Effects of seed crop husbandry, seed source, seed tuber weight and seed rate on the growth of ware potato crops

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SUMMARY

The results of 20 experiments which compared seed from July-planted crops with seed from earlier planted (April–May) crops either grown locally or from certified seed-producing areas are reported. The effects of dates of planting and harvesting of late-planted seed crops and seed storage temperature were examined in eight experiments. In five experiments, the effect of seed rate was studied on two weights of seed-tubers in the July-planted crops.

Tubers of several cultivars from the July-planted crops ended their dormancy close to the normal planting time of ware crops, 2–4 months later than tubers from spring-planted crops grown either locally or in areas certified for seed production. Tubers from seed crops planted in July produced fewer mainstems in ware crops than tubers from spring-planted crops, but effects on stem density were usually too small to have any significant effect on foliar ground cover and consequently on tuber yield. Date of planting the seed crops in July and date of harvest of the seed-tubers had no effect on sprout or ware crop growth in Record or Wilja. Ware tuber yields were similar for the different seed sources in 12 out of 15 experiments, suggesting little difference in the performance of tubers from seed crops planted early and late in the season.

At equivalent seed rates, small seed-tubers ($12{\cdot}5 \pm 2{\cdot}5$ g) from July-planted seed crops usually produced more stems and tubers and greater ware yields than larger tubers ($37{\cdot}5 \pm 2{\cdot}5$ g). For the smaller seed, the results suggested optimum seed rates for ware tuber yields of *c.* 0·88, 0·88 and 0·59 t/ha for Wilja, Record and Saturna, respectively. These are substantially lower than those currently used in the UK. For the larger seed, rates of *c.* 2·64, 2·64 and 1·76 t/ha were adequate for Wilja, Record and Saturna, respectively.

INTRODUCTION

Seed-tubers for ware potato crops in the UK are obtained from crops planted locally or in areas of certified production in the spring and harvested in the autumn of the previous year. Dormancy of the seed-tuber ends during the early part of winter in most cultivars and allows a long period for sprouting to occur before planting. To control or prevent sprout growth, seed-tubers of most cultivars need to be stored for much of this period at temperatures below ambient. Recent experiments (O'Brien & Allen 1992) have shown that very high multiplication rates can be obtained from seed-potato crops planted in July and harvested in September or early October. Such seed may differ from earlier planted seed in several respects. First, in short-season seed crops from late plantings, a greater proportion of small tubers will be present than in crops grown over a longer period; many below or at the lower end of the legally saleable size range (25–60 mm or 20–150 g) for certified seed-tubers. Recently Allen *et al.* (1992) have shown that seed tubers as small as 10 g in weight can produce similar ware yields to larger seed from both early- and late-planted seed crops although optimal planting densities for ware crops using such small seed-tubers have not been established. Second, as the ending of tuber dormancy may largely be a function of chronological time from tuber initiation (Davidson 1958; Sadler 1961; Burton 1963), seed-tubers planted in July may end their dormancy close to the time of replanting in ambient temperatures and have a considerably shorter period for sprouting than seed-tubers from crops planted at normal times in the UK. This seed may require little or no additional cooling during storage for suitable sprout growth at planting, with consequent savings in production costs. Also, tubers kept at temperatures between 10 and 20 °C before or

Table 1. *Details of eight experiments (1-8) on two potato cultivars (Record and Wilja) at four sites in 1985*

					Date of planting seed crop				
					10 July			30 July	
			Seed weight		Date of harvesting seed				
Expt	Cultivar	Ware site	(±2·5 g)		7 Sept	26 Sept	15 Oct	26 Sept	15 Oct
1	Record	Durham	17·5	27·5	✓	—	✓	✓	✓
2	Record	Lincs.	22·5	27·5	✓	—	✓	✓	✓
3	Record	Hants.	37·5	42·5	✓	—	✓	✓	✓
4	Record	Cambs.	47·5	52·5	✓	—	✓	✓	✓
5	Wilja	Durham	17·5	27·5	✓	✓	✓	✓	✓
6	Wilja	Lincs.	22·5	27·5	✓	✓	✓	✓	✓
7	Wilja	Hants.	37·5	42·5	✓	✓	✓	✓	✓
8	Wilja	Cambs.	47·5	52·5	✓	✓	✓	✓	✓

shortly after the resumption of bud growth typically produce few sprouts (Krijthe 1962) but many sprouts are produced on tubers after low-temperature storage (Allen *et al.* 1979). Thus, tubers from late-season seed crops replanted close to the end of their dormancy are likely to produce fewer sprouts and consequently mainstems than early-planted seed tubers, and optimum planting densities may be different. The effects of these different seed management regimes on ware crop production have not been established. Third, the difference in growing season may influence the productivity of the seed. For spring-grown crops in the UK, Jones (1981), O'Brien & Allen (1986*a*,*b*) and E. J. Allen (unpublished) found few important differences in sprout or ware crop growth between seed-tubers from crops planted and harvested on different dates at various sites or from crops receiving different rates of nitrogen fertilizer. However, data from other countries suggest that seed-tubers from spring-grown crops produce greater ware tuber yields than do seed-tubers from autumn crops (Fahem & Haverkort 1988). Whether these differences were due to effects of environment after planting of the ware crops at different times of the year or due to effects of the seed-tuber is not clear.

This paper reports the results of 20 experiments studying these effects in several potato cultivars.

EXPERIMENTAL DETAILS

Seed production

All ware experiments included seed-tubers from crops planted in July in Suffolk or Cambridgeshire and these are described as late-planted seed, although they are, obviously, once grown. The details of treatments and production of these late-planted seed crops are given by O'Brien & Allen (1992). Conventional once-grown seed, used in some experiments, was harvested in August from crops planted in April or May in East Anglia. Certified Scottish or Dutch (Saturna) seed tubers were from crops planted at normal dates (April or May) and delivered to Cambridge for selection and weighing in October or November. All late-planted and once-grown seed tubers were dipped in a solution of thiobendazole (1% a.i.) in October to control tuber-borne diseases. Seed for Expts 1–8 was stored in illuminated controlled-temperature cabinets. Seed for Expts 9–20 was stored at ambient temperatures in an illuminated shed protected from frost.

Ware production

Expts 1–8: Effects of seed crop husbandry in late-planted crops

In 1985 eight similar experiments compared crops of Record and Wilja grown at four sites from seed taken from combinations of date of planting in July and harvesting in September–October in Suffolk or Cambridgeshire with Scottish seed, after storage at two temperatures (4 and 8 °C). All field experiments used a randomized split-plot design with four replicates; details of the treatments are shown in Table 1. Storage temperatures were in mainplots and other treatments in subplots and the two seed weights used at each site were randomized between the four replicates. Seed tubers used for the different dates of planting and harvesting treatments in Expts 1–8 were obtained by bulking all tubers from the different seed rates used in the seed crop phase. Previous (unpublished) data at Cambridge showed no effect of planting density on sprout growth in several cultivars. Experiments at all except the Cambridge site had an irrigation facility and used the husbandry practised at the sites (Table 2).

Expts 9–15: Effects of seed source

Effects of seed source were examined in two years, 1986 and 1987, in four cultivars. In 1986 the effects

Table 2. *Details of ware production at four sites in 1985 (Expts 1–8)*

Expt	Site	Soil association	Date of planting	Date of harvesting	Area harvested (m^2/plot)
1, 5	Durham	Duneswick	2 May	11 Sept	2·07
2, 6	Lincolnshire	Downholland 1	15 April	12 Aug	2·19
3, 7	Hampshire	Frome	9 May	26 Sept*	2·29
4	Cambridgeshire	Hanslope	29 April	9 Aug	2·77
8	Cambridgeshire	Hanslope	29 April	21 Aug	2·77

* Defoliated on 2 September.

of all combinations of two seed weights (17·5 and 32·5 ± 2·5 g) and three seed sources (once-grown, late-planted and certified Scottish or Dutch seed) replicated three times in randomized blocks were examined in similar experiments at two sites in Wilja (Expts 9 and 10), Record (Expts 11 and 12) and Saturna (Expts 13 and 14). The sites used were Cambridge University Farm (CUF) and Engine Farm, Prickwillow, Cambridgeshire; the soils of the latter site were peat overlying clay belonging to the Adventurers Association (Soil Survey of England and Wales 1984). A within-row spacing of 15 cm was used for both seed weights at both sites. Fertilizer was applied to all experiments at the rate of 150 kg N, 96 kg P, 250 kg K and 113 kg Mg/ha at CUF and at the rate of 150 kg N, 96 kg P and 250 kg K/ha at Engine Farm. In 1987 (Expt 15) the effect of all combinations of four cultivars (Wilja, Maris Piper, Record and Saturna) and three seed sources (once-grown, late-planted and certified Scottish or Dutch seed) replicated three times in a randomized block design were examined at CUF. Seed weighing 22·5 ± 2·5 g was used and a fertilizer dressing of 100 kg N, 75 kg P, 188 kg K and 27 kg Mg/ha was applied at planting. The late-season seed-tubers used in Expts 9–15 were taken from the last harvest of the late-July planting. Further details of Expts 9–15 are shown in Table 3.

Expts 16–20: Effects of seed rate

Similar experiments in 1986 and 1987 at CUF examined the effects of all combinations of two seed weights (12·5 and 37·5 ± 2·5 g) and six within-row spacings replicated three times in randomized blocks. Seed for Expts 16–20 was taken from final harvests of crops planted in early July in Suffolk or Cambridgeshire. Record (Expt 16) was used in 1986 and the spacings were 10, 15, 20, 25, 30 and 37·5 cm. In 1987, Record (Expt 17), Wilja (Expt 18), Maris Piper (Expt 19) and Saturna (Expt 20) were used with spacings of 10, 15, 20, 30, 45 and 60 cm. Combinations of the different seed weights and spacings produced seed rates ranging from 0·29–1·76 t/ha with 12·5 g seed and 0·88–5·28 t/ha with 37·5 g seed. Fertilizer was applied at planting at the rate of 100 kg N, 95 kg P, 188 kg K and 75 kg Mg/ha in Expt 16 and at the rate of 100 kg N, 75 kg P, 188 kg K and 27 kg Mg/ha in Expts 17–20; further details of Expts 16–20 are shown in Table 3.

Table 3. *Details of ware production, Expts 9–20, 1986 and 1987*

Expt	Year	Site of production	Date of planting	Date of harvesting
9, 11, 13	1986	CUF	8 May	18–20 Sept
10, 12, 14	1986	Engine Farm	8 May	18–20 Sept
15	1987	CUF	14 April	6 Aug
16	1986	CUF	29 April	2 Sept
17	1987	CUF	17 April	25 Sept*
18	1987	CUF	17 April	17 Aug
19	1987	CUF	17 April	16 Sept*
20	1987	CUF	17 April	29 Sept

* Defoliated on 19 July.

Crop husbandry

In Expts 1–8 tubers were planted, using hand dibbers, *c.* 10 cm deep in ridges and the ridges were then re-made with hand hoes. In Expts 16–20, tubers were planted into furrows and then the ridges were split back. In all other experiments, tubers were pushed into the ridges by hand, sprouts vertically upwards, so that the distance from the soil surface to the uppermost surface of tubers was similar for all treatments. The ridges were then left undisturbed at CUF (Expts 9, 11 and 13) but were cultivated and re-made at Engine Farm (Expts 10, 12 and 14) as part of the weed control programme. Length of stems below the ground surface showed that the planting technique was successful, as there was no effect of any factor at either site, but tubers were considerably deeper at Engine Farm than at CUF. Experiments 9, 11, 13 and 15–20 at CUF were planted on light-gravelly soils of the Milton Association (Soil Survey of England and Wales 1984) and an area of 2·13 m^2 was harvested

Table 4. *Date of ending of dormancy in potato cultivars Record (Expts 1–4) and Wilja (Expts 5–8) stored at 8 °C (averaged over different seed weights) following different seed-crop treatments*

	Date of planting seed crop							
	10 July			30 July				
	Date of harvesting seed							
	7 Sept	26 Sept	15 Oct	26 Sept	15 Oct	Scottish seed	S.E. (days)	Error D.F.
Record	19 March	—	16 March	16 March	13 March	29 Dec	1·7	19
Wilja	10 March	13 March	8 March	9 March	12 March	20 Jan	2·0	23

Table 5. *Effects of seed-crop treatments and storage temperature on the length of the longest sprout (mm) and the number of sprouts > 3 mm per tuber near the date of planting in Wilja, Expts 5–8 (averaged over different seed weights)*

	Date of planting seed crop							
	10 July			30 July				
Storage temperature (°C)	Date of harvesting seed							
	17 Sept	26 Sept	15 Oct	26 Sept	15 Oct	Scottish seed	Mean	S.E.
	Length of the longest sprout (mm)							
4	1·5	1·2	1·3	1·1	1·3	3·3	1·6	
8	8·4	7·9	8·3	8·2	7·8	15·9	9·4	
Mean	5·0	4·6	4·8	4·7	4·6	9·6		0·14
S.E.			0·20				0·08	
	Number of sprouts > 3 mm per tuber							
4	0·05	0·05	0·08	0·00	0·04	1·66	0·31	
8	2·79	2·71	2·88	2·39	2·34	3·35	2·74	
Mean	1·42	1·38	1·48	1·19	1·19	2·51		0·075
S.E.			0·106				0·043	

Error D.F. = 47.

from each plot. Rows were 71 and 86 cm apart at CUF and Engine Farm, respectively, and the harvest area per plot was 1·81 m^2 for Expts 10, 12 and 14. With the exception of some incidence of secondary leaf roll virus in Maris Piper in 1987 (Expts 15 and 19) from late-planted seed, all other experiments were free of weed and disease infestation following routine spray programmes. Some wilting of leaves occurred for several days in July in all experiments at CUF in 1985 and 1987 but, apart from this, no other crop showed any obvious symptom of shortage of water. The number of emerged plants and a visual assessment of foliar ground cover in all plots was recorded at CUF at appropriate intervals. Methods of harvesting and grading were as previously reported (O'Brien & Allen 1992) and, except where indicated, all experiments were harvested without prior defoliation.

RESULTS

Experiments 1–15

There were no effects of date of planting or harvesting of late-planted seed crops on any aspect of sprout (Tables 4 and 5) or field growth of the subsequent crop in Expts 1–8. These experiments are, therefore, of further interest only in relation to effects of seed source and storage temperature and are presented with the experiments dealing with effects of seed source.

Sprouting

For each tuber, dormancy was considered to have ended when the first sprout reached 3 mm in length. The date of the end of dormancy for each plot was calculated as the mean of the dates for a sample of ten

Table 6. *Effects of seed-crop treatments and storage temperature on number of mainstems, number of above-ground stems, total number of tubers, number of tubers > 40 mm and tuber yield > 40 mm in Wilja grown at Durham in 1985 (Expt 5)*

Storage temperature (° C)	Date of planting seed crop: 10 July — Date of harvesting seed: 7 Sept	10 July: 26 Sept	10 July: 15 Oct	30 July: 26 Sept	30 July: 15 Oct	Scottish seed	Mean
			Number of mainstems ('000s/ha)				
4	125·0	115·8	118·4	105·3	103·9	172·4	123.5
8	80·3	78·9	84·2	69·7	82·9	122·4	86.4
Mean	102·6	97·4	101·3	87·5	93·4	147·4	
S.E. for comparing at the same temperature				7·75			
S.E. for all other comparisons				8·54			
			Number of above ground stems ('000s/ha)				
4	125·0	122·4	119·7	109·2	105·3	182·9	127·4
8	98·7	90·9	89·5	75·0	85·5	140·8	96·7
Mean	111·8	106·5	104·6	92·1	95·4	161·8	
S.E. for comparing at the same temperature				6·41			
S.E. for all other comparisons				7·00			
			Total number of tubers ('000s/ha)				
4	559	511	576	498	517	831	582
8	521	501	573	468	506	684	542
Mean	540	506	574	483	511	757	
S.E. for comparing at the same temperature				31·7			
S.E. for all other comparisons				34·5			
			Number of tubers > 40 mm ('000s/ha)				
4	396	386	405	375	378	488	405
8	371	344	361	339	368	417	367
Mean	383	365	383	357	373	452	
S.E. for comparing at the same temperature				18·7			
S.E. for all other comparisons				24·6			
			Tuber yield > 40 mm (t/ha)				
4	57·6	59·0	56·3	54·0	56·7	58·6	57·0
8	54·5	51·6	52·5	52·0	57·0	54·4	53·7
Mean	56·0	55·3	54·4	53·0	56·9	56·5	
S.E. for comparing at the same temperature				2·07			
S.E. for all other comparisons				2·58			

Error D.F. for comparing at the same temperature = 4.
Error D.F. for all other comparisons = 30.

tubers (O'Brien *et al.* 1983). In Expts 1–8, at a storage temperature of 4 °C, dormancy ended in Scottish seed around the time of planting of the ware crop. At 8 °C, all late-season seed-crop treatments ended dormancy in March at least 44 and 74 days later than Scottish seed in Wilja and Record, respectively (Table 4). As a result more and longer sprouts were present on Scottish seed tubers than on late-season seed at the time of planting; these effects were greater at 8 °C than at 4 °C storage (Table 5). Following storage at ambient temperatures in Expts 9–15, late-season seed usually ended dormancy *c.* 2–3 months later than Scottish (or Dutch) and spring-planted once-grown seed. In Expts 9 and 10, Wilja seed was delivered very late from Scotland (February) and broke dormancy about a month later than late-season seed and 4 months later than once-grown seed, although it had been capable of sprout growth prior to its delivery. As a result there were substantial differences in sprout growth between seed sources at the time of planting the ware crops.

Field growth

Crops from late-planted seed frequently emerged and produced peak leaf cover a few days later than those from once-grown and certified seed but they usually retained green leaf a little longer than other seed sources. Scottish (and Dutch Saturna) seed generally

Table 7. *Effect of seed source (averaged over seed weight) on the number of stems ('000s/ha) at two ware sites in Saturna in 1986 (Expts 13–14)*

Expt	Ware site	Stem type	Seed source: Once-grown	Late-planted	Dutch	S.E.	Error D.F.
13	CUF	Mainstems	122	127	180	9·2	
		Secondary stems	240	134	185	19·4	10
		Total	362	262	365	21·3	
14	Engine Farm	Mainstems	179	136	236	12·0	
		Secondary stems	81	34	45	14·6	10
		Total	261	170	281	19·4	

Table 8. *Effect of seed source (averaged over weed weights) on tuber yield > 30 mm (t/ha) in three potato cultivars at two ware sites in 1986*

Expt	Cultivar	Ware site	Seed source: Once-grown	Late-planted	Scottish or Dutch	S.E.
9	Wilja	CUF	46·0	48·5	49·4	1·07
10	Wilja	Engine Farm	40·6	55·5	56·3	1·59
11	Record	CUF	34·2	28·7	30·1	1·05
12	Record	Engine Farm	43·3	28·4	35·0	1·51
13	Saturna	CUF	32·6	26·5	30·5	1·07
14	Saturna	Engine Farm	39·7	32·9	38·1	2·14

Error D.F. (Expts 9–14) = 10.

Table 9. *Effect of seed source on tuber yield (t/ha) in four potato cultivars in 1987 (Expt 15)*

Cultivar	Seed source: Once-grown	Late-planted	Scottish or Dutch	Mean	S.E.
Wilja	56·1	51·4	57·4	55·0	
Maris Piper	55·8	59·8	54·7	56·8	
Record	39·7	36·8	43·6	40·0	
Saturna	48·0	42·5	48·2	46·2	
Mean	49·9	47·6	51·0		1·53
S.E.		3·05		1.76	

Error D.F. = 22.

produced substantially more mainstems and occasionally more secondary stems and consequently more above-ground stems and tubers than late-planted and once-grown seed (Tables 6 and 7). For all seed sources, there were considerable differences in the number of secondary stems produced at the two sites in Expts 9–14 even though the major husbandry factors at the sites were standardized. In Wilja, Record and Saturna (Table 7), all seed sources produced substantially more secondary stems at CUF than at Engine Farm. The major difference between the experiments at the two sites was the effective depth of planting which was *c.* 7 cm at CUF and double this at Engine Farm following post-planting cultivations and re-ridging.

In Expts 1–8, tuber yield differed between late-planted and Scottish seed only in Expt 1 (Record) at Durham where Scottish seed produced higher yields than all late-planted seed (Table 6). The reasons for the difference in yield between seed sources at Durham in Record only are not wholly clear, but the greater number of mainstems from Scottish seed was a major contributor. Although seed from ambient and 4 °C storage produced more mainstems than seed from

Table 10. *Weight (g) and dimensions of individual tubers (50–60 mm) of Wilja grown at two sites in 1986 (Expts 9 and 10)*

	Site	
	Cambridge University Farm (Expt 9)	Engine Farm (Expt 10)
Weight of tubers (g)	129·5	193·6
S.E.	3·91	4·10
Length of longest axis (cm)	8·00	10·69
S.E.	0·157	0·159
Error D.F.	10	10

8 °C storage, seed storage temperature had no effect on tuber yield in any experiment (Table 6). In other experiments reported by Allen *et al.* (1992), late-season seed stored at 10 °C produced higher tuber yields than seed from ambient storage in only one out of four comparisons. In Expts 2–8, late-planted seed produced tuber yields similar to other sources of seed and this was also found in Wilja (Expts 9 and 10), Record (Expt 11), Saturna (Expt 14) and in all cultivars in Expt 15 (Tables 8 and 9). There were some differences in the remaining experiments but little consistency. At Engine Farm, late-planted seed produced lower yields than once-grown and certified seed of Record (Expt 12), but yields from once-grown seed of Wilja (Expt 10) were lower than from the other two seed sources (Table 8). At CUF, late-planted seed of Saturna produced a lower yield than the other two sources of seed.

Tuber size and shape differed substantially between sites in Wilja in Expts 9 and 10. Within size grades, tubers from the peat soils at Engine Farm were considerably longer and in consequence heavier than tubers from the mineral soils at CUF (Table 10). These differences in tuber dimensions within size grades have also been observed for similar soil types in other cultivars and the results show that tubers of very different weights may be obtained from the same size grading.

There was no effect of seed weight on yield in Record in Expts 11 and 12 or in Saturna in Expt 13, but larger seed produced greater tuber yields than smaller seed in Expts 9, 10 and 14. As a constant within-row spacing was used, this was mainly a consequence of the increased seed rate achieved with the larger seed at each spacing.

Expts 16–20

In all experiments, interactions between seed weight and within-row spacing were found only in number of stems. The larger seed produced more mainstems and in consequence more above-ground stems than the smaller seed; effects were usually greatest at closer spacings but interactions were also caused by low numbers of stems in one treatment combination (Tables 11–13). Averaged over within-row spacings, the larger seed produced more stems and tubers (total, > 20, > 30 and > 40 mm) than the smaller seed but seed weight usually had no effect on the number of tubers > 50 mm in any variety or in the crisping fraction (40–70 mm) in Record or Saturna. Seed weight had no effect on tuber yield in any size grade in Record in Expts 16 and 17 or in Wilja (Expt 18) but yields > 30 mm were higher from the larger seed in Maris Piper (Expt 19) and Saturna (Expt 20) (Table 13).

For both seed weights, the number of stems and tubers (total, > 20, > 30 and > 40 mm) increased with decreasing within-row spacing over the whole range in all experiments, but the number and yield of tubers > 50 or 60 mm decreased with decreasing spacing (Tables 11–13). For yields > 30 mm, there were only small increases in yield with decreasing spacing in Record in Expts 16 and 17 and no increase at spacings closer than 20 cm in Wilja (Expt 18) or closer than 30 cm in Saturna (Expt 20) for either seed weight. In Maris Piper (Expt 19) yields > 30 mm increased for both seed weights with decreasing spacing over almost all the range. This crop was harvested very early in its growth and optimum seed rates would have been lower at a later harvest, as senescence at harvest in August was more advanced at the closer spacings. Tuber yields in the crisping fraction in Record and Saturna were close to maximum at spacings of 20 and 30 cm, respectively, for both seed weights (Tables 11–13). Thus, in these experiments, seed rates as low as 0·6 and 1·8 t/ha in Saturna were sufficient for maximum tuber yields from 12·5 and 37·5 ± 2·5 g seed, respectively. For Wilja and Record, seed rates of 0·9 and 2·6 t/ha appeared to be sufficient for the two seed weights. Even lower seed rates than these may be preferable in order to ensure a high proportion of large (> 50 mm) tubers in the sample. For similar seed rates, small seed produced more stems and tubers and higher tuber yields than larger seed in nine out of 14 comparisons in Expts 16–20 (Tables 11–13).

DISCUSSION

In Expts 1–8, date of planting or harvesting of the late-season seed-tubers had few effects on sprout or ware crop growth in any variety. The results confirm those found for ware crops grown from spring-planted crops by Jones (1981) and E. J. Allen, J. L. Jones & P. J. O'Brien (unpublished) and suggest no difference between seed-tubers from different seed crop management systems planted at similar times and stored in standardized conditions soon after harvesting. Effects of temperature of seed storage on

Table 11. *Effect of seed weight and within-row spacing on number of stems and tubers, tuber yield and the number of tubers > 20 mm per mainstem in Record (Expt 16)*

	Seed weight ±2·5 (g)	Within-row spacing (cm)							
		37·5	30	25	20	15	10	Mean	S.E.
				Number of stems ('000s/ha)					
Mainstems	12·5	37·5	50·0	62·5	75·0	95·3	142·2	77·1	
	37·5	56·3	59·4	75·0	104·7	114·1	182·8	98·7	
	Mean	46·9	54·7	68·7	89·9	104·7	162·5		3·09
	S.E.			4·38				1·78	
Above-ground stems	12·5	137·5	126·6	215·7	139·1	217·2	226·6	177·1	
	37·5	161·0	198·5	179·7	271·2	278·2	312·5	233·6	
	Mean	149·2	162·5	197·7	205·5	247·7	269·6		15·23
	S.E.			21·55				8·80	
				Number of tubers ('000s/ha)					
Total	12·5	533	539	586	667	716	991	672	
	37·5	431	566	619	717	826	1028	698	
	Mean	482	552	602	692	771	1009		34·2
	S.E.			48·4				19·8	
40–70 mm	12·5	295	281	309	383	384	420	346	
	37·5	266	333	342	375	372	438	354	
	Mean	281	308	326	379	378	429		25·3
	S.E.			35·7				14·6	
> 60 mm	12·5	64·1	68·8	81·3	43·8	42·2	14·1	52·4	
	37·5	67·2	73·5	43·8	42·2	35·9	26·6	48·2	
	Mean	65·6	71·1	62·5	43·0	39·1	20·3		8·60
	S.E.			12·16				4·96	
				Tuber yield (t/ha)					
> 30 mm	12·5	45·1	40·3	44·9	47·4	49·2	43·5	45·1	
	37·5	42·1	47·6	46·7	49·0	44·7	50·1	46·7	
	Mean	43·6	43·9	45·8	48·2	46·9	46·8		2·46
	S.E.			3·48				1·42	
40–70 mm	12·5	41·5	36·6	41·8	44·4	45·6	38·1	41·2	
	37·5	36·1	44·4	42·7	45·8	40·7	45·3	42·4	
	Mean	38·8	40·3	42·3	45·1	43·2	41·7		2·64
	S.E.			3·73				1·52	
> 60 mm	12·5	15·8	15·4	17·7	8·6	10·2	3·0	11·8	
	37·5	16·4	16·2	8·9	9·0	7·7	4·8	10·5	
	Mean	16·1	15·8	13·3	8·8	9·0	3·9		2·00
	S.E.			2·83				1·15	
				Number of tubers > 20 mm per mainstem					
	12·5	11·5	7·8	7·6	7·3	5·9	4·8	7·3	
	37·5	6·4	7·7	6·6	5·1	5·0	3·7	5·7	
	Mean	8·9	7·8	7·1	6·2	5·5	4·3		0·40
	S.E.			0·56				0·23	

Error D.F. = 22.

ware crop growth were also small and effects on tuber yields were found in only one out of 12 experiments. However, tubers from July-planted and spring-planted seed crops differed greatly in sprouting and in some aspects of field growth. In similar storage conditions, tubers from July plantings generally ended their dormancy 2–4 months later than tubers from spring-plated crops grown locally or in certified seed areas. As a result, at the time of planting the ware crops, tubers from July-planted crops had fewer and considerably shorter sprouts and were, therefore, physiologically younger (O'Brien *et al.* 1983) than tubers from spring-planted crops. At specific storage temperatures, differences in the dates of ending of dormancy between seed sources were usually similar to the interval between planting dates of both spring- and July-planted seed crops, which supports the view of Burton (1963), Davidson (1958) and Sadler (1961)

Table 12. *Effect of seed weight and within-row spacing on number of stems and tubers, and tuber yield in Record (Expt 17) in 1987*

Seed weight ±2·5 (g)	Within-row spacing (cm) and (in parentheses) seed rate (t/ha)							
	60	45	30	20	15	10		
12·5	(0·29)	(0·39)	(0·59)	(0·88)	(1·17)	(1·76)		
37·5	(0·88)	(1·17)	(1·76)	(2·64)	(3·52)	(5·28)	Mean	S.E.
			Number of above-ground stems ('000s/ha)					
12·5	28·1	37·5	57·8	71·9	93·8	136·0	70·8	
37·5	34·4	48·4	73·5	114·1	110·0	159·4	90·1	
Mean	31·3	43·0	65·6	93·0	102·4	147·7		3·70
S.E.			5·23				2·14	
			Number of tubers > 30 mm ('000s/ha)					
12·5	266	349	355	417	472	572	405	
37·5	303	364	427	578	542	689	481	
Mean	284	356	391	498	507	620		19·0
S.E.			26·9				11·0	
			Tuber yield > 30 mm (t/ha)					
12·5	24·8	30·5	30·1	35·2	35·5	34·9	31·8	
37·5	27·7	34·7	33·8	37·7	33·9	34·3	33·7	
Mean	26·2	32·6	31·9	36·5	34·7	34·6		1·49
S.E.			2·11				0·86	
			Tuber yield 40–70 mm (t/ha)					
12·5	22·5	27·2	27·1	31·9	31·1	27·0	27·8	
37·5	26·0	32·3	29·9	30·3	26·9	20·7	27·7	
Mean	24·2	29·8	28·5	31·1	29·0	23·9		1·34
S.E.			1·89				0·77	

Error D.F. = 22.

that dormancy depends mainly on chronological time from the date of initiation of tubers. At planting of the ware crop, tubers from July-planted crops had just ended dormancy following storage at ambient temperatures but no bud growth was visible on tubers following storage at 3–4 °C. At 8 °C storage, dormancy of tubers from July-planted crops ended *c.* 4–6 weeks before replanting. Thus, sprouts from the different seed sources were at different stages of development at replanting in soils in which soil temperatures at 10 cm were > 10 °C. As a result, tubers from July-planted crops which had fewer sprouts per tuber produced fewer mainstems than seed-tubers from spring-grown crops. These effects were reflected in the total number of tubers produced but were usually not large enough to cause differences in tuber yields between seed sources. In 12 out of 15 experiments, ware tuber yield did not differ between July- and any spring-planted seed tubers. Statistically significant effects of seed source on tuber yields were found only in Saturna (Expt 13), in Record (Expt 1), where small seed was planted moderately deeply, and in Wilja (Expt 10) and Record (Expt 12) at Engine Farm, where small seed was planted very deep (14 cm). As sprout length was greatest in Scottish seed, the deeper planting of seed-tubers is likely to have allowed earlier emergence, which led to differences in yield between sources which would be decreased by more synchronous emergence. Overall, the results show no difference in the performance of seed-tubers from different planting dates and seed sources, in agreement with the results of Jones (1981) and O'Brien & Allen (1986*b*) for seed tubers planted in the spring in different areas of the UK.

The manipulation of date of planting of seed crops in the range of environments within the UK offers great potential for controlling the dormant period of the seed for the benefit of the following ware crop. This may involve providing dormant tubers for much of the winter so that the cost of storage is reduced if no sprouting is to be practised. For overseas markets, transportation of dormant tubers would avoid many problems associated with uncontrolled sprouting, not least disease, without prejudicing growth of the ware crop. In these respects, the range of environments within the UK provides much greater scope for the commercial adoption of these possibilities than in other seed-exporting areas such as Holland. The most important practical development that is needed is a more precise relationship between seed production

Table 13. *Effect of seed weight and within-row spacing on tuber yield (t/ha) in Wilja (Expt 18), Maris Piper (Expt 19) and Saturna (Expt 20) in 1987*

	Seed weight ±2·5 (g)	Within-row spacing (cm) and (in parentheses) seed rate (t/ha)							
		60	45	30	20	15	10		
	12·5	(0·29)	(0·39)	(0·59)	(0·88)	(1·17)	(1·76)		
	37·5	(0·88)	(1·17)	(1·76)	(2·64)	(3·52)	(5·28)	Mean	S.E.
					Expt 18				
> 30 mm	12·5	22·7	35·6	32·4	40·6	39·0	43·8	35·7	
	37·5	34·9	34·6	38·8	50·1	40·0	37·7	39·4	
	Mean	28·8	35·1	35·6	45·3	39·5	40·8		1·90
	S.E.			2·69				1·10	
> 50 mm	12·5	16·7	20·5	13·9	19·5	16·2	5·7	15·4	
	37·5	19·0	18·1	17·5	15·5	4·4	1·4	12·7	
	Mean	17·9	19·3	15·7	17·5	10·3	3·5		1·73
	S.E.			2·45				1·00	
					Expt 19				
> 30 mm	12·5	26·3	31·9	35·0	32·6	32·9	47·9	34·5	
	37·5	32·6	37·2	38·7	38·9	42·9	43·2	38·9	
	Mean	29·5	34·6	36·9	35·8	37·9	45·5		1·50
	S.E.			2·12				0·87	
> 50 mm	12·5	19·9	19·5	19·6	18·6	9·8	15·5	17·2	
	37·5	19·9	22·9	11·7	11·4	6·4	7·5	13·3	
	Mean	19·9	21·2	15·7	15·0	8·1	11·5		1·32
	S.E.			1·87				0·77	
					Expt 20				
> 30 mm	12·5	42·1	47·1	53·3	49·4	55·2	56·8	50·6	
	37·5	43·6	50·5	57·0	60·9	63·7	62·4	56·3	
	Mean	42·8	48·8	55·1	55·2	59·4	59·6		1·46
	S.E.			2·07				0·84	
40–70 mm	12·5	35·9	42·8	47·0	39·9	46·5	44·1	42·7	
	37·5	37·9	44·3	49·9	50·3	50·5	40·8	45·6	
	Mean	36·9	43·6	48·5	45·1	48·5	42·4		1·60
	S.E.			2·27				0·93	

Error D.F. (Expts 18–20) = 22.

practices and those to be adopted in the succeeding ware phase. As there is clearly no physiological or agronomic reason why seed should not be produced in the traditional ware-producing areas, the present regulations for certified seed should be reconsidered. The removal of the area requirements for many grades and their replacement with more detailed standards relating to the actual health of the seed would be sensible. Wherever seed is produced, the seed producer must have a clear understanding of the needs of the ware producer if he is to produce the required seed.

Although there were few differences in tuber yield between sources at different sites of ware production, in Wilja there were large differences between sites in the weight and dimensions of tubers from the same size grade. Tubers from the peat soils at Engine Farm were substantially longer and heavier than tubers from the mineral soils at CUF. This effect of site has been found in other cultivars (e.g. Maris Piper) in experiments at Cambridge (Burstall *et al.* 1987) and such differences in weight and shape of tubers in the same size grade have implications for the processing and retail trades.

A difficulty in the use of number of above-ground stems as a measure of stem density is illustrated by the variation in the number of above-ground stems between sites in Expts 9–14 as a result of variation in the number of secondary stems. The results suggest that the number of above-ground stems produced was greatly influenced by depth of planting of the seed-tubers which may account for some of the variation in the number of stems frequently observed in experiments on different sites and in different seasons.

In ware crops grown from seed-tubers planted in July in Expts 9–20, seed-tuber weight (ranging from

12·5 to 37·5 ± 2·5 g and averaged over other treatments) had no effect on ware yields in Record in four experiments, in Saturna in Expt 13 or in Wilja in Expt 18. However, at similar spacings, yields were higher from larger seed in Wilja in Expts 9 and 10, in Saturna in Expt 14, in Maris Piper in Expt 19 and in Saturna in Expt 20. In all experiments, number of mainstems and consequently above-ground stems increased with increasing planting density (increasing seed weight and decreasing within-row spacing) over the whole range. However, number of tubers per mainstem decreased with increasing stem density so that effects of planting density on number of tubers were substantially smaller than on number of stems and were frequently absent. An understanding of the relationship between number of stems and number of tubers requires a knowledge of changes in number of tubers per stem. In the present experiments, variation in number of tubers per mainstem was usually small when between *c*. 47000 and 70000 seed-tubers were planted per hectare (20–30 cm within-row spacing); however, changes in plant density above and below this range caused greater variations in the number of tubers per mainstem. In most experiments only small differences in saleable tuber yield were found for a very wide range of planting densities. The virtual absence of effects of density in Record in Expts 16 and 17 substantiates the findings of many other unpublished experiments in East Anglia that in this cultivar saleable yield is less affected by changes in planting density than in other cultivars. The results suggest that for both weights of seed in Record, plant densities of 70000/ha are sufficient for maximum tuber yields but higher densities may be more appropriate if larger tubers are to be avoided as the number of tubers increases over the whole range of spacings. In Saturna and Wilja, for both weights of seed tubers, plant densities of no more than 47000 and 70000/ha, respectively, would appear to be sufficient for maximum yields. These equate to seed rates of 0·88 and 2·64 t/ha in Wilja (and Record) and 0·59 and 1·76 t/ha in Saturna for tubers weighing on average 12·5 and 37·5 g, respectively. These seed rates for Record and Wilja are substantially lower than those currently recommended (MAFF 1982) for seed tubers graded *c*. < 50 g, but are similar to those found for similar yields and seed weights in Record elsewhere (Allen & O'Brien 1987; Wurr *et al*. 1990).

In Wilja and Record, consistent numbers of mainstems were produced by seed weighing < 25 g from July-planted seed crops, and the smallest seed produced very close to one mainstem per seed-tuber. Such seed would, therefore, appear to be suitable for establishing consistent mainstem densities, whereas with larger seed the number of sprouts which grew into mainstems was more variable and therefore may not produce such consistent stem densities. This, together with the lower optimum seed rates for small seed, suggests that improvements and economies in potato production would result from a reduction in the minimum size grade for seed-tubers that may legally be sold in the UK.

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