THE EFFECT OF RATE AND TIMING OF POTASSIUM FERTILISER ON THE GROWTH AND NUTRITION OF YOUNG RADIATA PINE IN NORTHLAND: RESULTS AFTER SIX YEARS

By

M.F. SKINNER, J.A.C. HUNTER-SMITH,
J.D. GRAHAM AND M.O. KIMBERLEY

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The effect of rate and timing of potassium fertiliser on the growth and potassium nutrition of young radiata pine in Northland Results after six years.

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ABSTRACT

At three sites in Northland, foliage analysis of radiata pine trees fertilised with potassium fertiliser showed rapid uptake of K, and a decline with time over six years. The foliar K patterns of longevity to the fertiliser were similar between the 200 and 400 kg K/ha rates, and evidence is shown to suggest that an application rate between 100 and 200 kg K/ha is desirable to elevate and maintain foliar K concentrations.

INTRODUCTION

On the severely podzolised soils of the Auckland Region, and the gley-podzols of Westland, potassium (K) deficiency is becoming more widespread with the increased use of N and P fertilisers. There is currently little information worldwide on K responses in young crops; in New Zealand information on K responses exists for one trial at Whitecliffs (Northland), where N, P, K, and Cu gave an additional $6m^2$/ha over an NP treatment, measured over 3 years (FRI, unpublished data). A response was demonstrated where foliar K levels were in the deficiency range at about 0.3% at the time of fertilising.

The objective of this project was to quantify growth and nutritional responses to added K in young crops, on sites covering a range of foliar K concentrations where K alone was the only nutrient limiting growth.

MATERIALS AND METHODS

The approach

The approach was to work with young radiata pine and to follow the decline in foliar K over consecutive years. Over a 3 year period, a number of rates of K were applied, and the response in foliar K was monitored by foliage sampling.

Trial design

The design employed a modified factorial design in randomised complete blocks. The design is:

Rates (0,50,100,200,400 kg K/ha) by Time - K applied at trial establishment (Stage I), after 1 year (Stage II) and after 2 years (Stage III). There were 3 replications of each treatment. blocked by site variation. The treatment schedule is as follows:

				DAP added		
STAGE	Trt No	K kg/ha	Timing	Haititaimarangii	Rotu	Pipiwai
Stage 1	1	0	1988	yes	no	yes
	2	50	1988	yes	no	yes
	3	100	1988	yes	no	yes
	4	200	1988	yes	no	yes
	5	400	1988	yes	no	yes
Stage 2	6	50	1989	yes	no	yes
	7	100	1989	yes	no	yes
	8	200	1989	yes	no	yes
	9	400	1989	yes	no	yes
Stage 3	10	50	1990	yes	no	yes
	11	100	1990	yes	no	yes
	12	200	1990	yes	no	yes
	13	400	1990	yes	no	yes
Stage 1	14	0	1988	no	no	no
	15	100	1988	no	no	no

The sites

Three sites were chosen at:

- Te Kopura sand at Cape Karikari, Haititaimarangi Block, courtesy of Northern Pulp Ltd (now Juken Nissho Ltd). The trees were 5 years old. Trial FR 68/1.
- Te Kopuru, after pasture, at Dargaville, Rotu Block, courtesy of New Zealand Forest Products, (now CHH Forests Ltd). The trees were 4 years old. Trial FR 68/2.
- Whakakohe loam at Pipiwai, Ngatihine Block, courtesy of Taitokerau Forests. The trees were 4 years old. Trial FR 68/3.

Trial establishment

All three trials were established in the spring of 1988. At Haititaimarangi, the inner measurement plots are 10.5 m by 14..0 m with 3 rows of measurement trees (0.0147 ha); at Rotu, the plots are 12 m by 13.2 m with 3 rows of measurement trees (0.0158 ha), and at Ngatihine, the plots are 10 m by 14.4 m with 4 rows of measurement trees (0.0144 ha).

Fertiliser application and Measurements

At Haititaimarangi and Pipiwai N and P fertiliser as DAP was added as a broadcast treatment to the main body of the experiment. However treatments 14 and 15 were to enable the effect of the broadcast NP application (as DAP) to be assessed independently of K, and for a "K alone" effect to be observed. At Rotu, an ex-pasture site, N and P fertility was satisfactory. After three years N was applied at Rotu and copper applied at Haititaimarangi when their foliar levels indicated that the area required "maintenance" fertilising.

At all three trials total tree height and DBH were measured in each plot at time of plot establishment. Each timing stage of the experiment was fertilised in the spring of 1988,

1989, and 1990 respectively. Growth measurements were performed annually from 1988 (winter) and foliage sampled in late summer of each year.

RESULTS

Changes in the K status of the control plots of radiata pine at the three sites (and the effect of the DAP base dressing)

Haititaimarangi

With DAP applied as a base treatment, K concentrations in the control trees had fallen in the following year to 0.63% (Fig. 1) and continued to decline to 0.45%. The addition of DAP has caused a dilution effect in K nutrition through growth being substantially higher (but not statistically significant P.05) by 1994 in the DAP treated, non K plots, by about 42 m3/ha (Figure 2a). In the absence of the DAP treatment foliar K levels declined from 0.87% to remain around 0.55% (Fig 1a).

Rotu

DAP was not applied as a base dressing at this site (at the initiation of the trial) as the N and P fertility was adequate (P and N concentrations at about 0.15% and 1.4% respectively - data not shown - at the start of the trial). Foliar K levels declined slowly over the six years from 1988 to between 0.6% and 0.7%% by 1994 (Fig. 1).

Pipiwai

At this site weed competition was intense from manuka, ghania and hakea, and foliar P and N levels were deficient (0.08% P, and 1.1% N, data not shown). Between 1988 and 1994 foliar K values (controls) increased from 0.66% to 0.93% (Fig 1) and there was little effect of the DAP treatment (growth promoting with additional 23 m3/ha by 1994 although not statistically significant at P.05) on foliar K (Fig. 1c).

Site specific effects on K nutrition and radiata pine growth

Haititaimarangi

The effect of K rates and timing on foliar K concentrations

One year after application of K fertilisers, K foliar concentrations were markedly elevated (Figure 3a), from 0.6% (control) to about 1% (50, 100 and 200 kg K/ha) and about 1.4% (400 kg K/ha). The following year (1990) concentrations had fallen sharply: the 50 and 100 kg rates where similar to the controls at between 0.5% and 0.6% K; the 200 kg rate was at about 0.65%, and the 400 rate at about 0.7%. These levels were maintained for 2 years, until 1992. By 1994 all rates, including the controls were similar.

Application of K in the experiment's second year (1989) raised foliar K concentrations for all except the 50 kg/ha rat (Figure 3b). The 100 and 200 kg/ha rates were similar, and the 400 kg/ha rate higher. By 1994 there were still clear differences in K nutrition between the controls, the 100/200 rates and the 400 rate.

Applications of K in the 3rd year (1990) showed similar responses (Figure 3c).

The results at this site show that at least 100 kg K/ha is required to significantly raise foliar K levels, and that the effect is relatively short lived with an early application of K. Applying additional K does not increase the longevity of the nutritional response at the early age. However, as trees age it appears that the effectiveness of the K application increases.

The effect of K rates and timing on growth

A summary of volume comparisons for 1994 showing K0 compared with K400 applied in 1988, 1989 and 1990 clearly shows the lack of responsiveness to applied K (Fig. 4). The data have been adjusted by co variance. A complete picture with the unadjusted means in shown in Figures 4a, b and c. The appearance of a growth trend at the highest

rate (400 kg/ha) applied in 1990, when foliar K was approaching the critical level (Will, 1978), is an artefact related to the size of the trees at the initiation of the trial.

Rotu

The effect of K rates and timing on foliar K concentrations

In 1989, one year following the Stage I application of K, only the 400 kg rate increased foliar K significantly (P.05), from 0.85% to 1.03% (Figure 5a).. By 1989 the 200 kg rate had significantly raised foliar K levels, and maintained a significant differences through to 1993 (Figure 5a). There were increases in K levels at the other rates, but the changes were not significant. For the Stage II applications (applied 1989) all rates significantly raised foliar K concentrations. By 1990, the 50 kg rate had elevated foliar K from 0.68% to 0.78% (Figure 5b); the intermediate rates (100 and 200 kg/ha) had elevated K levels to 0.92% and 0.87% respectively, and the highest rate (400 kg/ha) to 1.08%. By 1994 foliar K levels were significantly elevated in all but the 50 kg/ha treatment (Figure 5b). For the Stage III application, the pattern of responses were similar (Figure 5c) with the 100 kg/ha and the 200 kg/ha rates being equivalent in maintaining foliar K significantly above that of the control.

The effect of K rates and timing on growth

Radiata pine productivity was not stimulated by addition of K fertiliser at any of the three Stages of application, or rates of application up to 400 kg/ha (see summary in Fig 4 and data in Figures 6 a, b & c)

Pipiwai

The effect of K rates and timing on foliar K concentrations

One year following the Stage I application of K in 1988, all rates raised foliar K levels, from 0.61% to 0.71% (50 kg rate) to a little over 0.9% at the 400 rate (Figure 7a). Between 1989 and 1994 the overall effect was that foliar K to remained elevated only at the higher rates of 200 and 400 kg K/ha (Figure 7a). Stage II application of K

(Figure 7b) showed similar responses with the 200 and 400 kg rates being the most effective in maintaining elevated foliar K levels. The results for the Stage III application (Figure 7c) shows that only the 400 kg rate is effective in maintaining foliar K significantly above the control.

The effect of K rates and timing on growth

Fig. 4 and Figs. 8a, b & c show that as at the Rotu site, radiata pine productivity was not significantly stimulated by addition of K fertiliser at any of the three stages or rates of application up to 400 kg K/ha.

DISCUSSION

At Haititaimarangi foliar K levels declined to between 0.4% and 0.5% K two years after the experiment was established. Growth gains to K fertiliser were not recorded. FRI unpublished data suggests 0.35% K as the critical level for radiata pine. At the Rotu site, baseline K levels declined during the period 1988 - 1990, but remained at between 0.6% and 0.7% during the stages of applications. The decline to 0.49% did not occur until 6 years had elapsed (1994). The Pipiwai site, although selected for its history of low foliar K turned out to be unsuitable for this experiment with increasing levels of K in the controls over time.

A possible course of action now will be to combine the control and the 50 kg K/ha treatments at the Rotu site where foliar K levels have been declining by 0.1% per year from 1992 and test the effect of reapplication of K fertiliser (at a high rate) on growth.

CONCLUSIONS

At all three sites foliar K concentrations remained above the probable critical level and there was an absence of significant growth response to K fertiliser at any of the rates of application. There were however marked responses in the trees' foliar K nutrition to the rate and timing treatments. The lowest rate of 50 kg K/ha was, at all sites, insufficient to maintain elevated foliar K levels for an extended period. The 400 kg K/ha rate was super-optimal, and the 200 kg rate was similar in effectiveness. The 100 kg K/ha rate gave variable results. It appears that for management, a rate somewhere in between 100 and 200 kg K/ha is required.

The critical level for intervention was not defined (in terms of growth responsiveness); however, it would appear that foliar K concentrations would need to be lower than 0.4% before a growth response could be expected

REFERENCES

Will, G.M. 1978: Nutrient deficiencies in *Pinus radiata* in New Zealand. NZ Journal of Forestry Science 8: 4-14.

ACKNOWLEDGMENTS

The authors acknowledge the assistance of Mr Lew Read, of Juken Nissho Ltd for help in the site selection process (Haititaimarangi), and ongoing help with annual measurements and foliage sampling. Mr Paul Smale helped to secure the Rotu site, and Mr Ian Page with the Pipiwai site.

Appendix 1

Significance of the "F ratios" for the effect of K fertilisers on foliar K concentrations

Trial at Haititaimarangi
Foliar K

		1989		1990		1991		1992		1993		1994	
Source	d.f	F	LSD	F	LSD	F	LSD	F	LSD	F	LSD	F	LSD
block	2	.854	.	n.d		.612		.465		.691		.630	
trt	13	.0001	0.25	n.d	n.d	.0001	0.12	.0001	0.12	.0005	0.13	.0013	0.15

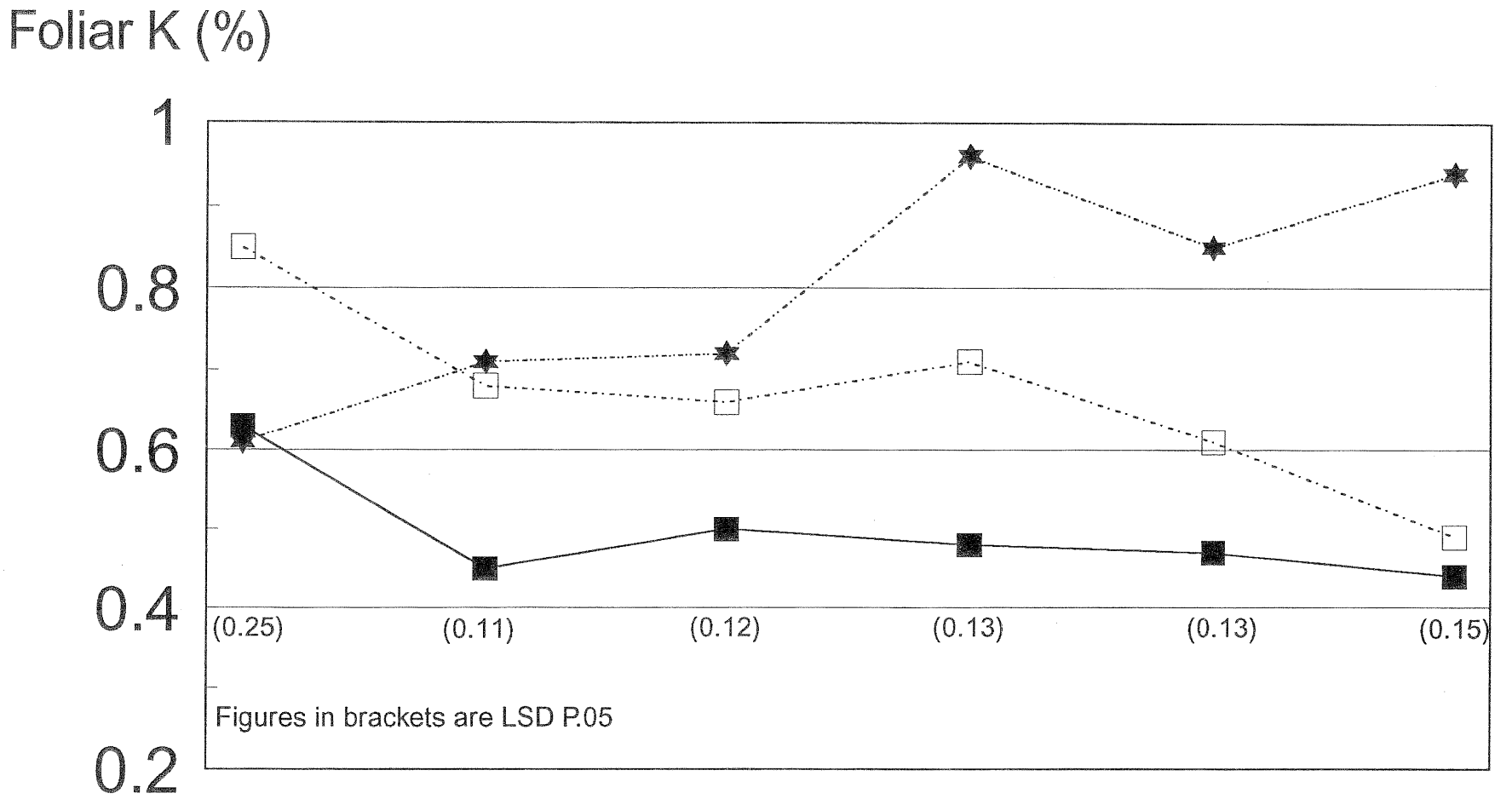
Trial at Rotu
Foliar K

		1989		1990		1991		1992		1993		1994	
Source	d.f	F	LSD	F	LSD	F	LSD	F	LSD	F	LSD	F	LSD
block	2	.0004		.0304		.2056		.0120		.1284		.1929	
trt	13	.0065	0.18	.0052	0.21	.0089	0.23	.0372	0.26	.0281	0.20	0.21	0.24

Trial at Pipiwai
Foliar K

		1989		1990		1991		1992		1993		1994	
Source	d.f	F	LSD	F	LSD	F	LSD	F	LSD	F	LSD	F	LSD
block	2	.230		.0003		.0001		.0001		.0063		.0422	
trt	13	.0009	0.14	.0006	0.14	.0258	0.15	.0258	0.15	.1152	0.13	.685	0.19

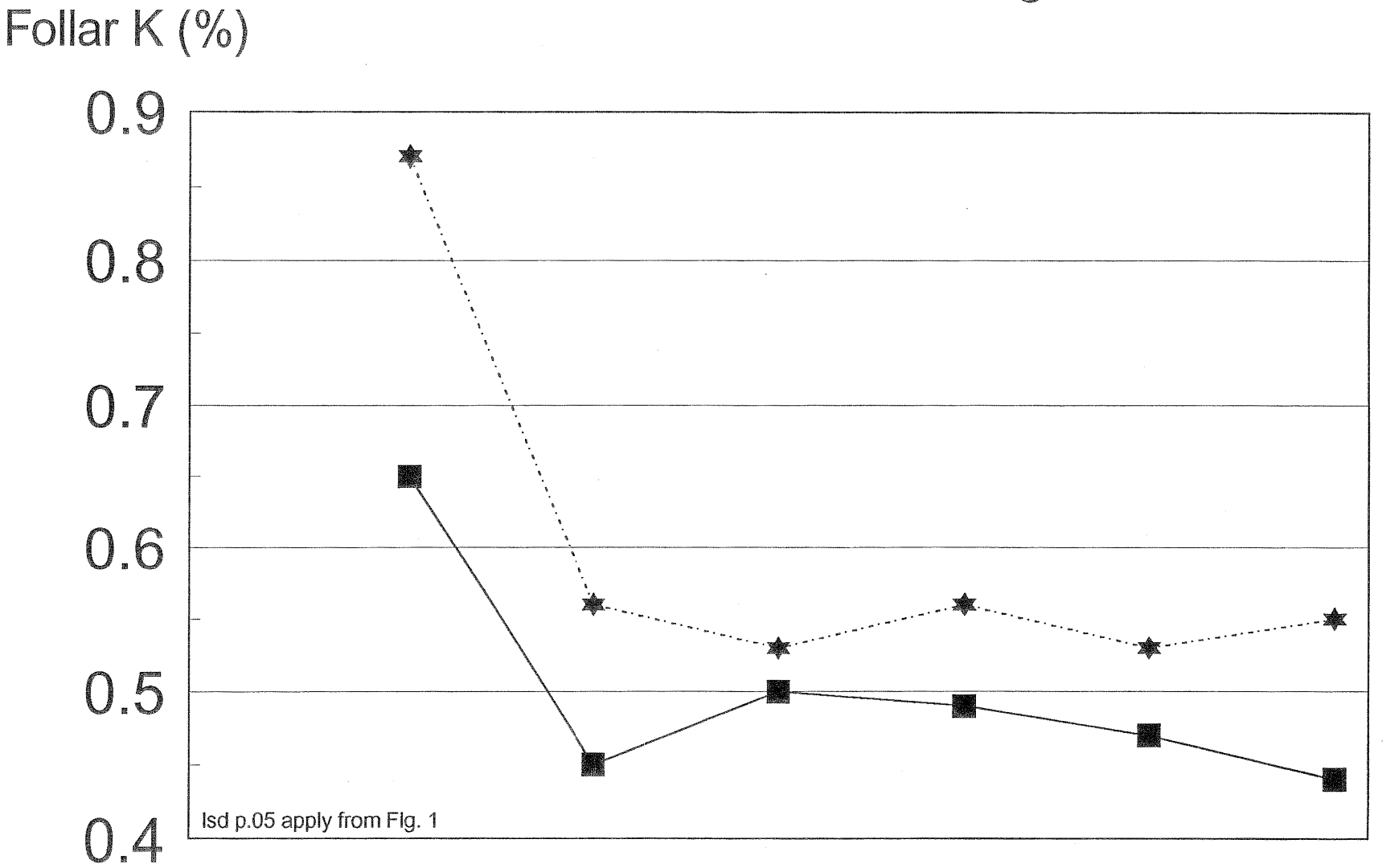
Figure 1. Changes in the controls (no K fertiliser) at the 3 sites



	1989	1990	1991	1992	1993	1994
Halt	0.63	0.45	0.50	0.48	0.47	0.44
Rotu	0.85	0.68	0.66	0.71	0.61	0.49
Pipiwai	0.61	0.71	0.72	0.96	0.85	0.94

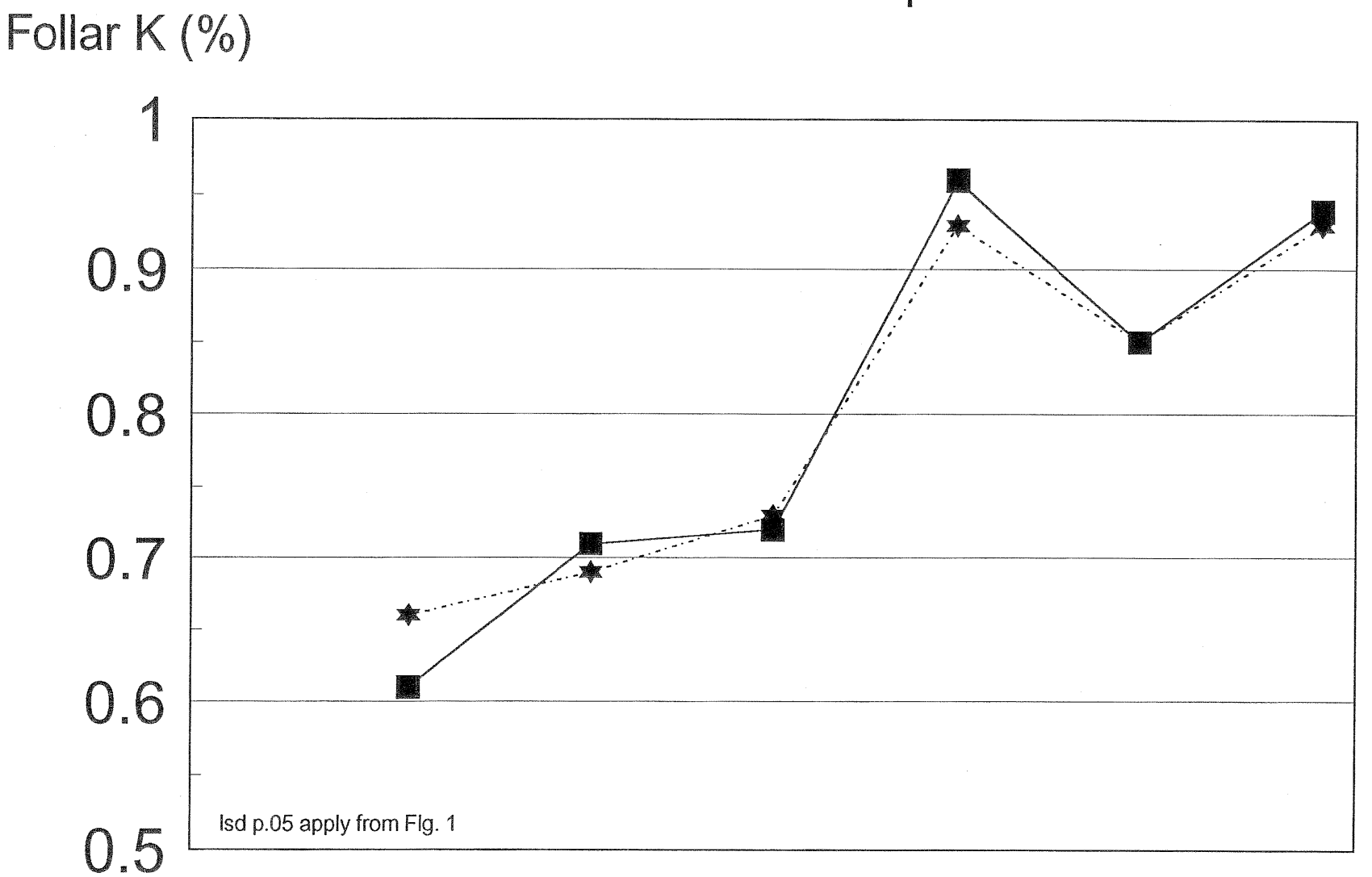
At Haltltalmarangl and Piplwal DAP was applied as a base treatment; at Rotu, DAP was not applled

Flgure 1a. The effect of the DAP treatment on foliar K concentratlons at Haitltaimarangl



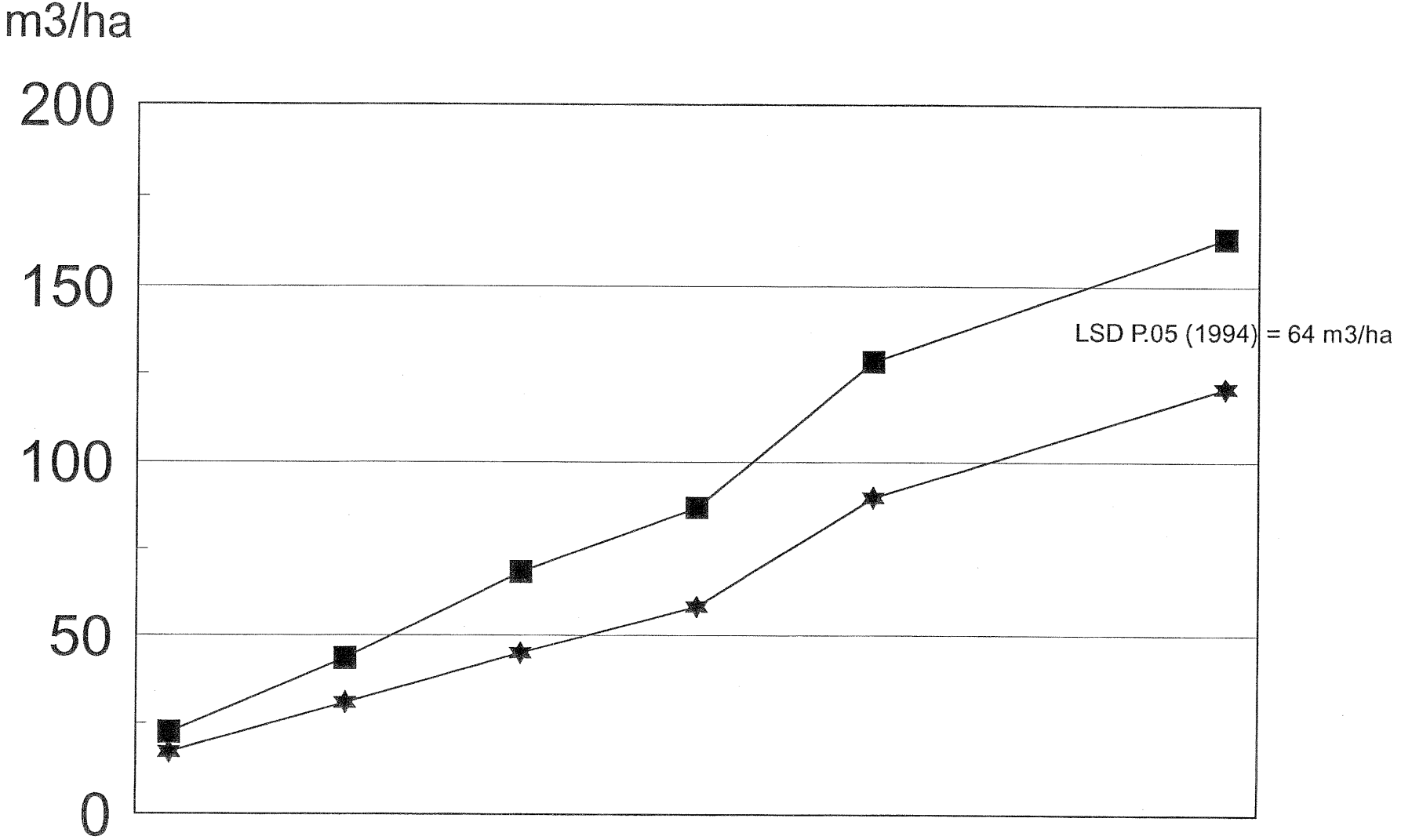
	1988	1989	1990	1991	1992	1993	1994
K 0, + NP ■		0.65	0.45	0.50	0.49	0.47	0.44
K 0, no NP ✸		0.87	0.56	0.53	0.56	0.53	0.55

Figure 1c. The effect of the DAP treatment on foliar K concentrations at Piplwal



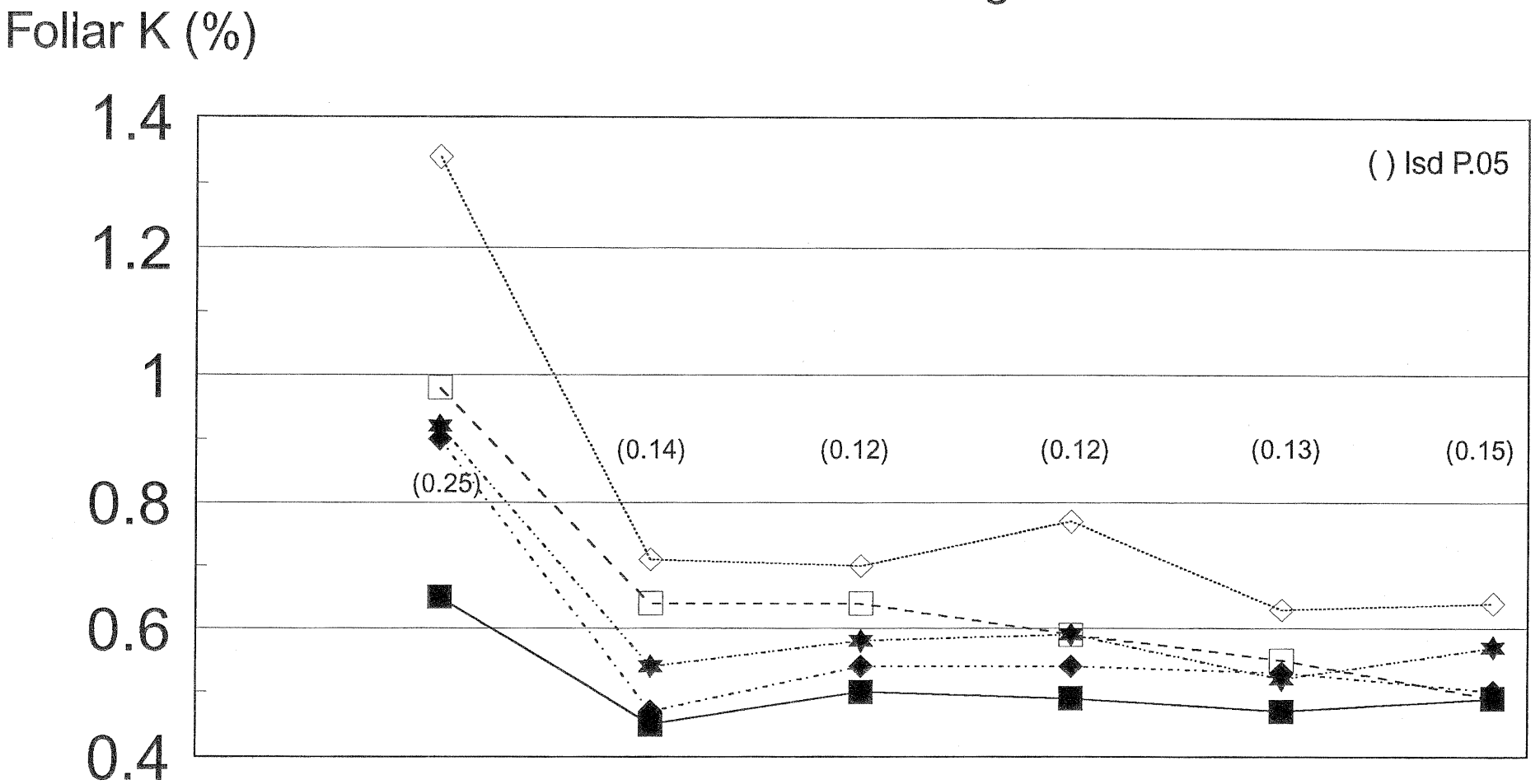
	1988	1989	1990	1991	1992	1993	1994
K 0, with NP		0.61	0.71	0.72	0.96	0.85	0.94
K 0, no NP		0.66	0.69	0.73	0.93	0.85	0.93

Figure 2a. Effect of DAP alone on volume growth (m3/ha) at Haltitalmarangl



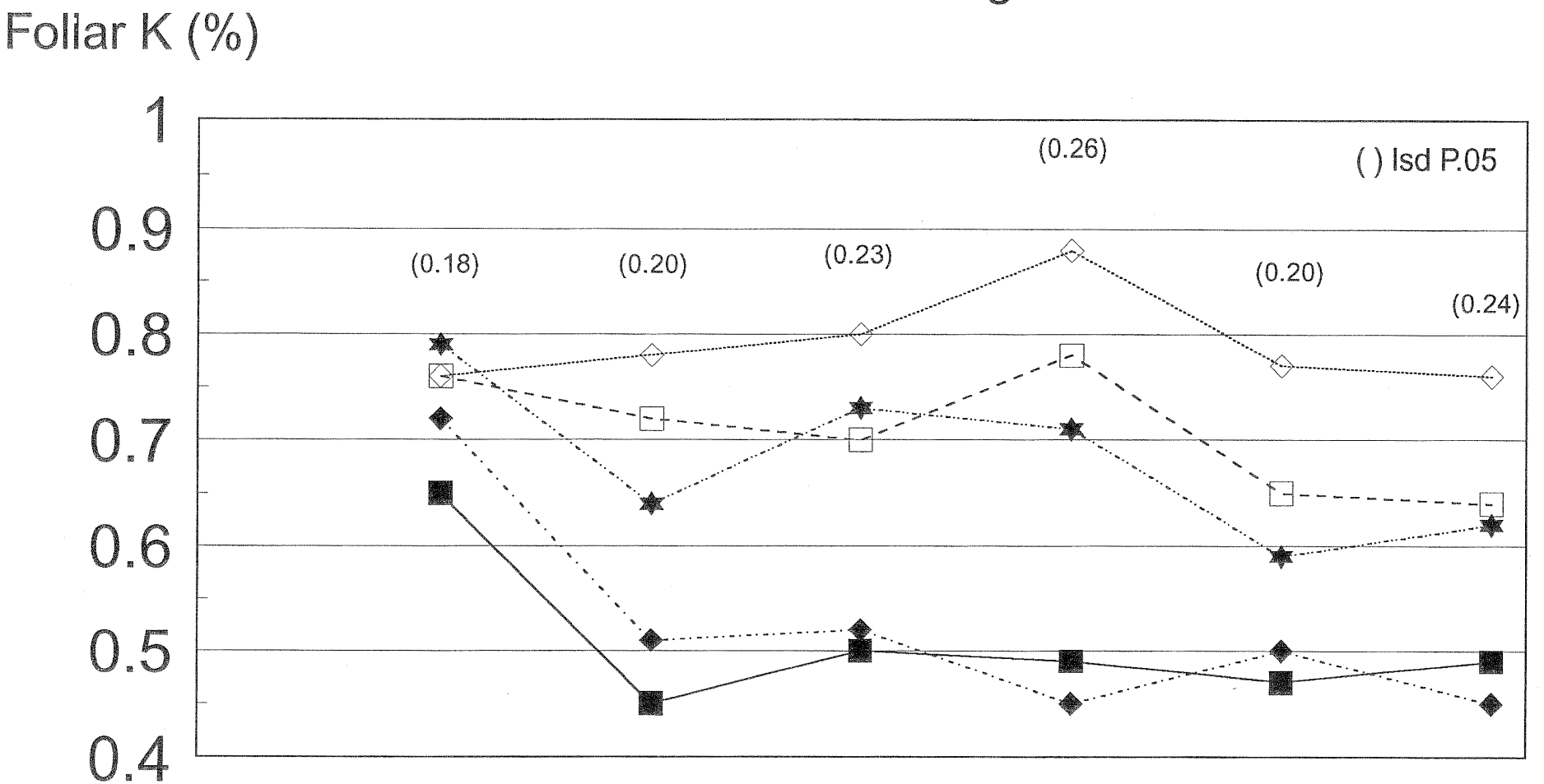
	1988	1989	1990	1991	1992	1993	1994
K 0, with NP ■	22.50	43.50	68.30	86.90	128.40		163.60
K0, no NP ★	17.10	30.90	44.90	58.30	89.80		120.60

Figure 3a. Effect of K rates applied in Stage I (sprlng 1988)) on follar K levels through to 1994 at Haltltalmarangi



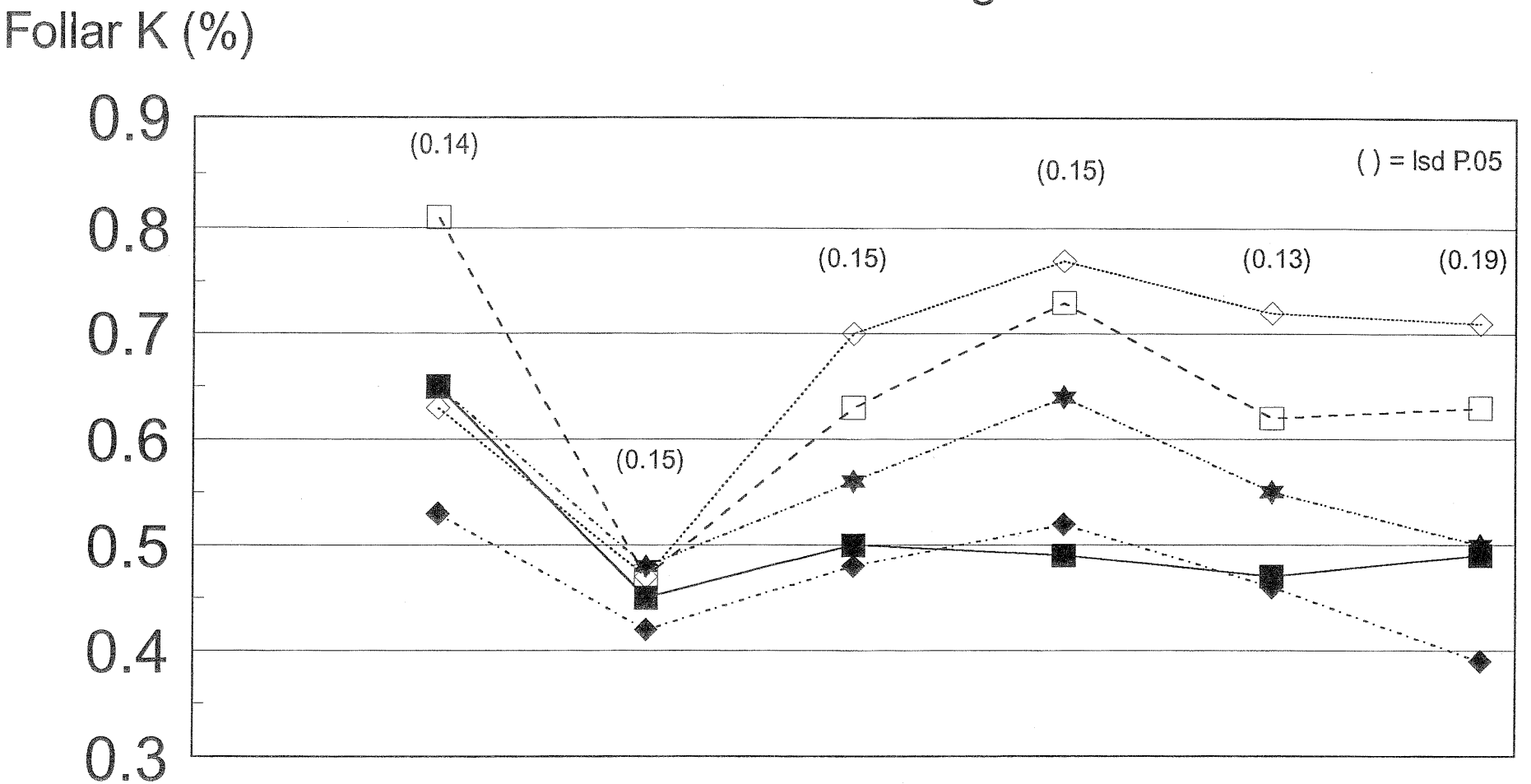
	1988	1989	1990	1991	1992	1993	1994
1 K 0		0.65	0.45	0.50	0.49	0.47	0.49
2 K 50		0.90	0.47	0.54	0.54	0.53	0.50
3 K 100		0.92	0.54	0.58	0.59	0.52	0.57
4 K200		0.98	0.64	0.64	0.59	0.55	0.49
5 K400		1.34	0.71	0.70	0.77	0.63	0.64

Figure 3b. Effect of K rates applied in Stage II (spring 1989) on foliar K levels through to 1994 at Haltitalmarangl



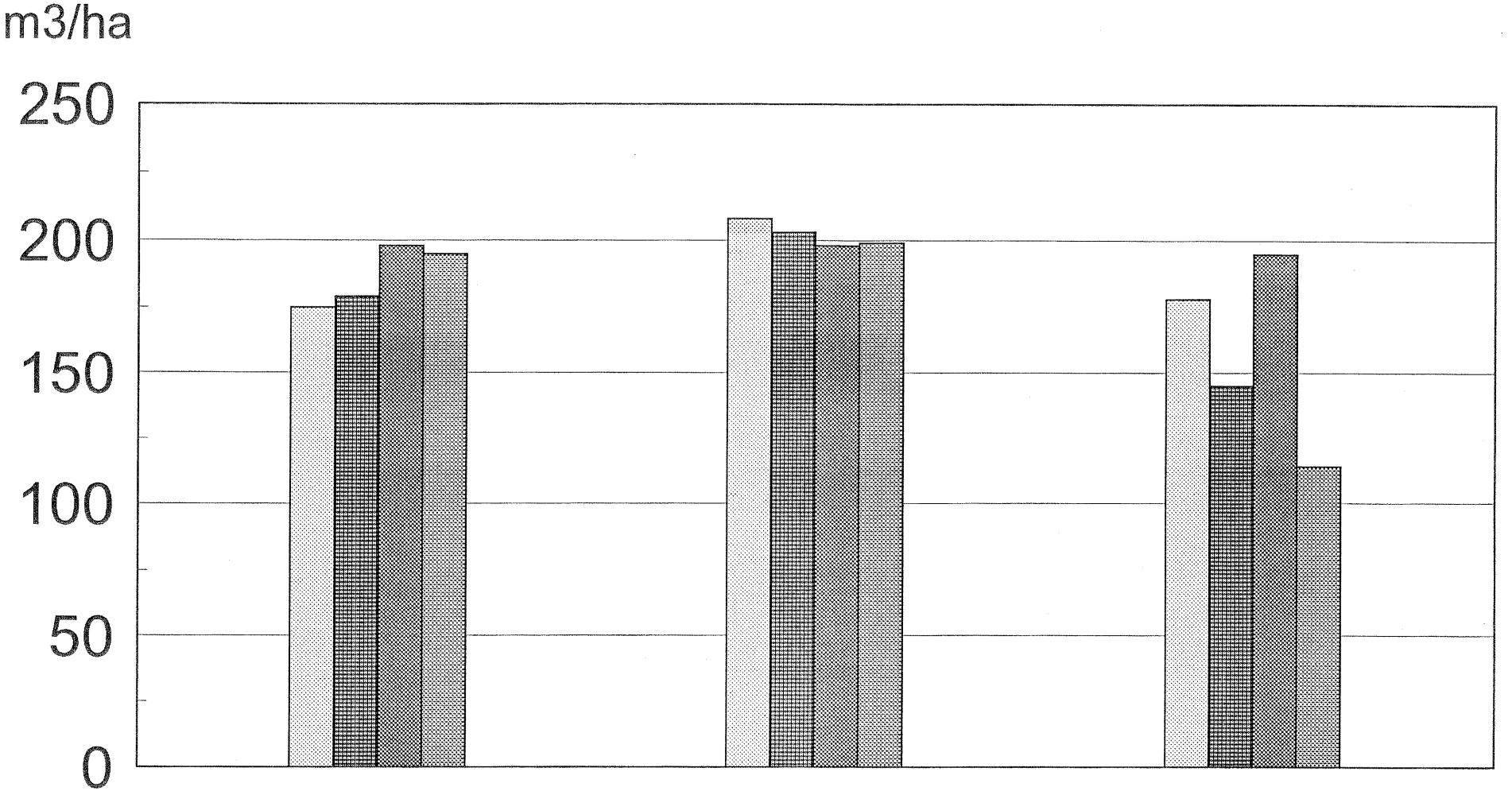
	1988	1989	1990	1991	1992	1993	1994
1 K 0		0.65	0.45	0.50	0.49	0.47	0.49
6 K 50		0.72	0.51	0.52	0.45	0.50	0.45
7 K 100		0.79	0.64	0.73	0.71	0.59	0.62
8 K 200		0.76	0.72	0.70	0.78	0.65	0.64
9 K 400		0.76	0.78	0.80	0.88	0.77	0.76

Figure 3c. Effect of K rates applied in Stage III (spring 1990) on foliar K levels through to 1994 at Haitltaimarangi



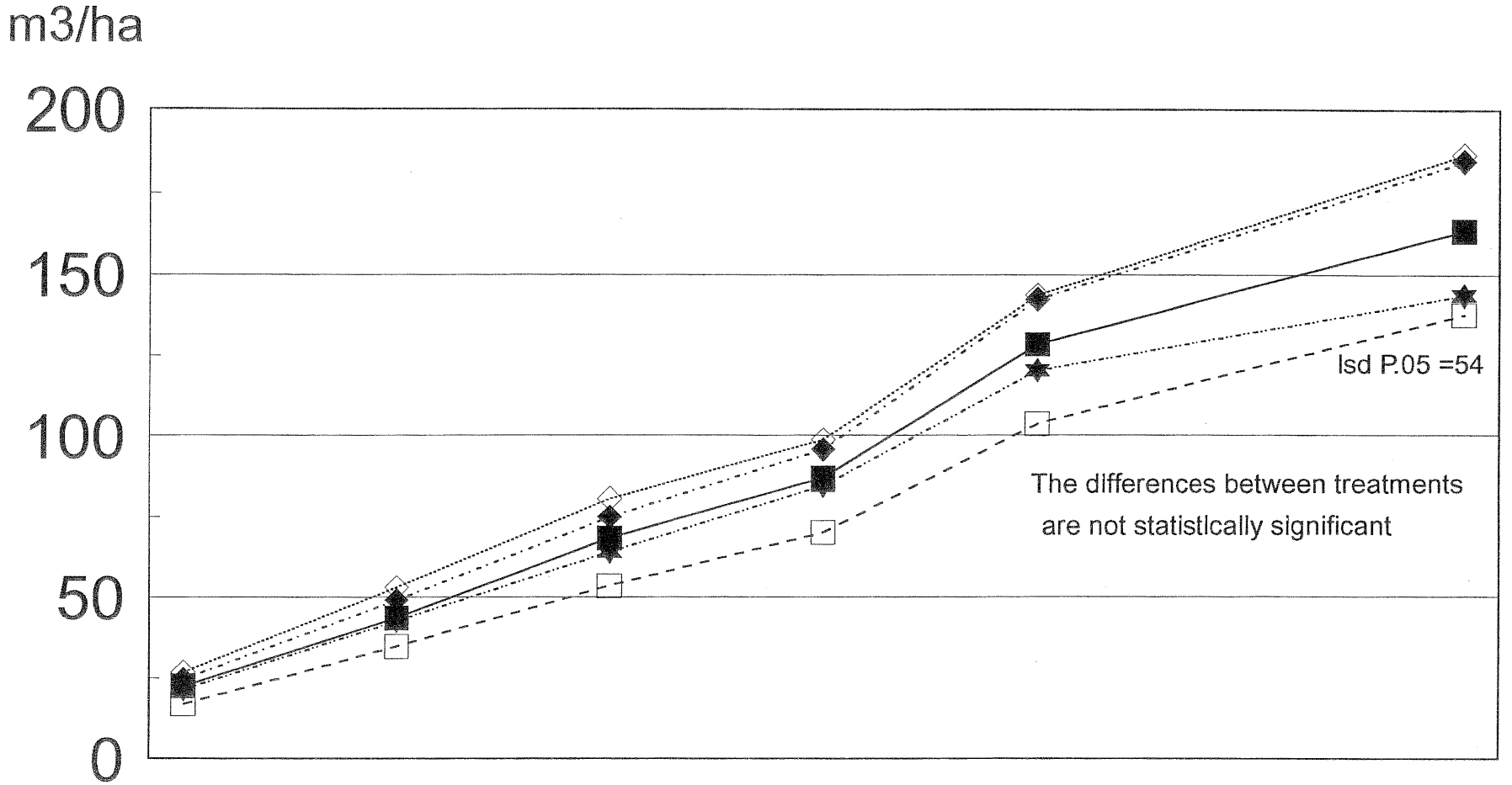
	1988	1989	1990	1991	1992	1993	1994
1K 0		0.65	0.45	0.50	0.49	0.47	0.49
10K 50		0.53	0.42	0.48	0.52	0.46	0.39
11K 100		0.65	0.48	0.56	0.64	0.55	0.50
12K 200		0.81	0.47	0.63	0.73	0.62	0.63
K400		0.63	0.47	0.70	0.77	0.72	0.71

Flg. 4. The effect of timing on rhe response to 400 kg K/ha at the 3 sites



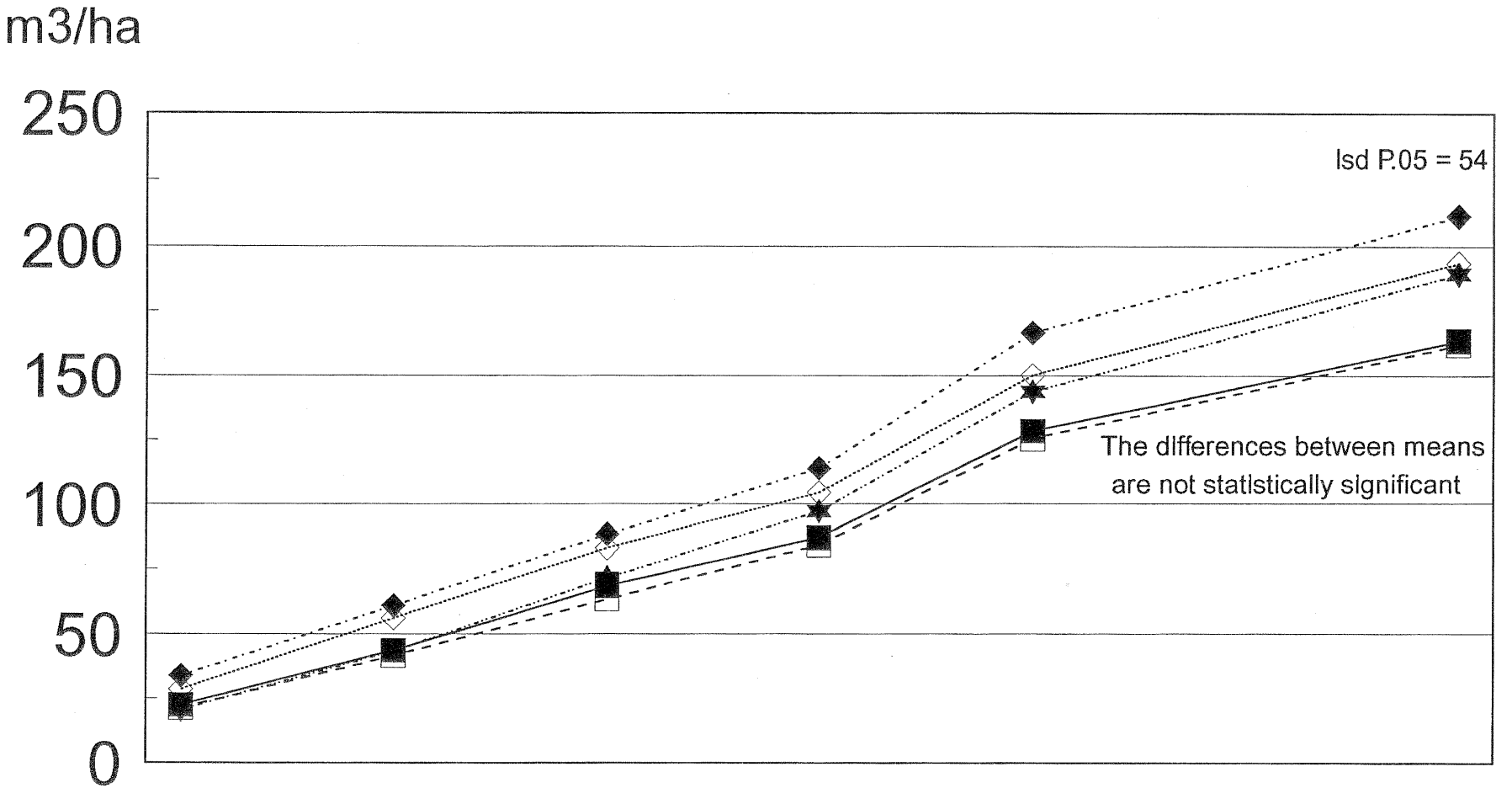
	HaitItaimarangi	Rotu	Plpiwai
control	175	208	178
K400 1988	179	203	145
K400 1989	198	198	195
K400 1990	195	199	114

Figure 4a. The effect of K fertilising In 1988 on subsequent volume growth through to 1994 at HaitItalmarangi



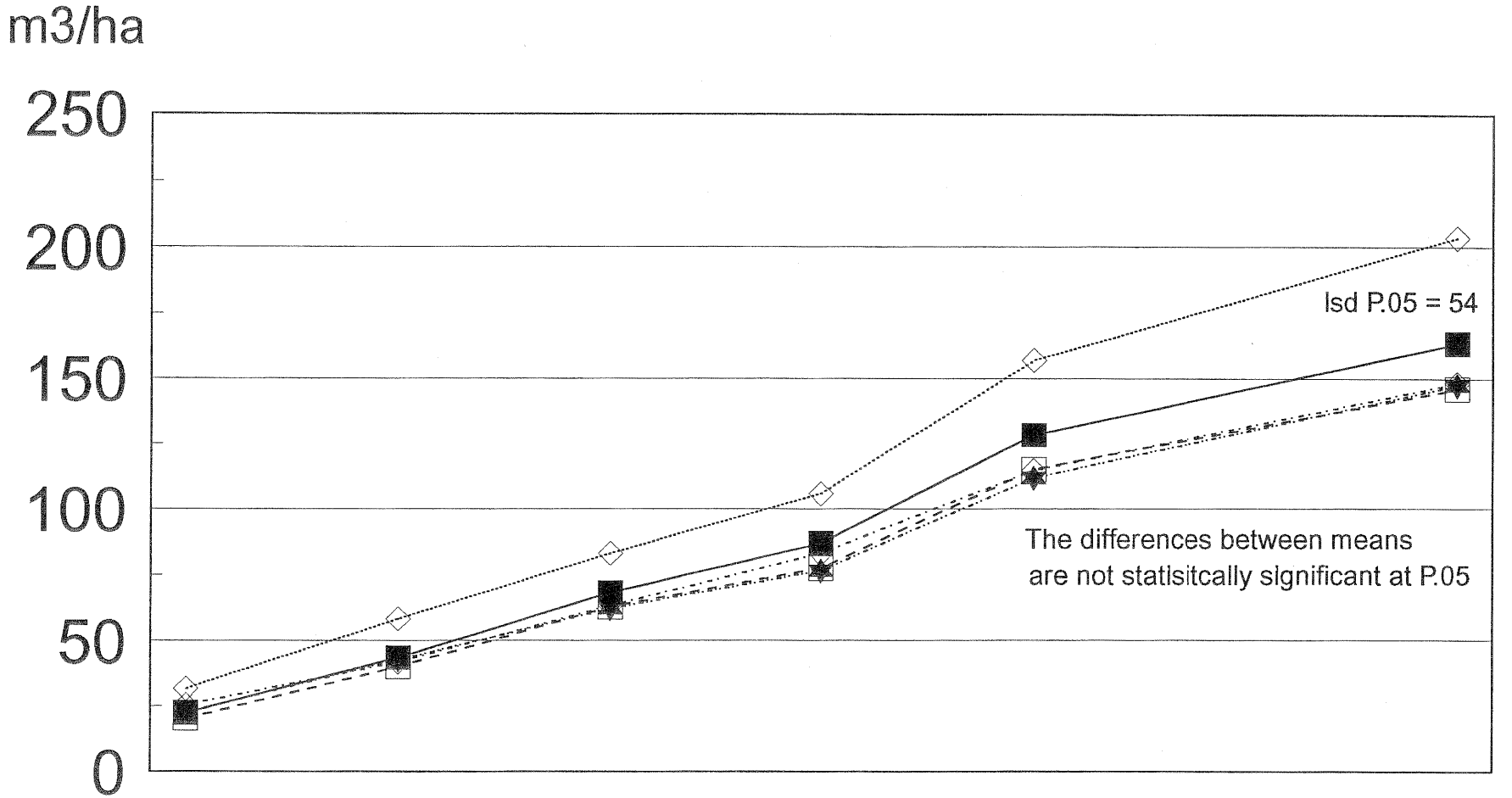
	1988	1989	1990	1991	1992	1993	1994
1 K 0	22.5	43.5	68.3	86.9	128.4		163.6
2 K 50	24.6	49.0	74.8	95.7	142.4		184.7
3 K 100	21.5	42.6	64.0	84.5	120.3		143.6
4 K200	17.0	34.7	53.5	70.0	103.7		137.7
5 K400	26.7	53.0	80.5	98.8	143.6		186.6

Figure 4b. The effect of K fertilising in 1989 on subsequent growth through to 1994 at Haitaimarangi



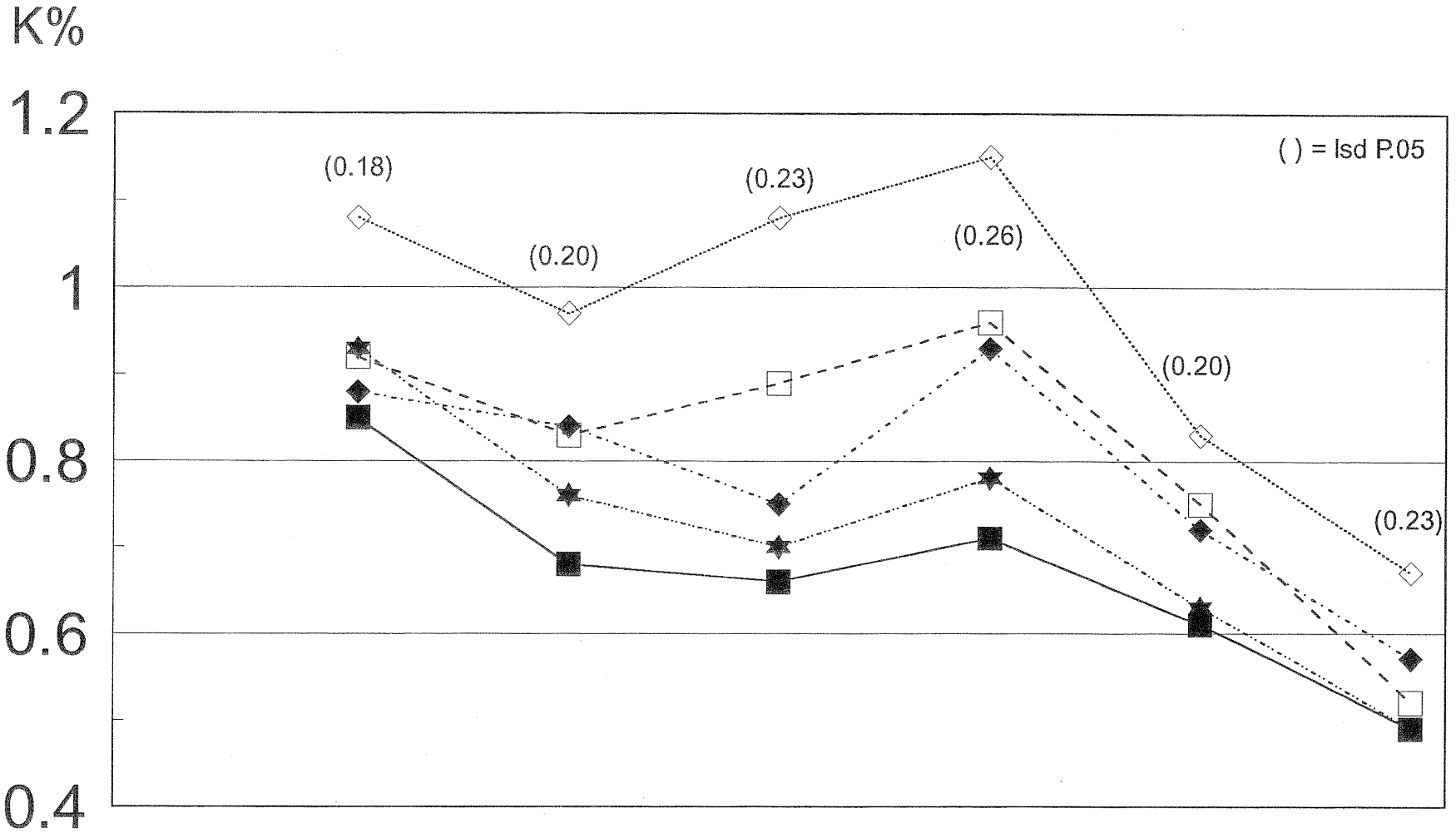
	1988	1989	1990	1991	1992	1993	1994
1 K 0	22.5	43.5	68.3	86.9	128.4		163.6
6 K 50	33.7	60.7	88.3	113.9	166.6		211.5
7 K 100	20.6	43.4	71.5	97.2	143.8		189.3
8 K 200	21.3	41.4	63.3	84.1	125.4		162.1
9 K 400	28.6	56.0	83.0	104.4	150.1		193.5

Figure 4c. The effect of K fertilisIng In 1990 on subsequent volume growth through to 1994 at HaititaImarangi



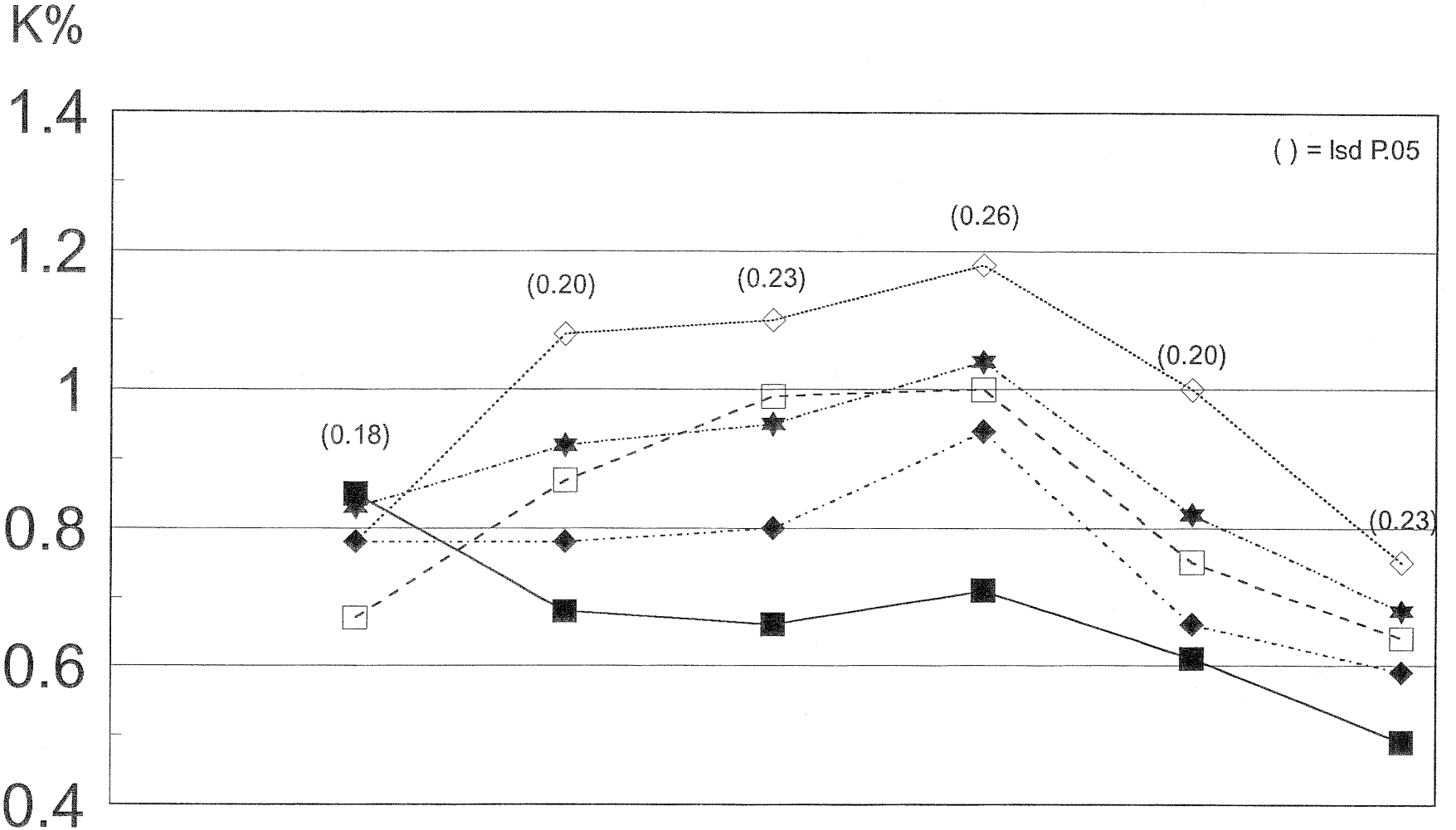
	1988	1989	1990	1991	1992	1993	1994
1 K 0	22.50	43.50	68.30	86.90	128.40		163.60
10 K 50	25.50	41.70	63.30	83.10	114.80		148.40
11 K 100	22.60	42.60	62.20	76.50	111.80		147.60
12 K 200	20.30	40.00	62.80	77.50	115.10		146.20
K400	31.67	58.40	83.20	105.80	157.20		203.60

Figure 5a. Effect of K rates applied in spring 1988 on foliar K levels through to 1994 at Rotu



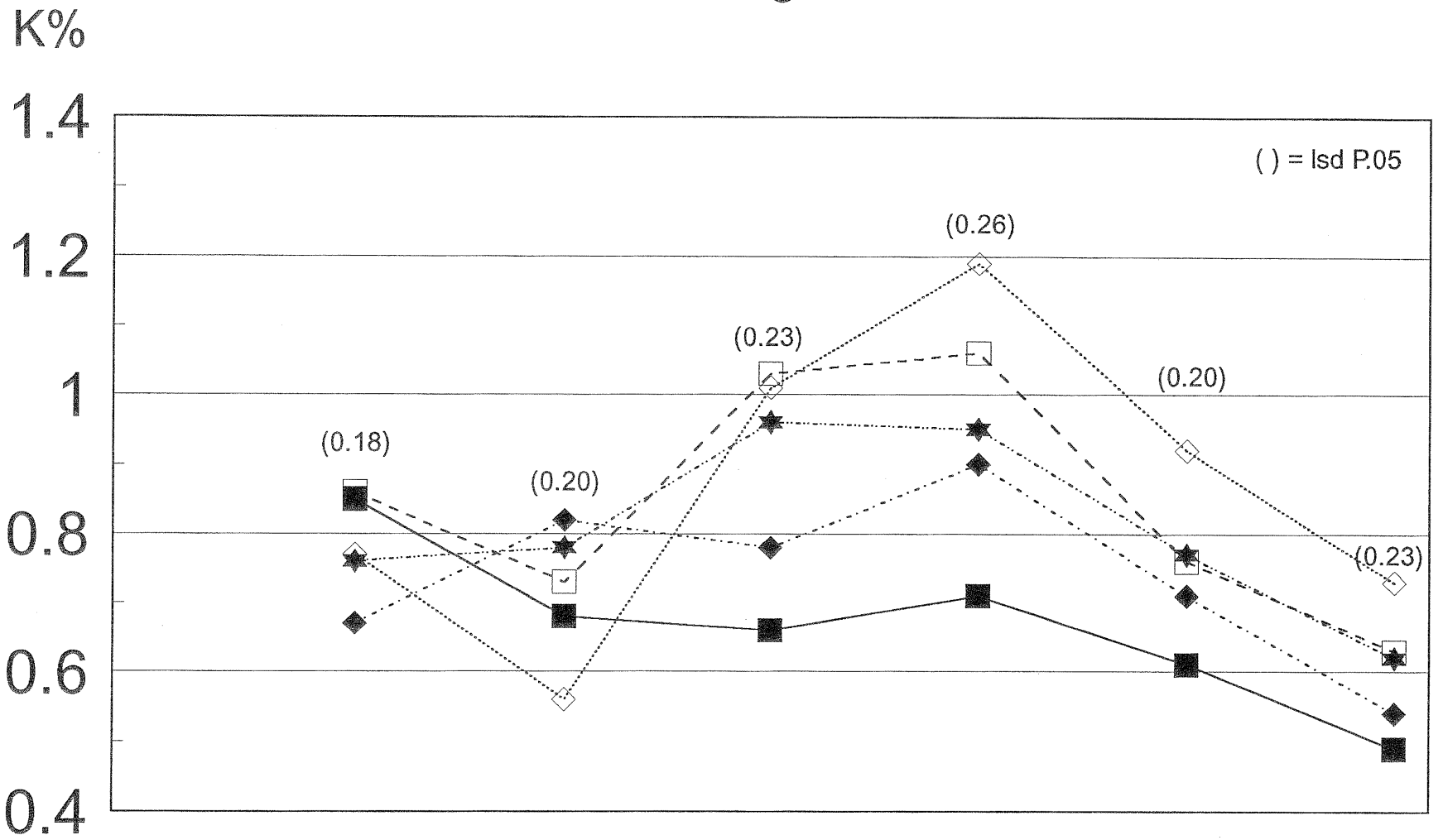
	1988	1989	1990	1991	1992	1993	1994
1 K 0		0.85	0.68	0.66	0.71	0.61	0.49
2 K 50		0.88	0.84	0.75	0.93	0.72	0.57
3 K 100		0.93	0.76	0.70	0.78	0.63	0.49
4 K200		0.92	0.83	0.89	0.96	0.75	0.52
5 K400		1.08	0.97	1.08	1.15	0.83	0.67

Figure 5b. Effect of K rates applied In spring 1989 on follar K levels through to 1994 at Rotu



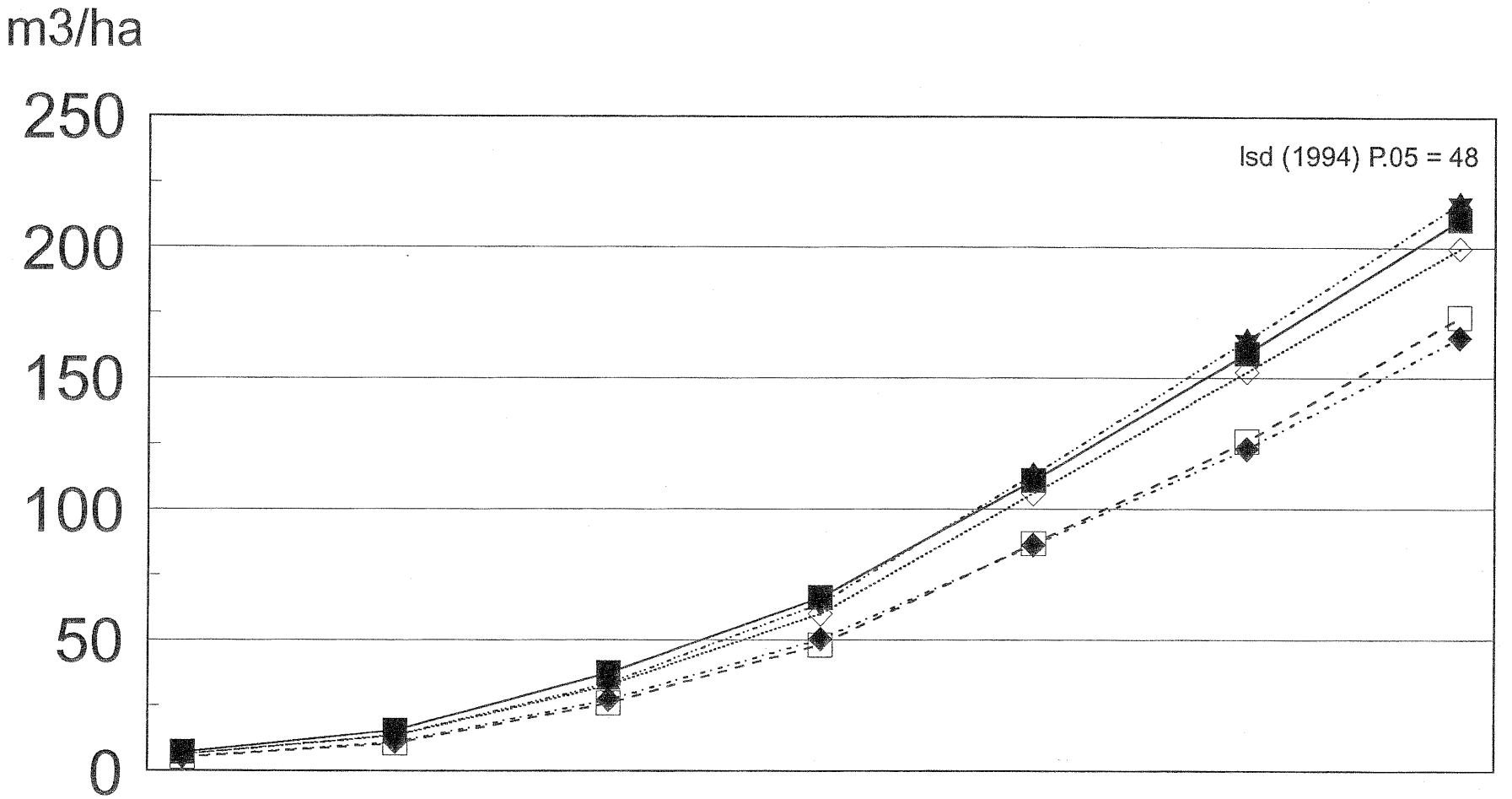
	1988	1989	1990	1991	1992	1993	1994
1 K 0		0.85	0.68	0.66	0.71	0.61	0.49
6 K 50		0.78	0.78	0.80	0.94	0.66	0.59
7 K 100		0.83	0.92	0.95	1.04	0.82	0.68
8 K 200		0.67	0.87	0.99	1.00	0.75	0.64
9 K 400		0.78	1.08	1.10	1.18	1.00	0.75

Figure 5c. Effect of K rates applied in spring 1990 on foliar K levels through to 1994 at Rotu



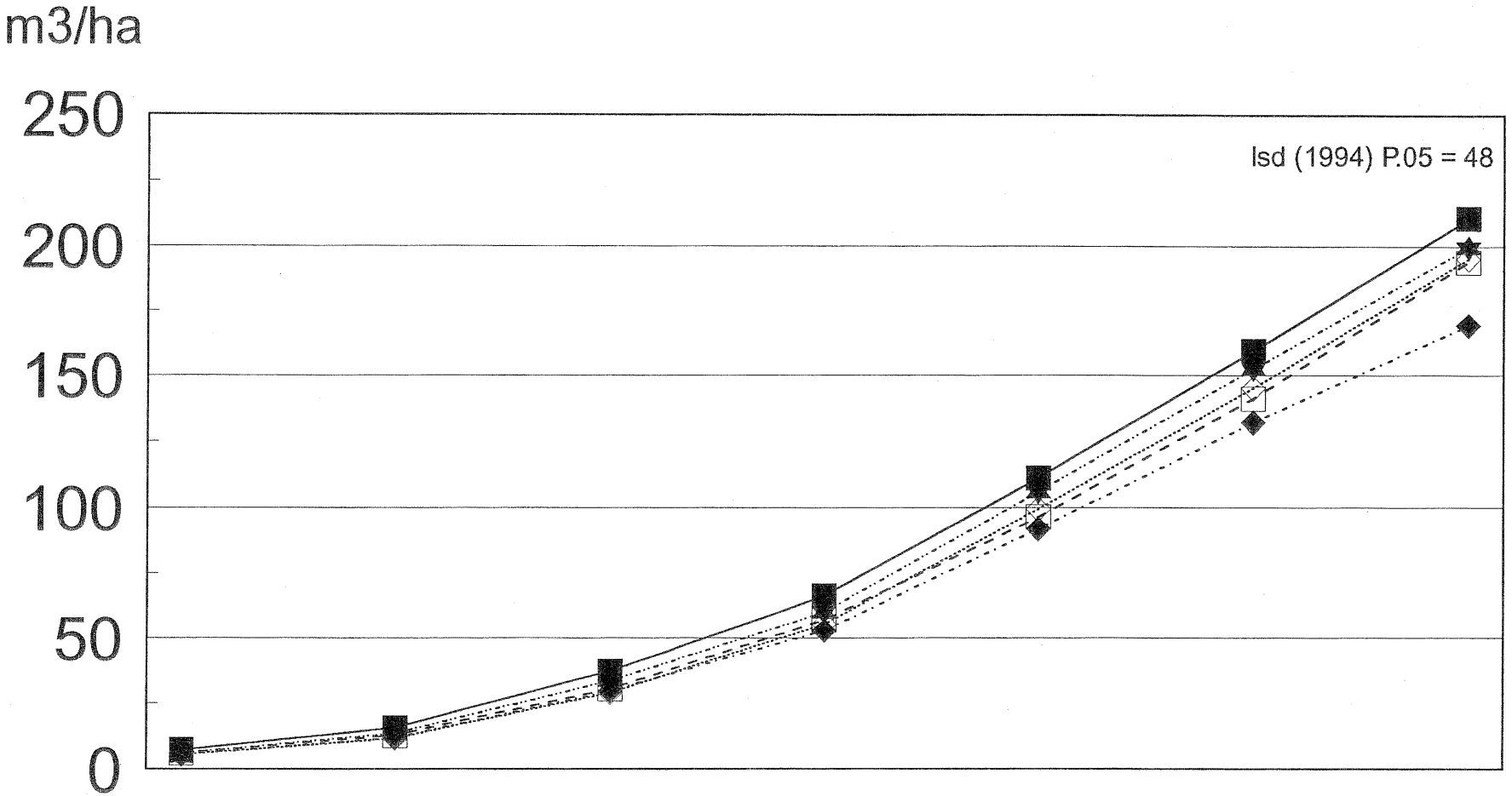
	1988	1989	1990	1991	1992	1993	1994
1K 0 ■		0.85	0.68	0.66	0.71	0.61	0.49
10K 50 ◆		0.67	0.82	0.78	0.90	0.71	0.54
11K 100 ✸		0.76	0.78	0.96	0.95	0.77	0.62
12K 200 ⊟		0.86	0.73	1.03	1.06	0.76	0.63
K400 ◇		0.77	0.56	1.01	1.19	0.92	0.73

Figure 6a. The effect of K fertilising in 1988 on subsequent volume through to 1994 at Rotu



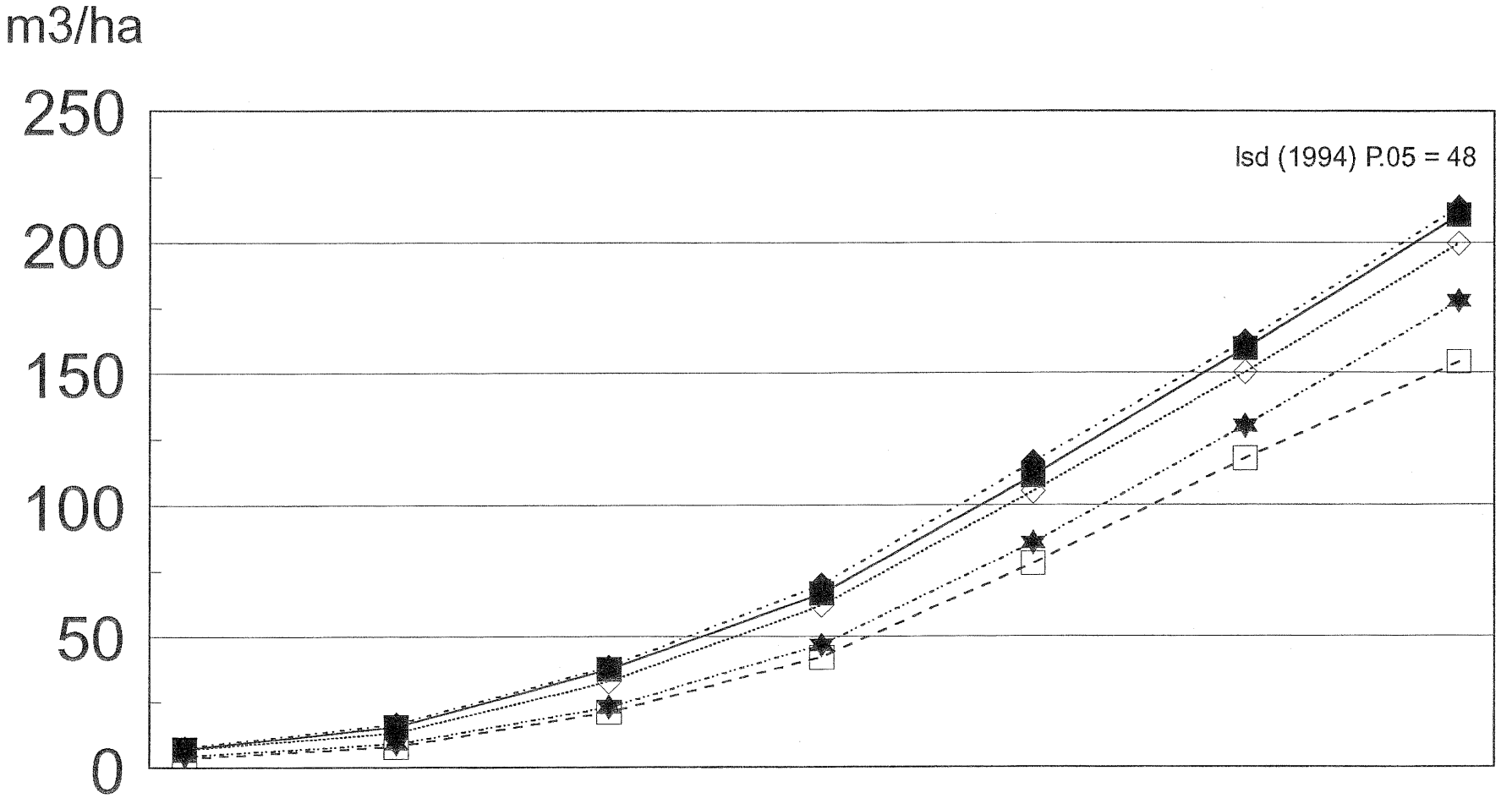
	1988	1989	1990	1991	1992	1993	1994
1 K 0	7.2	15.5	37.2	66.3	111.1	159.3	210.9
2 K 50	5.2	11.0	27.2	50.3	86.3	123.1	165.3
3 K 100	6.3	13.7	33.2	63.9	113.4	164.3	217.4
4 K200	5.2	10.7	25.9	48.1	86.9	126.0	173.2
5 K400	6.3	13.5	32.4	60.0	106.0	152.3	199.7

Figure 6b. The effect of K fertilising in 1989 on subsequent volume through to 1994 at Rotu



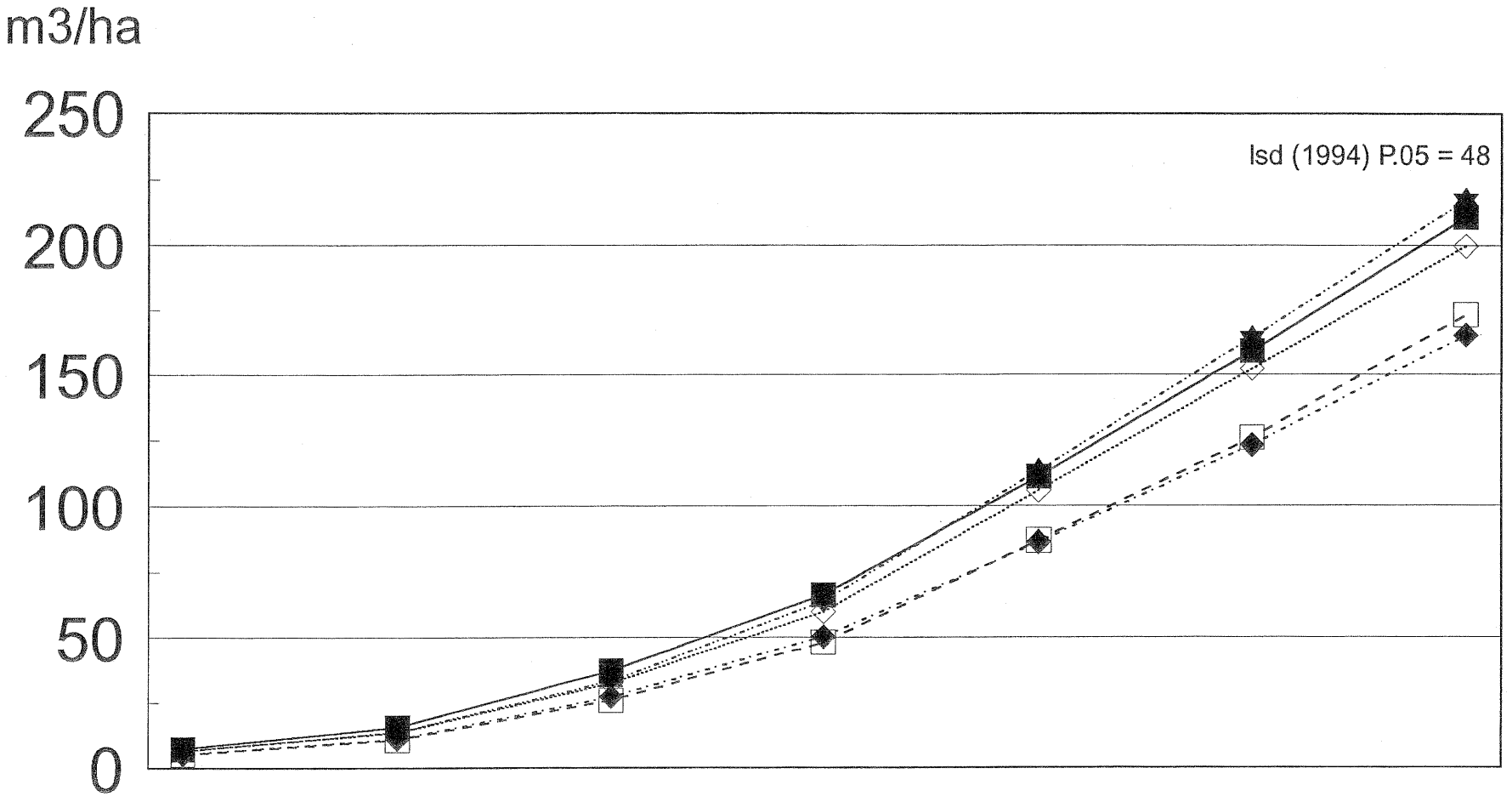
	1988	1989	1990	1991	1992	1993	1994
1 K 0	7.2	15.5	37.2	66.3	111.1	159.3	210.9
6 K 50	5.6	11.9	29.5	53.0	91.9	132.1	169.1
7 K 100	6.0	13.5	33.4	60.1	105.9	152.3	199.5
8 K 200	6.1	12.8	30.4	57.2	96.4	141.1	193.9
9 K 400	5.4	11.6	28.9	55.5	99.4	145.0	195.1

Figure 6c. The effect of K fertilising In 1990 on subsequent volume through to 1994 at Rotu



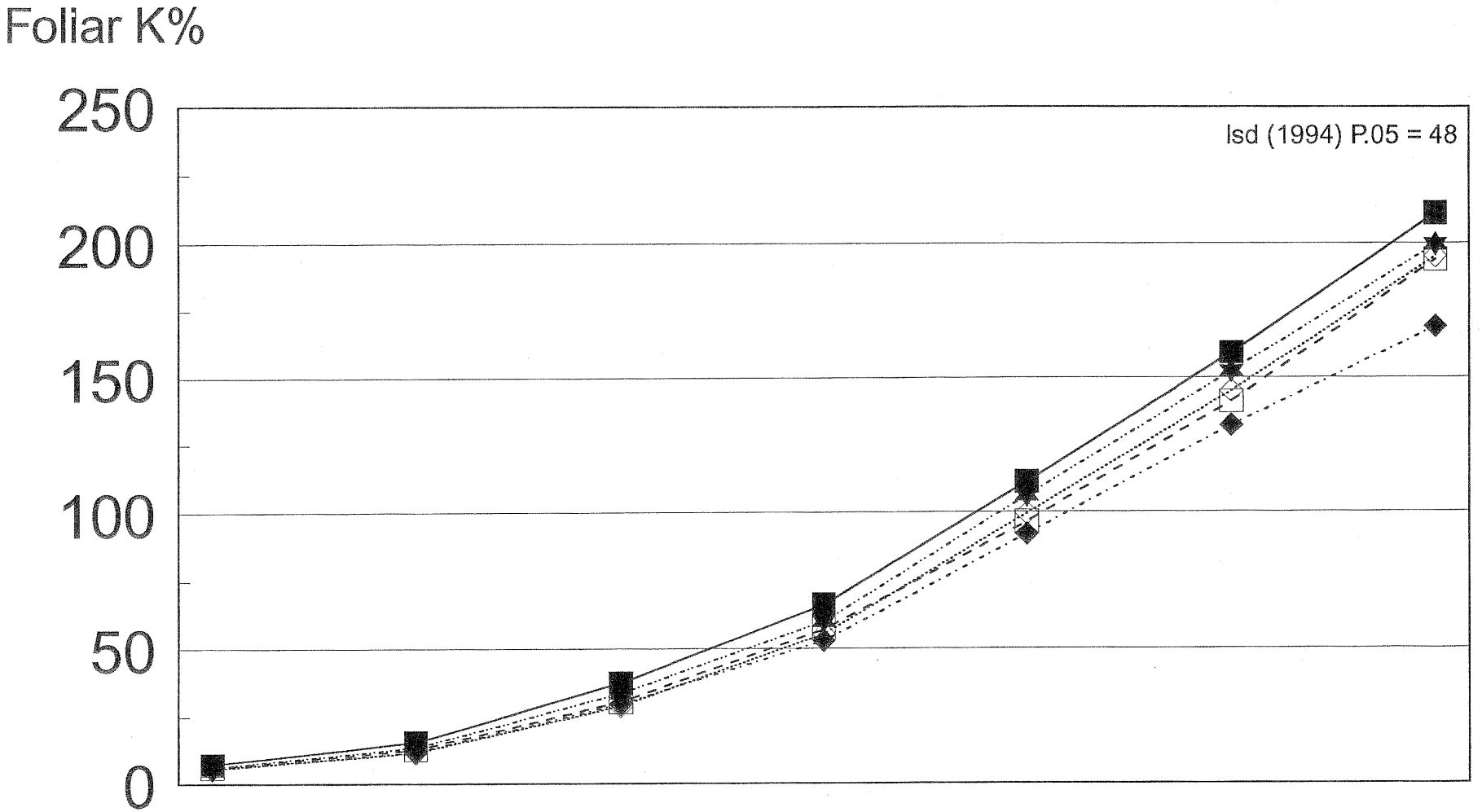
	1988	1989	1990	1991	1992	1993	1994
1 K 0	7.2	15.5	37.2	66.3	111.1	159.3	210.9
10 K 50	7.7	16.5	38.2	69.7	116.2	162.1	213.8
11 K 100	4.4	9.2	23.0	46.6	85.7	129.7	177.7
12 K 200	3.7	8.0	21.1	41.9	77.8	117.4	154.1
13 K400	6.9	13.2	32.7	61.8	105.2	150.1	199.8

Figure 6a. The effect of K fertlllslng in 1988 on subsequent volume through to 1994 at Rotu



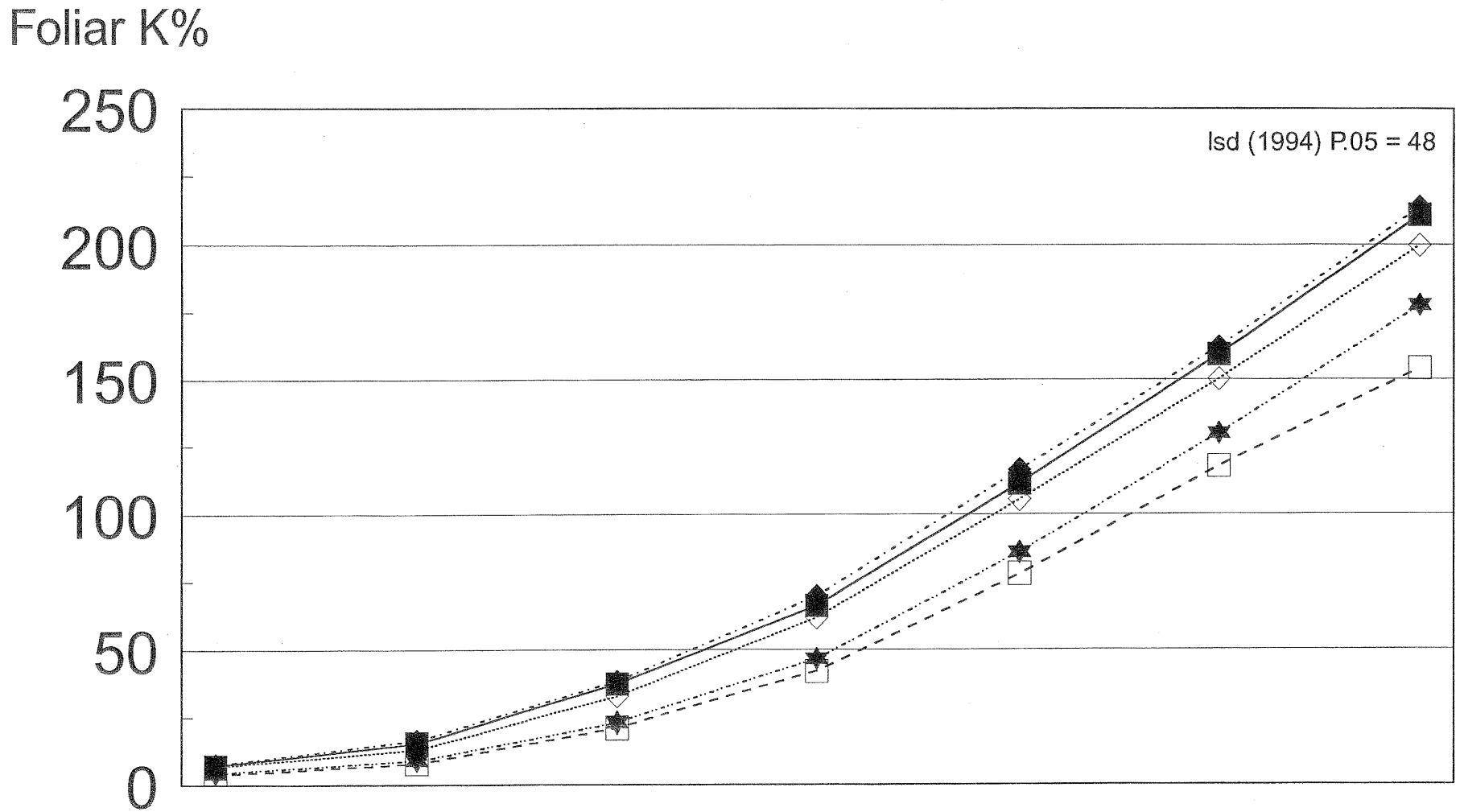
	1988	1989	1990	1991	1992	1993	1994
1 K 0	7.2	15.5	37.2	66.3	111.1	159.3	210.9
2 K 50	5.2	11.0	27.2	50.3	86.3	123.1	165.3
3 K 100	6.3	13.7	33.2	63.9	113.4	164.3	217.4
4 K200	5.2	10.7	25.9	48.1	86.9	126.0	173.2
5 K400	6.3	13.5	32.4	60.0	106.0	152.3	199.7

Figure 6b. The effect of K fertilising in 1989 on subsequent volume through to 1994



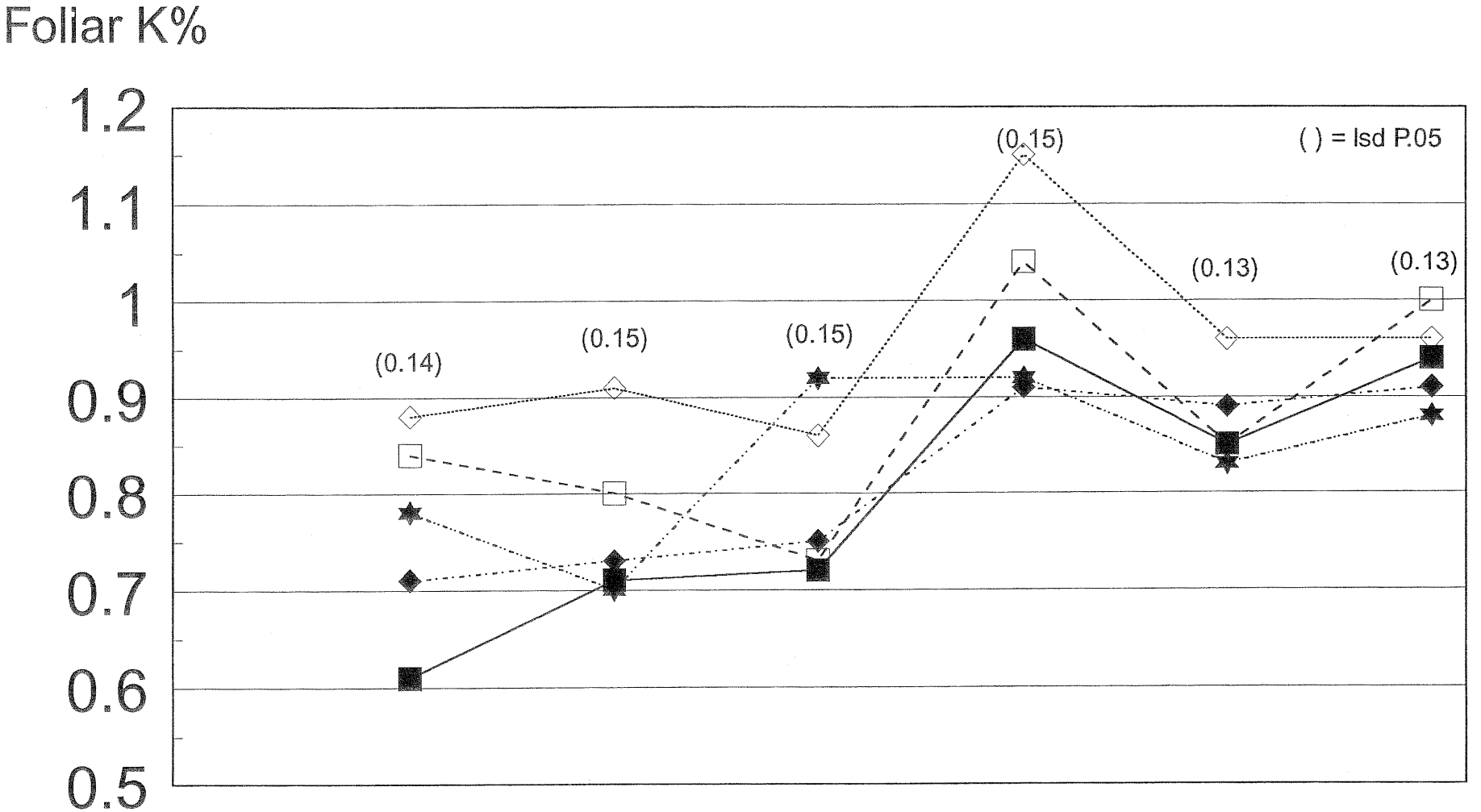
	1988	1989	1990	1991	1992	1993	1994
1 K 0	7.2	15.5	37.2	66.3	111.1	159.3	210.9
6 K 50	5.6	11.9	29.5	53.0	91.9	132.1	169.1
7 K 100	6.0	13.5	33.4	60.1	105.9	152.3	199.5
8 K 200	6.1	12.8	30.4	57.2	96.4	141.1	193.9
9 K 400	5.4	11.6	28.9	55.5	99.4	145.0	195.1

Figure 6c. The effect of K fertilising In 1990 on subsequent volume through to 1994



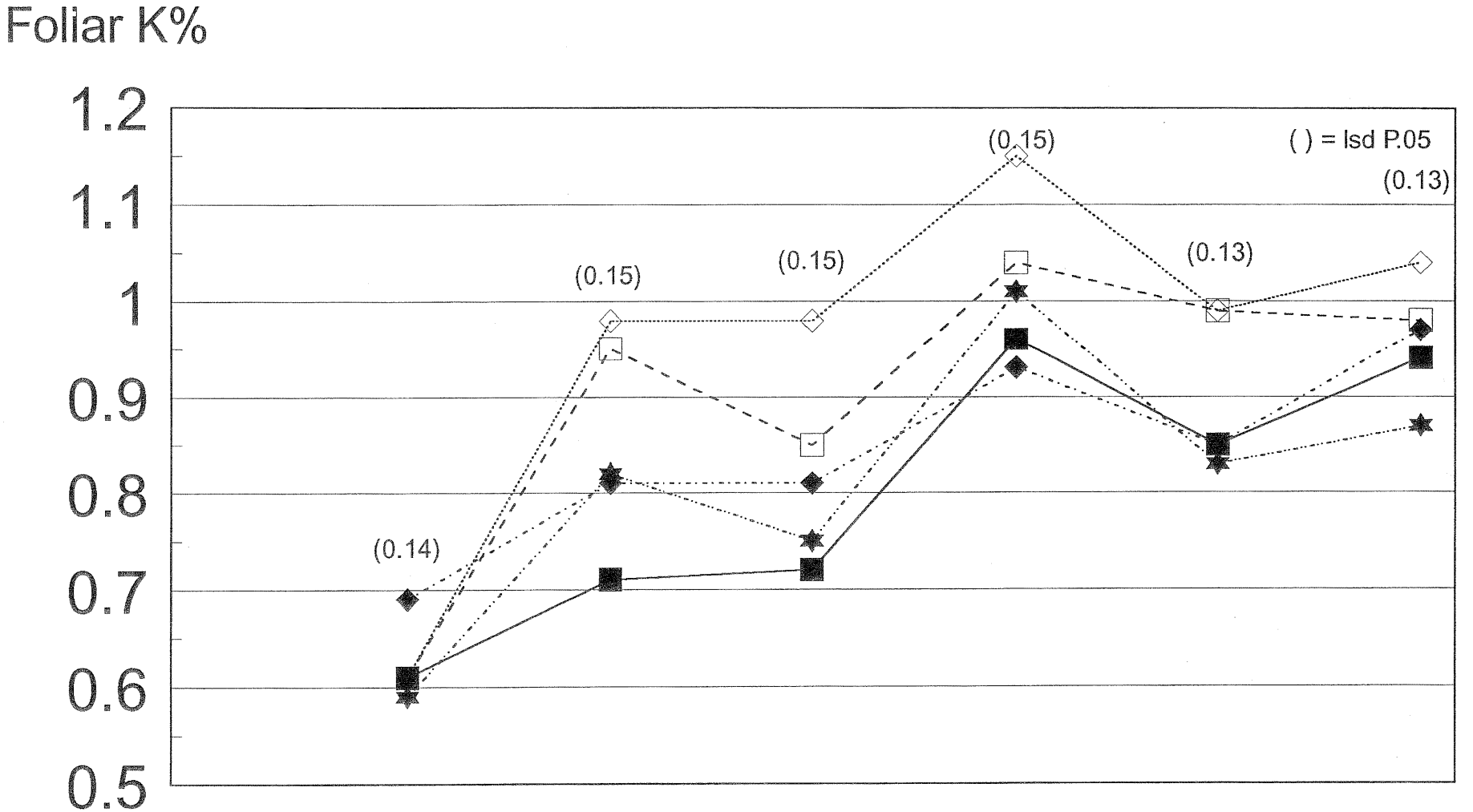
	1988	1989	1990	1991	1992	1993	1994
1K 0	7.2	15.5	37.2	66.3	111.1	159.3	210.9
10K 50	7.7	16.5	38.2	69.7	116.2	162.1	213.8
11K 100	4.4	9.2	23.0	46.6	85.7	129.7	177.7
12K 200	3.7	8.0	21.1	41.9	77.8	117.4	154.1
13K400	6.9	13.2	32.7	61.8	105.2	150.1	199.8

Figure 7a. Effect of K rates applied in spring 1988 on foliar K levels through to 1994 at Piplwai



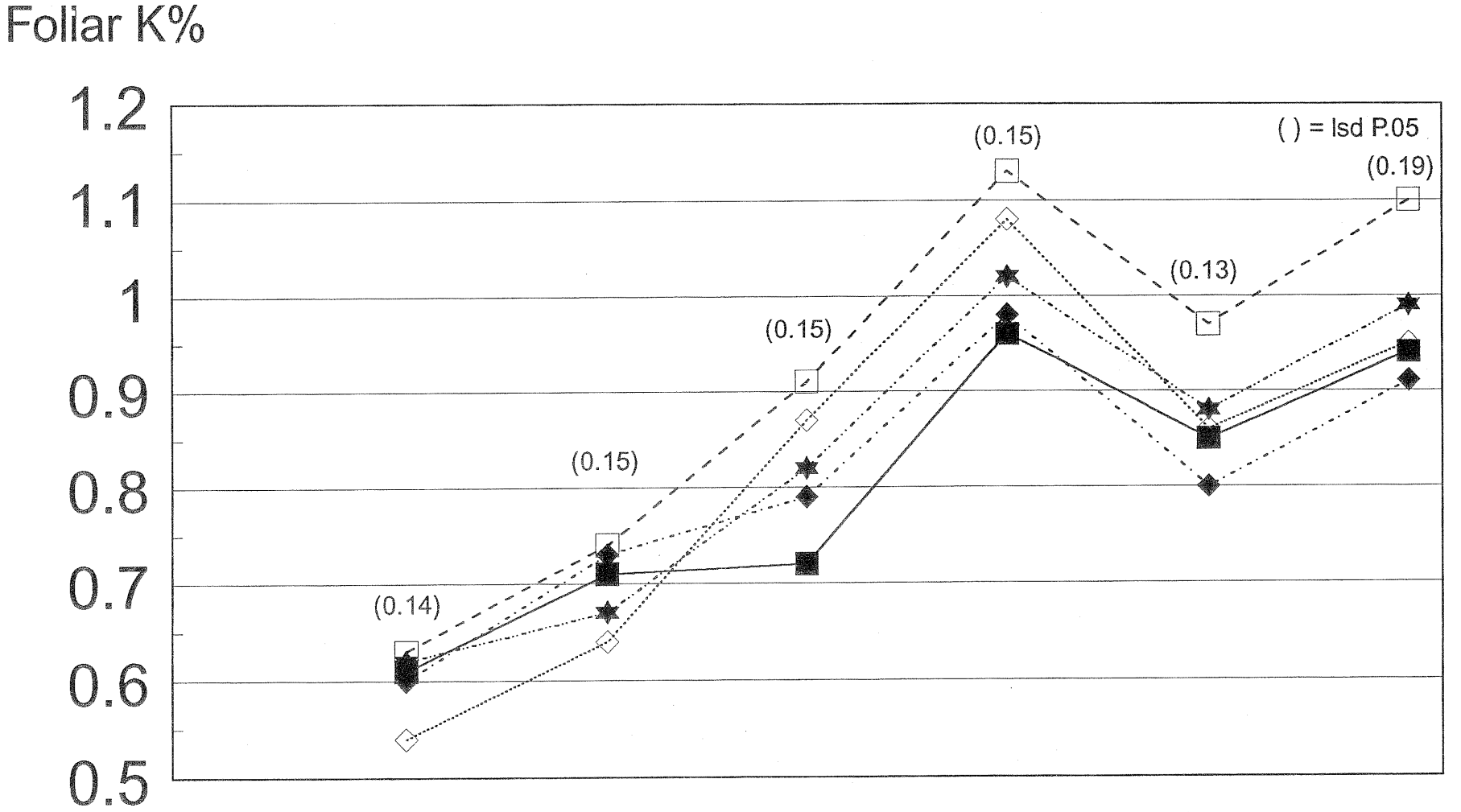
	1988	1989	1990	1991	1992	1993	1994
1 K 0		0.61	0.71	0.72	0.96	0.85	0.94
2 K 50		0.71	0.73	0.75	0.91	0.89	0.91
3 K 100		0.78	0.70	0.92	0.92	0.83	0.88
4 K200		0.84	0.80	0.73	1.04	0.85	1.00
5 K400		0.88	0.91	0.86	1.15	0.96	0.96

Figure 7b. Effect of K rates applied In spring 1989 on foliar K levels through to 1994 at Pipiwai



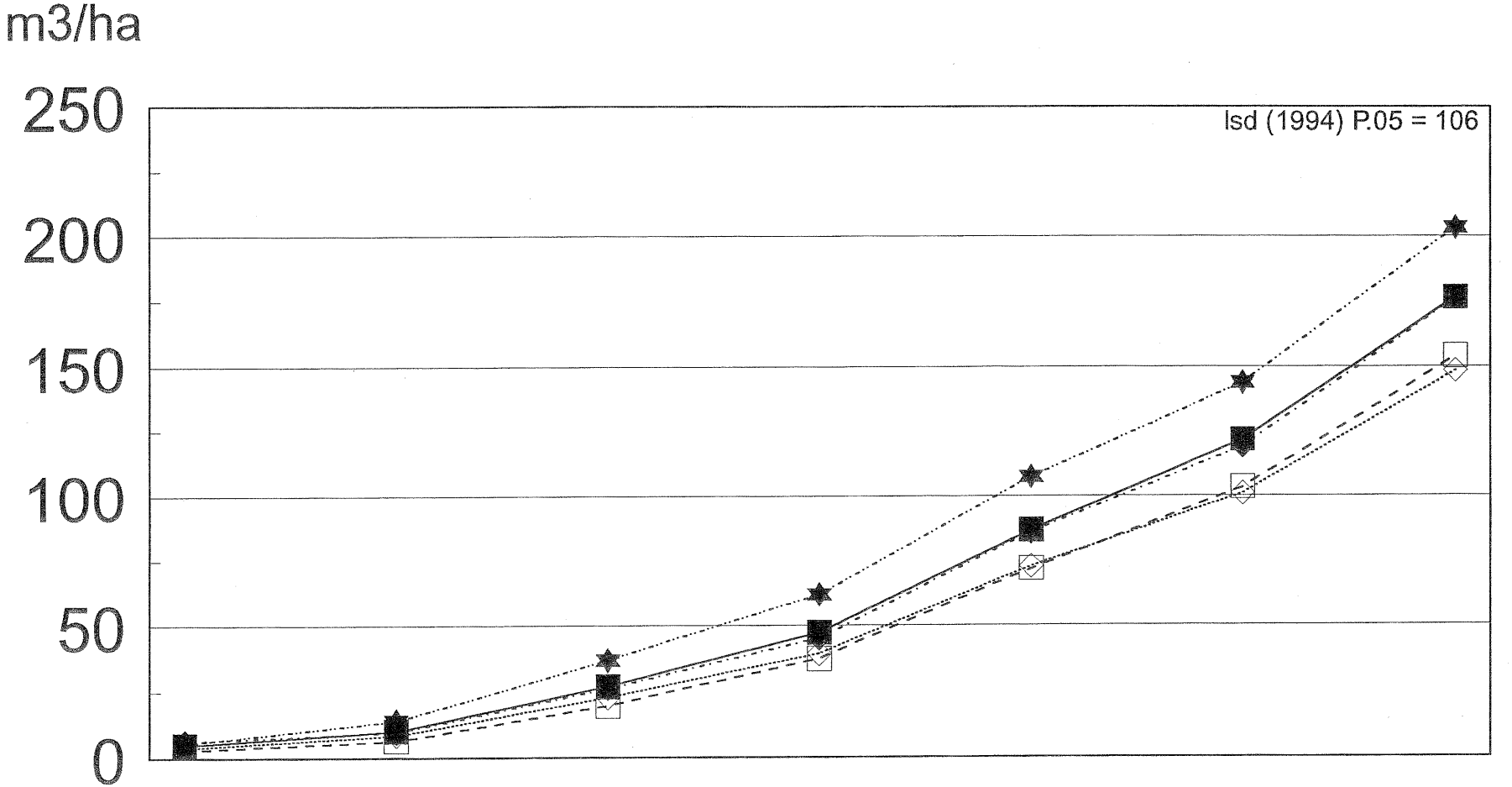
	1988	1989	1990	1991	1992	1993	1994
1 K 0 ■		0.61	0.71	0.72	0.96	0.85	0.94
6 K 50 ◆		0.69	0.81	0.81	0.93	0.85	0.97
7 K 100 ✸		0.59	0.82	0.75	1.01	0.83	0.87
8 K 200 ⊟		0.61	0.95	0.85	1.04	0.99	0.98
9 K 400 ◇		0.61	0.98	0.98	1.15	0.99	1.04

Figure 7c. Effect of K rates applied In spring 1990 on follar K levels through to 1994 at Plplwal



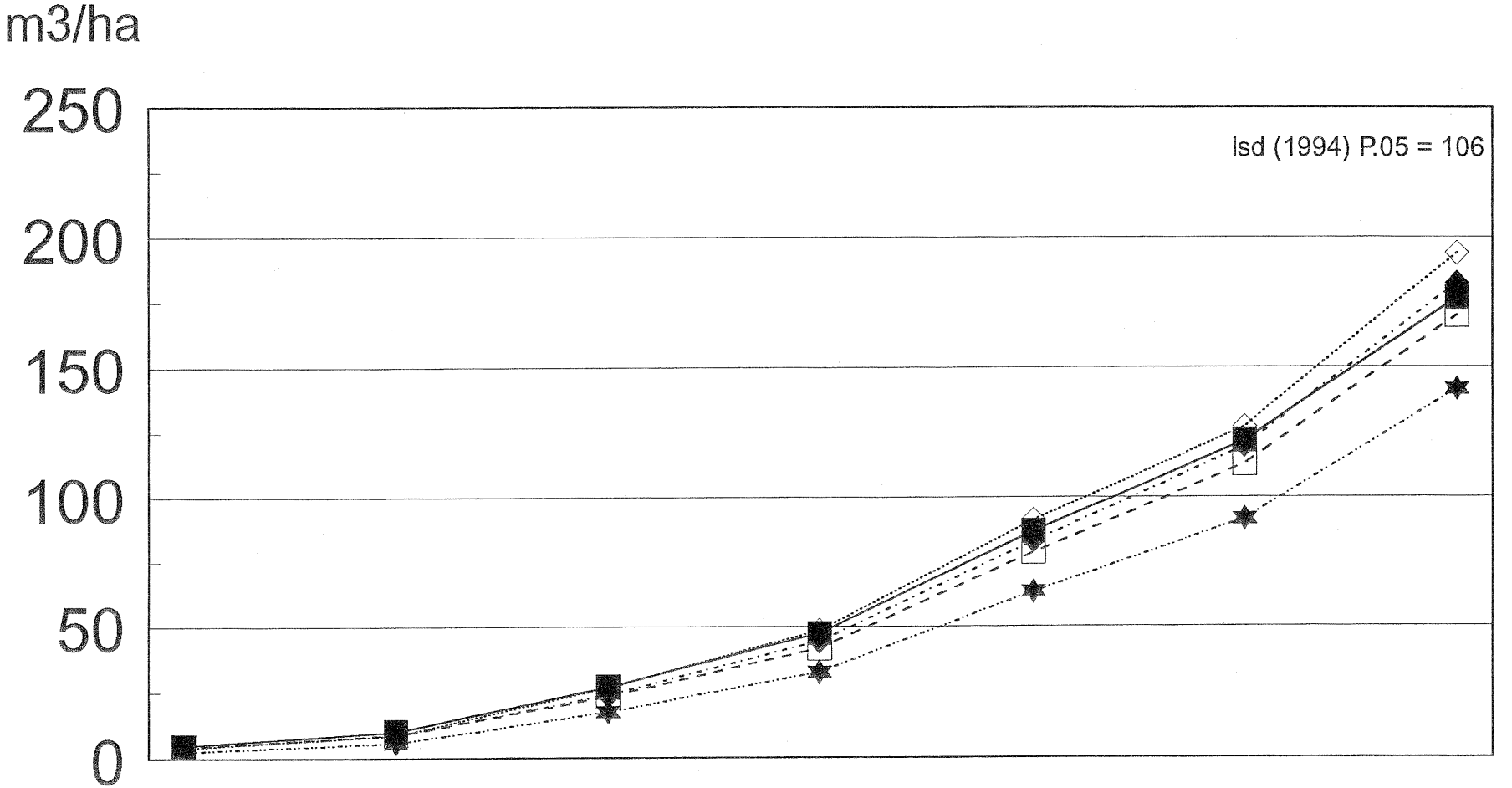
	1988	1989	1990	1991	1992	1993	1994
1K 0 ■		0.61	0.71	0.72	0.96	0.85	0.94
10K 50 ◆		0.60	0.73	0.79	0.98	0.80	0.91
11K 100 ★		0.62	0.67	0.82	1.02	0.88	0.99
12K 200 ⊟		0.63	0.74	0.91	1.13	0.97	1.10
K400 ◇		0.54	0.64	0.87	1.08	0.86	0.95

Figure 8a. The effect of K fertilising in 1988 on subsequent volume through to 1994 at Piplwai



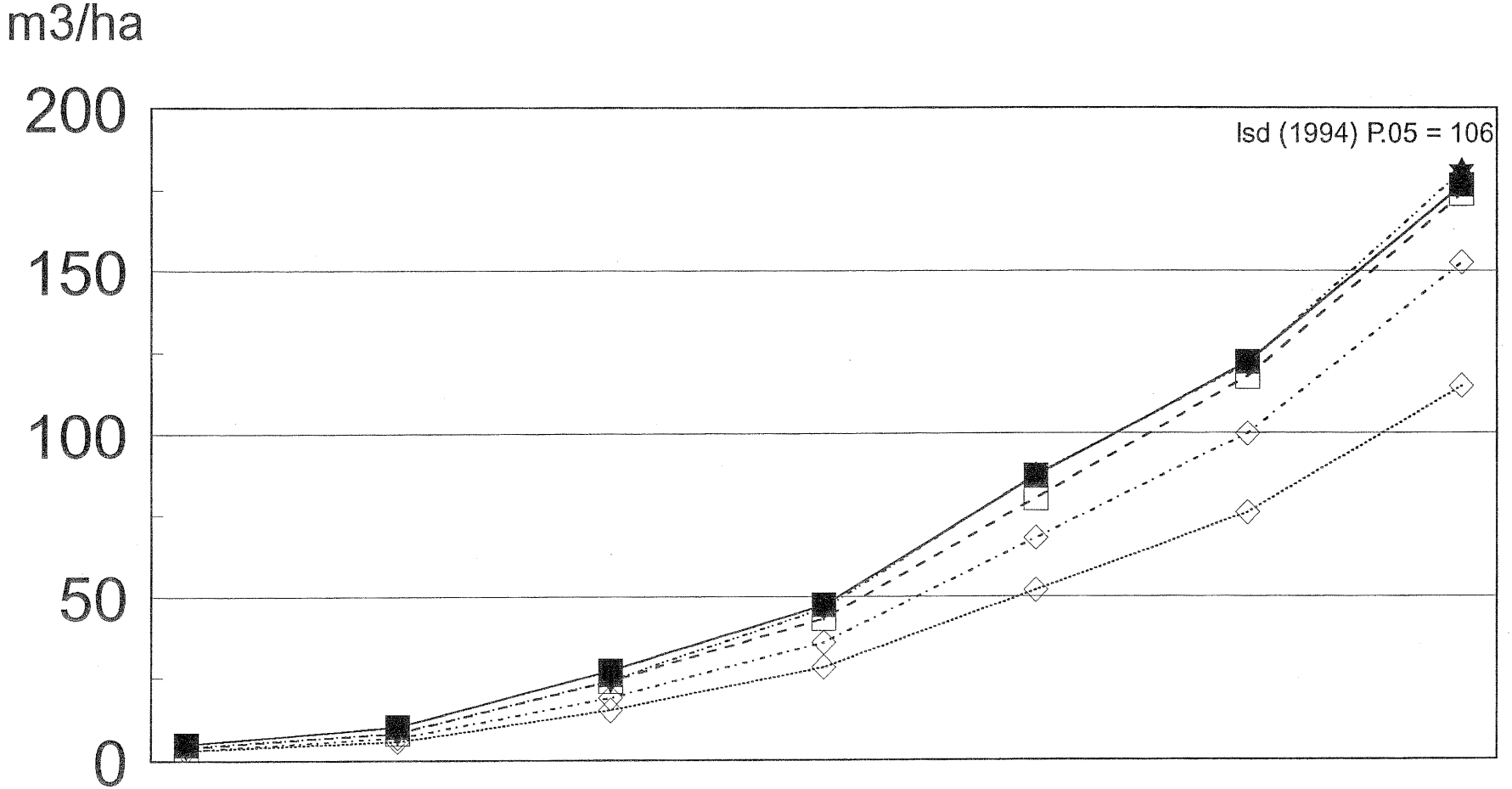
	1988	1989	1990	1991	1992	1993	1994
1 K 0	4.8	10.2	27.0	47.3	86.8	121.8	176.4
2 K 50	6.2	9.7	26.3	45.1	86.1	119.1	176.1
3 K 100	5.4	14.1	36.8	61.9	107.5	143.7	203.3
4 K200	2.9	6.5	19.8	37.4	71.9	103.4	153.9
5 K400	3.8	8.6	22.9	39.3	72.8	101.0	148.3

Figure 8b. The effect of K fertilising in 1989 on subsequent volume through to 1994 at Pipiwai



	1988	1989	1990	1991	1992	1993	1994
1 K 0	4.8	10.2	27.0	47.3	86.8	121.8	176.4
6 K 50	4.1	8.7	23.9	44.1	83.0	119.7	182.2
7 K 100	2.6	5.8	17.7	32.5	63.3	91.6	141.3
8 K 200	4.3	9.0	23.4	41.5	78.6	112.8	169.7
9 K 400	3.9	8.8	26.8	48.4	91.2	127.1	193.8

Figure 8c. The effect of K fertilising in 1990 on subsequent volume through to 1994 at Piplwai



	1988	1989	1990	1991	1992	1993	1994
1 K 0	4.8	10.2	27.0	47.3	86.8	121.8	176.4
10 K 50	3.0	6.8	18.8	35.7	68.0	99.8	152.6
11 K 100	4.0	8.3	24.0	46.2	87.2	121.3	180.8
12 K 200	3.8	8.3	23.9	43.1	80.0	117.4	173.8
K400	3.0	5.7	15.1	28.1	51.9	75.6	114.5