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Effects of site of seed production on seed yields and regrowth of progeny tubers in potatoes

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SUMMARY

Nine experiments are reported in which effects of site of seed production on dormancy, sprout and field growth of progeny tubers were recorded. The experiments used early varieties, Home Guard (four experiments), Red Craigs Royal (three experiments) and Arran Comet (two experiments) and in each, seed crops were grown with similar husbandry at sites differing in altitude and location in western England and Wales. There was no consistent effect of site of seed production on the timing of the end of dormancy, and the maximum effect in any year was $11 \pm 1{\cdot}2$ (S.E.) days. The small effects of site on dormancy influenced initial sprout lengths, and this effect usually persisted up to planting in Home Guard and Red Craigs Royal, although the effects were small in magnitude. There was no effect of site of seed production on sprout lengths at planting or on field growth and yields in Arran Comet. In the other two varieties there was no effect of site of seed production on yield at early harvests, but at later harvests seed from cooler upland sites sometimes significantly outyielded lowland seed. There was, therefore, no evidence to support the view that locally produced seed was advantageous for early potato production. The results, together with those of the concurrent series with maincrop varieties reported by Wurr (1979), show that on half the occasions on which yields were measured covering the whole of the harvesting period, site of seed production had no effect on yields. In these experiments with early varieties effects of site occurred only at harvests later than the commercial harvesting of such old seed. It is therefore suggested that site of seed production is a much less important determinant of tuber yield than hitherto suggested, and of little practical significance.

INTRODUCTION

The importance of healthy seed, free from virus and latent tuber diseases, for production of high-yielding ware potato crops is widely appreciated. In all parts of the world seed potato industries have developed which attempt to satisfy increasingly stringent health standards. It is frequently stated (Thomas & Eyre, 1950; Toosey, 1964*a*, *b*; Goodwin *et al.* 1969*a*, *b*) that the methods of production of seed influence its subsequent regrowth. Such suggestions imply that the physiological quality of seed tubers is also important, and there are many unconnected reports in the literature which ascribe effects to most factors in seed potato husbandry on some feature of seed tuber regrowth. Among the factors reported to affect regrowth of progeny tubers are time of planting, defoliation and harvesting of seed crops (Murphy *et al.* 1967; Goodwin *et al.* 1969*a*, *b*; Chase, 1974), site of seed production (Broadbent, Brown & Wright, 1961; Kozlowska, 1963; Cox, 1972), rate of nitrogen applied in seed crops (Thow, 1970) and temperature of seed storage after harvesting (Scott & Younger, 1973; Wurr, 1978*a*, *b*). Most reports of effects of site of seed production on progeny performance compared seed grown locally in the ware area with seed from cooler, seed-producing areas and found occasionally large, but frequently small, inconsistent effects on progeny tuber yield (Kawakami, 1952; Madec & Perennec, 1956; Broadbent *et al.* 1961; Goodwin *et al.* 1969*a*, *b*; Ronsen, 1971; Cox, 1972). Almost all of these comparisons confounded the effects of site of seed production with one or more husbandry practices at the sites and/or storage temperature of the seed after harvesting. In several reports the extent of virus infection of seed tubers from different

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Table 1. *Details of sites of seed production*

Site of seed production	Altitude (m)	Soil association	Soil derivation	Mean daily soil temperature (° C) at 10 cm depth from time of tuber initiation to final harvest		
				1974	1975	1976
Abbey Cwm-Hir (Powys)	380–390	Manod	Slaty mudstone and sandstone drift	12·8	16·5	16·0
Rhayader (Powys)	213–244	Denbigh 1	Slaty mudstone and sandstone drift	14·5	18·0	17·9
Tenby (Dyfed)	15–30	Milford	Devonian sandstone	16·0	19·4	19·3
Gower (West Glamorgan)	50–75	East Keswick 1	Devonian sandstone	—	18·5	—
Rosewarne (Cornwall)	30–40	Camborne–Rosewarne	Blue sandy slate	—	19·0	—
Wellesbourne (Warwickshire)	46	Wick	Brown earths	—	21·2	—

Table 2. *Dates of planting of seed crops of three varieties from* 1972 *to* 1976

Seed year	Variety	Experiment	Site of seed production: Abbey Cwm-Hir	Rhayader	Tenby	Gower	Rosewarne	Wellesbourne
1972	Home Guard	1	—	1. v	30. iv	—	—	—
1973	Home Guard	2	—	19. iv	18. iv	—	—	—
	Red Craigs Royal	5	—	19. iv	18. iv	—	—	—
1974	Home Guard	3	9. iv	9. iv	8. iv	—	—	—
	Red Craigs Royal	6	9. iv	9. iv	8. iv	—	—	—
1975	Home Guard	4	7. v	7. v	1. v	5. v	6. v	7. v
	Red Craigs Royal	7	7. v	7. v	1. v	—	—	—
	Arran Comet	8	7. v	7. v	1. v	—	—	—
1976	Arran Comet	9	15. iv	15. iv	14. iv	—	—	—

sites was unknown. Consequently the effects of site *per se* on progeny performance have not been established. Furthermore, there are few reports in the literature which are comprehensive in following the growth of the seed crop, seed tuber regrowth and, finally, growth of the progeny crops. Surprisingly, the literature contains few reports of effects of any factor in seed crop husbandry on seed yield. Therefore, both an understanding and the commercial implications of the effects of factors in seed production remain largely unknown. The most comprehensive experiments so far reported for effects of site are those of Wurr (1979), which suggested that final progeny tuber yield in some maincrop varieties was negatively related to mean daily soil temperature at the sites of seed production, and effects could be attributed to the physiological age of the seed at replanting. In other varieties there was no effect, and in some varieties and seasons the warmer sites did not produce consistent effects. Site of seed production did not appear as consistent or large an effect as might be expected. The absence of effects found by Wurr (1979) in some varieties contrasts with the views of many growers, who frequently favour seed from certain areas. As major seed-producing areas are widely separated geographically and there is production of seed in ware areas it is of considerable importance to establish the significance of site of seed production and the constituent husbandry practices.

This paper reports the results of experiments which studied the effects of factors in seed production on seed yields, sprout and field growth of progeny tubers. The large body of data has already been partly presented in thesis form (O'Brien, 1981).

THE EXPERIMENTS

Seed production

From 1972 to 1976 certified Scottish seed was multiplied at various sites differing in altitude, soil

Table 3. *Details of ware experiments*

Experiment	Ware year	Variety	Site of seed production	Date of defoliation of the seed crop	Storage temperature (°C)	Seed weight (size)	Plot size
1	1973	Home Guard	Rhayader; Tenby	10. vii; 25. vii; 8. viii; 22. viii	8; 13 8; 13	38–44 mm	11 rows wide, 3·05 m long
2	1974	Home Guard	Rhayader; Tenby	4. vii; 18. vii; 1. viii; 15. viii; 29. viii	8; 13	40 ± 5 g 50 ± 5 g 62·5 ± 7·5 g	11 rows wide, 3·74 m long
3	1975	Home Guard	Abbey Cwm-Hir; Rhayader; Tenby	4. vii; 26. vii; 15. viii	8; 13	40 ± 5 g 50 ± 5 g 62·5 ± 7·5 g	7 rows wide, 3·74 m long
4	1976	Home Guard	Abbey Cwm-Hir; Rhayader; Tenby; Gower; Rosewarne; Wellesbourne	25. vii	4; 8; 12	40 ± 5 g 50 ± 5 g 62·5 ± 7·5 g	7 rows wide, 3·3 m long
5	1974	Red Craigs Royal	Rhayader; Tenby	4. vii; 18. vii; 1. viii; 15. viii; 29. viii	8; 13	40 ± 5 g 50 ± 5 g 62·5 g ± 5 g	11 rows wide, 3·74 m long
6	1975	Red Craigs Royal	Abbey Cwm-Hir; Rhayader; Tenby	4. vii; 26. vii; 15. viii	8; 13	40 ± 5 g 50 ± 5 g 60 ± 5 g	7 rows wide, 3·74 m long
7	1976	Red Craigs Royal	Abbey Cwm-Hir; Rhayader; Tenby; Wellesbourne	25. vii	4; 8; 12	40 ± 5 g 50 ± 5 g 60 ± 5 g	5 rows wide, 2·2 m long
8	1976	Arran Comet	Abbey Cwm-Hir; Rhayader; Tenby	25. vii; 12. viii	4; 8; 12	55 ± 5 g 67·5 ± 7·5 g 87·5 ± 12·5 g	7 rows wide, 3·52 m long
9	1977	Arran Comet	Abbey Cwm-Hir; Rhayader; Tenby	5. vii; 5. viii	4; 8; 12	55 ± 5 g 67·5 ± 7·5 g 87·5 ± 12·5 g	7 rows wide, 3·3 m long

type and climate (Table 1). Details of varieties used and dates of planting and harvesting of seed crops at all sites in each season are shown in Tables 2 and 3. Seed for multiplication at the sites was selected and weighed in February in each season and stored in trays in a glasshouse (mean daily temperature 9–10 °C) until planting. Seed weighing 80 ± 15 g was used in all experiments. In any year, similar fertilizer dressings were applied to all seed crops at all sites. In 1972 the experimental areas received 133 kg N, 57 kg P and 140 kg K/ha and in 1973, 1974 and 1976 152 kg N, 65 kg P and 160 kg K/ha were applied. In 1975 all sites received 152 kg N, 90 kg P and 170 kg K/ha. In addition, in 1974 and 1975 the Rhayader site received applications of approximately 20 t/ha of farmyard manure. Within-row spacing at all sites was 15 cm in 1972 and 20 cm in all succeeding years. Between-row spacing was 66 cm from 1972 to 1975 and 71 cm in 1976 at Tenby and 76 cm at all other sites in all years. Thus the seed rate used at Tenby was between 7 and 13% higher than at other sites as a consequence of differences in row width. The seed rates used at all sites were high (ranging from 5·3 to 6·1 t/ha) and within the optimum range for yields of seed-size tubers (32 to 57 mm) in Home Guard (Bean, 1981). Frequent applications of an aphicide–fungicide mixture ensured freedom of all crops from virus diseases and, except in Expt 1 (1972), potato blight infection. In 1974, 1975 and 1976 the mean daily soil temperature 10 cm below the top of the ridge was measured at all sites using the sucrose-inversion technique of Jones (1972), and at some sites using a continuous (Grant's) recorder. Tuber initiation was recorded by frequent sampling of plants from discard rows. In all except two experiments in which a single defoliation and harvest was used (Table 3), seed crops were defoliated at intervals and tubers harvested (i.e. dug up) 1 week after each defoliation. In all experiments, at each defoliation five guarded rows 5 m in length were defoliated at all sites and a 2·5 m length of three randomly selected rows in the defoliated area was dug separately for subsequent recording of number and yield of tubers. Ungraded tubers were bulked over replicates for all seed treatments and tubers subsequently selected at random from the required weight classes for the ware experiments.

Immediately after harvest all tubers were stored in trays in an open barn (mean daily temperature 11–13 °C) at Aberystwyth. Tubers of the required weight for the ware phase of the experiment were dusted with thiabendazole (1% a.i.) to control black scurf and other tuber-borne diseases and placed apical end uppermost in wooden trays. From early October all seed lots were stored in a glasshouse (mean daily temperature 13 °C) or, in 1975 and 1976, in an artificially illuminated cabinet set at 12 ± 1 °C until dormancy had ended. Dormancy was considered to have ended when 95% of tubers in all treatments had produced a sprout 3 mm long. After the end of dormancy in all treatments in 1972, 1973 and 1974 half the seed lots were transferred from 13 °C to a second glasshouse (mean daily temperature 8 °C); in 1975 and 1976 the seed lot was divided into three for storage at 12 ± 1 °C, 8 ± 1 °C and 4 ± 0·5 °C in controlled-temperature cabinets. In the analysis and presentation of results, the criterion used to determine the end of dormancy was the mean date of production of a 3 mm sprout by all tubers in each treatment. In all experiments the number, length and position of all sprouts > 1 mm on ten randomly selected, numbered tubers in each replicate of all treatments were frequently recorded throughout storage commencing from the time of appearance of the first sprout > 1 mm. Initially, all numbered tubers were observed every 2–3 days in order to assess accurately the date of ending of dormancy. Despite frequent rotation of trays and illumination well in excess of the maximum used in commercial stores, some etiolation of sprouts occurred near the end of storage in 1976 in the cabinets in all varieties at all storage temperatures. In all experiments, all seed lots were transferred to a cool barn (mean daily temperature 7–9 °C) at Tenby 1–2 weeks before planting.

Ware production

Nine experiments were carried out from 1973 to 1977 at the University College of Wales Field Station, Trefloyne, Tenby on Devonian Sandstone soils of the Milford Association (Soil Survey of England and Wales, 1984). Details of treatments, seed weight and plot size used in individual experiments are shown in Table 3. Experiment 1 was a factorial arrangement of site, date of defoliation and storage temperature in three complete randomized blocks, the other experiments were single replicates of the combination of factors detailed in Table 3 with size of seed confounded with blocks which contained all the other combinations. In the analysis of the latter there is no 'test' for seed size. Estimated S.E.s for the other main effects and interactions were derived by first testing the several two-factor interactions between seed size (blocks) and other factors against three-factor and higher-order interactions containing seed size. Any which were not significantly different at the 5% level were pooled to form the 'error' term. Thus the 'error' is likely to be rather greater than would be the case in an orthodox randomized block design of the same size.

The ware experiments used the same fertilizer dressings as those applied to seed crops in the same year except Expts 3 and 6 in 1975, which used

Table 4. *Details of planting and sampling of ware experiments*

Ware year	Experiment	Variety	Date of planting	Date of sampling: Growth analysis (2 plants/plot)	Date of sampling: Tuber yield estimate	Length of row (m) taken for yield estimate
1973	1	Home Guard	14. iii	24. v; 7. vi; 28. vi	7. vi; 28. vi; 25. vii	2·44
1974	2	Home Guard	14. iii	2. iv; 16. iv; 30. iv; 14. v; 28. v	26. v; 10. v; 28. vi	3·3
	5	Red Craigs Royal	23. iii	7. v; 21. v; 4. vi; 18. vi	4. vi; 18. vi; 9. vii	3·3
1975	3	Home Guard	15. iii	28. iv; 12. v; 26. v; 10. vi	26. v; 10. vi	3·3
	6	Red Craigs Royal	21. iii	5. v; 19. v; 2. vi; 16. vi	2. vi; 16. vi	3·3
1976	4	Home Guard	8. iii	24. v*; 10. vi*	24.v; 10. vi; 12. vii	2·9
	7	Red Craigs Royal	26. iii	1. vi*; 16. vi*; 15. vii**	1. vi; 16. vi; 15. vii	1·8
	8	Arran Comet	8. iii	10. v; 6. vii*	20. v; 10. vi; 6. vii	2·9
1977	9	Arran Comet	5. iv	9. vi*; 22. vi*	9. vi; 22. vi; 8. viii	2·9

* Plots sampled for estimate of leaf area only.

152 kg N, 65 kg P and 160 kg K/ha. In all experiments row widths were 66 cm in 1973, 1974 and 1975 and 71 cm in 1976 and 1977. Within-row spacing was 30 cm in Expt 1 and 22 cm in all subsequent experiments. Ridges were rather cloddy in Expt 1, but good soil tilth was achieved in all other experiments.

Details of dates of planting and sampling and sampling areas for individual experiments are shown in Table 4. For growth analysis purposes plants were divided into component parts, namely stems, leaves (including part of the petioles), stolons (primary), tubers and other below-ground parts and, in Expts 2, 3, 5, 6 and 8, roots. After measurement and recording, all plant parts were dried in an oven at 90 °C for 48 h for dry-matter determination. Great care was taken to ensure that as much of the root system as possible was extracted from the soil beneath the sampled plants. Sampling for tuber yield estimates commenced at yields near the commercial minimum and ceased at or near the time of complete senescence in all plots. There was only sufficient seed from the earliest defoliation at the highest altitude site to provide for all the growth analysis samples in Expt 2 and, in addition, the first tuber yield sample in Expts 3 and 5. Further details of husbandry and cultivaticns and methods of sampling, recording and grading have been described by Allen (1977).

Weather 1972–7

Records for all years showed that mean daily air temperatures during seed crop growth were approximately 2 and 3 °C higher at Tenby than at Rhayader and Abbey Cwm-Hir, respectively. The spring rise in temperature was considerably earlier at the lowland site than at the two upland sites. The greatest difference in mean daily soil temperature between Tenby and the two upland sites occurred early and late in growth, when there was no or only limited ground cover. These effects are illustrated for 1974 in Fig. 1, and the weather data for all years are given by Allen (1977), O'Brien (1981) and Jones & Allen (1983). Data for soil temperature after tuber initiation for 1974, 1975 and 1976 are shown in Table 1.

Rainfall from May to September was above average at Tenby in 1972, 1974 and 1977, below average in 1973 and 1975, and well below average in 1976. At the two upland sites, summer rainfall was average in 1972, 1973 and 1974 but below average and similar to that at Tenby in 1975 and 1976. Summer rainfall at the upland sites exceeded that at Tenby by 13 and 71 mm in 1972 and 1973, respectively, but was lower by 26 mm at the high-altitude sites than at Tenby in 1974. Rainfall was similar at all sites in 1975.

In two years, 1975 and 1976, ware crop growth

Table 5. *Effects of site of seed production on number of above-ground stems per plant, date of tuber initiation and percentage foliar ground cover in seed crops of Home Guard (Expt 3) and Red Craigs Royal (Expt 6) in 1974*

Experiment ...	3	6	3	6	3	6
Date ...	30. v	7. vi	—	—	15. viii	15. viii
Site of seed production	Number of above-ground stems per plant		Estimated date of tuber initiation		Percentage foliar ground cover at final defoliation	
Abbey Cwm-Hir	4·8	3·8	11. vi	13. vi	95	90
Rhayader	5·1	4·2	9. vi	9. vi	45	65
Tenby	6·5	5·9	26. v	31. v	25	30

at Tenby was markedly different from that in other years as a result of unusual climatic conditions. In 1975, a period of very low temperatures from mid-March to mid-April resulted in a very slow rate of crop emergence and very small plants in the ware phase of Expts 3 and 6 (cf. Jones & Allen, 1983). Further, low rainfall in May and June combined with high potential transpiration rates from mid-May onwards caused very early senescence in this year. In 1976 the combination of adequate soil moisture, favourable spring temperatures and high radiation from early May onwards resulted in rapid and extensive foliage growth in May and higher tuber yields in June in all experiments than in other years.

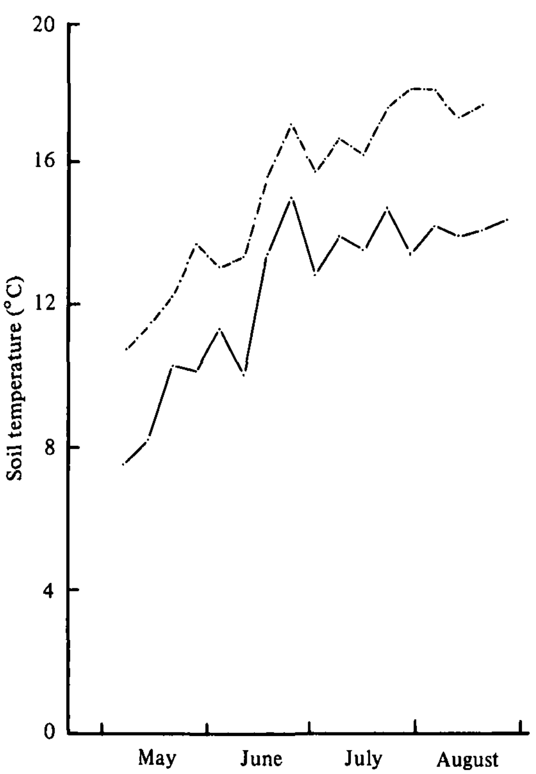

Fig. 1. Mean daily soil temperature at 10 cm depth at weekly intervals in 1974 at Trefloyne (Tenby) and Abbey Cwm-Hir. —·—, Trefloyne; ——, Abbey Cwm-Hir.

RESULTS

Seed crop growth and tuber yield

In all three varieties, effects of site of seed production on seed crop growth and tuber yield were similar in all years, and are illustrated for Home Guard and Red Craigs Royal from the most comprehensive data of 1974 (Expts 3 and 6). Onset of emergence, leaf growth and tuber initiation and growth at Tenby occurred 10–14 days earlier than at Rhayader and some 13–18 days earlier than at Abbey Cwm-Hir (Table 5). In 1975, emergence and tuber initiation in Home Guard and Red Craigs Royal at Tenby occurred a few days later than at the hottest site (Wellesbourne) and a few days earlier than at Gower and Rosewarne. With the exception of 1972 (Expt 1) onset of senescence and cessation of tuber growth occurred some 1–3 weeks earlier at Tenby than at the two upland sites, and was earliest at Wellesbourne in 1975. In 1972 the seed crop of Home Guard at both Tenby and Rhayader was substantially damaged by foliar blight infection by mid-August, so that there was no difference in foliar cover late in growth between sites in this year. Thus in all experiments (including Expt 1) tubers from warmer sites were chronologically older at harvest and probably experienced higher ridge temperatures late in growth than tubers produced at cooler sites. In all experiments seed from warm sites would be expected to commence sprout growth earlier than seed from cooler sites, for early tuber initiation (Burton, 1966) and hence chronologically old seed (Kawakami, 1952) have been reported to advance onset of sprout growth.

At all harvests up to mid-August crops at Tenby produced more tubers and higher yields in the seed fraction than crops grown at Rhayader and Abbey Cwm-Hir (Fig. 2). With further delay in harvesting to late August and early September

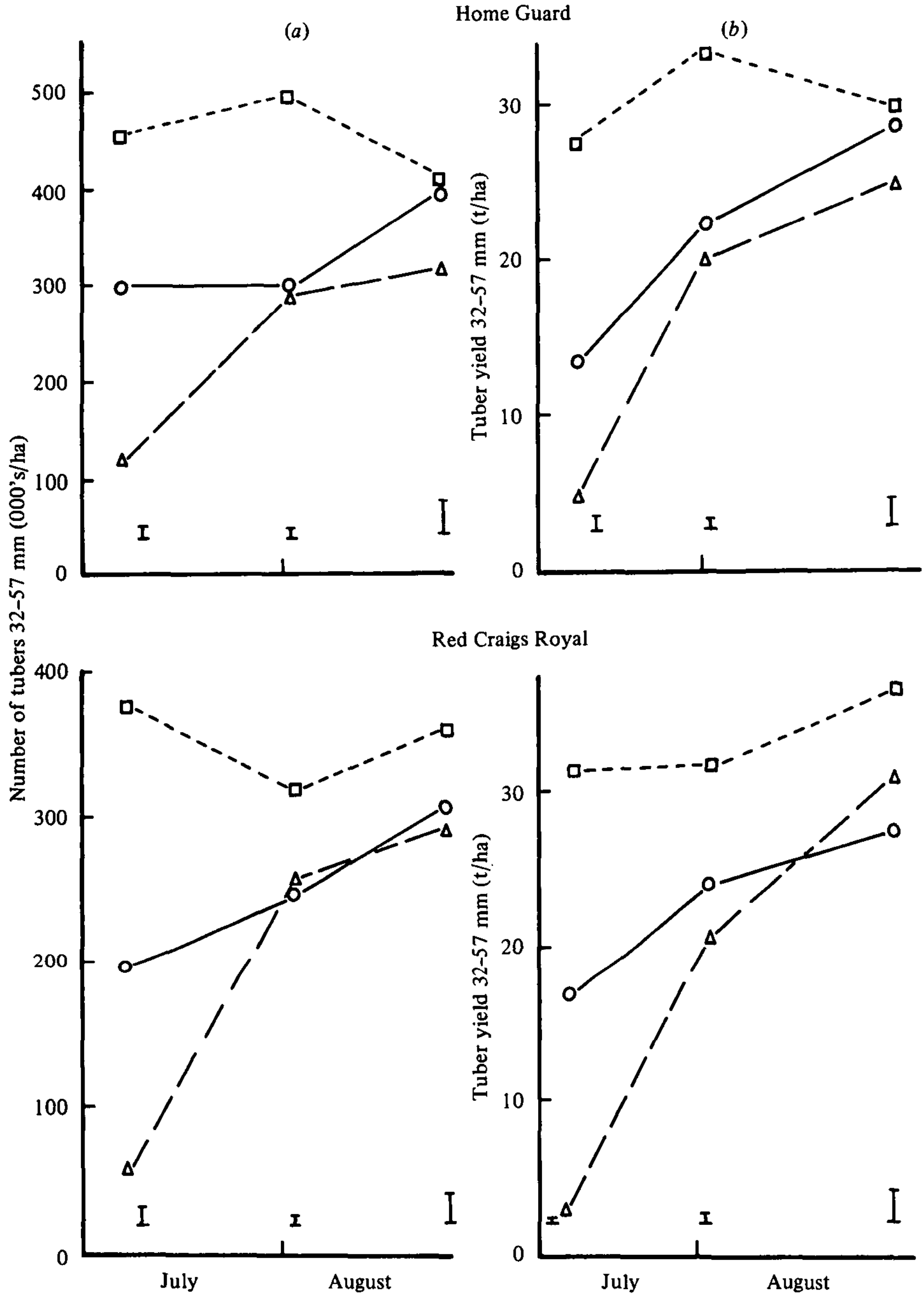

Fig. 2. Effect of site of seed production on (*a*) number and (*b*) yields of seed-size tubers in seed crops of Home Guard (Expt 3) and Red Craigs Royal (Expt 6) in 1974. ○—○, Rhayader; □---□, Tenby; △— —△, Abbey Cwm-Hir.

Table 6. *Effects of site of seed production and date of defoliation of the seed crop on sprout growth and emergence of the progeny crop of Home Guard in* 1974 (*Expt* 2)

Site of seed production	Date of defoliation of the seed crop (1973) 4. vii	18. vii	1. viii	15. viii	29. viii
			Date of onset of sprout growth (1973)		
Rhayader	1. x	12. x	24. x	31. x	4. xi
Tenby	5. x	16. x	23. x	28. x	29. x
S.E.			1·31		
			Length of longest sprout per tuber (mm), 27 ii.		
Rhayader	44·0	46·8	41·4	39·1	33·9
Tenby	49·5	49·1	45·5	39·0	41·3
S.E.			2·90		
			No. of emerged plants ('000s/ha), 8 iv.		
Rhayader	5·4	36·0	45·2	38·2	38·3
Tenby	41·3	40·6	48·2	28·2	43·6
S.E.			4·88		

there was little increase in seed yield at Tenby as more tubers > 57 mm were produced, but seed yield continued to increase at the two upland sites as more tubers attained the minimum seed size. Thus, at final harvests in late August and early September there was no effect of site on number or yield of tubers in the seed fraction in any experiment. However, considerably higher yield of seed-size tubers could be produced at lowland sites than at cooler, upland sites if crops were planted earlier (Jones, 1981) and at higher seed rates than in these experiments. At the single harvest in early August in 1975, seed yield of both Home Guard and Red Craigs Royal increased with increasing temperature of site of production.

Ware crop growth

Interactions

In one experiment (Expt 2, Home Guard) there were consistent, significant interactions between site of seed production and date of defoliation of the seed and, occasionally, storage temperature, on many aspects of growth. The interactions resulted from Tenby seed breaking dormancy after Rhayader seed at early defoliations, but earlier at the final defoliation (Table 6). By the end of storage sprouts from the earliest seed crop defoliation at Rhayader were shorter than from the earliest defoliation at Tenby as a result of reduced sprout growth rate towards the end of storage; sprout lengths from the latest defoliation were greater from Tenby than from Rhayader seed (Table 6). These effects were found in initial plant emergence, for the earliest defoliation date at Rhayader produced substantially fewer plants than any other defoliation date at either site (Table 6). This slow initial rate of emergence of early defoliated Rhayader seed was associated with a slow rate of sprout growth prior to planting. At all dates of sampling from early April, the number of above-ground stems increased with delay in seed crop harvesting at Rhayader, but decreased from seed crops defoliated after early August at Tenby (Table 7). From the final seed crop defoliation, Rhayader produced almost twice as many above-ground stems as Tenby seed, and these effects were very largely due to effects on number of secondary stems (Table 7). During May the effects of site on number of secondary stems were also affected by storage temperature. Seed from Rhayader produced approximately twice as many secondary stems and, consequently, above-ground stems as seed from Tenby following storage at 8 °C, but there was no effect at 13 °C (Table 8). A similar interaction between site and storage temperature was found on leaf area index (L) and root dry weight at the end of May (Table 8). The interactions between site and date of defoliation of the seed crop found in stem density were reflected in effects on leaf area indices, root dry weight (Table 7) and number and yields of tubers from mid-May onwards. As in stem density, the earliest defoliation at Rhayader and the latest defoliation at Tenby produced very low values for these variables. A second-order interaction was found on tuber yields at the final sampling date, 24 June (Table 9). The final defoliation at Rhayader substantially increased tuber yields compared with most earlier

Table 7. *Effects of site of seed production and date of defoliation of the seed crop on number of above-ground stems ('000s/ha), number of secondary stems per plant on 28 May 1974, leaf area index, and root dry weight (g/plant) on 14 May in the progeny crop of Home Guard (Expt 2)*

Site of seed production	Date of defoliation of the seed crop (1973): 4. vii	18. vii	1. viii	15. viii	29. viii
			No. of above-ground stems ('000s/ha)		
Rhayader	119	213	226	200	267
Tenby	181	145	211	172	148
S.E.			16·2		
			No. of secondary stems/plant		
Rhayader	1·5	3·9	4·1	3·8	4·5
Tenby	2·5	3·1	3·4	2·3	1·9
S.E.			0·69		
			Leaf area index		
Rhayader	0·48	0·65	0·59	0·60	0·76
Tenby	0·51	0·52	0·61	0·49	0·31
S.E.			0·056		
			Root dry wt. (g/plant)		
Rhayader	0·53	0·70	0·66	0·82	0·94
Tenby	0·61	0·68	0·82	0·67	0·59
S.E.			0·049		

Table 8. *Effects of site of seed production and storage temperature on (a) number of secondary stems per plant, (b) leaf area index and (c) root dry weight (g/plant) in the progeny crop of Home Guard on 28 May 1974 (Expt 2)*

Seed storage temperature (°C) ...	(a) 8	(a) 13	(b) 8	(b) 13	(c) 8	(c) 13
Site of seed production						
Rhayader	4·0	0 9	1·40	0·93	0·57	0·39
Tenby	2·1	0·8	0·86	0·72	0·44	0·39
S.E.	0·32		0·058		0·029	

Table 9. *Effects of site of seed production, date of defoliation of the seed crop and storage temperature on progeny tuber yields > 25 mm (t/ha) of Home Guard on 24 June 1974 (Expt 2)*

Seed storage temperature (°C)	Site of seed production	Date of defoliation of the seed crop (1973): 18. vii	1. viii	15. viii	29. viii
8	Rhayader	16·7	16·2	20·2	21·3
	Tenby	15·4	18·7	15·6	15·7
13	Rhayader	12·5	16·3	16·1	19·7
	Tenby	12·1	16·6	19·4	12·1
	S.E.		1·77		

defoliations following storage at both 8 and 13 °C, but the final defoliation at Tenby produced very low yields at 13 °C compared with the earlier defoliations, especially the penultimate defoliation. Effects of defoliation date at Tenby on yields were small after storage at 8 °C (Table 9). The combination of late defoliation of the seed crop from the cooler Rhayader site (which broke dormancy latest) and storage at the lower temperature (8 °C) resulted in the shortest sprouts at replanting. This was followed by later initiation and onset of growth of tubers (Tables 10 and 11), but eventually more stems and tubers, larger plants and higher tuber yields resulted from this treatment combination. A

Table 10. *Effects of site of seed production and date of defoliation of the seed crop on total number of tubers per plant and total tuber yields (g/plant) in the progeny crop of Home Guard on* 30 *April* 1974 (*Expt* 2)

Site of seed production	Date of defoliation of the seed crop (1973): 4. vii	18. vii	1. viii	15. viii	29. viii
			No. of tubers/plant		
Rhayader	12·2	4·8	3·5	4·6	4·6
Tenby	8·2	6·3	8·2	3·3	6·8
S.E.			1·78		
			Tuber yields (g/plant)		
Rhayader	16·4	6·0	2·7	2·8	3·6
Tenby	8·6	13·8	10·0	2·8	6·0
S.E.			2·65		

Table 11. *Effects of site of seed production and storage temperature on* (*a*) *total number of tubers per plant and* (*b*) *total tuber yield* (*g/plant*) *in the progeny crop of Home Guard on* 30 *April* 1974 (*Expt* 2)

Seed storage temperature (°C) ...	(*a*) 8	(*a*) 13	(*b*) 8	(*b*) 13
Site of seed production				
Rhayader	5·4	6·4	3·6	9·0
Tenby	3·1	9·9	2·3	14·2
S.E.	1·13		1·68	

Table 12. *Effect of site of seed production on the date of ending of dormancy in three varieties*

Variety ...	Home Guard				Red Craigs Royal			Arran Comet	
Experiment ...	1	2	3	4	5	6	7	8	9
Year ...	1972–3	1973–4	1974–5	1975–6	1973–4	1974–5	1975–6	1975–6	1976–7
Site									
Abbey Cwm-Hir	—	—	13. x	27. x	—	21. xi	15. xi	4. x	20. ix
Rhayader	12. x	21. x	19. x	23. x	11. xi	22. xi	15. xi	2. x	15. ix
Tenby	20. x	20. x	9. x	24. x	17. xi	11. xi	16. xi	4. x	26. ix
Gower	—	—	—	4. xi	—	—	—	—	—
Rosewarne	—	—	—	3. xi	—	—	—	—	—
Wellesbourne	—	—	—	28. x	—	—	24. xi	—	—
S.E. (days)	0·51	0·61	2·46	1·95	0·80	1·18	0·87	0·93	1·16

field growth pattern completely the reverse of this was found from Tenby-grown seed, so that late defoliations from this site produced very small plants and low yields, especially following storage at 13 °C. Although interactions between all three seed-management factors were found in Expt 2 and must be considered in examining the effects of these factors, the main effects of site on field growth were in the same direction in all other experiments which used Home Guard (Expts 1-4) and Red Craigs Royal (Expts 5–7).

Main effects

In all three varieties effects of site on dormancy and sprout growth varied between seasons and are presented for all experiments. In both Home Guard and Red Craigs Royal seed from Rhayader and Abbey Cwm-Hir usually produced larger progeny plants with more stems and foliage and higher tuber yields in late June and July than seed from Tenby, and effects on field growth are largely illustrated for two contrasting seasons, 1973 (Expt 1, Home Guard) and 1975 (Expt 6, Red Craigs Royal). There was no effect of site on any aspect of field growth in Arran Comet.

Sprout growth

In five out of nine experiments (Expts 1, 4, 5, 7 and 9) seed from the cool, upland sites Rhayader and Abbey Cwm-Hir broke dormancy earlier than seed from warmer sites (Table 12). There were no effects of site on the ending of dormancy in Expts 2 and 8, whilst in Expts 3 and 6 seed from the warm Tenby site broke dormancy earlier than seed from Rhayader and Abbey Cwm-Hir. In any experiment the maximum difference in date of breaking dormancy between sites did not exceed 11 days. In individual years effects on dormancy were usually consistent between varieties, but there was no consistent association between mean temperatures at the sites and the date of breaking dormancy.

Seed which commenced sprouting earliest invariably produced the longest sprouts per tuber at replanting. Thus at the end of storage sprouts of Home Guard and Red Craigs Royal were usually longer from seed grown at cool rather than warm sites (Table 13). There was no effect of site on sprout lengths of Arran Comet in either experiment. Seed from Rhayader generally produced more sprouts > 3 mm per tuber at the end of storage than seed from the warmer Tenby site in Home Guard and Arran Comet, but there was no effect in any experiment in Red Craigs Royal (Table 13). Thus it was possible to detect effects of site on all components of sprout development, but the effects were small in all experiments.

Table 13. *Effects of site of seed production on length of the longest sprout per tuber (mm) and number of sprouts > 3 mm per tuber (in parentheses) at the end of storage in three varieties*

Variety ...	Home Guard				Red Craigs Royal			Arran Comet	
Experiment ...	1	2	3	4	5	6	7	8	9
Site of seed production									
Abbey Cwm-Hir	—	—	36·0 (2·1)	60·4 (2·0)	—	19·3 (3·1)	19·5 (2·6)	29·9 (2·1)	33·3 (2·0)
Rhayader	33·6 (2·4)	41·6 (1·6)	34·8 (2·5)	54·4 (2·0)	27·4 (1·9)	19·3 (3·2)	19·8 (2·7)	32·2 (2·6)	32·6 (2·1)
Tenby	31·0 (2·9)	44·9 (1·5)	40·8 (1·9)	59·4 (1·6)	24·5 (2·1)	23·1 (3·1)	21·3 (2·6)	32·4 (2·3)	32·5 (2·2)
Gower	—	—	—	65·7 (2·1)	—	—	—	—	—
Rosewarne	—	—	—	60·8 (1·8)	—	—	—	—	—
Wellesbourne	—	—	—	61·6 (1·7)	—	—	17·9 (2·9)	—	—
S.E.	0·40 (0·09)	1·30 (0·09)	1·18 (0·09)	2·67 (0·15)	0·67 (0·07)	0·44 (0·13)	1·09 (0·12)	1·45 (0·10)	0·65 (0·09)

Field growth

There was no effect of site of seed production on emergence at any stage in Expts 2, 3, 4 and 7. In Expts 5 and 6 (Red Craigs Royal, 1974 and 1975 respectively) initial emergence was earlier (Table 14), and in Expts 1 and 6 more plants finally emerged from seed from Rhayader and Abbey Cwm-Hir than from seed from Tenby (Table 14). This reduction in final numbers of emerged plants was largely due to an increased number of plants with 'little potato disorder' from Tenby-grown seed (Table 14). The occurrence of this disorder in these two seasons suggests that poor soil conditions at planting (Expt 1) and low temperatures after planting (Expt 6) may be implicated in causing the disorder. However, the varieties differed in their response to these conditions, for Home Guard was not affected by 'little potato disorder' in the cold spring of 1975 (Expt 3), which suggests that low soil temperatures may be less important than soil conditions in causing this disorder in Home Guard.

In two out of four experiments (Expts 1 and 2) in Home Guard and two out of three experiments (Expts 5 and 6) in Red Craigs Royal, seed from Rhayader produced significantly more above-ground stems throughout most of growth than

Table 14. *Effect of site of seed production on (a) initial and (b) final number of emerged plants ('000s/ha) and (c) number of plants with 'little potato' disorder ('000s/ha) in progeny crops in Expt 1, Home Guard, 1973 and Expt 6, Red Craigs Royal, 1975*

	(a)	(b)		(c)	
Experiment ...	6	1	6	1	6
Year ...	1975	1973	1975	1973	1975
Site of seed production					
Abbey Cwm-Hir	20·6	—	66·8	—	0·2
Rhayader	21·3	46·4	63·7	2·4	3·0
Tenby	15·1	41·3	54·6	9·1	10·9
S.E.	1·36	1·23	1·54	1·33	1·24
Number of plants ('000s/ha) equivalent to 100% emergence	68·7	49·7	68·7	49·7	68·7

Table 15. *Effect of site of seed production on maximum number of above-ground stems ('000s/ha) in progeny crops of Home Guard and Red Craigs Royal*, 1973–6

Variety ...	Home Guard				Red Craigs Royal		
Experiment ...	1	2	3	4	5	6	7
Year ...	1973	1974	1975	1976	1974	1975	1976
Date ...	7. vi	26. v	10. vi	24. v	4. vi	2. vi	18. vi
Site of seed production							
Abbey Cwm-Hir	—	—	150·0	226·0	—	97·7	110·2
Rhayader	164·8	204·9	190·0	241·0	107·6	98·9	131·0
Tenby	107·4	171·5	182·1	242·0	94·9	86·2	148·2
Gower	—	—	—	221·0	—	—	—
Rosewarne	—	—	—	191·0	—	—	—
Wellesbourne	—	—	—	211·0	—	—	154·0
S.E.	8·45	7·28	10·8	9·1	3·8	3·5	10·8

Table 16. *Effects of site of seed production on maximum leaf area index (Expts 1–7), root dry weight (g/plant) and plant dry weight (less tubers) in progeny crops of Home Guard and Red Craigs Royal (Expts 3 and 6)*

	Leaf area index							Root dry weight		Plant dry weight (g)	
Variety ...	Home Guard				Red Craigs Royal			Home Guard	Red Craigs Royal	Home Guard	Red Craigs Royal
Experiment ...	1	2	3	4	5	6	7	3	6	3	6
Date of measurement ...		24. vi	10. vi	10. vi	18. vi	16. vi	18. vi	12. v	19. v	10. vi	16. vi
Site of seed production											
Abbey Cwm-Hir	—	—	0·94	2·38	—	0·86	2·45	—	0·39	—	8·94
Rhayader	1·42	1·35	1·13	2·78	1·75	0·76	2·48	0·53	0·35	10·9	8·01
Tenby	1·35	1·15	0·92	2·62	1·54	0·70	2·66	0·31	0·30	8·8	6·76
Gower	—	—	—	2·46	—	—	—	—	—	—	—
Rosewarne	—	—	—	2·87	—	—	—	—	—	—	—
Wellesbourne	—	—	—	2·14	—	—	2·54	—	—	—	—
S.E.	0·088	0·087	0·071	0·167	0·070	0·042	0·050	0·024	0·557	0·350	0·910

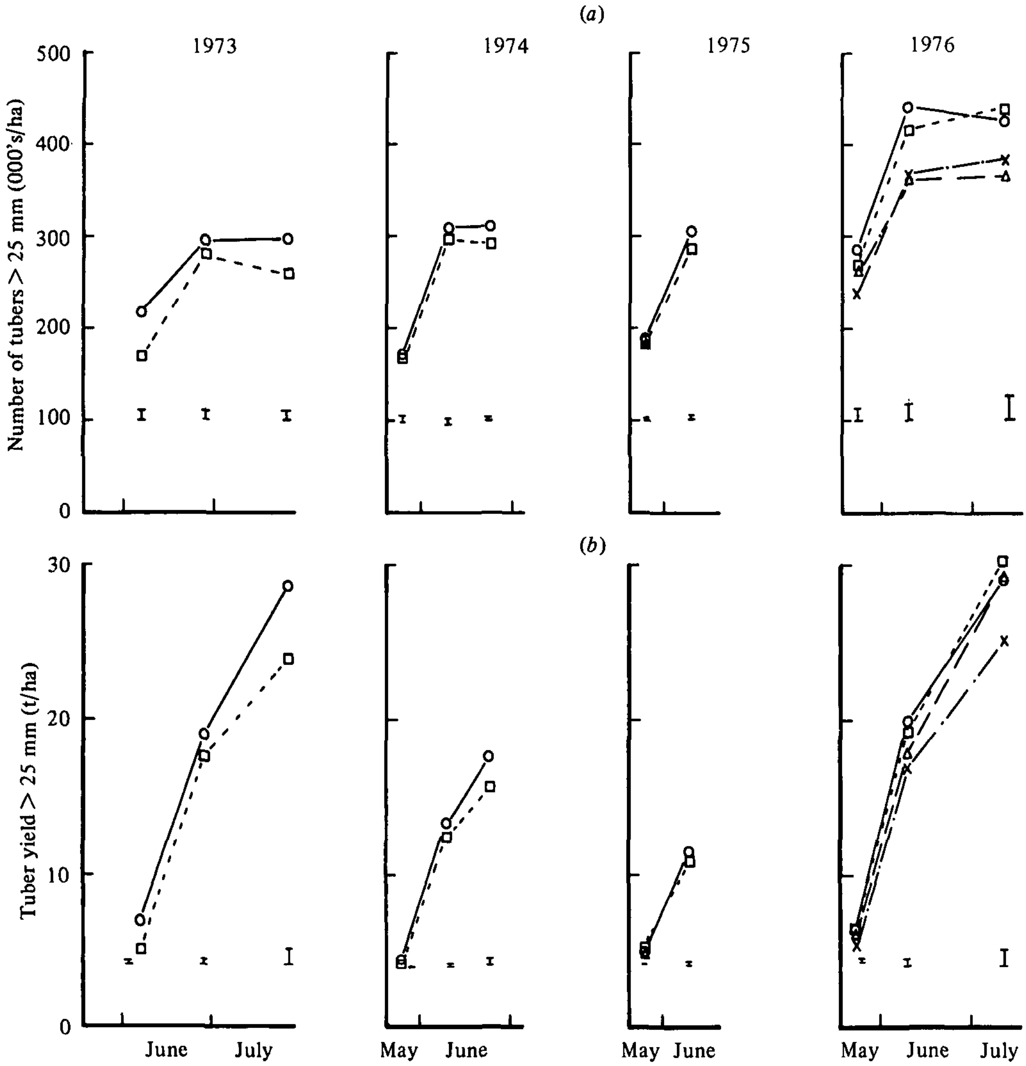

Fig. 3. Effect of site of seed production on (*a*) number of tubers > 25 mm and (*b*) tuber yields > 25 mm in progeny crops of Home Guard at different sampling dates in 4 years. ○—○, Rhayader; □---□, Tenby; △— —△, Abbey Cwm-Hir; ×—·—×, Wellesbourne.

seed from Tenby (Table 15). There was no significant effect of these two sites in any other experiment, but seed from the coolest site, Abbey Cwm-Hir, frequently produced fewest stems in both varieties. In 1976 (Expts 4 and 7), when substantially more above-ground stems were produced in both varieties than in previous years, numbers in Red Craigs Royal increased with increasing temperatures of site of seed production, in marked contrast to all previous years. In Home Guard in this year seed from Wellesbourne and Rosewarne produced fewer stems than seed from most other sites. Effects of site on the number of above-ground stems were almost wholly due to effects on the number of secondary stems in all experiments in Home Guard and in Expt 7 in Red Craigs Royal, and to the effect on the number of mainstems in Expts 5 and 6 in the latter variety.

These effects of site on stem density were closely reflected in effects on leaf area index (Table 16) and number of tubers (Figs 3 and 4) from early June onwards, and in plant and root dry weight throughout most of growth (Table 16). Thus in both Home Guard and Red Craigs Royal seed from the two cooler sites, Rhayader and Abbey Cwm-Hir usually produced larger plants with more foliage and more

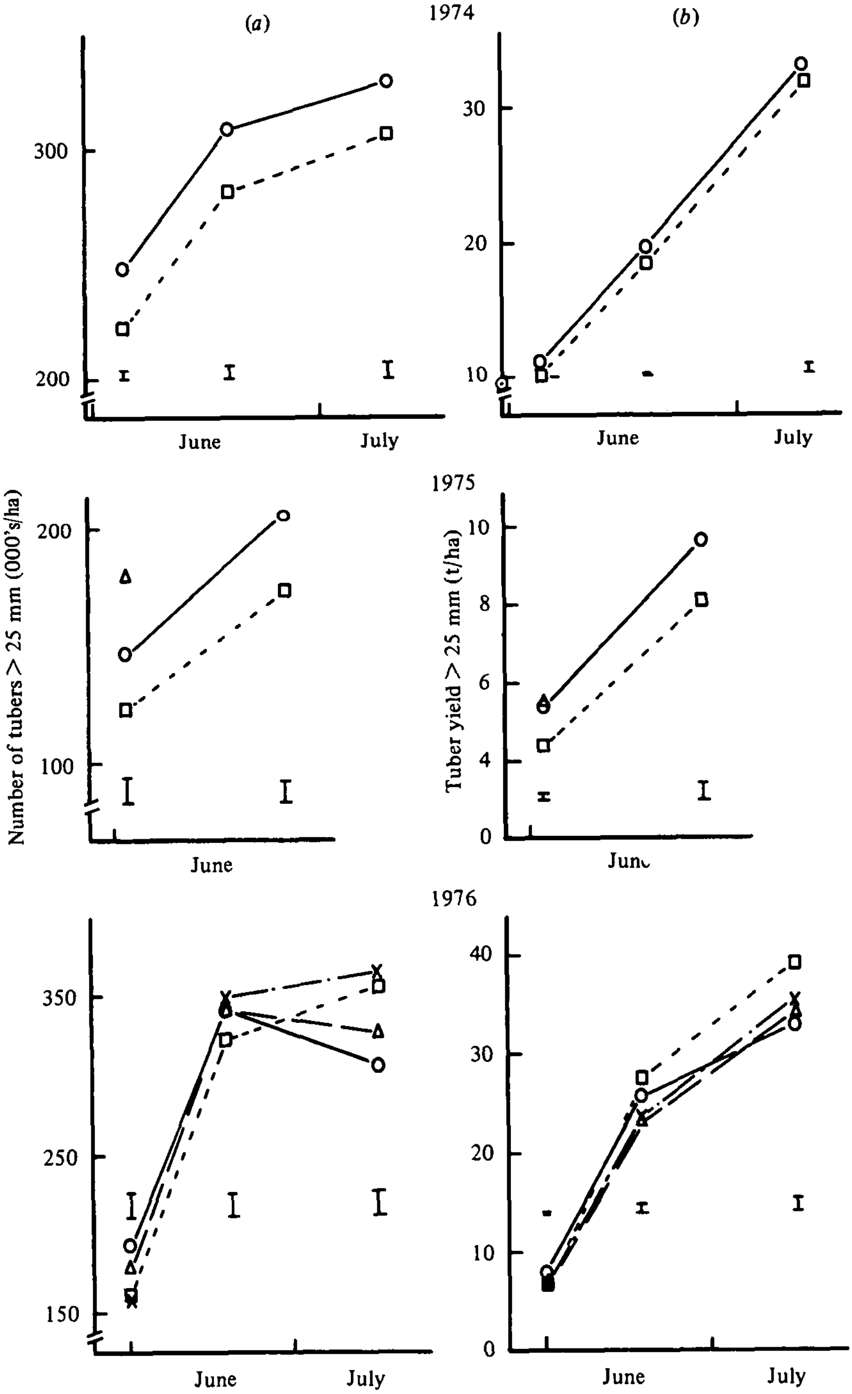

Fig. 4. Effect of site of seed production on (*a*) number of tubers > 25 mm and (*b*) tuber yields > 25 mm in progeny crops of Red Craigs Royal at different sampling dates in 3 years. ○—○, Rhayader; □---□, Tenby; △— —△, Abbey Cwm-Hir; ×—·—×, Wellesbourne.

Table 17. *Effect of site of seed production on tuber yields > 25 mm (t/ha) in progeny crops of Arran Comet at three sampling dates in 2 years*

Ware year ...	1976			1977		
Experiment ...	8			9		
Date of sampling ...	20. v	10. vi	6. vii	9. vi	22. vi	8. viii
Site of seed production						
Abbey Cwm-Hir	6·6	31·9	44·4	7·9	18·0	30·4
Rhayader	7·6	32·0	44·3	7·9	18·8	34·0
Tenby	6·7	32·5	44·6	8·7	19·7	31·4
S.E.	0·47	0·80	1·16	0·13	0·48	1·58

tubers and recoverable root at the time of the highest incident radiation (in late May and June) than seed from the warmer sites of Tenby and Wellesbourne. The amount of recoverable root dry weight decreased from shortly (within 3–5 weeks) after emergence. Effects of the Welsh sites on L were found in early June in Expt 1 (Home Guard) and at one sampling date in May and June in Expts 5 and 6 (Red Craigs Royal). Differences between Rhayader- and Tenby-produced seed in most aspects of growth were smaller in magnitude in 1975 than in previous years, and in 1976 were absent in leaf area index in Red Craigs Royal (Expt 7) and in number of tubers in Home Guard (Expt 4) at all harvests (Fig. 3) and in Red Craigs Royal at the first two harvests. At the final harvest (15 July) in Expt 7 (Red Craigs Royal) seed from the two warmest sites, Wellesbourne and Tenby, which produced the highest number of stems, also produced more tubers than seed from Rhayader and Abbey Cwm-Hir (Fig. 4).

In Home Guard and Red Craigs Royal from 1973 to 1975 seed from Rhayader produced significantly higher tuber yield > 25 mm than seed from Tenby on nine out of 13 occasions (Figs 3 and 4). At the remaining four, usually very early, harvests in these years there was no effect of these two sites on tuber yields. In 1976 there was no effect of these two sites on yields at any harvest in either variety, but seed from Abbey Cwm-Hir and Wellesbourne produced lower yields in both varieties at the penultimate harvests than seed from the other two sites. Final yield of Home Guard in 1976 was lower from Wellesbourne seed than from seed from any other site. Effects on total tuber yield and tuber yield > 38 mm were very similar to those on tuber yield > 25 mm. There were no effects of site on tuber yield in Arran Comet in either experiment (Table 17).

The results of Expts 1–7 show that reductions in tuber yield from seed grown at warm sites were associated with fewer stems and tubers and smaller plants. These effects on growth were not predictable from sprout measurements, for they occurred irrespective of any small effects of site on dormancy or number or length of sprouts.

DISCUSSION

The upland sites experienced consistently lower air and soil temperatures than the lowland sites, and for the three Welsh sites the range of temperatures over the five seasons probably covers the variation in annual temperatures found in the major seed-producing areas of the U.K. Despite these differences in temperature and the resulting differences in crop growth, the effect of site of seed production on the ending of dormancy and sprout growth was small. The literature indicates a general consensus that temperature is the dominant factor in reported effects of site of seed production on regrowth of progeny tubers (Toosey, 1964*a*; Burton, 1966; Wurr, 1979). The data of the experiments reported here showed no consistent association between temperature at the sites and duration of dormancy. This contrasts with the results of Wurr's (1979) experiments which, using the same sites of seed production and the same years (1974 and 1975) as some of the experiments reported here, generally indicated an earlier end of dormancy in maincrop varieties with increasing mean daily soil temperature of site of seed production. Any relationship between mean soil temperature during seed crop growth and dormancy end is probably complicated by effects of changes in the relationship between air and soil temperature during growth, effects of low temperatures (Wurr & Allen, 1976) and effects of time of removal of tubers from parent plants. The importance of these effects cannot be established from the current experiments. The effects of date of defoliation of seed crops suggest that the stage of growth of the crop at the time of defoliation and removal of tubers influences the duration of dormancy (P. J. O'Brien, J. L. Jones and E. J. Allen, unpublished) for the ending of dormancy was advanced considerably by defoliation and harvesting very early in the growth of the crop. In Wurr's experiments crops were defoliated late in growth, with 2–3 weeks between defoliation and harvesting. It is likely that ridge temperatures late in growth and after defoliation were substantially higher in Wurr's experiments, especially at the warmer sites than in those reported here, and this may account for the earlier end of dormancy of tubers from the warmer sites. A full explanation for the differences between the two series of experiments is not apparent. The magnitude of any effects of site was small in relation to the period available for sprout growth, and unlikely to be a consistent major influence on physiological age at replanting.

Effects of site of seed production on progeny tuber yield were found in two of the three varieties, but only in some seasons. These effects occurred in the two varieties, Home Guard and Red Craigs Royal, in which large effects on plant size were produced; in Arran Comet seed from all sites produced crops with complete ground cover, and as no effect on the timing of leaf growth or senescence was found there was no effect of site on tuber yields. Even where effects of site on plant size were found in the other two varieties they resulted in effects on yields only in the later stages of crop growth. In marked contrast to the belief of many early potato growers, locally grown seed produced no advantage in early yields over imported seed from higher altitudes. With delays in harvesting beyond mid-June in some years such seed produced lower yields than seed from higher altitudes. Thus the substantial economic advantages in home production of seed by early growers must be assessed in relation to the timing of harvesting of the ware crop. Clearly, there is no overall physiological benefit from the use of locally produced seed.

The detailed sampling in these experiments allowed the relationship between seed and ware crops to be studied, and identified the features of growth and development of the ware crop which created any effect on tuber yield. The effects of site on tuber yield which developed in the later stages of crop growth in some years were associated with increased number of above-ground stems from seed from upland sites. These effects occurred irrespective of whether site of seed production affected sprout growth or not. As the post-harvest environment was immediately standardized this suggests that site of seed production influences the regrowth of buds on tubers and/or buds on sprouts (stems). These effects may be influenced by the varieties used, for all varieties had short dormant periods and allowed a long period for sprout growth, which may have created effects which would not occur in varieties with longer dormancies. Although these effects of site on number of above-ground stems were clearly important, the results also show the much larger effects of season on number of above-ground stems (Table 15). The number of stems was much greater in 1976 than in other years notwithstanding the differences in seed rate, especially for seed from Tenby. These large effects of season illustrate the continuing difficulties of achieving consistent establishment of required stem densities in potatoes.

The increased ware yields of upland seed in Home Guard and Red Craigs Royal were similar to the results of Wurr (1979) with the maincrop varieties Désirée and Maris Piper. However, the effects of site on the ending of dormancy differed in the two series, and the effects on early yields cannot be attributed to the age of seed at replanting. In each of these concurrent series of experiments there was one variety in which site of seed production had no effect, Arran Comet and Pentland Crown, and, overall, site of seed production had no effect on tuber yield on half the occasions on which it was measured: 18 out of 36 harvests in the two series of experiments. As effects were shown to change with time it must be accepted that yield will be unaffected at some date of harvest. None the less, the impression remains that site of seed production is neither so large nor so consistent an effect as has previously been thought. In the reported experiments there was no association between temperature during seed crop growth and subsequent growth of the progeny tubers. As husbandry practices were standardized as far as possible at the sites it seems likely that many of the previously reported effects were caused by husbandry differences between sites. P. J. O'Brien, J. L. Jones and E. J. Allen (unpublished) found that date of planting had large effects on dormancy and sprout regrowth, which may influence field growth. In the current work, date of planting of seed crops was effectively determined by the occurrence of suitable conditions at the high-altitude sites; Tenby and Wellesbourne could have been planted up to 8 weeks earlier, if desired. However, with standardized husbandry, seed crop growth was still demonstrably different at the lower sites than at the higher ones (earlier emergence, tuber initiation and senescence), but effects of site on tuber regrowth were small. The main effects of site reported in this paper were averaged over seasonal dates of defoliation which were earlier than frequently used in practice in the U.K. P. J. O'Brien, J. L. Jones and E. J. Allen (unpublished) showed that there is little effect of date of defoliation in August on dormancy of these varieties, so there is no evidence that the lack of effects of sites was a consequence of the dates of harvest practised.

Recently, Wurr (1978*a*, *b*), Allen *et al.* (1979) and O'Brien *et al.* (1983) demonstrated consistent, close positively linear relationships between length of the longest sprout per tuber at replanting and number of day-degrees accumulated by seed tubers (i.e. physiological age) at replanting in several varieties. These authors also showed that physiological age was a major determinant of ware crop growth and tuber yield; increasing physiological age at replanting increased early growth and tuber yield but decreased yield later. This quantitative measure of physiological age means that unless treatments applied to seed crops markedly affect the end of dormancy they are unlikely to affect field growth and tuber yield, as sprout lengths at replanting are little affected. In the current experiments the maximum difference in the number of day-degrees > 4°C accumulated at replanting by seed from the different sites of seed production was approximately 100, and this difference in physiological age caused by site was too small to cause differences in early growth and tuber yield in the ware crop. Differences in yield at later harvests of the ware crop due to site of seed production did not always conform to the proposed model, for seed with the longest sprouts at replanting (i.e. oldest seed) sometimes still produced the highest yield. These effects were associated with an increased number of stems from upland seed which increased leaf area. There is, therefore, evidence for effects of site of seed production on regrowth of progeny tubers. However, the commercial importance of such effects is likely to be negligible, for it would be uneconomic to harvest crops in late June and July which did not have complete leaf cover and hence high tuber growth rates, as demonstrated by Bean (1981). As the increased number of stems did not result in differences in early ground cover in these experiments, the effects occurred too late to be commercially important in crops of inadequate leaf area.

The effect of any seed crop treatment on ware crop growth is dependent on other seed management factors used either in experiments or in practice. These may increase or decrease differences between seed crop treatments by influencing the number of day-degrees experienced by the seed at replanting. The interactions between site of seed production, date of defoliation of the seed crop and storage temperature found in Expt 2 are particularly relevant in this context. Although the effects of date of defoliation at both Rhayader and Tenby did not follow the consistent pattern of other experiments, the performance of the treatment combinations which broke dormancy 'abnormally' early conformed to the proposed 'model' of effects of physiological age. Thus early defoliated Rhayader seed and the latest defoliated Tenby seed which broke dormancy earlier than expected also produced growth patterns consistent with increasing age. The reduction in tuber yields late in growth from these two treatment combinations compared with any other was substantially greater following storage of seed at 13 than at 8 °C, so that seed of both these treatment combinations after storage at 13 °C probably exceeded the optimum physiological age for high tuber yield in mid and late June. In general, the effects of seed crop treatments on physiological age are likely to be smaller than those of storage temperature, as in most varieties the period available for sprout growth is much longer than the variation in the end of dormancy. However, manipulation of seed crop husbandry remains of practical importance, for in many cases it can be used at little cost to influence seed in a desired direction.

Seasonal variation in ware crop growth and tuber yield was very large in these experiments and requires comment. In 1976 (Expts 4, 7 and 8) most treatments produced complete foliar cover, and tuber bulking rates in early June were high in all three varieties, up to 9 t/ha per week in Red Craigs Royal and 8·4 t/ha per week in Arran Comet. In Home Guard and Red Craigs Royal in all other years few treatments produced complete leaf cover, and consequently rates of crop and tuber growth were low (2–4 t/ha per week), which contrasts with many reports of high crop rates from Trefloyne (Allen & Scott, 1980). These low growth rates were associated with the use of old seed, because dormancy ended early and seed was stored at fairly high temperatures (> 8 °C), for in Home Guard subsequent experiments at Trefloyne have shown that complete ground cover is frequently achieved only with seed of little or no age, 0–200 day-degrees > 4 °C (O'Brien *et al.* 1983). In 1976 larger leaf areas and higher bulking rates were produced from old seed in the excellent growing conditions. In contrast, in Expts 3 and 6 in 1975 both Home Guard and Red Craigs Royal produced very small leaf areas after experiencing approximately 3 weeks of low temperatures after planting. Similar effects have been previously noted at Trefloyne (Jones, 1981) and elsewhere (Griffith *et al.* 1984) and suggest that the expansion of leaves may be irreparably impaired by low temperatures during the pre-emergence phase of growth even if 'little potato disorder' is avoided. Al-Rawi (1981) showed that the susceptibility of a variety to restricted leaf expansion following low post-planting temperatures may well be determined long before the end of storage for in some varieties, e.g. Home Guard, growth of mainstems is largely determinate and differentiation of leaf primordia is completed before planting following storage of seed tubers at temperatures of 8 °C and above. In Vanessa he found that differentiation of leaf primordia was both later and slower than in Home Guard; thus few leaf primordia are differentiated at planting and therefore

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may escape most of the effects of low post-planting temperatures. The causes of the variation in size of leaf area which may be produced from the same stock of seed through ageing, date of planting and environmental conditions both before and after emergence are still, however, inadequately understood. An improvement in understanding of these aspects of leaf growth is essential for better agronomic practices which ensure an appropriate leaf-growth pattern for particular environments.

The data of Expts 2, 3, 5 and 6 showed that recoverable root dry weight decreased very early in growth, before maximum leaf cover was achieved, a similar result to that found with direct measurements of root growth by Lesczynski & Tanner (1976) and Steckel & Gray (1979). These results contrast with those of Asfary, Wild & Harris (1983), who found no decrease in total root length of Vanessa even late in growth. This suggests continuing root growth, and the discrepancy in results indicates that the turnover of roots in potatoes is still unclear. Plants from seed grown at the upland sites produced significantly more root dry weight throughout most of growth than plants from seed grown at Tenby, and if these effects were reflected in potential water uptake by crops, as would be expected, then at time of rapid leaf expansion serious limitations in water uptake by plants from Tenby seed may occur. Even plants with small leaf areas may be unable to meet the evaporative demands of their foliage; in Expts 3 and 6 such small plants died unusually early (late June) during the long dry period, suggesting inadequate water uptake when soil moisture deficits were estimated to be in the range 42–47 mm. This is a similar deficit to that calculated as limiting for similar seed of Home Guard by Jones (1981).

The seed crops in Powys were grown at stem densities close to optimal for final harvest, for seed tuber yield increased throughout the harvesting period. In contrast, seed crops at Tenby were grown at too low densities to produce maximum seed tuber yield, for yields were maximal before the final harvest, and the continuing growth of the crop in August resulted in increased yields of oversize tubers. Thus the higher the final yield expected the greater must be the seed rate (i.e. stem density) to ensure the majority of tubers remain within the seed-size fraction. There appear to be no published data for the effects of increasing seed rates and stem densities in seed crops; the results here suggest that a considerable range of seed rates would be required in the different seed-growing areas of the U.K.

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