J. agric. Sci., Camb. (1984), **103**, 443–458
With 1 text-figure
Printed in Great Britain

Comparisons of growth and early yields of potato varieties of contrasting maturity classification at three sites

By R. L. GRIFFITH, E. J. ALLEN*, SUSAN A. O'BRIEN* and P. J. O'BRIEN*
Department of Agriculture (Crop Husbandry), University College of Wales, Aberystwyth, Dyfed

(*Received* 17 *April* 1984)

SUMMARY

Six experiments which compared a range of contrasting varieties are reported. Two experiments were at a very early, coastal site in N. Pembrokeshire (Trefin), two at a site in South Pembrokeshire (Trefloyne) and two at a coastal site in N. Norfolk (Brancaster). No variety was in every experiment but several were in the majority of experiments. In some experiments sprout growth was manipulated by control of storage temperatures. A variety classified as early or second early produced the highest yields in all experiments but the yields of the best maincrop varieties were high and substantially better than many early varieties. The highest-yielding variety at the first harvest maintained this advantage throughout June and July. At two sites (Trefin and Brancaster) the highest-yielding variety was consistent from year to year but overall the ranking order of varieties for yields was inconsistent, e.g. Arran Comet was the highest-yielding variety at Trefin in both years and one of the lowest yielding at Brancaster.

The results suggest that it is unwise to attempt to rank varieties for early yields by an overall score. The maturity classification of varieties is not necessarily an accurate guide to the utility of a variety. A consideration of the physiological age of the seed and growing conditions provided some explanation of these effects and their implication for breeding are discussed.

INTRODUCTION

In the United Kingdom potato varieties are classified into three maturity groups, early, second early and maincrop which broadly indicate the appropriate time of harvesting. The classification is not meant to be rigid but early varieties are generally associated with lower yields later in the season than second earlies and maincrops and to obtain the highest yields over a long period several changes in variety are assumed to be necessary. Few direct comparisons of contrasting varieties have been reported and some available data suggest that differences between varieties are smaller than hitherto assumed. Gunasena & Harris (1971) found that Craigs Royal (second early) produced similar high final yields (80 t/ha) to Pentland Dell (maincrop) and Allen (1977) reported that early varieties out-yielded maincrops only for a short period at the beginning of harvesting. Moreover, several authors have reported that the growth pattern of varieties, especially many classified as earlies (O'Brien *et al.* 1983; O'Brien & Allen, 1981) can be modified by management of the seed tuber. The low yields of early varieties later in the season may be primarily determined by the use of old seed of certain varieties, for O'Brien *et al.* (1983) have shown that in some early varieties old seed leads to smaller leaf areas which senesce earlier than younger seed, thereby reducing yields later in the season.

Such results suggest that high yields early in the season may be achieved without prejudice to later yields and this possibility has considerable implications for the breeding and testing of new varieties as well as the most effective use of existing varieties. This paper presents comparisons of contrasting potato varieties grown at three different sites and harvested during the first 2–3 months of the season (May–July). In some experiments sprout

* Present address: Department of Applied Biology, University of Cambridge.

Table 1. *Details of varieties used in Expts* 1–6

Variety	Origin	Maturity classification
Home Guard	British	Early
Arran Comet	British	Early
Maris Bard	British	Early
Pentland Crown	British	Maincrop
Stormont Enterprise	British	Maincrop
Désirée	Dutch	Maincrop
Primura	Dutch	Early
Pentland Javelin	British	Early
F46/11	British	Early
Spunta	Dutch	Second early
Renova	Dutch	Second early
Juliver	Dutch	Maincrop
Draga	Dutch	Maincrop
Aminca	Dutch	Early
Wilja	Dutch	Second early
Estima	Dutch	Second early
Ulster Sceptre	British	Early
Red Craigs Royal	British	Second early
Maris Piper	British	Maincrop
Foxton	British	Maincrop
Record	Dutch	Maincrop
Vanessa	Dutch	Early

growth of varieties was manipulated by control of storage temperature so as to achieve the required physiological age for early harvests. As the data covered five seasons, the influence of site and season in relation to the testing of varieties could be assessed.

THE EXPERIMENTS

Two experiments were carried out on the farm of Mr I. Davies, Park Court, Trefin, S.W. Dyfed on light, gravelly soil of the Arfon Series (Rudeforth & Bradley, 1972). Both experiments used 66 cm rows. A fertilizer dressing of 166 kg N, 107 kg P and 138 kg K/ha was applied by hand over the ridges prior to planting. Sampling, grading and recording techniques were essentially as reported by Allen (1977). Details of the varieties grown are given in Table 1.

Experiment 1, 1976–7

Treatments were five varieties Home Guard, Arran Comet, Maris Bard, Pentland Crown and Stormont Enterprise replicated four times in a randomized-block design. Plots were four rows wide and 6·1 m long. Seed tubers of 55–65, 65–75, 75–85 and 85–95 g were used for the four replicates and spaced 30 cm apart in the row. Numbers of plants and stems were recorded on two rows on 8 and 22 April and yields estimated from ten plants per plot on 31 May, 10 June and 1 July.

The seed of Arran Comet, Pentland Crown and Stormont Enterprise was 'once-grown' from mid-Wales and weighed out at University College of Wales in late January when Arran Comet had considerable sprout growth. The seed was placed apical end uppermost in trays and stored at 12 °C in a glasshouse with supplementary heating until planting. The seed of the other varieties was selected from the farmer's own Scottish seed in his glasshouse on 11 February. After selection the seed was placed apical end uppermost in trays and left in the farm glasshouse until planting. Sprout measurements were made on ten tubers per seed size of each variety on 12 March and the experiment planted by hand on 20 March.

Experiment 2, 1977–8

There were six treatments comprising Home Guard, Arran Comet, Maris Bard, a once-grown stock (OG) and a certified stock (CC), Pentland Crown and Désirée, replicated four times in a randomized-block design. The once-grown stock of Maris Bard was the progeny of the certified seed used in Expt 1 and had been multiplied in a field of early potatoes. It had been defoliated and harvested early (early July and mid-July respectively) and consequently had an early end to dormancy which resulted in very long sprouts (advanced physiological age) by planting. The seed of Pentland Crown and Désirée was 'once-grown' in mid-Wales while for the remaining three varieties the seed was from the purchased certified stock of the farmer. The seed from Trefin was weighed out in the farm glasshouse on 22 December and only Maris Bard (certified stock) had no sprout growth. Tubers were placed in trays as in Expt 1 and remained in the farm store until planting. Seed of Désirée and Pentland Crown were weighed out at University College of Wales on 13 January when there was some sprout growth. Tubers were placed in trays as in Expt 1 and stored at 12 °C until planting. Sprout measurements were taken on 9 February on ten tubers of each size on all varieties and the experiment planted on 3 March. Plots were four rows wide and 5·3 m long. Seed tubers of 70–80, 80–90, 90–100 and 110–115 g were used for the four replicates and spaced 27 cm apart in the row. Numbers of plants and stems were counted on 30 March, 7 April and 1 May using 10·6 m of row. Growth analyses using two adjacent plants per plot were carried out on 4 and 18 May and yields estimated from ten plants per plot on 30 May, 7 and 16 June.

Two experiments were carried out at Trefloyne Field Station on Old Red Sandstone soils of the Pembroke Series (Soil Survey Record, No. 24 1974). Both experiments used 71 cm rows and received fertilizer dressings of 154 kg N, 66 kg P and 160 kg K/ha applied over the opened ridges prior to planting.

Experiment 3, 1978–9

Treatments were nine varieties, Primura, Home Guard, Arran Comet, Pentland Javelin, F46/11 (earlies), Spunta, Renova (second earlies), Juliver and Draga (maincrops) replicated three times in a randomized-block design. Plots were three rows wide and 11·25 m long. Seed tubers of 40–50, 50–60 and 60–70 g were used for the three replicates and spaced 25 cm apart in the row. Number of plants and above-ground stems were recorded on 18 May using one complete row. Growth analysis (two plants per plot) and estimates of yields (ten plants per plot) were carried out on 21 June, 3, 16 and 31 July.

All seed was 'once-grown' in mid-Wales. Seed was selected before the onset of sprout growth and placed in trays as in Expts 1 and 2. The seed was stored in a frost-free glasshouse until planting (average daily temperature 8·4 °C). Sprout measurements were taken on 8 March using ten seed tubers of each size and the experiment planted by hand on 19 April.

Experiment 4, 1979–80

In this experiment 11 varieties were compared; Aminca and Maris Bard (earlies) and Wilja (second early) were added to those in Expt 3 and Home Guard deleted. There were three replicates; plot dimensions and seed size were as in Expt 3. Numbers of plants and above-ground stems were not recorded in this experiment. Growth analysis and estimates of yield were carried out as in Expt 3 on 18, 27 June, 8 and 28 July.

Seed production, treatment, selection and storage were as in Expt 3. The average daily temperature of the glasshouse was 9·9 °C. Sprout measurements were taken on 3 March using ten tubers of each seed size and the experiment planted by hand on 21 March.

Two experiments were carried out at Deepdale Farms Limited, Brancaster, Norfolk on light, sandy soils of the Wick Series. Rows were 76 cm apart and tubers spaced 20 cm apart. Both sites were stone-separated prior to planting.

Experiment 5, 1979–80

Nine varieties, Home Guard, Arran Comet, Maris Bard (earlies), Red Craigs Royal, Wilja, Estima (second earlies), Maris Piper, Pentland Squire and Désirée (maincrop) were compared in three randomized blocks. Seed of 40–55 g was used for all replicates. Plots were four rows wide and 5 m long. Plant and stem emergence were recorded every 3–4 days using one whole row per plot. Yields were estimated from 14 plants per plot on 24 June, 8 and 22 July.

All seed was once-grown in mid or west Wales and selected in late December when all seed had broken dormancy. The first three varieties were stored at 6 °C, the next three at 8 °C and the three maincrop varieties at 12 °C. Sprout measurements were made on 30 tubers per variety on 29 February and the seed moved to Norfolk. The experiment was planted by hand on 21 March. A liquid fertilizer dressing of 150 kg N, 86 kg P, 167 kg K and 30 kg Mg/ha was applied at planting. Four applications of 25 mm of water were made by rain-gun on 14, 22 May and 4, 18 June.

Table 2. *Number of day-degrees* > 4 °C *experienced by seed from onset of sprouting* (3 *mm sprout*) *to planting in three varieties*

Variety	Experiment 1	2	3	4	5	6
Home Guard	640	390	890	—	270	—
Arran Comet	630	340	880	760	300	—
Maris Bard (once grown)	—	740	—	—	—	—
Maris Bard (certified)	330	80	—	430	230	530

Experiment 6, 1980–1

Seven varieties, Maris Bard, Ulster Sceptre, Vanessa (earlies), Wilja, Estima (second earlies), Record and Foxton (maincrop) were compared in three randomized blocks. Seed of 70–80, 80–90 and 90–100 g was used for the three replicates; plots were the same size as in Expt 5. Emergence was not recorded and yields were estimated from 14 plants per plot on 8, 22 June and 6 July.

Seed of all varieties was stored at 6 °C until mid-February when the two maincrop varieties were transferred to 12 °C. Sprout measurements were made on ten tubers per seed size of each variety on 3 March and the experiment planted by hand on 5–6 March.

A liquid fertilizer dressing of 145 kg N, 61 kg P and 119 kg K/ha was applied at planting. Three applications of 25 mm of water were made by rain-gun on 7, 22 June and 7 July. In all experiments the control of weeds was satisfactory and the application of fungicides and aphicides ensured that both blight (*Phytophthora infestans*) and virus diseases were controlled.

In all experiments the yields per hectare were obtained by harvesting the area occupied by the stated number of plants irrespective of any missing plants. From growth analysis samples on some occasions, yields are presented per plant and care should be exercised if these values are converted to yield per hectare as the sample area was small and inappropriate for such conversion.

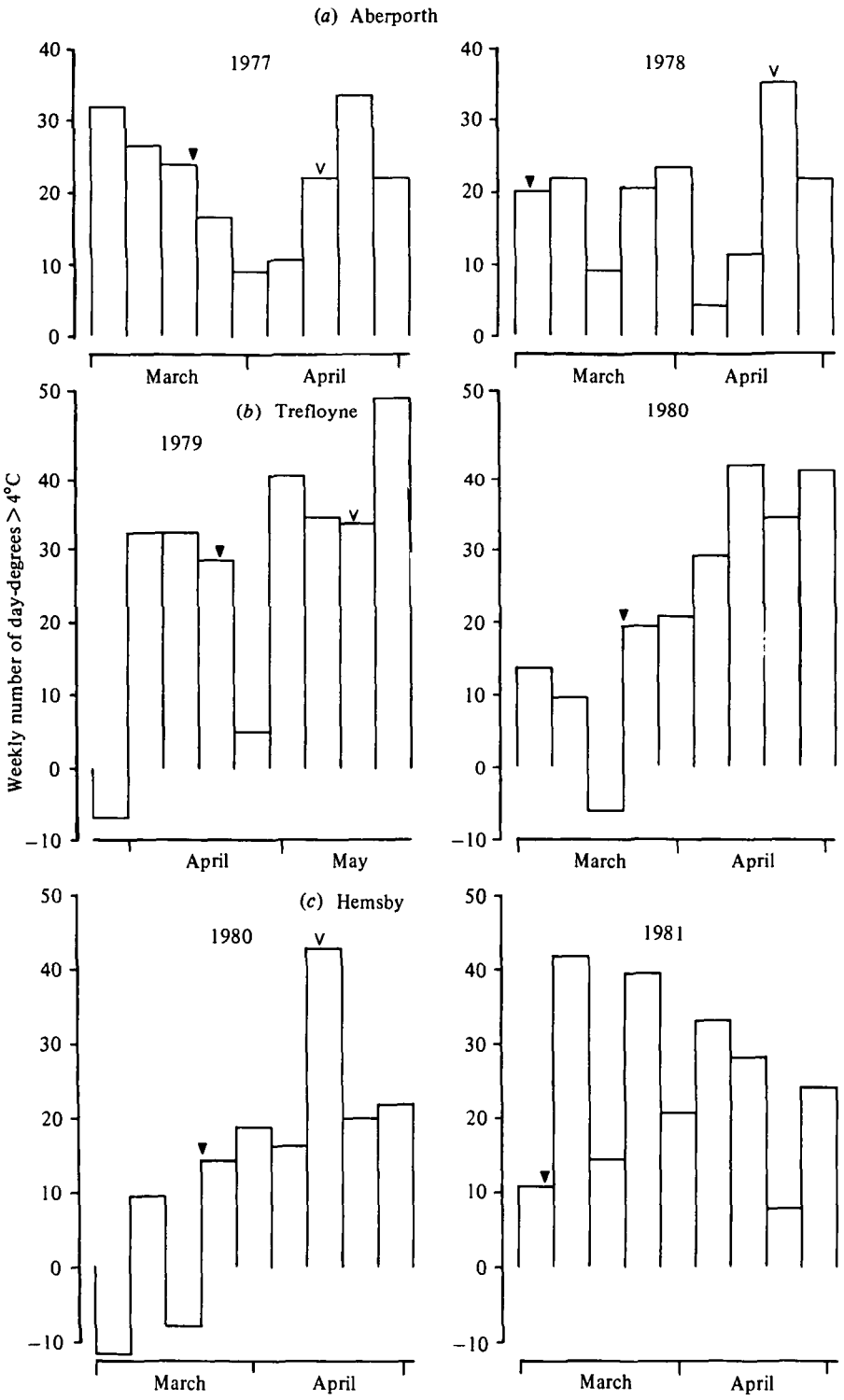

Fig. 1. For description, see opposite.

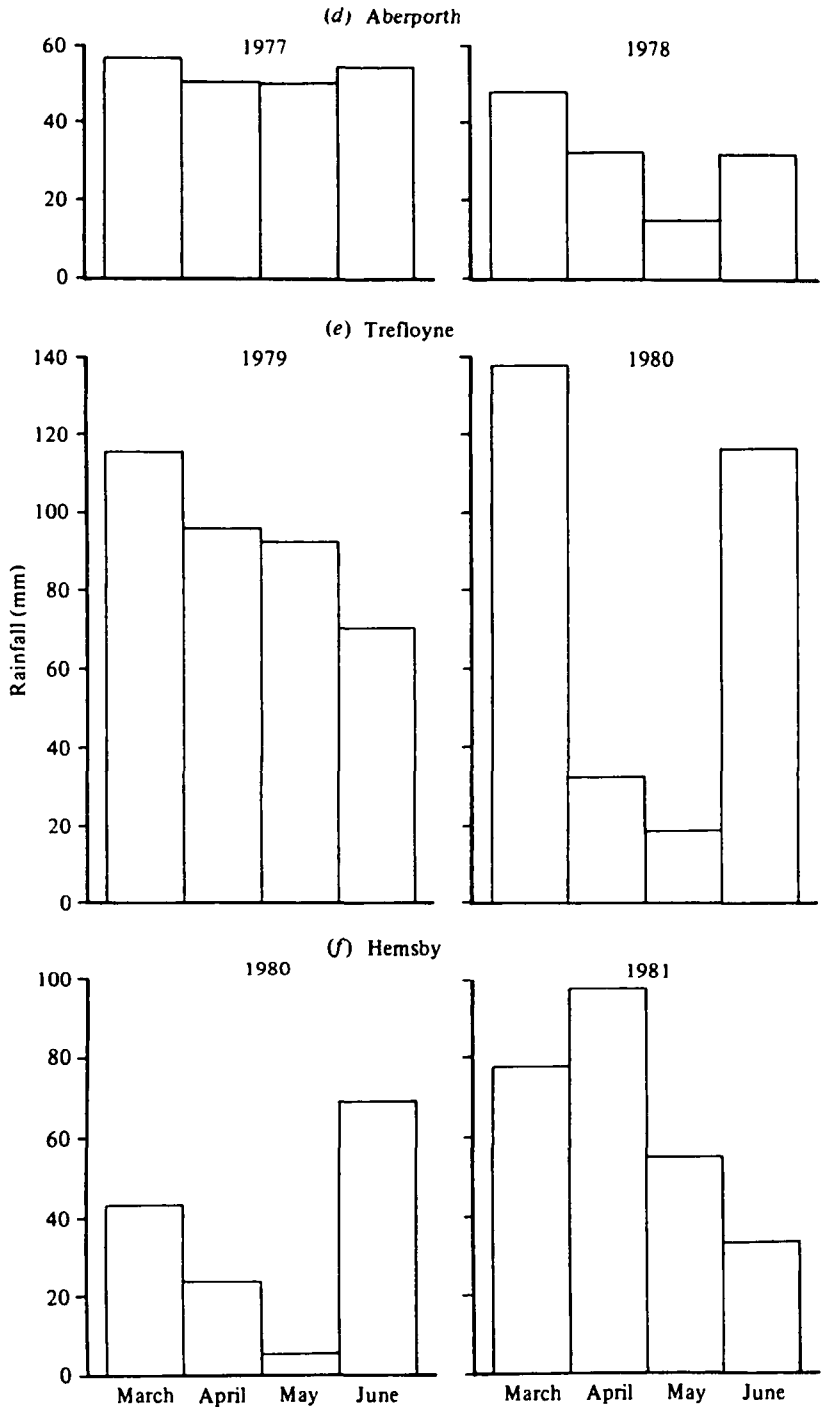

Fig. 1. Weekly number of day-degrees > 4 °C (*a–c*) and total monthly rainfall (*d–f*) in 2 years at Aberporth (north Pembrokeshire), Trefloyne (south Pembrokeshire) and Hemsby (Norfolk), ▼, Time of planting, ∨, time of 50 % plant emergence.

Table 3. *Sprout growth per tuber, number of emerged plants and stems, Expt* 1

	Home Guard	Arran Comet	Maris Bard	Pentland Crown	Stormont Enterprise	S.E.
Length of longest sprout (mm)	50·4	27·8	21·2	15·7	14·9	1·71
Total sprout length (mm)	73·2	61·1	60·1	26·9	38·7	2·45
Number of sprouts > 3 mm	3·0	3·3	4·6	2·8	4·3	0·26
Number of emerged plants ('000s/ha) 22. iv. 77	43·5	41·9	31·1	28·8	22·6	0·62
Number of above-ground stems/plant 30. v. 77	4·9	5·2	5·7	5·3	5·8	0·26
Number of mainstems/plant 30. v. 77	2·0	2·8	5·2	1·9	4·2	0·34

Table 4. *Tuber yields (t/ha) and number of tubers ('000s/ha), Expt* 1

		Home Guard	Arran Comet	Maris Bard	Pentland Crown	Stormont Enterprise	S.E.
Total yield	31. v. 77	8·0	11·6	9·7	5·7	5·5	0·66
Yield > 25 mm	31. v. 77	5·2	8·6	4·8	2·5	2·8	0·54
Total yield	10. vi. 77	12·6	17·9	16·5	11·0	11·6	1·05
Yield > 25 mm	10. vi. 77	10·7	15·9	13·9	9·2	9·2	1·09
Total yield	1. vii. 77	21·5	31·3	29·0	25·3	24·8	1·97
Yield > 25 mm	1. vii. 77	20·1	30·2	26·8	24·3	23·6	1·87
Yield > 38 mm	1. vii. 77	13·2	23·3	17·2	18·0	16·0	1·72
Number of tubers	31. v. 77	1193	1054	2023	994	1153	101·6
	10. vi. 77	890	984	1257	760	959	66·1
	1. vii. 77	780	790	979	696	815	37·1

From the records of temperature in storage and observation of the end of dormancy the numbers of day-degrees experienced by the seed of the varieties in the majority of experiments are shown in Table 2. Where no direct observation of the end of dormancy was made, the timing of this event was obtained from records of the same variety in other experiments.

Only at Trefloyne in 1980 was wilting of plants observed in prolonged dry weather in July. In all other experiments growth was not observed to be affected by water availability. The monthly rainfall figures and weekly number of day-degrees > 4 °C (air) are given in Fig. 1.

RESULTS

Experiment 1 (1977)

The early varieties produced substantially more sprout growth and emerged earlier than the maincrop varieties (Table 3). Final emergence was complete in all varieties and there were no effects of variety on number of above-ground stems. However, Maris Bard and Stormont Enterprise produced predominantly mainstems and had significantly more than other varieties (Table 3). Pentland Crown produced substantially more secondary stems than mainstems.

At the first harvest (31 May) Arran Comet produced the highest total yield and all early varieties significantly outyielded the maincrops (Table 4). Arran Comet had markedly higher saleable yield (> 25 mm) than all other varieties and the other two earlies were higher yielding than the maincrops. At the two subsequent harvests Arran Comet produced the highest total and graded yields although Maris Bard was usually not significantly lower yielding. Maris Bard lost many of its small tubers so that although it had the most tubers throughout harvesting the differences between varieties in number of tubers became smaller and the effects on total yield were also found in graded yields. Nonetheless, Arran Comet produced significantly higher yield in the > 38 mm grade than other varieties as a consequence of having the lowest number of tubers of all varieties which resulted in increased mean

Table 5. *Sprout growth per tuber, number of emerged plants* ('000*s*/*ha*) *and number of stems per plant, Expt* 2

	Home Guard	Arran Comet	Maris Bard (OG)	Maris Bard (CC)	Pentland Crown	Désirée	S.E.
Length of longest sprout (mm)	21·9	17·7	38·4	5·6	11·1	11·7	0·70
Total sprout length (mm)	42·0	40·9	100·9	17·1	25·8	21·1	1·74
Number of sprouts > 3 mm	2·7	3·7	4·1	2·8	3·7	2·4	0·26
Number of emerged plants							
7. iv. 78	46·6	29·5	33·5	5·6	31·4	30·1	2·28
1. v. 78	48·4	48·4	40·1	49·1	47·2	48·8	1·35
Number of above-ground stems/plant							
18. v. 78	4·4	5·9	1·5	5·5	8·1	3·8	0·55
Number of mainstems/plant							
18. v. 78	2·5	2·9	1·4	5·0	2·4	2·0	0·38

Table 6. *Leaf area indices, Expt* 2

Date of sampling	Home Guard	Arran Comet	Maris Bard (OG)	Maris Bard (CC)	Pentland Crown	Désirée	S.E.
4. v. 78	0·56	0·72	0·37	0·18	0·47	0·37	0·047
18. v. 78	1·49	2·43	0·57	1·38	1·63	1·43	0·139
30. v. 78	2·49	4·01	0·80	3·28	3·41	2·79	0·203
7. vi. 78	2·95	4·76	1·43	3·16	3·63	2·96	0·267
16. vi. 78	2·60	4·84	1·44	3·32	3·68	3·50	0·353

Table 7. *Tuber yields* (*t*/*ha*) *and number of tubers* ('000*s*/*ha*), *Expt* 2

	Home Guard	Arran Comet	Maris Bard (CC)	Maris Bard (OG)	Pentland Crown	Désirée	S.E.
Total yield							
30. v. 78	19·2	20·6	16·8	11·6	16·7	17·8	0·93
Yield > 25 mm							
30. v. 78	17·8	19·3	14·1	10·4	14·6	15·9	0·98
Total yield							
7. vi. 78	24·8	30·5	24·7	16·8	25·9	22·4	0·95
Yield > 25 mm							
7. vi. 78	23·8	29·2	22·0	15·6	24·5	21·1	0·95
Total yield							
16. vi. 78	27·3	35·1	32·0	21·4	30·9	28·8	1·53
Yield > 25 mm							
16. vi. 78	26·4	34·1	29·8	20·4	29·9	27·4	1·49
Number of tubers > 25 mm							
30. v. 78	450	592	440	222	451	548	30·4

tuber size. At the second harvest the yields of the maincrop varieties were not significantly lower than Home Guard and at the final harvest the two maincrops exceeded Home Guard although not significantly. Thus, by the end of June the maincrop varieties appeared to have surpassed the yields of the most popular early variety but not those of two less widely-grown varieties.

Experiment 2 (1978)

The growth of the once-grown stock of Maris Bard was quite different from all other varieties. Sprout growth commenced in October and, by planting, the length of the longest sprout was substantially greater than that of all other varieties. Emergence commenced earlier than other varieties

Table 8. *Sprout growth per tuber* (9 *March*), *number of emerged plants and stems* ('000*s*/*ha*), *Expt* 3

	Primura	Juliver	Spunta	Renova	Draga	Home Guard	Arran Comet	Pentland Javelin	F46/11	S.E.
Length of longest sprout (mm)	12·2	10·0	19·9	11·6	5·7	57·4	33·8	12·7	8·9	1·30
Total sprout length (mm)	27·6	24·5	36·8	24·0	14·0	60·8	38·8	25·3	21·4	1·91
Number of sprouts > 3 mm	3·3	3·6	2·8	3·0	2·5	1·3	1·4	3·0	3·2	0·24
No. of emerged plants 18. v. 79	39·8	42·3	25·4	22·9	2·5	14·4	30·1	51·2	45·3	3·66
No. of above-ground stems 21. v. 79	272	172	124	210	124	176	199	189	219	17·7
No. of main stems/plant 21. v. 79	1·7	2·3	1·8	1·3	1·8	2·2	1·1	2·1	3·2	0·80
No. of secondary stems/plant 21. v. 79	2·6	0·9	0·7	2·0	0·5	1·1	2·4	1·2	1·0	0·32
No. of above-ground stems/plant 21. v. 79	4·3	3·2	2·5	3·3	2·3	3·3	3·5	3·3	4·2	0·31

Table 9. *Leaf area indices*, *Expt* 3

Date of sampling	Primura	Juliver	Spunta	Renova	Draga	Home Guard	Arran Comet	Pentland Javelin	F46/11	S.E.
21. vi. 79	4·2	2·8	2·4	2·5	2·9	2·0	3·0	2·7	2·8	0·31
3. vii. 79	4·7	3·9	3·9	3·7	4·0	2·3	4·2	3·8	3·7	0·33
16. vii. 79	4·7	4·1	3·4	4·3	5·2	2·6	3·7	3·3	3·7	0·36
31. vii. 79	0·6	2·3	2·8	3·1	3·1	1·5	1·8	0·4	1·8	0·38
% change peak L to 31. vii. 79	87	44	28	28	40	42	57	89	51	—

but approximately 20% of plants failed to emerge owing to 'little potato disorder'. The emerged plants were smaller than those of other varieties and produced lower leaf area indices (L). The number of tubers was less than in all other varieties and yield was also less than other varieties. The data for this seed stock of Maris Bard were analysed with all other varieties and are presented but further reference to this stock is limited to the implications of 'little potato disorder' in assessing varieties.

At planting, sprout lengths in Home Guard and certified Maris Bard, Arran Comet and Pentland Crown were less than in Expt 1 (Table 5). As in Expt 1, Arran Comet and Home Guard emerged earlier than the maincrop varieties but Maris Bard (CC) emerged later than the maincrop varieties. The growth of the leaf surface was extremely rapid in Arran Comet and it had the highest leaf area indices throughout the experiment (Table 6). Its L value exceeded 4 before the end of May and throughout June was significantly greater than all other varieties (Table 6). Initially, Home Guard had larger leaf area indices than the remaining varieties but by 18 May there were no significant differences between these varieties. During June leaf area indices increased in the maincrops and Maris Bard but decreased in Home Guard and on 16 June Pentland Crown had significantly larger L than Home Guard.

At the first harvest on 30 May, yield was high; the mean yield for the experiment was 17·1 t/ha and Arran Comet produced the highest total yield and yield in the grade > 25 mm and these yields were significantly higher than all varieties except Home Guard (Table 7). Home Guard was not significantly higher yielding in these grades than any other variety but it produced significantly greater yields in the grade > 38 mm than the maincrop varieties. At the second harvest (7 June) Arran Comet produced significantly larger yields in total and in the grade > 32 mm than all other varieties. There were no significant differences in these yields between Home Guard, Maris Bard and Pentland Crown but Désirée produced significantly lower yields than Pentland Crown. Home Guard and Arran Comet did not differ significantly in yield of tubers > 38 mm but both outyielded other varieties. At the final harvest Arran Comet still had the highest total and graded yields but these were not significantly greater than Pentland Crown and Maris Bard. Home Guard and Désirée produced similar yields which were not significantly different from Pentland Crown and Maris Bard (Table 7). Yield at the final harvest was high in relation to the length of the growing season. Although tuber initiation was not recorded accurately it is unlikely to have occurred before mid-April in any variety and therefore a total bulking period of no more than 8 weeks produced an average rate of 4·5 t/ha/week. Rate of bulking may have been related to the size of the leaf surface since the two varieties with the smallest leaf areas (Home Guard and Désirée) had the lowest rates of bulking.

As in Expt 1, Arran Comet produced the highest yields throughout the period of harvesting. In contrast, Maris Bard (CC) approached the yield of Arran Comet only at the final harvest and was not significantly different from the maincrops.

Experiment 3 (1979)

There were large differences between varieties in all aspects of sprout growth (Table 8). Arran Comet and Home Guard produced only one or two sprouts of greater length than other varieties. There were few differences between the remaining varieties except that Draga had very short sprouts. Emergence did not seem to be determined by sprout length at planting as Pentland Javelin and F46/11 were the first varieties to complete emergence and Home Guard was especially slow. This delay in emergence in Home Guard (and Arran Comet) was associated with coiled sprouts and in Home Guard some plants failed to emerge owing to 'little potato disorder'.

There were considerable differences between the varieties in number of above-ground stems and in the composition of this population (Table 8). Primura and F46/11 produced the most above-ground stems but in the former most were secondary stems and in the latter, main stems. Only Home Guard failed to produce a leaf area index of 3 (Table 9) and the largest peak L values were produced by Primura (early) and Draga (maincrop). These peak values occurred at different times. Primura produced its leaf surface very rapidly and its L exceeded 4 in mid-June; Draga was much later in producing its leaf area and reached its peak in July. All varieties decreased in leaf area in the later part of July as a consequence of increasing moisture stress in a prolonged period of dry, sunny weather. Primura and Pentland Javelin were close to complete senescence by the end of July while Spunta and Renova lost relatively little leaf area at this time.

At the first and second harvests, Primura and the four British earlies produced the highest total yields and most were significantly higher than the other Dutch varieties (Table 10). At the third harvest, Primura was the highest-yielding variety and significantly better than all varieties except F46/11, Pentland Javelin and Renova. Between the third and fourth harvests four varieties bulked little (Juliver, F46/11, Arran Comet and Pentland Javelin) and at the final harvest Primura was still

Table 10. *Tuber yields (t/ha), Expt* 3

	Date of sampling	Primura	Juliver	Spunta	Renova	Draga	Home Guard	Arran Comet	Pentland Javelin	F46/11	S.E.
Total yield	21. vi. 79	10·2	7·2	7·1	7·8	2·2	11·5	10·3	13·9	10·9	1·02
Yield > 25 mm	21. vi. 79	7·7	5·7	5·0	5·7	1·1	10·6	9·8	12·8	9·9	1·15
Total yield	3. vii. 79	31·7	23·1	25·4	22·3	14·6	26·5	28·8	31·7	28·6	1·72
Yield > 32 mm	3. vii. 79	28·9	21·4	22·1	20·3	12·5	24·9	27·8	29·9	27·0	1·75
Total yield	16. vii. 79	45·2	35·0	37·6	42·6	31·4	35·4	36·9	41·0	41·2	1·87
Yield > 32 mm	16. vii. 79	43·7	33·9	35·5	41·4	30·5	33·5	36·4	40·1	40·3	1·93
Total yield	31. vii. 79	49·8	35·5	45·4	48·0	41·1	40·2	39·7	40·8	41·0	2·02
Yield > 38 mm	31. vii. 79	44·3	32·4	39·1	43·8	39·0	36·0	37·1	36·0	37·8	1·97

Table 11. *Sprout growth per tuber* (3. iii. 80) *Expt* 4

	Primura	Juliver	Spunta	Aminca	Renova	Draga	Maris Bard	Arran Comet	Pentland Javelin	F46/11	Wilja	S.E.
Length of longest sprout (mm)	7·9	4·8	16·0	16·9	10·2	2·7	15·1	18·3	10·3	11·5	10·7	0·92
Total sprout length (mm)	19·3	15·9	30·8	25·6	16·4	6·3	23·6	27·1	19·6	28·1	21·6	1·38
No. of sprouts > 3 mm	3·2	3·0	2·7	2·1	1·9	0·9	2·3	1·7	2·7	3·7	2·6	0·22

Table 12. *Tuber yields (t/ha) and number of tubers ('000s/ha), Expt 4*

	Primura	Juliver	Spunta	Aminca	Renova	Draga	Maris Bard	Arran Comet	Pentland Javelin	F46/11	Wilja	S.E.
Total yield 18. vi. 80	20·7	19·8	23·9	26·3	24·3	9·6	24·9	23·0	25·0	28·4	21·1	1·27
Yield > 25 mm 18. vi. 80	19·9	19·2	22·6	25·3	23·3	8·3	24·0	22·3	24·2	27·3	20·8	1·23
Total yield 27. vi. 80	27·5	25·4	31·1	31·4	31·6	15·3	31·0	29·0	29·6	36·6	30·4	1·52
Yield > 32 mm 27. vi. 80	26·2	24·6	29·1	29·7	30·2	13·7	30·0	27·4	28·2	35·2	28·2	1·56
Total yield 8. vii. 80	35·1	35·0	38·7	42·0	43·9	29·3	43·5	35·6	37·3	47·1	38·5	2·31
Yield > 32 mm 8. vii. 80	33·9	34·3	36·8	40·6	42·7	28·4	42·4	34·2	35·8	45·8	37·0	2·24
Total yield 28. vii. 80	40·3	44·4	45·7	49·8	58·1	47·2	59·7	41·8	43·3	59·9	46·7	2·59
Yield > 32 mm 28. vii. 80	39·3	43·6	43·8	48·6	57·0	46·7	58·7	40·5	41·9	59·2	45·3	2·57
Number of tubers 18. vi. 80	655	558	710	739	676	510	568	478	720	781	628	55·0

Table 13. *Sprout growth per tuber on 29 February 1980 and number of emerged plants ('000s/ha), Expt 5*

	Arran Comet	Home Guard	Maris Bard	Red Craigs Royal	Wilja	Estima	Maris Piper	Pentland Squire	Désirée	S.E.
Length of longest sprout (mm)	10·1	15·8	6·8	7·2	5·3	4·7	8·3	10·1	12·2	0·22
Total sprout length (mm)	30·3	33·1	23·1	20·2	14·4	14·0	22·5	24·4	19·6	1·07
No. of sprouts > 3 mm	4·2	3·0	4·5	3·6	2·9	3·0	3·6	3·7	2·3	0·22
Number of emerged plants 21. iv. 80	62·3	59·2	54·8	3·5	16·7	26·8	57·8	51·3	54·0	4·82
Number of emerged plants 24. iv. 80	64·5	63·6	63·6	12·3	43·4	39·5	62·3	55·7	62·3	4·34

Table 14. *Tuber yields (t/ha) and number of tubers ('000s/ha), Expt 5*

	Arran Comet	Home Guard	Maris Bard	Red Craigs Royal	Wilja	Estima	Maris Piper	Pentland Squire	Désirée	S.E.
Total yield										
24. vi. 80	18·7	11·1	20·3	17·8	18·1	21·6	20·0	18·1	15·9	0·83
Yield > 32 mm										
24. vi. 80	13·6	7·4	15·3	12·1	14·5	18·3	15·2	16·3	12·2	0·73
Total yield										
8. vii. 80	25·6	15·7	31·4	23·3	27·2	36·1	32·1	27·7	26·4	1·22
Yield > 32 mm										
8. vii. 80	20·8	13·0	28·2	21·3	24·8	33·9	29·1	25·8	24·5	1·33
Total yield										
22. vii. 80	29·2	20·9	39·6	32·6	35·9	47·6	41·2	37·4	32·8	1·42
Yield > 32 mm										
22. vii. 80	24·9	18·0	36·3	30·8	33·9	46·3	38·7	36·1	31·3	1·46
Number of tubers										
24. vi. 80	856	632	817	617	339	624	896	501	537	30·1

Table 15. *Tuber yields (t/ha) and number of tubers ('000s/ha), Expt 6*

	Date of sampling	Estima	Wilja	Maris Bard	Vanessa	Ulster Sceptre	Foxton	Record	S.E.
Total yield	8. vi. 81	16·5	12·8	14·9	12·7	11·3	8·6	6·7	0·66
Yield > 32 mm	8. vi. 81	13·6	4·5	8·9	9·6	6·5	0·1	2·8	0·65
Total yield	22. vi. 81	22·3	18·3	18·0	21·5	13·9	16·7	13·6	1·45
Yield > 32 mm	22. vi. 81	20·7	15·0	14·8	20·4	11·3	10·1	12·2	1·55
Total yield	6. vii. 81	29·3	21·3	21·2	21·0	15·3	18·9	17·9	1·94
Yield > 32 mm	6. vii. 81	27·9	17·4	17·8	19·5	12·2	11·9	16·4	2·08
Number of tubers	22. vi. 81	548	625	669	435	529	919	500	52·4

Table 16. *Coefficient of variation* (C.V.) *for total and saleable graded yields Expts* 1–6

Experiment ...	1 Date of sampling	C.V. (%)	2 Date of sampling	C.V. (%)	3 Date of sampling	C.V. (%)	4 Date of sampling	C.V. (%)	5 Date of sampling	C.V. (%)	6 Date of sampling	C.V. (%)
Total yield	31. v. 77	15·7	30. v. 78	10·7	21. vi. 79	19·7	18. vi. 80	9·7	24. vi. 80	5·7	8. vi. 81	9·6
	10. vi. 77	14·4	7. vi. 78	7·8	3. vii. 79	11·4	27. vi. 80	9·1	8. vii. 80	8·4	22. vi. 81	14·1
	1. vii. 77	14·6	16. vi. 78	10·2	16. vii. 79	8·3	8. vii. 80	10·3	22. vii. 80	7·0	6. vii. 81	16·2
					31. vii. 79	8·1	28. vii. 80	9·2				
Saleable graded yield	31. v. 77	21·7	30. v. 78	12·5	21. vi. 79	26·3	18. vi. 80	10·1	24. vi. 80	9·1	8. vi. 81	17·2
	10. vi. 77	17·8	7. vi. 78	8·4	2. vii. 79	12·5	27. vi. 80	9·5	8. vii. 80	12·9	22. vi. 81	18·0
	1. vii. 77	14·8	16. vi. 78	10·3	16. vii. 79	8·8	8. vii. 80	10·0	22. vii. 80	7·6	6. vii. 81	20·4

the highest-yielding variety although not significantly higher than Renova and Spunta.

Primura had more tubers than most varieties and the ranking order of varieties for graded yields was not the same as for total yields. The four British earlies produced similar yields in the grade > 32 mm at the first harvest and all significantly out-yielded other varieties (Table 10). Although Draga was significantly lower yielding than other varieties at the second and third harvests there were few other significant differences between varieties. At the final harvest Primura produced the highest graded yields and, as in total yields, Renova and Spunta were not significantly different.

In this experiment the variety with the highest total yield again remained constant throughout (Primura) although the ranking of varieties for saleable yields was more variable than in Expts 1 and 2. Arran Comet produced high early yields, but was not outstanding and no higher yielding than Home Guard throughout the rest of the season. Its yield relative to most other varieties decreased with delay in harvesting and was modest by final harvest.

Experiment 4 (1980)

Table 11 shows that sprouts were shorter than in Expt 3 but the relative values of varieties common to both experiments were unchanged. Arran Comet had much shorter sprouts than in Expt 3. F46/11 produced the highest total yield at all harvests and was significantly higher yielding than most varieties (Table 12). The ranking order of varieties for yield did not change much during the season; Renova, Aminca, and Maris Bard were the closest to F46/11 throughout and at the final harvest differences between F46/11, Renova and Maris Bard were small. Arran Comet produced significantly lower yields than F46/11 at the first harvest and its yields decreased relative to other varieties during the season. Draga had very low yields throughout.

Experiment 5 (1980)

The reduced storage temperatures for the early varieties reduced their sprout lengths compared with previous experiments and only Home Guard produced substantially longer sprouts than the maincrop varieties (Table 13). The maincrop varieties emerged as early as the earlies and several days in advance of Wilja and Estima. The emergence of Red Craigs Royal was severely delayed by coiled sprouts. Final emergence was complete in all varieties. Despite its slightly later emergence Estima produced the highest yields throughout the season and differences were significant for all comparisons at the second and third harvests. Maris Piper (maincrop) and Maris Bard (early) produced similar yields

throughout, ranked second to Estima and were significantly higher yielding than all other varieties (Table 14). The other maincrops were significantly higher yielding than Home Guard throughout. The relative yield of Home Guard and Arran Comet decreased as harvesting was delayed and Home Guard was the lowest-yielding variety throughout the season.

Experiment 6 (1981)

As in Expt 5 Estima produced the highest total and saleable yields at all dates of harvesting (Table 15). Differences between other early varieties were small although Maris Bard was again the second highest yielding at the first harvest. The two maincrop varieties were very low yielding initially but at the final harvest not significantly lower yielding than any variety except Estima.

DISCUSSION

The experiments covered five seasons with a wide range of yields and may be taken as a small but representative sample of the environments in which crops are grown for harvesting before the end of July. The coefficients of variation (Table 16) were of similar size as those reported in many other experiments and only large differences achieve the usual levels of significance. In spite of this it is possible to detect some remarkable variations in differences between specific varieties at the different sites and at the different times of harvesting within a site. Of the varieties present in most experiments Arran Comet ranged from clearly the highest yielding (Expts 1 and 2) through the moderate (Expts 3 and 4) to the low yielding (Expt 5). Its yields in Expts 3–5 decreased relative to the other varieties as harvesting was delayed. There were, however, some consistent features in the data. In all experiments, the variety with the highest initial yield maintained its position throughout although the magnitude of the advantage usually decreased with delay in harvesting. In Expts 4 and 5 the final harvest was in late July and at this time the highest-yielding varieties had large leaf surfaces and high bulking rates so it seems unlikely that they would lose their advantage much before the end of the growing season. The results suggest that, in general, high early yields are not prejudicial to high yields later in the season. The impression that high early yields are prejudicial to later yields is the consequence of experiments using early varieties such as Home Guard in which old seed is planted and its inadequate leaf cover reduces bulking rates and yields later in the season.

When assessing the differences in effects of treatments such as varieties shown by individual experiments there is usually confounding of the physical characteristics of the site, seasonal weather and various aspects of source and management of the seed. Nonetheless, consideration of the three early varieties, Arran Comet, Home Guard and Maris Bard, which were in most experiments, provides some evidence of how these factors interact. At Trefin, Arran Comet produced a growth pattern which was almost ideal for producing high, early tuber yields. This was the 'earliest' environment and although planting was early, emergence occurred quickly as a consequence of long sprouts and sufficiently high soil temperatures. The advantages of using old seed for rapid emergence were not eroded by any subsequent disadvantages in size or longevity of the leaf surface. This growth pattern would ensure the superiority of yields of Arran Comet for the whole of the harvesting period. In contrast, at Trefloyne and Brancaster in subsequent years Arran Comet produced more modest yields. At Trefloyne the seed was physiologically older mainly as a consequence of later planting and emergence was delayed as a consequence of coiled sprouts and Arran Comet was lower yielding than several varieties throughout harvesting. At Brancaster quite young seed was similarly affected by coiled sprouts and emergence was also delayed and yields poor. Temperatures after planting were sometimes lower at these sites than at Trefin (Fig. 1) and soil conditions rather cloddier on the heavier soils at Trefloyne. Of greater significance for Norfolk in 1981 was the period of low temperature (mean soil temperature at 10 cm, 3·1 °C for 2 days) shortly after planting and the period of cold, frosty weather in late April (mean soil temperature at 10 cm, 4·3 °C for 5 days) just as emergence was beginning. The available temperature data are not extensive but suggest that small differences in mean soil temperature (1 or 2 °C) may markedly affect emergence and subsequent growth of some potato varieties. In such conditions, the potential advantages of increased physiological age can be negated by delay in emergence. Arran Comet always produced a complete plant stand and a full leaf cover but away from Trefin so did several other varieties which emerged more or as quickly. Jones (1981) showed that the rate of post-planting sprout elongation decreased above a certain sprout length in some varieties and in adverse circumstances (low temperature and poor soil conditions) this was associated with coiling of stems and 'little potato disorder'. The Brancaster experiment shows that in Arran Comet coiling of very short sprouts can occur. Similar, more dramatic, effects were found in Home Guard. Only at Trefin did this variety yield nearly as much as the highest-yielding early and at this site the old seed emerged quickly and completely and produced a full leaf cover. However, the leaf area began to decrease in June and the

yield of Home Guard decreased relative to the other varieties as harvesting was delayed. As in Arran Comet, the old seed of Home Guard at Trefloyne did not emerge quickly but additionally failed to produce a complete plant stand. Consequently, leaf area indices were lower than on other varieties and yields were initially high but decreased relative to other varieties as harvesting was delayed. These effects were even more marked at Brancaster where, despite using younger seed, emergence was delayed, leaf area indices were low and yields were the lowest at the first harvest and remained so throughout the season.

The results for Maris Bard illustrate the effects of age directly. The home-produced seed in Expt 2 was too old and produced incomplete emergence of small plants whilst the certified stock was physiologically much younger and produced higher yields though not significantly greater than some maincrop varieties. In the previous year the Maris Bard seed was older than in Expt 2 and emerged quickly and produced yields almost as high as Arran Comet. At Trefloyne (Expt 4) and Brancaster seed of greater age than that planted in Expt 1 emerged quickly and produced high yields throughout as a complete leaf cover was achieved.

It seems clear that the maximum benefit of increasing age of seed in some early varieties can be obtained only in environments in which rapid and complete emergence occurs and a large leaf surface is produced. Thus, only environments such as Trefin with mild temperatures and light soils are likely to grow old seed of Arran Comet and particularly Home Guard successfully in most or all seasons. At harsher sites the advanced age of seed is likely to be disadvantageous because coiled sprouts and/or 'little potato disorder' will delay emergence and reduce leaf cover and thereby reduce tuber bulking. As these varieties have only a short dormant period considerable ageing of seed will usually occur by planting. In early varieties with longer dormancies there will be considerable variation in age (i.e. sprout length) by planting as a consequence of variation in temperatures and early yields will usually increase with age as in Maris Bard in these experiments and others at Trefloyne (O'Brien *et al.* 1983). The temperatures during January and February are crucial to the age of such varieties for if they are low (< 5 °C) little or no ageing will occur and seed will emerge slowly. Such effects will also occur in maincrops which do not usually have much sprout growth at planting but which can clearly emerge and yield as well as earlies at some sites. Increasing the age of seed of such varieties by increasing storage temperature as in Expts 2 and 5 can improve their early yields considerably. However, this is still inadequate for some varieties such as Record and Foxton which both produced poor, early yields in Expt 6.

The inference from this interpretation of the results is that the yield estimates of varieties from experiments can be markedly affected by the age of seed planted and the environmental conditions after planting. These effects are, however, more explicable than hitherto accepted. The consequences of this analysis for the testing of varieties are that there is little justification for attempting an overall score for earliness and the present maturity classification is not necessarily a good guide to the usefulness of varieties for specific environments and management practices.

For breeders, the results suggest that there is little justification in breeding for earliness through varieties which achieve advanced physiological age by the time of planting since such seed may be suitable in only a minority of sites used for the early crop. The greatest opportunity exists for varieties which have reasonably long dormant periods (and consequently do not achieve advanced age before planting) but emerge and expand their leaf surface more rapidly in the prevailing temperatures than existing varieties. In this respect the objectives of early and maincrop breeding are not really different as illustrated by the success of F46/11 (maincrop × maincrop) in these experiments. The major limitation to the use of maincrop varieties very early in the season is often their propensity to produce larger numbers of tubers but the character can be altered through selection. Considering all varieties, sprout length at planting was not closely related to emergence, as found by Jones (1981), so there may be some prospect of producing varieties which achieve reasonably advanced age with short sprouts and still emerge rapidly. Such varieties would be suited to mechanical planting and allow commercial exploitation of the advantages of ageing.

The authors thank the collaborating farmers, Mr I. Davies, Park Court, Trefin, Dyfed and Greens of Soham, Soham, Cambs for the provision of sites and help in carrying out the experiments and Miss J. Amies for help in preparing the manuscript. The seed of the Dutch varieties was supplied by Beeson & Wiskar Ltd. The first two experiments were part of a research programme funded by the Potato Marketing Board.

REFERENCES

ALLEN, E. J. (1977). Effects of date of planting on growth and yield of contrasting potato varieties in Pembrokeshire. *Journal of Agricultural Science, Cambridge* **89**, 711–735.

GUNASENA, H. P. M. & HARRIS, P. M. (1971). The effect of CCC, nitrogen and potassium on the growth and yield of two varieties of potatoes. *Journal of Agricultural Science, Cambridge* **76**, 33–52.

JONES, J. L. (1981). Effect of date of planting on contrasting potato varieties. Ph.D. thesis, University College of Wales, Aberystwyth.

O'BRIEN, P. J. & ALLEN, E. J. (1981). The concept and measurement of physiological age. *Proceedings of the 8th Triennial Conference of the European Association for Potato Research, Munich*, pp. 64–66.

O'BRIEN, P. J., ALLEN, E. J., BEAN, J. N., GRIFFITH, R. L., JONES, SUSAN A. & JONES, J. L. (1983). Accumulated day-degrees as a measure of physiological age and the relationships with growth and yield in early potato varieties. *Journal of Agricultural Science, Cambridge* **101**, 113–131.

RUDEFORTH, C. C. & BRADLEY, R. U. (1972). Soils, land classification and land use in West and Central Wales. *Special Soil Survey No.* 6. Soil Survey, Rothamsted.

SOIL SURVEY RECORD No. 24 (1974). 1. Soils in Dyfed II (Pembroke/Haverfordwest).