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NITROGEN, PHOSPHORUS AND POTASSIUM FERTILITY REQUIREMENTS FOR OPTIMIZING PROTEIN LEVELS IN MALTING BARLEY - PROJECT REPORT 1992

C.A. GRANT AND M.C. THERRIEN
AGRICULTURE CANADA, BRANDON RESEARCH STATION
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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 for 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, sufficient N should be applied 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

1990

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 average 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 sulphur 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 $acre^{-1}$, 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 $acre^{-1}$, respectively) was sprayed on the clay loam soil on June 14 and Estaprop (0.71 l $acre^{-1}$) 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, with 4 being severe, 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 will be presented when analysis from all years are completed. Grain yield, protein content and malting quality were determined at maturity (12% moisture). Final yield was taken on August 13 on the sandy loam and September 12 on the clay loam soil.

1991

In 1991, sites were again selected on a Souris fine sandy loam and a Newdale clay loam, however, a new plot area was utilized to avoid carry-over of nutrients from the previous season. Soil samples were taken in the fall of 1990 and tested for N, P, K, S, pH and conductivity. Samples were tested for moisture content to 120 cm, immediately prior to seeding and again at the completion of the season, immediately after harvest. Procedures for weed control, seeding and fertilization were the same as in 1990. As in 1990, cultivars used were Ellice and Argyle. Seeding dates were May 10 on the Souris fine sandy loam site and May 30 on the Newdale clay loam site.

Common root rot severity was measured at early tillering on the fine sandy loam site, but incidence was very low at the clay loam site, so ratings were not taken there. Net blotch was also measured at heading on the fine sandy loam, but not on the clay loam site, due to low disease incidence. Biomass yield and nutrient content were measured at early heading on two 1 meter lengths of row.

Nutrient analysis is not complete. Grain yield, protein content and malting quality were determined at maturity (12% moisture). Final yield was taken in early August on the fine sandy loam and early September on the clay loam sites.

1992

In 1992, sites were selected on the Souris fine sandy loam and Newdale clay loam, adjacent to where the sites were in 1991. Soil samples were taken in the fall of 1991 and tested for N, P, K, S, pH and conductivity. Samples were tested for moisture content to 120 cm, immediately prior to seeding and again at the completion of the season, immediately after harvest. Procedures for weed control, seeding and fertilization were the same as in 1991. As in 1990 and 1991, cultivars used were Ellice and Argyle. Seeding dates were May 4 on the Souris fine sandy loam site and May 7 on the Newdale clay loam site.

Common root rot severity was measured at early tillering on the fine sandy loam site, but incidence was very low at the clay loam site, so ratings were not taken there. Net blotch was also measured at heading on the fine sandy loam, but not on the clay loam site, due to low disease incidence. Biomass yield and nutrient content were measured on July 10 on the fine sandy loam and July 16 on the clay loam, at early heading on two 1 meter lengths of row.

Nutrient analysis is not complete. Grain yield, protein content and malting quality were determined at maturity (12% moisture). Final yield was taken August 25 on the fine sandy loam and August 26 on the clay loam sites.

RESULTS

Note: Tables and figures for disease incidence and protein in 1990 and 1991 were presented in the previous reports and will not be included here. Data for yield in these years is repeated, for your information.

1990

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

On the clay loam, yield was increased slightly with application of low levels of N fertilizer in Ellice but not Argyle (Table 1, Figs 1 and 2). 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 when one or both of these nutrients were omitted. On the sandy loam, grain yield was increased by the addition of N, but was not significantly influenced by P application (Table 1, Figs 3 and 4). Ellice showed a slight increase in yield ($P<0.10$) with application of KCl, while Argyle showed an NxK interaction ($P<0.10$) with slightly higher yields when KCl was applied with N levels above 30 kg ha^{-1}.

Protein levels were at the high end of the range for commercial standards, with the exception of Ellice on the clay loam soil. High levels of protein (13.5 to 16%) for Ellice on the clay loam were likely due to lodging-induced stress. Protein content of both cultivars on the fine sandy loam and of Ellice on the clay loam increased with increasing N fertilization, while that of Argyle on the clay loam soil was not influenced by fertilizer treatment. Grain protein content was generally unaffected by P or K content, although protein content of Argyle on the fine sandy loam was increased by application of KCl.

1991

In 1991, on the sandy loam soil, common root rot incidence was relatively low, variability was high and common root rot was not influenced by fertilizer treatment. Net blotch was influenced by fertilizer treatment in both cultivars. In Ellice, net blotch tended to be slightly greater when P was applied then when no P was added. In Argyle, net blotch was also higher when P was added, but decreased with high levels of applied N. Common root rot and net blotch incidence were very low on the clay loam soil, therefore, ratings were not taken.

Grain yield was slightly higher on the clay loam soil than on the fine sandy loam soil (Table 1, Figs. 5 to 8). Ellice tended to outyield Argyle on the clay loam soil, particularly at the higher N levels. The superior yield of Ellice as compared to Argyle was likely due to lodging which occurred in Argyle at the higher N levels. Grain yield of Ellice showed a significant linear and quadratic response to N application, increasing with each N addition to 60 kg ha^{-1} of applied N, then remaining relatively constant when N level was increased to 120 or 150 kg N ha^{-1} (Table 1, Fig. 5). Argyle showed a significant quadratic response to applied N, increasing with N applications to 60 kg N ha^{-1}, then decreasing with N additions above 60 kg N ha^{-1}, due primarily to lodging (Fig. 6). Ellice showed no significant response to KCl or P additions, but Argyle showed a significant increase in yield in response to applications of KCl. This may be due to improved straw strength in Argyle with applied KCl.

Grain yield of the two cultivars on the sandy loam soil was similar at low fertility levels, but, in contrast to the case on the clay loam soil, Argyle tended to outyield Ellice on the sandy loam soil at the higher N levels. The difference between the two cultivars may relate to the greater disease resistance of Argyle. Yield of both cultivars showed a significant linear and quadratic response to N application, increasing to approximately 90 kg ha^{-1} applied N, then levelling off or decreasing slightly (Table 1, Figs. 7 and 8). Grain yield was also increased slightly by KCl applications in both cultivars. A NxP interaction occurred in Argyle, but not Ellice, with yield being higher where P was applied with KCl and high levels of N (Figure 8).

1992

Disease level on the barley grown on the clay loam soil was low and ratings were not taken. Foliar diseases on Argyle on the sandy loam were reduced with N application ($p<0.0089$) and increased with KCl appication ($p<0.0077$). On Ellice on the sandy loam, disease levels were again increased with KCl application ($p<0.0158$). Disease incidence was higher in Ellice than in Argyle ($p<0.0111$), due mainly to the inherent resistance in

Argyle. Variability in disease was also high.

Grain yield in 1992 was extremely high on both sites (Table 1, Figs. 9 to 12). On the clay loam soil, Argyle outyielded Ellice at all N levels, while on the sandy loam soil, Ellice outyielded Argyle slightly at the low N levels and the two cultivars were similar in yield at the high N levels. On the clay loam soil, there was a very strong linear and a strong quadratic response to N, with yield increasing almost linearly to 90 kg N ha^{-1} and then increasing at a lesser rate between 90 and 150 kg N ha^{-1}, the highest level used in this study (Figs. 9 and 10). Neither cultivar showed a response to P application on the clay loam soil, but yield of Ellice was increased slightly with KCl applications, particularly at the higher N levels.

Grain yield on the fine sandy loam was lower and slightly more variable than on the clay loam, with a lower response to N applications (Figs. 11 and 12). In spite of the placement of fertilizer 2.5 cm below and 2.5 cm to the side of the seed-row, seedling damage was noted at the higher N levels on this soil, leading to reduced stand density. The sensitivity of crops to seedling damagem from fertilizer additions was noted in a number of experiments this year and may have been due to the cold soil temperatures and slow crop growth early in the growing season. This damage combined with some moisture stress through the growing season may have reduced the response to N fertilizer. Ellice showed no yield response to either P or KCl fertilizer, while Argyle produced higher grain yield with the application of P, particularly at N levels of 90 kg N ha^{-1} or greater. This was reflected in a significant NxP interaction.

1990-92

When the grain yield data was combined over the three years of the study, yields of Argyle and Ellice were virtually identical on the clay loam and very similar on the fine sandy loam soil (Figs. 13 to 16). Yield of Ellice on the clay loam showed a strong linear and quadratic response to N, increasing to approximately 90 kg N ha^{-1} and then increasing only slightly between 90 and 150 kg N ha^{-1} (Table 1. Fig. 13). Yield of Argyle showed a similar pattern (Fig. 14). Only Ellice showed a response to P application and the response was only significant at the $P < 0.10$ level. Both Argyle and Ellice showed higher yield with application of KCl, with a tendency for the difference to be greater at the higher N levels.

On the fine sandy loam, grain yield of both Ellice and Argyle showed a linear and quadratic response to N application, as on the clay loam soil (Figs 15 and 16). Grain yield increased at a high rate to 60 kg N ha^{-1}, then increased only slightly between 60 and 150 kg N ha^{-1}. The lower response to N application in the fine sandy loam soil as compared to the clay loam soil presumably relates to the lower available water on the fine sandy loam. Neither Ellice nor Argyle showed a significant response to KCl application when data was combine for the three years of the study. However, Argyle demonstrated a response to P, with an NxP interaction which indicated that the response to P was greater at higher N levels (Fig. 16).

Malting Quality

Materials and methods

After harvest, a subsample of grain was taken from each plot, and a 350 g sample was cleaned using a Clipper cleaner. Samples were malted in a Carlsberg micromalting unit, dried to desiccation in a commercial vacuum-pulled freeze-drying unit and the malt ground to uniform 0.1 mm size in a Wiley mill. Alpha-amylase enzyme, free amino nitrogen, viscosity and soluble protein were determined colorimetrically on an auto-analyzer. Coarse and fine extract were determined by first coarse grinding (to a uniform size of 0.5 mm) and then fine grinding (to a uniform size of 0.1 mm) a subsample of malted barley, weighing each ground subsample initially, extracting the malt with distilled water at 70 deg. C., and drying and weighing the material that did not go into solution. Extract was then determined as a percentage of the total weight of sample that went into solution as malt. Diastatic power (enzyme activity) was determined using a controlled digest of reagent grade sucrose in the presence of the malt extract.

The malting quality factors examined, as well as their significance in determining malting quality, are summarized in Table 2.

Table 2. Malting quality factors examined in the present study.

Factor	Abbreviation	Major effects
Alpha-Amylase	ALPHA	A measure of the actual amount of active enzyme present.
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.
Amino N	AMINO	Amount of proteinaceous N available in the malt for use by yeast as a nutrient. Excessive amounts however, make chill haze in beer, an undesirable effect.
Coarse Extract	CE	The percentage of dry malt that

		is soluble in hot (70 deg. C) water, after coarse grinding. This is indicative of the amount of extractable malt in a commercial malthouse and is sometimes referred to as "malthouse yield".
Fine Extract	FE	The percentage of dry malt that is soluble in 70 deg C. water after fine grinding. This is indicative of the total amount of malt that can be extracted from a given sample.
Malt Extract Difference	DIFF	The mathematical difference between the coarse and fine malt extract yield. The lower values indicate a better quality malt.
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%.

Results

1990

Enzyme levels were largely unaffected by treatments at either site. There was a significant drop in alpha-amylase for Argyle at the sandy loam (SL) site with increasing N, and a significant drop in enzyme level with added KCl in Argyle at the clay loam (CL) site (Table 2). However, values for enzyme levels were erratic in nature (Figs.17-18), probably due to the relatively high stress levels, as measured by the low yields (Figs. 1-4).

Diastatic power was significantly increased with N treatment in all cultivar x N treatment combinations, except Argyle on the CL soil. Argyle on CL, in fact, performed exactly opposite from other treatment x cultivar combinations for most of the malting quality characteristics examined. This can only be explained by a specific genotype by environment interaction, as this pattern is not repeated elsewhere. Addition of K reduced DP for Argyle, but not for Ellice. However, like enzyme levels, DP levels were highly variable with respect to treatments and may reflect the relatively high environmental stress levels experienced in 1990.

Both coarse and fine extract were significantly reduced with increasing N in most cultivar x N combinations. This is in sharp contrast to the observed increases in DP. Thus, it would appear that reduced malt yield was a result of environmental stress and not a result of reduced enzyme activity.

The remaining three malting quality parameters examined, namely viscosity, amino N and soluble protein content, all increased with increasing N levels. Addition of K was able to reduce amino N content in Ellice at both sites, but not Argyle, indicating a cultivar-specific response. These responses fit expectations for an increase of kernel soluble N levels with increasing applied N fertilizer.

1991

Fertility treatments had no effect on the level of enzyme present in 1991. The only exception was a significant P and K response on Ellice barley on SL, with P enhancing and K reducing the level of enzyme present. Since the observed response was unique, this effect was probably due to genotype by environment interaction.

Diastatic power generally followed the same patterns as enzyme levels, being unaffected by treatment. The one exception was again Ellice, on CL instead of SL, and there was a significant increase from N treatment. Comparing the acute response of Ellice to the nil response of Argyle at the same site (Fig. 19 vs. Fig. 20), this would suggest a unique response that are genotype and environment specific.

As with 1990 data, both coarse and fine extract decreased significantly with increasing soil N levels, and was independent of enzyme levels or DP. Variability for CE and FE was low, and both cultivars responded in a similar fashion (Figs. 21-24). This pattern would suggest that any added soil N reduces malt yields, a very undesirable effect.

Response levels of amino N, viscosity, and soluble protein were similar to that observed in 1990. Levels generally increased with increasing applied N, and decreased with applied K. Thus, it appears that the addition of KCl may reduce kernel N levels and viscosity where these levels may pose a problem in malting quality. In some cases (Table 2), addition of P elevated levels of kernel N and viscosity and may pose a problem in maintaining malting quality. However, this was not observed in a consistent manner and may only occur in a narrow range of circumstances.

The variety Argyle had better overall malting quality than Ellice at either site (Tables 4 to 8). Argyle consistently had higher DP, and lower VISC and PROT, than Ellice. Response patterns to fertility treatments differed with each cultivar.

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 fine sandy loam site. Severe lodging at the clay loam 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 exception of Ellice on the clay loam soil. High levels of protein (13.5 to 16%) for Ellice on the CL were likely due to lodging-induced stress. The 1990 and 1991 crop years provided useful information on nutrient management for optimizing yield and also provided information on the interactive effects of fertilizer amendments on malting quality.

1992

Malting data not yet available.

SUMMARY OF CONCLUSIONS

1990

1. Applications of KCl reduced root rot intensity at the fine sandy loam site. Root rot was not a problem at the clay loam site.

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.

1991

1. Common root rot incidence at the fine sandy loam site was not influenced by fertilizer treatment. At the clay loam site, root rot was not a problem.

2. Net blotch on the fine sandy loam site was increased slightly by the addition if P fertilizer in both cultivars. In Argyle, net blotch decreased with high levels of applied N. Net blotch on the clay loam site was not a problem.

3. Yield on the clay loam site increased with N applications to approximately 60 kg N ha^{-1}. Above this level, yield of Ellice remained relatively constant, while that of Argyle decreased significantly.

4. Yield of both cultivars on the fine sandy loam soil increased with N applications to approximately 90 kg ha^{-1}, then remained constant or decreased slightly as N level was increased to 150 kg N ha^{-1}.

5. Grain yield of Argyle on the clay loam soil increased with applications of KCl, but P did not influenced yield in either cultivar on the clay loam soil.

6. Grain yield of both Ellice and Argyle on the fine sandy loam soil increased slightly with application of KCl. Yield of Argyle also increased with application of P, but only at the higher N levels.

1992

1. As in 1991, leaf disease in Argyle on the sandy loam soil decreased with N application. Leaf disease in both cultivars on the sandy loam increased with KCl application.

2. Grain yield on the clay loam soil was extremely high and increased almost linearly to 90 kg N ha^{-1} and at a lesser rate from 90 to 150 kg N ha^{-1}. Neither cultivar responsed to P but Ellice yield increased slightly with KCl application.

3. Seedling damage occurred on the sandy loam soil with high N levels, even with fertilizer banded 2.5 cm below and 2.5 cm to the side.

4. On the sandy loam soil, grain yield of both Argyle and Ellice increased with N applications, but at a lesser rate than on the clay loam. Ellice did not respond to P or KCl, while yields of Argyle were higher with P, particularly at high N levels.

1990-1992

1. On the clay loam soil, yield of both Argyle and Ellice increased with N applications to 90 kg, then increased only slightly from 90 to 150 kg N ha^{-1}. Only Ellice responded to P and the response was small ($P<0.1$). Both cultivars responded to KCl, with the effect being greatest at the high N levels.

2. On the sandy loam soil, grain yield of both cultivars increased to 60 kg N ha^{-1} then increased only slightly from 60 to 150 kg N ha^{-1}. Neither cultivar responded to KCl, but Argyle responded to P when N levels were high.

Table 1: F values from GLM analysis of grain yield as influenced by N, P, and K fertilization in Ellice and Argyle barley on a clay loam and fine sandy loam soil, from 1990 to 1992, with values combined over the three year period.

SOURCE OF VARIATION	DF	Clay Loam								Fine Sandy Loam							
		Ellice				Argyle				Ellice				Argyle			
		1990	1991	1992	mean	1990	1991	1992	mean	1990	1991	1992	mean	1990	1991	1992	mean
N	1	** 11.0	*** 27.2	*** 2132.5	*** 657.9	NS	NS	*** 636.8	*** 316.4	*** 251.9	*** 85.0	*** 27.6	*** 162.4	*** 537.5	*** 201.3	*** 65.5	*** 342.0
NxN	1	NS	*** 38.6	*** 107.0	*** 84.6	NS	*** 30.6	*** 22.4	*** 38.8	*** 21.8	*** 36.1	** 7.1	*** 31.4	*** 31.4	*** 49.6	* 6.2	*** 36.4
P	1	** 11.2	NS	NS	+ 3.5	** 13.0	NS	NS	NS	NS	NS	NS	NS	NS	NS	* 4.5	* 4.8
K	1	NS	NS	** 9.4	** 9.9	** 8.1	** 13.4	NS	** 7.3	+ 2.8	*** 23.8	NS	NS	NS	*** 22.3	NS	NS
NxP	1	NS	NS	NS	NS	+ 3.2	NS	NS	NS	NS	NS	NS	NS	NS	* 5.6	+ 3.5	* 5.9
NxK	1	NS	NS	NS	+ 3.5	+ 3.2	NS	NS	NS	NS	NS	NS	NS	+ 3.24	NS	NS	NS
YEAR	2				*** 277.9				*** 672.0				*** 294.0				*** 112.3
YEARxN	2				*** 504.8				*** 327.3				*** 7.5				** 7.5
CV		7.3	10.1	6.9	9.0	10.3	9.89	10.6	11.4	13.6	12.0	19.6	18.7	11.1	11.1	22.5	18.5
R^2		0.28	0.47	0.96	0.89	0.26	0.40	0.88	0.89	0.77	0.63	0.35	0.74	0.87	0.77	0.48	0.69

+ P value < 0.1; * P value < 0.05; ** P value < 0.01; *** P value < 0.0001;

Table 2. Summary of Significance for Specific Malting Quality Characteristics 1990-91:

		SLOAM 1990		CLAY 1990		SLOAM 1991		CLAY 1991	
		ELLICE	ARGYLE	ELLICE	ARGYLE	ELLICE	ARGYLE	ELLICE	ARGYLE
ALPHA	N	3.72	38.81***	1.51	1.58	0.45	1.95	0.78	1.78
	P	1.30	0.05	0.02	0.83	4.56*	2.04	0.80	0.61
	K	2.48	0.79	2.54	4.27*	6.73**	1.36	3.32	10.68***
	REP	0.11	0.19	0.57	0.12	4.89**	6.79***	0.45	6.49***
	N*P	0.02	3.92	1.52	1.56	1.32	0.49	0.91	1.70
	N*K	11.53**	0.87	3.27*	3.46*	0.89	1.99	0.51	0.52
DP	N	77.5***	16.30***	2.78*	3.86**	2.26	1.09	12.8***	1.78
	P	1.78	1.35	0.01	0.26	1.70	5.99*	0.29	1.05
	K	2.38	12.55***	1.97	6.44*	0.21	0.03	2.97	0.46
	REP	0.82	0.06	0.97	0.93	15.6***	8.93***	19.0***	72.73***
	N*P	0.89	0.89	2.45	2.62*	0.77	0.68	0.60	1.31
	N*K	1.95	2.92	7.2***	8.61***	1.20	4.18**	2.15	0.57
AMINO	N	92.8***	92.97***	2.64*	10.85***	20.7***	1.10	14.5***	11.04***
	P	0.91	2.30	7.88**	0.23	0.27	5.18*	1.71	0.99
	K	20.33***	0.00	34.9***	0.15	15.8***	1.28	15.2***	22.32***
	REP	0.75	0.00	0.65	1.17	7.2***	0.96	4.41**	23.48***
	N*P	0.03	0.57	1.98	2.85*	2.70*	2.03	0.65	0.98
	N*K	1.95	21.27***	5.05**	7.02***	1.27	2.00	2.04	0.30
F.EXT	N	72.0***	34.5***	10.9***	6.43***	9.5***	13.37***	17.22***	9.72***
	P	0.00	0.12	0.13	0.81	12.0***	0.50	0.38	0.02
	K	5.82*	6.55*	1.74	11.41**	12.4***	2.01	2.05	3.38
	REP	0.01	0.29	3.76	0.19	11.5***	19.55***	35.79***	5.54**
	N*P	1.59	7.90**	3.17*	1.32	1.95	0.70	0.86	0.12
	N*K	1.22	3.47	3.07*	1.03	1.25	1.49	0.84	0.26
C.EXT	N	75.6***	109.83***	5.4***	2.85*	10.6***	18.5***	21.6***	11.06***
	P	0.24	1.65	1.28	3.69	0.81	0.03	0.49	0.01
	K	0.29	2.26	15.8***	7.80**	7.88**	3.08	1.21	0.04
	REP	0.01	0.01	0.01	0.70	15.48***	5.17**	7.17***	3.89*
	N*P	1.68	4.33*	3.08*	2.03	1.60	1.62	1.17	0.64
	N*K	3.02	2.71	4.03**	1.73	2.99*	1.32	0.17	0.57
DIFF	N	26.3***	76.02***	0.29	3.93**	0.67	2.21	6.00***	6.32
	P	0.41	1.80	0.76	1.18	2.92	0.13	0.13	0.00
	K	1.44	0.00	9.2**	29.07***	0.01	5.89*	0.05	1.07
	REP	0.00	0.08	2.02	1.33	5.84**	5.66**	15.52***	3.03*
	N*P	0.59	0.28	2.87*	1.81	1.29	0.51	0.58	0.86
	N*K	10.75**	0.47	6.0***	2.38	1.24	1.66	0.40	0.47
VISC	N	2.02	44.55***	6.5***	4.84**	1.08	2.10	3.60**	2.28
	P	3.10	0.17	0.12	1.00	2.45	0.22	0.22	0.08
	K	4.36*	1.20	20.4***	3.72	2.62	2.42	0.79	19.04***
	REP	0.03	0.08	0.69	3.25	5.43**	8.17***	1.32	3.02*
	N*P	0.96	0.76	5.06**	0.44	0.70	0.68	0.46	0.96
	N*K	0.11	0.22	2.95*	7.22***	0.40	0.75	0.98	0.77
SPRO	N	49.60***	1.31	0.53	4.37**	1.61	0.66	7.98***	5.88***
	P	0.05	0.00	0.01	3.28	12.87***	7.28**	0.22	0.00
	K	0.95	5.33*	0.18	0.07	10.44**	3.43	8.7***	10.17**
	REP	0.11	1.14	0.07	2.47	7.45***	8.22***	4.93**	14.63***
	N*P	2.78	0.11	0.79	0.92	1.65	1.26	0.96	2.05
	N*K	0.73	0.16	0.86	6.60***	0.87	1.94	0.87	1.35

*;**;***; INDICATE SIGNIFICANCE AT THE 5, 1, AND 0.1% LEVEL OF SIGNIFICANCE, RESP.

Table 3. Comparison of malting quality parameters for Argyle vs. Ellice at two sites in 1991.

Cultivar	Alpha	DP	Amino	Fine Ext.	Coarse Ext.	Visc.	Sol. Pro.
ARGYLE	24.5	331.9	0.58	59.7	53.5	1.3	5.2
ELLICE	23.7	314.0	0.55	61.8	55.0	1.3	5.6

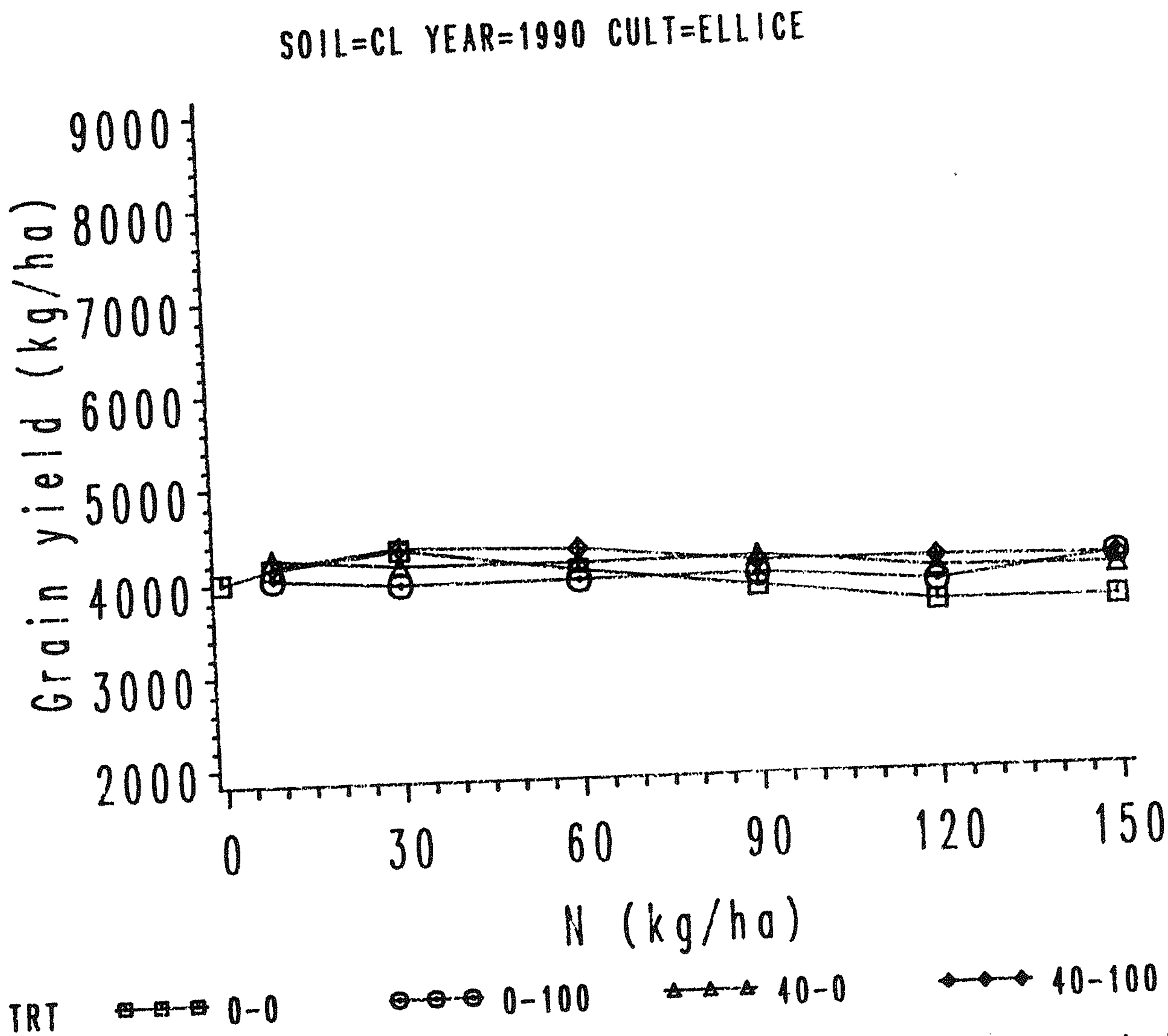


Fig. 1 Grain yield as influenced by N, P and KCl

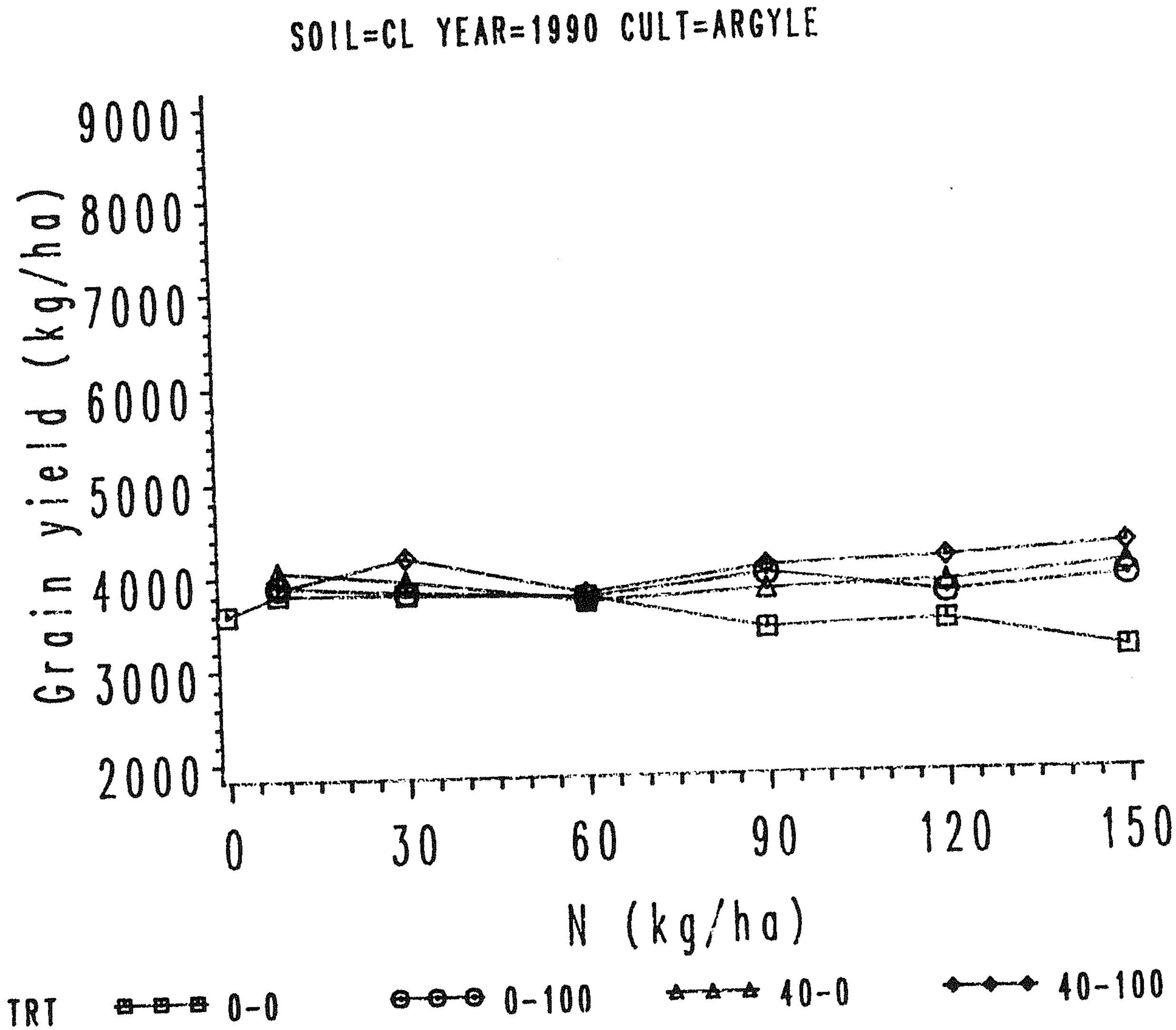


Fig. 2 Grain yield as influenced by N, P and KCl

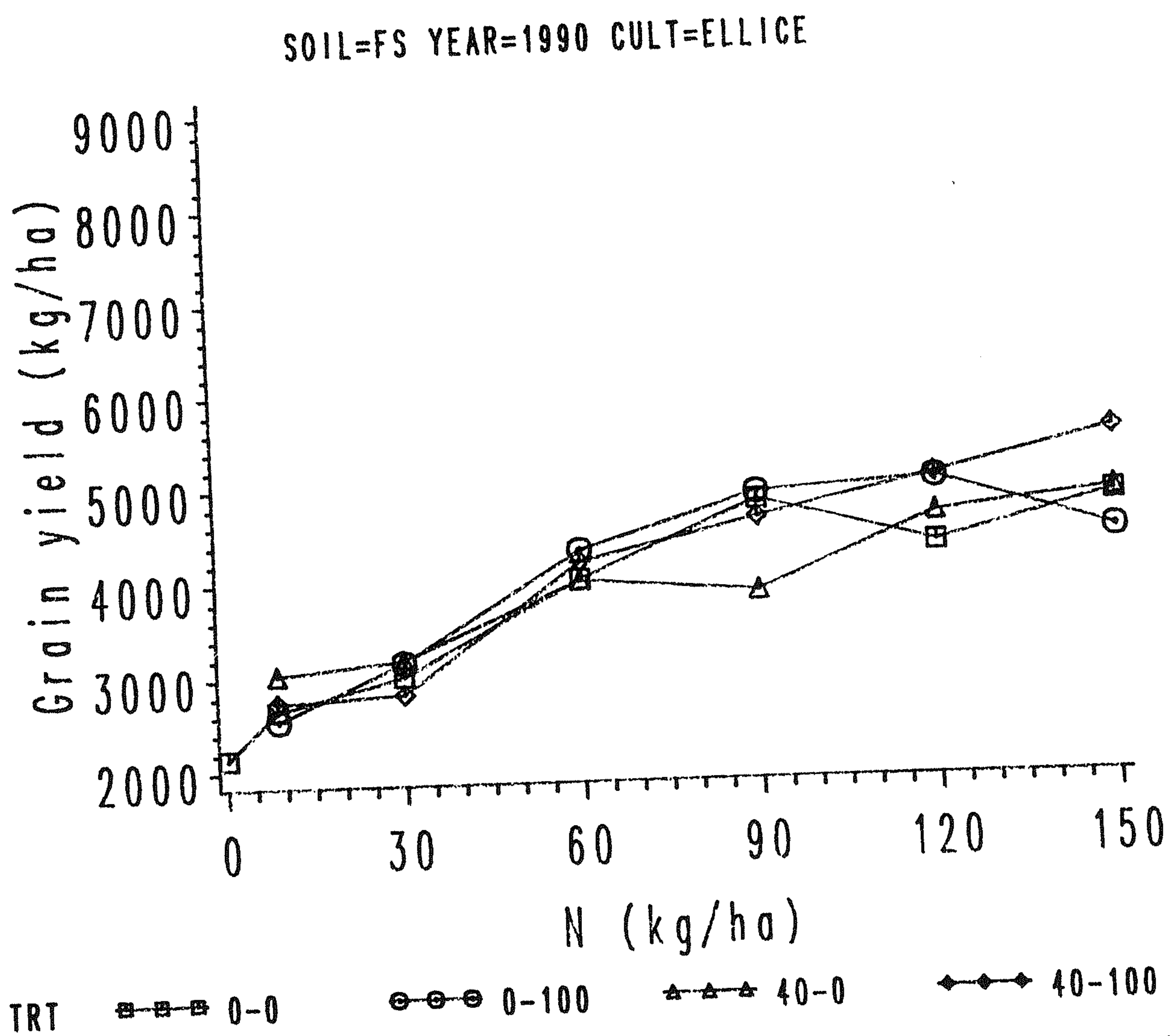


Fig. 3 Grain yield as influenced by N, P and KCl

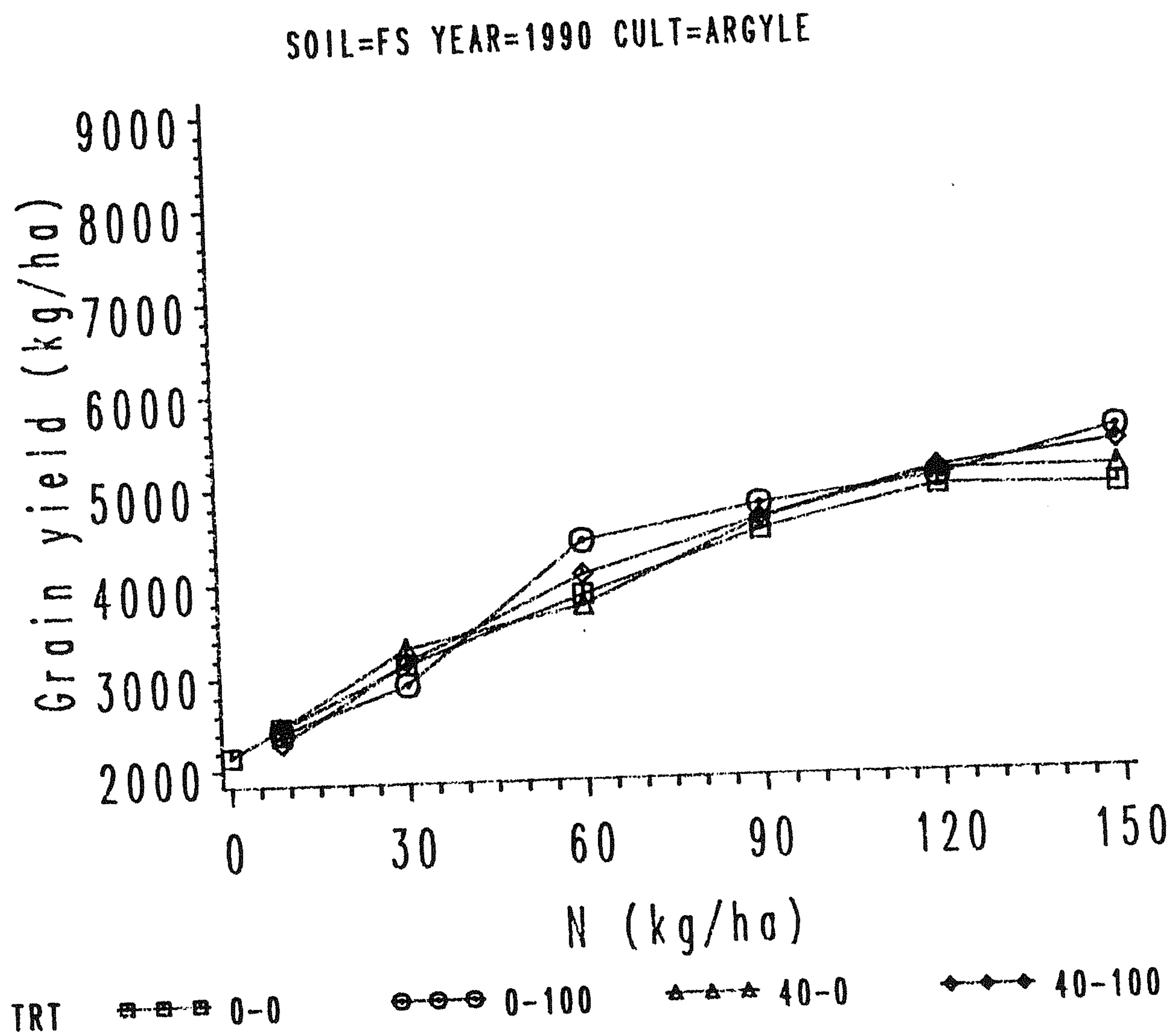


Fig. 4 Grain yield as influenced by N, P and KCl

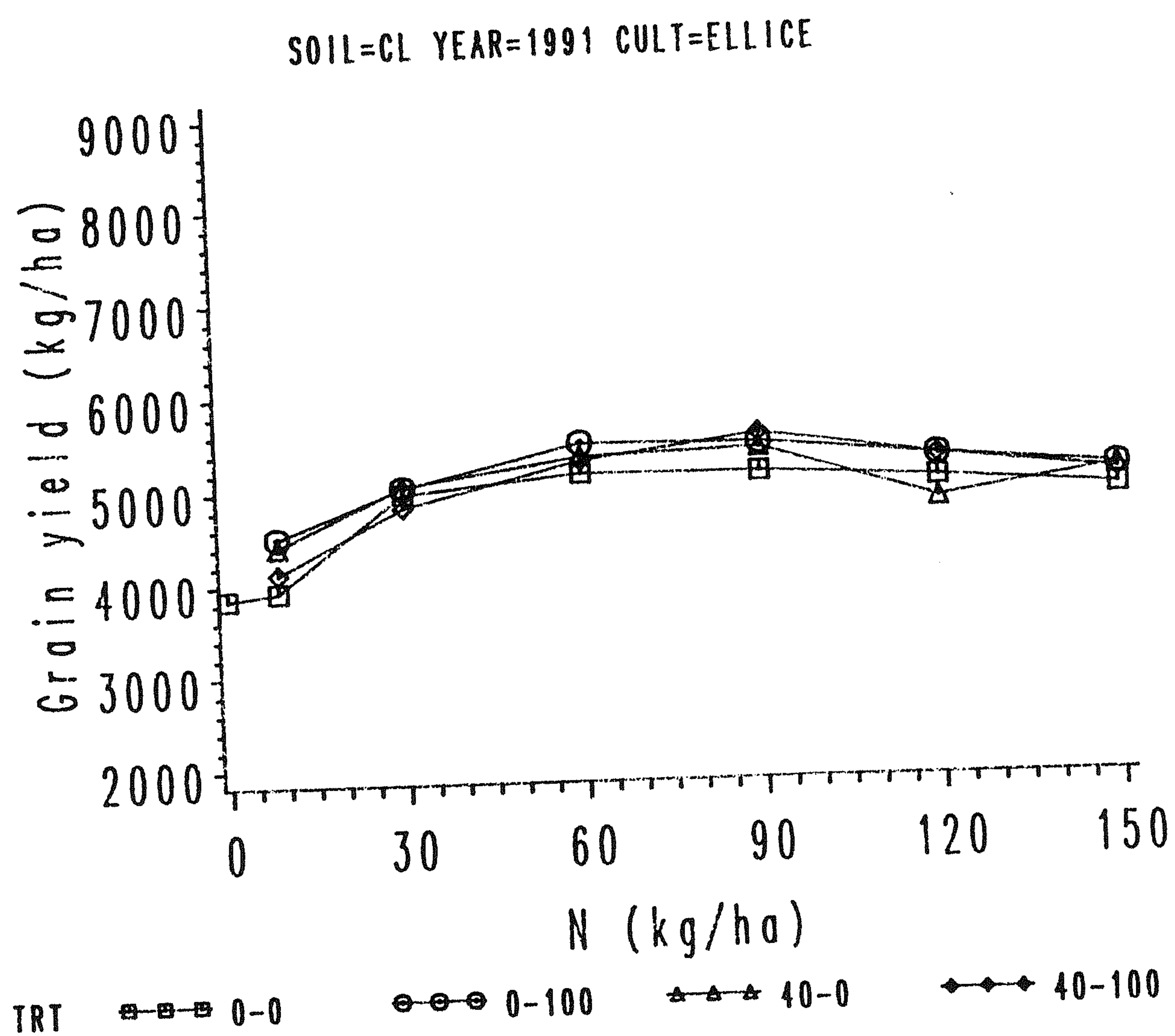


Fig. 5 Grain yield as influenced by N, P and KCl

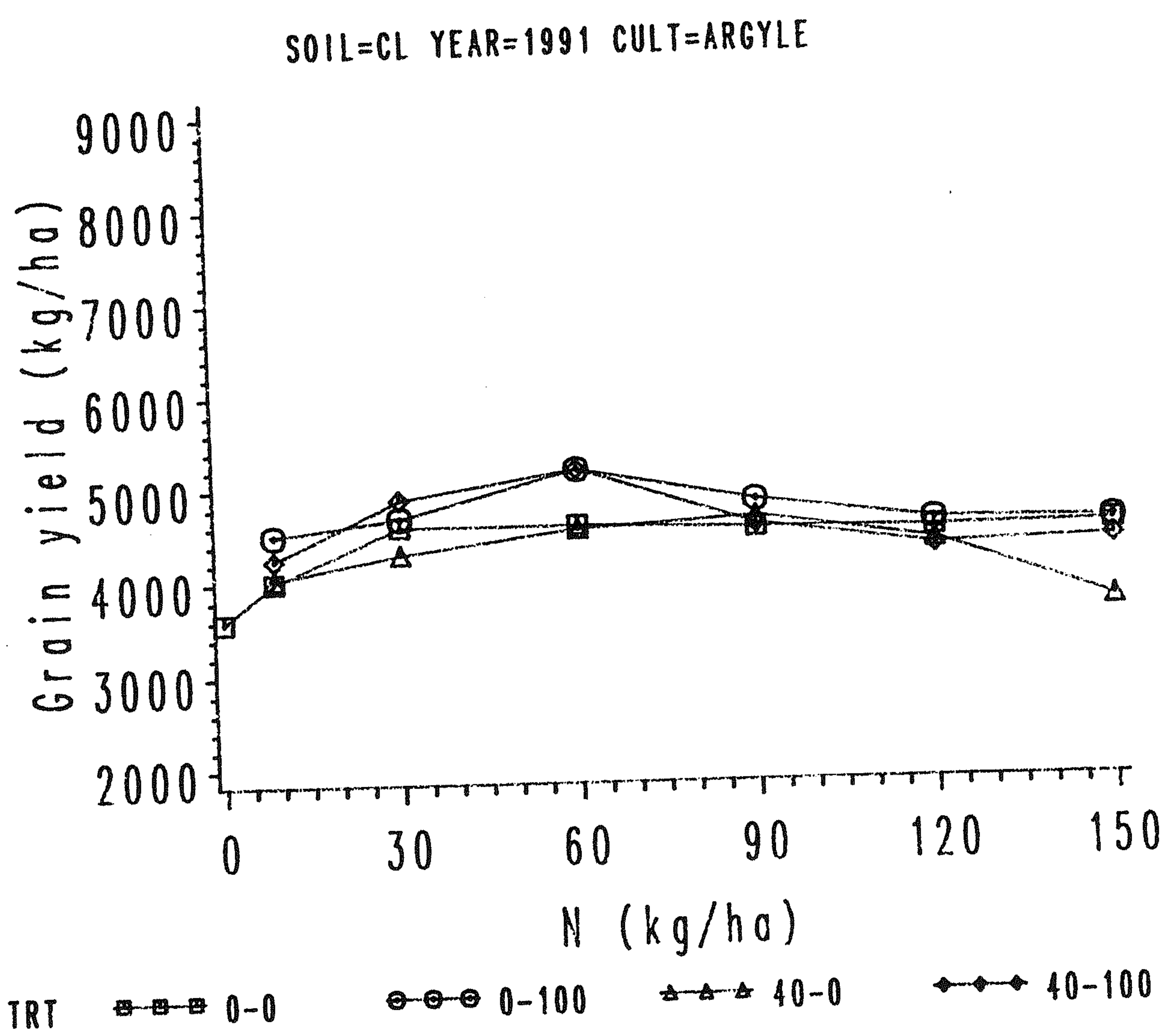


Fig. 6 Grain yield as influenced by N, P and KCl

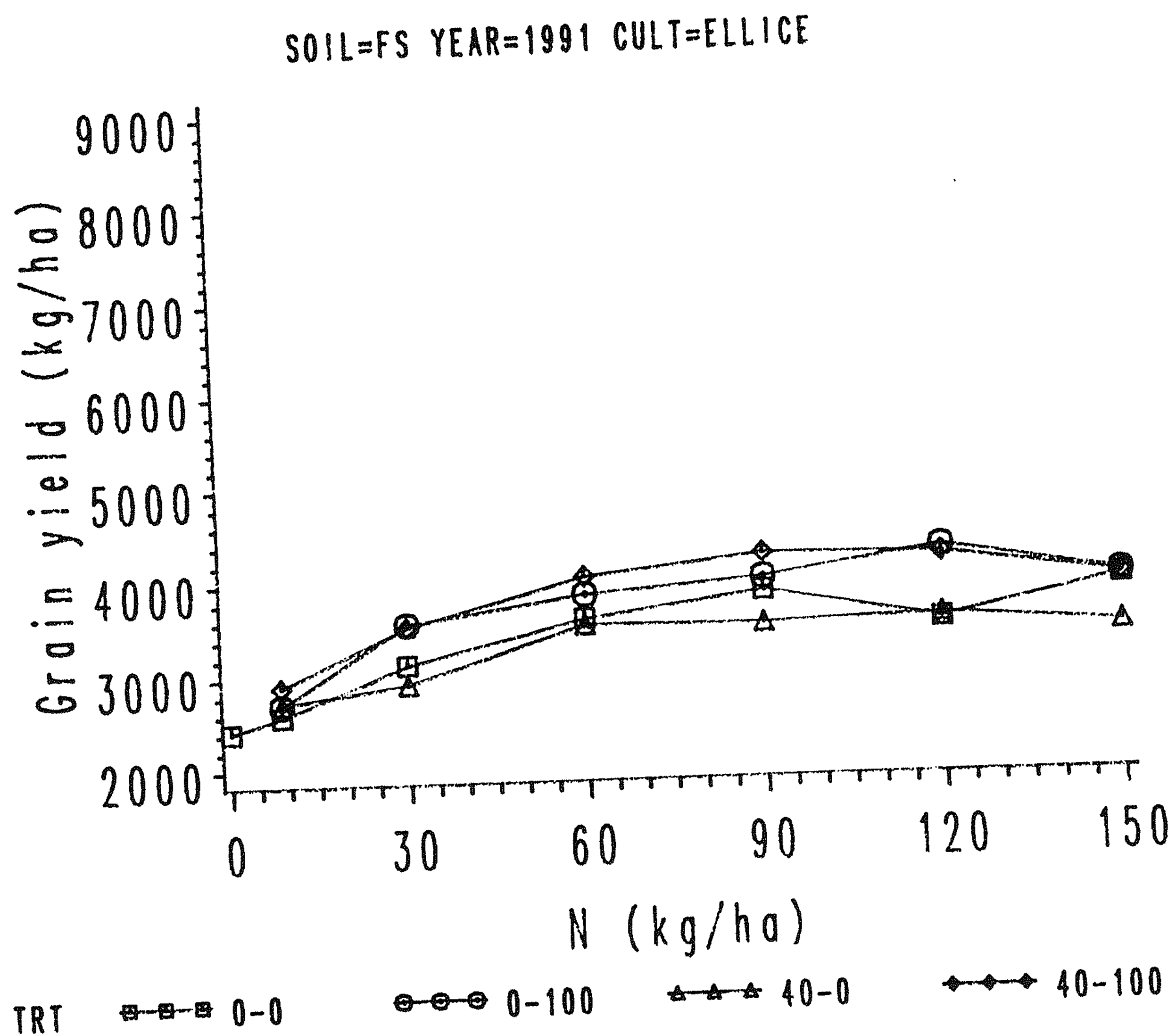


Fig. 7 Grain yield as influenced by N, P and KCl

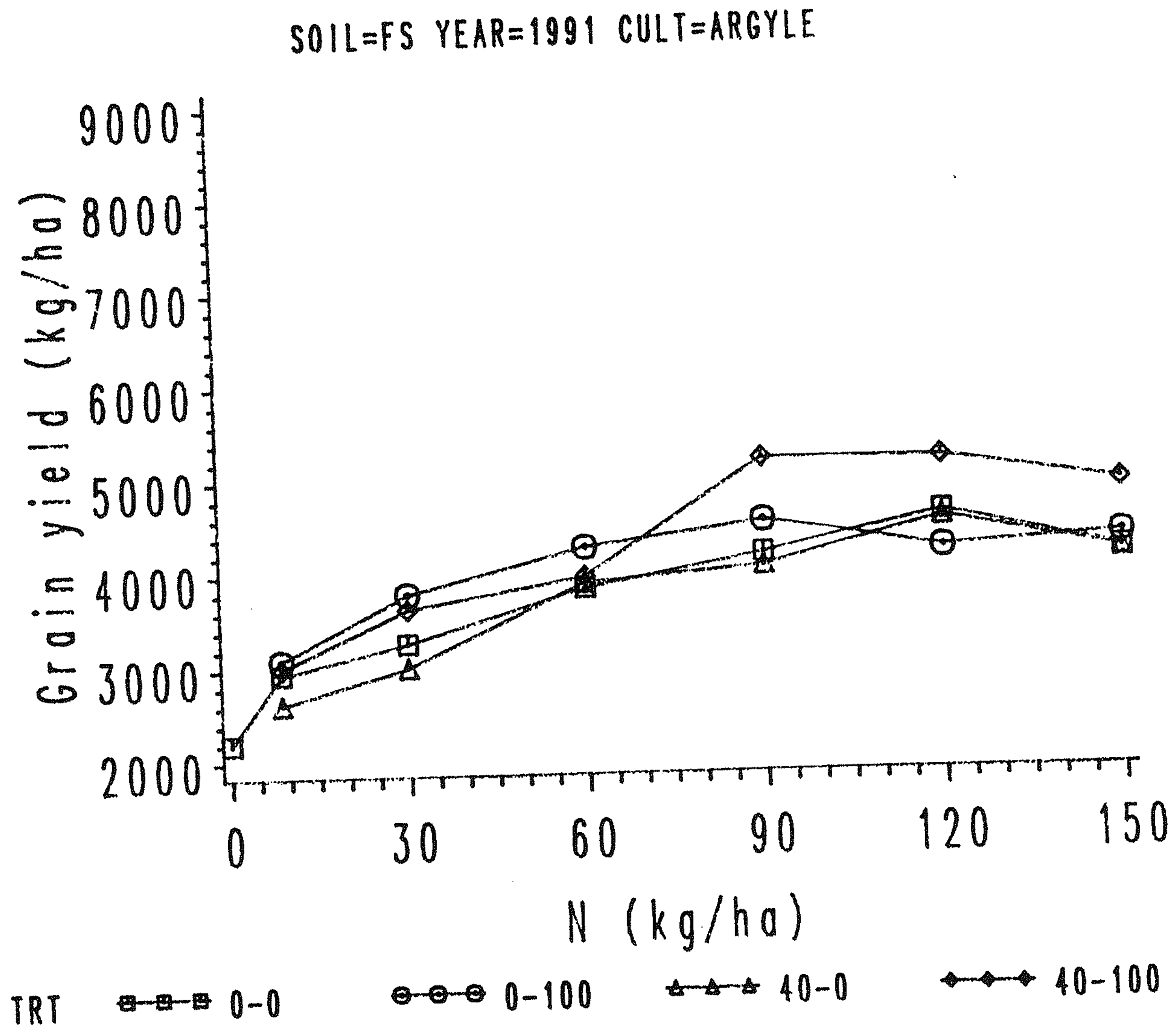


Fig.8 Grain yield as influenced by N, P and KCl

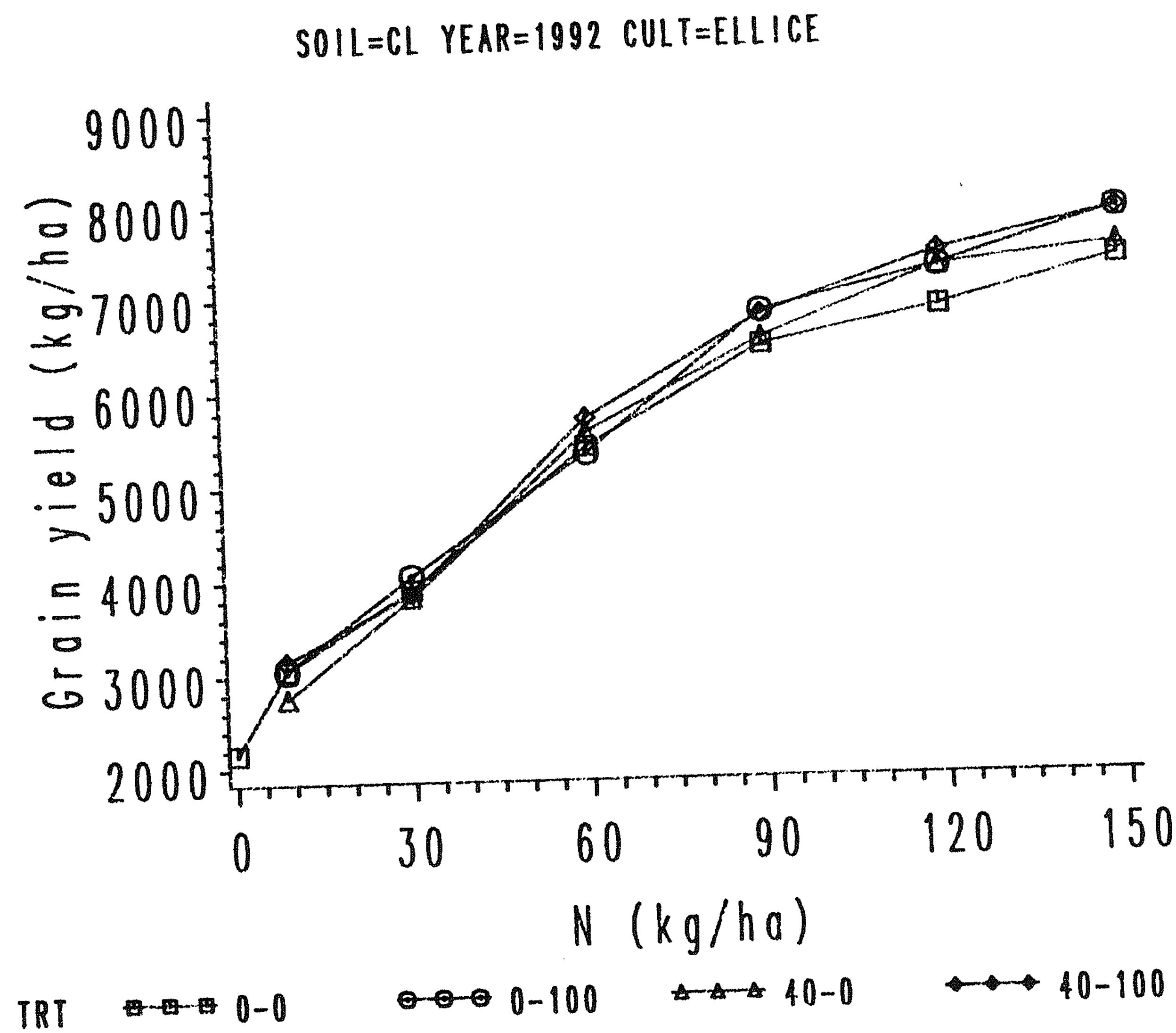


Fig. 9 Grain yield as influenced by N, P and KCl

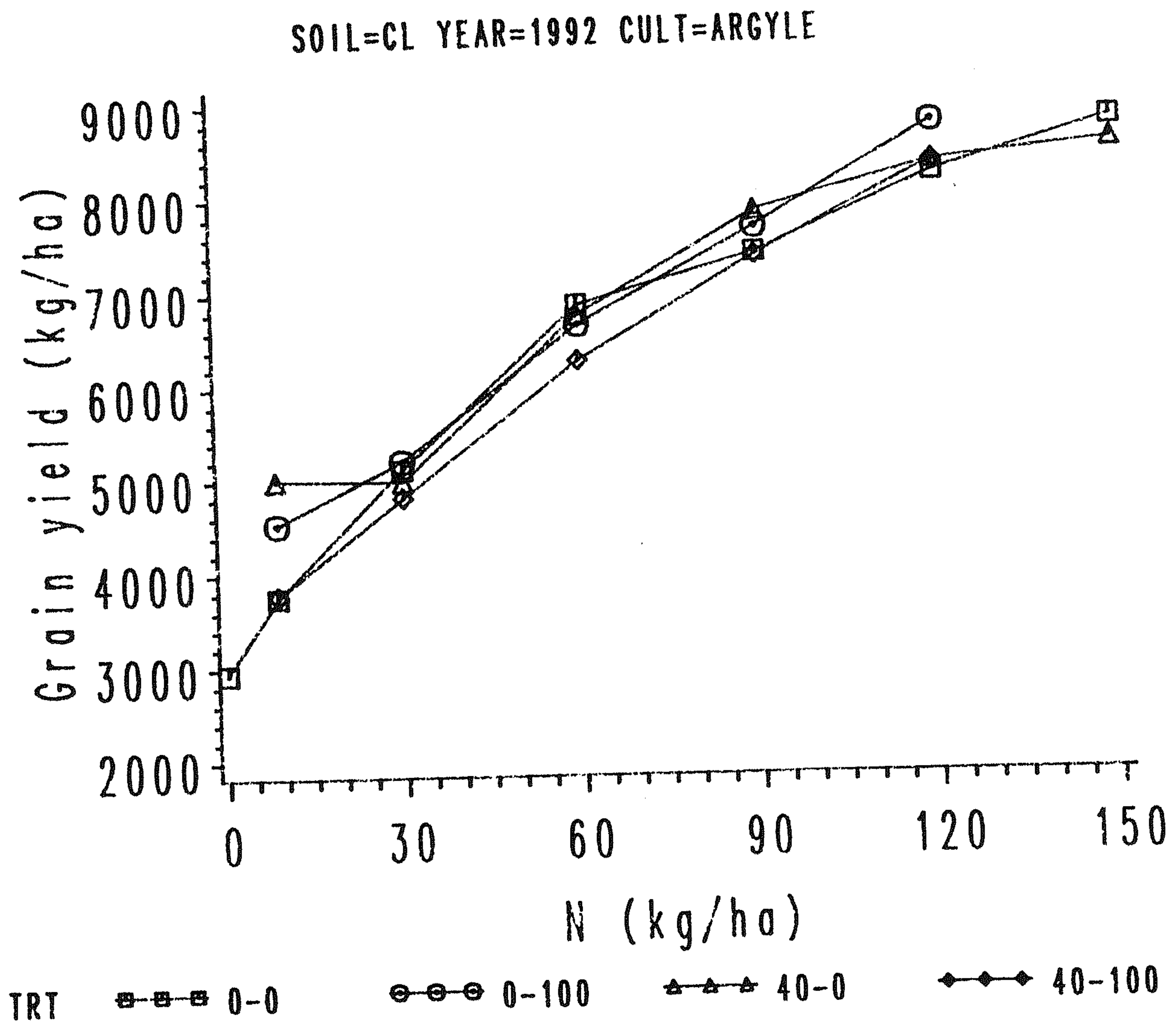


Fig. 10 Grain yield as influenced by N, P and KCl

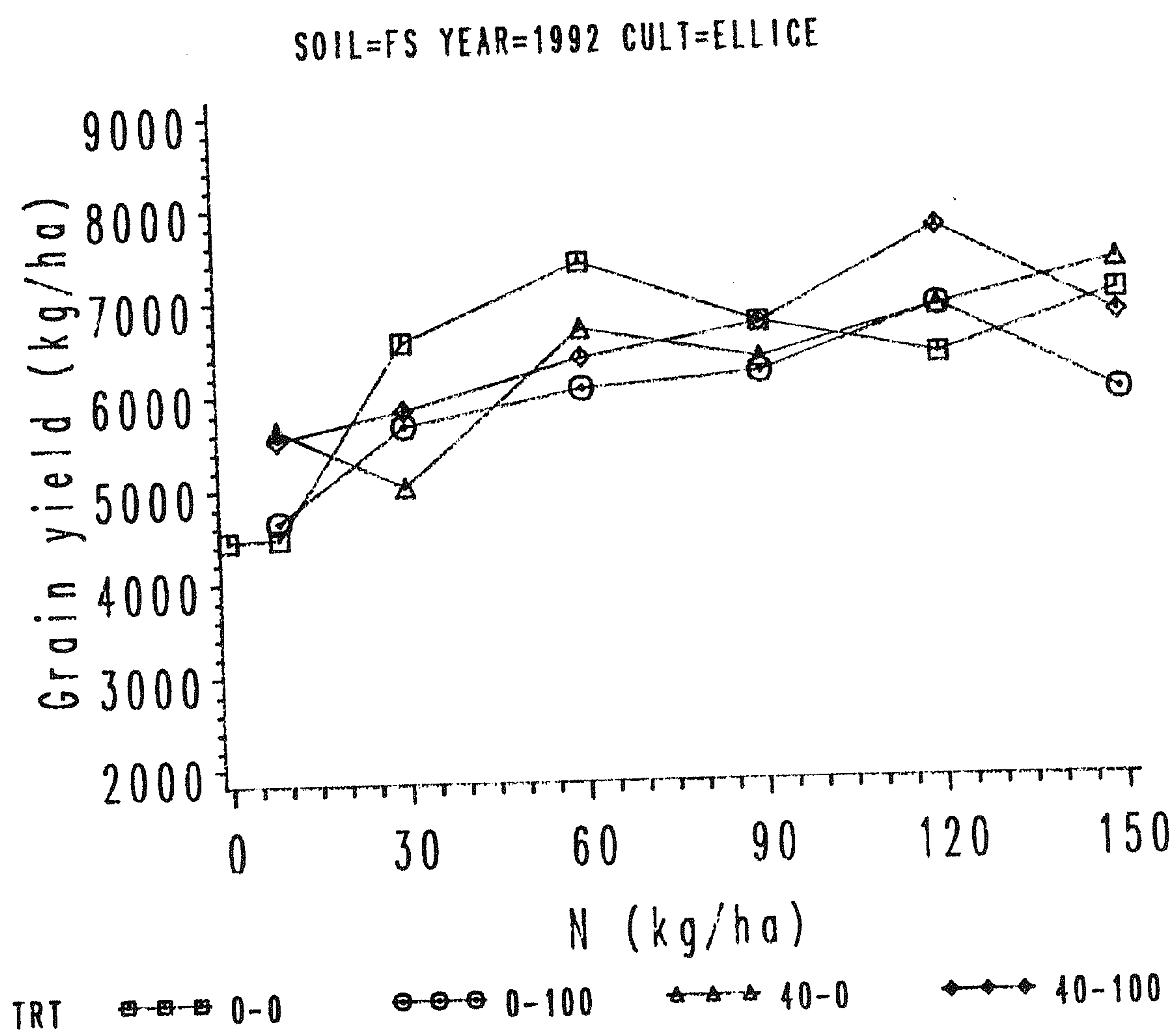


Fig.11 Grain yield as influenced by N, P and KCl

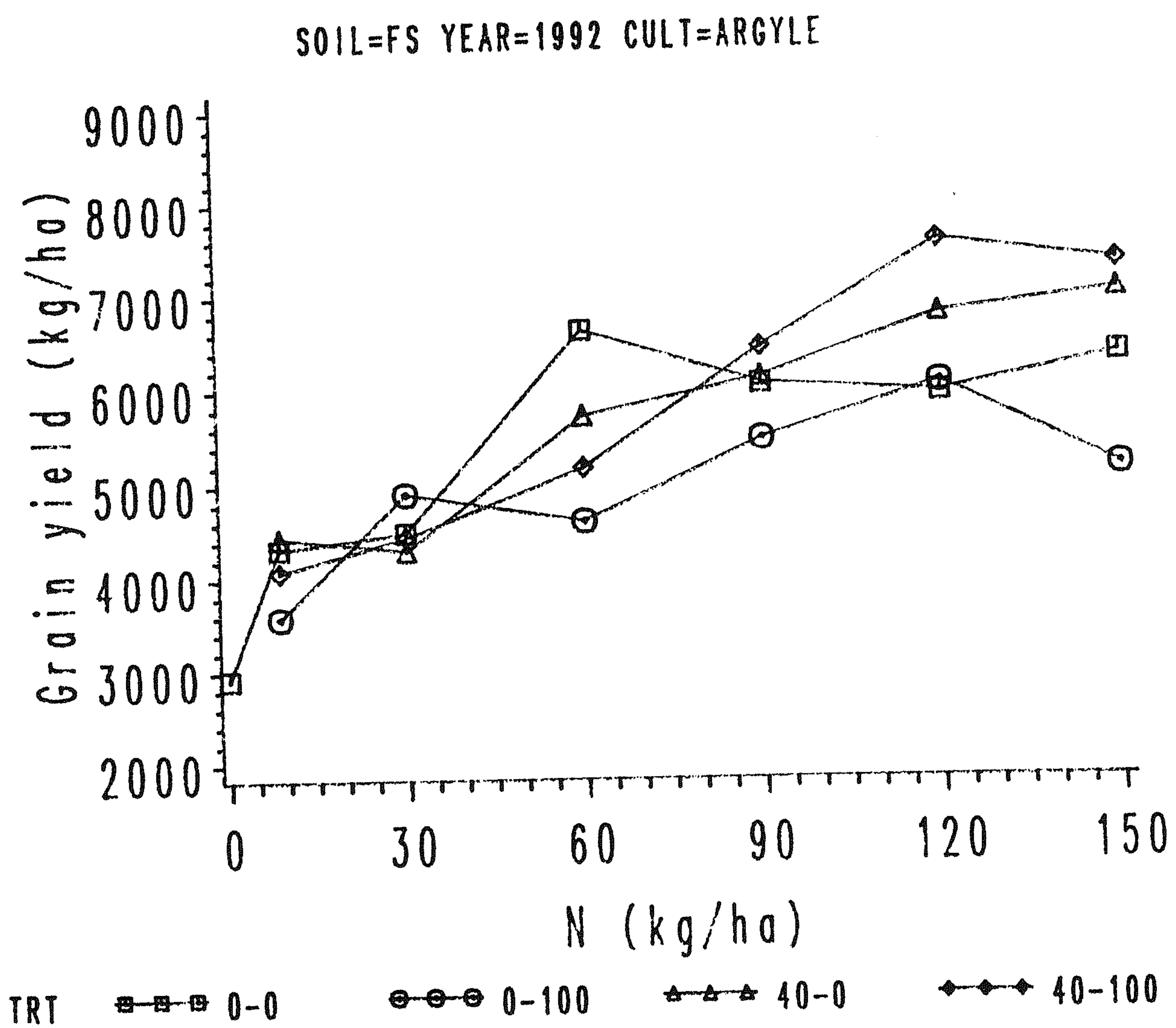


Fig. 12 Grain yield as influenced by N, P and KCl

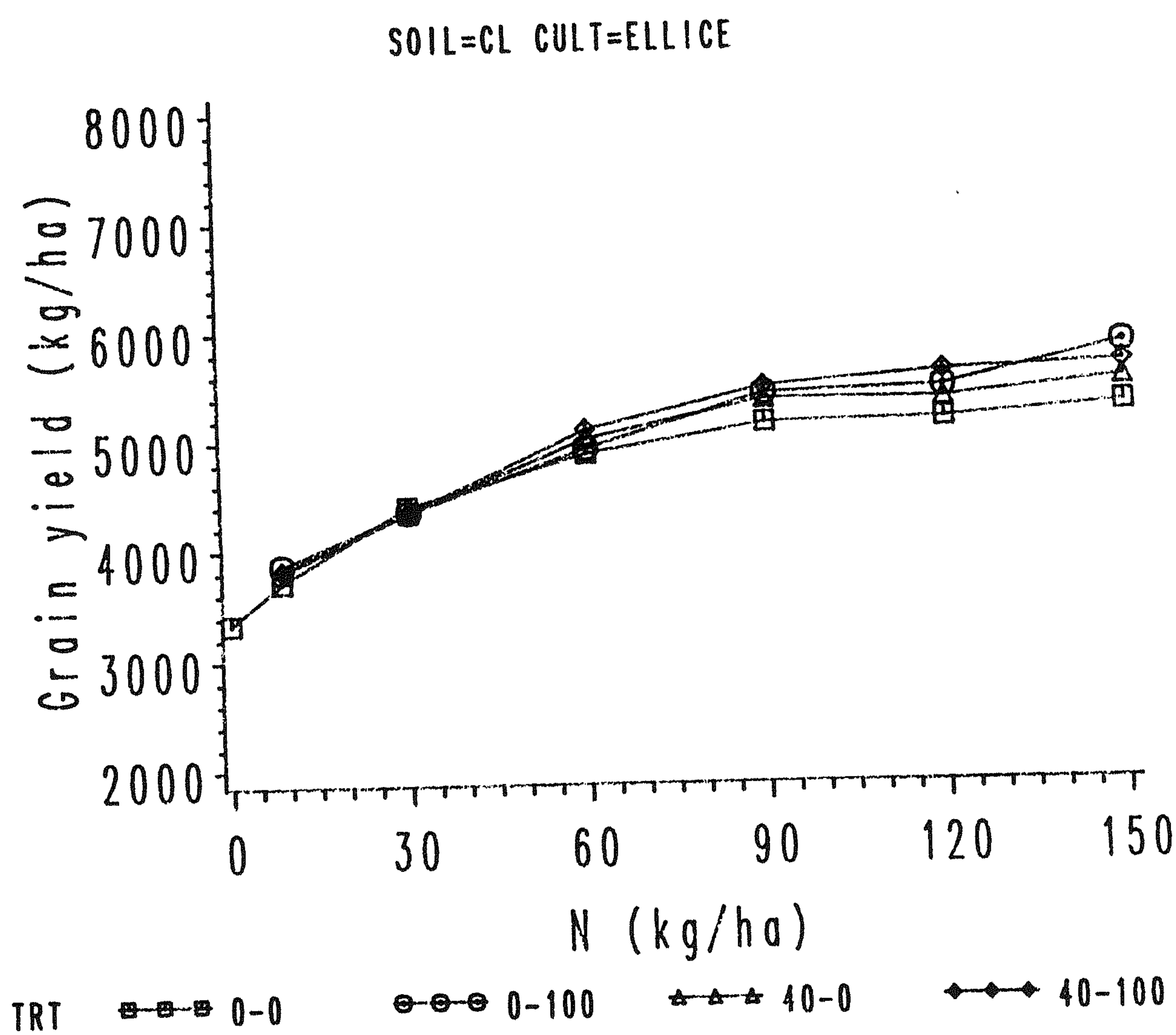


Fig. 13 Grain yield as influenced by N, P and KCl, averaged over years

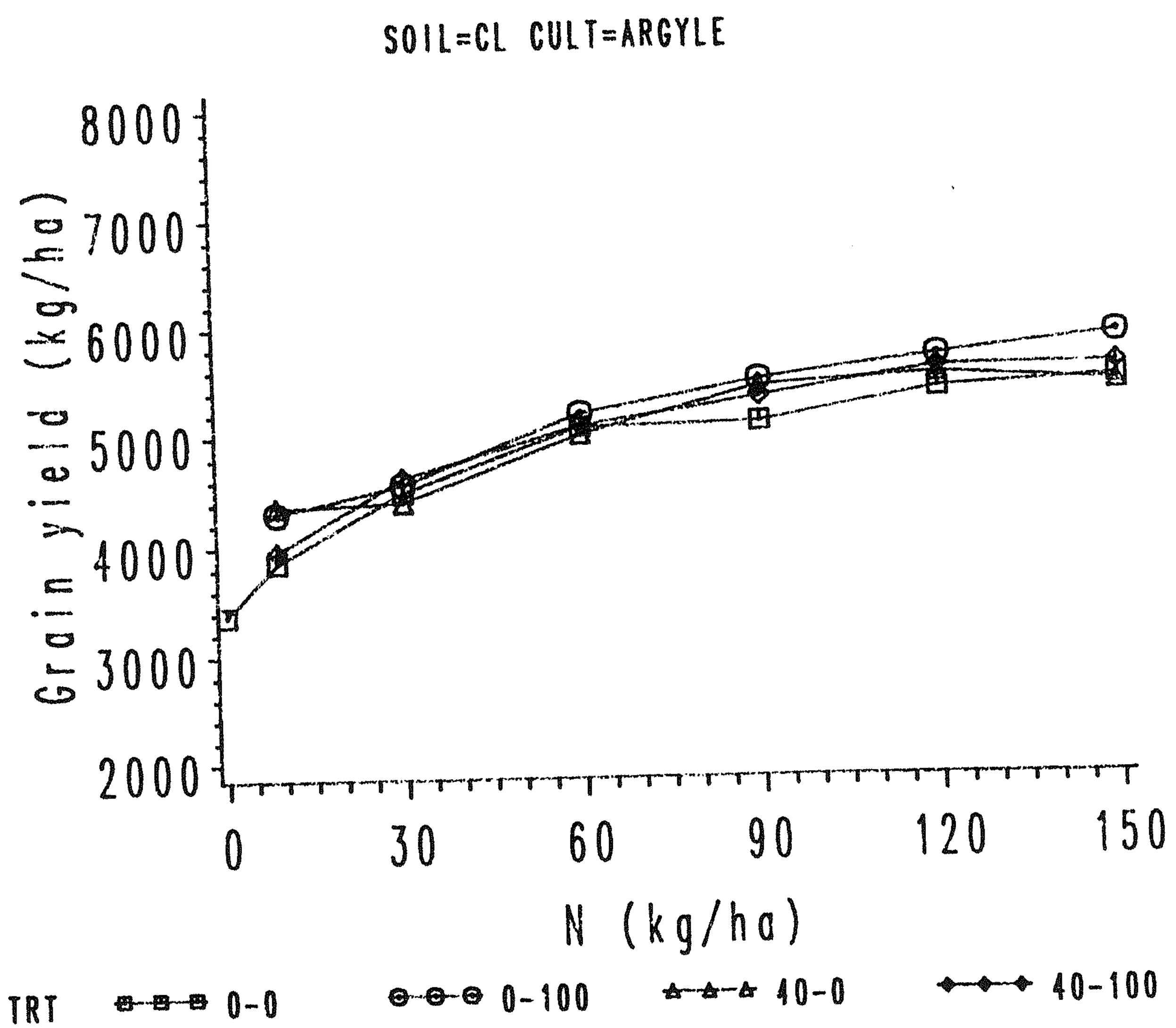


Fig. 14 Grain yield as influenced by N, P and KCl, averaged over years

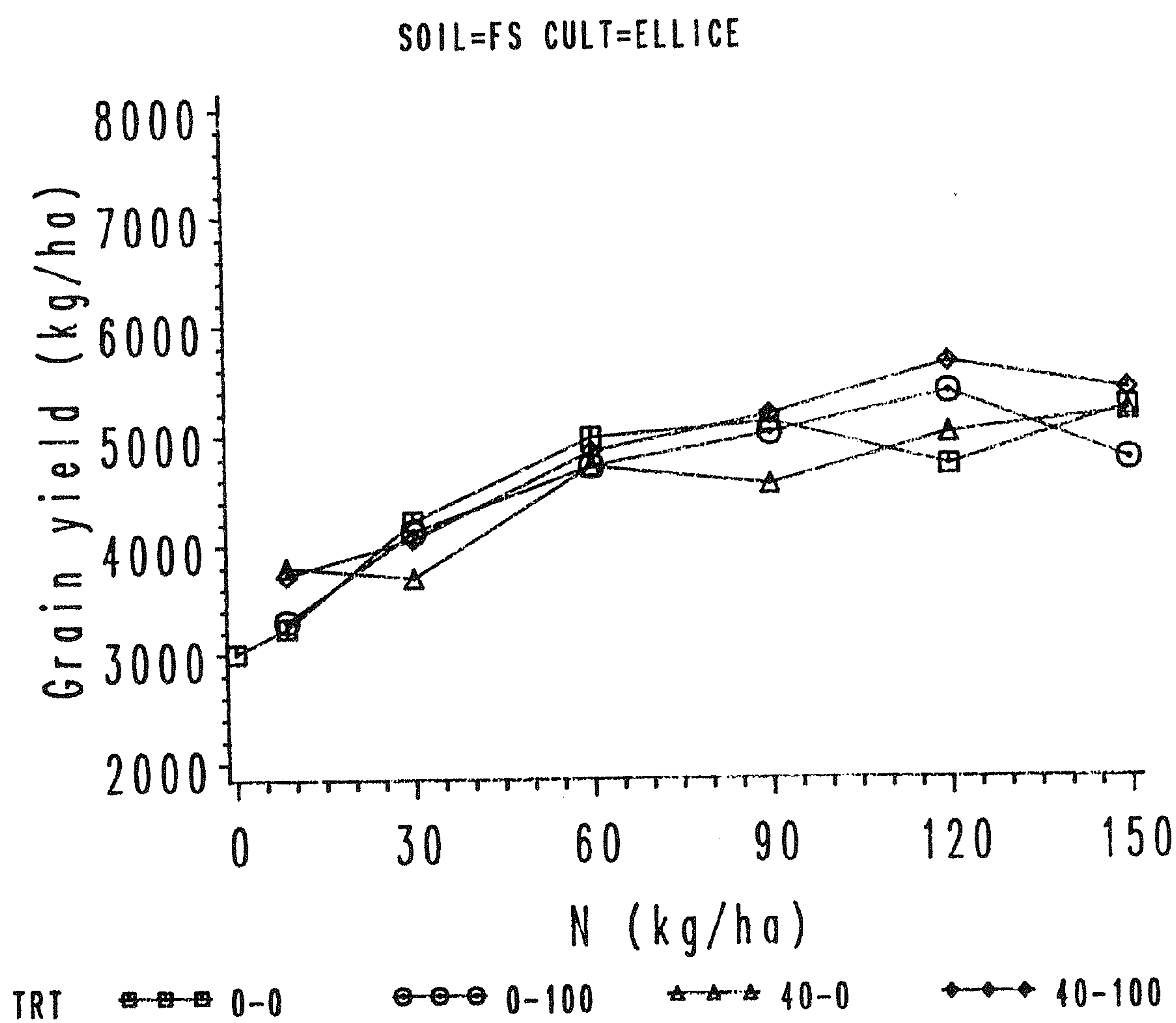


Fig. 15 Grain yield as influenced by N, P and KCl, averaged over years

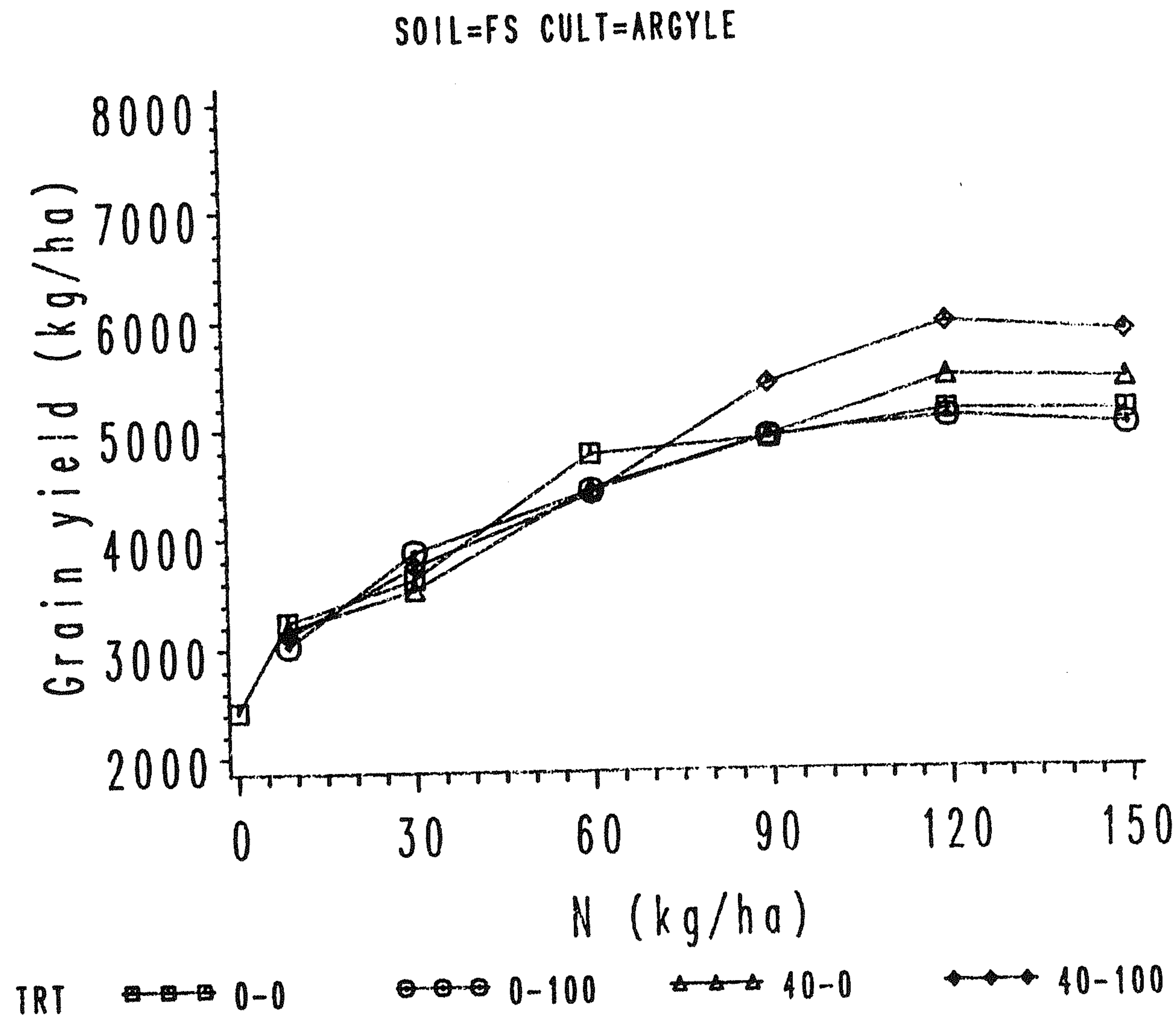
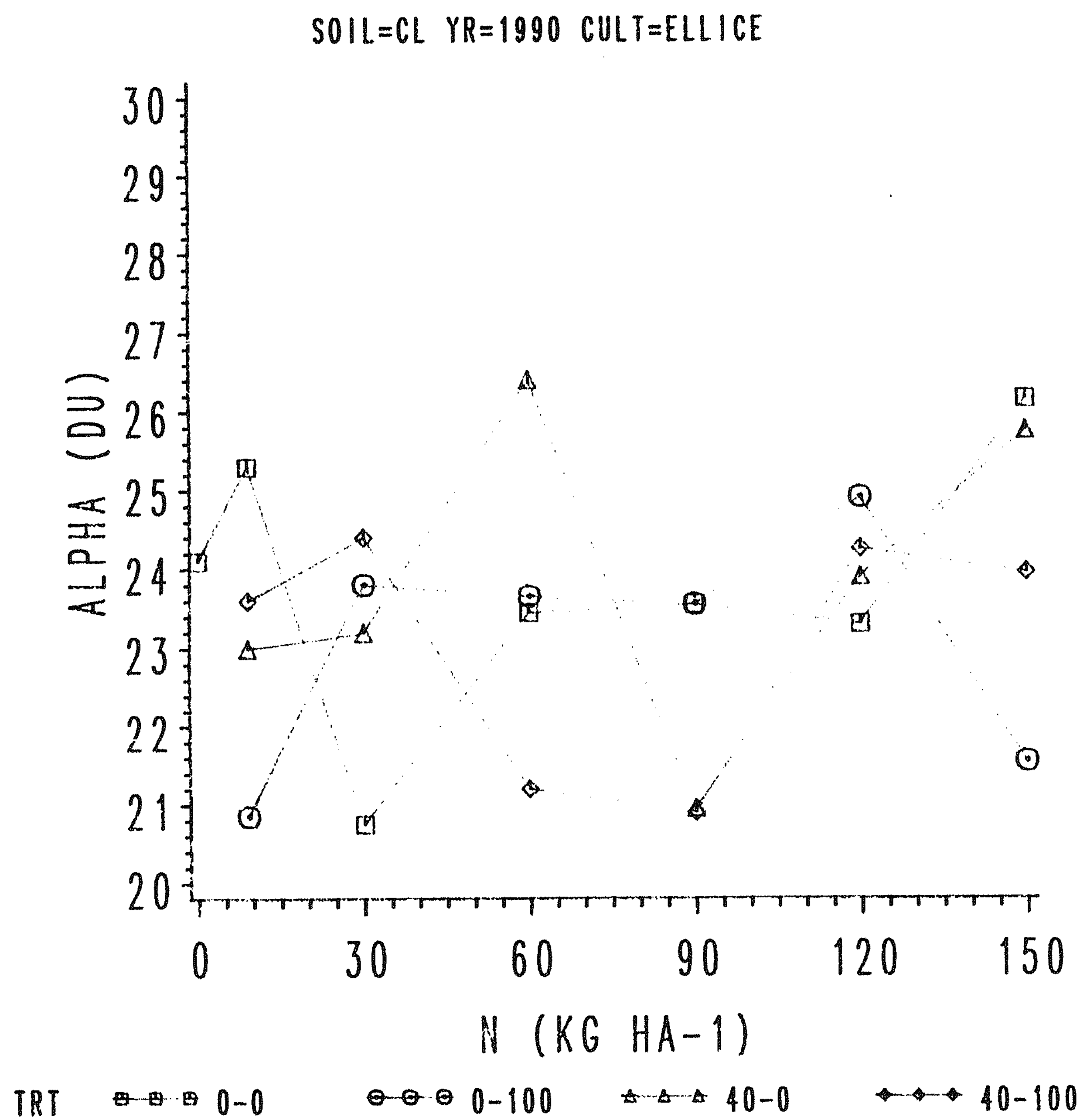


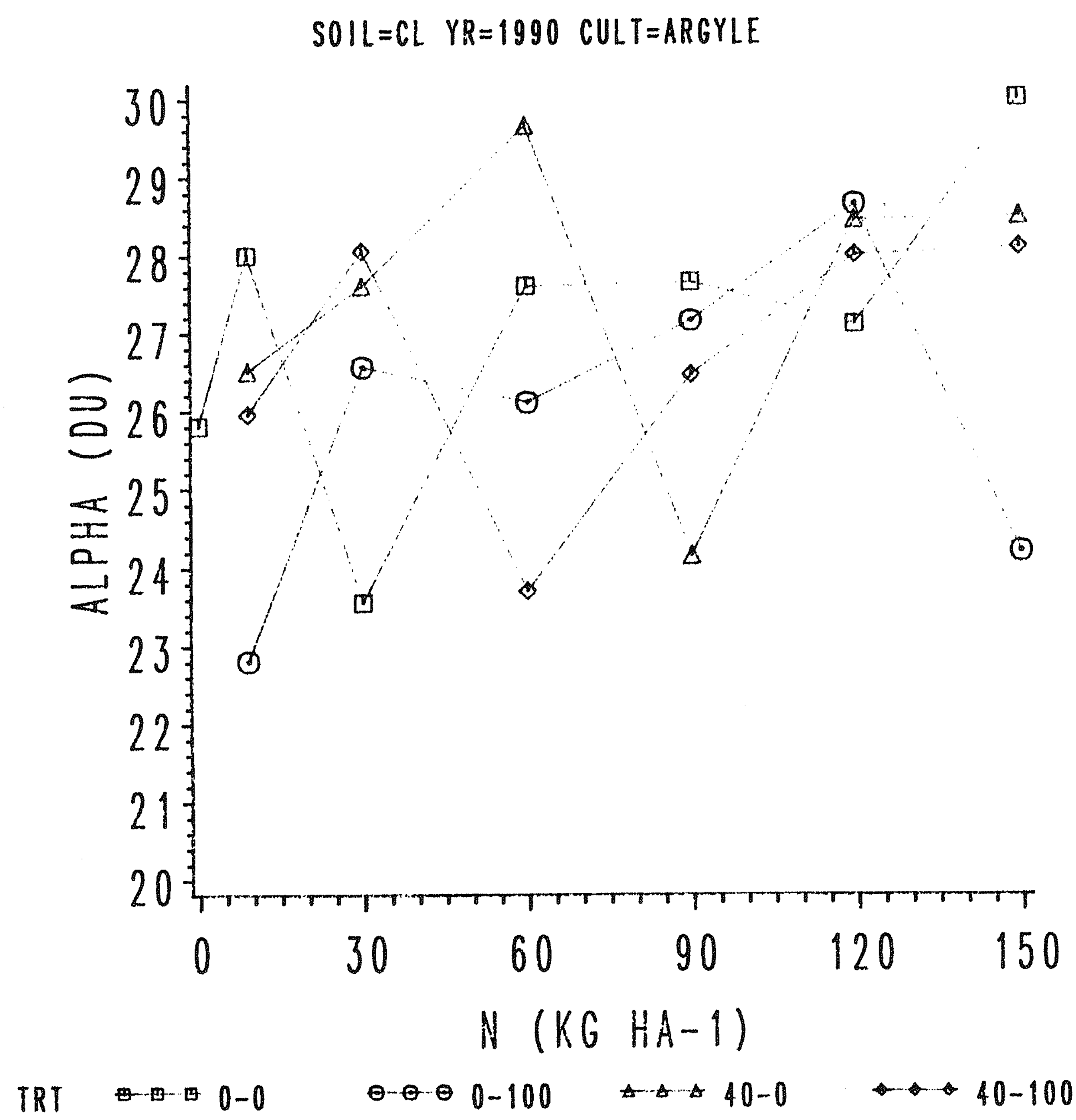
Fig. 16 Grain yield as influenced by N, P and KCl, averaged over years

Fig. 17



SOIL=CL YR=1990 CULT=ELLICE
ALPHA (DU)
30
29
28
27
26
25
24
23
22
21
20
0
30
60
90
120
150
N (KG HA-1)
TRT
0-0
0-100
40-0
40-100

Fig. 18



SOIL=CL YR=1990 CULT=ARGYLE
ALPHA (DU)
30
29
28
27
26
25
24
23
22
21
20
0
30
60
90
120
150
N (KG HA-1)
TRT
0-0
0-100
40-0
40-100

Fig. 10

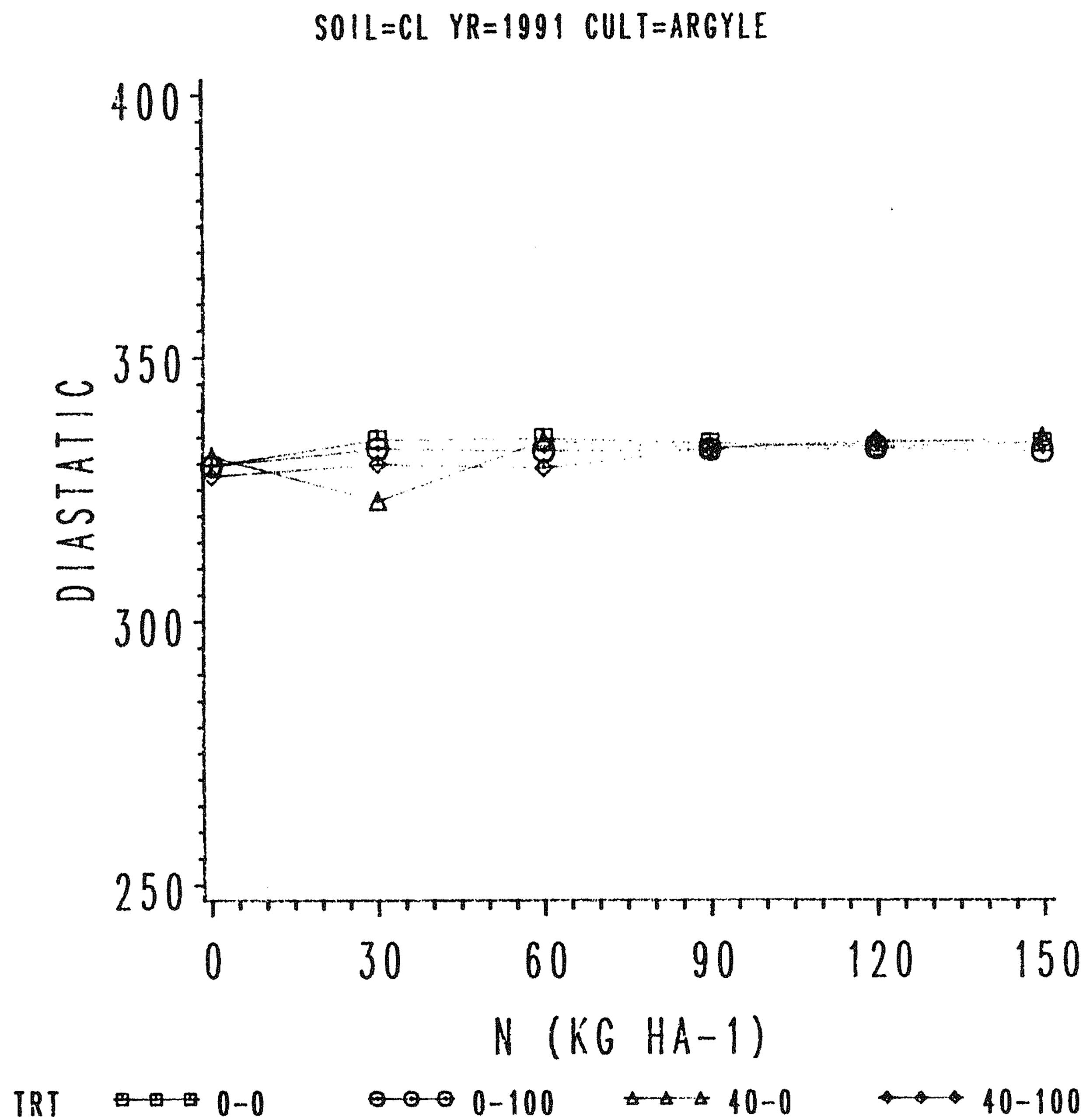

SOIL=CL YR=1991 CULT=ARGYLE
DIASTATIC
400
350
300
250
0
30
60
90
120
150
N (KG HA-1)
TRT
0-0
0-100
40-0
40-100

Fig. 20

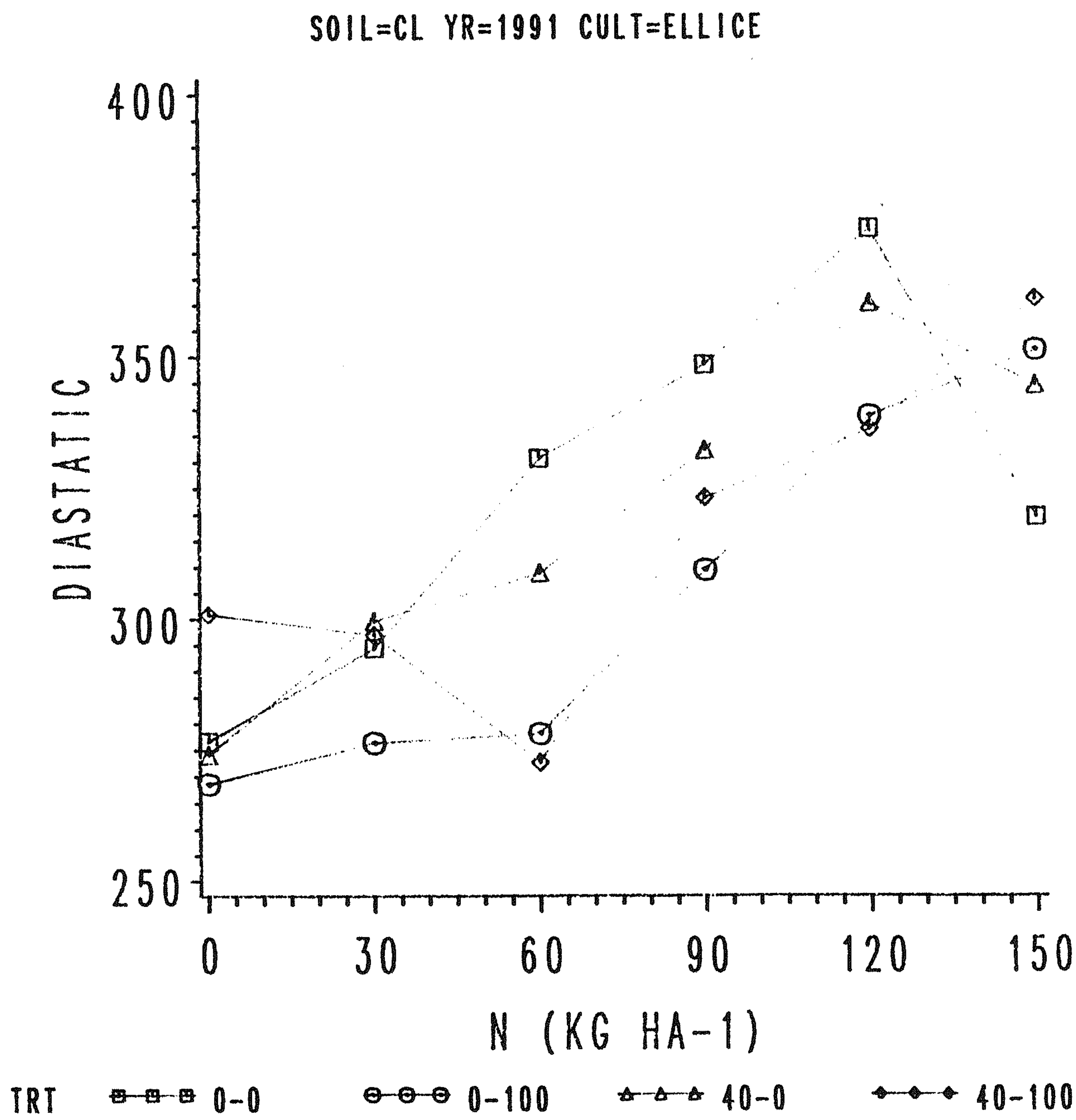

SOIL=CL YR=1991 CULT=ELLICE
DIASTATIC
400
350
300
250
0
30
60
90
120
150
N (KG HA-1)
TRT
0-0
0-100
40-0
40-100

Fig. 21

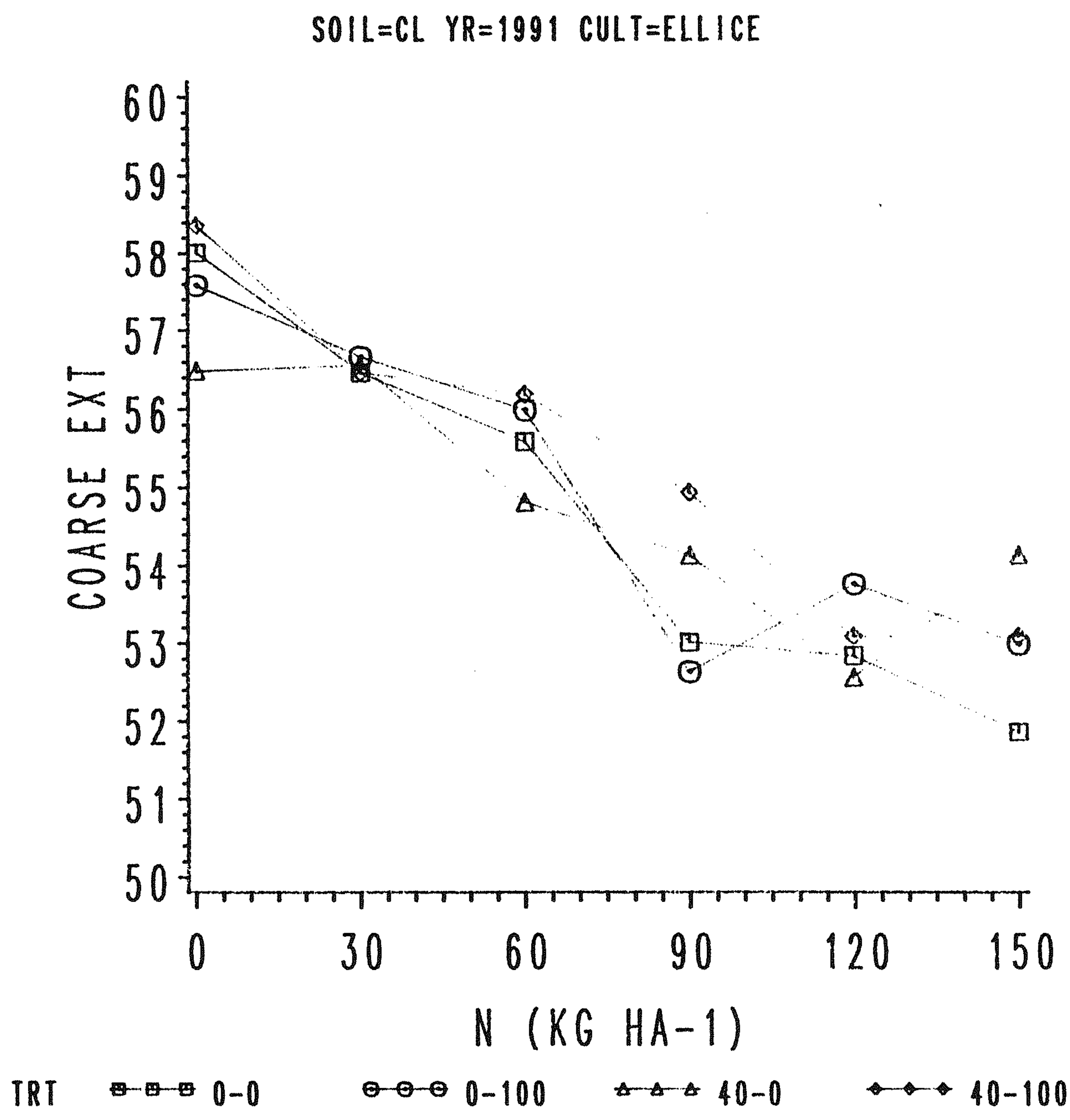
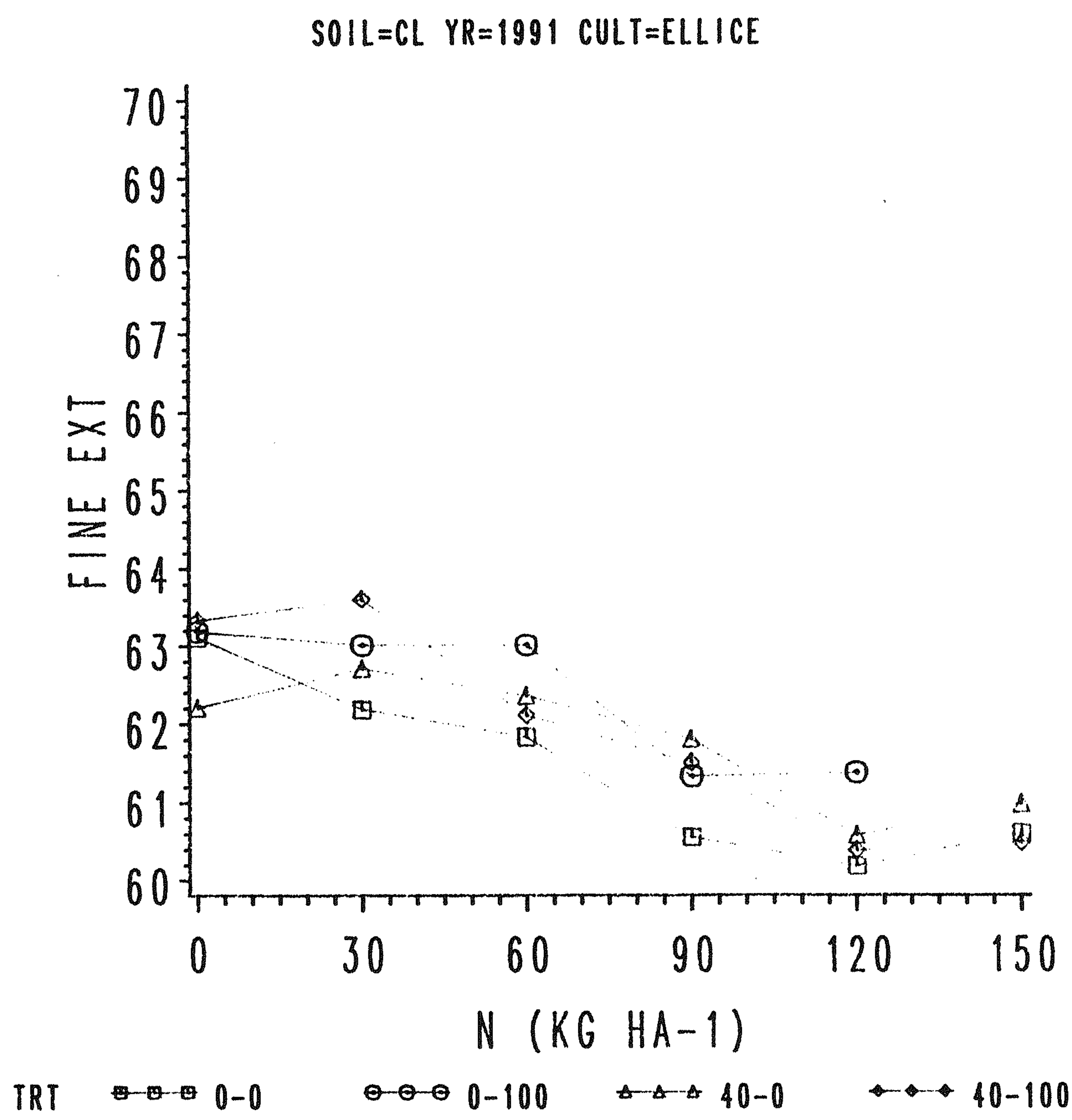

SOIL=CL YR=1991 CULT=ELLICE
COARSE EXT
60
59
58
57
56
55
54
53
52
51
50
0
30
60
90
120
150
N (KG HA-1)
TRT
0-0
0-100
40-0
40-100

Fig. 22



SOIL=CL YR=1991 CULT=ELLICE
FINE EXT
70
69
68
67
66
65
64
63
62
61
60
0
30
60
90
120
150
N (KG HA-1)
TRT
0-0
0-100
40-0
40-100

Fig. 23

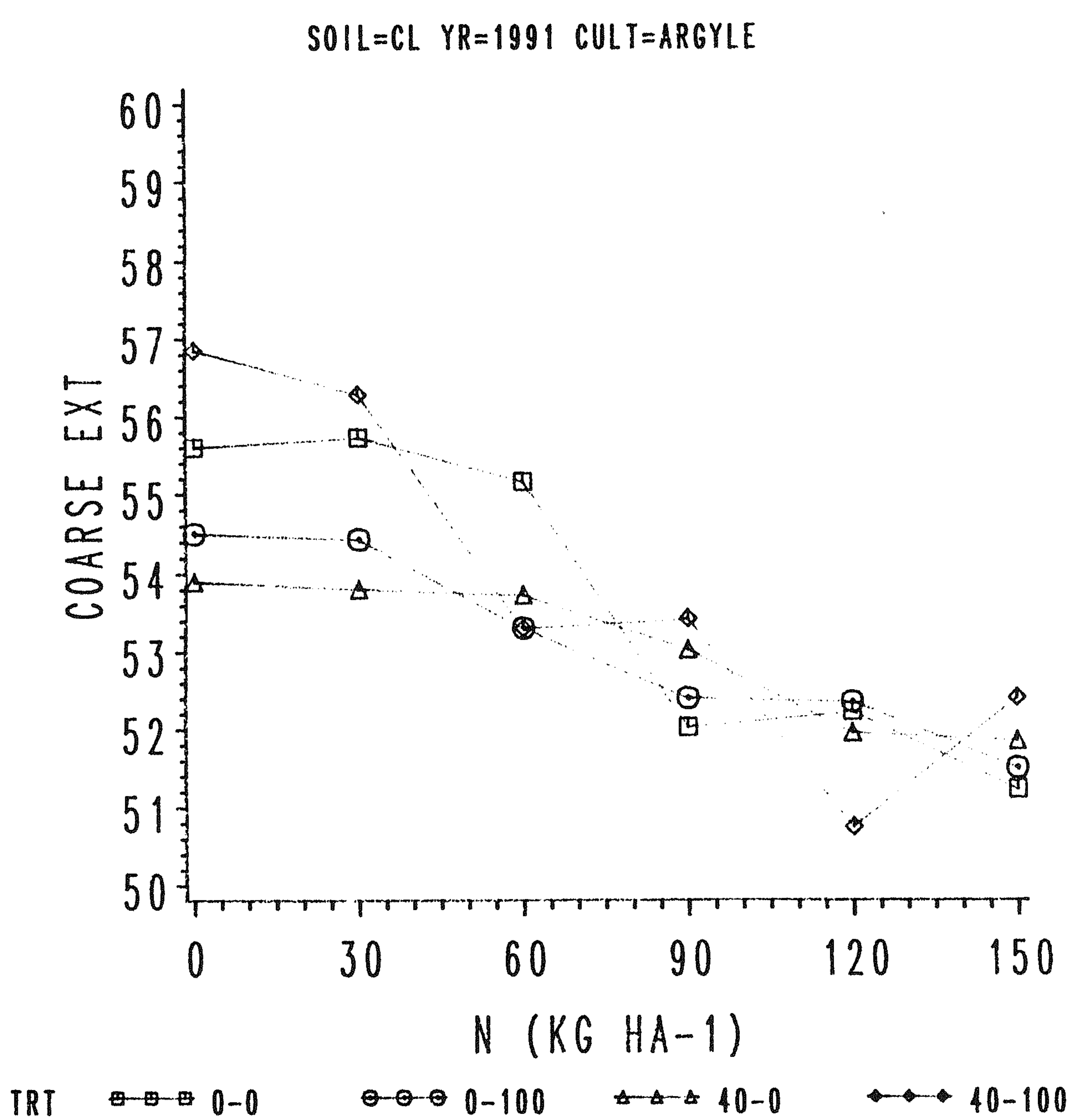
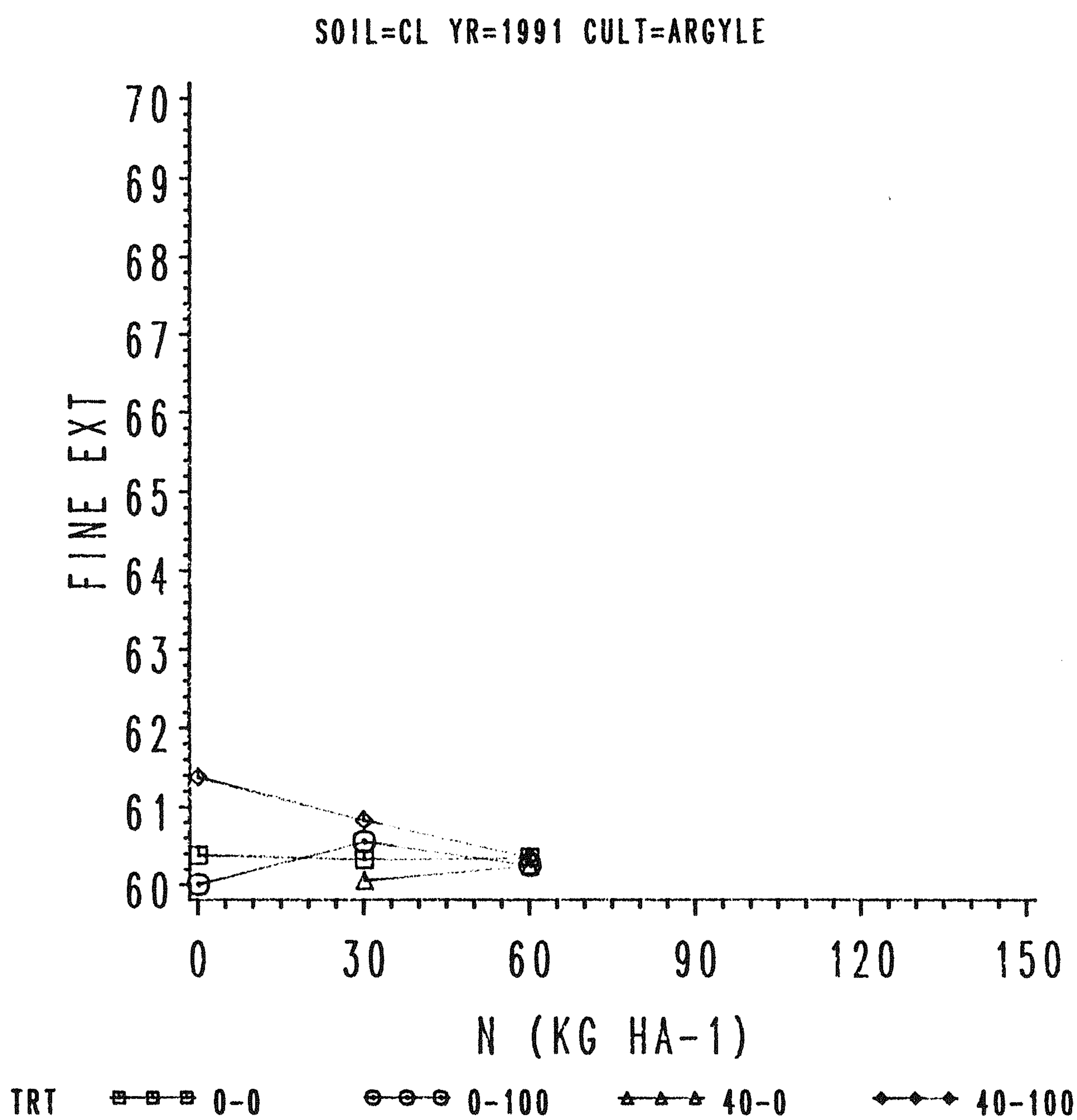

SOIL=CL YR=1991 CULT=ARGYLE
COARSE EXT
60
59
58
57
56
55
54
53
52
51
50
0
30
60
90
120
150
N (KG HA-1)
TRT
0-0
0-100
40-0
40-100

Fig. 24


SOIL=CL YR=1991 CULT=ARGYLE
FINE EXT
70
69
68
67
66
65
64
63
62
61
60
0
30
60
90
120
150
N (KG HA-1)
TRT
0-0
0-100
40-0
40-100