J. agric. Sci., Camb. (1983), **101**, 103–111
With 6 text-figures
Printed in Great Britain

Nitrogen and potassium uptake by high-yielding potato crops

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(*Received* 25 *November* 1982)

SUMMARY

Results are presented from two experiments (1973 and 1974) in which high potato yields were obtained (60–70 t/ha). In both, Désirée and Maris Piper accumulated much more N and K (> 200 and 300 kg/ha respectively) than was applied as fertilizer (160 kg N and 189 kg K/ha). Increasing planting density (to levels above commercial practice) increased nutrient accumulation but had only small effects on yields. Thus, high yields are associated with but not necessarily caused by large accumulations of nutrients. As a general principle, increasing fertilizer rates above those shown to be optimal will not increase yields.

INTRODUCTION

The average annual applications of fertilizer N and K to potatoes are still increasing steadily and in 1979 reached 193 and 213 kg/ha respectively (Church, 1980). Such average figures suggest that a significant number of crops must receive substantially in excess of 200 kg N/ha and 250 kg K/ha and Church's survey data confirm this for more than 25 % of crops exceeded this rate of N application and almost 33 % exceeded the rate for K application. The justification for these application rates seems open to doubt, especially for nitrogen. The published data on responses to N invariably cover only the range up to approximately 200 kg/ha and large responses to the final increment in rate of N application are rare so that recommended rates are generally less than 200 kg/ha (Boyd, Hill & Batey, 1968; Birch *et al.* 1967; Archer, Victor & Boyd, 1976). Webber, Boyd & Victor (1976) recommended 200 kg N/ha for potato crops in arable rotations on Magnesian limestone soils. Farrar & Boyd (1976) and Berryman *et al.* (1973) found responses to more than 200 kg N/ha but these were in a minority and in the latter case referred to broadcast applications made on the flat before planting which could be reduced with other methods of fertilizer application. The differences between rates of application of K and published optimum values are smaller and beneficial effects of large dressings of K on tuber quality have been demonstrated (Van Der Zaag & Meijers, 1970). Evans (1975) advocated the use of 250 kg N/ha divided between planting and tuber initiation and 311 kg K/ha for growers aiming for the highest yields. This recommendation was based on the contention that the greater total nutrient accumulation of crops with greater tuber yields than usually found in experiments could be satisfied only by increased fertilizer applications. The limited data on nutrient recovery of potato crops would not support this view for Gunasena & Harris (1971) showed that high-yielding crops (> 75 t/ha) recovered substantially more N and K than was applied as fertilizer. Moreover, the data of Dyson & Watson (1971) show that large fertilizer dressings (376 kg N/ha) are sometimes very inadequately taken up and small yields result. This paper presents data for the uptake of N and K by high-yielding crops of Désirée and Maris Piper which in 1973 and 1974 achieved very high rates of plant and tuber growth. Data on the yields of these crops have already been presented (Ifenkwe & Allen, 1978*b*).

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THE EXPERIMENTS

The full details of the experiments are given in Ifenkwe & Allen (1978*a*) and only a summary is given here. Experiment 1 followed spring barley and Expt 2 followed long-term but largely unfertilized grass.

Experiment 1, 1973

Treatments were all combinations of two row widths, 66 and 132 cm, two varieties, Désirée and Maris Piper, and five planting densities, 24960,

Table 1. *Final tuber yields (t/ha) in 1973 and 1974*

		Seed tuber density ('000s/ha)					s.e.
		25	30	37·5	50	75	—
Désirée	1973	49·72	58·53	55·34	60·16	66·40	3·50
	1974	—	55·32	59·02	63·63	66·15	1·72
Maris Piper	1973	61·68	55·47	63·73	68·12	60·99	3·50
	1974	—	63·26	66·39	67·89	69·96	1·72

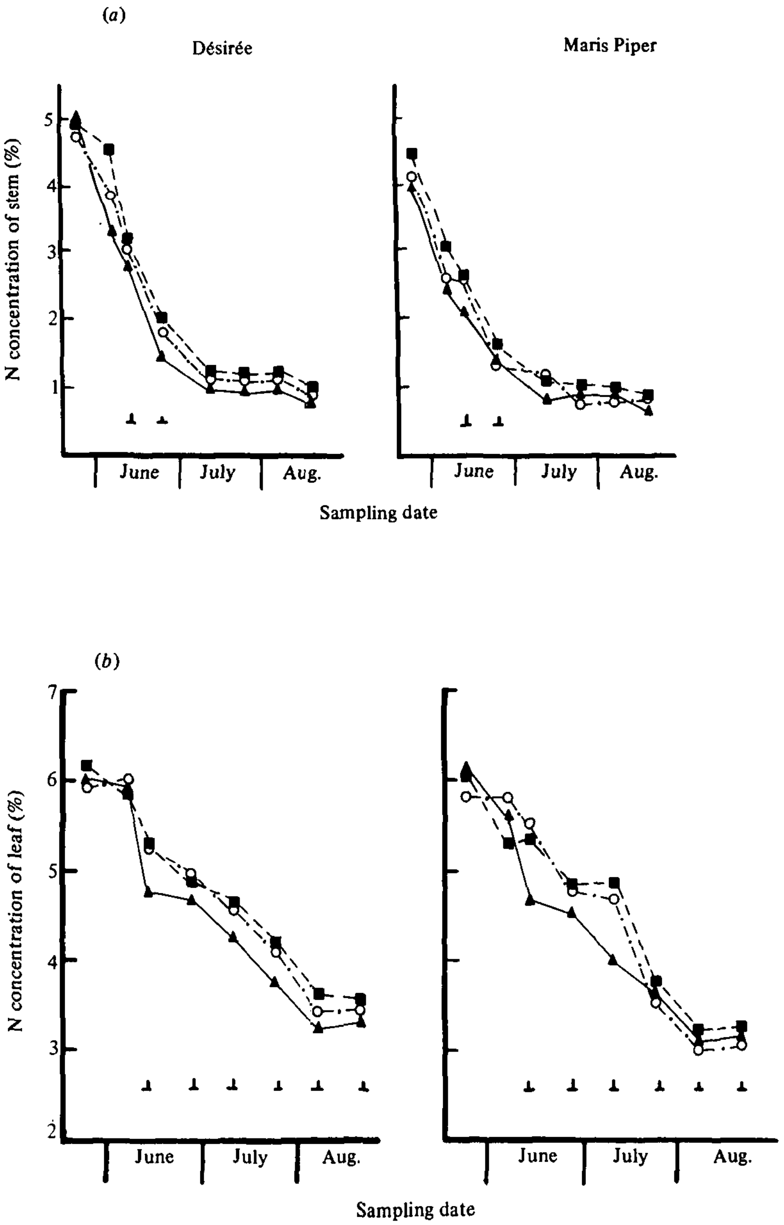

Fig. 1. Effect of planting density on N concentration in (*a*) stem and (*b*) leaf in two varieties. Expt 1, 1973. ■--■, 24960 seed tubers/ha; ○-·-·-○, 37440 seed tubers/ha; ▲——▲, 74880 seed tubers/ha; vertical bars, s.e.

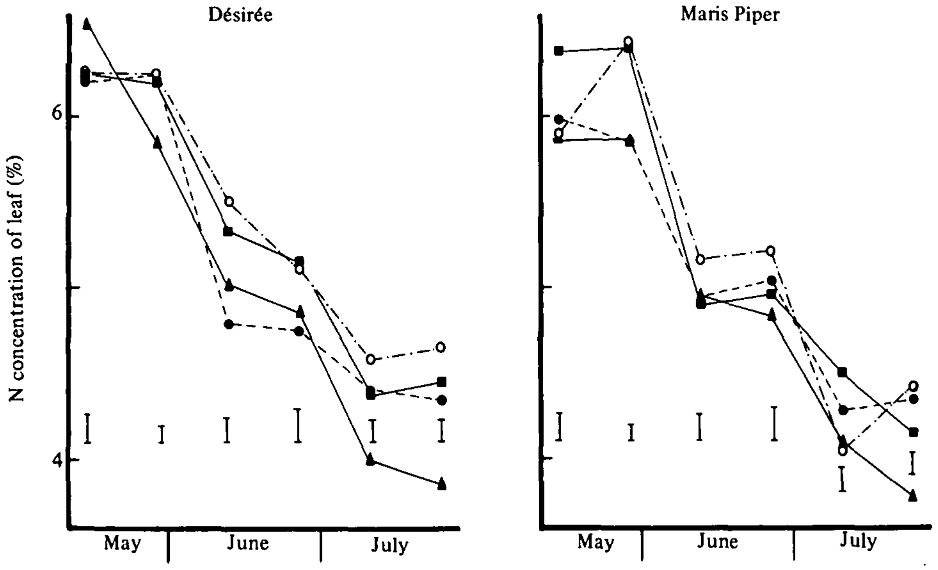

Fig. 2. Effect of planting density on N concentration of leaves, in two varieties. Expt 2, 1974. ■——■, 29950; ○-·-·-○, 37440; ●- - -●, 49920; ▲——▲, 74880 seed tubers/ha.

29950, 37440, 49920 and 74880 seed tubers/ha, replicated twice in a randomized-block design.

Growth analysis sampling (two plants/plot) was carried out throughout the growing season from 23 May to 5 September. The final harvest on 5 September was taken before complete senescence when leaf area indices were approximately 1 and decreasing rapidly. There was no incidence of potato blight in this experiment.

Experiment 2, 1974

Treatments were as in Expt 1 except that the lowest planting density was omitted. The final sample for nutrient analysis was taken on 24 July and sampling ceased on 7 August when a small focus of potato blight was in one plot.

Each experiment received a fertilizer application of 160 kg N, 70 kg P and 189 kg K/ha applied by hand over the opened ridges at planting.

At each growth analysis, oven-dried samples of leaves, stems and petioles, underground stems and roots and stolons and tubers were milled through an 0·5 mm screen and analysed for N and K concentration using the method of Thomas, Sheard & Meyer (1967) as modified by Faithful (1971). At the earliest samples the small quantities of individual plant parts were bulked over replicates before chemical analysis; subsequently, material from individual plots was analysed and the data subjected to statistical analysis. The fresh tuber samples were selected by a proportional sampling technique, similar to that of Wurr & Allen (1974), and at least 500 g of material were dried and milled before sampling for chemical analysis.

RESULTS

Effects of variety and row width on yields and nutrient uptake were small in relation to the effects of plant density and the data for nutrient uptake are presented for the range of densities in individual varieties. The final yields in each experiment are shown in Table 1. The highest final yields were usually produced by the highest density although the response to the final increments in density was always small. In Expt 2 the yields of 70 t/ha on 7 August were extremely high and represent a mean rate of tuber dry weight increment of almost 15 $g/m^2/day$ from initiation on 10 May to final harvest. This value underestimates crop growth rate but no data on non-tuber dry weight were taken at the final harvest.

N concentration of plant parts

In all treatments in both experiments, the N concentration of leaves and stem decreased during much of growth (Figs 1 and 2). Decreases were very small in August in Expt 1 and values for all densities remained above 3% at the end of sampling. In Expt 1 N concentration of both haulm components generally decreased with increasing plant density throughout growth (Fig. 1);

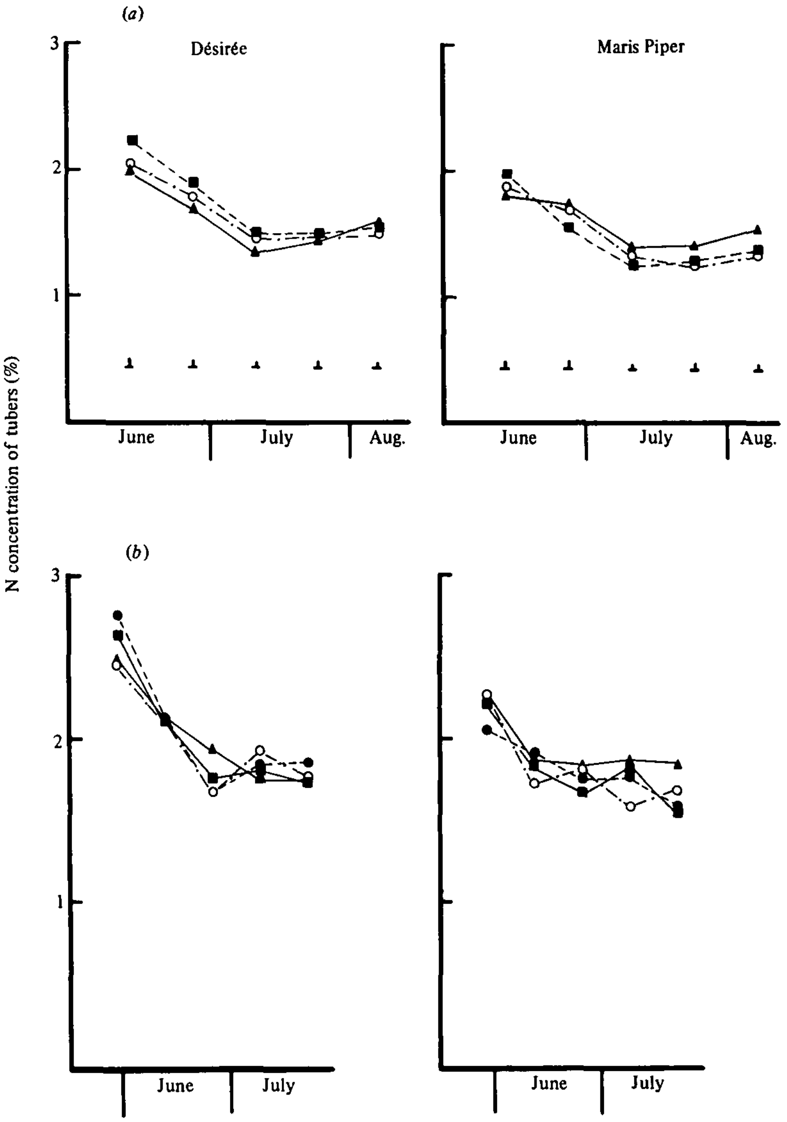

Fig. 3. Effect of planting density on N concentration of tubers of two varieties in (*a*) Expt 1, 1973 and (*b*) Expt 2, 1974. ■ - - ■, 24960 seed tubers/ha; ○–·–·–○, 37440 seed tubers/ha; ▲——▲, 74880 seed tubers/ha; vertical bars, S.E.; 1973. ■——■, 29950; ○–·–·–○, 37440; ●· · · ●, 49920; ▲——▲, 74880 seed tubers/ha; 1974.

however, in Expt 2 effects of density were less consistent.

In both experiments N concentration of tubers decreased up to early July and then stabilized or increased slightly (Fig. 3). In Expt 1 in Désirée, tuber nitrogen concentration decreased with increasing density up to the final sampling when the highest density had the highest N concentration. In contrast, in Maris Piper tuber nitrogen concentration increased with increasing density after the first sampling. In Expt 2 density had little effect on N concentration of any plant part and it was not possible to study tuber N concentration late in the season as sampling ceased on 7 August.

K concentration of plant parts

In both experiments K concentration of all plant parts decreased from early in growth in all treatments. Density had little effect on K concen-

Table 2. *Effect of density and variety on K concentration of tubers*

	Sampling date									
	29 May		12 June		26 June		10 July		24 July	
No. of seed tubers/ha	Désirée	Maris Piper	Désirée	Maris Piper	Désirée	Maris Piper	Désirée	Maris Piper	Désirée	Maris Piper
24960	3·39	3·29	3·21	3·26	2·69	2·68	2·56	2·68	2·41	2·45
29950	3·29	3·19	3·27	3·14	2·74	2·88	2·64	2·61	2·54	2·54
37440	3·34	3·31	3·05	3·13	2·73	2·64	2·53	2·58	2·50	2·45
49920	3·18	3·21	3·06	3·11	2·66	2·73	2·40	2·66	2·23	2·18
S.E.	0·073		0·056		0·086		0·080		0·070	
Mean	3·30	3·25	3·15	3·16	2·70	2·73	2·53	2·63	2·42	2·40
S.E.	0·037		0·028		0·043		0·040		0·035	

tration of leaves or stems in both experiments and in Expt 1 had little effect on the K concentration of tubers. However, in Expt 2 tuber K concentration was usually lowest at the highest seed tuber density (Table 2).

N uptake

N accumulated in leaves and stems reached maximum values in June and then decreased slowly in all treatments in both experiments (Fig. 4). Increasing density increased N uptake in all plant parts throughout growth.

Tuber and total N uptake increased linearly throughout growth and increasing density increased total N uptake in both experiments (Fig. 5). In Expt 1, all densities except the lowest recovered more than was applied as fertilizer and in both varieties the highest plant density achieved this by the end of June. In Expt 2 all densities in both varieties recovered more N than was applied as fertilizer and all achieved this by the end of June.

K uptake

In general, treatment effects were similar to those reported for N accumulation. Total K uptake increased up to 10 July in Expt 2 in all densities but the rate of increase in total accumulated K slowed in the higher densities in the next 2 weeks (Fig. 6). In this experiment, all treatments accumulated substantially more K than was applied as fertilizer and as with N most treatments achieved this before the end of June.

DISCUSSION

In both experiments, these high-yielding potato crops accumulated much more N and K than they received in fertilizer applications. It was particularly striking that the accumulation of N proceeded linearly over the whole of the sampling period for all densities. Even the final increments in density increased N accumulation considerably, although producing only small effects on tuber yields. There is, therefore, no evidence that increasing total N accumulation is effective in increasing tuber yields. The high yields in these experiments and others at Trefloyne (Allen, 1977; Allen *et al.* 1979) are associated with but not necessarily the consequence of large N accumulation by the crops. While in some circumstances it may be necessary to use heavy fertilizer applications in order to achieve the highest yields, this is not a generally applicable principle and a more effective discriminant of yield variation must be sought. It has been suggested in other papers that in the absence of disease and water stress, this discriminant is the amount of radiation intercepted by the crop (Allen & Scott, 1980).

No detailed recording of soil N has been undertaken at Trefloyne but it seems probable that the earlier rise in spring temperatures than in most other parts of the United Kingdom enhanced both early N release and early crop growth. Neither of the sites used in these experiments would be regarded as high in available N for although the farm had considerable grass (but little clover) in its rotation prior to experimentation applications of fertilizer N were very limited. It seems likely that the rapid early leaf growth generally observed in experiments at Trefloyne is associated with rapid root penetration which affords effective uptake of available soil nitrogen. A detailed study of root growth at this site is clearly justified.

In these experiments leaf N remained above 2·5–3·25 %, the levels at which Kerketta (1976) found senescence to occur. There was also no indication of an acceleration in the depletion of leaf N towards the end of the season. This is

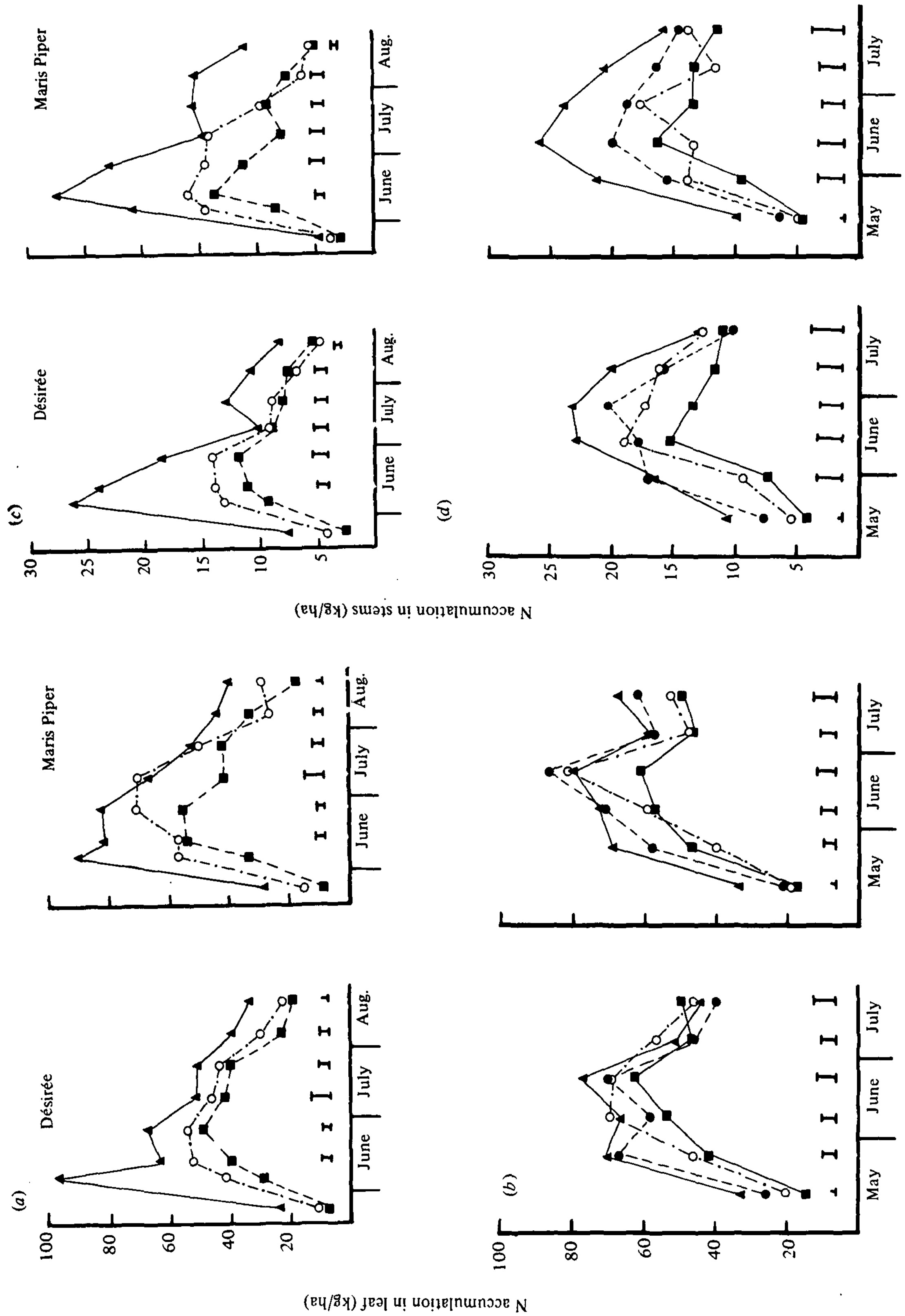

Fig. 4. Effect of planting density on N accumulation in leaves in (*a*) Expt 1 and (*b*) Expt 2 and in stems in (*c*) Expt 1 and (*d*) Expt 2 in two varieties. ■——■, 24960 seed tubers/ha; ○-·-·-○, 37440 seed tubers/ha; ▲——▲, 74880 seed tubers/ha; vertical bars, S.E.; 1973. ■——■, 29950; ○-·-·-○, 37440; ●- - -●, 49920; ▲——▲, 74880 seed tubers/ha; 1974.

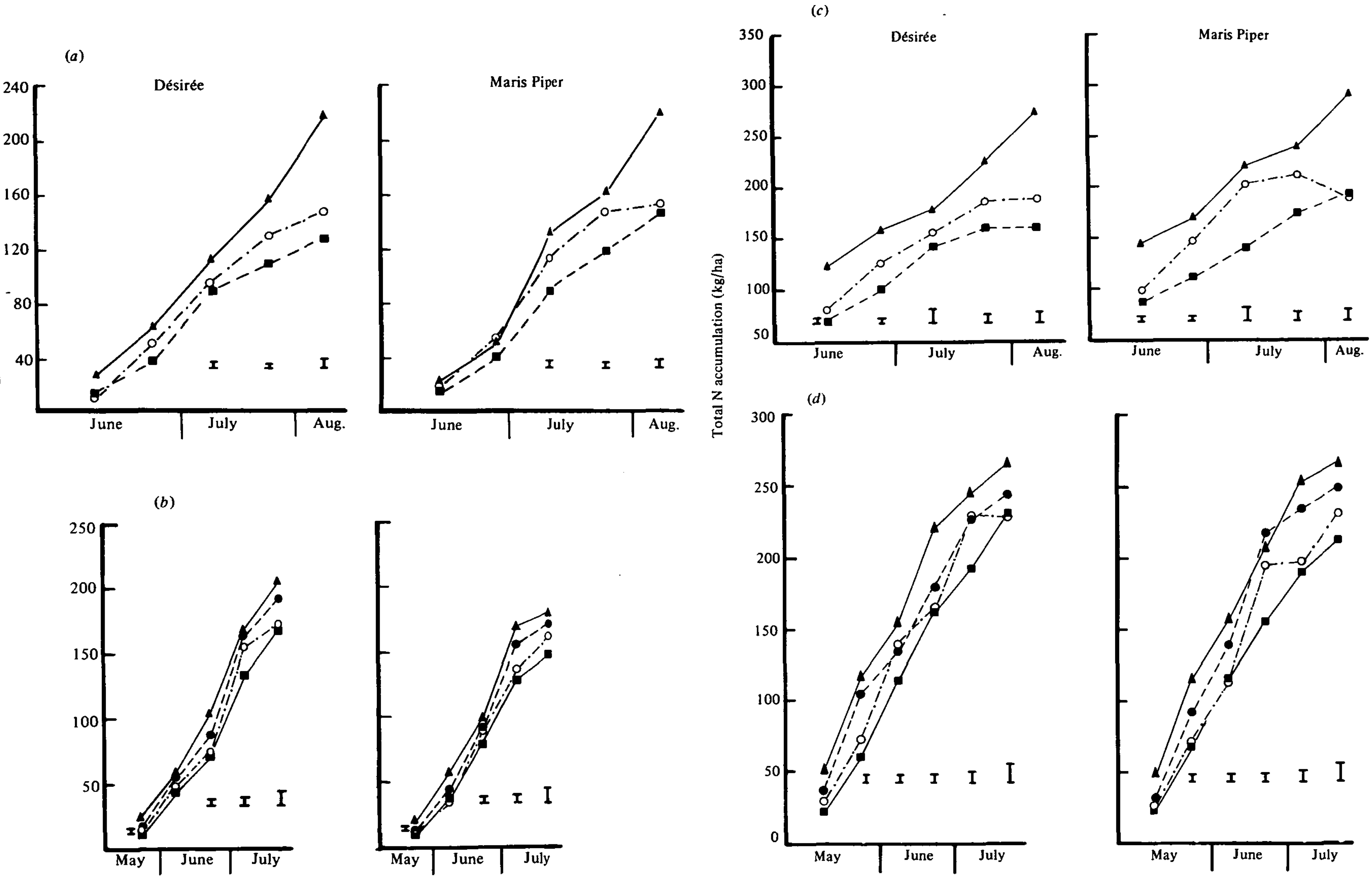

Fig. 5. Effect of planting density on N accumulation in tubers in (a) Expt 1 and (b) Expt 2 and in total in (c) Expt 1 and (d) Expt 2 in two varieties. ■— —■, 24960 seed tubers/ha; ○-·-·-○, 37440 seed tubers/ha; ▲——▲, 74880 seed tubers/ha; vertical bars S.E.; 1973. ■——■, 29950; ○-·-·-○, 37440; ●- - -●, 49920; ▲——▲, 74880 seed tubers/ha; 1974.

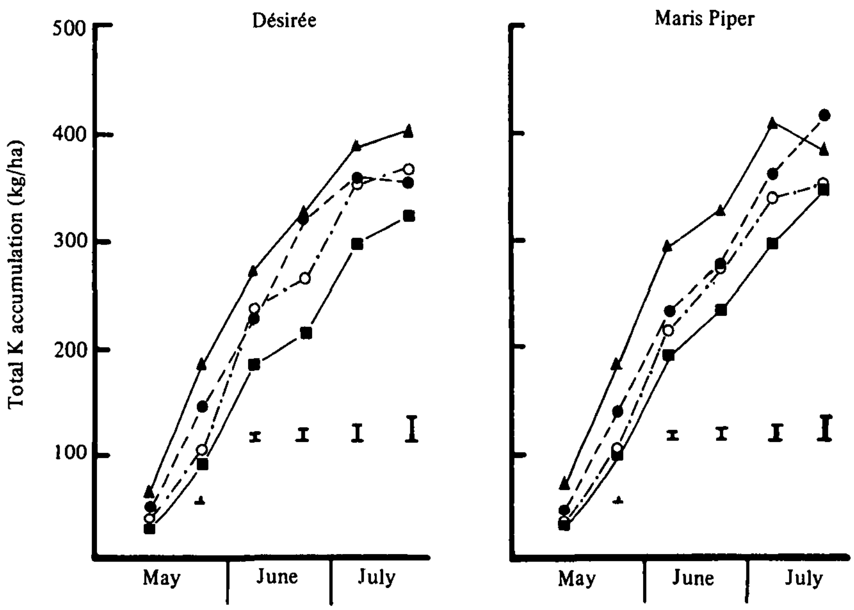

Fig. 6. Effect of planting density on total K accumulation in two varieties in Expt 2. ■——■, 29950; ○–·–·–○, 37440; ●- - -●, 49920; ▲——▲, 74880 seed tubers/ha; vertical bars, S.E.

potentially important for it suggests that N withdrawal from leaves may be different in crops at Trefloyne from crops at other sites. This may be important in the maintenance of both leaf area and photosynthetic efficiency at the end of the growing season. The K status of the soil at Trefloyne was average (index 2) and Ralph & Ridgman (1981) have shown that potatoes are responsive to residues of previous applications of K as well as current applications. Thus the yields of potatoes at Trefloyne may be increased after a rotation of crops receiving full fertilizer dressings.

The authors thank members of the research group at Trefloyne for their help in carrying out these experiments and Miss S. A. Jones for preparation of graphs in the final draft.

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