INTERPRETIVE SUMMARY - 1990

Project: MB-4 Leader: C. Grant

N, P, and K Fertility Requirements for Optimizing Protein Levels in Malting Barley

This study is showing that balanced fertilization with N, P and K can optimize both yield and quality of malting barley. Initial results showed yield and lodging increased markedly with N rate, however the lodging was offset by K, and to a lesser extent by P fertilization. N fertilization had a negative impact on protein levels, but had a positive impact on other parameters of malting quality. K tended to have the opposite effect malting quality. However, KCl consistently reduced common root rot.

NITROGEN, PHOSPHORUS AND POTASSIUM FERTILITY REQUIREMENTS FOR OPTIMIZING PROTEIN LEVELS IN MALTING BARLEY

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Introduction

Among the major factors cited for rejection of producer malting barley samples is excess protein. The average percentage protein of the Canadian barley crop varies from year to year as the environmental factors vary, but generally falls in the range of 12.0 to 12.7%. However, the protein content preferred by the malting and brewing industries is between 10.5 and 12.5%. Excess protein leads to costly production problems for both the maltsters and brewers.

The protein content of barley is determined by both genetic and environmental factors. The major environmental factors influencing the expression of the genetic potential protein content of the specific variety are moisture and soil fertility. There tends to be an inverse relationship between yield and protein content, at a given level of N fertility. As yield increases, protein content decreases, if N is kept constant. This is due to the dilution effect. Increasing yield tends to increase the volume of material through which the protein must be distributed. Therefore, when moisture levels are high and the yield potential is high, protein tends to be low. Additions of fertilizer N tend to increase protein content of barley. However, the initial increments of N applied to a crop will generally be used to increase yield until the yield potential is constrained by some other factor, generally moisture or another nutrient. After that, protein content will begin to increase significantly.

For optimum economic returns, fertilizer applications should be managed to apply sufficient N to attain the highest possible yield, without increasing protein content beyond the acceptable levels. Current recommendations for major crops in Manitoba are based on the long term average moisture levels, from arid to irrigated, for the specific area where the crop is to be grown. In malting barley, effects of moisture and the availability of other nutrients can have a major impact on the potential yield of the crop and on the amount of N required to attain the optimal yield/protein balance.

Although N and moisture levels are the factors which generally have the greatest impact on grain protein level, availability of phosphorus (P), potassium (K) and sulphur (S) also influence both grain yield and protein. Severe deficiency of P, K or S can interfere with protein synthesis. Less severe deficiencies may inhibit yield to a greater extent than protein production and lead to increased percentage protein, although total protein production per hectare is reduced. Potassium may also have important effects on translocation of nitrogen within the plant, which will influence both yield and protein level. In addition, KCl fertilizer has been shown to influence disease incidence, which impacts on total yield and grain quality. Therefore, for optimum profitability, a fertilizer management system must consider the balance among the major nutrients rather than simply N and moisture in isolation.

This research program was designed with the following objectives:

1. To determine N, P and KCl fertilization which will optimize grain yield at various moisture levels, while maintaining protein content within required limits.
2. To determine the effects of N, P and KCl management on malting quality of barley.
3. To evaluate the effect of KCl fertilization on disease incidence in malting barley at varying levels of N, P and soil moisture.
4. To determine the effects of KCl fertilization on N use efficiency of malting barley.

Materials and Methods

Plots were established in the spring of 1990 on two sites, a Souris fine sandy loam on the Brandon Research Station and a Newdale Clay Loam, near Clanwilliam. Under normal conditions, the sandy soil is prone to drought and the clay loam soil is relatively moist. Soil samples were taken in the fall of 1989 and analyzed for N, P, K, S, pH and conductance. Moisture content to 120 cm was measured in the spring, prior to seeding.

An overall application of 50 kg S ha-1 as elemental sulfur was applied to the sandy loam soil on April 23 and the clay loam soil on May 22, 1990. Roundup was sprayed on the clay loam site on May 22. Treflan and Avadex (0.61 and 1.42 l/acre, respectively) were applied as a tank mix on the sandy loam soil on May 4 and the clay loam soil on May 28. Seeding was conducted on the sandy loam soil on May 10 to 11 and on the clay loam soil on May 28. Ellice, a two-row and Argyle, a six-row cultivar were sown on each site. Fertilizer was side-banded through the drill at time of seeding 2.5 cm below and to the side of the seed-row. Fertilizer was supplied in a full factorial with N as ammonium nitrate at 6 levels from 0 to 150 kg N ha^{-1}, K as potassium chloride at 0 and 100 kg K ha^{-1}, and P as monoammonium phosphate at 0 and 40 kg P_2O_5 ha^{-1}. A Banvel-MCPA tank mix (95 ml and 340 ml/acre, respectively) was sprayed on the clay loam soil on June 14, and Estaprop (0.71 l/acre) was sprayed on the clay loam soil on June 26.

Common root rot severity was measured at early tillering (June 15) on the phosphate treated 0, 30 and 150 kg N ha^{-1} treatments, with and without KCl. Root rot was rated on a scale of 1 to 4 on 5 plants per plot. Biomass yield and nutrient content were measured at early heading (July 9 on the sandy loam and July 20 on the clay loam) on two 1 meter lengths of row. Nutrient analysis at heading is not completed and so cannot be presented. Grain yield, protein content and malting quality were determined at maturity (14% moisture). Final yield was taken on August 13 on the sandy loam and September 12 on the clay loam soil.

Results

On the sandy loam, root rot was reduced in both cultivars by the additions of either KCl or N (Table 1). No root rot was found on the clay loam site.

On the sandy loam, grain yield was increased by the addition of N, but was not significantly influenced by KCl or P application (Table 2, Figs 1 and 2). When cultivars were combined, there was a small but significant increase in grain yield with KCl application. On the clay loam, yield was increased with application of low levels of N fertilizer in Ellice but not Argyle (Table 2, Figs 3 and 4). However, with application of higher levels of fertilizer N, severe lodging occurred, reducing yield. At the higher levels of N, application of KCl or P increased yield as compared to treatments receiving high levels of N and no P or KCl. This was presumably due to a reduction in lodging. Highest yield in both Ellice and Argyle was obtained with the application of 30 kg N ha-1 with P and KCl, although in Ellice yield was not significantly different from that with no P and KCl. Grain yield of both cultivars through the range of N levels was generally slightly higher with the application of both KCl and P than with one or both of these nutrients were omitted.

Malting Quality

Malting quality factors were significantly affected by fertility management regimes at both sites in 1990. Six malting quality factors were examined. The factors examined, as well as their significance in determining malting quality, are summarized in Table 3.

The variety Argyle had better overall malting quality than Ellice at either site (Tables 4 to 7). Argyle consistently had higher DP, and lower VISC and PROT, than Ellice. Response patterns to fertility treatments differed with each cultivar. Analysis of Variance (ANOVA) indicated significant ($p<0.01$) cultivar effects both within and between sites.

Application of N increased AMINO, DP and PROT in Ellice on both the sandy loam and clay loam soils. With Argyle, application of N increased DP on the clay loam soil, and increased DP and AMINO but decreased ALPHA on the sandy loam soil.

Application of P generally had no effect on malting quality. The addition of K, however did have a marked effect on most of the malting quality factors examined. Both cultivars were affected, with the greatest response occurring at the SL site. Severe lodging at the CL site confounded results, rendering them inconsistent, for the most part. In general, addition of K lowered malting quality by decreasing ALPHA, DP, and AMINO, and increasing DIFF and VISC. There were consistent and significant K x N interactions for 20 of the 32 cultivar/site/trait combinations. Generally, effects of K on malting quality factors were greatest at the highest N levels.

Protein levels were at the high end of the range for commercial standards, with the exeption of Ellice on the CL soil (Figs 5 to 8). High levels of protein (13.5 to 16%) for Ellice on the CL were likely due to lodging-induced stress. Kernel plumpness data, which is not yet completed will help to determine if lodging was the cause.

The 1990 crop year provided useful information on nutrient management for optimizing yield and also provided information on the interactive effects of fertilizer amendments on malting quality.

SUMMARY OF CONCLUSIONS

1. Applications of KCl reduced root rot intensity on the sandy loam soil. Root rot was not a problem on the clay loam soil.
2. Yield on the sandy loam soil was increased by N application and increased slightly by KCl application, while P had no significant effect.
3. Yield on the clay loam soil increased with low applications of N but decreased with high N applications. Lodging led to a reduction in crop yield with high N. Application of KCl and P moderated the effect of high N, maintaining yield at higher levels than where KCl and P were not applied.
4. Nitrogen and KCl influenced malting quality on both soils. Interactions between K and N occurred with most of the yield and quality factors, even on the clay loam soil, which was well-supplied with K. Phosphorus had little effect on malting quality.

PLANS FOR 1991

We plan to continue this study without major modification in 1991. The study will be conducted on the same sandy loam site but shifted to a different clay loam site, since soil test N levels on the previous location tested high in the fall of 1990.

Table 1: Common root rot in malting barley as influenced by KCl and N applications (1 = clean, 4 = severe)

Treatment (N-P-K)	ARGYLE	ELLICE
8-0-0	2.95 a[1]	3.20 ab
8-0-100	1.85 b	2.95 ab
30-0-0	2.55 ab	3.05 ab
30-0-100	2.80 a	2.80 a
150-0-0	2.55 ab	2.25 cd
150-0-100	2.00 a	2.00 d
0-0-0	3.20 a	3.55 a
0 K	2.68 a	2.83 a
100 K	2.22 b	2.58 b

[1] Numbers followed by the same letter do not differ at the 5% significance level.

Table 2: ANOVA for effects of N, P and K application on grain yield of Ellice and Argyle barley on a clay loam and sandy loam soil.

Source of Variation	Clay Loam		Sandy Loam	
	Ellice	Argyle	Ellice	Argyle
N	2.53*	ns	50.89***	95.12***
P	8.89**	11.75**	ns	ns
K	ns	7.58**	ns	ns
N x P	ns	ns	2.48*	ns
N x K	ns	ns	ns	ns
P x K	ns	ns	ns	ns
REP	2.87*	ns	10.49***	8.10
CV	7.79	10.1	12.8	11.1
R-square	0.33	0.36	0.81	0.87
EMS	9951	149724	261095	201839

*, **, *** significant at the P<0.05, P<0.01 and P<0.0001 level, respectively.

Table 3. Malting quality factors examined in the present study.

Factor	Abbreviation	Major effect(s) on malting quality
Alpha-Amylase	ALPHA	A measure of the actual amount of active enzyme present. Generally, the higher the value, the better the 'quality'.
Diastatic Power	DP	A measure of the enzyme's ability to convert starch into sugar. The sugar is the by-product desired in the manufacture of beer, whiskey and malt confections. The higher the value, the better the product.
Amino N	AMINO	Amount of proteinacious N available in the malt for use by yeast as a nutrient. Generally, the more is present, the better is the yeast's ability to convert sugar to alcohol.
Malt Extract Difference	DIFF	The mathematical difference between the crude and refined malt extract yield. The lower values indicate a better yield.
Viscosity	VISC	The measure of the viscosity of the extracted malt. A less viscous malt extract is desired.
Kernel Protein	PROT	Total amount of N present in the kernel x 5.6 expressed as a percentage. Maltsters prefer a value of between 10 and 13%.

Table 4: Alpha amylase (ALPHA), diastatic power (DP), amino acid content (AMINO) of Ellice and Argyle barley as influenced by N, P and K application on a clay loam and sandy loam soil.

	CLAY LOAM								SANDY LOAM							
	ELLICE				ARGYLE				ELLICE				ARGYLE			
TREATMENT	ALPHA	DP	AMINO	PROTEIN	ALPHA	DP	AMINO	PROTEIN	ALPHA	DP	AMINO	PROTEIN	ALPHA	DP	AMINO	PROTEIN
8.6-0-0	28.0	292	0.515	13.72	25.3	340	0.490	12.94	27.0	280	0.550	12.60	27.6	348	0.460	12.26
8.6-40-0	26.5	275	0.520	14.18	23.0	281	0.440	12.71	26.6	262	0.505	12.04	26.2	336	0.445	12.15
8.6-0-100	22.8	222	0.500	13.95	20.8	247	0.395	12.94	28.8	274	0.470	12.82	26.0	284	0.440	12.04
8.6-40-100	26.0	231	0.505	14.22	23.6	270	0.390	13.50	27.8	264	0.480	12.94	28.0	304	0.450	12.71
30-0-0	23.6	220	0.470	14.40	20.8	237	0.400	12.60	29.2	281	0.530	12.82	27.1	365	0.475	11.92
30-40-0	27.6	258	0.530	15.75	23.2	264	0.420	13.50	29.6	280	0.530	12.82	27.8	354	0.445	11.92
30-0-100	26.6	250	0.565	15.19	23.8	267	0.420	13.61	29.2	298	0.520	12.82	26.8	329	0.420	12.26
30-40-100	28.0	313	0.595	14.18	24.4	342	0.440	12.60	27.6	276	0.520	12.60	28.4	340	0.430	12.38
60-0-0	27.6	256	0.540	15.52	23.4	270	0.465	13.39	30.0	329	0.585	12.72	26.0	342	0.450	11.70
60-40-0	29.6	336	0.625	14.51	26.4	374	0.500	12.94	26.8	269	0.530	12.72	27.2	372	0.475	12.04
60-0-100	26.1	271	0.570	13.95	23.6	302	0.450	12.94	28.3	284	0.505	12.72	25.2	338	0.465	12.26
60-40-100	23.7	232	0.505	14.62	21.2	256	0.390	13.28	30.5	292	0.490	13.16	25.8	344	0.470	12.49
90-0-0	27.6	296	0.605	14.51	23.6	310	0.480	13.05	29.7	309	0.555	13.50	25.2	361	0.500	12.38
90-40-0	24.2	240	0.515	14.85	21.0	261	0.420	13.05	27.3	292	0.560	12.82	24.2	344	0.485	12.15
90-0-100	27.2	257	0.590	15.98	23.6	282	0.440	13.84	28.0	290	0.580	13.16	25.8	364	0.480	12.60
90-40-100	26.4	260	0.555	14.51	20.9	260	0.365	12.49	27.4	302	0.540	13.28	26.4	337	0.500	12.49
120-0-0	27.1	276	0.600	16.20	23.3	284	0.485	13.73	31.2	365	0.615	13.72	26.7	395	0.530	12.60
120-40-0	28.4	270	0.590	16.42	23.9	284	0.455	13.95	30.4	350	0.615	13.28	24.6	337	0.510	12.49
120-0-100	28.6	320	0.640	14.51	24.9	359	0.475	12.82	27.8	297	0.550	13.50	22.9	338	0.540	12.15
120-40-100	28.0	302	0.605	15.08	24.2	327	0.420	13.16	27.8	322	0.560	13.84	23.6	346	0.535	12.49
150-0-0	30.0	347	0.660	14.40	26.2	380	0.535	13.28	29.0	336	0.615	13.27	25.5	398	0.535	12.38
150-40-0	28.5	314	0.625	14.51	25.8	334	0.485	13.50	30.6	354	0.645	14.06	23.6	356	0.505	12.38
150-0-100	24.2	245	0.545	14.96	21.6	272	0.380	13.05	28.1	354	0.585	13.50	24.4	380	0.585	12.60
150-40-100	28.1	266	0.580	16.88	24.0	288	0.400	13.61	27.4	335	0.565	13.61	24.2	370	0.580	12.60

Table 5: ANOVA for effects of N, P and K application on alpha-amylase (ALPHA), diastatic power (DP), amino acid content (AMINO) and protein content of Ellice and Argyle barley on a clay loam and sandy loam soil.

SOURCE OF VARIATION	CLAY LOAM								SANDY LOAM							
	ELLICE				ARGYLE				ELLICE				ARGYLE			
	ALPHA	DP	AMINO	PROTEIN	ALPHA	DP	AMINO	PROTEIN	ALPHA	DP	AMINO	PROTEIN	ALPHA	DP	AMINO	PROTEIN
N	ns	3.49*	11.77***	5.04**	ns	2.72*	ns	ns	ns	14.95***	19.28***	9.99***	10.15***	4.83**	50.86***	ns
P	ns	ns	ns	ns	ns	ns	7.65**	ns	ns	ns	ns	ns	ns	ns	ns	ns
K	4.09*	6.05*	ns	ns	ns	ns	33.83***	ns	ns	ns	29.31***	ns	ns	9.93**	ns	12.45**
N x P	ns	ns	2.72*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
N x K	3.31*	8.09***	6.68**	6.35**	3.07*	6.72**	4.90**	ns	3.05*	ns	ns	ns	2.54*	ns	6.83**	ns
P x K	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	6.35*	ns	ns	4.28*
REP	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV	6.94	9.05	5.46	4.28	7.27	10.44	6.89	4.81	4.81	7.02	4.56	2.96	4.37	7.18	3.60	2.17
R square	0.58	0.73	0.79	0.71	0.54	0.69	0.76	0.28	0.53	0.77	0.84	0.69	0.73	0.62	0.91	0.037
EMS	3.47	610	0.00095	0.5056	2.898	951	0.000917	0.496	189	455	0.0006	0.186	1.274	635	0.000309	0.0880

*, **, *** significant at the P<0.05, P<0.01 and P<0.0001 level, respectively.

Table 6: Fine fraction extract (FF), coarse fraction extract (CF), difference (DIFF) and viscosity (VISC) of Ellice and Argyle barley as influenced by N, P and K application on a clay loam and sandy loam soil.

Treatment $kg\ ha^{-1}$ N-P-K	CLAY LOAM								SANDY LOAM							
	ELLICE				ARGYLE				ELLICE				ARGYLE			
	FF	CF	DIFF	VISC	FF	CF	DIFF	VISC	FF	CF	DIFF	VISC	FF	CF	DIFF	VISC
8.6-0-0	61.6	64.6	3.05	1.40	61.0	64.8	3.75	1.35	63.8	60.6	3.15	1.30	62.5	59.6	2.90	1.18
8.6-40-0	58.0	63.8	5.75	1.34	60.2	64.4	4.25	1.32	65.2	61.8	3.40	1.37	62.5	58.8	3.70	1.26
8.6-0-100	58.6	63.8	5.25	1.18	57.0	62.9	5.85	1.48	64.0	61.8	2.20	1.20	62.9	58.8	4.10	1.42
8.6-40-100	59.3	65.0	5.70	1.19	59.3	63.8	4.55	1.30	64.2	61.8	2.40	1.21	63.8	60.8	3.00	1.20
30-0-0	58.4	64.0	5.60	1.32	58.2	64.8	6.55	1.27	64.5	63.2	1.30	1.27	63.1	58.4	4.70	1.14
30-40-0	59.3	62.9	3.60	1.32	60.2	64.8	4.65	1.08	64.6	62.8	1.80	1.32	63.1	59.4	3.70	1.34
30-0-100	59.5	64.2	4.70	1.34	60.7	64.6	3.90	1.28	64.4	61.6	2.80	1.20	63.6	60.4	3.15	1.20
30-40-100	58.8	64.2	5.40	1.34	60.0	63.1	3.10	1.28	63.3	61.0	2.30	1.38	64.2	61.0	3.20	1.23
60-0-0	59.2	65.4	6.20	1.28	61.6	65.0	3.45	1.08	63.1	61.2	1.90	1.28	62.9	57.8	5.10	1.27
60-40-0	56.5	63.3	6.80	1.29	60.7	62.7	2.00	1.22	62.7	60.0	2.70	1.30	62.9	59.6	3.30	1.33
60-0-100	59.0	63.1	4.15	1.26	59.5	63.1	3.60	1.38	64.6	63.2	1.40	1.36	62.7	57.8	4.90	1.40
60-40-100	58.4	64.0	5.60	1.32	55.8	63.5	7.70	1.51	65.2	62.6	2.60	1.18	62.5	58.0	4.50	1.36
90-0-0	58.2	63.4	5.20	1.45	59.6	61.8	2.10	1.18	64.0	60.4	3.60	1.27	61.9	57.6	4.30	1.40
90-40-0	58.8	63.6	4.85	1.42	57.0	62.1	5.10	1.46	62.9	58.6	4.30	1.34	61.4	56.4	5.05	1.48
90-0-100	57.9	63.3	5.40	1.24	57.9	63.1	5.20	1.39	64.2	60.0	4.20	1.14	62.1	57.2	4.90	1.40
90-40-100	60.0	63.3	3.30	1.30	56.4	62.1	5.75	1.49	63.6	59.8	3.75	1.16	63.8	59.8	3.95	1.34
120-0-0	58.8	63.1	4.35	1.44	58.2	63.3	5.05	1.42	62.1	58.4	3.70	1.35	61.7	56.8	4.90	1.37
120-40-0	57.9	63.3	5.40	1.35	58.8	62.7	3.95	1.34	61.7	58.4	3.30	1.24	60.8	55.2	5.60	1.35
120-0-100	59.5	62.0	2.45	1.27	57.9	62.3	4.40	1.40	62.9	58.8	4.10	1.14	62.1	55.4	6.70	1.44
120-40-100	58.8	62.9	4.10	1.25	58.4	61.9	3.45	1.40	62.9	57.8	5.10	1.30	62.1	55.6	6.90	1.48
150-0-0	56.5	63.3	6.80	1.36	58.2	60.4	2.15	1.42	61.0	58.2	2.85	1.16	62.5	54.4	8.10	1.46
150-40-0	57.4	62.9	5.55	1.36	58.4	62.5	4.10	1.42	61.3	57.4	3.90	1.21	60.6	53.4	7.25	1.45
150-0-100	58.4	62.5	4.10	1.29	56.5	61.9	5.40	1.51	61.7	56.0	5.70	1.20	61.0	53.8	7.25	1.45
150-40-100	58.6	61.2	2.55	1.33	57.0	63.3	6.25	1.46	61.5	56.4	5.10	1.24	60.6	53.8	6.80	1.52

Table 7: ANOVA for effects of N, P and K application on fine fraction extract (FF), coarse fraction extract (CF), difference (DIFF) and viscosity (VISC) of Ellice and Argyle barley on a clay loam and sandy loam soil.

	CLAY LOAM								SANDY LOAM							
	ELLICE				ARGYLE				ELLICE				ARGYLE			
SOURCE OF VARIATION	FF	CF	DIFF	VISC	FF	CF	DIFF	VISC	FF	CF	DIFF	VISC	FF	CF	DIFF	VISC
N	3.69*	6.11**	2.97*	ns	5.28**	11.47***	ns	7.47***	49.11***	43.32***	13.83***	ns	14.59***	32.78***	18.31***	16.65***
P	4.33*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
K	9.15**	10.74**	31.00***	ns	14.96**	ns	8.66**	22.32***	11.68**	ns	4.49*	7.55**	6.12*	ns	ns	ns
N x P	ns	ns	ns	ns	2.92*	3.02*	2.69*	4.83**	3.06*	ns	ns	ns	ns	ns	ns	ns
N x K	ns	ns	2.54*	6.81**	3.82*	2.92*	5.58**	2.81*	8.57***	5.62**	3.89**	ns	3.15*	ns	ns	ns
P x K	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	7.06*	ns	ns	5.49*
REP	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV	1.41	1.25	19.14	5.09	1.99	1.28	26.70	5.49	0.74	1.49	24.24	6.02	1.00	1.99	20.16	4.83
R-square	0.66	0.66	0.71	0.65	0.73	0.77	0.66	0.78	0.92	0.90	0.78	0.55	0.80	0.87	0.79	0.80
EMS	0.681	0.628	0.837	0.0045	1.36	0.652	1.398	0.0065	0.22	0.802	0.614	0.0057	0.390	1.305	0.982	0.0043

*, **, *** significant at the P<0.05, P<0.01, and P<0.0001 level, respectively.

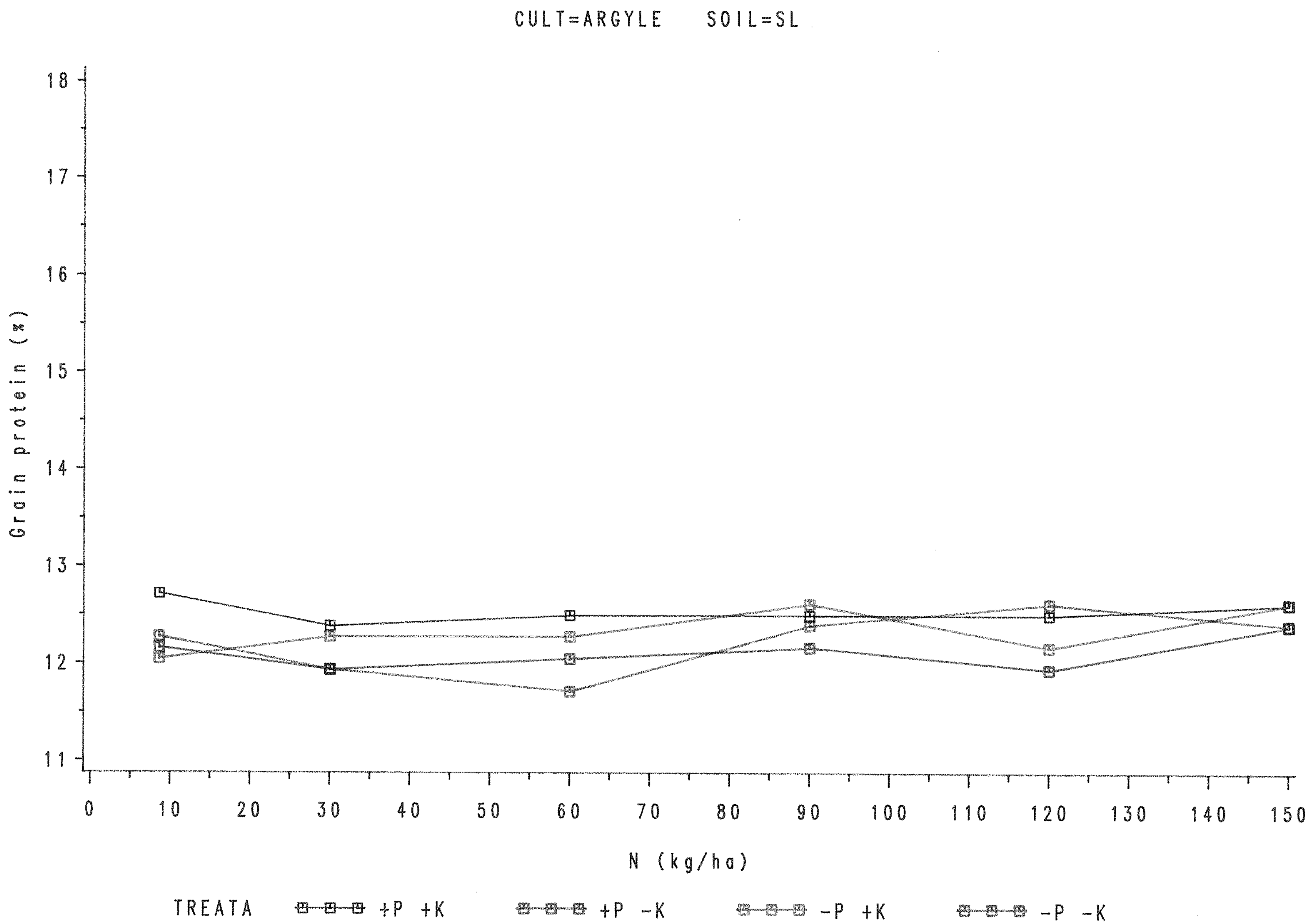

Fig. 6 Grain protein as influenced by fertilizer application

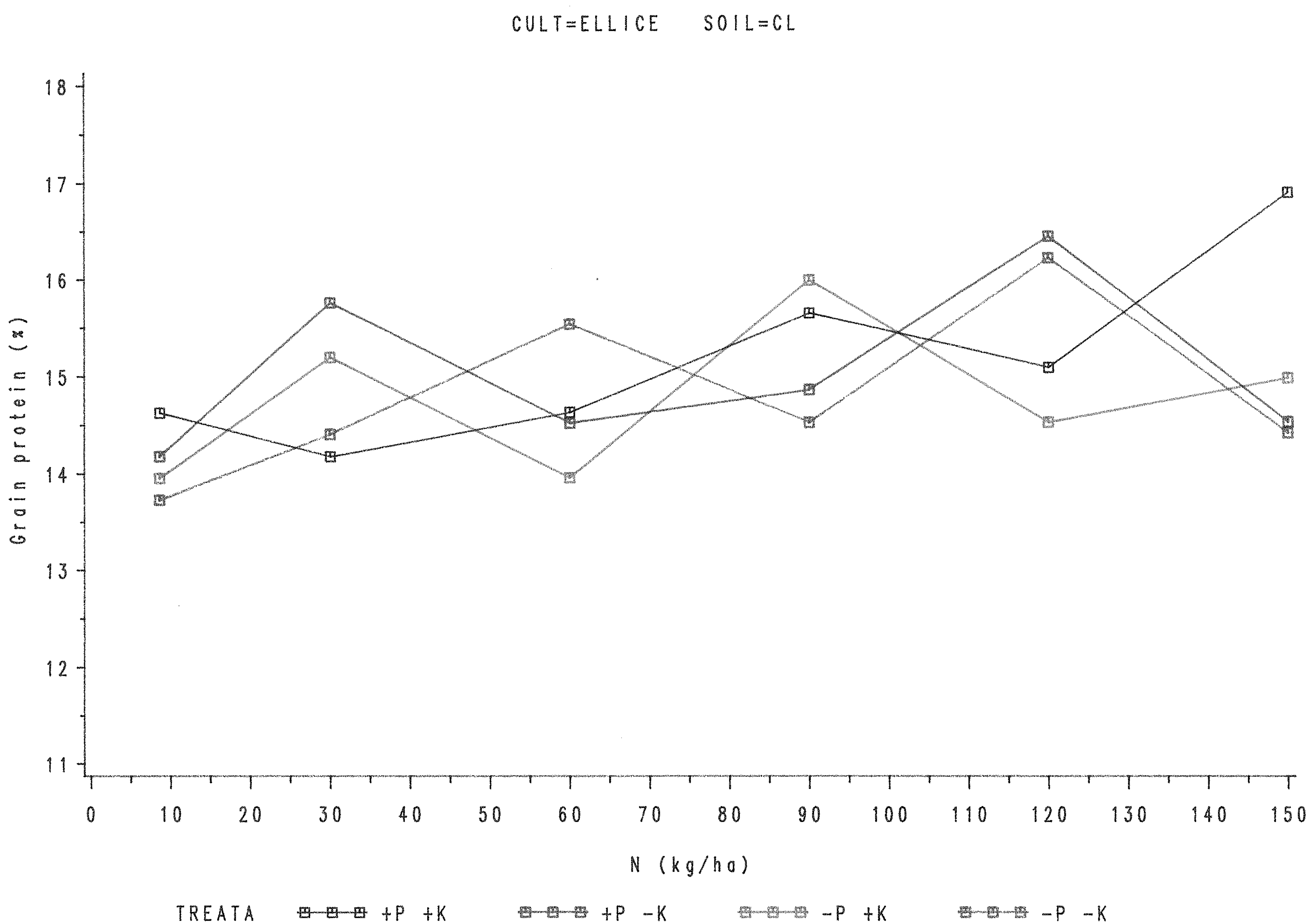

Fig. 7 Grain protein as influenced by fertilizer application

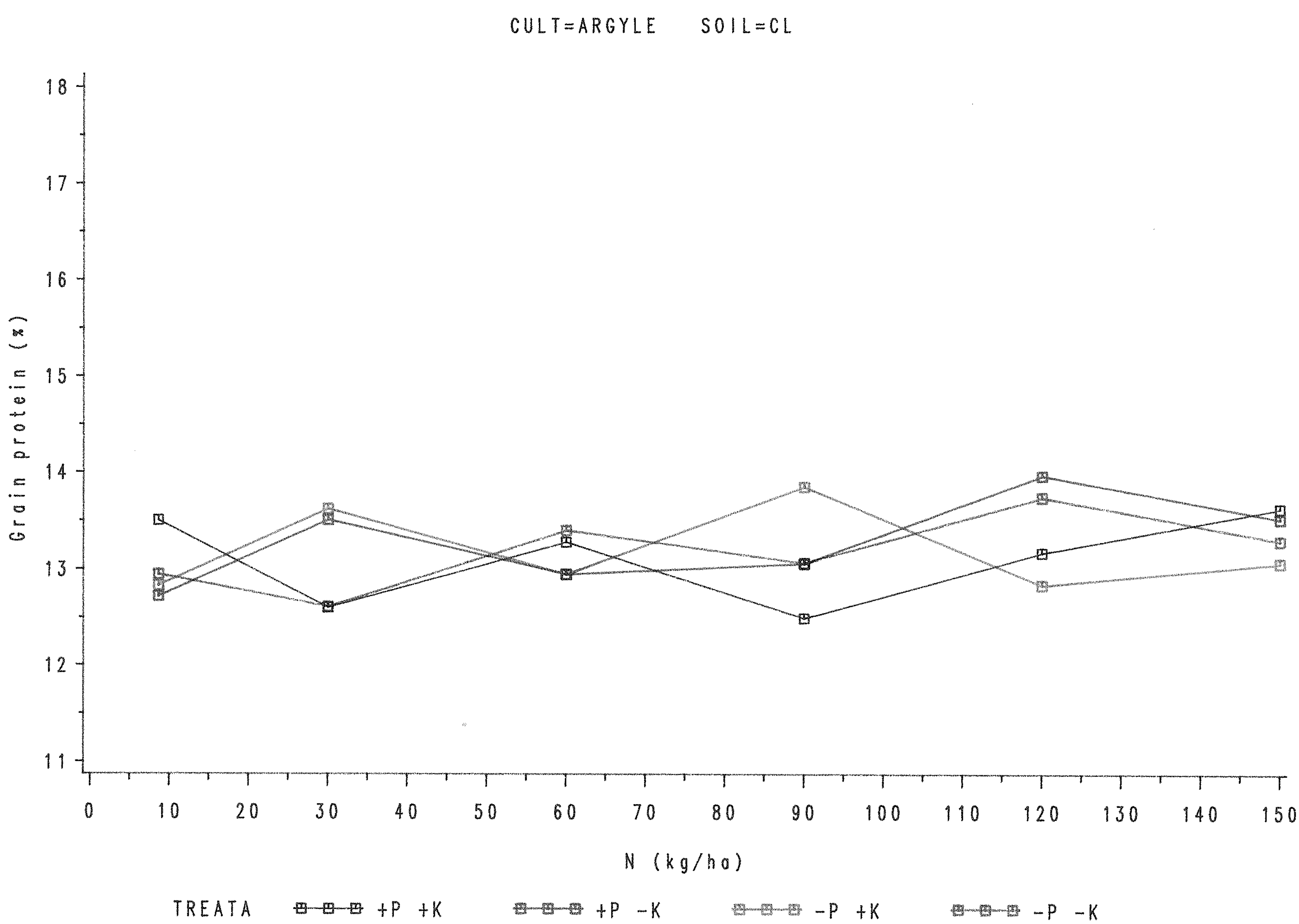

Fig. 8 Grain protein as influenced by fertilizer application

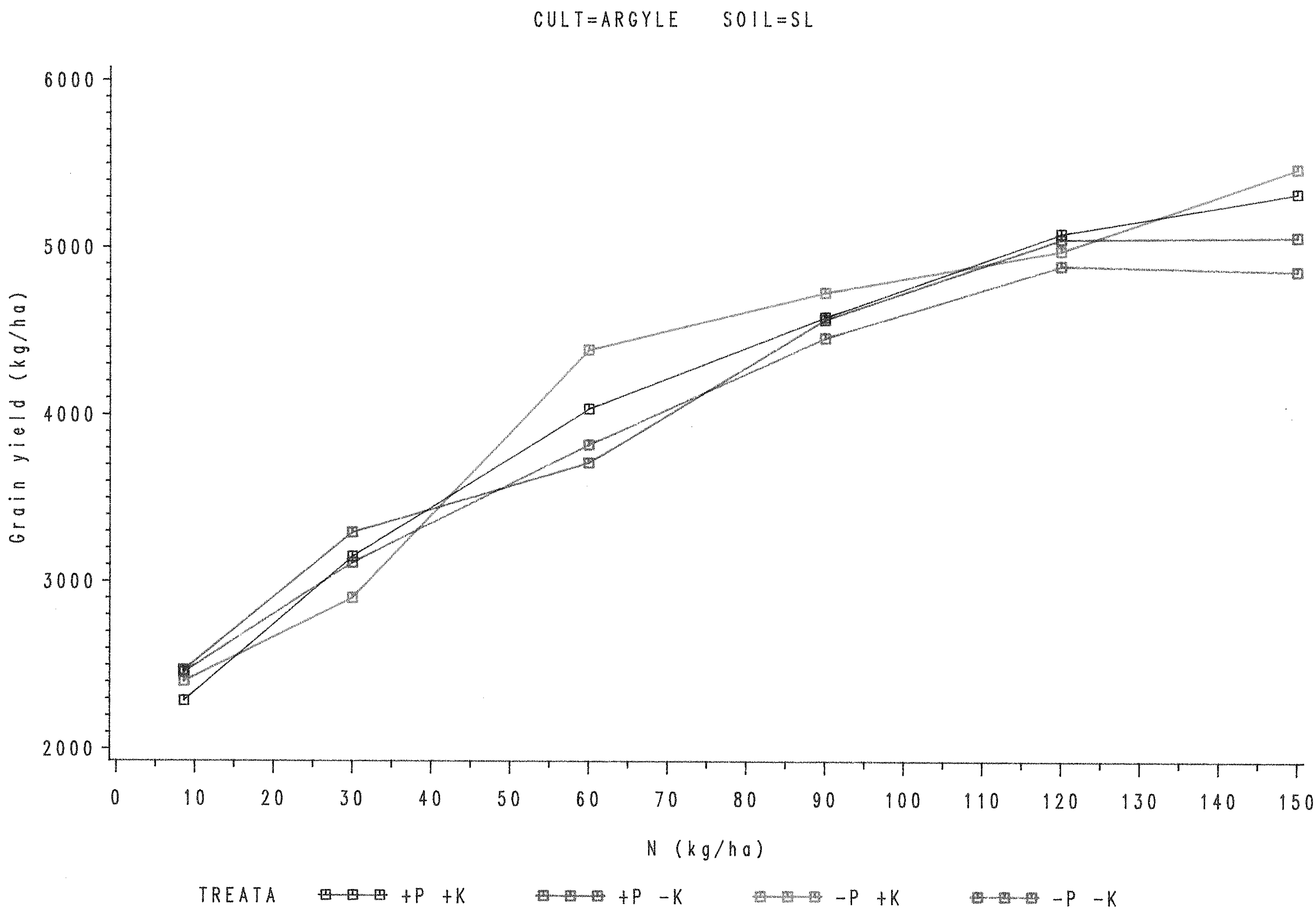

Fig.2 Barley yield as influenced by fertilizer applications

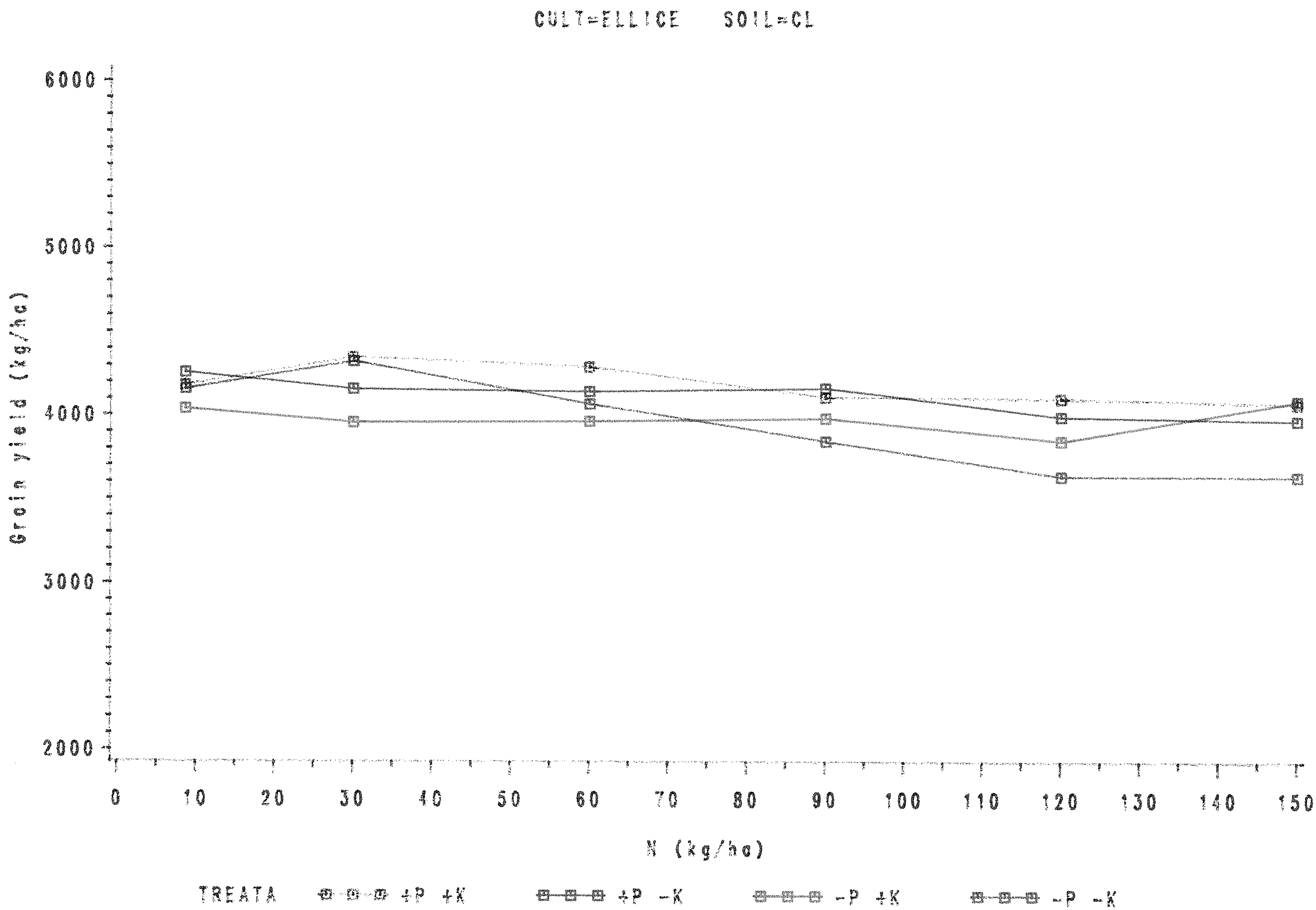

Fig. 3 Barley yield as influenced by fertilizer applications

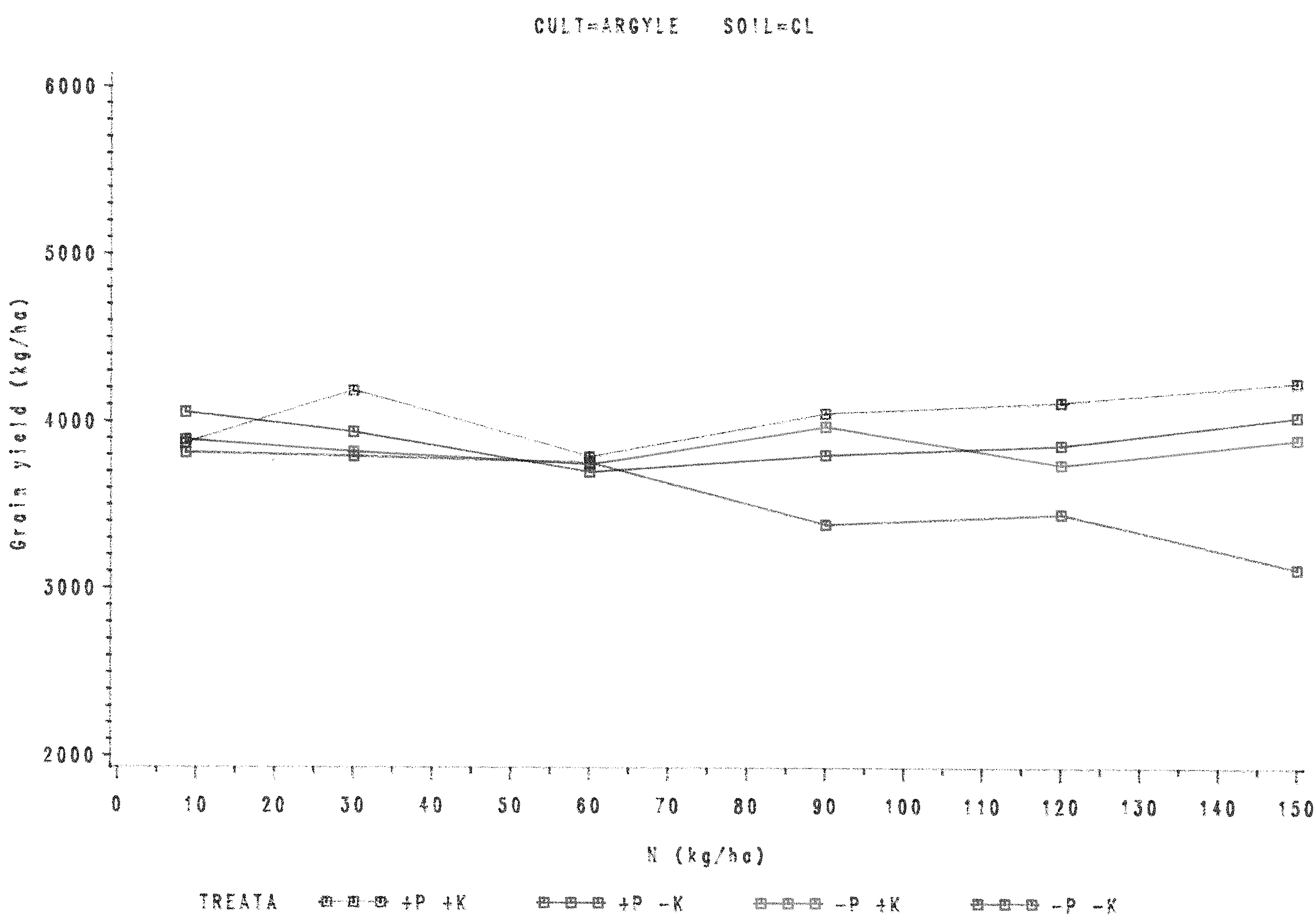

Fig.4 Barley yield as influenced by fertilizer applications

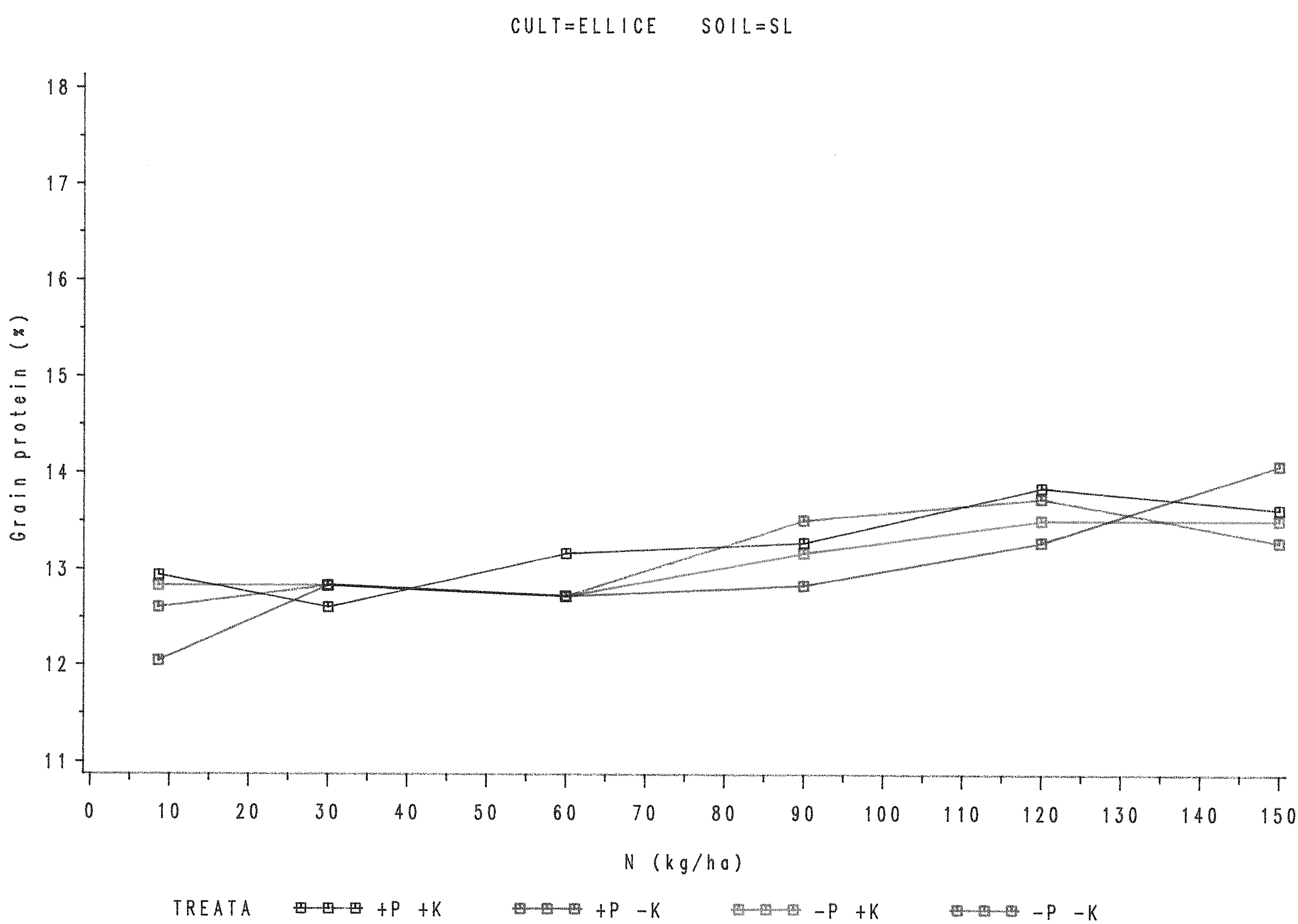

Fig. 5 Grain protein as influenced by fertilizer application

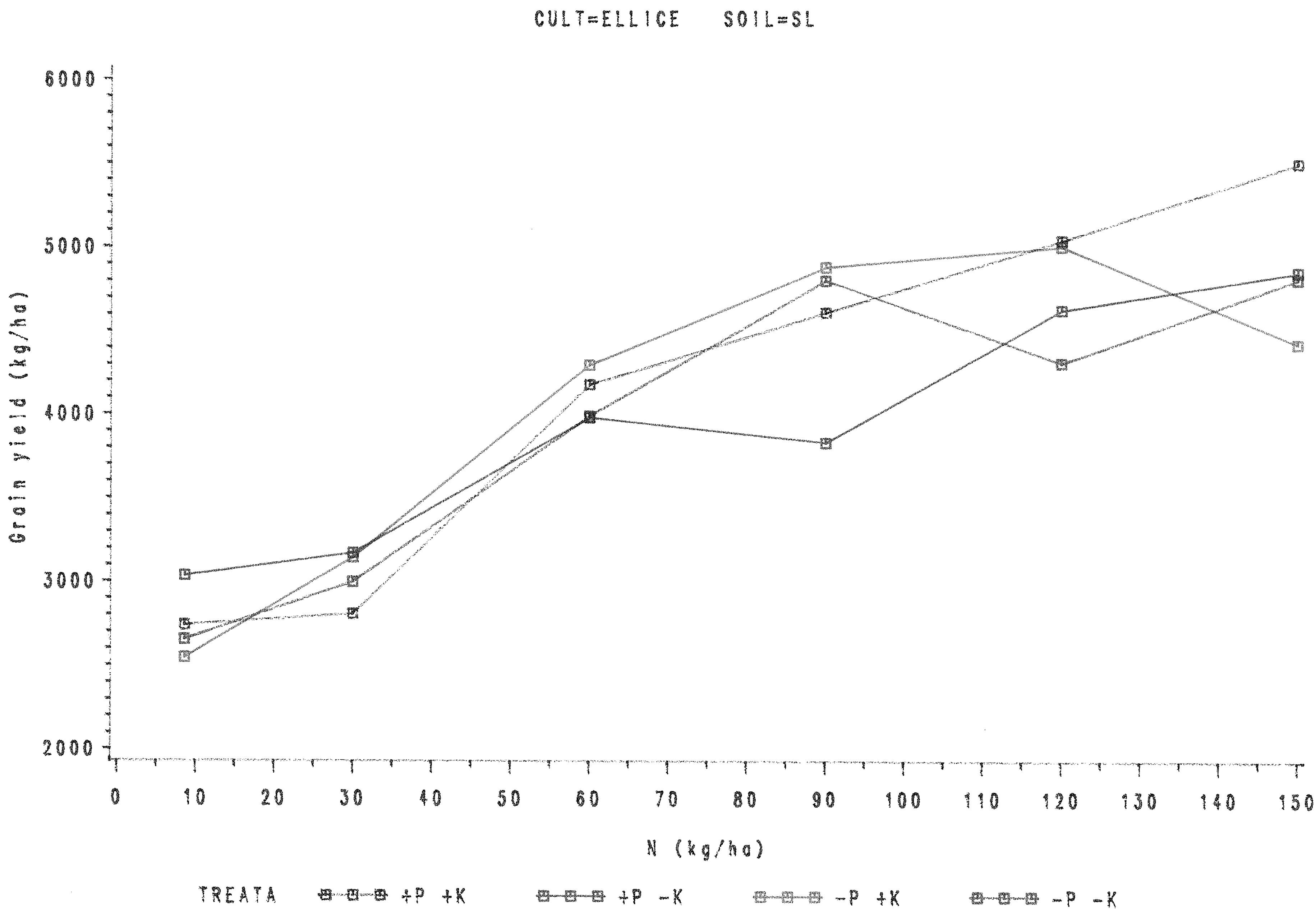

Fig. 1 Barley yield as influenced by fertilizer applications