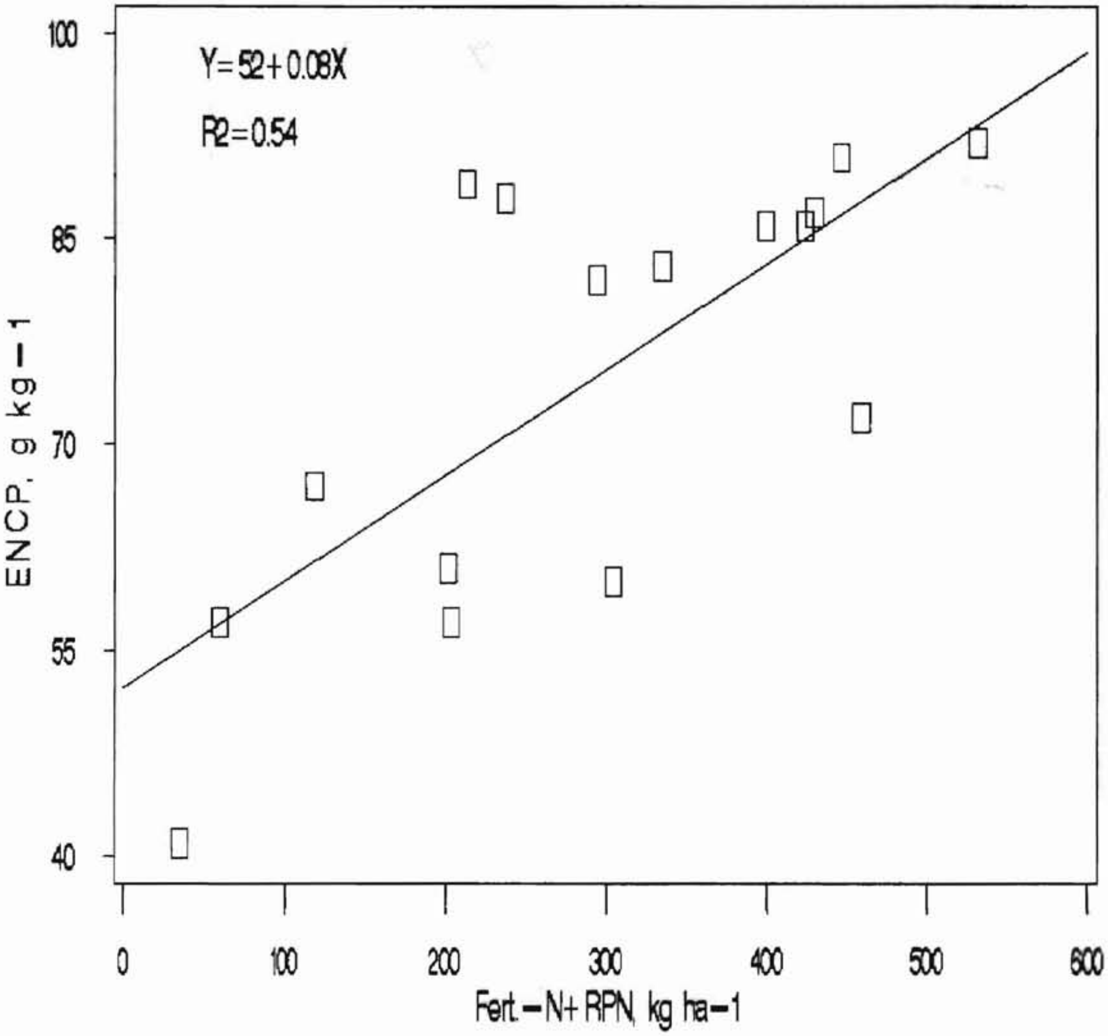

Figure 17. 1995 OPREC Ensilage Crude Protein Results

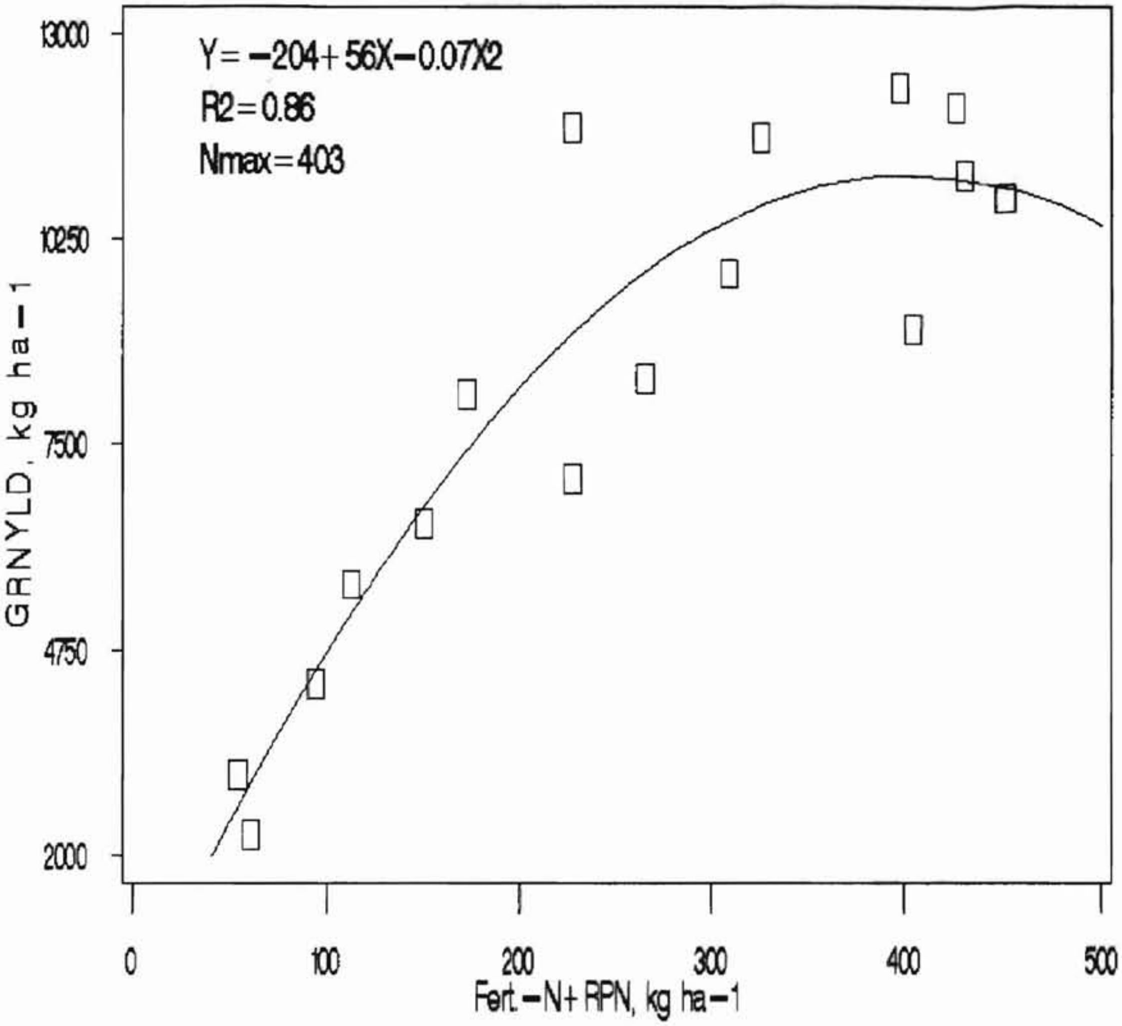

Figure 18. 1996 OPREC Grain Yield Results

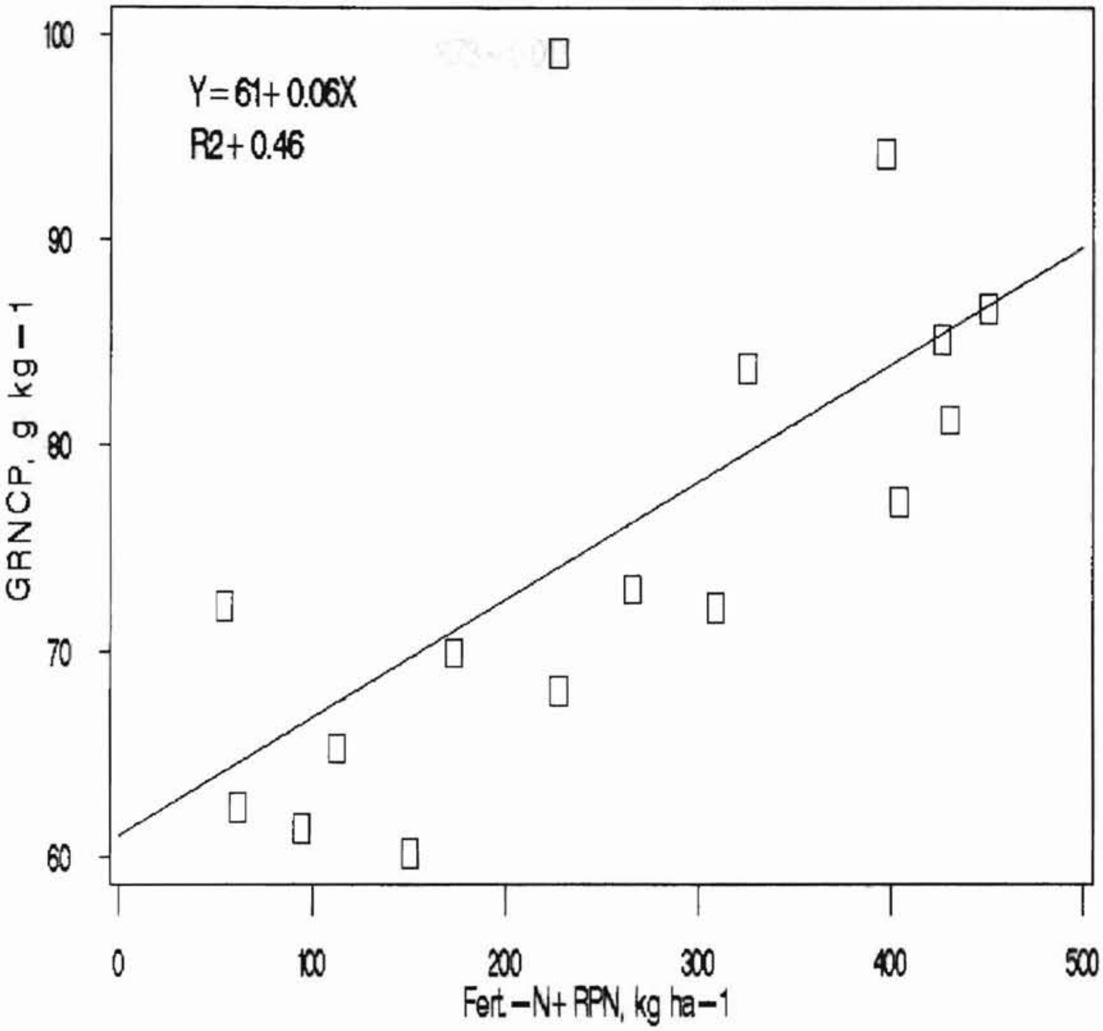

Figure 19. 1996 OPREC Grain Crude Protein Results

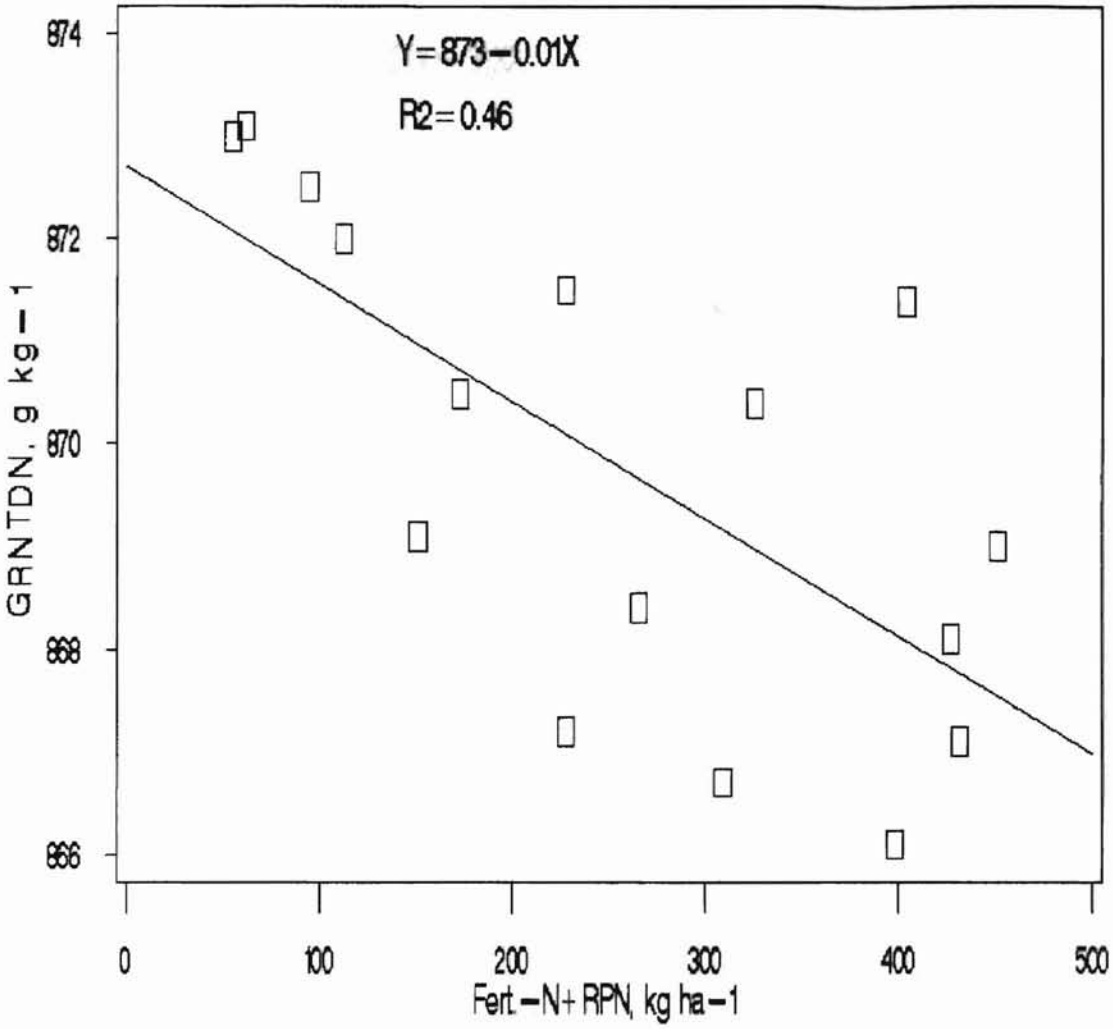

Figure 20. 1996 OPREC Grain Total Dig. Nutrients Results

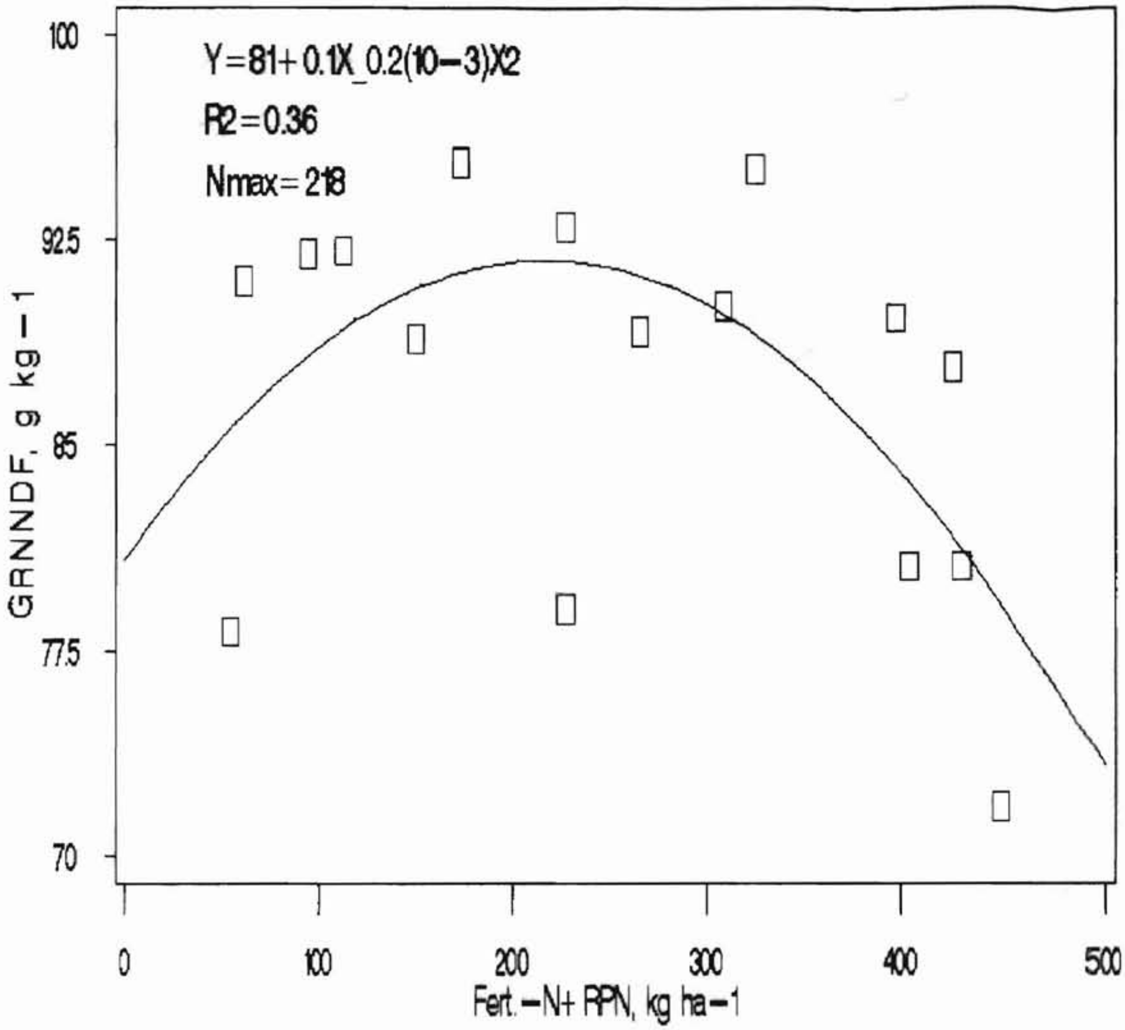

Figure 21. 1996 OPREC Grain Neutral Detergent Fiber Res.

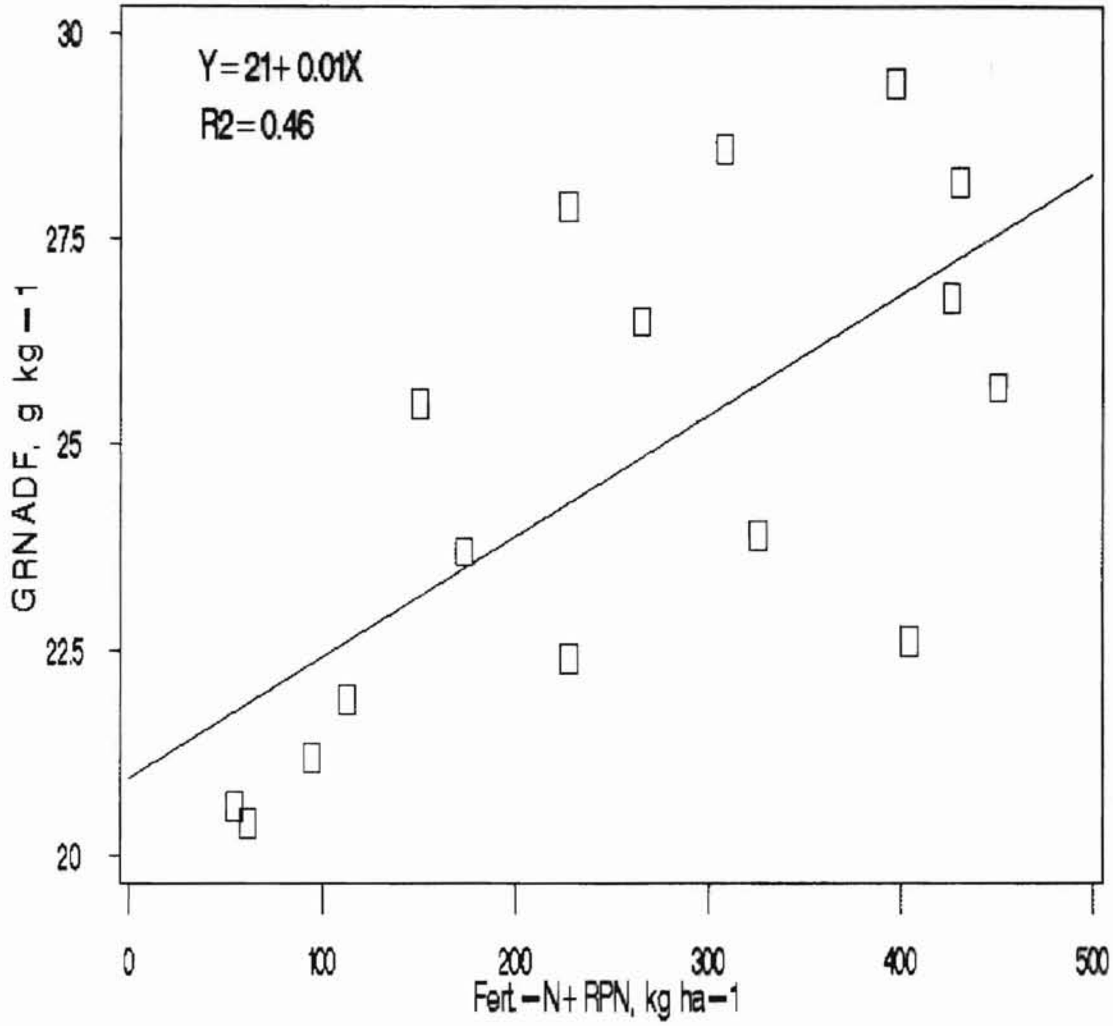

Figure 22. 1996 OPREC Grain Acid Detergent Fiber Results

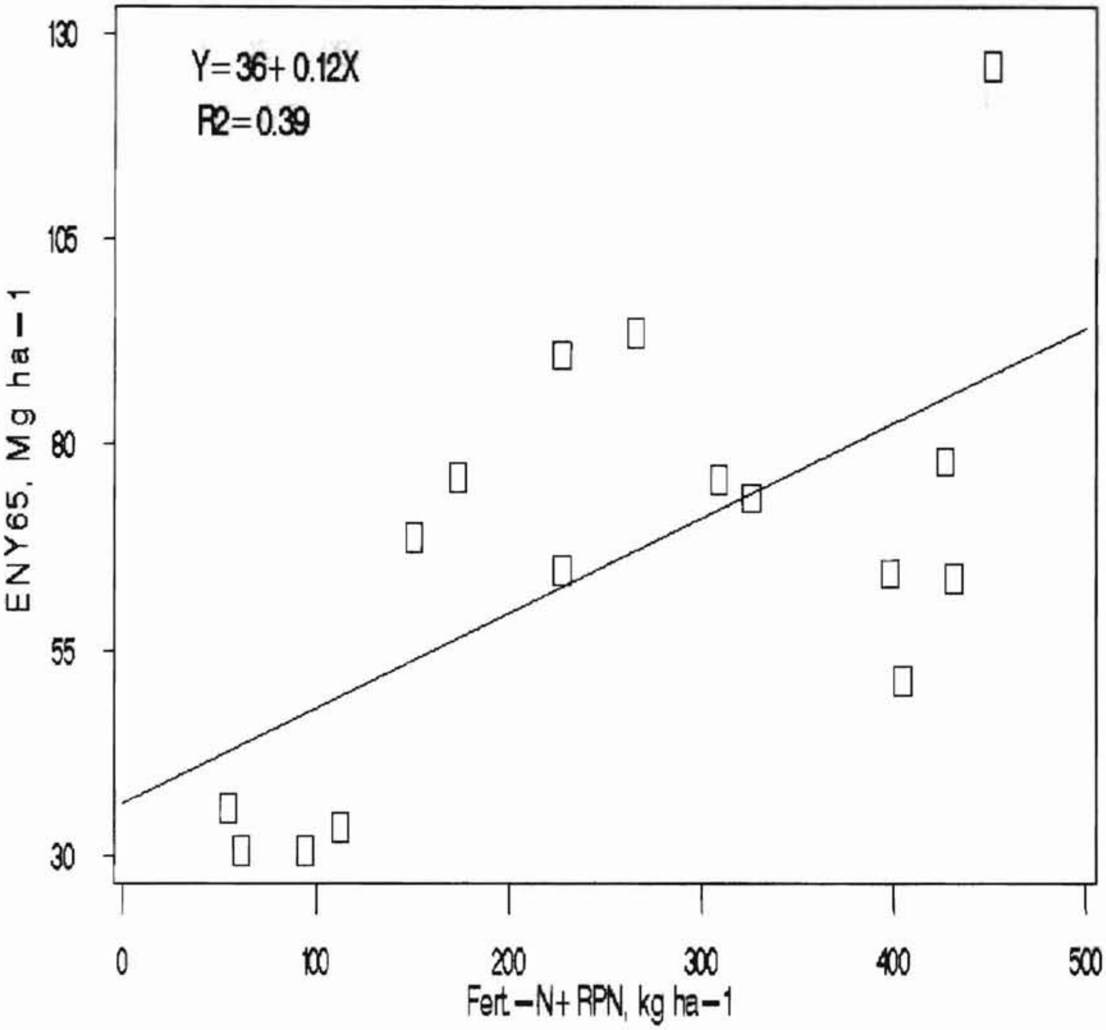

Figure 23. 1996 OPREC Ensilage Yield Results

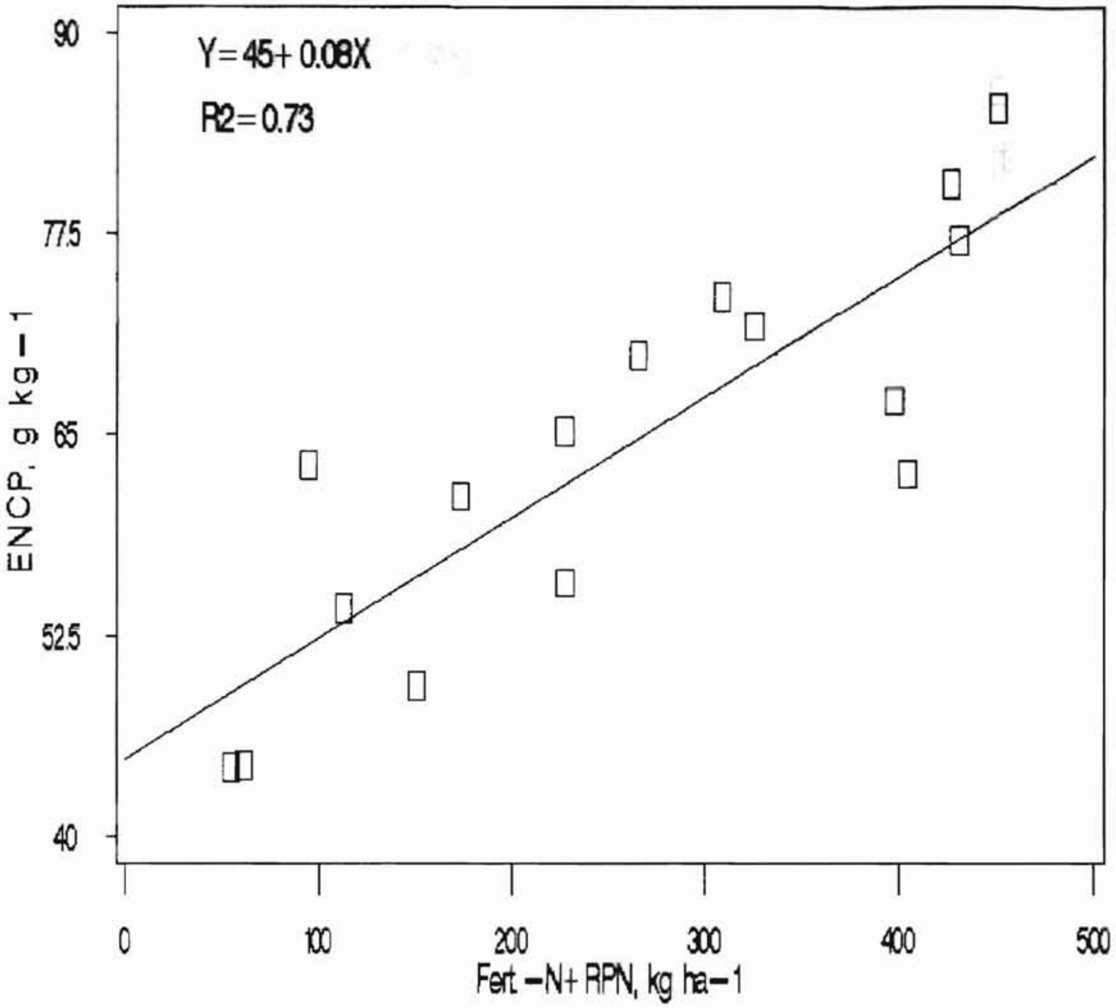

Figure 24. 1996 OPREC Ensilage Crude Protein Results

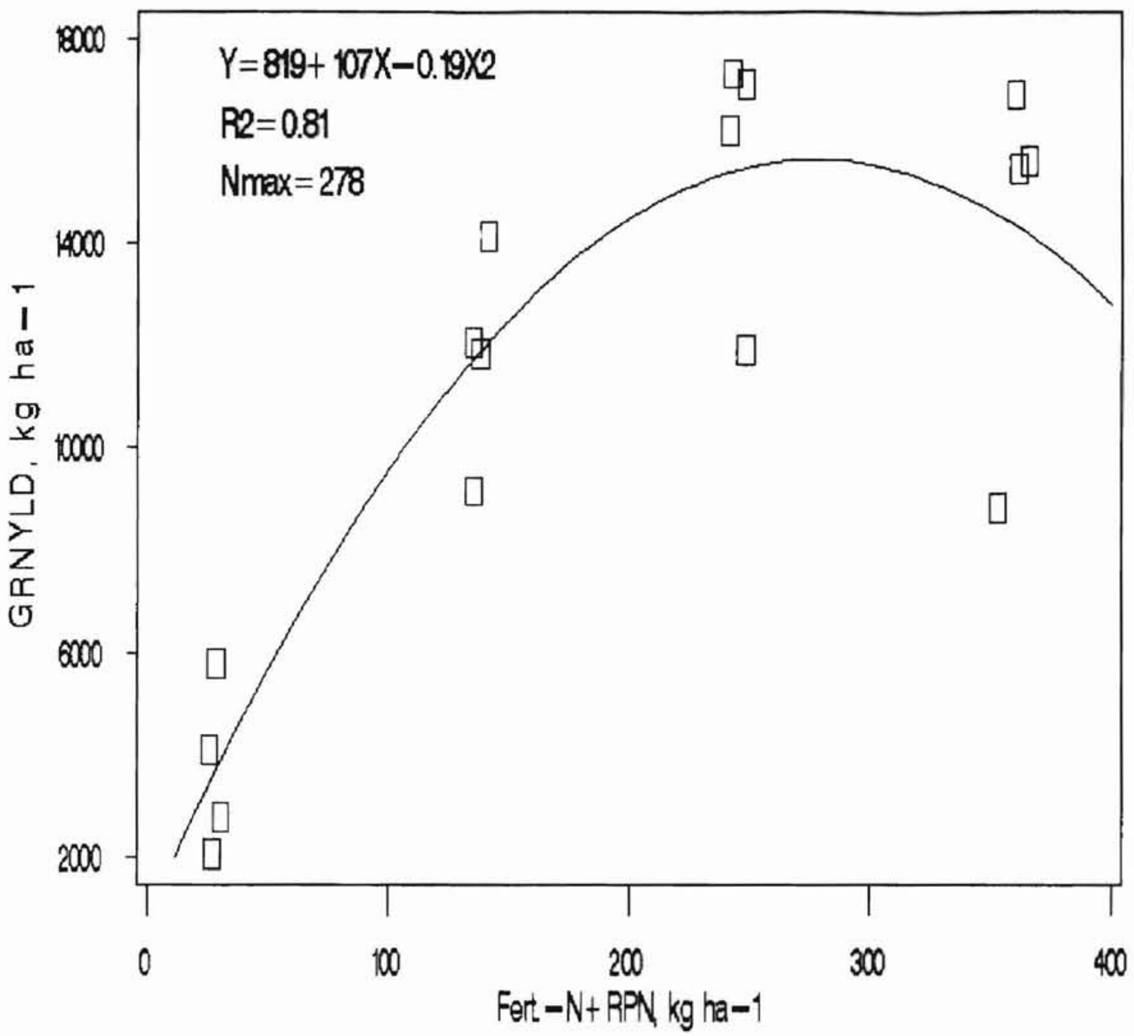

Figure 25. 1997 OPREC Grain Yield Results

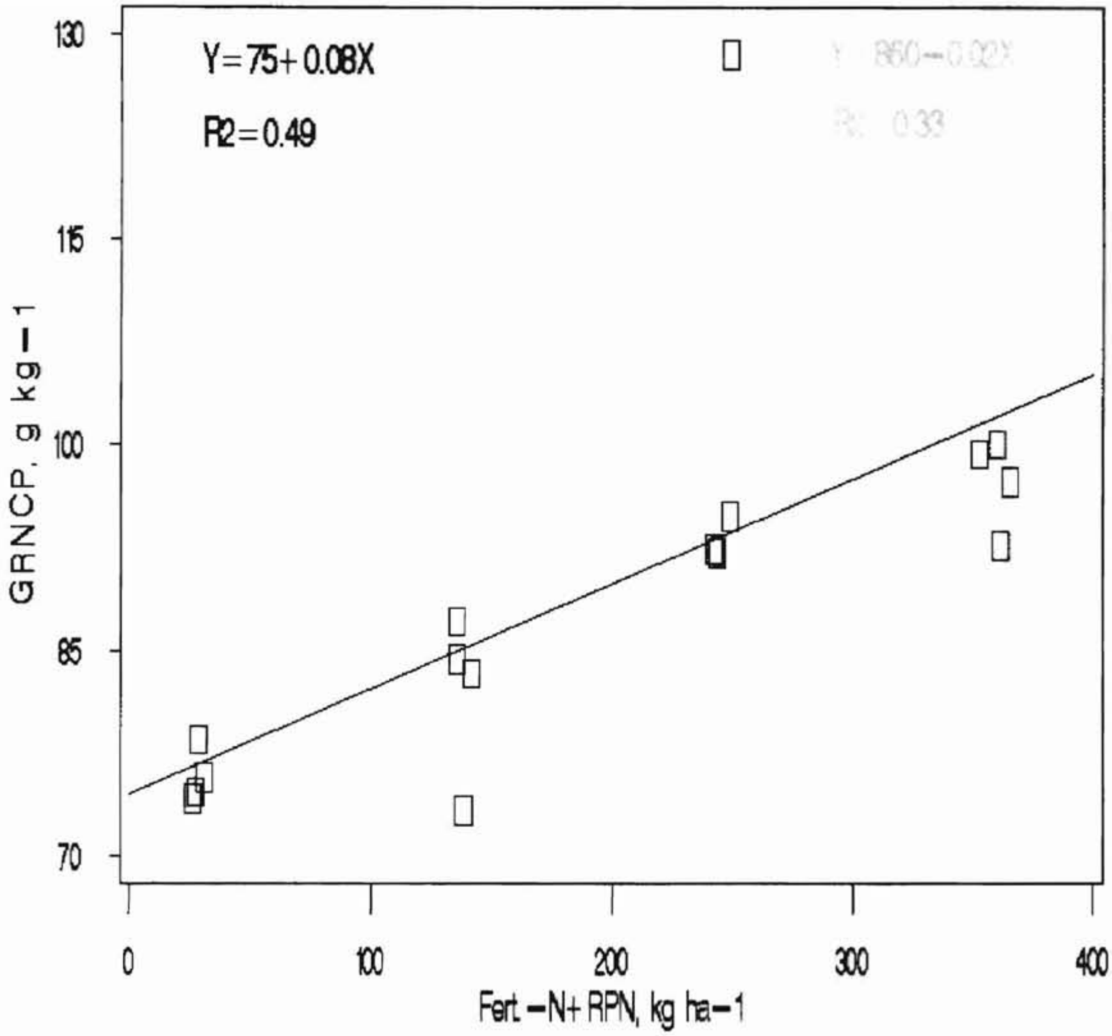

Figure 26. 1997 OPREC Grain Crude Protein Results

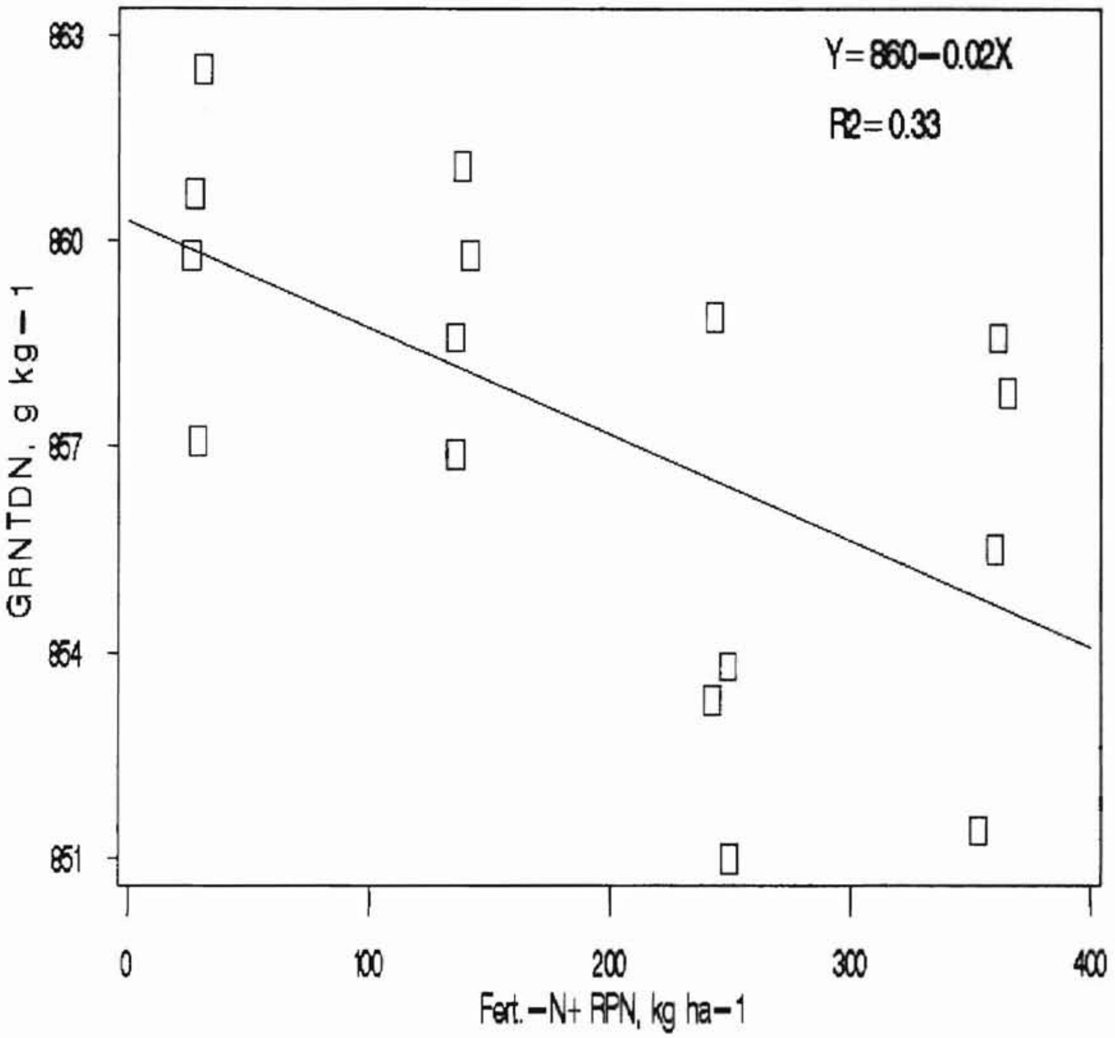

Figure 27. 1997 OPREC Grain Total Digestible Nutrients Res

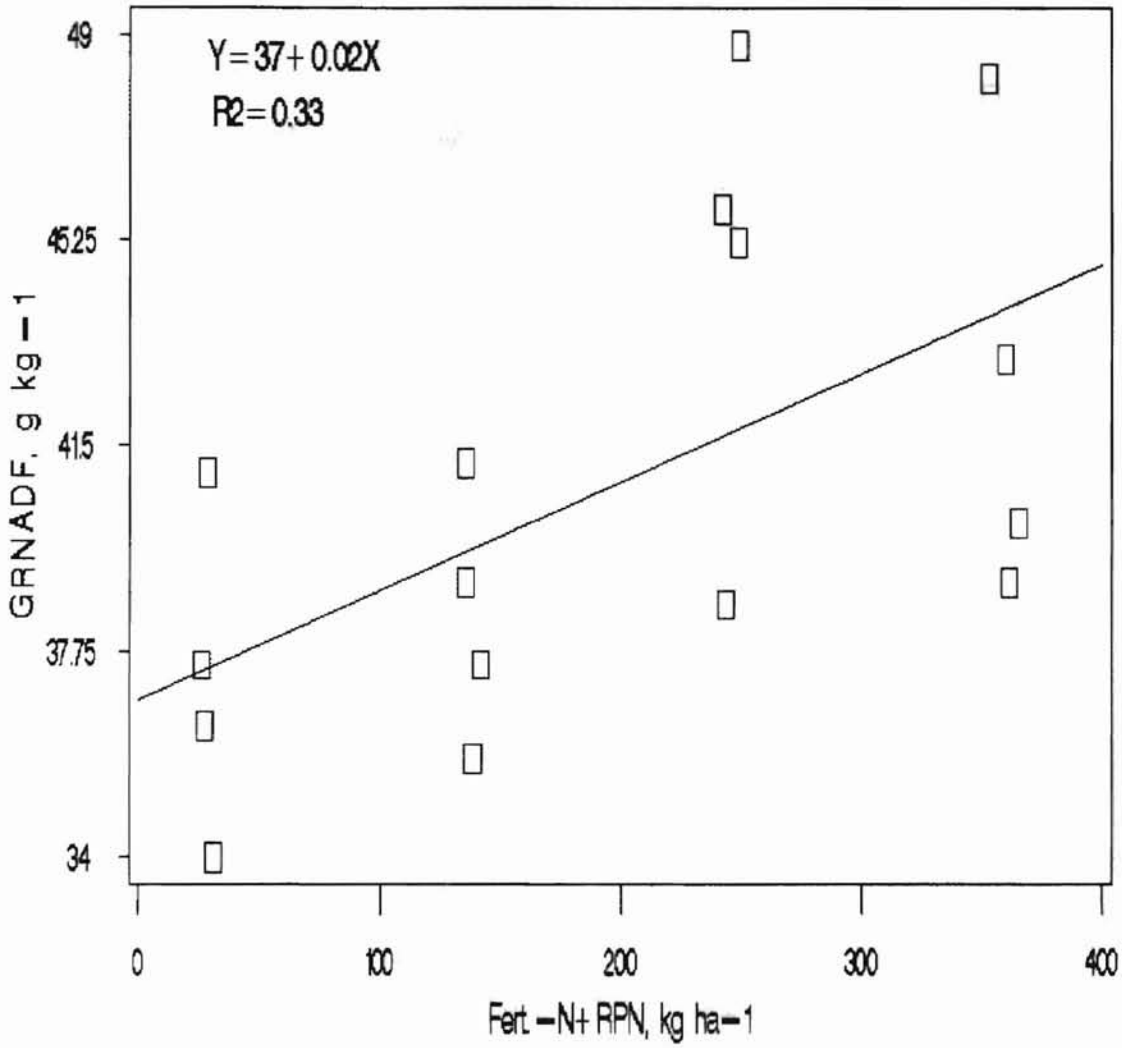

Figure 28. 1997 OPREC Grain Acid Detergent Fiber Results

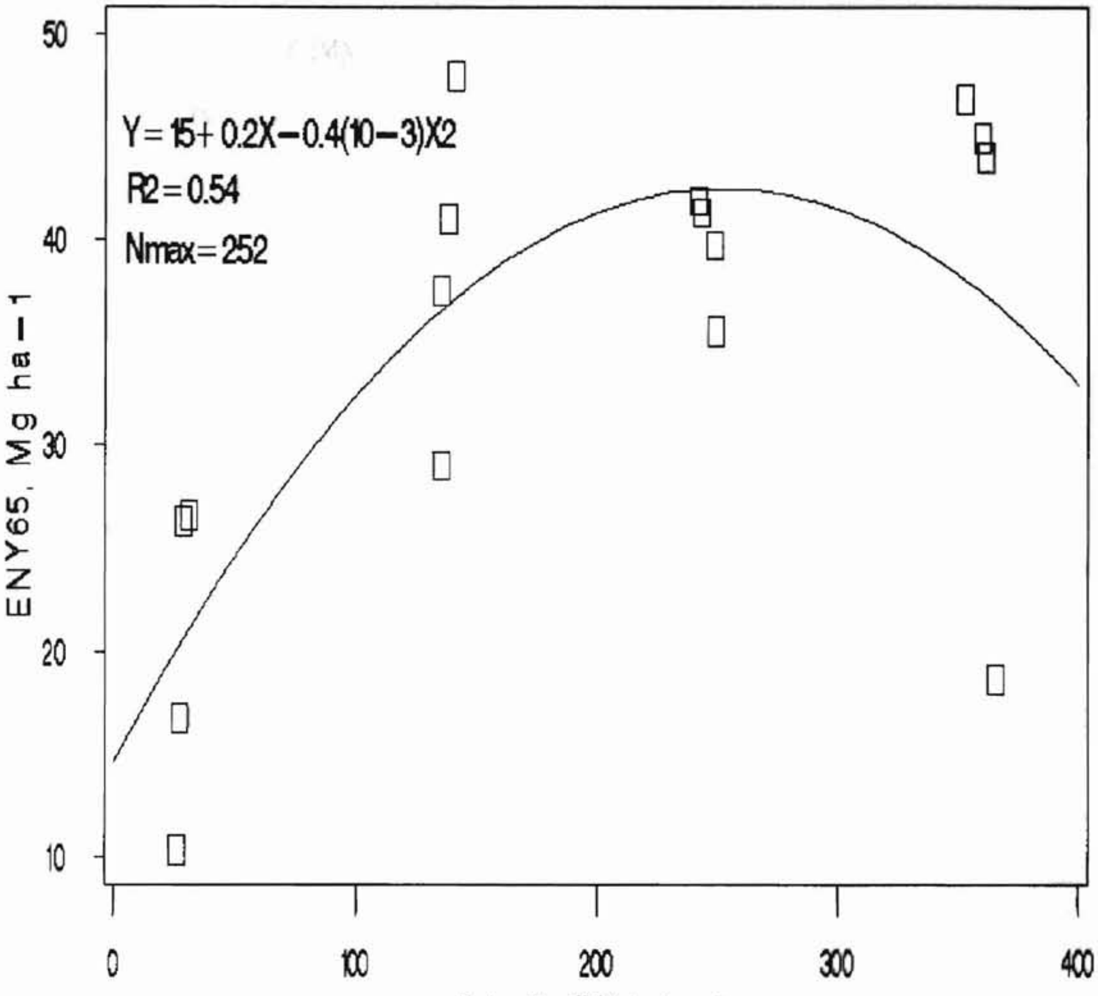

Figure 29. 1997 OPREC Ensilage Yield Results

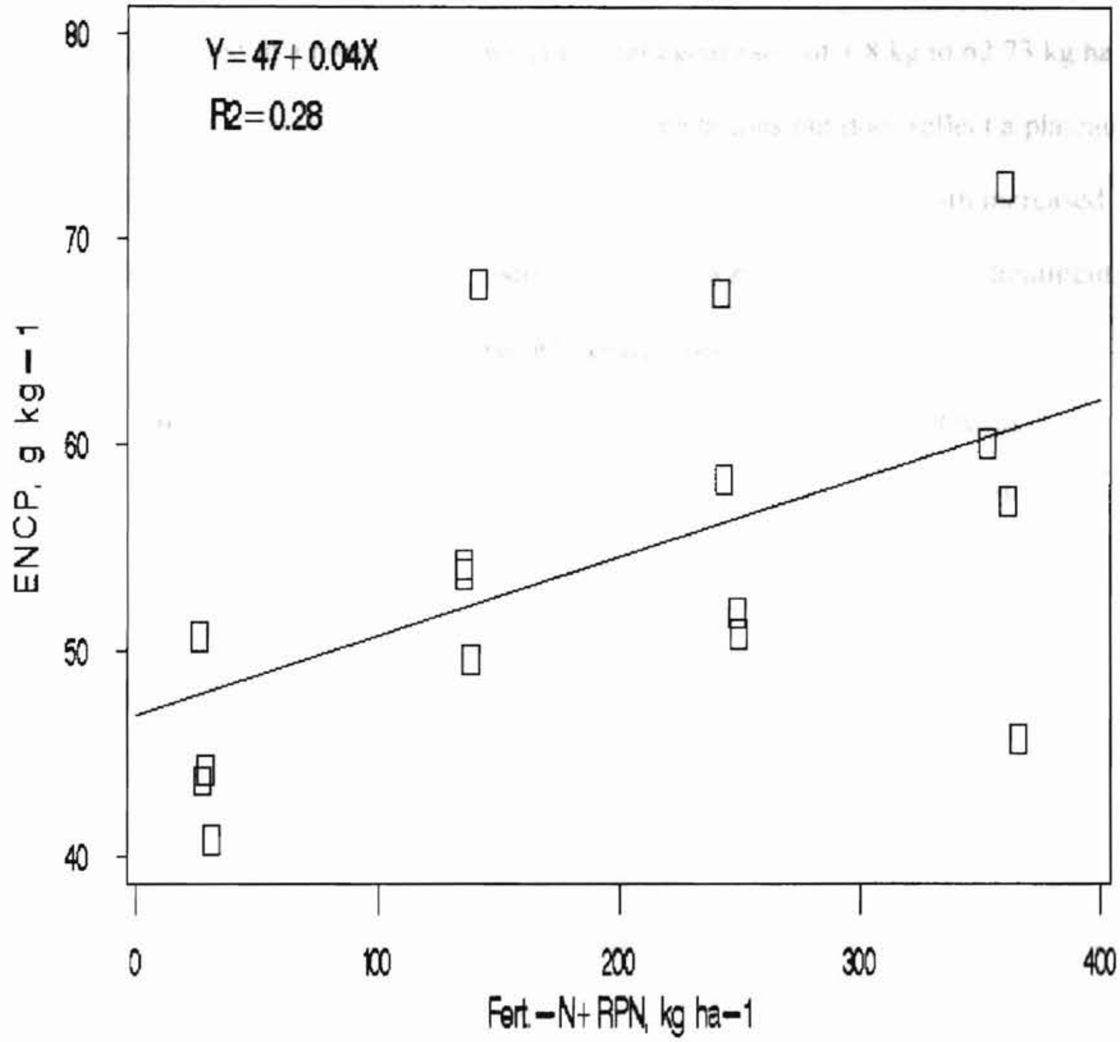

Figure 30. 1997 OPREC Ensilage Crude Protein Results

(Figure 31). Predicted maximum yield was identified at 10030 kg ha^{-1} with a N_{max} value of 291. This resulted in a nitrogen to corn grain yield goal ratio of 1.8 kg to 62.73 kg ha^{-1} of corn grain. This ratio is higher than OSU recommendations but does reflect a plateau area in the model curve where no additional grain yield will be achieved with increased N rate. Grain CP indicated a significant positive linear response to increasing N treatment rates (Figure 32). Both variables had large R^2 values associated with the regression model indicating a large portion of the variability associated with the variables is accounted for by N treatment rate. Thus a strong relationship existed between these two grain variables and N rate. Ensilage yield and CP also exhibited positive linear responses to increasing N rates (Figure 33,34). The low yield value for ensilage resulted from less N than current recommendations while the high yield value is in line with current OSU recommendations. The associated R^2 values for both variables indicate a strong relationship with N treatment rate. The only 1995 variable to show a significant modeling response was ensilage CP. Again, a large R^2 value gives a good indication of the strength between this variable and N treatment rate. The ensilage yield and remaining nutritive value variables were essentially rendered non-significant due to seasonal hailstorms and insect infestation. In 1996 GRNYLD, CP, an ADF all showed significant modeling responses to N treatment rates. Grain yield had a positive linear response to N treatment rate with a large R^2 value indicating a large portion of the variability being accounted for by the N treatment rate, thus a strong relationship exists (Figure 36). The high yield range value when related to the associated N rate has a nitrogen to corn grain yield goal ratio of 2.1:1. This is higher than current or previous OSU recommendations, however the data indicates that yields continued to increase with increasing rates of N. Grain CP also showed a positive linear response to increasing N treatment rate (Figure

37). The R^2 value while lower is still above 50 percent. Acid detergent fiber also indicated an inverted quadratic response to N treatment rate (Figure 38). The predicted lowest response to N treatment rate is 28 g kg^{-1} with and associated N_L value of 186. Therefore, ADF continued to decrease with increasing N rate until reaching the predicted N_L point where it began to increase with increasing N rate. This indicates that beyond 186 kg ha^{-1} that grain indigestibility will continue to increase. This would be a negative response for grain feeders. The associated R^2 value is lower indicating just below 50 percent of the variability was accounted for by N rate. In both the CP and ADF variables it is apparent that other sources of influence accounted for a portion of the variability around their response. The only ensilage variable to show a significant response to N treatment rate was CP. It showed a positive linear response with a R^2 value that indicates less than half of the variation is accounted for by N rate (Figure 39). In 1997 only grain components showed significant responses to N treatment rates. Grain yield had a positive linear response to N rate with the high yield range value and associated N rate equaling a 1.73:1 nitrogen to corn grain yield goal ratio (Figure 40). This is again higher than current OSU recommendations but similar to recommendations prior to 1993. Both 1996 and 1997 GRNYLD responses indicate higher nitrogen to corn grain yield goal ratios with potentially continuing linear responses. These responses do not agree with current lower OSU recommendations. The grain CP response also reflects a positive linear response to N treatment rate with a large R^2 value indicating a strong relationship between these variables (Figure 41). The grain CP response values indicated good quality in terms of feed value with the high value reaching 114 g kg^{-1}. The grain ADF showed a quadratic response to N rate with an N_{max} value of 107(Figure 42). However, for this year ADF values increased with increasing N rate until reaching the N_{max} point where values began to decrease with increasing N rate. Therefore, digestibility also follows this pattern. This response is opposite the 1996 result for this variable. The small R^2 value indicates a low degree of variability accounted for by N rate. Acid detergent responses were high enough (from low to high) to be undesirable in terms of a feed product.

Chickasha (Dryland)

The Chickasha dryland study was conducted from1994 through 1996. The 1995 crop year was a difficult year for dryland studies as temperatures and heat indexes were high. Results are reported in Table 14. For the duration of this dryland study no grain harvest was taken due to lack of kernel set and fill during periods of high temperatures and heat indexes. After three years attempting a grain harvest the decision was made to abort those efforts.

The 1994 ensilage variables that responded with either quadratic or linear models were ENY65, CP, TDN, and ADF. A quadratic model best described the ENY65 response (Figure 43). The predicted maximum yield of 23 Mg ha^{-1} was associated with a higher N_{max} value than current OSU recommendations. However, this yield response did identify a plateau area, N_{max} area, where yield did not respond to additional N. The low R^2 value indicated that a large percentage of variability was unaccounted for by N rate thus other sources were linked with yield response. This site-year plus the Goodwell 1997 site-year are the only times in this study that maximum ensilage yield came with inflated N rate predictions or observed values when compared to OSU recommendations.

Table 13. Regression Analysis Results for Corn Grain and Ensilage Yield and Nutritive Response to Applied Fertilizer Nitrogen + Residual Profile Nitrate at the Southcentral Agronomy Research Station, Chickasha, Ok, Grady County (Irrigated).

		Fert.-N + RPN			
Year	Variable	Yield Range L-H[†]	Model Response	Ratio or N-Rate[‡]	N_{max}
1994	GRNYLD, kg ha^{-1}	2195-10410	QR^2-0.96	1.8:1(10030)[§]	291
	GRNCP, g kg^{-1}	70-105	LR^2-0.90*	16-313	---
	GRNTDN, g kg^{-1}	868-880	NS[¶]	--	---
	GRNNDF, g kg^{-1}	35-73	NS	--	---
	GRNADF, g kg^{-1}	12-27	NS	--	---
	ENY65, Mg ha^{-1}	18-71	LR^2-0.64*	17-313	---
	ENCP, g kg^{-1}	29-78	LR^2-0.77*	11-222	---
	ENTDN, g kg^{-1}	579-647	NS	--	---
	ENNDF, g kg^{-1}	536-673	NS	--	---
	ENADF, g kg^{-1}	310-398	NS	--	---
1995	ENY65, Mg ha^{-1}	21-37	NS	--	---
	ENCP, g kg^{-1}	50-123	LR^2-0.78*	37-385	---
	ENTDN, g kg^{-1}	595-703	NS	--	---
	ENNDF, g kg^{-1}	496-681	NS	--	---
	ENADF, g kg^{-1}	239-378	NS	--	---

*, Significant at the 0.05 probability level

¶, Non-significant at the 0.05 probability level

†, Yield Range = Low Yield (L) – High Range (H)

‡, Ratio = Kilograms of nitrogen to produce 62.73 kg ha^{-1} of corn grain, N-Rate = Total fertilizer nitrogen amount or range associated with yield or response results

§, Predicted maximum yield

Table 13 (cont'd.). Regression Analysis Results for Corn Grain and Ensilage Yield and Nutritive Response to Applied Fertilizer Nitrogen + Residual Profile Nitrate at the Southcentral Agronomy Research Station, Chickasha, Ok, Grady County (Irrigated).

		Fert.-N + RPN			
Year	Variable	Yield Range L-H†	Model Response	Ratio or N-Rate‡	N_{max}
1996	GRNYLD, kg ha^{-1}	2557-10193	LR^2-0.70*	35-334	---
	GRNCP, g kg^{-1}	80-137	LR^2-0.52*	121-342	---
	GRNTDN, g kg^{-1}	854-871	NS§	--	---
	GRNNDF, g kg^{-1}	75-162	NS	--	---
	GRNADF, g kg^{-1}	23-45	QR^2-0.48*	186(28)¶	186(N_L)
	ENY65, Mg ha^{-1}	25-64	NS	--	---
	ENCP, g kg^{-1}	55-97	LR^2-0.43*	146-250	---
	ENTDN, g kg^{-1}	612-784	NS	--	---
	ENNDF, g kg^{-1}	271-624	NS	--	---
	ENADF, g kg^{-1}	135-288	NS	--	---
1997	GRNYLD, kg ha^{-1}	671-11288	LR^2-0.75*	20-311	---
	GRNCP, g kg^{-1}	84-114	LR^2-0.69*	24-311	---
	GRNTDN, g kg^{-1}	852-857	NS	--	---
	GRNNDF, g kg^{-1}	81-103	NS	--	---
	GRNADF, g kg^{-1}	41-47	QR^2-0.33*	107(44)	107
	ENY65, Mg ha^{-1}	16-69	NS	--	---
	ENCP, g kg^{-1}	37-79	NS	--	---
	ENTDN, g kg^{-1}	576-703	NS	--	---
	ENNDF, g kg^{-1}	408-635	NS	--	---
	ENADF, g kg^{-1}	238-402	NS	--	---

*, Significant at the 0.05 probability level

§, Non-significant at the 0.05 probability level

†, Yield Range = Low Yield (L) – High Yield (H)

‡, Ratio = Kilograms of nitrogen to produce 62.73 kg ha^{-1} of corn grain, N-Rate = Total fertilizer nitrogen amount or range associated with yield or response results

¶, Predicted maximum yield

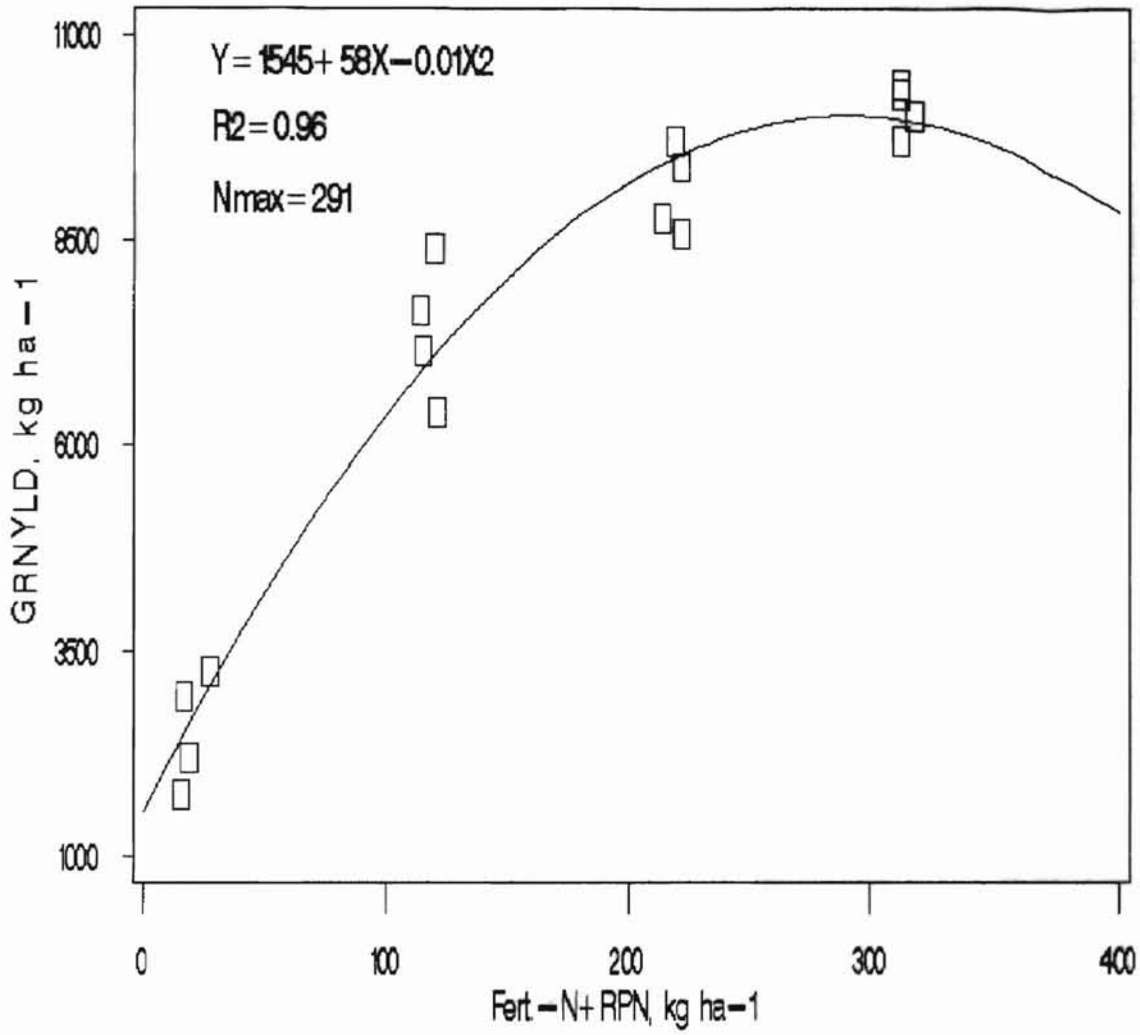

Figure 31. 1994 SCARS Irrigated Grain Yield Results

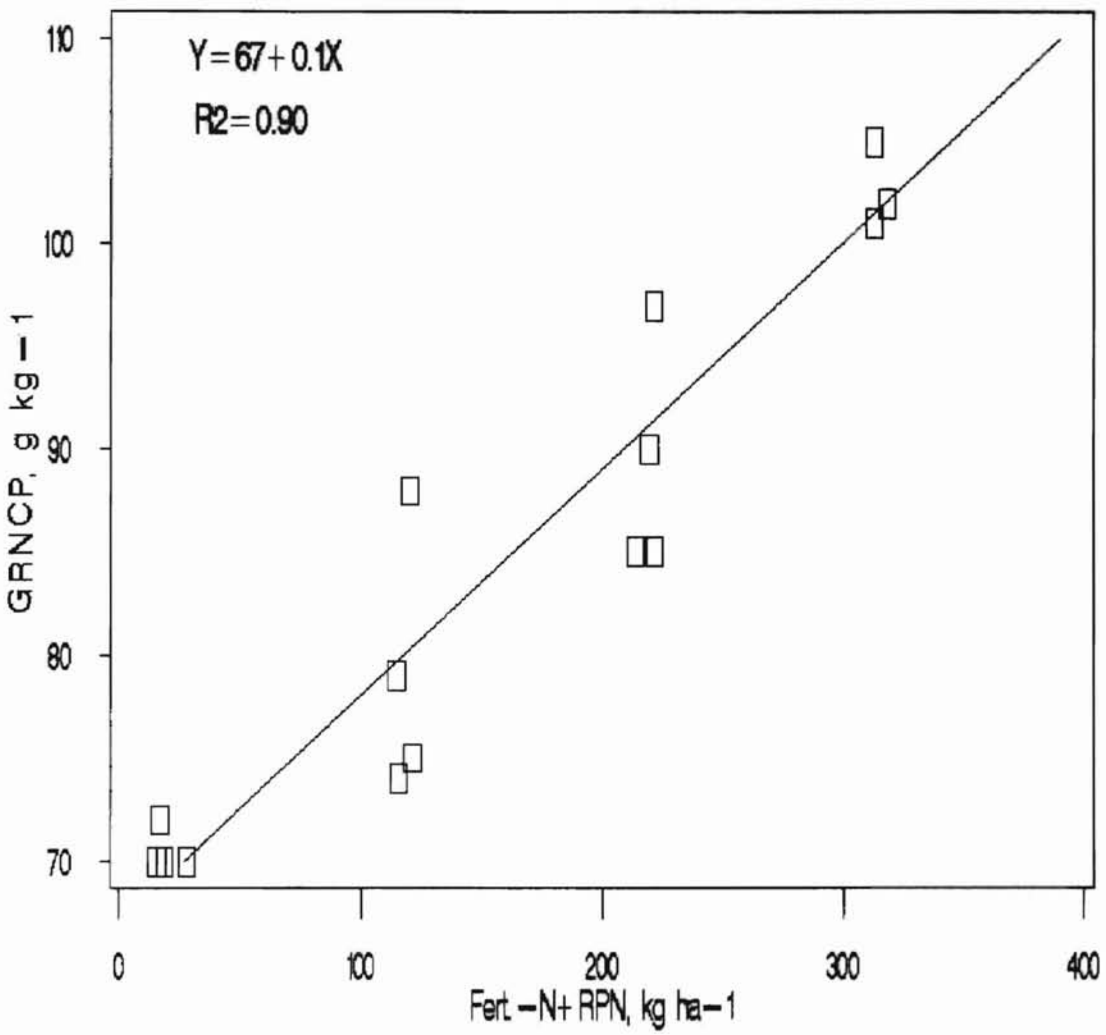

Figure 32. 1994 SCARS Irrigated Grain Crude Protein Res.

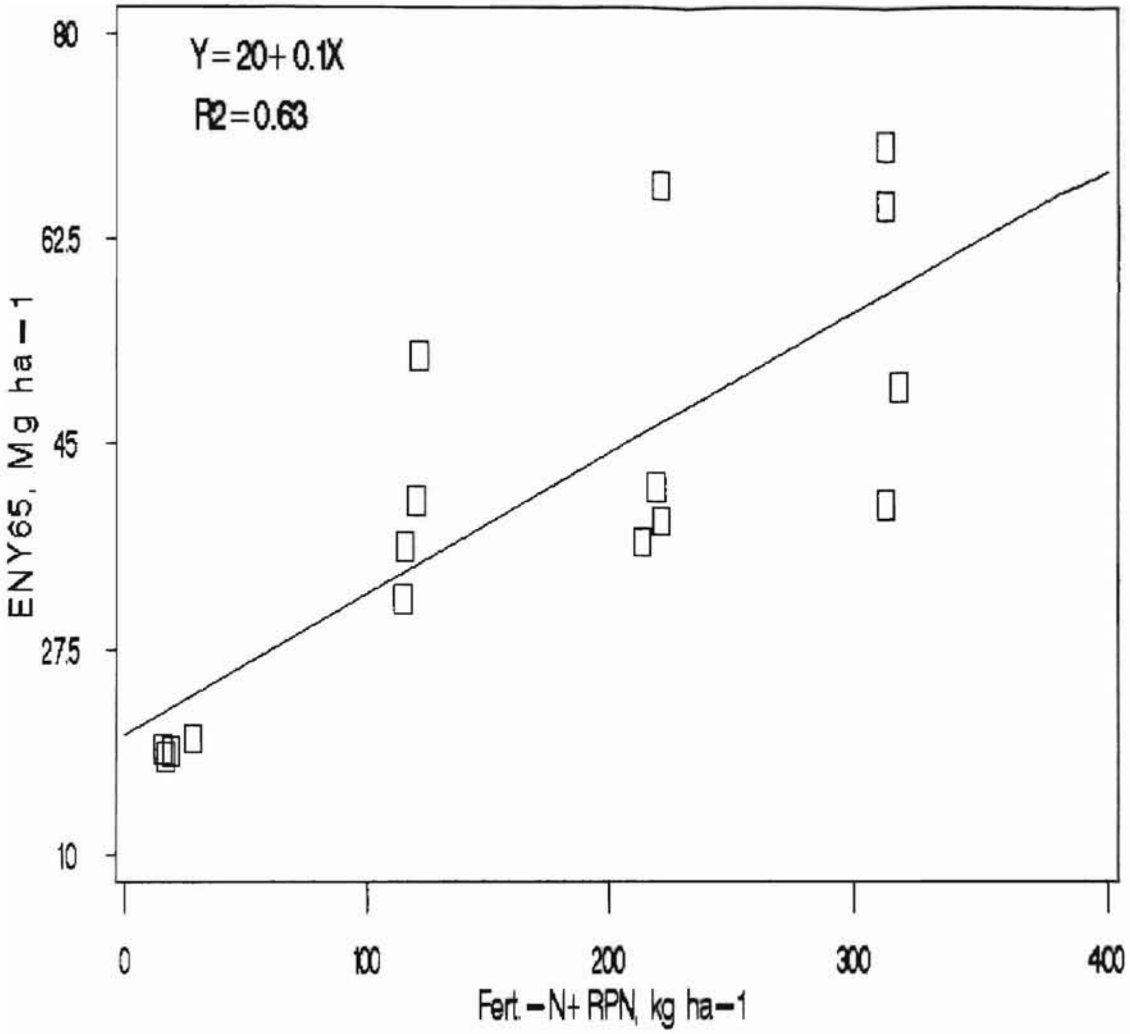

Figure 33. 1994 SCARS Irrigated Ensilage Yield Results

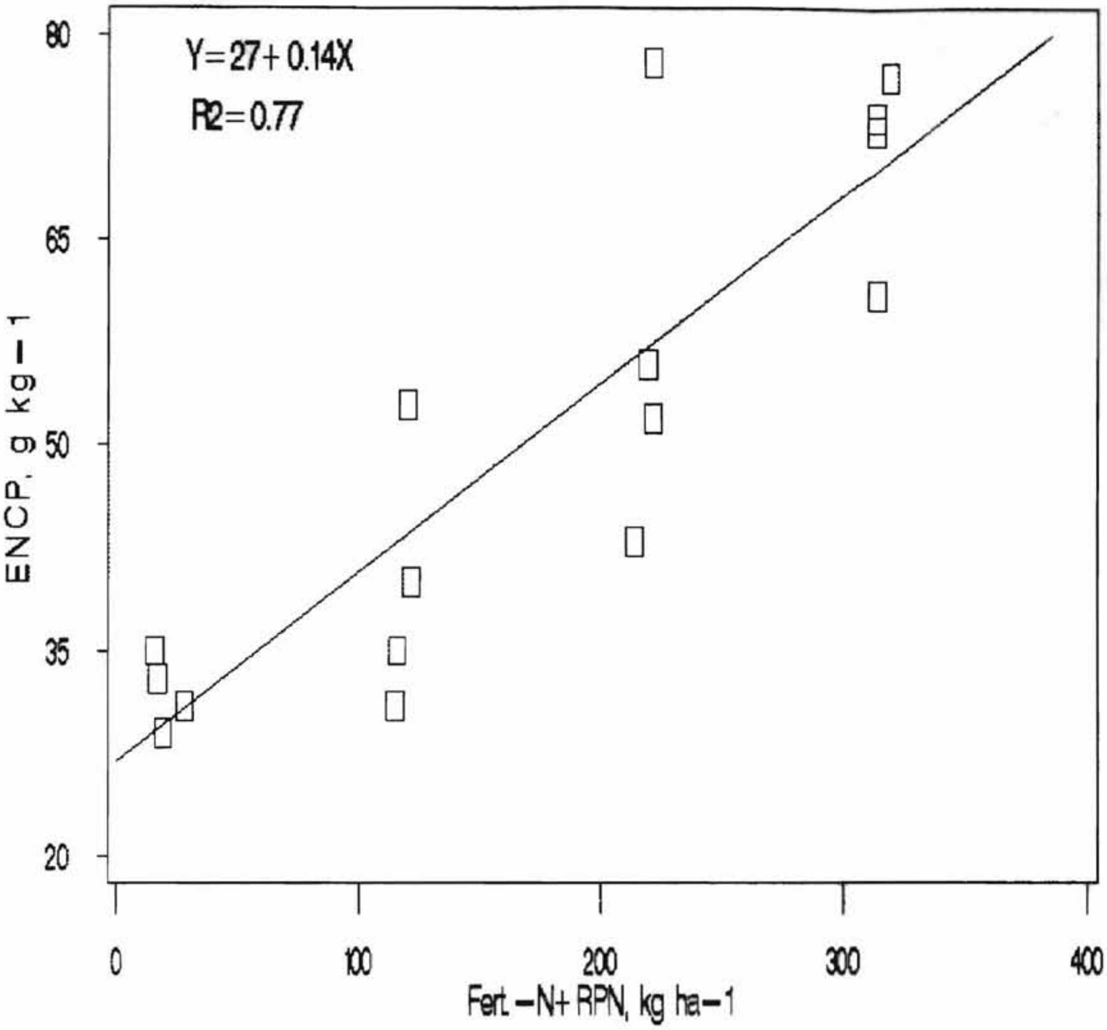

Figure 34. 1994 SCARS Irrigated Ens. Crude Protein Res.

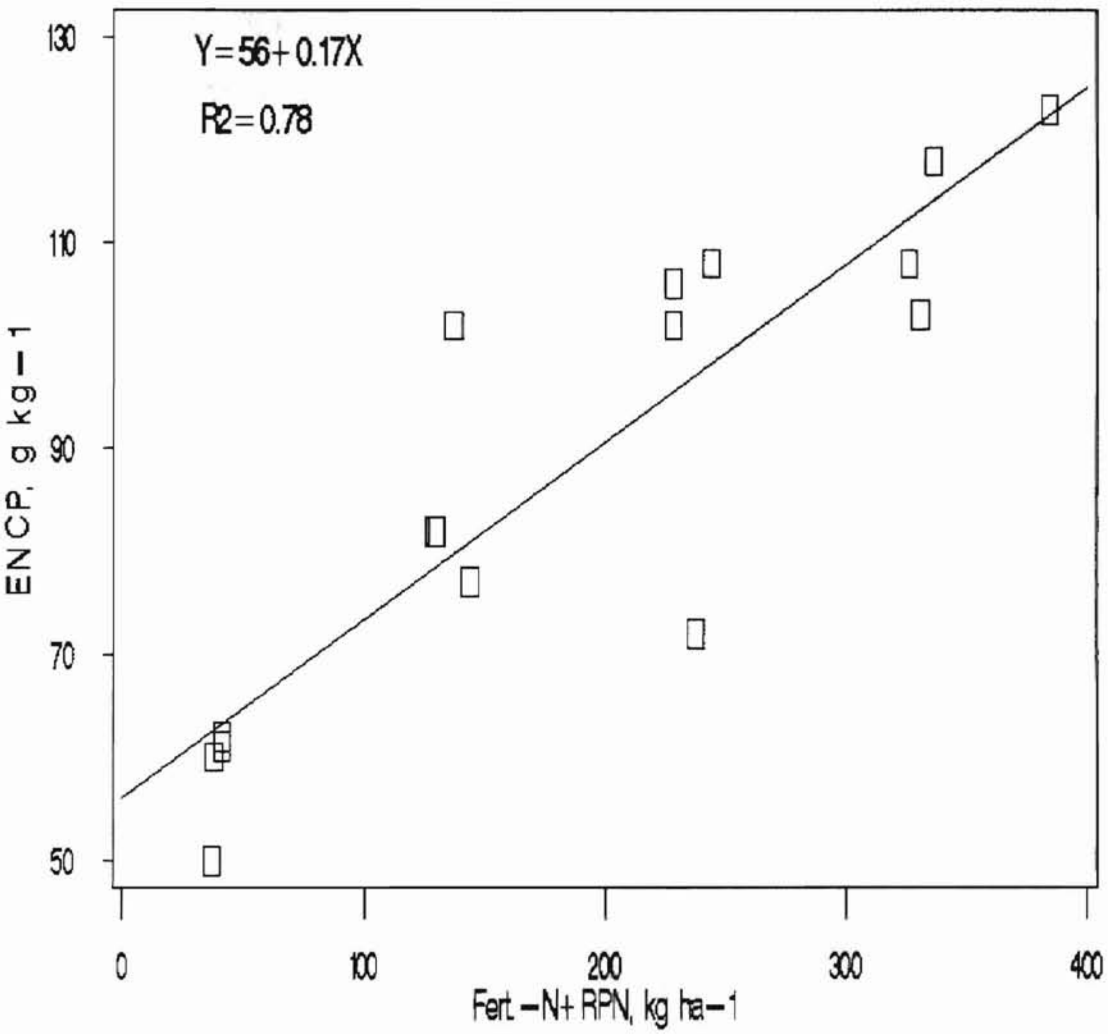

Figure 35. 1995 SCARS Irrigated Ens. Crude Protein Res.

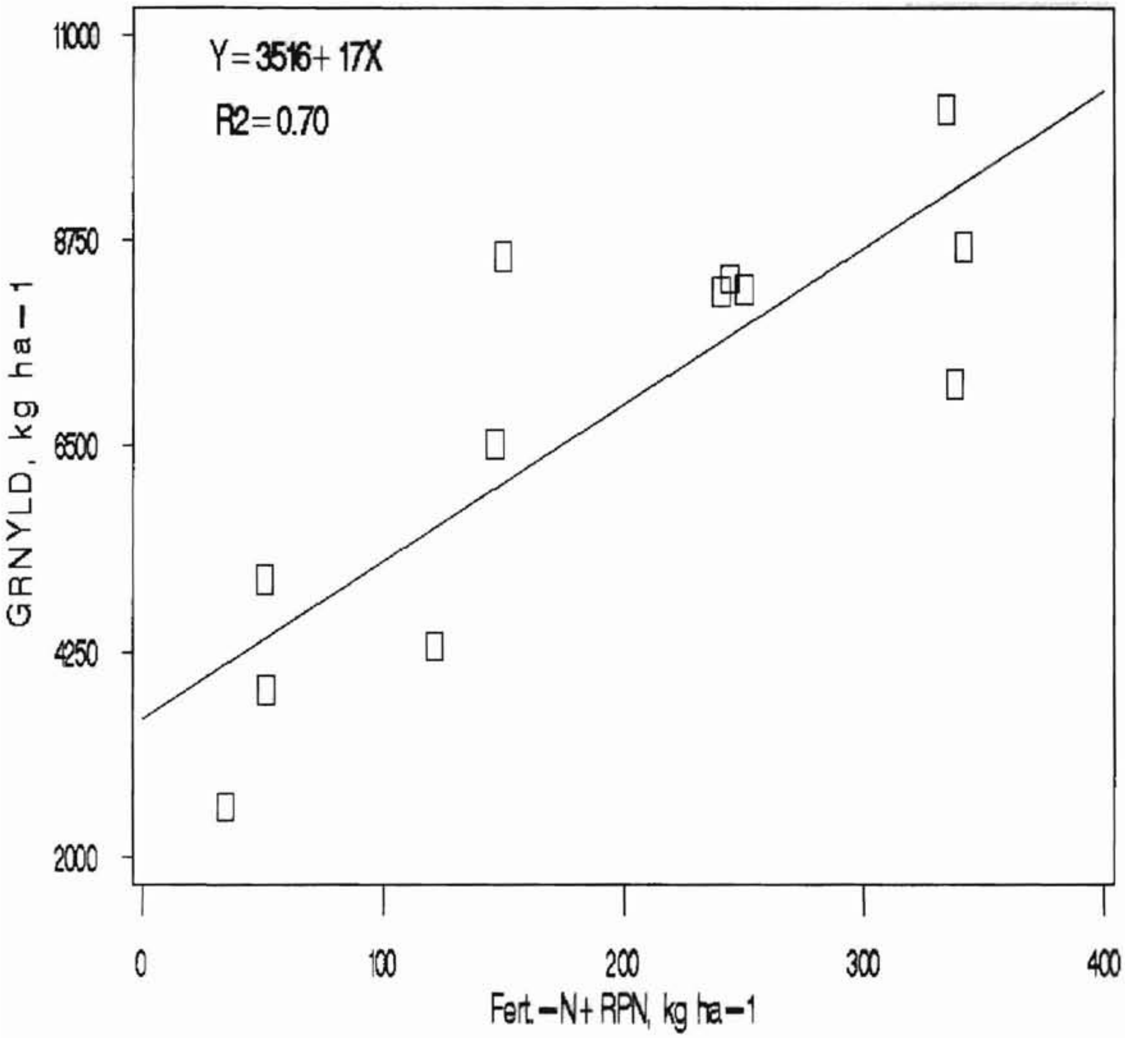

Figure 36. 1996 SCARS Irrigated Grain Yield Results

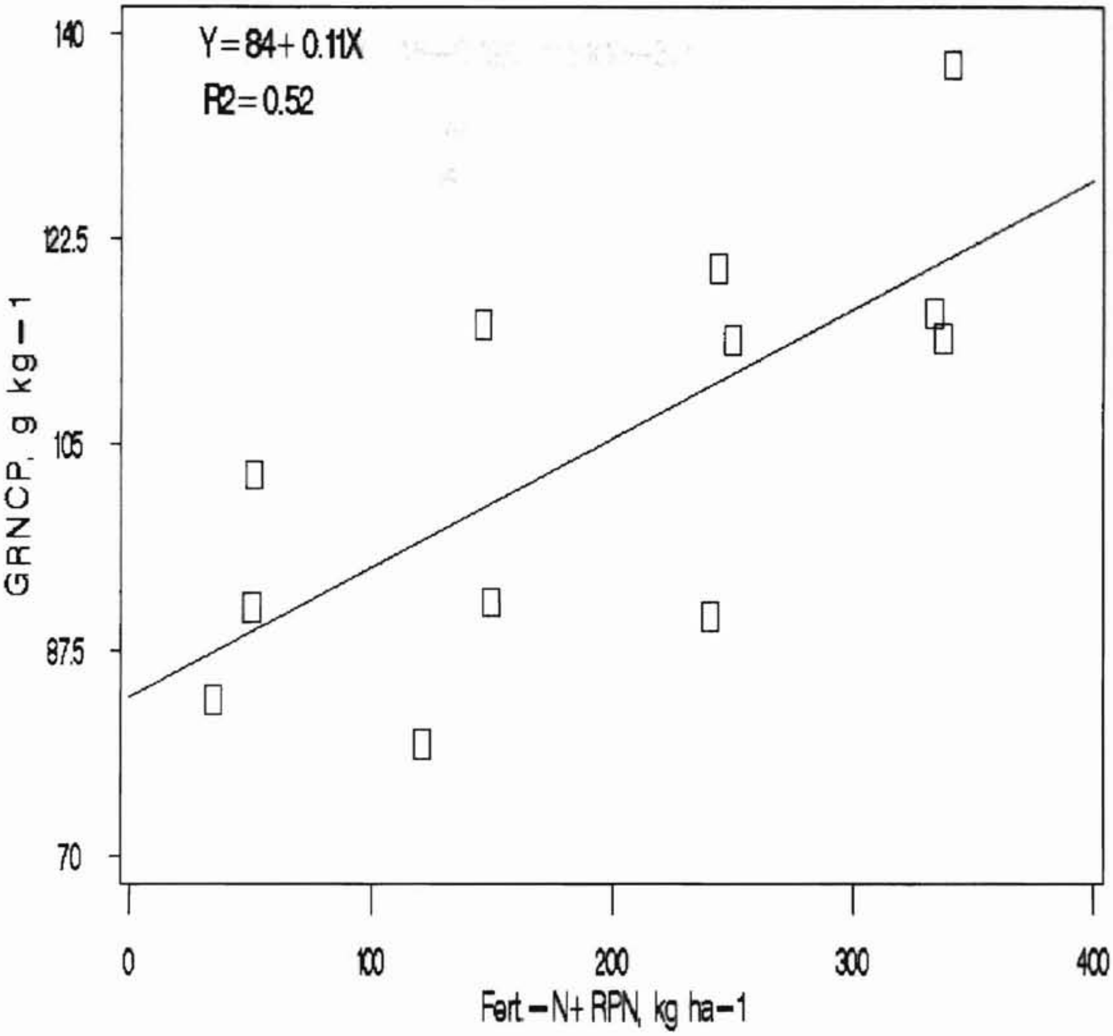

Figure 37. 1996 SCARS Irrigated Grain Crude Protein Res.

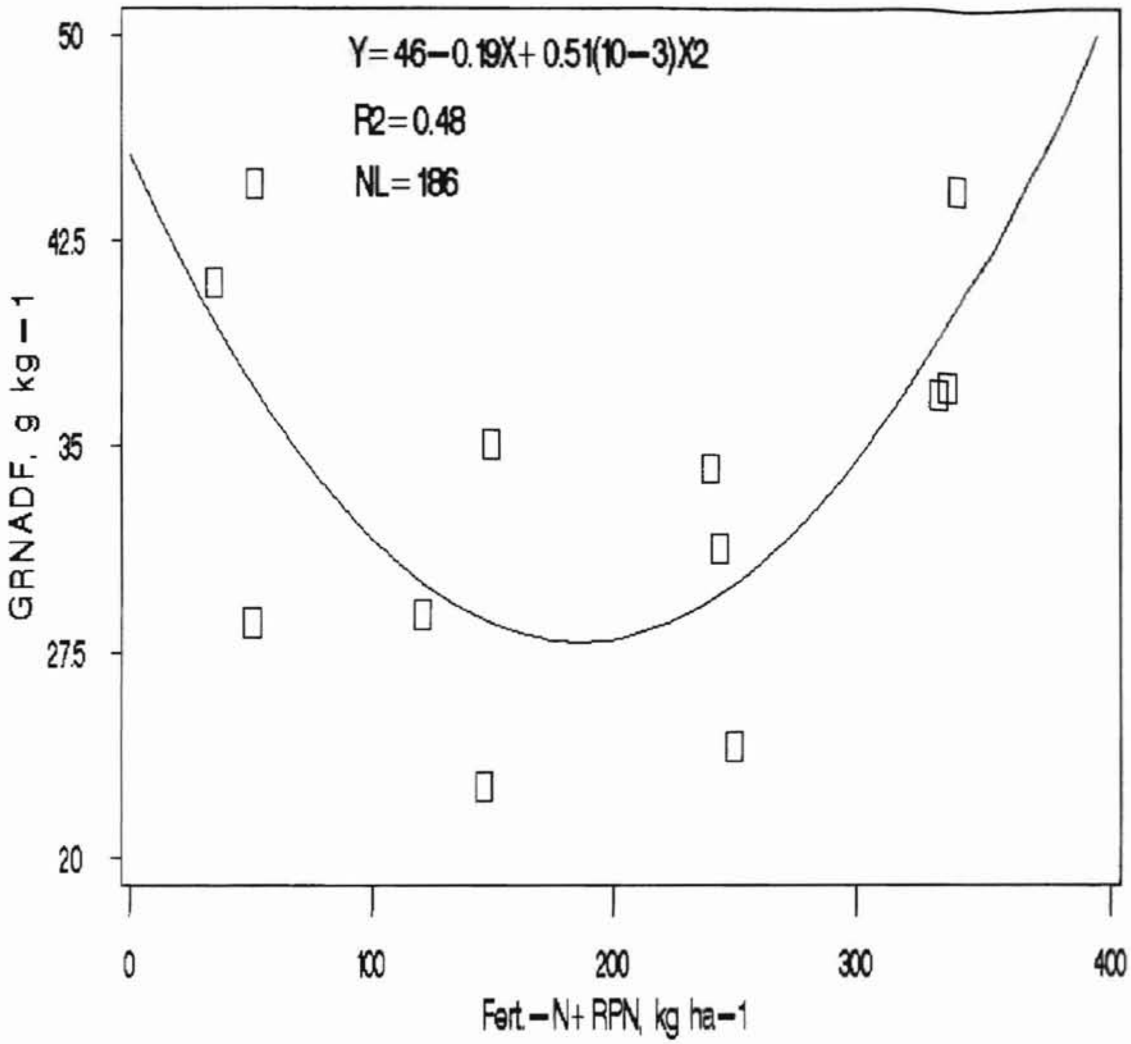

Figure 38. 1996 SCARS Irr. Grain Acid Detergent Fiber Res.

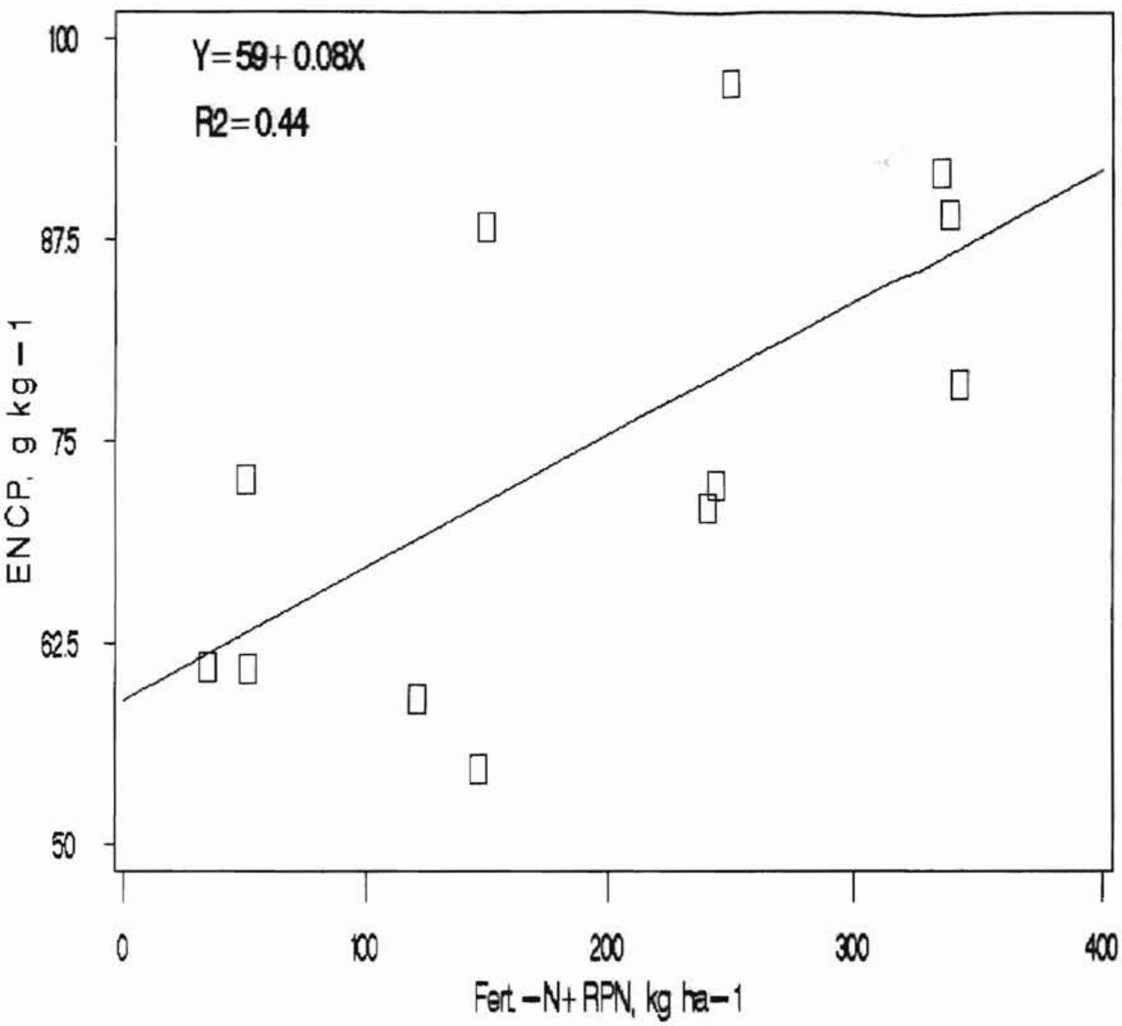

Figure 39. 1996 SCARS Irr. Ensilage Crude Protein Results

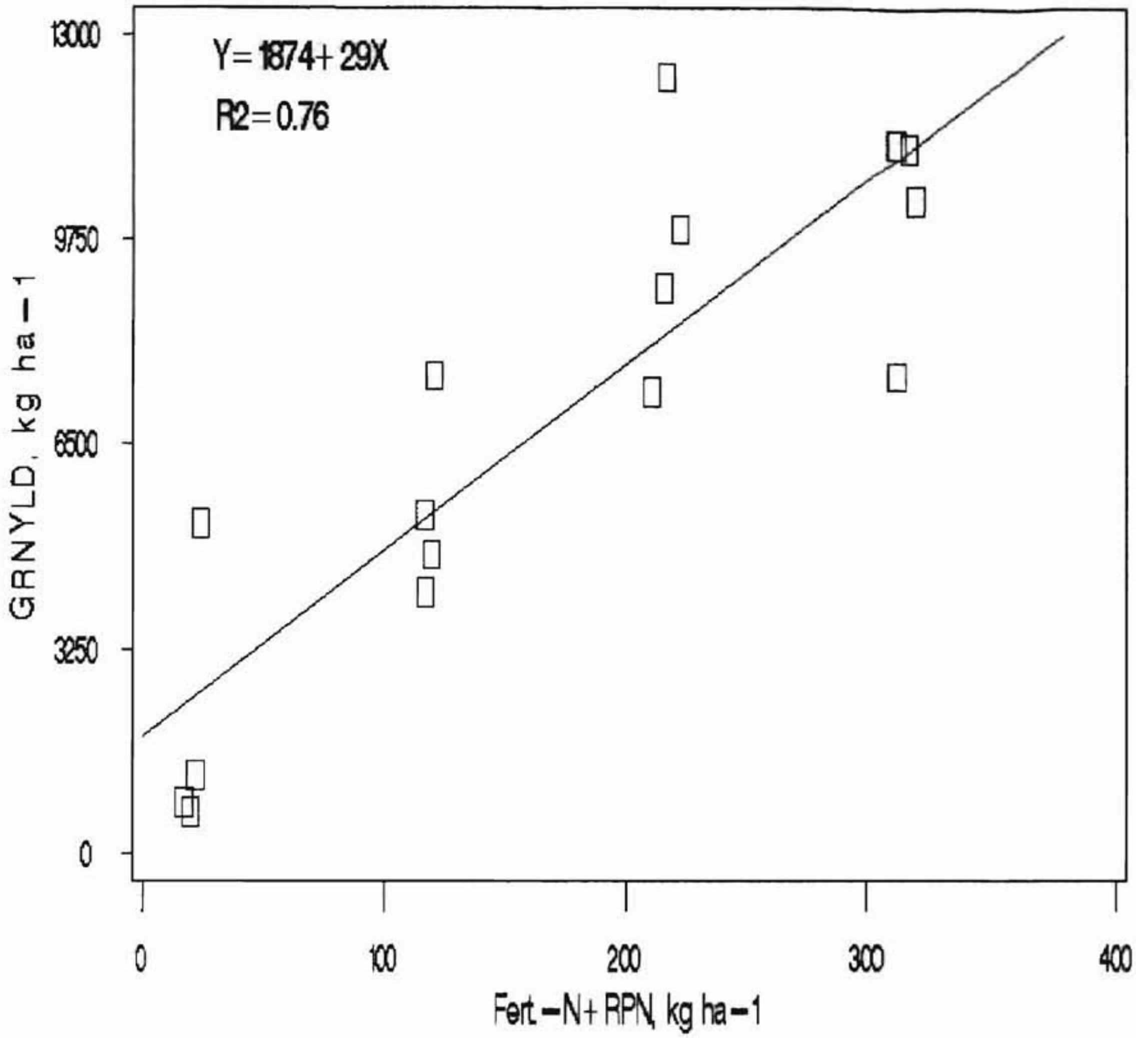

Figure 40. 1997 SCARS Irrigated Grain Yield Results

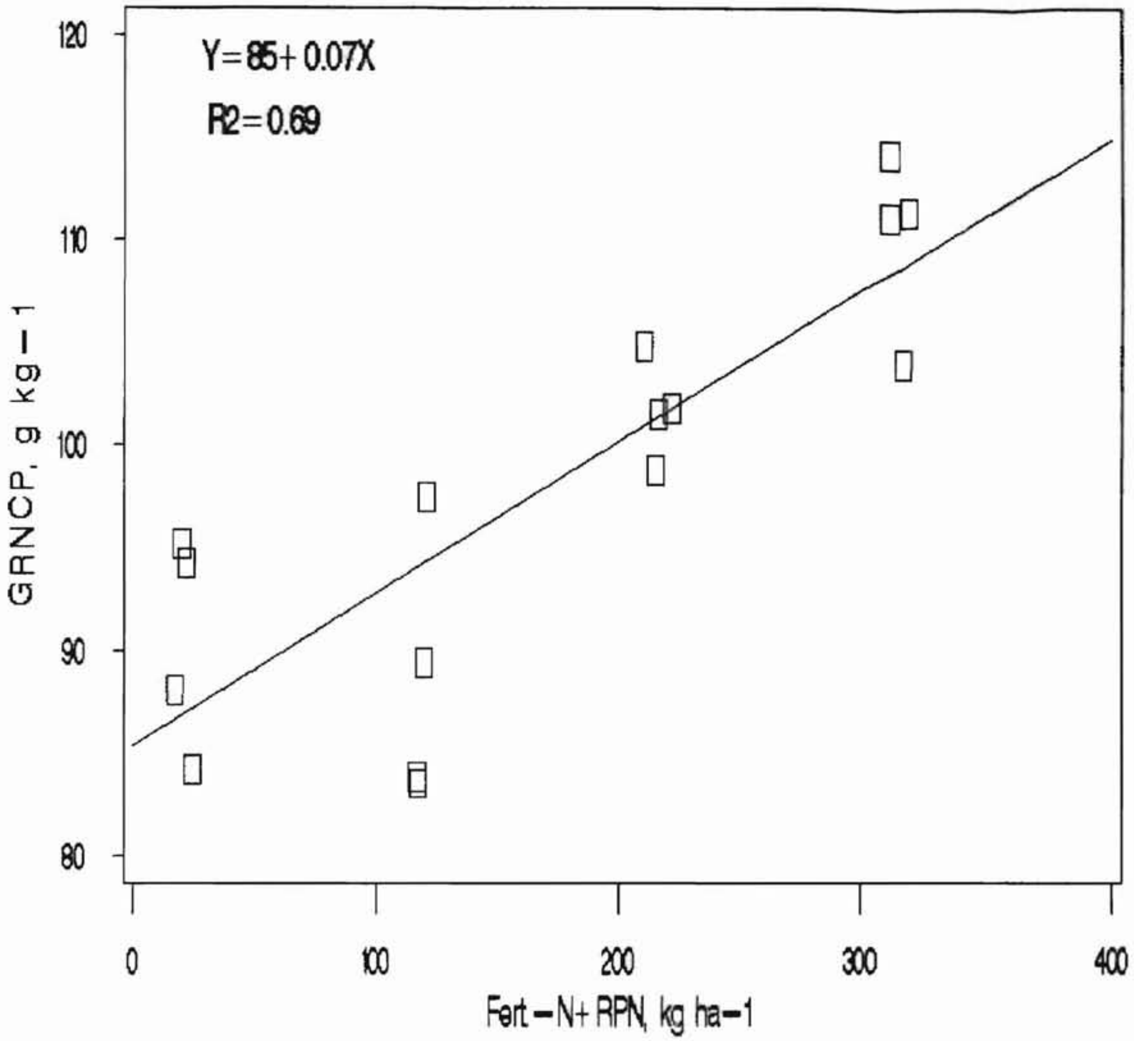

Figure 41. 1997 SCARS Irrigated Grain Crude Protein Res.

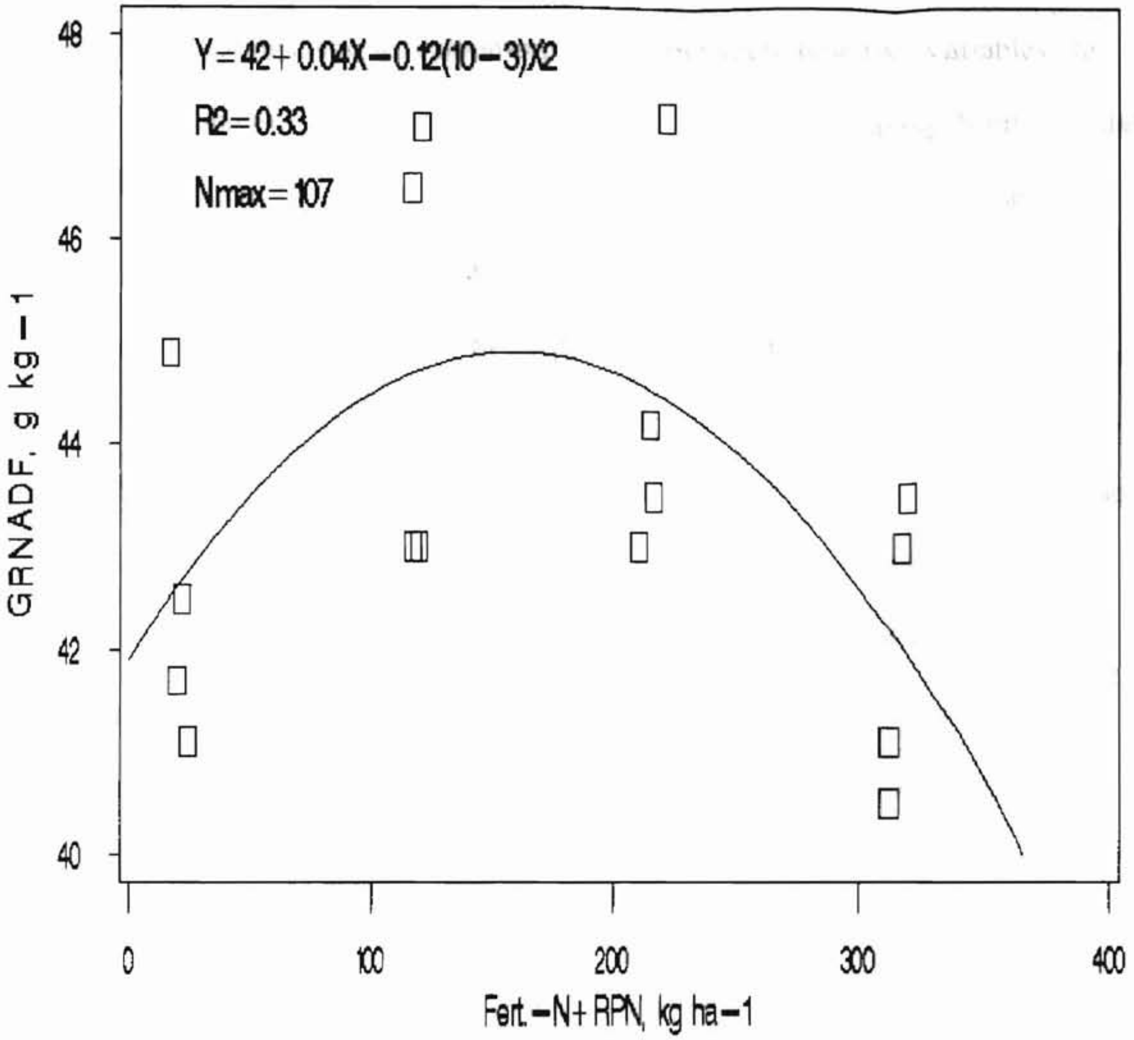

Figure 42. 1997 SCARS Irr. Grain Acid Detergent Fiber Res.

Ensilage CP showed a positive linear response to N treatment rate (Figure 44) and had a large R^2 value indicating a strong relationship existed between these two variables. In this linear yield response, crude protein continued to respond to increasing N rates. Total digestible nutrients and ADF both showed quadratic responses to N treatment rate (Figures 45, 46). Once again the relationship between ADF and TDN is reflected in the yield responses. The predicted maximum responses came at a common N_{max} or N_L predicted value of 140 kg ha^{-1}. The pivotal point was where ADF ceased to increase with increasing N rates and began to decrease with increasing N rates. The opposite was true for TDN as it decreased with increasing N rates to this point and then began to increase with increasing N rates. Again this response is expected as the two variables have an inverse relationship. Since these variables are related to digestibility then one can assume that digestibility will follow the same response curves. The only variable in the 1995 data to respond to N rates was CP. Again, the lack of data responses for this year is most likely related to the difficult crop year in terms of high temperatures and heat indexes. This variable showed a positive linear response to increasing N treatment rate (Figure 47). A high R^2 value indicates a large portion of variability is accounted for by N treatment rate thus a strong relationship exists between variables. The yield range high value is an excellent reflection of CP in an ensilage product.

Table 14. Regression Analysis Results for Corn Grain and Ensilage Yield and Nutritive Response to Applied Fertilizer Nitrogen + Residual Profile Nitrate at the South-Central Agronomy Research Station, Chickasha, Ok, Grady County (Dryland).

		Fert.-N + RPN			
Year	Variable	Yield Range L-H†	Model Response	Ratio or N-Rate‡	N_{max}
1994	ENY65, Mg ha^{-1}	12-27	QR^2-0.37*	142(23)§	142
	ENCP, g kg^{-1}	51-119	LR^2-0.75	19-255	---
	ENTDN, g kg^{-1}	583-637	QR^2-0.45	140(524)	140(N_L)
	ENNDF, g kg^{-1}	571-652	NS¶	--	---
	ENADF, g kg^{-1}	324-400	QR^2-0.44	140(381)	140
1995	ENY65, Mg ha^{-1}	21-30	NS	--	---
	ENCP, g kg^{-1}	51-133	LR^2-0.77*	36-290	---
	ENTDN, g kg^{-1}	604-660	NS	--	---
	ENNDF, g kg^{-1}	543-630	NS	NS	---
	ENADF, g kg^{-1}	294-419	NS	NS	---

*, Significant at the 0.05 probability level

¶, Non-significant at the 0.05 probability level

†, Yield Range = Low Yield (L) – High Yield (H)

‡, Ratio = Kilograms of nitrogen to produce 62.73 kg ha-1 of corn grain, N-Rate = Total fertilizer nitrogen amount or range associated with yield or response results

§, Predicted maximum yield

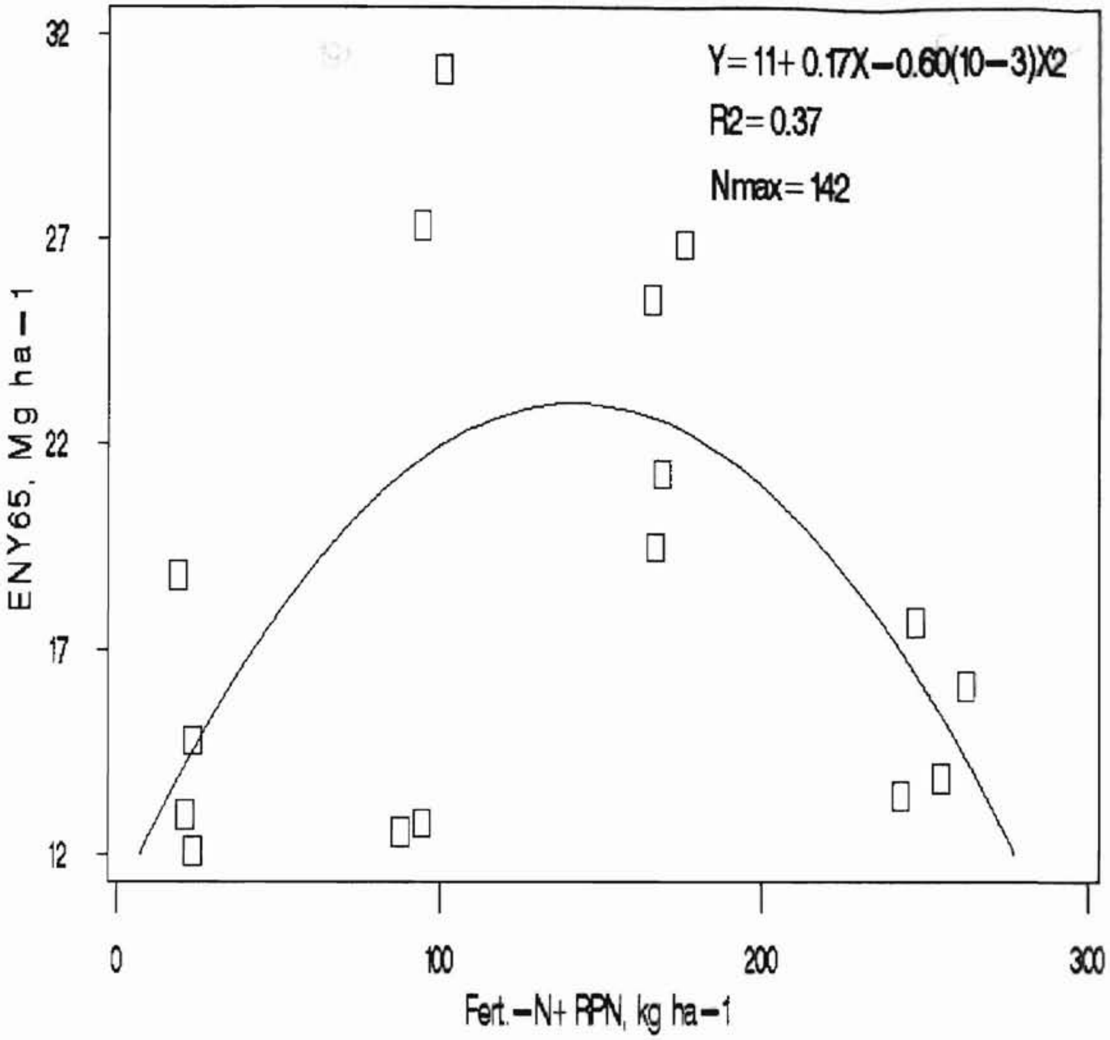

Figure 43. 1994 SCARS Dryland Ensilage Yield Results

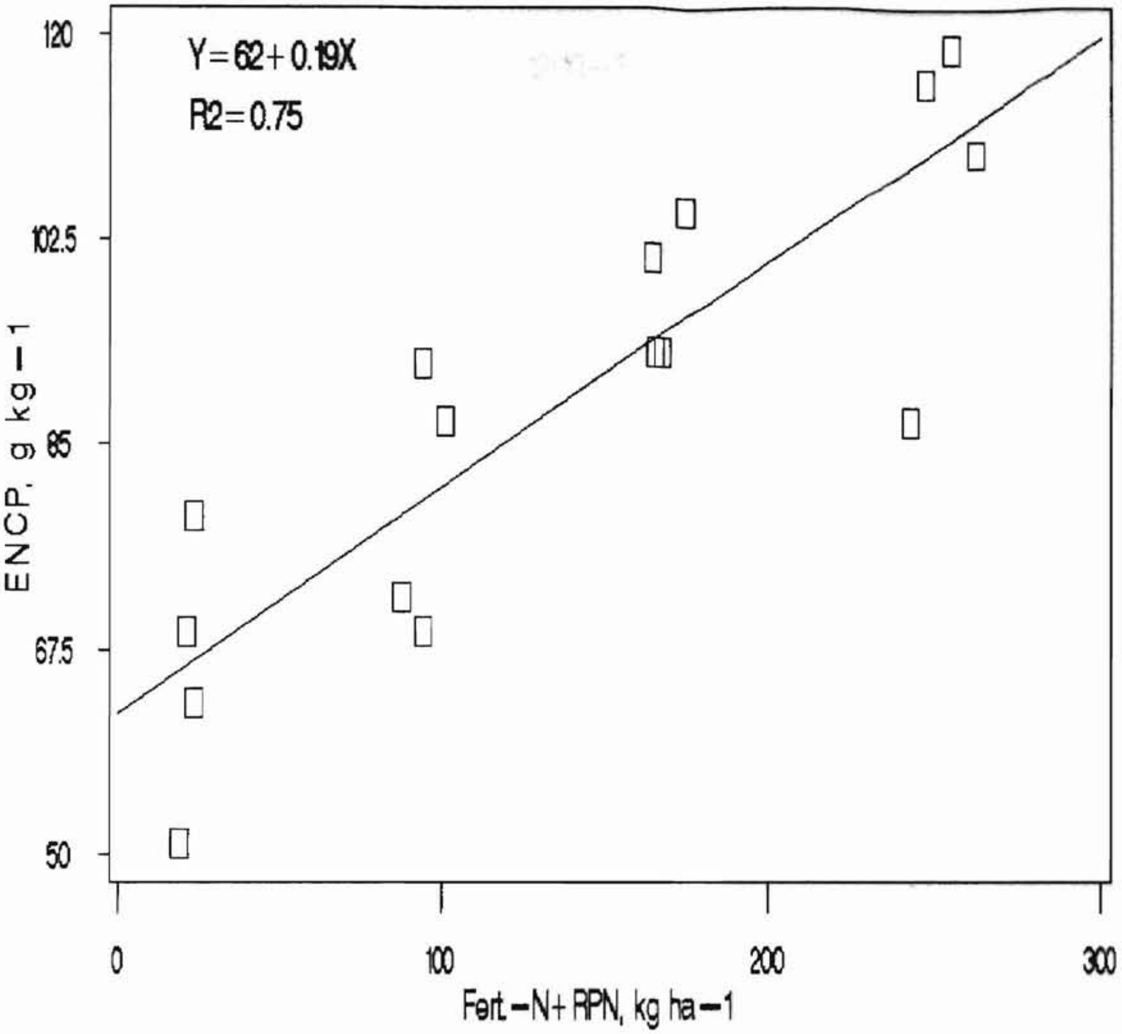

Figure 44. 1994 SCARS Dryland Ensilage Crude Protein Res.

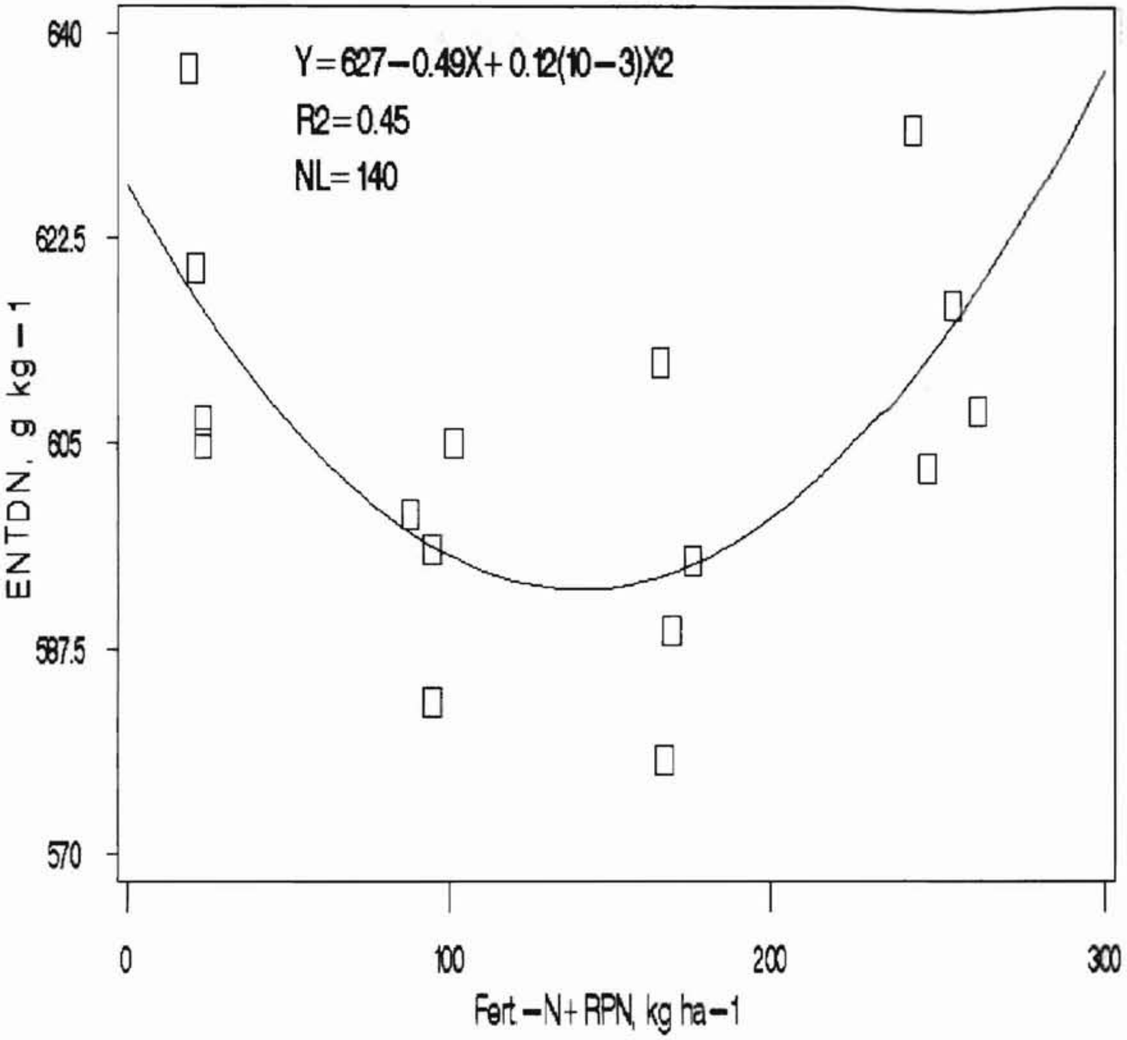

Figure 45. 1994 SCARS Dryland Ens. Total Dig. Nutrients

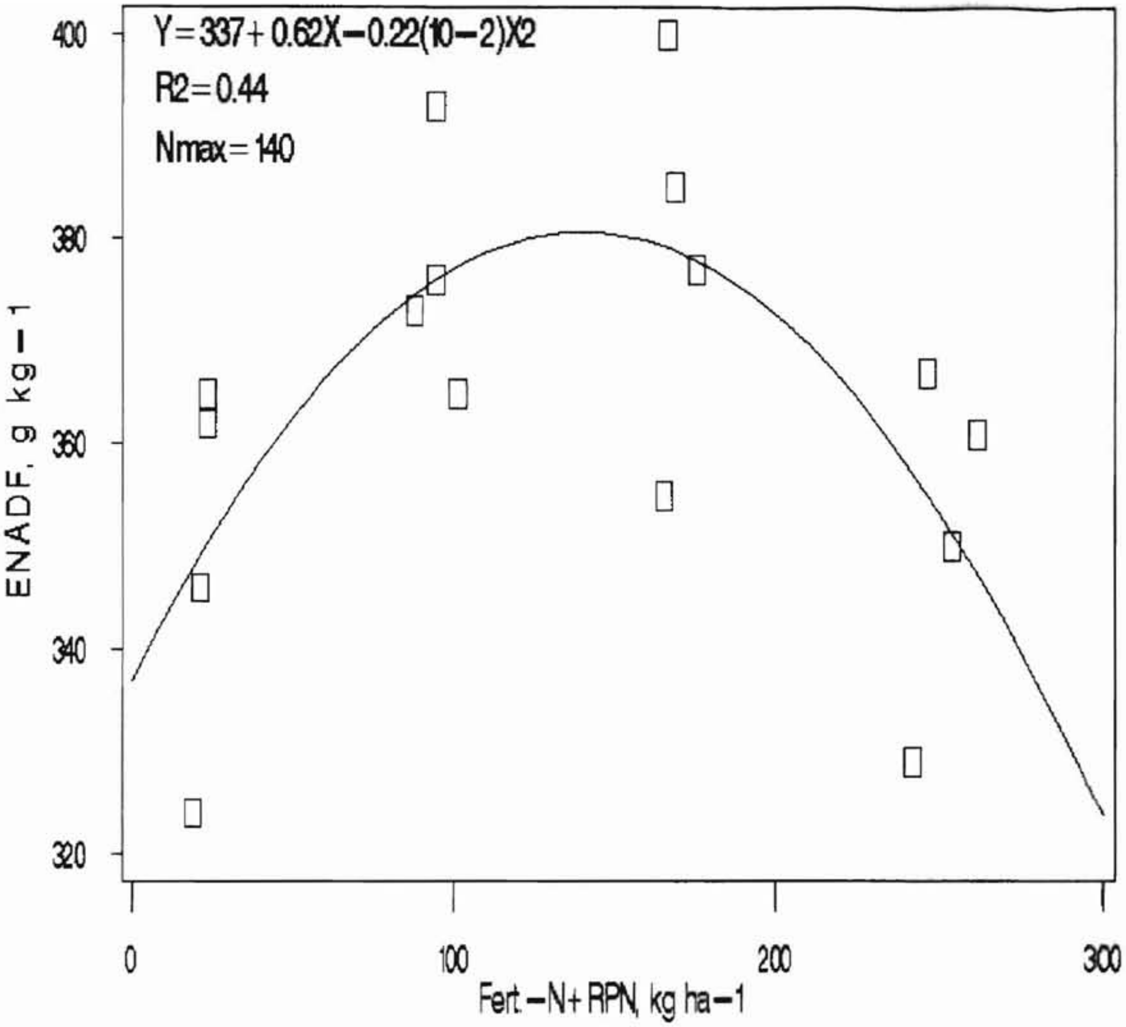

Figure 46. 1994 SCARS Dryland Acid Detergent Fiber Results

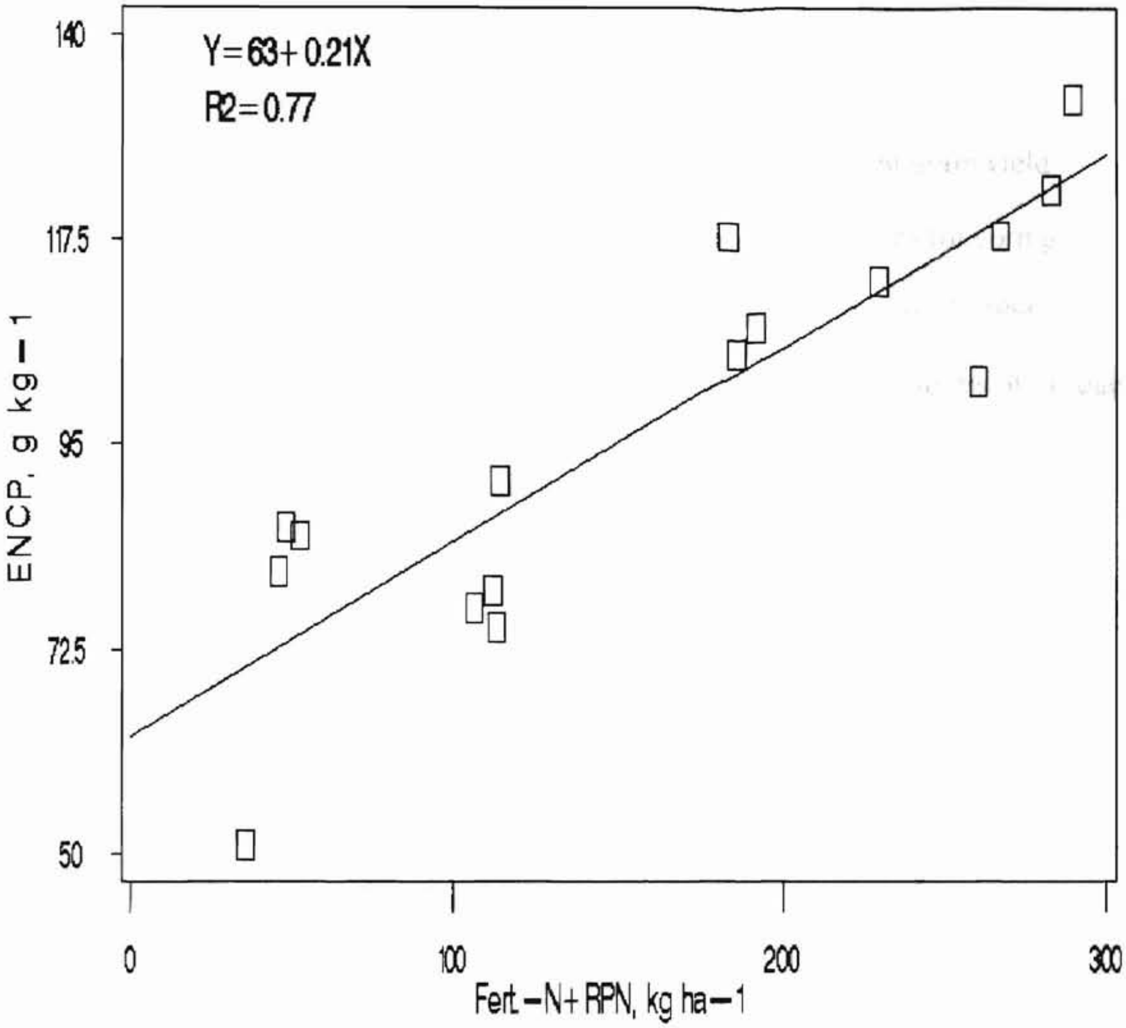

Figure 47. 1995 SCARS Dryland Ensilage Crude Protein Res.

CONCLUSIONS

With the exception of the Chickasha irrigated site all significant grain yield model responses verified OSU's lowering the nitrogen recommendations for corn grain yield response. Three of these sites [Webbers Falls , Choska, and Goodwell (1996 and 1997 crop years only)] identified plateau affects related to grain yield in terms of nitrogen fertilization rates. Their nitrogen to corn grain yield goal ratio's (kg of N to produce 1 Metric Grain Yield Unit or 62.73 kg ha^{-1} of corn grain yield) were 1.65:1, 1.36:1, 2.03:1and 1.1:1 respectively. This data response is significant in that the current nitrogen recommendations are based on yield goals and would continue to increase with increasing yield goal projections. However, the data at these sites indicate that no further yield increase was seen beyond their respective N_{max} (nitrogen rate at predicted maximum yield) points. Area site-specific recommendations are warranted due to the different production management requirements of each location.

In the eastern side of the state a 1.65:1 nitrogen to corn grain yield goal ratio would be recommended at the Webbers Falls site under irrigated conditions while a 1.36:1 ratio would be recommended for the Choska dryland site. The 1.65:1 ratio is somewhat higher than current OSU recommendations but still lower than previous recommendations. The 1.36:1 dryland recommendation is very reflective of current OSU recommendations. However, further years' data are needed to verify these results as only 1 years' grain data was retrieved from each of these sites due to reasons previously mentioned. In the panhandle only irrigated production conditions were used as this is the common practice for this area. Ratios of 2.03:1 and 1.1:1 were indicated by the 1996 and 1997 data, respectively. The 1995 data had a linear response to N rate but due to harsh production conditions that year lower yield responses were noted resulting in impractical ratios going as high as 3.6:1. Therefore, while reported in the results section that year's data was not included in this discussion. An average of the two years ratios resulted in a 1.5:1 nitrogen to corn grain yield goal ratio and is the recommendation for this site based on the useable grain data. The decision to average across statistically different years is based on the need for one recommendation for a site where one type of production management practice is used and both years' analysis resulted in quadratic (plateau) yield responses. While slightly higher than current grain yield goal based recommendations, the 1.5:1 ratio supports OSU's recommendations of lower N fertilizer rates.

The Chickasha irrigated site clearly indicated higher ratios. The three-grain years had ratios of 1.8, 2.1, and 1.73. The 1994 grain yield response was quadratic and the 1996 and 1997 years indicated positive linear responses to N rate. However in all three years associated N rates to yield responses are higher than current OSU recommendations. The data indicate that a positive linear yield response was prevalent with increasing N rate at this site with associated nitrogen to corn grain ratios as high as an average of 1.9:1. This is higher than prior 1993 OSU recommendations.

With the exception of two site-years and the exclusion of the 1995 OPREC site-year all significant ensilage yield responses indicate that comparable to higher yields are achieved with lower N rates when compared to current OSU recommendations. Three site-years identified quadratic responses to N treatment rate (Choska – 1994, OPREC – 1997, and SCARS – 1994). The Choska location data indicated a higher predicted yield response per associated N rate when compared to current OSU recommendations. However, the other two site-years indicated the opposite, a lower predicted yield responses per comparable N rate. The remaining significant site-year responses (

OPREC – 1996, SCARS (I) – 1994) showed positive linear responses to N rate. The 1996 OPREC ensilage linear yield response when considered with the 1997 quadratic response data indicated a variable condition exists at this site in terms of yield response models to associated N rate. The 1994 irrigated SCARS location was the only site-year for the Southcentral area to show a significant ensilage yield response to N rate. This site-year indicated a larger yield response with per associated nitrogen rate when compared to the current OSU recommendations.

However, the above discussion must be buffered with the fact that the responses are associated with small R^2 values indicating that a large portion of the variability around yield response was not accounted for by N treatment rate. Thus a weak relationship is indicated between these two variables. While it may be concluded that the data suggests ensilage yield response calibrations should be re-considered, it must also be concluded that a high amount of variability existed around this variable in the study.

Nutritive responses, in general, agreed with literature findings. Comparisons cannot be made with OSU recommendations as these variables are not included as part of the production management scenarios. Crude protein is the primary nutritive component that responded to N treatment rate. With the exception of one site-year all significant regression models across grain and ensilage yield products reflected a positive linear response to increasing N rate. Acid detergent fiber and TDN nutritive values were very site specific in terms of response. The response models and associated R^2 values were inconsistent in terms of regression relationship. However, when significant the inverse relationship that exists between these two variables was seen in every occasion.

In conclusion, additional years data are necessary in the Eastern locations across all variables to verify results. Future work is recommended in terms of ensilage yield data to address both yield recommendations and the amount of variability that was noted within and across locations in this study.

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VITA

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