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An analysis of the effects of seed weight, seed rate and date of harvest on the yield and economic value of seed-potato crops

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SUMMARY

Five experiments were carried out in two seasons which studied the effects of seed weight, seed rate and date of harvesting on yield of seed crops of Record (four experiments) and Maris Piper (one experiment) in Scotland. Small seed (35 g) produced more above-ground stems and tubers and higher seed yields at equal seed rates than large seed (105 g). Increasing seed rate with both seed weights increased yield of seed-size tubers. The value of the seed crop was measured as the number of ware hectares which could be replanted from the yield of 20–55 mm tubers and calculated using recommended seed rates (Ministry of Agriculture, Fisheries and Food, 1982). Small seed produced more replantable hectares than large seed at equal seed rates in all experiments with Record and increasing seed rate increased the number of replantable hectares. However, when seed retained for replanting at the same seed rate was taken into account, small seed produced more replantable hectares only when total yield reached approximately 40 t/ha. Seed yield was much higher in Maris Piper than in Record and effects of seed weight were small. Increasing seed rate increased the number of replantable ware hectares but the effect was much reduced after retention of seed for replanting.

The effect of pricing policy for seed and ware on returns to the seed grower was also established. The sale of seed (and ware tubers) at fixed prices per tonne produced lower returns than selling seed at varying prices per tonne in relation to tuber size and equivalent to a fixed ware cost per hectare planted especially where seed yields were high. Delaying harvesting increased sale value but crops reached 85–90% of the final value before many oversize tubers (> 55 mm) were found and large yields of such tubers from low seed rates produced lower returns than from increased seed rates.

The number of ware hectares produced per seed hectare (even net of seed retained for replanting) was high especially in Maris Piper. The results show that the area devoted to seed potato production in U.K. is much too high for the ware area and the significance for the future of seed production is discussed.

INTRODUCTION

There are several reports which show that economic optimum seed rates for ware potatoes decrease with decreasing seed size (Jarvis, 1971; Jarvis & Shotton, 1971; Allen, 1978). If seed is purchased at a fixed price per tonne, irrespective of size, greater returns frequently result from the use of smaller seed, as yield is not affected as much by size of tubers as by number of tubers planted over the whole legal seed range (25–55 mm or 20–130 g). Alternatively, a higher price may be paid per tonne of small seed than large seed while achieving similar returns from the crop. In Holland, the price of seed is inversely related to the size of the seed but in the United Kingdom a considerable amount of seed is sold at a fixed price per tonne with little regard to the constituent tuber sizes. For ware production, efficient use of seed can be achieved only by relating seed rate to size and number of seed tubers planted and there is considerable advantage in using smaller seed as a smaller total quantity of seed would be required with consequent savings in handling, transport, storage and planting time. However, in many seed crops a proportion of over-size (ware) tubers are usually produced and the average size of the seed tubers is frequently close to the upper limit of the seed fraction. Increases in seed rate and/or carefully timed defoliation could ensure that few over-size tubers were produced but the economic implications of such changes and indeed of the economics of seed production generally are

Table 1. *Details of sites, husbandry practised and dates of harvesting*

Experiment	Grower and location	Soil type	Fertilizer (kg/ha) N	Fertilizer (kg/ha) P	Fertilizer (kg/ha) K	Row width (cm)	Date of planting	Herbicide	Irrigation	Dates of harvesting
1 (Record)	Mr A. Logan, Kilduncan, St Andrews, Fife	Sandy clay loam	188	81	220	81	17. iv. 81	Gramoxone	—	29. vii 12. viii 25. viii
2 (Maris Piper)	Mr G. Middleton, Montrose, North Angus	Loamy sand	188	81	220	76	14–15. iv. 81	—	—	14. vii 28. vii 11. viii
3 (Record)	Mr A. Logan, Kilduncan, St Andrews, Fife	Silty loam	150 +FYM	64	175	81	30. iv. 82	Gramoxone and linuron	✓	14. vii 28. vii 12. viii
4 (Record)	Mr D. Russell, Kinross	Sandy loam and deep litter manure from poultry	150	64	175	76	28. iv. 82	Gramoxone	—	15. vii 29. vii 10. viii
5 (Record)	Mr J. Millar, Brechin, Angus	Sandy loam	169	73	178	76	29. iv. 82	Gramoxone	—	14. vii 28. vii 11. viii

Table 2. *Seed-rate treatments in each experiment*

Experiment	Seed weight (g)	Seed rates (t/ha)							
		1·08	1·44	1·91	2·87	4·31	5·74	7·18	8·61
1	35	—	✓	✓	✓	✓	✓	—	—
	105	—	—	—	✓	✓	✓	✓	✓
3	35	—	—	—	—	—	—	—	—
	105	—	—	—	—	—	—	—	—
		Seed rates (t/ha)							
		1·15	1·53	2·04	3·06	4·59	6·12	7·66	9·19
2	35	—	✓	✓	✓	✓	✓	—	—
	105	—	—	—	✓	✓	✓	✓	✓
4, 5	35	✓	✓	✓	✓	✓	✓	—	—
	105	—	—	✓	✓	✓	✓	✓	✓

difficult to establish as there are few published data relating to graded yields of seed crops grown in seed-producing areas. In this paper the results of five experiments which studied the effects of seed weight, seed rate and date of harvesting on graded yields of two varieties on five sites in Scotland are reported. In each experiment three harvests were taken and tubers graded into narrow fractions so that the effects of delaying harvest on the economic returns from the seed crops could be established.

THE EXPERIMENTS

Five experiments were carried out on different sites in Scotland, two in 1981 (varieties Record and Maris Piper) and three in 1982 (Record). The details of sites and general husbandry are given in Table 1. In all cases the cultivations, fertilizer application and ridging were carried out by the farmer and the experimental area was left ridged by passage of the planter with the planting mechanism disengaged. The rows were therefore contiguous with field rows and all post-planting operations were carried out by the farmer. Planting was by hand into the shallow ridges which were re-shaped by hand hoeing where necessary. Treatments comprised two seed weights, 35 and 105 g (weighed ± 10%) planted at 5 (1981) or 6 (1982) within-row spacings and replicated three times in a randomized-block design. The spacings were 40 (1982 only), 30, 22·5, 15, 10 and 7·5 cm for 35 g seed and 60 (1982 only), 45, 30, 22·5, 18 and 15 cm for 105 g seed, producing a wide range of seed rates which overlapped at four seed rates. The seed rates for each site are given in Table 2. In each year seed was selected from unsprouted tubers of one seed crop of FS1 (Record 1981) or FS2 grade shortly before planting. Some limited sprout growth occurred between selection and completion of planting in 1982.

The plots were 13·2 m long comprising three harvest areas of 3·6 m and three rows wide. The harvests began before any tubers exceeded 50 mm in even the lowest seed rates. At each harvest the above-ground stems were counted in each harvest area and the tubers dug by hand.

RESULTS

Tuber yields were much higher in 1981 than in 1982 and the results of the two experiments with Record at Kilduncan (Expts 1 and 3) are used to illustrate the major effects. The data for the remaining three experiments are summarized in Appendix Tables 1–10 and any important differences between the groups of experiments are referred to specifically in the text.

Number of stems

There were relatively few secondary stems in any treatment and the number of above-ground stems (and mainstems) increased linearly with increasing seed rate in both seed weights (Table 3). At equal seed rates, small seed produced significantly more stems than large seed. In Record there was little effect of site on the number of stems produced by each seed rate. Maris Piper produced more stems than Record.

Number of tubers

In all experiments the total number of tubers increased linearly with increasing density (seed rate or number of stems) (Table 4). At equal seed rates small seed produced more tubers than large seed but there was little effect of seed weight at equal mainstem or above-ground stem densities. At Kilduncan small seed produced substantially more tubers in Expt 1 than in Expt 3 at all seed rates. In 1982 both seed weights at Kilduncan produced fewer tubers than at the other two sites

Table 3. *Effect of seed weight and seed rate on number of mainstems and above-ground stems in Expts 1 and 3*

	Seed weight (g)	Seed rate (t/ha) 1·08	1·44	1·91	2·87	4·31	5·74	7·18	8·61	S.E.
		No. of mainstems ('000s/ha)								
Expt 1	35	—	89	120	185	249	347	—	—	8·1
	105	—	—	—	96	120	131	198	216	
Expt 3	35	80	116	142	212	329	420	—	—	15·0
	105	—	—	97	130	205	262	353	395	
		No. of above-ground stems ('000s/ha)								
Expt 1	35	—	104	132	197	252	358	—	—	8·6
	105	—	—	—	107	139	178	217	238	
Expt 3	35	82	118	146	226	348	423	—	—	14·2
	105	—	—	99	132	208	267	368	412	

Table 4. *Effect of seed weight and seed rate on total number of tubers ('000s/ha) in Expts 1 and 3 (first harvests)*

	Seed weight (g)	Seed rate (t/ha) 1·08	1·44	1·91	2·87	4·31	5·74	7·18	8·61	S.E.
Expt 1	35	*	556	604	770	936	1083	—	—	
	105	*	—	—	497	639	658	822	830	46·0
Expt 3	35	316	406	520	607	734	809	—	—	46·9
	105	—	—	346	493	613	660	875	889	

* Seed rate not used.

which were remarkably similar (Table 4 and Appendix Table 1). Large seed produced similar numbers of tubers in the 2 years at Kilduncan.

Maris Piper produced more tubers than Record; its lowest densities produced almost as many tubers as the highest densities of Record (Appendix Table 1).

Tuber yield

In Expt 1 the effect of increasing seed rate of either seed weight on total yield was relatively small (Table 5). At the lowest equal seed rate small seed produced greater total yield than large seed at all harvests. Yields of seed-size fractions, 20–32 and 32–40 mm, increased with increasing seed rate at all harvests and at equal seed rates small seed always outyielded large seed. Yields of these sizes decreased between harvests. Yields of larger tubers (40–55 mm) increased between harvests at the higher seed rates of both seed weights. Increasing seed rate with small seed had little effect on yields of this size at the first harvest but at subsequent harvests and for large seed throughout, increasing seed rate increased yield of large seed tubers over much of the range. At equal seed rates, small seed produced higher yield than large seed at the later harvests. Yield of over-size tubers was substantial only at low densities at final harvest when yield decreased with increasing seed rate and at equal seed rates large seed produced higher yield than small seed.

In Expt 3 yields were much smaller than in Expt 1 and at final harvest only approached the yields achieved at the first harvest in Expt 1 (Table 6). The effect of increasing seed rate was much greater at these lower yields than in Expt 1, as would be expected. Total yield increased with increasing seed rate over the whole range at the first harvest and much of the range at the two subsequent harvests. At the first two harvests, yields of the smaller seed-size fractions increased with initial increases in seed rate and then decreased in both seed weights. At final harvests yield of these tubers increased over the whole range of seed rates in both seed weights and at all harvests at equal seed rates small seed produced higher yield than large seed. Yield of small seed sizes increased between the first two harvests and decreased slightly between the final two harvests. Yield of larger seed increased with delay in harvesting but at final harvest seed rate had little effect on yield in either seed weight. Only a few over-size tubers

Table 5. *Effect of seed weight and seed rate on tuber yield (t/ha), Expt 1*

	Seed weight (g)	Seed rate (t/ha) 1·44	1·91	2·87	4·31	5·74	7·18	8·61	S.E.
				First harvest (29. vii)					
Total	35	38·0	36·8	40·1	41·6	41·3	—	—	1·36
	105	—	—	33·3	43·3	37·6	41·8	42·0	
> 40 mm	35	30·9	28·5	27·5	24·4	19·6	—	—	1·93
	105	—	—	26·5	35·4	28·2	30·2	29·3	
20–32 mm	35	1·2	1·4	2·1	2·7	3·7	—	—	0·36
	105	—	—	1·1	1·1	1·1	1·6	1·9	
32–40 mm	35	5·8	6·8	10·4	14·3	17·7	—	—	0·91
	105	—	—	5·6	6·7	8·2	9·8	10·5	
40–55 mm	35	26·3	26·3	24·7	23·2	19·1	—	—	1·43
	105	—	—	20·4	28·8	26·9	28·4	27·7	
				Second harvest (12. viii)					
Total	35	46·7	50·2	56·6	55·8	53·0	—	—	2·24
	105	—	—	48·9	56·7	50·5	55·6	55·3	
> 40 mm	35	43·0	43·4	49·0	42·8	36·4	—	—	2·49
	105	—	—	45·6	51·5	43·0	47·0	46·5	
20–32 mm	35	0·9	0·9	1·1	1·9	2·3	—	—	0·23
	105	—	—	0·6	0·9	1·1	1·6	1·4	
32–40 mm	35	3·6	5·7	6·3	10·8	13·9	—	—	0·70
	105	—	—	2·7	4·1	6·2	6·8	7·1	
40–55 mm	35	23·1	25·1	34·4	35·9	31·0	—	—	2·13
	105	—	—	22·3	28·0	30·9	34·2	35·4	
				Third harvest (25. viii)					
Total	35	54·9	58·9	63·1	62·0	57·7	—	—	3·20
	105	—	—	56·4	63·7	58·5	56·4	58·3	
> 40 mm	35	50·6	54·2	56·3	51·3	42·6	—	—	3·26
	105	—	—	53·7	59·0	52·7	49·5	50·1	
20–32 mm	35	0·9	0·9	1·5	1·8	2·9	—	—	0·26
	105	—	—	0·5	1·1	1·1	1·3	1·4	
32–40 mm	35	3·4	3·8	5·2	8·7	12·0	—	—	0·59
	105	—	—	2·1	3·5	4·6	5·5	7·1	
40–55 mm	35	20·5	28·3	36·3	39·3	34·9	—	—	2·08
	105	—	—	18·5	24·2	30·3	33·3	34·9	
> 55 mm	35	30·1	25·9	20·1	12·0	7·7	—	—	3·05
	105	—	—	35·3	34·8	22·4	16·2	15·2	

(> 55 mm) were found at the final harvest when low seed rates produced larger yield than higher seed rates of both seed weights. Effects in Expts 4 and 5 were similar to those in Expt 3 (Appendix Tables 3 and 4).

Maris Piper produced much higher seed yield than Record in 1981 (Appendix Table 2) and even at the final harvest most of the total yield was within the seed fraction. Yield of individual seed sizes increased with increasing seed rate at all harvests but differences between seed weights at equal seed rates were smaller than in Record. There was, however, a consistently large increase in total yield from the first increase in seed rate only where large seed was used. As with Record the effect of the wide range of seed rates on total yield was quite small.

Value of seed crops

In most previous analyses of the effects of different seed rates on financial returns it has been usual to use the ratio of seed : ware price as a means of creating a range of economic circumstances so that economic optimum seed rates may be calculated (Ministry of Agriculture, Fisheries and Food, 1982). A ratio of 2 : 1 is usually taken as normal and a similar approach could be taken with the current

Table 6. *Effect of seed weight and seed rate on tuber yield (t/ha), Expt 3*

	Seed weight (g)	Seed rate (t/ha) 1·08	1·44	1·91	2·87	4·31	5·74	7·18	8·61	S.E.
First harvest (14. vii)										
Total	35	6·1	8·0	10·2	10·4	12·4	13·1	—	—	0·89
	105	—	—	5·9	10·4	11·1	12·5	14·3	14·5	
> 40 mm	35	0·1	0·1	0·6	0·3	0·2	0·5	—	—	0·16
	105	—	—	0·2	0·3	0·2	0·1	0·3	0·2	
20–32 mm	35	2·7	3·6	4·5	5·3	6·5	7·9	—	—	0·44
	105	—	—	3·2	4·5	5·4	5·9	8·3	8·6	
32–40 mm	35	3·1	4·0	4·7	4·3	5·0	4·2	—	—	0·69
	105	—	—	2·3	5·3	5·0	6·0	5·0	5·1	
Second harvest (28. vii)										
Total	35	15·5	17·9	20·6	24·0	22·9	25·1	—	—	1·43
	105	—	—	19·8	23·0	22·8	26·3	28·0	26·0	
> 40 mm	35	8·9	10·8	9·2	10·5	6·7	8·0	—	—	1·36
	105	—	—	12·8	12·5	8·3	10·2	6·4	5·8	
20–32 mm	35	1·7	1·9	2·7	3·0	5·0	6·1	—	—	0·41
	105	—	—	1·6	2·4	3·5	4·2	5·6	6·7	
32–40 mm	35	4·7	5·1	8·4	10·4	10·8	10·5	—	—	1·17
	105	—	—	5·3	7·9	10·8	11·5	15·5	13·1	
40–55 mm	35	8·3	10·8	9·2	10·5	6·7	8·0	—	—	1·35
	105	—	—	11·8	12·5	8·3	10·0	6·4	5·8	
Third harvest (12. viii)										
Total	35	26·3	31·6	31·8	37·3	33·2	34·8	—	—	1·81
	105	—	—	30·7	34·8	35·4	34·7	40·6	39·2	
> 40 mm	35	21·4	24·2	23·6	27·9	19·7	18·7	—	—	2·24
	105	—	—	26·2	27·5	24·2	20·9	24·1	22·0	
20–32 mm	35	0·9	1·1	2·3	2·0	3·1	4·8	—	—	0·34
	105	—	—	0·9	1·8	2·5	3·4	3·8	3·9	
32–40 mm	35	4·0	6·1	5·7	7·1	10·0	10·7	—	—	0·70
	105	—	—	3·3	5·3	8·4	10·0	12·2	12·7	
40–55 mm	35	16·1	16·8	20·5	23·0	18·8	17·9	—	—	1·76
	105	—	—	18·5	23·7	22·4	20·2	22·1	20·3	
> 55 mm	35	5·3	7·4	3·1	4·9	0·9	0·8	—	—	1·22
	105	—	—	7·6	3·8	1·8	0·7	2·0	1·7	

data as at this stage in seed multiplication, the cost of seed will exceed the price realized for the seed produced. However, in practice the seed:ware price ratio is a very difficult relationship to quantify accurately as the seed and ware prices may refer to two consecutive and frequently very different trading seasons. The seed price is influenced by the prevailing ware price and for the seed grower influences his seed cost for the following year. The seed grower also requires knowledge of the following year's seed price to use the relationship for his subsequent production. Use of the relationship requires knowledge of the following year's ware crop prices. If a year of low seed prices is followed by a year of high ware prices it is possible for ware to be worth more than seed; J. N. Bean and E. J. Allen (unpublished data) have shown that this frequently occurs in early potato crops. As a consequence of these difficulties, many ware growers prefer to take a fixed figure as cost of seed per ware acre for calculating economic returns. If this figure is fixed and seed rate is determined by seed weight, the price per tonne of seed is meaningful only if it is also related to the average weight of a seed tuber, in practical terms number of tubers per 50 kg. Ware growers may therefore either always use seed of a specific size (allowing constant within-row spacing) or more commonly adjust within-row spacing according to the number of seed tubers per 50 kg. There may be large changes

Table 7. *Effect of seed rate, seed weight and date of harvest on number of replantable hectares, Expts* 1 *and* 3

Date of harvest	Seed weight (g)	Seed rate (t/ha) 1·08	1·44	1·91	2·87	4·31	5·74	7·18	8·61	S.E.
					Expt 1 (1981)					
29. vii	35	*	12·8	13·6	15·4	17·4	18·5	—	—	0·56
12. viii		*	10·2	12·0	15·6	19·3	19·6	—	—	0·87
25. viii		*	9·1	11·9	15·9	18·9	20·4	—	—	0·64
29. vii	105	*	—	—	10·6	14·2	14·2	16·0	16·5	0·56
12. viii		*	—	—	9·1	11·9	14·3	16·1	16·7	0·87
25. viii		*	—	—	7·5	10·5	13·2	14·9	16·3	0·64
					Expt 3 (1982)					
14. vii	35	3·7	5·0	6·3	6·6	7·9	8·8	—	—	0·53
28. vii		6·6	7·8	9·6	11·2	11·8	13·0	—	—	0·60
12. viii		8·2	9·7	11·7	13·0	14·0	15·5	—	—	0·53
14. vii	105	—	—	3·8	6·4	7·0	7·9	9·5	9·7	0·53
28. vii		—	—	7·9	10·2	11·1	12·7	14·5	14·0	0·60
12. viii		—	—	8·5	12·1	13·9	14·6	16·8	16·6	0·53

* Seed rate not used.

in price per tonne and seed rate without altering either the ware growers' seed costs or the return from the crop. If differential pricing of seed is accepted, the real value of the seed in a crop is the number of hectares of an optimum yielding ware crop which may be planted from the progeny tubers from one hectare of seed crop. This may be calculated as:

$$\Sigma \frac{\text{yield of seed in individual size fraction}}{\text{optimum ware seed rate for size fraction}}.$$

This has been calculated for all experiments using the size fractions 20–32, 32–40, 40–50 and 50–55 mm and the recommended seed rates for ware crops of Record (Ministry of Agriculture, Fisheries and Food, 1982). A bottom limit of 20 mm rather than the legal 25 mm is used because the rigorous hand grading resulted in tubers falling in grades 5 mm less than would occur in commercial harvesting and grading. For all size fractions, the average number of tubers per 50 kg was calculated from the data and the appropriate seed rate selected; for the smallest seed (20–25 and 25–32 mm) the number of tubers was 2000–4500 per 50 kg. These counts are beyond the range of the Ministry of Agriculture, Fisheries and Food (1982) recommendations and the conservative seed rate rate of 1·2 t/ha was used for both grades. The results of these calculations of number of replantable hectares are shown in Table 7 and Appendix Tables 5 and 6. The number of replantable hectares increased with increasing seed rate at all harvests and at equal seed rates small seed produced more replantable hectares than large seed. In Expt 1 delaying harvesting reduced the number of replantable hectares at low seed rates and produced only small increases at high seed rates. In Expt 3 when harvesting began at very low yields, delaying harvesting increased the number of replantable hectares at all seed rates. In Expt 1 the number of replantable hectares was close to its maximum in all treatments before many tubers were larger than 55 mm. In Maris Piper (Appendix Table 5) the number of replantable hectares was much larger than in Record for all seed rates but generally increased with increasing seed rate with both seed weights and in most comparisons small seed produced more replantable hectares than large seed at equal seed rates.

At many stages in seed multiplication seed is retained for replanting in the following year and by taking account of the seed retained (in terms of the hectares of ware crop which are sacrificed) the saleable value of the seed in a crop to the seed producer can be estimated. In Table 8 the results for Expts 1 and 3 are shown and the number of replantable hectares produced by high seed rates of small seed is markedly reduced (as the retained seed would plant many more hectares of ware crop than of the seed crop). As a consequence the number of replantable hectares increases over only part of the range of increasing seed rate for both seed weights at the first two harvests in Expt 1. At the final harvest in both seed weights the number of replantable hectares still increased over the whole range of seed rates. Delaying harvest increased the number of replantable hectares at high seed rates of small seed but decreased the number at low seed rates. With large seed, the number decreased with

Table 8. *Effect of seed rate, seed weight and date of harvest on number of replantable hectares net of seed retained for replanting at same seed rate), Expts 1 and 3*

Date of harvest	Seed weight (g)	Seed rate (t/ha) 1·08	1·44	1·91	2·87	4·31	5·74	7·18	8·61	S.E.
					Expt 1					
29. vii	35	*	11·6	12·0	13·0	13·8	13·7	—	—	0·56
12. viii		*	9·0	10·4	13·2	15·7	14·8	—	—	0·87
25. viii		*	7·9	10·3	13·5	15·3	15·6	—	—	0·64
29. vii	105	*	—	—	9·8	12·8	12·5	13·8	13·8	0·56
12. viii		*	—	—	8·2	10·6	12·6	13·9	14·1	0·87
25. viii		*	—	—	6·6	9·2	11·5	12·7	13·7	0·64
					Expt 3					
14. vii	35	2·9	3·8	4·7	4·2	4·3	4·0	—	—	0·53
28. vii		5·8	6·6	8·0	8·8	8·2	8·2	—	—	0·60
12. viii		7·4	8·5	10·1	10·6	10·4	10·7	—	—	0·53
14. vii	105	—	—	3·1	5·5	5·7	6·2	+	+	0·53
28. vii		—	—	7·2	9·3	9·8	11·0	12·3	11·4	0·60
12. viii		—	—	7·8	11·1	12·6	12·9	14·6	14·0	0·53

* Seed rate not used.
\+ Treatments did not produce sufficient large seed to allow retention of necessary seed.

delay in harvest at all except the highest seed rate where there was no change. In this experiment small seed always produced more replantable hectares (net of seed retained) at equal seed rates than large seed. However, with lower yields in Expts 3–5 effects were different (Table 8 and Appendix Table 7). At early harvests the number of replantable hectares produced by small seed initially increased with seed rate and then decreased while at final harvest the number remained constant at the higher seed rates. With large seed the number of replantable hectares increased over most of the range of seed rates at all harvests and at equal seed rates large seed produced more replantable hectares than small seed. These results suggest that when yields are low seed growers should retain large seed while selling small seed. (In higher-yielding years retention of over-size tubers would allow the sale of more ware hectares from the seed-size fractions.) Delaying harvest increased the number of replantable hectares for all seed rates of both seed weights.

In arriving at the total value of seed crops account must also be taken of the over-size tubers which may be produced. In Table 9 and Appendix Table 8 the total sale value has been calculated by adding the sales of over-size tubers (> 55 mm) at £70/t to the replantable hectares (net of seed retained) at £300/ha. In Expt 1 sale value increased only with the first two increments in seed rate with small seed and the first increment with large seed. Delaying harvest increased sale value at a decreasing rate in all treatments and at equal seed rates small seed produced higher value crops than large seed. In Expt 3 sale values increased with delay in harvest but were still lower at final harvest than at the beginning of harvesting in Expt 1. Effects of increasing seed rate were similar to Expt 1 with small seed; however, in large seed sale values increased over much of the range of seed rates and at equal seed rates large seed produced higher sale values than small seed.

In Maris Piper (Appendix Table 9) sale values were much higher than in Record and delaying harvesting increased sale values in all seed rates. Initial increases in seed rate of both seed weights increased sale values but further increases had little effect. At equal seed rates large seed produced higher sale values than small seed.

The adoption of valuing seed according to its size has been resisted by many seed growers because they believe their total returns will be reduced. In Table 10 and Appendix Tables 9 and 10 the sale value of the crops based on selling seed at a fixed price (£100) per tonne and over-size tubers at £70/t are shown. A price of £100/t is equivalent to £300/ha at the recommended seed rates of more than 3 t/ha of most seed sizes for well grown crops of Record destined for processing (Ministry of Agriculture, Fisheries and Food, 1982). Where seed-size tubers constituted the majority of the yield, throughout all experiments in 1982, Expt 2 and the early harvests in Expt 1, selling at a fixed price reduced the sale value of the crop compared

Table 9. *Effect of seed rate, seed weight and date of harvesting on sale value* (£) of crop net of retained seed, Expts 1 and 3*

Date of harvesting	Seed weight (g)	Seed rate (t/ha) 1·08	1·44	1·91	2·87	4·31	5·74	7·18	8·61	S.E.
					Expt 1					
29. vii	35	†	3792	3760	4107	4240	4145	—	—	149
12. viii		†	4097	4404	4985	5184	4813	—	—	192
25. viii		†	4477	4899	5441	5444	5208	—	—	259
29. vii	105	†	—	—	3350	4312	3844	4254	4261	149
12. viii		†	—	—	4086	4841	4627	5078	5008	192
25. viii		†	—	—	4449	5212	5014	4952	5172	259
					Expt 3					
14. vii	35	883	1138	1400	1273	1290	1200	—	—	159
28. vii		1777	1988	2405	2646	2466	2469	—	—	178
12. viii		2575	3065	3242	3508	3170	3268	—	—	153
14. vii	105	—	—	943	1643	1708	1857	2176	2121	159
28. vii		—	—	2243	2794	2952	3318	3698	3432	178
12. viii		—	—	2880	3597	3904	3917	4512	4309	153

* Seed valued at £300/replantable hectare and yield > 55 mm at £70/t.
† Seed rate not used.

Table 10. *Effect of seed rate, seed weight and date of harvesting on sale value* (£) of crop net of retained seed, Expts 1 and 3*

Date of harvesting	Seed weight (g)	Seed rate (t/ha) 1·08	1·44	1·91	2·87	4·31	5·74	7·18	8·61	S.E.
					Expt 1					
29. vii	35	†	3654	3610	3912	4102	4088	—	—	119
12. viii		†	4162	4451	5204	5345	5102	—	—	181
25. viii		†	4580	5107	5696	5817	5524	—	—	251
29. vii	105	†	—	—	3141	4121	3707	4109	4124	119
12. viii		†	—	—	4183	4945	4667	5157	5170	181
25. viii		†	—	—	4577	5315	5168	5142	5401	251
					Expt 3					
14. vii	35	586	774	986	994	1170	1256	—	—	89
28. vii		1519	1782	2040	2388	2250	2463	—	—	143
12. viii		2470	2929	3075	3558	3253	3399	—	—	163
14. vii	105	—	—	566	1003	1061	1209	1361	1383	89
28. vii		—	—	1946	2291	2261	2592	2758	2563	143
12. viii		—	—	2816	3357	3459	3411	3954	3816	163

* Seed 20–55 mm valued at £100/t and tubers > 55 mm at £70/t.
† Seed rate not used.

with selling at prices related to tuber size and equivalent to a fixed cost per ware hectare planted. This was most important in Maris Piper as a consequence of its high yield of seed and fixed price selling reduced the value of most crops in this variety by at least 25%. Effects of seed rate, seed weight and date of harvesting were not materially altered by the change in valuation of the crop.

DISCUSSION

The results cover a wide range of total and seed yields and allow current practices in seed production to be evaluated. In Record, small seed produced more stems, tubers, seed yield and gross replantable hectares than large seed at equal seed

Table 11. *Areas of certified seed in United Kingdom and of ware potatoes in Great Britain* (*Potato Marketing Board*, 1986)

Year	Seed area (ha)	Ware area (ha)	Ratio ware: previous year's seed
1964	49851	220234	
1965	41246	221425	4·44
1966	33189	203873	4·94
1967	34618	213516	6·43
1968	34473	211747	6·12
1969	31200	185947	5·39
1970	33635	204997	6·57
1971	31289	194454	5·78
1972	28495	179967	5·75
1973	25971	170443	5·98
1974	24177	165216	6·36
1975	23370	156804	6·49
1976	23847	171098	7·32
1977	29774	169586	7·11
1978	31448	152487	5·12
1979	32431	156669	4·98
1980	31347	159653	4·92
1981	28697	149903	4·78
1982	28742	150458	5·24
1983	27992	154708	5·38
1984	27765	157235	5·62
1985	26212	152788	5·50

rates. Increasing seed rate had only small effects on total yield in Expt 1 but increased total yields over the whole range for both seed weights at all harvests in Expt 3 when yields were lower than in Expt 1. However, increasing seed rate with both seed weights increased gross replantable hectares at all harvests in both experiments. The advantages of small seed were markedly reduced (Expt 1) or reversed (Expt 3) once the retention of seed for future planting was considered. The method of calculation penalized the high seed rates severely as growers would rarely plant at these rates and net replantable hectares increased over part of the range of seed rates at all harvests in Expt 3 and only increased over the whole range when total yields reached more than 50 t/ha at the third harvest in Expt 1. The results for Expt 3 showed that where total yields are low and almost all tubers are within the seed fraction, seed growers should retain the larger tubers for their own replanting and sell the more valuable small seed to ware producers. Individual seed growers may view the retention of seed for replanting in different ways; clearly retaining large tubers rather than seed-size tubers would reduce the cost to the seed grower.

The net multiplication rates in Record exceeded ten throughout harvesting in Expt 1 and at final harvest in Expt 3 and reached values twice as great in Maris Piper as a consequence of the high yield of largely seed-size tubers in this variety. These figures would suggest that the current seed area is grossly excessive in relation to the total potato area. In Scotland alone in 1983 20330 ha were certified for seed when the total potato area in Great Britain was 182700 ha (Potato Marketing Board, 1986). This suggests a gross multiplication rate of approximately nine. Of course, some of the seed produced in Scotland is exported from U.K. but 7661 ha of seed were certified in the rest of the U.K., seed is imported from Holland and Eire and some seed was produced on ware farms for their own consumption. Thus the real multiplication rate is much lower and Table 11 shows the relationship between the ware area in Great Britain and the previous year's seed area for U.K. from 1964 to 1985. Despite a large decrease in overall area devoted to potatoes and an increase in yield, the ratio of ware to seed has not changed materially and has not exceeded 8 in any period, a result which suggests no improvement in real yield of seed per hectare over this period. Overall, it seems an inescapable conclusion that the area devoted to seed production is far too great. As Maris Piper is the most heavily planted variety the results show that a large reduction in the seed area would be immediately possible.

Recent evidence (Allen, 1978 and unpublished data) has shown the importance of using seed according to size and the suitability of smaller seed for ware production. As a result the demand for the type of seed production envisaged in this analysis has been created. In meeting this demand the seed producer should see the advantages to him in such a system. In these experiments selling seed at a fixed price per tonne reduced the value of the crop especially where seed yields were high and the major part of the total yield. In Maris Piper and others which set many tubers, most seed crops are likely to have a large yield of seed and their value will be maximized only by selling the crop according to its constituent sizes. Only where there were many over-size tubers were there no differences between pricing methods in selling the crop. The view that over-size tubers are essential to the profitability of the crop is also erroneous. Returns, however calculated, were lower from seed rates producing the highest yields of over-size tubers than from higher seed rates which in most cases could be defoliated earlier. It was found that the continuing growth (and hence increasing total yield) increased the value of all crops. However, the results also show that the rate of increase decreased with time and crops reach 85–90% of their maximum value before any over-size tubers are present. The basis for a premium price for seed is primarily the cost of producing seed of specific size and certified health and a restricted growing season should be

an essential consequence of demanding a premium. Therefore, defoliation when there are few over-size tubers is the most desirable time if the seed producer is to retain the confidence of the ware purchaser in producing a quality crop. The value of the crop at defoliation will be influenced by the grower's choice of seed weight and seed rate and his control of other factors which influence seed yield. In this respect the use of little or no physiological ageing will increase the seed yield of many varieties especially earlies (O'Brien *et al.* 1986). This analysis would suggest that relatively short growing seasons can achieve both high returns to the seed growers and the production of seed which ware growers wish to buy. The reduction of the growing season in many crops would be effective in reducing disease infection.

The conclusions drawn from these experiments may be strengthened by a number of likely changes in ware production. First, there is evidence that seed of smaller than 20 mm is capable of producing full yields (unpublished). As a consequence of the adoption of such seed the value of seed crops early in their growth will be greatly enhanced. A similar pattern of effects of seed rate and date of harvesting may be anticipated but beginning earlier so that defoliation close to maximum value would be possible before any over-size tubers were present. In the present analysis the ware seed rate used for the smallest seed was relatively high and thus the values of crops at early harvests are likely to be underestimates. The commercial development of small seed is dependent on viable systems of production, harvesting and utilization but the attraction of very low seed rates (0·2–0·5 t/ha) is likely to stimulate this approach. Secondly, in many unpublished recent experiments in East Anglia very small responses to increasing seed rate have been found in many varieties which result in optimum seed rates (for all seed sizes) which are lower than currently recommended. Further, the increasing importance of large tubers in determining profitability of a ware crop (Burstall, Thomas & Allen, 1986) will result in growers seeking to assess more critically and control more accurately their seed rates. It is, therefore, probable that seed rates will decrease and the advantages of closely graded, smaller seed in achieving even flow through planters will be important. Thus, as increasing yields are also likely to lead to a reduction in area of ware potatoes it is inevitable that less seed will be required and a relatively small area would provide sufficient certified seed if the seed were graded and sold as envisaged here.

The development of these opportunities is likely to be most effective where there is direct contact between seed producer and ware buyer. If the latter purchased whole crops this would avoid one of the risks associated with small seed at present. Small seed is frequently present in only small quantities in certified crops and saleable quantities may be achieved only by bulking together several crops. This practice may involve differences in health status of seed and ware growers are likely to suspect this practice as any virus infected plants will produce small-size tubers and their importance will be enhanced by bulking produce. It might be preferable for each ware grower to deal directly with one seed grower so that he could regularly purchase the right quantity of seed, graded according to his specifications.

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Appendix Table 1. *Effect of seed weight and seed rate on number of above-ground stems and number of tubers, first harvest Expts 2, 4 and 5*

	Seed weight (g)	Seed rate (t/ha) 1·15	1·53	2·04	3·06	4·59	6·12	7·66	9·19	S.E.
No. of above-ground stems ('000s/ha)										
Expt 2, Maris Piper	35	*	173	197	290	444	599	—	—	14·6
	105	*	—	—	208	294	373	463	565	
Expt 4, Record	35	90	132	180	239	328	435	—	—	19·5
	105	—	—	141	149	194	278	413	424	
Expt 5, Record	35	88	113	198	243	320	453	—	—	13·4
	105	—	—	114	154	220	283	361	430	
No. of tubers ('000s/ha)										
Expt 2, Maris Piper	35	*	832	1006	1136	1328	1252	—	—	81·0
	105	*	—	—	977	1190	1202	1288	1405	
Expt 4, Record	35	419	543	643	762	884	1017	—	—	37·8
	105	—	—	526	638	751	902	1001	1053	
Expt 5, Record	35	389	485	665	758	911	1192	—	—	63·0
	105	—	—	504	570	758	908	1022	1153	

* Seed rate not used.

Appendix Table 2. *Effect of seed rate, seed weight, and date of harvesting on tuber yields (t/ha), (a) total, (b) 20–32 mm, (c) 32–40 mm, (d) 40–55 mm, Expt 2*

Date of harvesting	Seed weight (g)	Seed rate (t/ha) 1·53	2·04	3·06	4·59	6·12	7·66	9·19	S.E.
14. viii	(*a*)								
	35	33·5	32·3	34·4	38·3	38·3	—	—	2·79
	105	—	—	33·6	36·8	33·8	34·9	39·7	
	(*b*)								
	35	1·5	3·4	3·9	4·3	4·5	—	—	0·72
	105	—	—	3·4	3·7	5·8	5·9	5·9	
	(*c*)								
	35	10·5	13·7	15·9	18·4	18·1	—	—	1·99
	105	—	—	16·5	18·3	18·5	18·0	21·0	
	(*d*)								
	35	20·7	14·8	13·7	14·7	15·0	—	—	3·26
	105	—	—	13·3	14·3	9·0	10·5	12·1	
28. vii	(*a*)								
	35	48·3	44·4	53·5	52·9	55·9	—	—	4·37
	105	—	—	43·1	59·1	50·0	56·6	55·1	
	(*b*)								
	35	1·0	1·9	2·0	2·7	3·5	—	—	0·33
	105	—	—	2·4	2·0	3·3	3·3	3·7	
	(*c*)								
	35	5·4	9·8	11·5	15·7	13·3	—	—	1·80
	105	—	—	10·8	11·9	16·4	15·2	17·3	
	(*d*)								
	35	33·6	30·8	32·0	31·4	34·8	—	—	4·00
	105	—	—	28·0	41·6	26·3	33·2	31·5	
11. viii	(*a*)								
	35	51·8	56·5	57·1	62·0	62·2	—	—	4·99
	105	—	—	49·0	64·2	57·7	64·9	60·1	
	(*b*)								
	35	1·0	1·5	2·5	2·6	3·7	—	—	0·47
	105	—	—	1·6	2·5	3·2	3·8	3·8	
	(*c*)								
	35	6·7	10·8	12·4	13·9	15·4	—	—	2·18
	105	—	—	10·0	11·7	15·0	19·5	19·1	
	(*d*)								
	35	31·5	39·2	34·3	40·5	35·6	—	—	5·55
	105	—	—	32·5	43·4	30·4	38·5	35·1	

Appendix Table 3. *Effect of seed rate, seed weight and date of harvesting on tuber yields (t/ha), (a) total, (b) 20–32 mm, (c) 32–40 mm, (d) 40–55 mm, Expt 4*

Date of harvesting	Seed weight (g)	Seed rate (t/ha) 1·15	1·53	2·04	3·06	4·59	6·12	7·66	9·19	S.E.
15. vii	(*a*)									
	35	8·7	9·6	10·7	11·5	11·0	11·6	—	—	0·65
	105	—	—	9·5	10·2	11·2	11·7	13·0	12·2	
	(*b*)									
	35	4·0	5·4	6·8	7·6	8·1	8·6	—	—	0·49
	105	—	—	5·5	5·2	7·5	8·8	9·7	8·7	
	(*c*)									
	35	3·2	2·8	2·9	2·9	1·6	1·5	—	—	0·54
	105	—	—	3·0	3·6	2·8	1·7	2·1	1·6	
	(*d*)									
	35	1·0	0·8	0·3	0·1	0·1	0	—	—	
	105	—	—	0·5	0·6	0	0	0	0·1	
29. vii	(*a*)									
	35	20·2	22·7	22·0	25·9	26·1	24·9	—	—	2·00
	105	—	—	23·6	28·6	25·9	28·7	26·4	26·9	
	(*b*)									
	35	1·2	3·0	2·5	5·1	6·2	6·5	—	—	0·36
	105	—	—	1·4	2·2	4·5	4·0	5·8	6·8	
	(*c*)									
	35	5·5	8·8	10·3	14·0	13·1	13·2	—	—	1·32
	105	—	—	8·9	12·1	14·1	14·8	13·2	13·7	
	(*d*)									
	35	13·2	10·8	9·1	6·3	6·2	4·5	—	—	1·82
	105	—	—	13·3	14·2	7·0	9·5	6·9	5·8	
10. viii	(*a*)									
	35	33·0	34·2	36·0	35·7	35·4	35·0	—	—	2·37
	105	—	—	31·0	41·6	35·1	38·9	33·7	36·6	
	(*b*)									
	35	1·0	1·7	1·5	3·5	5·0	5·8	—	—	0·30
	105	—	—	1·1	2·4	2·8	4·0	5·1	5·3	
	(*c*)									
	35	5·5	4·8	8·7	9·9	14·0	14·2	—	—	0·98
	105	—	—	5·1	8·3	9·7	13·4	13·7	13·0	
	(*d*)									
	35	23·0	26·0	23·9	21·4	15·6	13·9	—	—	1·88
	105	—	—	19·8	28·4	20·5	20·6	14·1	17·7	

Appendix Table 4. *Effect of seed rate, seed weight and date of harvesting on tuber yields (t/ha), (a) total, (b) 20–32 mm, (c) 32–40 mm, (d) 40–55 mm, Expt 5*

Date of harvesting	Seed weight (g)	Seed rate (t/ha) 1·15	1·53	2·04	3·06	4·59	6·12	7·66	9·19	S.E.
14. vii	(*a*)									
	35	11·6	13·0	15·0	15·6	17·6	19·7	—	—	0·97
	105	—	—	14·7	11·0	16·8	17·5	18·0	19·4	
	(*b*)									
	35	2·9	4·0	5·6	7·0	7·5	10·0	—	—	1·73
	105	—	—	3·1	4·0	5·5	7·1	8·6	10·0	
	(*c*)									
	35	3·9	5·7	6·1	6·4	6·5	7·4	—	—	0·71
	105	—	—	7·3	4·8	6·9	6·4	6·5	6·1	
	(*d*)									
	35	4·5	3·0	2·8	1·8	2·7	1·3	—	—	0·56
	105	—	—	4·0	1·5	3·6	3·2	1·9	2·2	
28. vii	(*a*)									
	35	23·3	24·8	26·3	27·5	29·9	31·4	—	—	1·21
	105	—	—	24·6	25·7	33·0	29·6	33·8	33·8	
	(*b*)									
	35	1·4	1·6	2·3	4·8	4·9	7·4	—	—	0·43
	105	—	—	1·7	2·8	4·0	5·0	6·3	7·4	
	(*c*)									
	35	5·7	8·2	11·0	12·2	15·3	16·5	—	—	0·94
	105	—	—	7·7	9·8	15·7	15·0	17·2	15·8	
	(*d*)									
	35	16·0	14·6	12·8	10·1	9·2	6·8	—	—	1·18
	105	—	—	14·1	12·9	12·9	8·8	9·6	9·8	
11. viii	(*a*)									
	35	30·7	32·9	31·2	31·0	34·4	36·7	—	—	1·72
	105	—	—	31·7	30·5	36·1	35·1	38·1	38·7	
	(*b*)									
	35	1·0	0·9	1·9	3·8	5·0	6·6	—	—	0·34
	105	—	—	1·7	1·7	3·1	3·3	4·8	5·5	
	(*c*)									
	35	4·9	5·7	8·1	11·4	14·2	14·2	—	—	1·14
	105	—	—	4·9	6·9	13·5	14·0	13·5	15·8	
	(*d*)									
	35	21·2	23·9	19·9	15·6	14·5	15·2	—	—	1·77
	105	—	—	21·9	20·6	18·5	17·1	18·4	16·5	

Appendix Table 5. *Effect of seed rate, seed weight and date of harvesting on gross number of replantable hectares and number of replantable hectares net of seed retained for replanting at same seed rate in Maris Piper, Expt 2*

Date of harvesting	Seed weight (g)	Seed rate (t/ha) 1·53	2·04	3·06	4·59	6·12	7·66	9·19	S.E.
		Gross number of replantable hectares							
14.vii	35	16·0	17·3	18·5	20·7	21·0	—	—	1·20
28. vii		18·0	20·3	21·6	24·5	25·4	—	—	1·26
11. viii		17·8	23·8	23·6	27·1	27·1	—	—	1·75
14. vii	105	—	—	18·1	19·9	19·9	20·3	22·7	1·20
28. vii		—	—	20·1	26·0	23·4	25·6	26·5	1·26
11. viii		—	—	20·7	26·9	24·2	30·7	29·9	1·75
		Number of replantable hectares net of seed retained for replanting							
14. vii	35	14·5	15·3	15·4	16·1	14·9	—	—	1·20
28. vii		16·5	18·3	18·5	19·9	19·3	—	—	1·26
11.viii		16·3	21·8	20·5	22·5	21·0	—	—	1·75
14. vii	105	—	—	16·9	18·1	17·5	17·3	19·1	1·20
28. vii		—	—	18·9	24·2	21·0	22·6	22·9	1·26
11. viii		—	—	19·5	25·1	21·8	27·7	25·4	1·75

Appendix Table 6. *Effect of seed rate, seed weight and date of harvesting on number of replantable hectares, Expts 4 and 5*

Date of harvesting	Seed weight (g)	Seed rate (t/ha) 1·15	1·53	2·04	3·06	4·59	6·12	7·66	9·19	S.E.
		Expt 4								
15. vii	35	5·3	6·1	7·2	7·7	7·5	7·9	—	—	0·39
29. vii		8·4	10·6	10·3	13·4	13·8	13·5	—	—	0·84
10. viii		11·3	12·5	13·9	15·2	16·4	16·7	—	—	0·85
15. vii	105	—	—	6·2	6·3	7·6	8·2	9·1	8·0	0·39
29. vii		—	—	10·2	12·7	13·1	13·9	13·7	14·4	0·84
10. viii		—	—	10·1	15·7	14·1	17·1	15·9	17·0	0·85
		Expt 5								
14. vii	35	5·9	7·1	8·6	9·6	10·3	12·2	—	—	0·58
28. vii		9·6	10·4	11·9	13·5	14·7	16·6	—	—	0·58
11. viii		10·3	11·7	12·5	14·2	16·2	17·7	—	—	0·58
14. vii	105	—	—	7·5	6·2	9·2	10·1	11·0	12·1	0·58
28. vii		—	—	10·0	11·8	15·6	14·6	17·0	17·3	0·58
11. viii		—	—	11·1	11·9	15·7	15·6	16·9	18·1	0·58

Appendix Table 7. *Effect of seed rate, seed weight and date of harvesting on number of replantable hectares (net of seed retained for replanting), Expts 4 and 5*

Date of harvesting	Seed weight (g)	Seed rate (t/ha)								s.e.
		1·15	1·53	2·04	3·06	4·59	6·12	7·66	9·19	
					Expt 4					
15. vii	35	4·1	4·6	5·1	4·7	2·9	1·8	—	—	0·40
29. vii		7·2	9·1	8·3	10·3	9·2	7·4	—	—	0·85
10. viii		10·1	10·9	11·8	12·1	11·8	10·6	—	—	0·86
15. vii	105	—	—	5·5	5·1	5·8	5·8	6·1	4·4	0·40
29. vii		—	—	9·5	11·5	11·3	11·5	10·7	10·8	0·85
10. viii		—	—	9·4	14·5	12·3	14·7	12·9	13·3	0·86
					Expt 5					
14. vii	35	4·8	5·6	6·6	6·5	5·8	6·0	—	—	0·59
28. vii		8·5	8·9	9·8	10·5	10·1	10·4	—	—	0·58
11. viii		9·1	10·1	10·5	11·1	11·6	11·6	—	—	0·58
14. vii	105	—	—	6·8	5·0	7·4	7·7	8·0	8·5	0·59
28. vii		—	—	9·3	10·6	13·8	12·2	14·4	13·7	0·58
11. viii		—	—	10·4	10·7	13·9	13·2	13·9	14·5	0·58

Appendix Table 8. *Effect of seed rate, seed weight and date of harvesting on sale value* (£) of crop net of retained seed, Expts 4 and 5*

Date of harvesting	Seed weight (g)	Seed rate (t/ha)								s.e.
		1·15	1·53	2·04	3·06	4·59	6·12	7·66	9·19	
					Expt 4					
15. vii	35	1233	1375	1536	1399	879	531	—	—	118
29. vii		2166	2717	2488	3089	2752	2213	—	—	253
10. viii		3270	3397	3665	3667	3566	3203	—	—	270
15. vii	105	—	—	1653	1536	1736	1738	1814	1331	118
29. vii		—	—	2845	3460	3389	3446	3217	3241	253
10. viii		—	—	3142	4508	3817	4434	3873	4010	270
					Expt 5					
14. vii	35	1434	1681	1975	1948	1726	1812	—	—	176
28. vii		2549	2678	2950	3134	3039	3132	—	—	172
11. viii		2980	3199	3211	3339	3503	3472	—	—	181
14. vii	105	—	—	2044	1504	2221	2319	2395	2539	176
28. vii		—	—	2862	3171	4138	3699	4205	4106	172
11. viii		—	—	3336	3266	4232	3967	4229	4358	181

* Seed valued at £300/replantable hectare and yield > 55 mm at £70/t.

Appendix Table 9. *Effect of seed rate, seed weight and date of harvesting on sale value (£) of crop net of seed retained, Maris Piper, Expt 2*

Date of harvesting	Seed weight (g)	Seed rate (t/ha) 1·53	2·04	3·06	4·59	6·12	7·66	9·19	S.E.
Seed valued at £300/replantable hectare and yield > 55 mm at £70/t									
14. vii	35	4376	4580	4636	4858	4467	—	—	363
28. vii		5510	5595	6103	6173	6075	—	—	426
11. viii		5746	6890	6689	7096	6798	—	—	527
14. vii	105	—	—	5079	5441	5244	5190	5735	363
28. vii		—	—	5782	7482	6564	7107	7030	426
11. viii		—	—	6169	7987	7157	8506	7741	527
Seed valued at £100/t and yield > 55 mm at £70/t									
14. vii	35	3286	3190	3372	3765	3777	—	—	275
28. vii		4568	4372	5096	5180	5450	—	—	388
11. viii		4794	5491	5450	6032	5971	—	—	474
14. vii	105	—	—	3316	3632	3329	3437	3914	275
28. vii		—	—	4243	5790	4860	5494	5405	388
11. vii		—	—	4740	6208	5481	6366	5921	474

Appendix Table 10. *Effect of seed rate, seed weight and date of harvesting on sale value* (£) of crop net of retained seed, Expts 4 and 5*

Date of harvesting	Seed weight (g)	Seed rate (t/ha) 1·15	1·53	2·04	3·06	4.59	6·12	7·66	9·19	S.E.
Expt 4										
15. vii	35	821	895	997	1053	972	1009	—	—	67
29. vii		2002	2255	2184	2553	2549	2431	—	—	199
10. viii		3187	3353	3535	3519	3483	3422	—	—	226
15. vii	105	—	—	899	943	1026	1056	1172	1032	676
29. vii		—	—	2354	2843	2553	2832	2594	2632	199
10. viii		—	—	2943	4067	3424	3831	3307	3600	226
Expt 5										
14. vii	35	1138	1268	1453	1517	1669	1847	—	—	93
28. vii		2320	2453	2612	2708	2940	3071	—	—	119
11.viii		2955	3211	3067	3070	3388	3598	—	—	162
14. vii	105	—	—	1440	1035	1601	1670	1703	1828	93
28. vii		—	—	2416	2553	3262	2915	3311	3302	119
11. viii		—	—	3060	2991	3556	3465	3718	3800	162

* Seed value at £100/t and yield > 55 mm at £70/t.