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Effects of date of planting on growth and yield of contrasting potato varieties in Pembrokeshire

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SUMMARY

Four experiments over 2 years which examined the effects of date of planting (from mid-March to early May) on the growth and yield of early, second early and maincrop potato varieties are described. In two experiments the seed used was physiologically old (heavily sprouted) and in the other two experiments relatively young seed (limited sprout development) was used. In the early variety, Home Guard, tuber yield at maturity was unaffected by delay in planting when physiologically old seed was used but increased leaf area and higher tuber yields resulted from later planting of younger seed. With both types of seed the maincrop varieties, Desirée and Maris Piper, produced larger leaf areas from later planting in one year but smaller leaf areas in the other year. In both years with both types of seed, tuber yields at the end of August were higher from the earlier plantings of these varieties. The physiologically young seed of Red Craig's Royal behaved in a similar manner to the maincrop varieties and the physiologically old seed behaved in a similar way to Home Guard.

Any yield advantages of early varieties over maincrop varieties from any date of planting were small and short-lived and the physiological reasons for differences between varieties are discussed in the light of these results. It is suggested that the current classification of varieties is unjustified and that variety testing should take more account of the effects of physiological age.

Tuber yields from the maincrop varieties were very high (60–80 t/ha) and this is attributed to the synchrony of leaf growth and increasing light receipts which may be readily achieved in the mild springs of W. Wales.

INTRODUCTION

There have been few detailed studies of the effect of date of planting on the growth and yield of the potato crop and the importance of this factor is not clearly established, in marked contrast to the situation in the other major root crop, sugar beet (Hull & Webb, 1970; Draycott, Webb & Wright, 1973; Scott *et al.* 1974). Dyke (1956) using survey and experimental data showed that although the effects of early planting were variable, planting after mid-April reduced yields, and much of the maincrop acreage was planted after this time. The effect of date of planting appeared to differ with the maturity class of varieties; if yield at maturity was the criterion, early varieties appeared to have a later optimum date of planting than maincrops. A more recent survey (P.M.B. 1969) has confirmed that many maincrop potatoes are still planted so late as to risk yield losses. Bremner & Radley (1966) found that leaf production of all varietal types was increased by progressively later planting but this only resulted in significantly increased yields of the early variety, Ulster Chieftain.

There are no substantial data on the effects of date of planting on yields of early varieties in areas where early potato production is important. In these areas planting may be carried out from January to April using seed with varying sprout growth. As wet weather conditions often interfere with planting, within any one year the planting period may be long and during delays in planting sprout growth will continue. Madec & Perennec (1955) have shown that increased sprout growth, which they termed physiological age, influences the overall growth pattern and especially the rate of tuber bulking. As the harvesting of early potato crops begins in late May at low yield levels (7–10 t/ha) and continues until early July, when yields are 25–40 t/ha, differences in bulking rates caused by physiological age may influence res-

ponses to date of planting. Growers are therefore interested in the interrelation of these two factors and the present paper is the first from a series of experiments which have examined the influence of physiological age in early potato production in W. Wales.

Four experiments are reported which examined the effect of date of planting on the growth and yield of varieties of all maturity classes. The two most popular early varieties, Home Guard and Red Craig's Royal, were used as a wide range of physiological age could readily be achieved. In view of the suggestion that early and maincrop varieties differ in response to date of planting, two maincrop varieties, Desirée and Maris Piper, were included.

THE EXPERIMENTS

Four experiments were carried out in 1973 and 1974 at the U.C.W. Field Station, Trefloyne, Tenby on Old Red Sandstone soils of the Pembroke Series. Two experiments used home-produced seed which was sprouted from the time of lifting so as to achieve apical dominance and well-developed sprouts by the time of the first planting. The other experiments used seed which was usually imported and which was stored so as to minimize sprout development.

Experiment 1. 1973

There were eight treatments comprising all combinations of four varieties, Home Guard (early), King Edward, Desirée and Maris Piper (maincrop) and two dates of planting, 16 March and 18 April, arranged in three randomized blocks. Plots were 3·05 m long and 9 rows wide. Seed was produced at Trefloyne from imported Scottish seed, burned off in mid-August 1972, lifted and boxed immediately in early September 1972. The seed was stored in an unheated stone building at Trefloyne until planting. Seed was graded 38–44 mm and spaced 30·5 cm apart in the row. Two adjacent plants were removed from each plot for growth analysis on 6 June, 20 June and 6 August and yield estimates were taken from a 2·44 m length of row on 27 June, 11 July and 29 August. On the latter three dates the foliage of two random plants was used for growth analysis.

Experiment 2. 1974

There were twelve treatments comprising all combinations of four varieties, Home Guard, Craig's Royal (second early), Desirée and Maris Piper, and three dates of planting, 21 March, 11 April and 2 May, arranged in three randomized blocks. Plots were 7·31 m long and 5 rows wide. Seed was produced in 1973 at Cefnceido, Rhayader (270 m above sea level) from Scottish FS seed, planted on 2 May 1973, burned off on 31 July, lifted and boxed in the second week of September. The seed was stored in an unheated glasshouse at Frongoch Farm, Aberystwyth, until planting. Seed weighing 80–90 g, 90–100 g and 100–110 g was used for the three replicates, and spaced 30·5 cm apart in the row.

Numbers and lengths of sprouts were recorded on ten randomly selected, numbered tubers of each seed size at intervals during the sprouting period. Two plants were removed for growth analysis on 17 May (first two planting dates only), 29 May, 18 June, 23 July and 6 August. Yield estimates were taken from either a 1·83 m or 2·44 m length of row on 29 May (first planting date only), 18 June, 23 July, 6 August and 28 August.

Experiment 3. 1973

There were twelve treatments comprising all combinations of three varieties, Home Guard, Desirée and Maris Piper and four dates of planting, 16 March, 27 March, 9 April, 18 April, arranged in two randomized blocks. Plots were 3·05 m long and 6 rows wide. Seed was Scottish FS grade, delivered to Aberystwyth in mid-January, boxed at the end of January and stored in an unheated glasshouse until planting. Seed weighing 65–75 g was used and spaced 30·5 cm apart in the row.

Four yield estimates were taken from 2·44 m lengths of the central four rows at fortnightly intervals from 4 July. As the tubers were to be used for seed and some hardening of the tuber skins was desirable, the requisite length of row was defoliated to ground level with a knife on the dates given and the tubers lifted 7–10 days later.

Experiment 4. 1974

There were sixteen treatments comprising all combinations of four varieties, Home Guard, Red Craig's Royal, Desirée and Maris Piper and four dates of planting, 21 March, 4 April, 18 April and 2 May, arranged in two randomized blocks. Plots were 6·10 m long and four rows wide. Seed of Home Guard and Red Craig's Royal was Scottish FS delivered in January and boxed in mid-January. Seed of the maincrop varieties was produced at Cefnceido but stored outside and in an open-fronted barn until the delivery of the Scottish seed. After boxing, the seed was stored in an unheated glasshouse until planting. Seed weighing 30–40 g and 40–55 g was used for the two replicates and spaced 30·5 cm apart in the row. Numbers and lengths of sprouts were recorded on ten random tubers of each seed size at each planting date.

Two adjacent plants were removed for growth analysis on 25 May (first three planting dates

only), 24 June, 23 July, 6 August and 28 August. Yield estimates were taken from six-plant samples, comprising three plants from each of the two centre rows of the plot, on 24 June, 23 July, 6 August and 28 August. As in Expt 3, the progeny tubers were to be used for seed and the requisite plants were defoliated on the dates given and the tubers lifted 7–14 days later.

In all experiments the row width was 66·0 cm and the cultivations and general husbandry were essentially the same. The experiments followed barley in 1973 and long-term grass ley in 1974, and in both years the land was ploughed in November. The land was ridged up using 3-row rear-mounted bodies in the first week of March, following no preparatory cultivations in 1973 and one pass of a rotary harrow in 1974. A fertilizer dressing of 151 kg N and P_2O_5/ha and 191 kg K_2O/ha was applied by hand over the ridges just prior to each planting. The ridges were closed by 3-row front-mounted ridging bodies. A herbicide, monolinuron/paraquat in 1973 and trietazine/linuron in 1974, was applied by knapsack sprayer at the appropriate rate for early potatoes on this soil type within 10 days of each planting. Weed control was excellent in 1974 but in 1973 some hand weeding was used especially for the last planting dates. Routine spraying using a knapsack sprayer with fungicide/aphicide mixtures was carried out from early June in both years. First applications were with mancozeb fungicides with a change to tin based chemicals by the end of June. The aphicide was always dimethoate. Control of potato blight was achieved until early August in all experiments and later in some, the implications of these variations are discussed later.

All plants were lifted with a hand fork and the plants intended for growth analysis were placed in labelled bags and moved to the laboratory. The plants were washed as necessary and cool stored before stripping into component parts, leaf, above ground stem + petioles, tubers and other below ground parts. The leaf area was determined by the disk method as modified by Bremner & Taha (1966). The cross-sectional area of the punch was 2·55 cm^2 in 1973 and 2·01 cm^2 in 1974. In 1973 50 disks were punched and in 1974, 25–50. The component parts were dried for 48 h at 90 °C to determine dry weights.

RESULTS

The two seasons differed considerably and the limited weather data available for 1974 are shown in Table 1. In 1973 the period from 16 to 31 March was rainless, some rain fell during April and heavy rain occurred early in May. However, the period from mid-May to early July was virtually rainless and signs of serious moisture stress became apparent on most plots. The remainder of the growing season was well-supplied with rainfall, although soil moisture deficits probably remained on most plots until the final harvests. In 1974 there were few periods without rainfall and from mid-June onwards the soil was near to field capacity. The spring was cold with persistent easterly winds

Table 1. *Weather data* 1974

		Rainfall (mm)	Mean soil temperature at 10 cm (09.00 h) (°C)
March	1–7	32	3·6
	8–14	5	2·9
	15–21	36	5·5
	22–28	0	7·5
April	29–4	2	7·0
	5–11	0	10·0
	12–18	17	9·0
	19–25	0	9·0
May	26–1	2	8·1
	2–8	12	9·0
	9–15	42	10·6
	16–22	8	11·9
	23–29	6	11·9
June	30–5	13	12·6
	6–12	18	11·8
	13–19	0	14·5
August	1–7	1	16·5
	8–14	47	15·7
	15–21	12	15·3
	22–28	13	15·0

Table 2. *Sprout data per tuber at first planting date Expt* 1 1973 (*means of* 20 *tubers*)

Variety	Length of longest sprout (mm)	Total sprout length (mm)	No. of sprouts ⩾ 3 mm	No. of sprouts with root primordia
Home Guard	76·3	80·5	1·3	1·25
King Edward	14·4	21·8	2·0	1·25
Desirée	7·8	20·8	2·9	0·70
Maris Piper	14·0	30·6	3·6	3·0

which affected early growth, especially of early planted treatments. A sharp but localized frost on 30 April/1 May caused foliar damage to emerged plants of Home Guard and to a lesser extent Maris Piper on Expt 4, but very little damage to Expt 2.

Experiment 1

Table 2 shows the sprout lengths and numbers of sprouts per tuber at the time of the first planting. The definition of a sprout was that proposed by Wurr (1975). Home Guard, which was observed to have visible sprout growth by the end of September 1972, had very long, single sprouts, and all maincrop varieties had slightly greater numbers of much shorter sprouts. There was little increase in sprout length during the interval between the two planting dates.

Numbers of above-ground stems (Allen & Wurr, 1973) were recorded throughout the season and are shown in Fig. 1. There was little difference in the final population between dates of planting for any variety but in all treatments the numbers of above-ground stems were higher than would be obtained through the development of the sprouts ⩾ 3 mm in length recorded at planting. This was partly accounted for by the development of secondary stems even in the maincrop varieties (Fig. 2).

Figures 3 and 4 present data for leaf and stem dry weights and leaf area index (L). In all these characters there was a marked difference between the three maincrop varieties and the early variety in their response to date of planting. In the maincrop varieties the early planting resulted in greater dry weights and higher L values for most of the growing season. In Home Guard there was little difference between dates of planting until August when the late planting had greater leaf dry weight and L. From the early planting, leaf and stem growth in the maincrop varieties was prolific and the plants were markedly taller than those of Home Guard (Table 3), while in the late planting the differences were small. When sampling ceased on 29 August there was no leaf left on any Home Guard plots (Table 4) but all maincrops had some leaf especially from the second planting although senescence was advanced on all plots. A small amount of potato blight was apparent on Maris Piper plots and this discovery prompted the termination of sampling.

The varieties differed in their response to date of planting in number of tubers and yield (Fig. 5). Differences between the two dates of planting for final number of tubers were small in all varieties although early planted King Edward appeared to suffer a more marked reduction in total number of tubers than the other varieties during the sampling period. The tuber yields both per plant and per hectare show that for maincrop varieties at any date of lifting and for Home Guard before maturity, early planting resulted in higher yields. In Home Guard at maturity there was no difference between the two dates of planting. The maincrop varieties bulked at a much faster rate than Home Guard and there was some evidence that later planting resulted in bulking at a slower rate in the maincrop varieties. From either date of planting the yield differences between the varieties were particularly interesting, for the initial yield advantage of Home Guard was small and short-lived. From the first date of planting the tuber yield per plant on 6 June was significantly greater in Home Guard than from the other varieties, but by 20 June the yield per plant was less than from Maris Piper although still greater than the other two maincrop varieties. Thus, at the first yield estimate 1 week later Maris Piper outyielded Home Guard, which in turn was slightly higher yielding than Desirée and significantly higher yielding than King Edward. By 11 July, Home Guard was markedly inferior to all the maincrop varieties in terms of total yield. A similar pattern of yield development was found from the second date of planting but displaced in time by 3–4 weeks (the planting interval). As all the maincrop varieties had more tubers than Home Guard the period of advantage of Home Guard in ware yield (> 32 mm, Fig. 5) was longer than for total yield, but the pattern of yield development was similar. The final yields were low in Home Guard but very high in the maincrop varieties especially from the first date of planting.

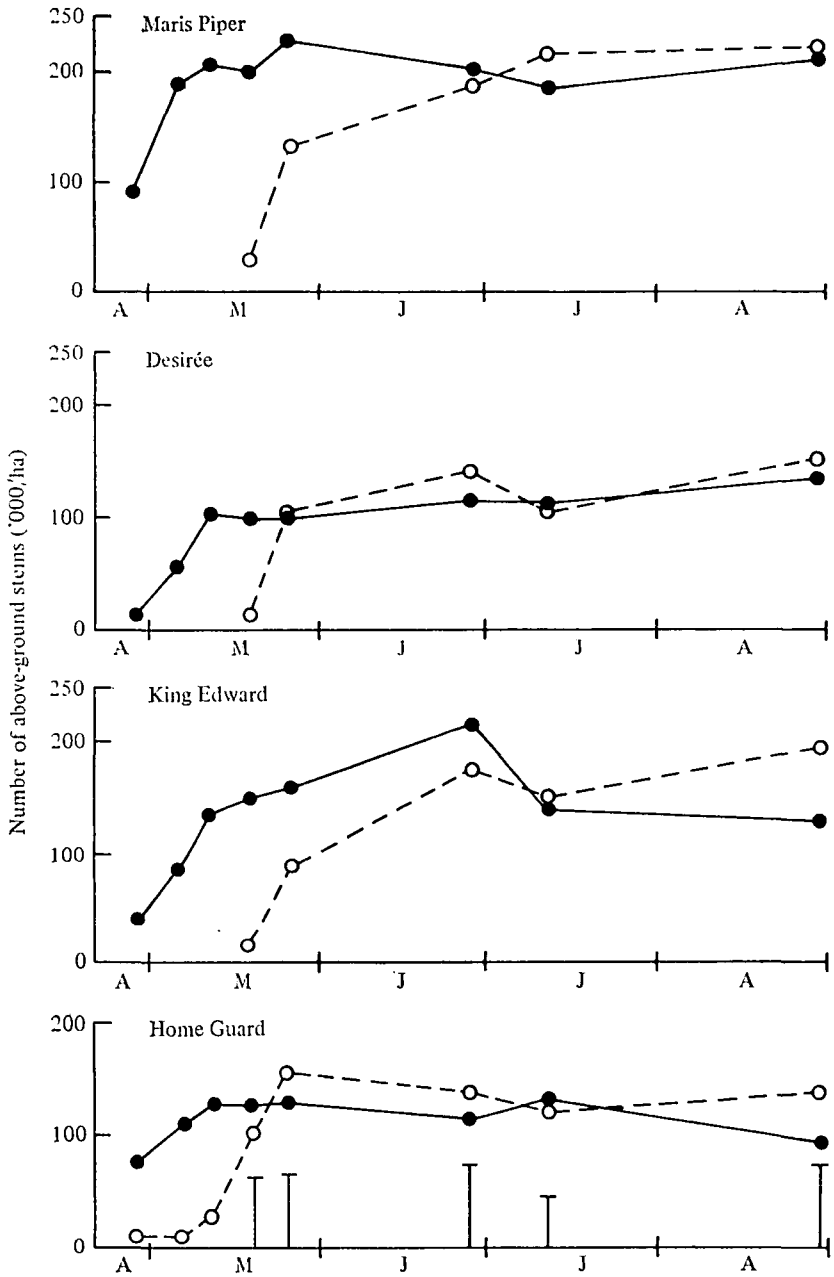

Fig. 1. Effect of date of planting on number of above-ground stems in four varieties. Expt 1, 1973. ●——●, 16 March; ○- - -○, 18 April; T L.S.D. ($P = 0{\cdot}05$) for comparisons of any two points within one date of sampling.

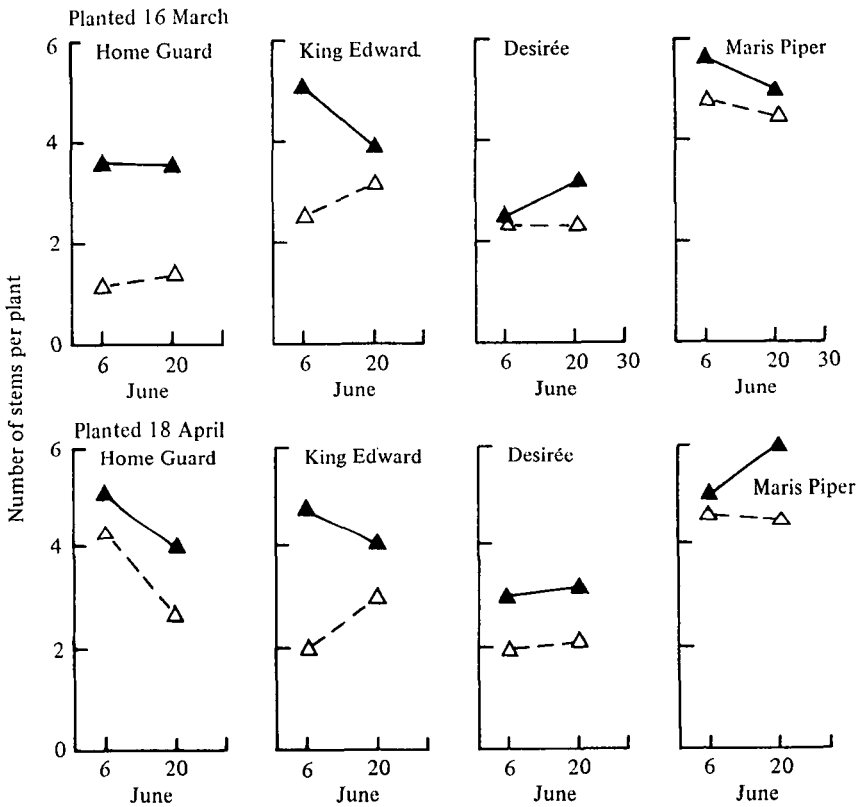

Fig. 2. Numbers of above-ground stems and mainstems per plant for two dates of planting of four varieties. Expt 1, 1973, ▲——▲, above-ground stems, △ – – △, main stems. (The difference between the two symbols on any date of sampling represents the number of secondary stems.)

Experiment 2

Although this experiment had similar treatments and seed to Expt 1, the results were quite different in many respects and a full presentation of the results is necessary. Figure 6 presents the sprouting data and shows that Home Guard produced several long sprouts per tuber, in contrast to Expt 1, and total sprout length and length of the longest sprout per tuber in this variety were significantly greater than in any other variety. Although Maris Piper commenced sprout growth shortly after Home Guard it grew very slowly and had the shortest sprouts when planting commenced. Desirée and Craig's Royal were notable for their rapid sprout growth in December and January with slower growth subsequently. Above-ground stem counts were made on the harvest rows and as Fig. 7 shows, the final numbers from later plantings were higher than from the first planting date in the two maincrop varieties, lower in Home Guard and there were no differences between planting dates in Craig's Royal. These differences were associated with the numbers of main and secondary stems which developed. As Fig. 8 shows, a delay in planting with Maris Piper and Desirée resulted in many more secondary stems developing. In the two early varieties delay in planting had little effect on stem development and in both few secondary stems developed, in contrast to the results of Expt 1 in 1973.

Figures 9 and 10 present data for stem, leaf and 'underground' dry weight and L. Differences in underground dry matter due to date of planting were small for all varieties until early August when later planting resulted in increased dry-matter yields for all varieties. Stem dry weight responded similarly and the increased dry-matter yield resulting from later planting was especially marked by the second delay in planting with the maincrop varieties. The last planting date produced plants of Maris Piper and Desirée which were ultimately visibly taller than plants from earlier plantings. The peak leaf dry weight was not increased in any variety by the first delay in planting although leaf senescence was delayed in

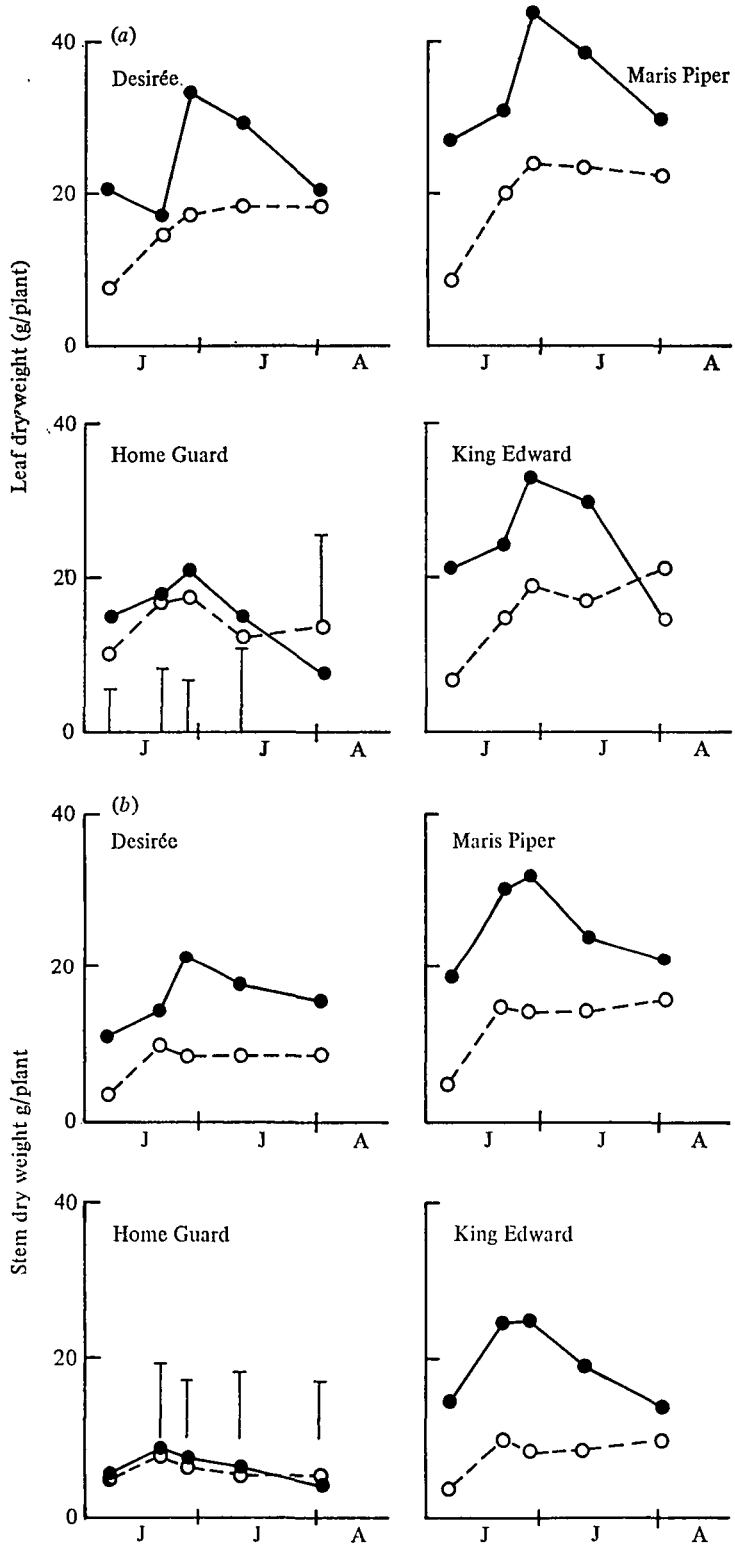

Fig. 3. Effect of date of planting on (*a*) leaf dry weight and (*b*) stem dry weight in four varieties. Expt 1, 1973. ●——●, 16 March; ○---○, 18 April; T L.S.D. ($P = 0{\cdot}05$) for comparisons of any two points within one date of sampling.

Maris Piper and Home Guard, resulting in greater amounts of leaf dry weight by late July. In all varieties, further delay in planting resulted in a later peak in leaf dry weight and in Maris Piper and Home Guard the amount of leaf produced was greater than from earlier plantings. As leaf thickness was markedly reduced by the final delay in planting large increases in L resulted in July and early August in both these varieties and Desirée. The effect in Home Guard was short-lived as by 6 August there was no difference in L between the last two planting dates, but in the two maincrops the differences were still large. At this stage a blight infection on an early planted plot of Maris

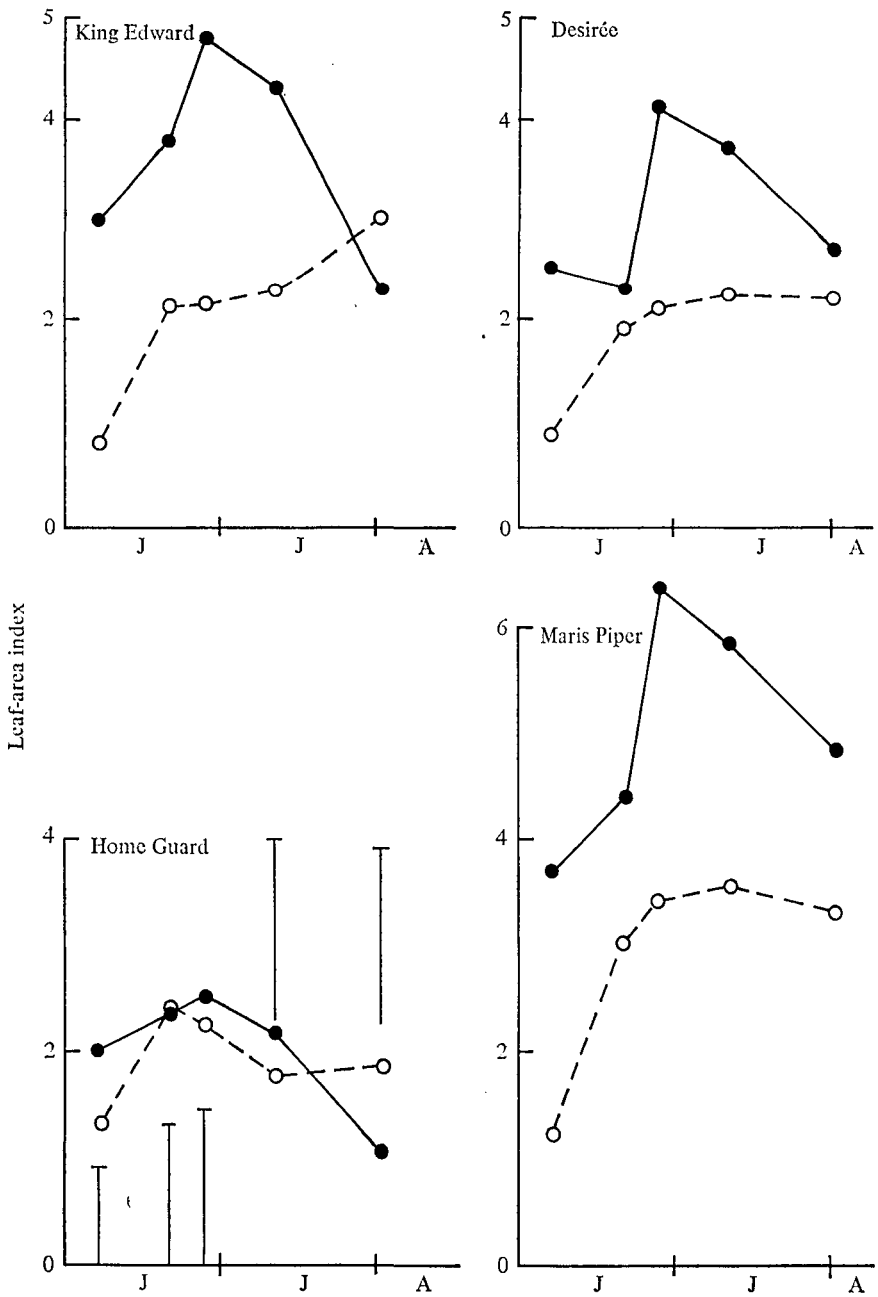

Fig. 4. Effect of date of planting on leaf-area index in four varieties. Expt 1, 1973. ●——●, 16 March; ○- - -○, 18 April; T L.S.D. ($P = 0{\cdot}05$) for comparisons of any two points within one date of sampling.

Table 3. *Average mainstem lengths (cm)*: (*a*) 6 *June*, (*b*) 20 *June*, *Expt* 1, 1973

	Date of planting			
	16 March	18 April	16 March	18 April
	(*a*)		(*b*)	
Home Guard	18·2	22·4	39·4	39·0
King Edward	42·3	16·6	61·6	35·8
Desirée	32·8	16·5	52·8	33·2
Maris Piper	49·6	19·8	69·3	46·5
S.E.	3·32		3·24	

Table 4. % *Green leaf cover*, 29 *August*, *Expt* 1

	Date of planting	
	16 March	18 April
Home Guard	0	0
King Edward	20	25
Desirée	35	40
Maris Piper	20	35

Piper was noticed and spread slowly during the remainder of August, not affecting the two earlies as they were completely dead by the middle of the month but infecting Desirée plots by the end of the month.

Figure 11 shows that tuber yield assessed per plant and per hectare, are in reasonable accord especially for the maincrops. It can be seen that the earliest planting date was rarely disadvantageous and a significant yield reduction in the two maincrop varieties was caused by the second delay in planting at all harvesting dates. The greater variation in tuber yields assessed from growth analysis samples and from the lifting of many plants for yield estimates in the early varieties arose from the proportion of seed tubers which never emerged, or emerged and senesced very quickly. These averaged about 8% overall and almost all were in Home Guard. No selection of plants for sampling was carried out but all growth analysis samples contained two emerged plants while yield estimates contained a proportion of non-emerged plants. As this effect is the direct result of using seed of this type yields have not been corrected for any 'missing' plants. The increases in yield of Home Guard during August when no leaf was present are the results of the variation in numbers of emerged plants present in the yield estimate samples.

Apart from these effects and the effects of increasing blight infection already mentioned, August was notable for the minimal bulking rates of all treatments. Even the later planted maincrop varieties with considerable leaf produced little increase in tuber yield. Thus, judged on yields at the end of August, the latest planting date resulted in ware tuber yields approximately 20 t/ha lower than from the average of the two earlier plantings in both maincrop varieties. Differences between planting dates were much smaller in Craig's Royal and even smaller in Home Guard. A comparison of varieties at individual planting dates showed that any superiority of the early varieties in early tuber yields was small and from the first planting it had been eliminated by the end of the first week in June consequent upon the faster bulking rate of the maincrop varieties.

Yields of maincrop varieties were very high at the termination of the experiment and substantially greater than those from the early varieties.

Experiment 3

As no growth analysis data were taken and the bulking rates are of no especial interest only the total and graded yields from the first and last harvests are shown in Table 5. In Maris Piper, the first planting date resulted in higher yields at both harvest dates and the differences between later plantings were small and inconsistent. In Home Guard and Desirée the first two dates of planting produced similar yields and both exceeded yields from the two later plantings. In Home Guard all planting dates produced yields at maturity which were equal to or higher than any achieved in Expt 1. In this variety and Maris Piper, plants from the first two dates of planting emerged rapidly and developed into substantially larger plants than from any later planting. Notwithstanding their greater size, they survived the long dry period better than the smaller plants from later plantings, and in the case of Maris Piper were still green and bulking at the time of the final harvest. In Desirée the plants from all planting dates were smaller than expected and all were virtually dead by the final harvest.

Experiment 4

Table 6 presents the sprout records taken on the day of each planting. Differences between varieties

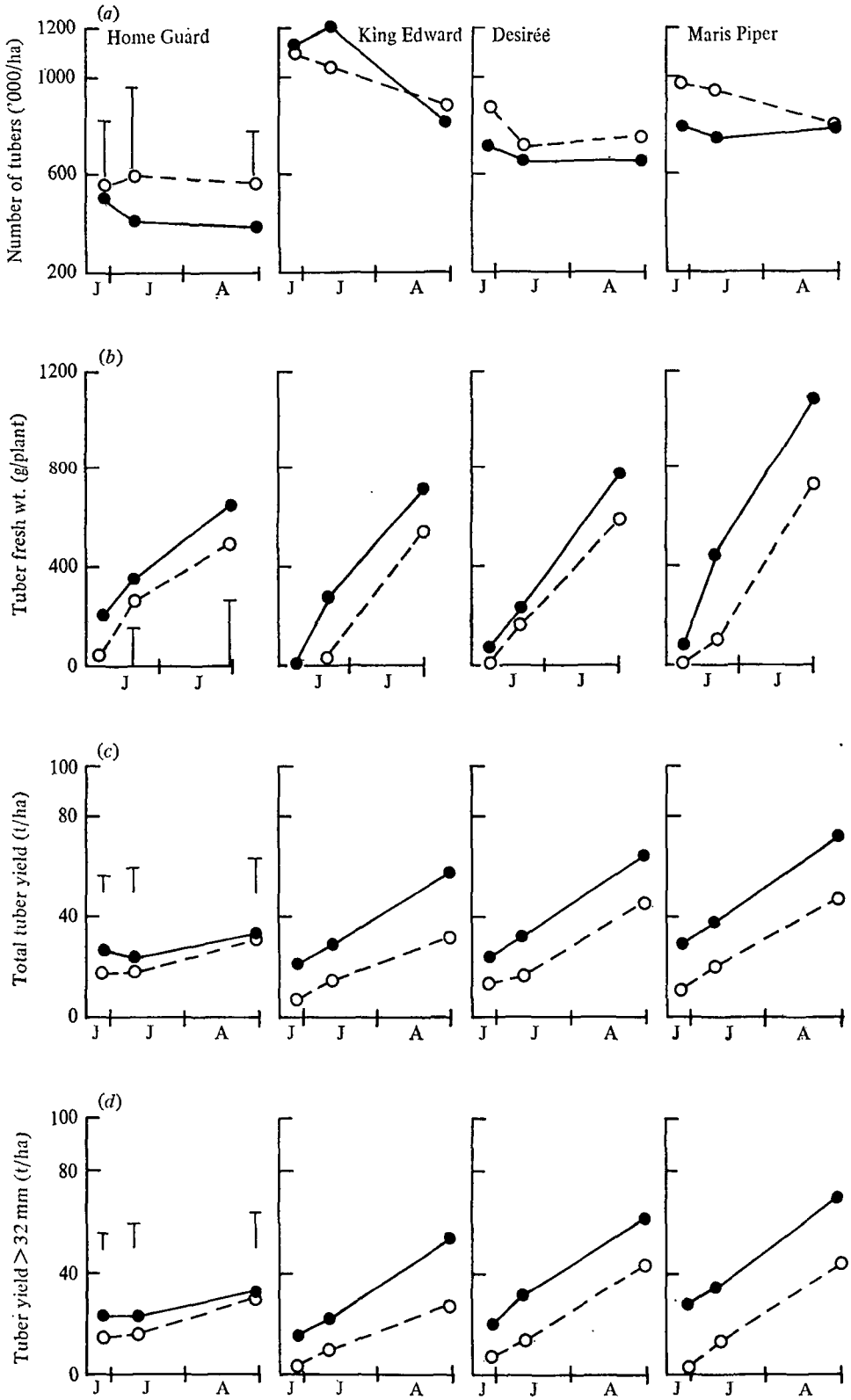

Fig. 5. Effect of date of planting on (*a*) number of tubers (000's/ha); (*b*) tuber fresh weight; (*c*) total tuber yield and (*d*) tuber yield > 32 mm, in four varieties. Expt 1, 1973. ●——●, 16 March; ○---○, 18 April; T L.S.D. ($P = 0{\cdot}05$) for comparisons of any two points within one date of sampling.

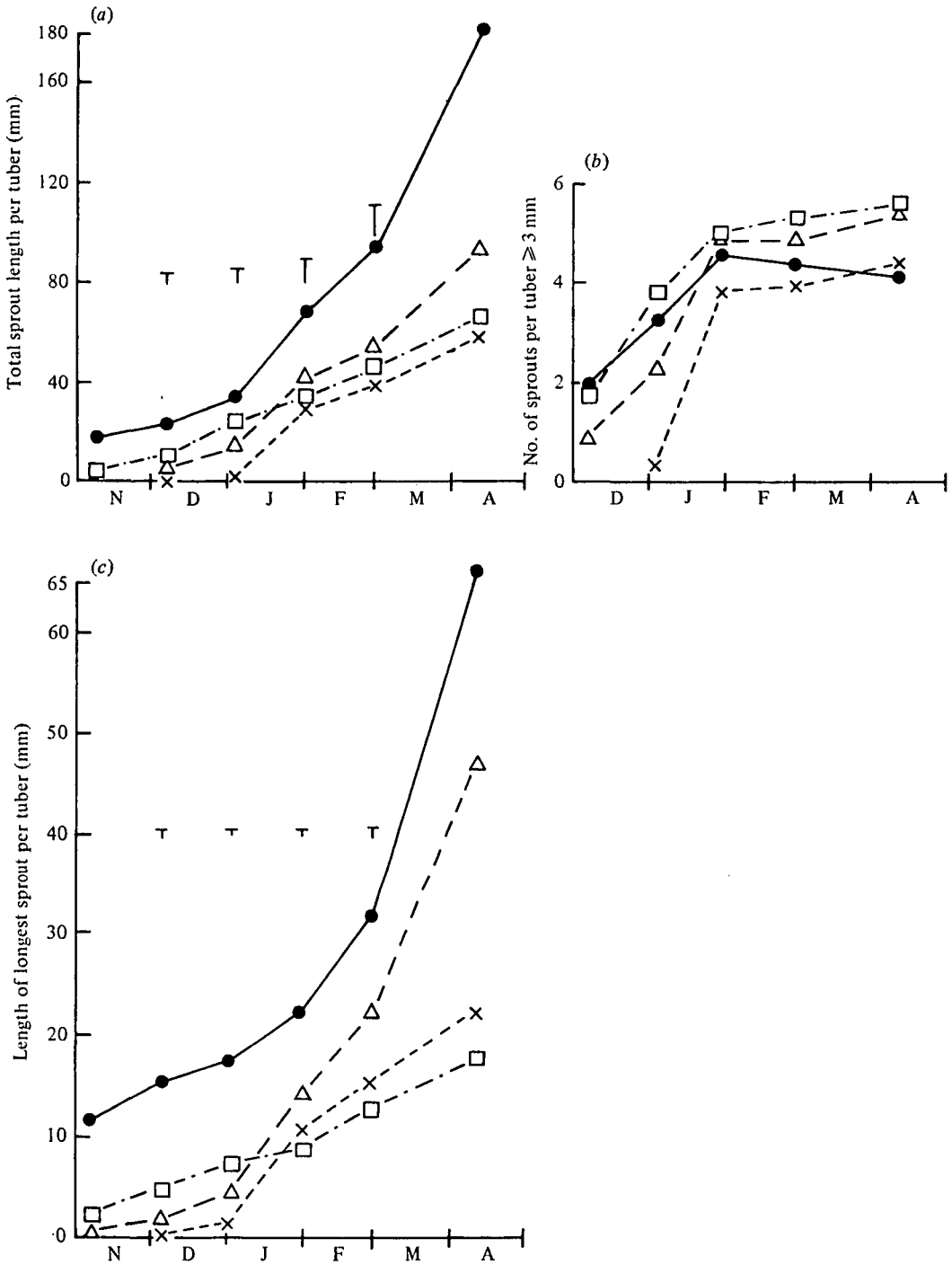

Fig. 6. Effect of variety on (*a*) total sprout length per tuber; (*b*) number of sprouts ⩾3 mm per tuber and (*c*) length of longest sprout. Expt 2, 1974. ●——●, Home Guard; △– – –△, Craig's Royal; □–·–·–□, Maris Piper; ×– – –×, Desirée; T L.S.D. ($P = 0{\cdot}05$) for comparisons of any two points within one date of sampling.

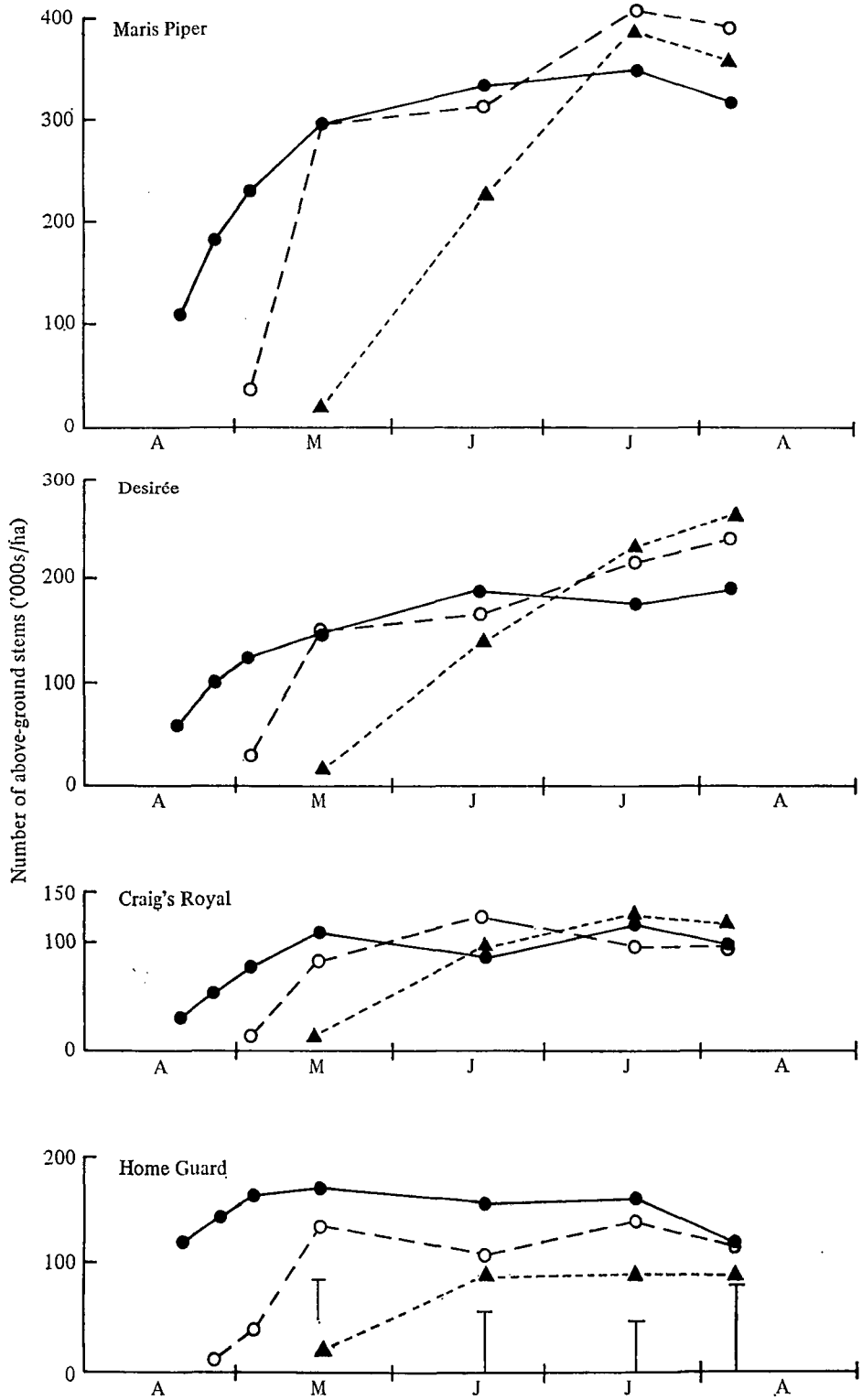

Fig. 7. Effect of date of planting on number of above-ground stems in four varieties. Expt 2, 1974. ●——●, 21 March; ○---○, 11 April; ▲---▲, 2 May; T L.S.D. ($P = 0{\cdot}05$) for comparisons of any two points within one date of sampling.

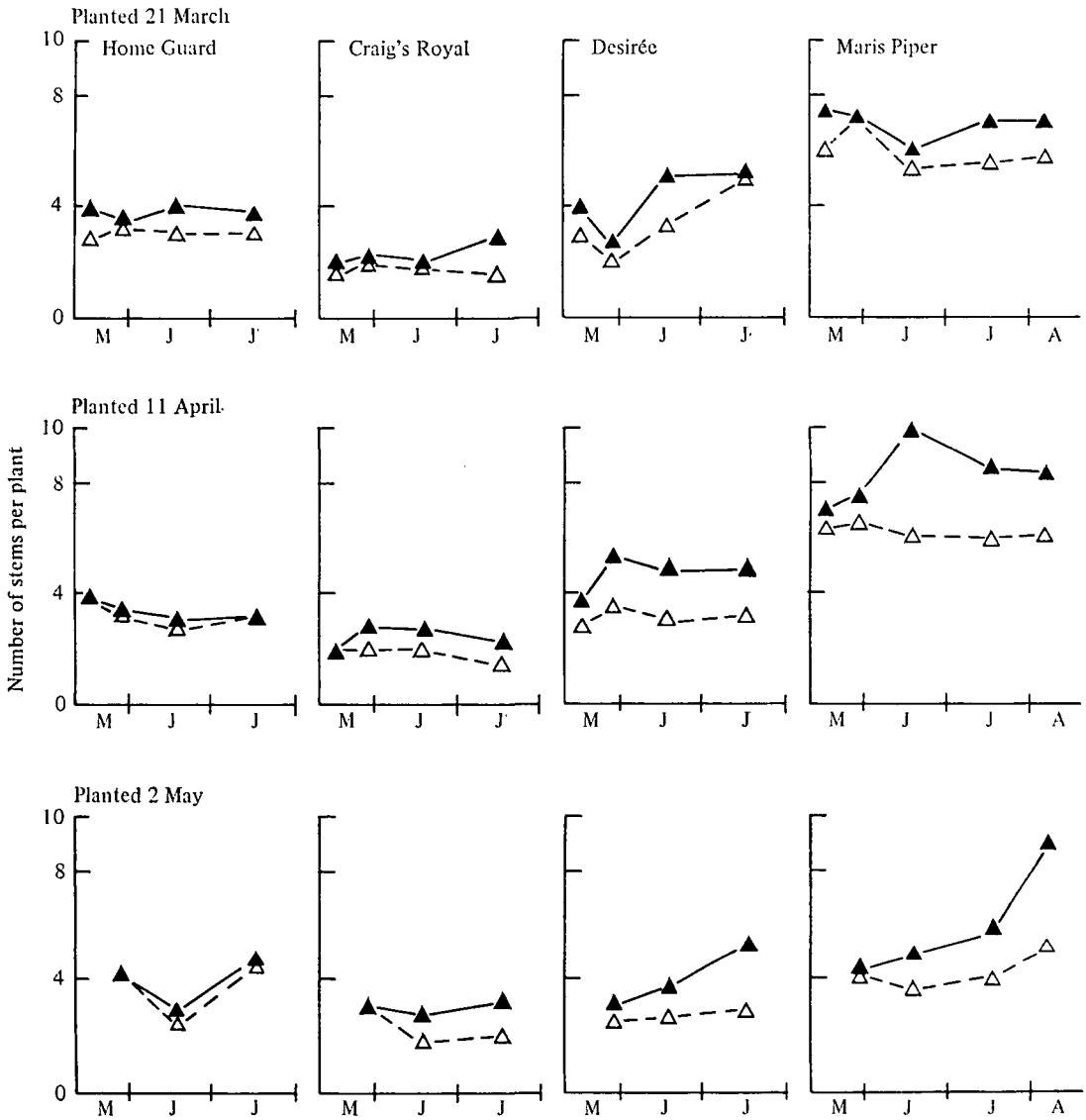

Fig. 8. Numbers of above-ground stems and mainstems per plant for three dates of planting of four varieties. Expt 2, 1974. ▲——▲, above-ground stems; △– – –△, mainstems. (The difference between the two symbols on any date of sampling represents the number of secondary stems.)

in the numbers and total lengths of sprouts were small initially but became greater as the sprouts on Home Guard grew more rapidly than the sprouts on the other varieties. Several sprouts developed in all varieties and the lengths of sprouts by the last date of planting were small compared with those obtained in Expt 2.

Delay in planting resulted in more above-ground stems by July (Fig. 12) in all varieties except Desirée, but by the final harvest differences between planting dates were smaller and inconsistent. The above-ground stems for all dates of planting were predominantly mainstems, especially in the two early varieties.

Although the earlier plantings resulted in higher dry-matter yields of stem and underground parts (Fig. 13) in the early part of the season, the later plantings produced greater dry-matter yields from July onwards. Although the effects of delaying planting on leaf growth (Fig. 14) were similar to

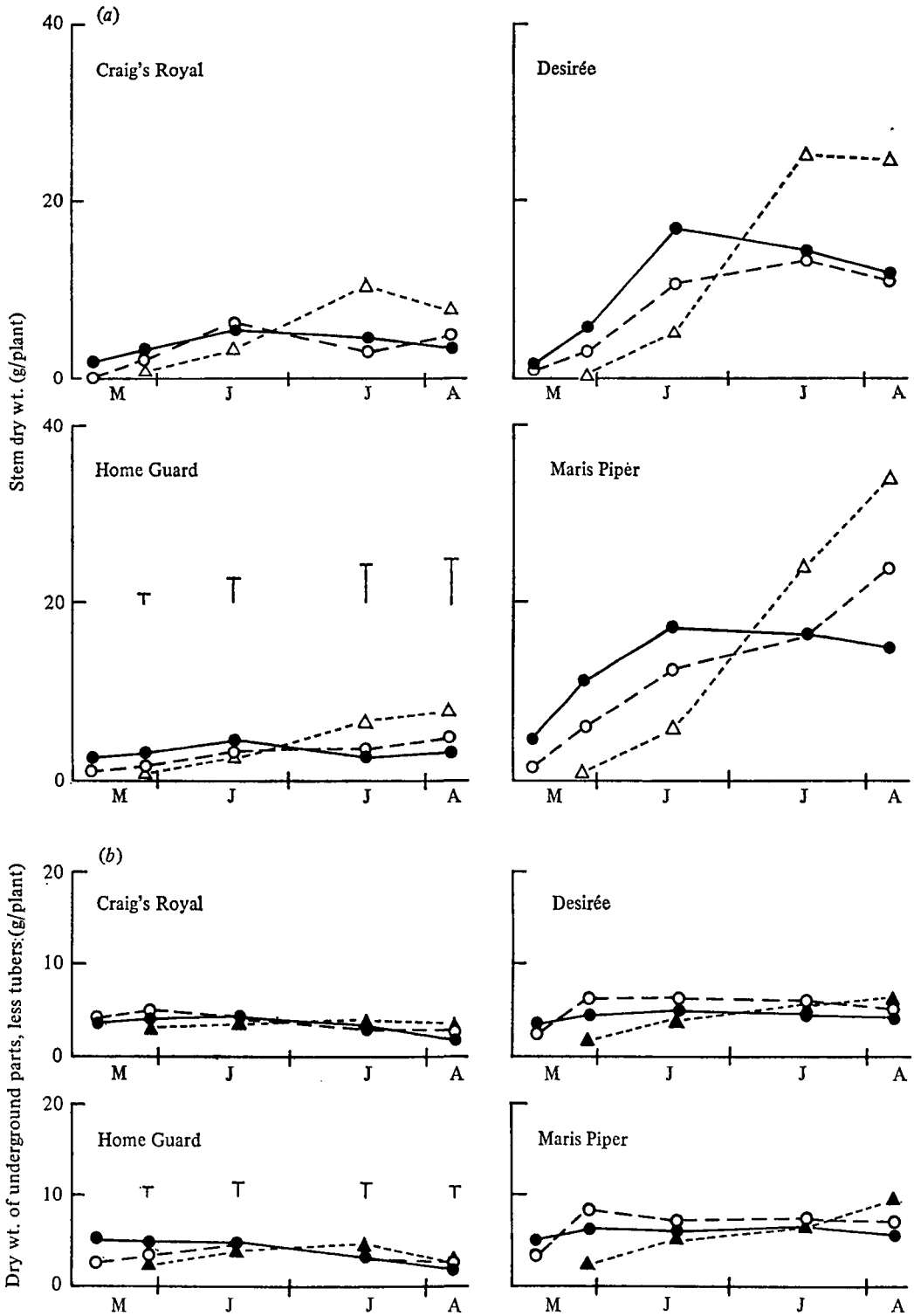

Fig. 9. Effect of date of planting on (*a*) stem dry weight and (*b*) under-ground parts dry weight (less tubers) of four varieties. Expt 2, 1974. ●——●, 21 March; ○---○, 11 April; ▲---▲, 2 May; T L.S.D. ($P = 0{\cdot}05$) for comparisons of any two points within one date of sampling.

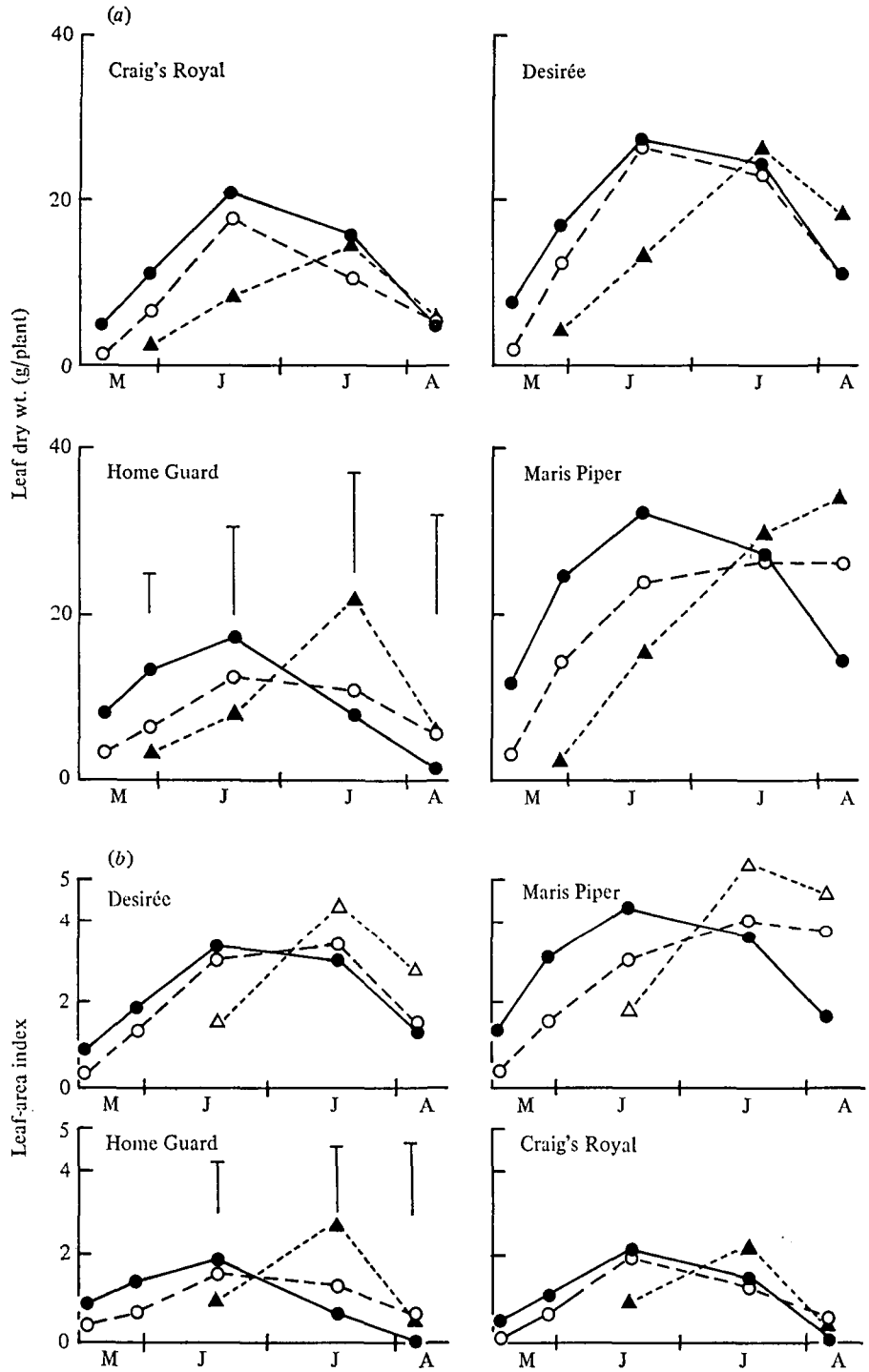

Fig. 10. Effect of date of planting on (*a*) leaf dry weight and (*b*) leaf area index of four varieties. Expt 2, 1974. ●——●, 21 March; ○- - -○, 11 April, ▲- - -▲, 2 May; T L.S.D. ($P = 0{\cdot}05$) for comparisons of any two points within one date of sampling.

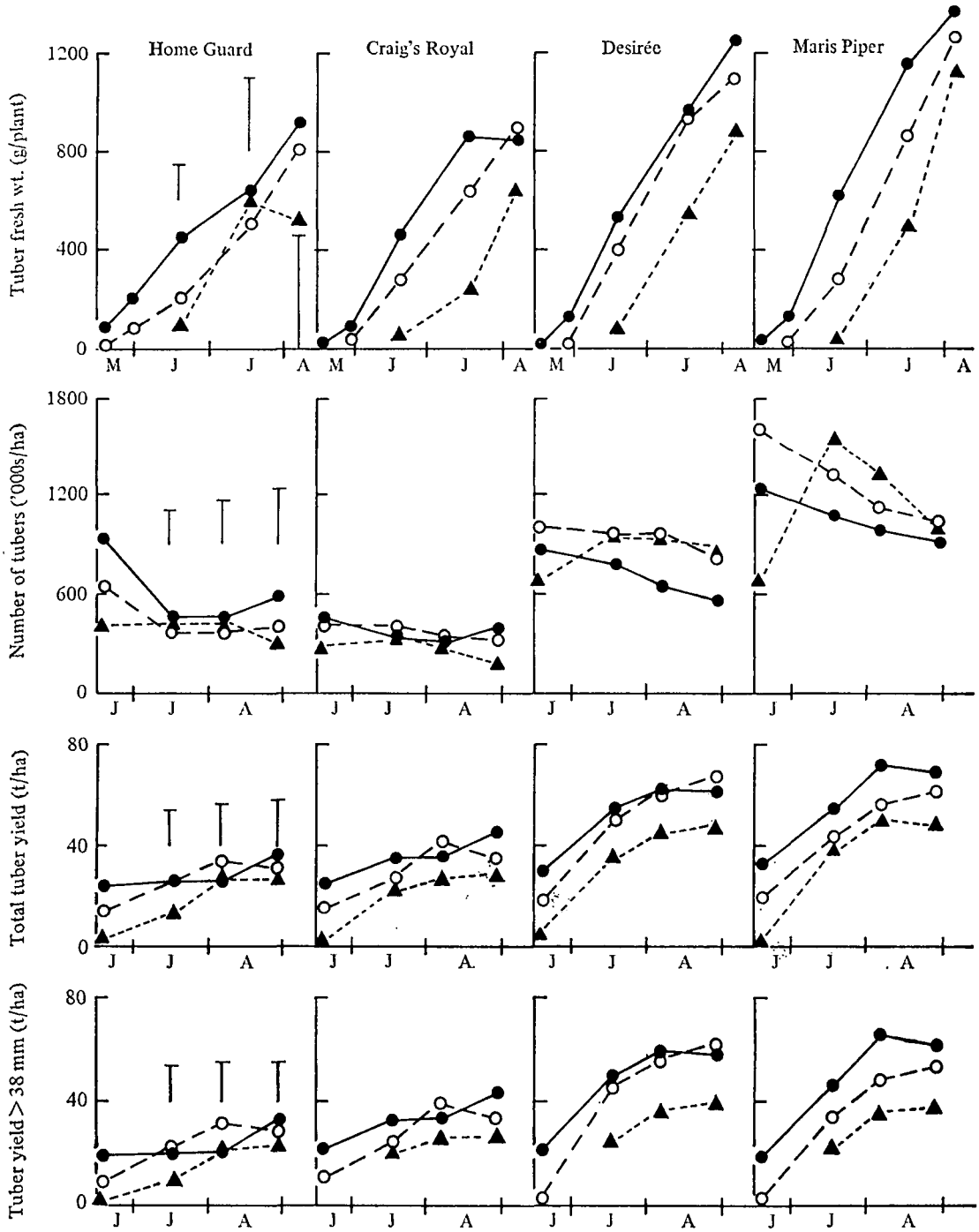

Fig. 11. Effect of date of planting on (*a*) tuber fresh weight; (*b*) total number of tubers; (*c*) total tuber yield and (*d*) tuber yield >38 mm of four varieties. Expt 2, 1974. ●——●, 21 March; ○——○, 11 April; ▲- - -▲, 2 May; T L.S.D. ($P = 0{\cdot}05$) for comparisons of any two points within one date of sampling.

Table 5. *Total and ware (>38 mm) tuber yields (t/ha) for Expt* 3 1973

	Date of planting			
	16 March	27 March	8 April	18 April
4 July				
Home Guard	29·9(22·7)	32·5(23·2)	21·6(9·5)	16·2(5·5)
Desirée	20·0(13·6)	22·1(12·7)	15·5(5·5)	18·8(9·2)
Maris Piper	26·9(17·7)	22·8(7·2)	23·6(3·5)	15·8(0·6)
S.E.	2·09(0·90)			
15 August				
Home Guard	32·6(28·3)	27·7(20·3)	27·5(19·8)	25·6(16·0)
Desirée	33·1(28·7)	36·2 (32·6)	21·8(14·4)	24·1(18·6)
Maris Piper	59·7(54·1)	42·9(32·7)	46·5(37·2)	42·1(35·6)
S.E.	6·35(6·92)			

Table 6. *Number and lengths of sprouts per tuber at each planting date, Expt* 4 1974

	Date of planting					
	21 March			4 April		
	Length of longest sprout (mm)	Total sprout length (mm)	No. of sprouts ⩾3 mm	Length of longest sprout (mm)	Total sprout length (mm)	No. of sprouts ⩾3 mm
Home Guard	5·0	16·6	3·2	13·4	44·4	5·0
Red Craig's Royal	4·8	15·9	3·0	12·6	37·6	4·8
Desirée	10·8	22·0	2·7	14·6	28·4	3·1
Maris Piper	7·7	19·7	3·5	10·8	31·1	4·1

	Date of planting					
	18 April			2 May		
	Length of longest sprout (mm)	Total sprout length (mm)	No. of sprouts ⩾3 mm	Length of longest sprout (mm)	Total sprout length (mm)	No. of sprouts ⩾3 mm
Home Guard	16·3	60·9	5·8	20·2	60·1	4·6
Red Craig's Royal	14·1	45·7	4·6	16·4	44·9	3·8
Desirée	15·7	31·8	2·8	17·5	32·4	2·4
Maris Piper	11·8	30·6	3·3	12·7	33·9	3·3

those on stem and underground dry-matter yield, there were some exceptions. In Red Craig's Royal the first planting date resulted in the greatest leaf dry weight until the end of July. As delay in planting resulted in large reductions in leaf thickness, the L values from July onwards were increased by delay in planting for all varieties. In all treatments, L was decreasing after late July and for both earlies there was no leaf by final harvest. The increases in stem and leaf dry weight resulting from delay in planting were very large especially in Maris Piper and in all varieties they occurred at a time when tuber bulking was already established in its linear phase.

Figure 15 presents the total number of tubers per hectare. In Desirée and Home Guard there were no differences at the final harvest between dates of planting, although the later plantings produced more tubers initially, they suffered greater tuber loss. In Maris Piper, number of tubers increased with delay in planting while in Red Craig's Royal the earlier plantings had more tubers at the final harvest since tuber loss appeared to be greater from the later plantings. Total and ware tuber

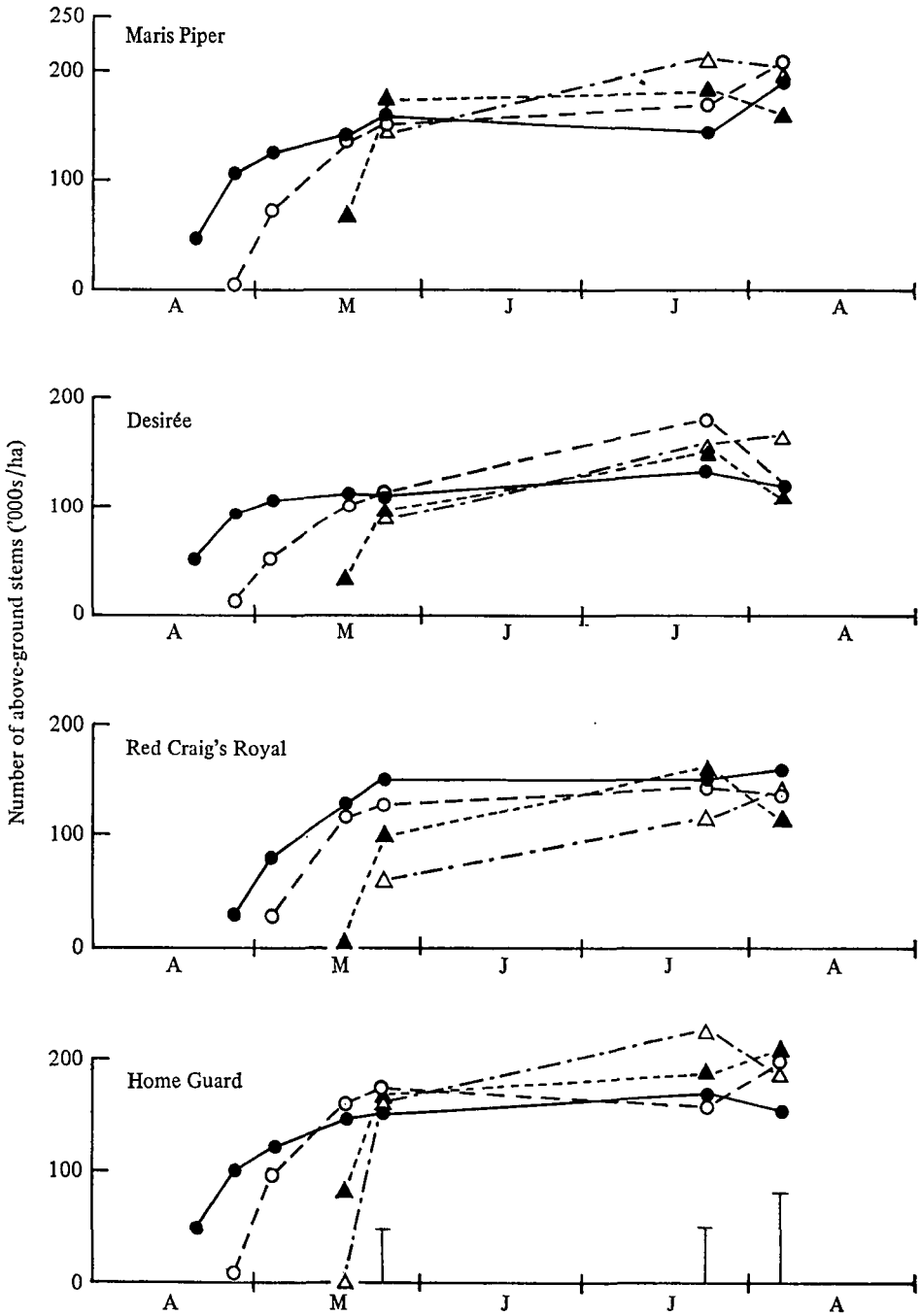

Fig. 12. Effect of date of planting on number of above-ground stems in four varieties. Expt 4, 1974. ●——●, 21 March; ○— —○, 4 April; ▲- - -▲, 18 April; △—·—·—△, 2 May; T L.S.D. ($P = 0{\cdot}05$) for comparisons of any two points within one date of sampling.

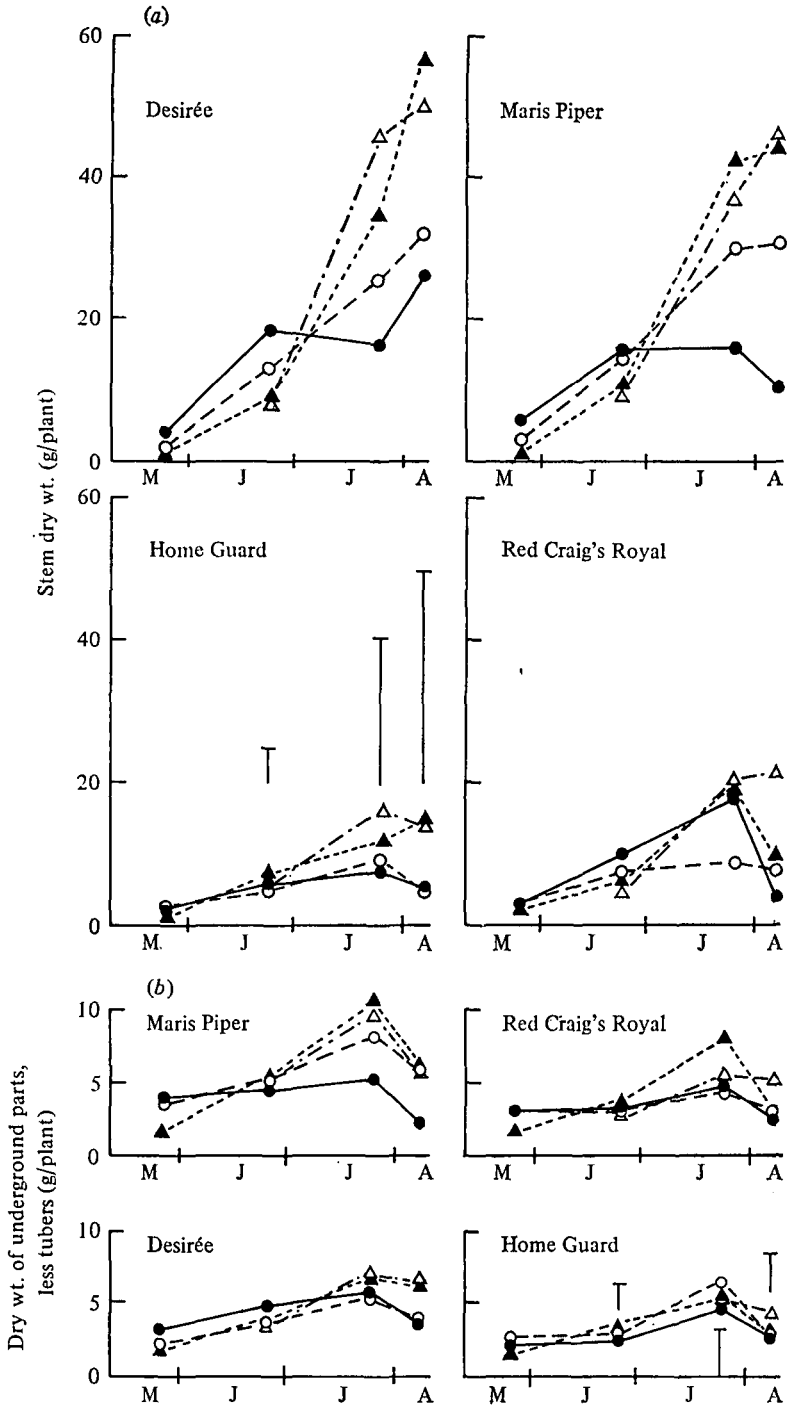

Fig. 13. Effect of date of planting on (*a*) stem dry weight and (*b*) underground parts dry weight (less tubers) of four varieties. Expt 4, 1974. ●——●, 21 March; ○----○, 4 April; ▲----▲, 18 April; △—·—·△, 2 May; T L.S.D. for comparisons of any two points within one date of sampling.

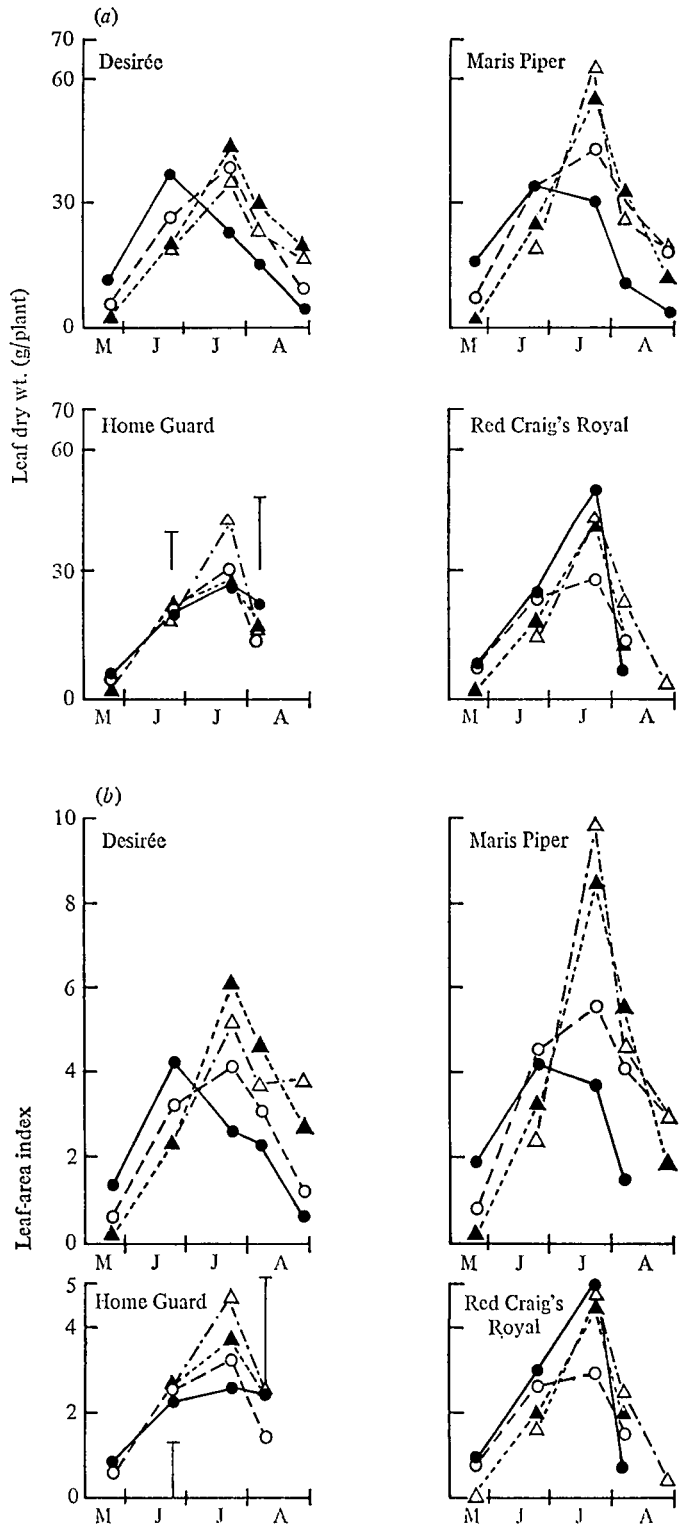

Fig. 14. Effect of date of planting on (*a*) leaf dry weight and (*b*) leaf area index in four varieties. Expt 4, 1974. ●——●, 21 March; ○— —○, 4 April; ▲- - - - -▲, 18 April; △·—·—·△, 2 May; T L.S.D. for comparisons of any two points within one date of sampling.

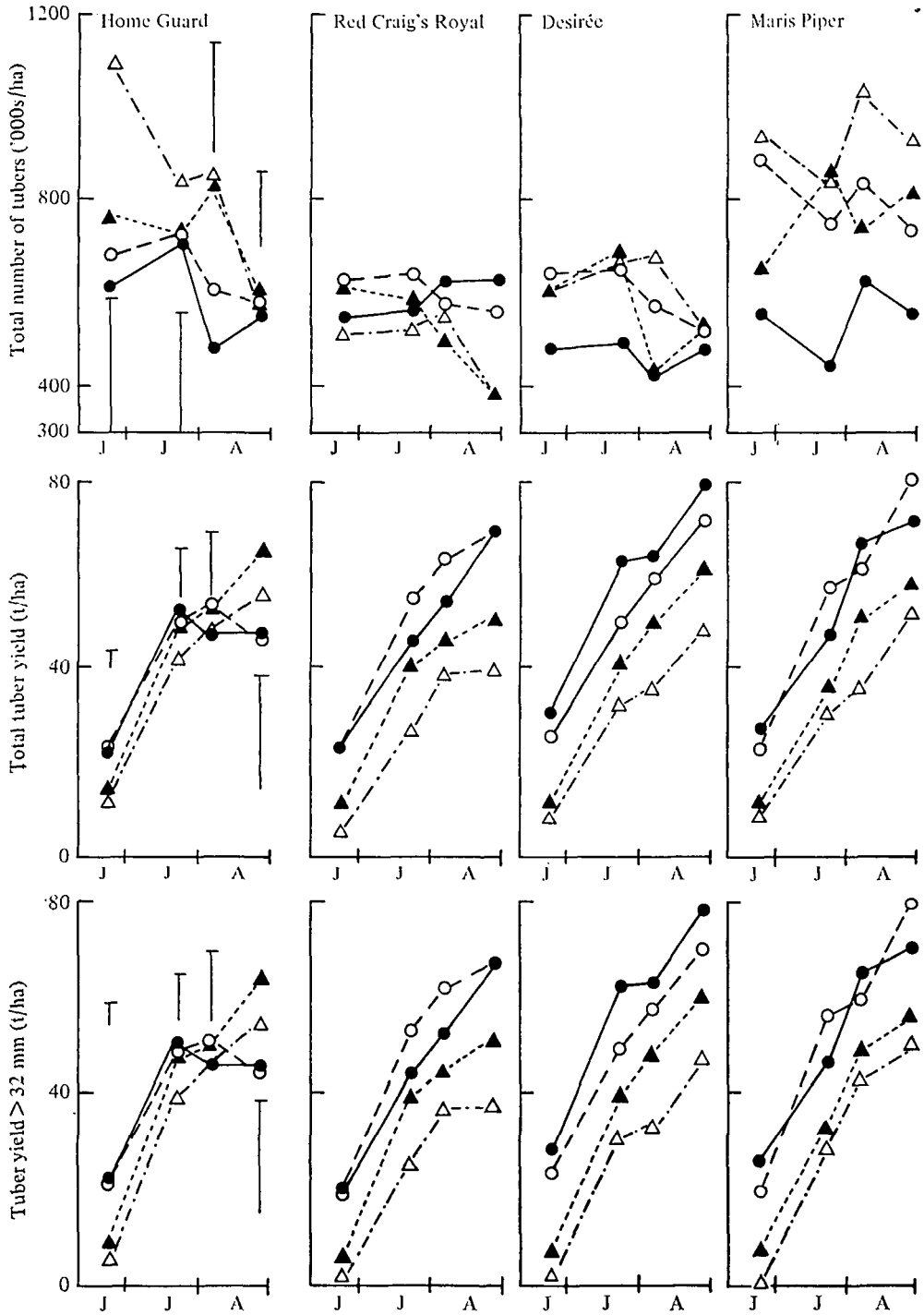

Fig. 15. Effect of date of planting on (*a*) total number of tubers; (*b*) total tuber yield and (*c*) tuber yield > 32 mm of four varieties. Expt 4, 1974. ●——●, 21 March; ○– – –○, 4 April; ▲– · – · –▲, 18 April; △·—·—·△, 2 May; T L.S.D. for comparisons of any two points within one date of sampling.

Table 7. *Tuber fresh weights* (g/*plant*), 25 *May* 1974, *Expt* 4

	Date of planting	
	21 March	4 April
Home Guard	4·7	7·5
Red Craig's Royal	19·0	10·7
Desirée	42·9	8·8
Maris Piper	71·2	1·7

yields (Fig. 15) of all varieties except Home Guard were greater from the earlier plantings. Although the yields from the second date of planting of Maris Piper and Red Craig's Royal exceeded those from the first planting date on some occasions the differences were small and yields from any later plantings were always substantially lower. In Home Guard yields early in the season were higher from the earlier plantings but by maturity yields were greatest from the third date of planting and the final date of planting produced higher yields than the two earliest plantings. Yields of the two earlies were much higher than achieved in Expt 2 and, especially with Red Craig's Royal, compared more favourably with the maincrops. Notwithstanding the smaller seed size used in this experiment, the yields of the two maincrops were slightly higher than in Expt 2. As in that experiment it was notable that tuber bulking rates of some treatments were reduced during August, although their leaf area was still substantial.

There was no occasion on which the early varieties produced higher tuber yields than the maincrops. Even at the first growth analysis sample on 25 May tuber yields of the maincrop varieties from the first date of planting were greater than those of the earlies (Table 7). At this stage tubers were present on plants of all varieties from the second date of planting.

DISCUSSION

The results confirm that physiological age affects the response of early varieties to date of planting for old seed did not increase in leaf area when planted later in either season while the younger seed of these varieties increased substantially in leaf area when planted later in Expt 4. As a result of these changes in leaf area, tuber yields from younger seed of early varieties were increased through later planting while delay in planting of old seed only delayed the attainment of any yield level. Old seed of varieties such as Home Guard and Red Craig's Royal would appear only suitable for early harvests at low yield levels, these yields being achieved through sustained, slow bulking rates not, as is often implied (e.g. Prytherch, 1973), through fast bulking rates. The low bulking rate of such seed limits its value to the early lifting period and the earliest date of planting used here was beneficial. Growers who wish to harvest throughout June should not use only old seed, for higher yields at the end of this period may be achieved by either younger seed of the same early varieties or by using another variety, even a maincrop variety. These higher, later yields are achieved through faster bulking rates. For very late lifting of early varieties, as in a seed crop, later planting may be advantageous as a higher bulking rate may result from the increased leaf area. These experiments do not indicate the likely effects of date of planting on early varieties which do not sprout as readily as Home Guard nor the effects of planting earlier than mid-March. Many growers do plant earlier and depending upon season January planting is sometimes possible especially in the freer draining, coastal soils. Further experiments are in progress to examine these two questions.

The results also indicate that season is important, for the maincrop varieties responded quite differently to date of planting in 1973 and in 1974. Delay in planting reduced plant size and tuber yields in 1973 and increased plant size but not yields in 1974. Thus, it is not axiomatic that later planting results in improved growing conditions which are reflected in increases in plant size of maincrop varieties. The type of response exemplified by the results of Bremner & Radley (1966) would appear to be but one of a series of possible responses determined by the interaction of climatic and physiological factors. In 1973 it is likely that shortage of water was an important limiting factor. In this context the methods of cultivation and planting are of importance for Beveridge (1966) showed that leaving ridges open for as little as 18 h could result in reduced yields especially if the season were dry. In these experiments all ridges were drawn at the same time and thus were left open for up to 6 weeks before splitting. This system was adopted in an attempt to ensure reasonably similar tilths for all dates of planting. It was successful in that the tilth created initially was well preserved in the ridges before planting and the soil conditions within the finished ridges were similar for all dates of planting. (A system of early ridging in autumn is practised by some Pembrokeshire early potato growers.) The tilth produced by this system was cloddier in 1973 than in 1974 and in view of the effects reported by Beveridge (1966) and the fact that 1973 was a dry season it seems possible that this method of cultivation may have contributed to the poor performance of the late planted maincrop varieties by increasing early water loss. If such a system of cultivation had not been adopted it is likely that

the two dates of planting would have had markedly different tilths for the soil was very dry at the time of second planting and would have been difficult to cultivate to a good tilth. Although the method of cultivation may have contributed to the poor performance of late plantings in Expt 1, the magnitude of the effects was such that it seems likely that in seasons in which dry conditions prevail for much of the early part of the season late plantings will not result in increased plant size or yields of maincrop varieties. The work of Dyson & Watson (1971) showed that maincrop varieties planted in early May at Rothamsted do not necessarily produce large plants and tuber yields, for with King Edward in two seasons maximum L was barely 3 and duration of linear tuber bulking rate was only 6 weeks.

As the experiments were all terminated at the end of August, before the end of all growth, the possibility of later planted treatments 'catching up' must be assessed. The maincrop varieties and the earliest planting of Red Craig's Royal in 1974 were not completely dead by the end of sampling so that some further tuber growth of these treatments was likely (in the absence of blight) but it would seem that the later dates of planting would require the majority or all of September to approach the levels of yield achieved by the earliest plantings at the end of August. The low bulking rates towards the end of sampling, the presence of blight and the necessity for an early start to harvesting and consequently early burning off would prevent such a long growing season in practice.

The growth patterns of the early varieties in these experiments were much affected by the sprouting regime. Different sprouting treatments were not included within one experiment but a comparison of Expts 2 and 4 in 1974 shows that older seed of Home Guard gave higher, early yields but lower, later tuber yields than younger seed. Notwithstanding these effects of sprouting, differences in tuber yield between varieties were smaller in the early part of the season than was expected. Maincrops initiated tubers only slightly later than the earlies but bulked faster and were inferior in yield to the early varieties for a relatively short period. This period would cover the highest price range but for crops in W. Wales lifted after mid-June maincrop varieties had distinct advantages. It is therefore of considerable interest to consider the fundamental reasons for differences between varieties. A simple classification into maturity groups would appear unsatisfactory for the growth of a variety was much influenced by the sprouting regime.

It is suggested that earliness in a genotype is principally a reflexion of advanced physiological age (Madec & Perennec, 1955) and varieties which sprout early and rapidly will age quickly so that by planting time they will be very old physiologically. However, if the aging process is moderated or prevented, the growth pattern of the variety may be quite different. A combination of better growing conditions consequent upon later planting and seed of younger age allowed Home Guard in Expt 4 to achieve a growth pattern much more closely associated with maincrops than earlies and to produce high tuber yields. In Expts 1 and 2 the growth of Home Guard followed the pattern which has been regarded as necessary for good early yields, namely few stems per plant, a low overall rate of accumulation of dry matter and a very high proportion of the dry matter partitioned to the tubers. From this seed the largest early yield advantages over maincrops resulted. A comparison of this pattern of growth with that of the maincrops would suggest that an alternative route to high early yields would be through much higher growth rates even though a lower proportion of dry matter was partitioned to the tubers. As this type of growth pattern would produce high L values and bulking rates the varieties (or treatments) would produce high tuber yields over a longer period than the aged seed of a variety such as Home Guard. Varieties of the Home Guard type could become restricted to production for the very earliest harvests.

As the growth pattern of varieties would appear to be much influenced by the physiological age of the seed used it may be suggested that the testing of varieties should take more account of this factor. As variety trials cannot consider many agronomic variables (in some cases, none), the interrelations between age and date of planting are of crucial importance. Using the younger seed and the third planting date of Expt 4 one would consider Home Guard, Desirée and Maris Piper to be largely equivalent in terms of tuber yield. From other planting dates or with older seed quite different conclusions would be reached. True genetic differences between varieties will remain difficult to assess until it is possible to measure age by a quantifiable scale and understand the effects of age on the growth of individual varieties for, if this were known, it would be possible to compare varieties at an appropriate and definable age. It would seem that the current classification of varieties into maturity classes is much too rigid. There are many varieties which are classified as earlies whose characteristics differ markedly from Home Guard. Most of these varieties have made no significant impact on commercial production and their responses to date of planting (and other agronomic practices) are unknown. The dominance of the early potato acreage in U.K. by first Arran Pilot and now Home Guard may be attributed to

the propensity of those varieties to sprout early and rapidly. This type of response is often difficult to control in the high ambient temperatures of the western part of the country but offers reliable early yields without recourse to any degree of temperature control in store. The possibility of achieving high early yields from varieties which do not age rapidly in ambient conditions has not been seriously considered. It may be anticipated that the performance of such varieties will be much affected by the way in which their seed is produced and sprouted and they will not perform well if simply treated in the same way as a variety such as Home Guard. Data supporting this view will be presented in a subsequent paper. In general in many experiments at Trefloyne increases in the amount of sprout development of such varieties has improved their early tuber yields (P. J. O'Brien, & J. N. Bean, personal communication) and this has been achieved both by varying the husbandry of the seed crop and the conditions of storage. In the latter context it has already been briefly reported (Wurr & Allen, 1976) that a cold treatment may be used to break the dormancy of the variety Vanessa and result in an earlier onset of sprout growth.

The yields from early plantings of maincrops were very high in these experiments and it is likely that this was associated with the leaf growth of these treatments being very much 'in phase' with the increase in incident radiation. Gunasena & Harris (1971) obtained higher yields of the second early variety Craig's Royal planted mid-March than from the maincrop variety Pentland Dell planted later and atttributed this to the better light interception of the early variety. Watson (1952) argued that improvement in early growth and light interception would be beneficial to potato yields. These results support this and Fig. 10 shows that an L of 3 was achieved by the end of the third week in May from the earliest planting date with Maris Piper in Expt 2. The great superiority in yield from plantings of maincrops up to mid-April over later plantings which was not so marked in the results of Bremner & Radley (1966) may be attributed to the very good use of the high light intensities of May and June achieved by the earlier plantings. The later plantings were unable to achieve the same interception early on, often because emergence occurred in late May and thus were attempting to 'catch up' in conditions of declining radiation, which in 1974 were accentuated by persistent rainfall and cloud cover. In eastern England the opportunities for improving early development may be limited for the risk of frost vitiating effects are much greater, and emergence is difficult to obtain before early May no matter how early planting is made because early soil temperatures are so much lower. The mild, relatively moist conditions of W. Wales would appear ideal for maincrop as well as early potato production.

In the experiments in which stem morphology was recorded it was found that the varieties differed in the types of stem which composed their above ground stems. When heavily sprouted, the earlies produced a proportion of secondary stems but when sprout development was restricted they produced very few secondary stems and stem morphology did not appear to be affected by delay in planting. The secondary stems from heavily sprouted seed were probably associated with damage to the stem apex which commonly occurs with such long sprouts. It was surprising that the frost damage did not produce much secondary development. The damaged mainstems recovered through growth from axillary buds above ground and therefore secondary stems below ground were rare. Maincrop varieties produced many more secondary stems than previously reported by Allen & Wurr (1973) especially when planted late. This may be associated with the increased sprout development in Expt 2 and crops reported by Allen & Wurr were in E. Anglia and planted with seed with substantially less sprout development than found in these experiments. There is little information on the effects of variation in types of stem but in W. Wales maincrop varieties produce more secondary stems than reported from E. Anglia. It may be expected that such variation would affect plant population density relationships in that a crop of wholly mainstems may not respond in the same way as one with the same total number of stems comprising mainstems and secondary stems.

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