Potato Council & NIAB-CUF Grower Collaboration Project (R295) Report for 2013

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Vivaldi in Hill Farm Field 5, Frederick Hiam Ltd., Tuddenham, Suffolk 26 July 2013

Table of contents

Summary

1. In 2013, comparisons of contrasting agronomic practices were done with McCain Ltd., Frederick Hiam Ltd. and Three Musketeers Ltd.

2. Seed rate comparisons were done in Vivaldi, Maris Peer, Markies and Russet Burbank and comparisons for nitrogen application rates were done in Vivaldi. In addition the effects of depth of destoner operation were assessed in Vivaldi.

3. For the 25 valid comparisons done since 2007 where N applications had been reduced, on average, from 202 to 169 kg N/ha the estimated increase in the financial margin over seed and N costs was £460/ha. Similarly, since 2007, 39 valid comparisons have tested the effects of reducing seed rates. Analysis has shown that an average reduction in seed rate from 2.50 to 2.05 t/ha was associated with an increase in financial margin of £223/ha.

4. Whist these conclusions are not directly applicable to the wider UK crop, they demonstrate that significant increases in financial return can be achieved by better use of seed and N fertilizer.

5. Analysis of seed rate comparisons in Russet Burbank show that seed rates can be reduced without any adverse effects on total or ware yield or tuber count. Furthermore, there was no evidence that reduced plant populations were associated with any negative effects on tuber dry matter concentration or internal defects.

Introduction

The 'Grower Collaboration' project is funded by Potato Council (Project R295) and started in 2007. It is a mechanism of knowledge transfer that scales up results from small-plot research to larger scale (e.g. split-field) demonstrations of principle. The project involves collaboration between NIAB-CUF, Potato Council, growers and their agronomists and other supply-chain partners. This structure promotes understanding of the constraints within current production systems and then helps identify opportunities for future improvement in production practices. The collaborating growers and agronomists are responsible for providing cropping information (see below) and for planting the strips that compare contrasting agronomies. Staff at NIAB-CUF were responsible for devising 'improved' agronomies based on the information supplied by the grower. A key component of the process is the accurate and systematic documentation of 'standard' and 'improved' practises so that it is possible to objectively compare these contrasting agronomies.

Materials and Methods

In spring 2013, cropping information (Table 1) was collated by growers and agronomists for a selection of candidate crops and sent to NIAB-CUF for processing. Fertilizer and seed rate recommendations were calculated for a sub-set of these crops using the information supplied.

Table 1. Summary of typical information used by NIAB-CUF to calculate seed rates and nitrogen application rates

Information used by NIAB-CUF to calculate optimum seed rate	Information used by NIAB-CUF to calculate optimum nitrogen application rate
Variety	Variety
Planting configuration and average row widths	Field location
Seed size (mm) and seed count (number/50 kg)	Intended planting date of ware crop
Emergence date of seed crop	Intended defoliation/harvest date(s) of ware crop
Intended planting date of ware crop	Intended ware crop yield (total or marketable)
Intended ware crop yield (total or marketable)	Soil texture and organic matter content
Intended ware crop size specification	Previous crop
Grower intended ('standard') seed rate	Organic manure usage history
	Form, timing and method of nitrogen applications
	Historic information: problems with skin-set, tuber dry matter concentration, defoliation of excessive canopies etc.
	Grower intended ('standard') nitrogen application rate

The dates of seed crop emergence and ware crop planting were factors accounted for in determining NIAB-CUF seed rate recommendations but these were not used by growers to determine their 'standard' seed rates. Cases where the current 'standard' grower's plans differed substantially (*i.e.* by at least 10 %) from recommendations based on the best information available to NIAB-CUF were identified and opportunities for making comparisons

of 'standard' with 'NIAB-CUF modified' recommendations were then discussed with collaborating growers. Some seed rate comparisons were set up with varieties for which only limited data were available including varieties forming part of part of a project to derive seed rates rapidly (Potato Council Project R446). For these comparisons, the seed rates were experimental rather than representing recommended rates. In each case a width of *c.* 24 m within a field received modified agronomy whilst standard agronomy was applied to the rest of the crop. These unreplicated comparisons are not experiments and their limitations must be appreciated in regard to any confounding influences on the results and the variation associated with estimates of the variates recorded, particularly of crop samples from limited areas. Furthermore, since comparisons were only tested if the modified agronomy differed by more than 10 % from standard agronomy the results from these comparisons should not be used to make inferences about potato agronomy in general. In other cases, even where there were no substantial differences between 'standard' and 'NIAB-CUF-modified' recommendations, crops were identified with a view to recording performance in relation to agronomic inputs and environmental conditions. When appropriate other comparisons tested the effect of standard and reduced N application rate on growth and yield. A set of protocols and templates for data recording were sent to growers for recording the appropriate data on the crops so that each grower could collect data and send updates to NIAB-CUF during the season. Staff from NIAB-CUF visited all of the crops following establishment and some data were also collected during these visits to complement data collected by growers. Emergence (EM), ground cover (GC) and yield data were usually collected from three or four replicate areas.

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Results and Discussion

Sites and monitored crops

In 2013, a total of 20 crops were monitored and key details for these crops are shown in Table 2. In some cases, the same 'standard' crop was used for comparison against crops grown with improved seed and improved N application rates. In three instances, comparisons were done between increased and standard seed rates. For one of these (Vivaldi, Frederick Hiam Ltd.) the comparison was to provide data for seed rate development and was not a test of best practise. The remaining two tested increased seed rate comparisons in Russet Burbank and were comparisons suggested by the grower (B&C Potatoes Ltd.). At one site (Vivaldi, Frederick Hiam Ltd.) comparisons were established that investigated the effect of de-stoning depth on crop yield and these comparisons were designed to link with Potato Project R459 (Improving Cultivation Practices).

Table 2. Summary of crops monitored as part of Potato Council and NIAB-CUF grower collaboration program in 2013

Grower Group	Sector	Varieties	Number of seed-rate comparisons	Number of nitrogen rate comparisons	Number of depth of de-stoning comparisons
McCain (Tame Valley Potatoes)	Processing	Russet Burbank	4	0	0
McCain (Tame Valley Potatoes)	Processing	Markies	2	0	0
McCain (B&C Potatoes Ltd.)	Processing	Russet Burbank	6	0	0
Frederick Hiam Ltd.	Fresh Market	Vivaldi	2	3	3
3Ms Ltd.	Fresh Market	Maris Peer	2	0	0

Three Musketeers Ltd. (3Ms Ltd.)

Three Musketeers Ltd (3Ms) are a Suffolk-based farming and marketing company based at Bentwaters, Suffolk and they joined the Grower Collaboration program in 2013. Much of 3Ms production is based on supplying early salad potatoes and for this reason a comparison was setup in 2013 that tested standard (grower) and modified (NIAB-CUF) plant populations in a crop of Maris Peer. Seed and cropping details for this crop are shown in Table 3 and following discussions with 3Ms it was decided that a target yield for this crop would be *c.* 30 t/ha and its value would be maximised when 75 % of the yield was less than 45 mm in size. Calculation showed that this size specification should be achieved when the mean tuber size (mu) was *c.* 40 mm.

Table 3. Details of seed and ware crops for comparison of Grower and NIAB-CUF seed rates for Maris Peer

Field name	Angel Hill
Variety	Maris Peer
Seed crop	
Stock number	n.a.
Seed size (mm)	40-45
Count (no./50 kg)	905
Seed emergence	10 June 2012
Certification grade	n.a.
Ware crop	
Intended total yield (t/ha)	30
Intended date of planting	7 May 2013
Intended plant populations and within row spacings	
Grower population (000/ha)	91.2
Grower spacing (cm)	24.0
NIAB-CUF population (000/ha)	71.2
NIAB-CUF spacing (cm)	30.7

The comparison was planted on 7 May and 50 % plant emergence was achieved 34 days later on 10 June (Figure 1). Regular measurements of ground cover were not made during the season but intermittent observation showed that the canopy of both crops expanded rapidly and achieved complete (100 %) ground cover. The crop was sampled on two occasions 4 July (24 days after emergence (DAE)) and 27 Aug (78 DAE). The first sampling was taken when the yield was very small and tubers were still initiating and, in consequence, tuber population data are unlikely to be reliable. However, at the first sampling, achieved plant populations were similar to those intended for the 'standard' crop

but were larger than intended for the 'modified' crop. Due to the modified crop having more stems per plant that the standard crop, the crop grown with a reduced plant population had a numerically larger stem population but these estimates of stem population were associated with large errors and are unlikely to be real.

The second sampling was taken on 27 August and for the standard and modified crops the achieved plant population was close to that intended and both crops had produced a similar number of stems per plant resulting in a difference in stem population of *c.* 70 000/ha. For both the standard and modified crops the total (> 10mm) tuber population was larger than expected but the modified crop had *c*. 100 000/ha fewer tubers than the standard crop. Due to the unexpectedly large tuber population, the crop was allowed to grow-on and produce a total yield substantially more than was originally planned in order to maximise crop value. There was no evidence that reducing the plant population reduced total yield and the average yield was 43.7 t/ha. Due to the reduction in tuber population, the mean tuber size in the modified crop was larger than that in the standard crop (40.4 ± 0.8 mm compared with 39.0 ± 0.45 mm). However, both of these values were sufficiently similar to the target mean tuber size of 40 mm so that both crops produced an acceptable proportion of tubers > 45 mm.

When estimated from the plant population at the final sampling, the standard seed rate was 5.0 ± 1.15 t/ha compared with 3.9 ± 0.24 t/ha in the modified crop. These data suggest that reducing the seed rate by 1.1 t/ha was not associated with any reduction in total or marketable yield.

Figure 1. Comparison of standard and modified plant populations for Maris Peer, 3Ms Ltd, Angel Hill Field

Grower:	3Ms	3Ms
Field name:	Angel Hill	Angel Hill
Unique ID:	TMS12013122	TMS12013121
Part Field Name:	Standard Seed Rate	Modified Seed Rate
Variety:	Maris Peer	Maris Peer
Intended yield:	30 t/ha	30 t/ha
Intended use:	Salad	Salad
Planting date (start):	7 May	7 May
Date of 50 % emergence:	10 Jun	10 Jun
Total N applied:	160 kg N/ha	160 kg N/ha
Seed size:	40-45 mm	40-45 mm
Seed count:	905 per 50 kg	905 per 50 kg
Planned density:	91.2 000/ha	71.2 000/ha
Planned spacing:	24.0 cm	30.7 cm
Achieved density:	90.7 000/ha	75.7 000/ha
Achieved spacing:	24.1 cm	28.9 cm

Yield Samples (S.E. in italics)

		Standard Seed Rate			Modified Seed Rate	
		4 Jul	27 Aug		4 Jul	27 Aug
Plants (000/ha)		91.2	90.3		80.2	71.1
		2.58	*2.74*		*5.96*	*4.34*
Stems (000/ha)		384.8	404.8		405.7	331.9
		13.69	*27.57*		*37.85*	*19.01*
Stems/plant		4.2	4.5		5.0	4.7
		0.19	*0.30*		*0.14*	*0.17*
Tubers (000/ha)	> 10 mm	670	1244	> 10 mm	679	1142
		139.0	*81.2*		*75.5*	*36.5*
Tubers (000/ha)	> 45 mm	0	96	> 45 mm	0	114
		0.0	*16.1*		*0.0*	*29.3*
Tuber yield (t/ha)	> 10 mm	2.5	43.8	> 10 mm	2.1	43.5
		1.00	*1.65*		*0.64*	*3.83*
Tuber yield (t/ha)	> 45 mm	0.0	8.0	> 45 mm	0.0	10.1
		0.00	*1.34*		*0.00*	*2.61*
DM (%)			18.4			17.0
			0.27			*0.68*
Mean tuber size (mm)			39.0			40.4
			0.45			*0.83*

Frederick Hiam Ltd.

Frederick Hiams Ltd are a large farming and vegetable packing company mainly based in East Anglia which joined the Grower Collaboration project in 2013. Following discussions with Frederick Hiam Ltd. and Potato Council it was decided to set up a series of comparisons in crops of Vivaldi grown for pre-pack bakers that would provide data for refining seed rate recommendations as well as increasing and decreasing the N application rate relative to the standard application rate of 180 kg N/ha. In addition, comparisons were

also setup that compared the effects of standard de-stoner depth (*c*. 30 cm) with a shallower treatment (*c*. 25 cm) and a deeper treatment (*c*. 33 cm). These comparisons were designed to link to a Potato Council funded project on improving cultivation practices (Project R459). Further details of the seed and comparisons are given in Table 4. The planting configuration used by Frederick Hiams was three rows planted in a 182.9 cm (72 inch) bed. With this configuration, within-row spacings may be large (> 70 cm) even for typical plant population. This wide spacing is problematic when developing sampling protocols able to detect relatively small changes in population and this necessitated increasing the sample area from 1.5 m of bed (2.75 m^2) used at the first sampling to 3.0 m of bed (5.5 m^2) at the second. However, the increase in sample area was achieved as the expense of the number of replicates sampled per treatment which was reduced from four to three. There were no regular observations of the time-course of emergence or of ground cover development. The date of 50 % plant emergence was estimated by farm-staff to be 15 May for all treatments. On the basis of infrequent visits to the crop, there were no discernable effects of the treatments on ground cover development which was rapid and all treatments achieved complete (100 %) ground cover. All treatments received their first application of desiccant on 17 August.

Table 4. Details of seed and ware crops for comparison of Grower and NIAB-CUF seed rates for Vivaldi

Field name	Hill Farm 5
Variety	Vivaldi
Seed crop	
Stock number	69204
Seed size (mm)	45-55
Count (no./50 kg)	473
Seed emergence	n.a.
Certification grade	n.a.
Ware crop	
Intended total yield (t/ha)	53
Intended date of planting	2 April
Intended plant populations, within row spacings, nitrogen application rates and depth of destoner operation	
Grower population (000/ha)	22.4
Grower spacing (cm)	73.2
NIAB-CUF population (000/ha)	24.7
NIAB-CUF spacing (cm)	66.5
Grower N application rate (kg N/ha)	180
NIAB-CUF N application rate (kg N/ha)	200
NIAB-CUF N application rate (kg N/ha)	160
Grower standard destoner depth (cm)	30
NIAB-CUF destoner depth (cm)	25
NIAB-CUF destoner depth (cm)	33

Comparisons of seed rate in Vivaldi

A seed rate comparison compared two plant populations: a 'standard' population of 22 400/ha and a 'modified' population of 24 700/ha. The modified population was included to provide data for improving seed rate recommendations and does not constitute best practise. For this reason, this comparison will be excluded from the summary tables. Data from the first sampling (particular plant, stem and tuber population) should be treated with caution due to the relatively small sample area. However, harvest data suggested that whilst differences in plant population were achieved both the achieved plant population in standard and modified crops were larger than intended (Figure 2). At the first sampling on 26 July, the total tuber yield was already similar to the intended yield for both the standard and modified crops. However, due to the relatively large tuber populations, the mean tubers size averaged only 47.5 mm in the two comparisons which would not produce many baker-size potatoes.

The second sampling was taken on 12 September several weeks after the crop had been defoliated. For both the standard and modified crops the achieved plant populations were similar to those intended. Both the standard and modified crops produced similar number of stems per plant resulting in the modified crop having *c*. 10 000 more stems per hectare the standard crop. When compared with the earlier harvest, total tuber populations had increased by over 100 000 tuber/ha for both comparisons. Total tuber yield in the standard crop was 57.3 t/ha compared with 65.0 t/ha in the modified crop. This difference is unlikely to be a consequence of the smaller plant population in the standard crop and is most-likely a consequence of inadvertently sampling poor areas of crop. Despite having a larger tuber population, the crop grown at the modified plant population had a larger mean tuber size at the final sampling ad this was a consequence of having a larger tuber yield. However, neither crop would have produced a large proportion of baking size potatoes due to the relatively small mean tuber size.

Figure 2. Comparison of standard and modified plant populations for Vivaldi, Frederick Hiam Ltd, Hill Farm Field 5, Tuddenham, Suffolk.

Grower:	Frederick Hiam	Frederick Hiam
Field name:	Hill Farm 5	Hill Farm 5
Unique ID:	FHI12013169	FHI12013170
Part Field Name:	Standard Crop	Modified Population
Variety:	Vivaldi	Vivaldi
Intended yield:	53 t/ha	53 t/ha
Intended use:	General Ware	General Ware
Planting date (start):	2 Apr	2 Apr
Date of 50 % emergence:	15 May	15 May
Total N applied:	180 kg N/ha	180 kg N/ha
Seed size:	45-55 mm	45-55 mm
Seed count:	473 per 50 kg	473 per 50 kg
Planned density:	22.4 000/ha	24.7 000/ha
Planned spacing:	73.2 cm	66.5 cm
Achieved density:	24.3 000/ha	28.1 000/ha
Achieved spacing:	67.5 cm	58.4 cm

Yield Samples (S.E. in italics)

		Standard Crop			Modified Population	
		26 Jul	12 Sep		26 Jul	12 Sep
Plants (000/ha)		25.5	23.1		30.1	26.1
		1.49	*0.61*		*1.75*	*0.61*
Stems (000/ha)		109.4	84.5		125.8	94.8
		21.87	*6.43*		*13.84*	*6.40*
Stems/plant		4.2	3.7		4.3	3.6
		0.65	*0.38*		*0.65*	*0.32*
Tubers (000/ha)	> 10 mm	488	593	> 10 mm	485	608
		56.0	*48.0*		*45.0*	*19.2*
Tubers (000/ha)	> 40 mm	333	428	> 40 mm	306	464
		41.9	*34.5*		*46.2*	*5.8*
Tuber yield (t/ha)	> 10 mm	44.4	57.3	> 10 mm	43.7	65.0
		4.88	*5.91*		*6.70*	*5.22*
Tuber yield (t/ha)	> 40 mm	39.5	52.9	> 40 mm	38.2	61.9
		4.68	*6.08*		*7.32*	*5.02*
DM (%)		17.5	16.0		17.4	15.8
		0.23	*0.09*		*0.53*	*0.25*
Mean tuber size (mm)		48.2	50.7		47.2	53.3
		0.78	*1.13*		*1.03*	*1.25*

Comparisons of N application rates in Vivaldi

The grower standard N application for this crop was a total of 180 kg N/ha and this was compared with a NIAB-CUF recommendation of 160 kg N/ha and an increased N application rate of 200 kg N/ha. The increased rate was included to provide a test of N recommendation as well as a demonstration of principle for a Potato Council open day held at the site in August. For both the reduced and increased N application rates the achieved plant populations at both sampling dates were similar to those intended (Figure 3 and Figure 4). However, there was an apparent decrease in stem population between the two samplings

and this was most noticeable when the N application rate had been increased. There is no plausible explanation for this and this is likely to be a consequence of crop variability.

Figure 3. Comparison of standard and reduced N application rates for Vivaldi, Frederick Hiam Ltd, Hill Farm Field 5, Tuddenham, Suffolk.

Grower:	Frederick Hiam	Frederick Hiam
Field name:	Hill Farm 5	Hill Farm 5
Unique ID:	FHI12013169	FHI12013171
Part Field Name:	Standard Crop	Reduced N
Variety:	Vivaldi	Vivaldi
Intended yield:	53 t/ha	53 t/ha
Intended use:	General Ware	General Ware
Planting date (start):	2 Apr	2 Apr
Date of 50 % emergence:	15 May	15 May
Total N applied:	180 kg N/ha	160 kg N/ha
Seed size:	45-55 mm	45-55 mm
Seed count:	473 per 50 kg	473 per 50 kg
Planned density:	22.4 000/ha	22.4 000/ha
Planned spacing:	73.2 cm	73.2 cm
Achieved density:	24.3 000/ha	24.6 000/ha
Achieved spacing:	67.5 cm	66.7 cm

Yield Samples (S.E. in italics)

	Standard Crop			Reduced N	
	26 Jul	12 Sep		26 Jul	12 Sep
Plants (000/ha)	25.5	23.1		25.5	23.7
	1.49	*0.61*		*1.49*	*2.10*
Stems (000/ha)	109.4	84.5		103.9	81.4
	21.87	*6.43*		*8.74*	*10.11*
Stems/plant	4.2	3.7		4.1	3.4
	0.65	*0.38*		*0.29*	*0.13*
Tubers (000/ha) > 10 mm	488	593	> 10 mm	601	564
	56.0	*48.0*		*39.4*	*66.6*
Tubers (000/ha) > 40 mm	333	428	> 40 mm	429	457
	41.9	*34.5*		*27.5*	*54.8*
Tuber yield (t/ha) > 10 mm	44.4	57.3	> 10 mm	58.4	73.7
	4.88	*5.91*		*2.44*	*6.14*
Tuber yield (t/ha) > 40 mm	39.5	52.9	> 40 mm	52.5	70.9
	4.68	*6.08*		*2.42*	*6.15*
DM (%)	17.5	16.0		16.8	16.4
	0.23	*0.09*		*0.44*	*0.28*
Mean tuber size (mm)	48.2	50.7		48.1	57.4
	0.78	*1.13*		*0.66*	*1.09*

For the reduced N comparison, total (> 10 mm) and ware (> 40 mm) tuber yields were numerically larger than the standard crop at both samplings. Similarly, when the N application rate had been increased from 180 to 200 kg N /ha, total and ware-sized tuber yields were also larger. It is unlikely that these effects are a consequence of N nutrition and more likely to be due to the unusually low yield in the standard crop. At the final sampling,

the total yield in the reduced N crop (73.7 t/ha) was numerically larger than that found in the crop grown at the increased rate of N (65.7 t/ha) suggesting that when 160 kg N/ha had been applied the N supply was still adequate.

Figure 4. Comparison of standard and increased N application rates for Vivaldi, Frederick Hiam Ltd, Hill Farm Field 5, Tuddenham, Suffolk.

Grower:	Frederick Hiam	Frederick Hiam
Field name:	Hill Farm 5	Hill Farm 5
Unique ID:	FHI12013169	FHI12013172
Part Field Name:	Standard Crop	Increased N
Variety:	Vivaldi	Vivaldi
Intended yield:	53 t/ha	53 t/ha
Intended use:	General Ware	General Ware
Planting date (start):	2 Apr	2 Apr
Date of 50 % emergence:	15 May	15 May
Total N applied:	180 kg N/ha	200 kg N/ha
Seed size:	45-55 mm	45-55 mm
Seed count:	473 per 50 kg	473 per 50 kg
Planned density:	22.4 000/ha	22.4 000/ha
Planned spacing:	73.2 cm	73.2 cm
Achieved density:	24.3 000/ha	25.5 000/ha
Achieved spacing:	67.5 cm	64.3 cm

Yield Samples (S.E. in italics)

		Standard Crop			Increased N	
		26 Jul	12 Sep		26 Jul	12 Sep
Plants (000/ha)		25.5	23.1		27.3	23.7
		1.49	*0.61*		*1.05*	*0.00*
Stems (000/ha)		109.4	84.5		102.1	68.0
		21.87	*6.43*		*6.82*	*6.17*
Stems/plant		4.2	3.7		3.7	2.9
		0.65	*0.38*		*0.17*	*0.26*
Tubers (000/ha)	> 10 mm	488	593	> 10 mm	522	506
		56.0	*48.0*		*45.8*	*11.4*
Tubers (000/ha)	> 40 mm	333	428	> 40 mm	358	401
		41.9	*34.5*		*20.6*	*14.2*
Tuber yield (t/ha)	> 10 mm	44.4	57.3	> 10 mm	48.5	65.7
		4.88	*5.91*		*2.22*	*1.57*
Tuber yield (t/ha)	> 40 mm	39.5	52.9	> 40 mm	43.3	63.0
		4.68	*6.08*		*2.14*	*1.90*
DM (%)		17.5	16.0		16.9	16.5
		0.23	*0.09*		*0.27*	*0.14*
Mean tuber size (mm)		48.2	50.7		48.6	56.4
		0.78	*1.13*		*0.61*	*0.84*

Comparisons of destoner depth in Vivaldi

The purpose of these comparisons was to complement a large body of data that is being collected as part of a Potato Council program that is trying to improve cultivation practices. In these comparisons the performance of the crops grown on soils destoned to standard

depth (*c*. 30 cm) were compared with crops grown on shallowly destoned soil (*c*. 25 cm) and more deeply destoned soils (*c*. 33 cm). When averaged over both sampling dates, the achieved plant population for both the shallower destone (Figure 5) and deep destone (Figure 6) comparisons were reasonably similar to those intended although they were numerically larger. In common with all the other comparisons, there was an increase in total tuber population between the first sampling on 26 July (43 DAE) and on 12 September (120 DAE). When compared to destoning at 30 cm, destoning at 25 or 33 cm was apparently associated with increases in total tuber yield of c. 12 and 15 t/ha respectively. Again, there is no plausible explanation why shallower or deeper destoning should be better than the standard depth and the difference is probably due to an abnormally low yield in the standard crop.

Figure 5. Comparison of standard and decreased destoner depth Vivaldi, Frederick Hiam Ltd, Hill Farm Field 5, Tuddenham, Suffolk.

Grower:	Frederick Hiam	Frederick Hiam
Field name:	Hill Farm 5	Hill Farm 5
Unique ID:	FHI12013169	FHI12013168
Part Field Name:	Standard Crop	Shallow Destone
Variety:	Vivaldi	Vivaldi
Intended yield:	53 t/ha	53 t/ha
Intended use:	General Ware	General Ware
Planting date (start):	2 Apr	2 Apr
Date of 50 % emergence:	15 May	15 May
Total N applied:	180 kg N/ha	180 kg N/ha
Seed size:	45-55 mm	45-55 mm
Seed count:	473 per 50 kg	473 per 50 kg
Planned density:	22.4 000/ha	22.4 000/ha
Planned spacing:	73.2 cm	73.2 cm
Achieved density:	24.3 000/ha	25.2 000/ha
Achieved spacing:	67.5 cm	65.1 cm

Yield Samples (S.E. in italics)

		Standard Crop			Shallow Destone	
		26 Jul	12 Sep		26 Jul	12 Sep
Plants (000/ha)		25.5	23.1		27.3	23.1
		1.49	*0.61*		*1.82*	*0.61*
Stems (000/ha)		109.4	84.5		112.1	87.5
		21.87	*6.43*		*10.77*	*1.82*
Stems/plant		4.2	3.7		4.1	3.8
		0.65	*0.38*		*0.44*	*0.09*
Tubers (000/ha)	> 10 mm	488	593	> 10 mm	501	544
		56.0	*48.0*		*12.0*	*38.6*
Tubers (000/ha)	> 40 mm	333	428	> 40 mm	365	423
		41.9	*34.5*		*18.7*	*15.8*
Tuber yield (t/ha)	> 10 mm	44.4	57.3	> 10 mm	49.2	69.8
		4.88	*5.91*		*1.06*	*4.08*
Tuber yield (t/ha)	> 40 mm	39.5	52.9	> 40 mm	45.0	66.4
		4.68	*6.08*		*1.47*	*4.16*
DM (%)		17.5	16.0		16.5	15.7
		0.23	*0.09*		*0.43*	*0.41*
Mean tuber size (mm)		48.2	50.7		49.6	55.8
		0.78	*1.13*		*0.49*	*1.30*

Figure 6. Comparison of standard and increased destoner depth Vivaldi, Frederick Hiam Ltd, Hill Farm Field 5, Tuddenham, Suffolk.

Grower:	Frederick Hiam	Frederick Hiam
Field name:	Hill Farm 5	Hill Farm 5
Unique ID:	FHI12013169	FHI12013167
Part Field Name:	Standard Crop	Deep Destone
Variety:	Vivaldi	Vivaldi
Intended yield:	53 t/ha	53 t/ha
Intended use:	General Ware	General Ware
Planting date (start):	2 Apr	2 Apr
Date of 50 % emergence:	15 May	15 May
Total N applied:	180 kg N/ha	180 kg N/ha
Seed size:	45-55 mm	45-55 mm
Seed count:	473 per 50 kg	473 per 50 kg
Planned density:	22.4 000/ha	22.4 000/ha
Planned spacing:	73.2 cm	73.2 cm
Achieved density:	24.3 000/ha	23.4 000/ha
Achieved spacing:	67.5 cm	70.1 cm

Yield Samples (S.E. in italics)

		Standard Crop			Deep Destone	
		26 Jul	12 Sep		26 Jul	12 Sep
Plants (000/ha)		25.5	23.1		23.7	23.1
		1.49	*0.61*		*1.05*	*1.61*
Stems (000/ha)		109.4	84.5		94.8	95.4
		21.87	*6.43*		*2.98*	*12.29*
Stems/plant		4.2	3.7		4.0	4.1
		0.65	*0.38*		*0.28*	*0.44*
Tubers (000/ha)	> 10 mm	488	593	> 10 mm	488	605
		56.0	*48.0*		*15.8*	*37.5*
Tubers (000/ha)	> 40 mm	333	428	> 40 mm	340	460
		41.9	*34.5*		*13.5*	*28.2*
Tuber yield (t/ha)	> 10 mm	44.4	57.3	> 10 mm	48.5	72.3
		4.88	*5.91*		*2.76*	*4.25*
Tuber yield (t/ha)	> 40 mm	39.5	52.9	> 40 mm	44.2	68.4
		4.68	*6.08*		*3.23*	*3.91*
DM (%)		17.5	16.0		17.1	15.7
		0.23	*0.09*		*0.61*	*0.13*
Mean tuber size (mm)		48.2	50.7		50.2	54.3
		0.78	*1.13*		*0.80*	*0.81*

In summary, the comparisons in the Vivaldi crop were compromised by an unusually small yield in the crop that was produced using a standard seed and N application and had been destoned at a standard depth. There was some indirect evidence that reducing the N application rate from 180 to 160 kg N/ha was not detrimental to yield potential and, when compared to the crop that received 160 kg N/ha there was no advantage of applying 200 kg N/ha. The comparisons of destoning depth were inconclusive but there was no evidence that shallower destoning was associated with any loss of total or ware yield and this is consistent with a much larger body of evidence derived from replicated experiments.

McCain Ltd

McCain Ltd joined the grower collaboration program in 2011 and nominated two host growers: B&C Farming Ltd, Norfolk and James Daw of Tame Valley Potatoes, Staffordshire. The main objective of work was to test new seed rate recommendations for Russet Burbank that had been derived from recent work at NIAB-CUF (Potato Council Project R296). In all cases, the objective of the seed rate recommendation was, for a given target yield, to maximise the yield of potatoes > 90 mm in length and to keep the ware-tuber count less than 61 per 10 kg for tubers > 45 mm diameter.

B&C Potatoes Ltd

At B&C Farming Ltd comparisons were made between the standard McCain seed rate recommendation and a reduced (NIAB-CUF) seed rate recommendation for a single stock of Russet Burbank grown in two fields. A grower comparison was also included at both locations that tested an increased tuber population. Seed and cropping details for B&C Farming are given in Table 5.

Table 5. Details of seed and ware crops for comparison of McCain and B&C seed rates for Russet Burbank

Field name	Booton 31	Medler Reservoir
Variety	Russet Burbank	Russet Burbank
Seed crop		
Stock number	71971	71971
Seed size (mm)	30-40	30-40
Count (no./50 kg)	1392	1392
Seed emergence	12 June	12 June
Certification grade	SE2	SE2
Ware crop		
Intended total yield (t/ha)	50	50
Intended date of planting	20 April	20 April
Intended plant populations and within row spacings		
McCain population (000/ha)	39.96	39.96
McCain spacing (cm)	27.4	27.4
NIAB-CUF population (000/ha)	32.3	32.3
NIAB-CUF spacing (cm)	33.8	33.8
Grower population (000/ha)	42.0	42.0
Grower spacing (cm)	26.0	26.0

The comparison of standard (McCain) with either modified (NIAB-CUF) or grower (B&C) plant populations at Booton 31 field are shown in Figure 7 and Figure 8, respectively. The comparison of the McCain and NIAB-CUF plant populations was compromised because the

achieved McCain plant population was smaller than intended whilst the achieved NIAB-CUF plant population was larger than intended. The consequence was that the difference in achieved plant populations was too small to make a valid comparison worthwhile. This problem was further compounded by the tuber population being larger in the NIAB-CUF area than in the McCain area and this was a consequence of plants in the NIAB-CUF area producing more stems per plant and more tubers per stem. Crops in the McCain and NIAB-CUF area exceeded the target yield and the average total (> 10 mm) and ware (> 45 mm) tuber yields were 66.2 and 55.7 t/ha, respectively. Due to its larger tuber population, the crop in the NIAB-CUF area had a slightly smaller mean tuber size, a smaller proportion of tubers > 90 mm in length and a larger count (67 per 10 kg compared with 63 per 10 kg). Tuber dry matter concentrations were similar for both comparisons and averaged 22.7 %. Since the achieved plant population were too different from those intended, this comparison will be excluded from the summary tables.

The grower (B&C) comparison at Booton increased the intended plant population relative to the standard, McCain recommendation. However, the achieved grower plant population was larger than intended and the difference between the achieved McCain and grower plant populations was too small (*c.* 900 plant/ha) to constitute a useful comparison. Total tuber populations and yields were similar for both comparisons and averaged 501 000/ha and 63.1 t/ha, respectively. Both crops had similar yields > 45 mm (53.5 t/ha on average) but the crop grown in the McCain area had a larger proportion of tubers > 90 mm in length and also had a smaller count (63 compared with 66 tubers per10 kg).

Figure 7. Comparison of standard (McCain) with modified (NIAB-CUF) plant populations for Russet Burbank grown at Booton 31 field.

Grower:	B&C Farming	B&C Farming
Field name:	Booton 31	Booton 31
Unique ID:	BCF12013212	BCF12013211
Part Field Name:	McCain	NIAB-CUF
Variety:	Russet Burbank	Russet Burbank
Intended yield:	50 t/ha	50 t/ha
Intended use:	French-fries	French-fries
Planting date (start):	20 Apr	20 Apr
Date of 50 % emergence:	10 May	10 May
Total N applied:	238 kg N/ha	238 kg N/ha
Seed size:	30-40 mm	30-40 mm
Seed count:	1392 per 50 kg	1392 per 50 kg
Planned density:	40.0 000/ha	32.3 000/ha
Planned spacing:	27.4 cm	33.8 cm
Achieved density:	37.4 000/ha	35.5 000/ha
Achieved spacing:	29.3 cm	30.8 cm

Yield Samples (S.E. in italics)

		McCain 11 Sep		NIAB-CUF 11 Sep
Plants (000/ha)		37.4		35.5
		2.29		*1.75*
Stems (000/ha)		103.0		103.9
		16.80		*11.77*
Stems/plant		2.7		2.9
		0.38		*0.26*
Tubers (000/ha)	> 10 mm	502	> 10 mm	568
		17.6		*11.5*
Tubers (000/ha)	> 40 mm	378	> 40 mm	427
		15.8		*3.1*
Tuber yield (t/ha)	> 10 mm	63.6	> 10 mm	68.8
		0.95		*2.54*
Tuber yield (t/ha)	> 45 mm	53.4	> 45 mm	57.9
		0.83		*3.59*
Tuber yield (%)	> 90 mm	56.3	> 90 mm	49.4
		3.01		*4.48*
DM (%)		22.8		22.5
		0.21		*0.07*
Mean tuber size (mm)		53.4		53.1
		0.71		*0.91*

Figure 8. Comparison of standard (McCain) with grower (B&C) plant populations for Russet Burbank grown at Booton 31 field.

Grower:	B&C Farming	B&C Farming
Field name:	Booton 31	Booton 31
Unique ID:	BCF12013212	BCF12013210
Part Field Name:	McCain	B&C
Variety:	Russet Burbank	Russet Burbank
Intended yield:	50 t/ha	50 t/ha
Intended use:	French-fries	French-fries
Planting date (start):	20 Apr	20 Apr
Date of 50 % emergence:	10 May	10 May
Total N applied:	238 kg N/ha	238 kg N/ha
Seed size:	30-40 mm	30-40 mm
Seed count:	1392 per 50 kg	1392 per 50 kg
Planned density:	40.0 000/ha	42.0 000/ha
Planned spacing:	27.4 cm	26.0 cm
Achieved density:	37.4 000/ha	38.3 000/ha
Achieved spacing:	29.3 cm	28.6 cm

Yield Samples (S.E. in italics)

		McCain 11 Sep		B&C 11 Sep
Plants (000/ha)		37.4		38.3
		2.29		*2.35*
Stems (000/ha)		103.0		84.8
		16.80		*6.55*
Stems/plant		2.7		2.2
		0.38		*0.13*
Tubers (000/ha)	> 10 mm	502	> 10 mm	499
		17.6		*44.0*
Tuber yield (t/ha)	> 10 mm	63.6	> 10 mm	62.5
		0.95		*3.96*
Tuber yield (t/ha)	> 45 mm	53.4	> 45 mm	53.5
		0.83		*2.67*
Tuber yield (%)	> 90 mm	56.3	> 90 mm	51.6
		3.01		*3.19*
DM (%)		22.8		22.4
		0.21		*0.22*
Mean tuber size (mm)		53.4		52.9
		0.71		*0.23*

The comparisons in Medler Reservoir field were the same as those in Booton 31. The comparison between the McCain and NIAB-CUF plant populations is shown in Figure 9 whilst the comparison between McCain and B&C plant population is shown in Figure 10. The achieved plant populations for both the McCain and NIAB-CUF crops were similar to the intended and this resulted in appreciable reductions in both stem and total tuber populations in the crop planted at the modified seed rate. For both comparisons, the average total tuber yield at Medler Reservoir was 54.4 t/ha and there was little difference in total yield between the standard and modified crops. However, due to the reduction in tuber

population, the yield > 45 mm and the proportion of yield > 90 mm in length was numerically larger where the NIAB-CUF plant population was used than where the McCain spacing was used. Altering the plant population from McCain to NIAB-CUF was also associated with a change in tuber count from 66 to 56 tuber per 10 kg. Tuber dry matter concentrations were little affected by changes in tuber population and averaged 22.0 %.

The achieved plant population for the B&C comparison was also similar to that intended but the difference in plant population between the McCain and B&C comparisons were less than 10 % which resulted in the B&C comparison having only slightly larger mainstem and tuber populations. Numerically, the total yield within the McCain and B&C areas were similar and averaged 55.0 t/ha. The crop grown in McCain area had a larger yield > 45 mm and also had a larger proportion of the total yield > 90 mm in length. The tuber count was also slightly larger in the crop grown at the intended B&C spacing than at the intended McCain spacing (68 compared with 66 tubers per 10 kg).

Figure 9. Comparison of standard (McCain) with modified (NIAB-CUF) plant populations for Russet Burbank grown at Medler Reservoir field.

Grower:	B&C Farming	B&C Farming
Field name:	Medler Reservoir	Medlers Reservoir
Unique ID:	BCF12013215	BCF12013214
Part Field Name:	McCain	NIAB-CUF
Variety:	Russet Burbank	Russet Burbank
Intended yield:	50 t/ha	50 t/ha
Intended use:	French-fries	French-fries
Planting date (start):	22 Apr	22 Apr
Date of 50 % emergence:	15 May	15 May
Total N applied:	250 kg N/ha	250 kg N/ha
Seed size:	30-40 mm	30-40 mm
Seed count:	1392 per 50 kg	1392 per 50 kg
Planned density:	40.0 000/ha	32.3 000/ha
Planned spacing:	27.4 cm	33.8 cm
Achieved density:	39.2 000/ha	31.9 000/ha
Achieved spacing:	27.9 cm	34.3 cm

Yield Samples (S.E. in italics)

		McCain 11 Sep		NIAB-CUF 11 Sep
Plants (000/ha)		39.2		31.9
		0.91		*1.75*
Stems (000/ha)		121.2		101.2
		9.46		*8.20*
Stems/plant		3.1		3.2
		0.29		*0.37*
Tubers (000/ha)	> 10 mm	451	> 10 mm	371
		34.4		*40.3*
Tubers (000/ha)	> 40 mm	332	> 40 mm	287
		12.9		*23.0*
Tuber yield (t/ha)	> 10 mm	54.6	> 10 mm	54.2
		2.25		*2.54*
Tuber yield (t/ha)	> 45 mm	42.1	> 45 mm	46.9
		3.05		*2.47*
Tuber yield (%)	> 90 mm	59.0	> 90 mm	68.6
		6.27		*3.75*
DM (%)		22.2		21.8
		0.39		*0.37*
Mean tuber size (mm)		50.8		54.7
		0.90		*1.05*

Figure 10. Comparison of standard (McCain) with grower (B&C) plant populations for Russet Burbank grown at Medler Reservoir field.

Grower:	B&C Farming	B&C Farming
Field name:	Medler Reservoir	Medler Reservoir
Unique ID:	BCF12013215	BCF12013213
Part Field Name:	McCain	B&C
Variety:	Russet Burbank	Russet Burbank
Intended yield:	50 t/ha	50 t/ha
Intended use:	French-fries	French-fries
Planting date (start):	22 Apr	22 Apr
Date of 50 % emergence:	15 May	15 May
Total N applied:	250 kg N/ha	250 kg N/ha
Seed size:	30-40 mm	30-40 mm
Seed count:	1392 per 50 kg	1392 per 50 kg
Planned density:	40.0 000/ha	42.0 000/ha
Planned spacing:	27.4 cm	26.0 cm
Achieved density:	39.2 000/ha	41.9 000/ha
Achieved spacing:	27.9 cm	26.1 cm

Yield Samples (S.E. in italics)

		McCain 11 Sep		B&C 11 Sep
Plants (000/ha)		39.2		41.9
		0.91		*2.35*
Stems (000/ha)		121.2		130.3
		9.46		*13.42*
Stems/plant		3.1		3.2
		0.29		*0.45*
Tubers (000/ha)	> 10 mm	451	> 10 mm	506
		34.4		*20.8*
Tuber yield (t/ha)	> 10 mm	54.6	> 10 mm	55.3
		2.25		*2.83*
Tuber yield (t/ha)	> 45 mm	42.1	> 45 mm	37.8
		3.05		*2.82*
Tuber yield (%)	> 90 mm	59.0	> 90 mm	51.1
		6.27		*5.66*
DM (%)		22.2		23.0
		0.39		*0.43*
Mean tuber size (mm)		50.8		48.8
		0.90		*0.50*

James Daw, Tame Valley Potatoes

In 2013, the work with James Daw (who as part of Tame Valley Potatoes grows for McCain) concentrated on testing standard (McCain) and reduced seed (NIAB-CUF) rates for crops of Russet Burbank and Markies. Seed and cropping details for these crops are shown in Table 6. All the comparisons were done in Wind Pump field and were planted on 7th May.

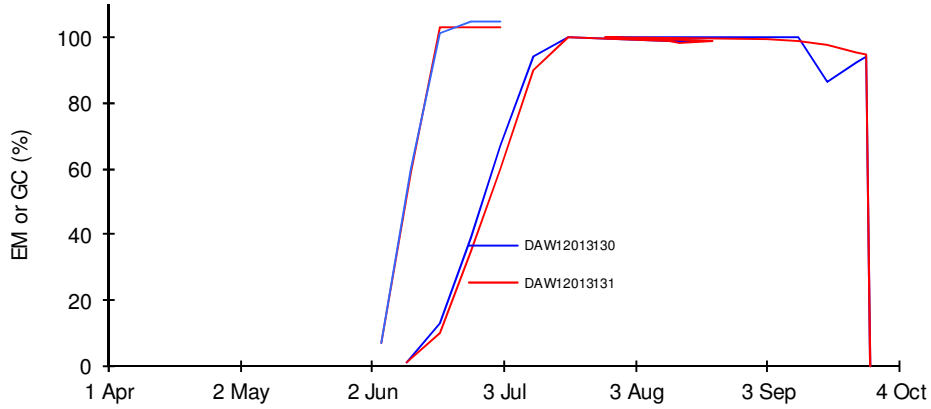
Table 6. Details of seed and ware crops for comparison of Tame Valley Potatoes and NIAB-CUF seed rates for Russet Burbank and Markies.

Field name	Mercer Wind Pump	Mercer Wind Pump	Mercer Wind Pump
Variety	Russet Burbank	Russet Burbank	Markies
Seed crop			
Stock number	71106	71106	74885
Seed size (mm)	40-50	30-40	35-45
Count (no./50 kg)	640	1235	853
Seed emergence	16 June 2012	16 June 2012	26 June 2012
Certification grade	n.a.	n.a.	n.a.
Ware crop			
Intended total; yield (t/ha)	50	50	50
Intended date of planting	7 May 2013	7 May 2013	7 May 2013
Intended plant populations (no./ha) and within row spacing (cm)			
McCain population (000/ha)	28.0	36.5	31.2
McCain spacing (cm)	39.1	30.0	35.1
NIAB-CUF population (000/ha)	25.0	31.8	25.5
NIAB-CUF spacing (cm)	43.7	34.4	42.9

Both Markies plant population comparisons attained 50 % plant emergence on 10 June, 34 day after planting (Figure 11). When averaged over both samplings, the achieved plant population was larger than intended particularly for the standard (McCain) comparisons. The number of stems produced per plant was consistently larger in the NIAB-CUF area and, in consequence, the stem population was numerically larger in the NIAB-CUF comparisons than in the McCain comparison. For this reason, this comparison will be excluded from the summary tables. The similarity in stem population also meant ground cover development was similar for both the standard and modified crops and these two crops would be expected to have similar yields. When averaged over both harvests, the total tuber population in the McCain comparison was 516 000/ha compared with 538 000/ha in the area planted at the NIAB-CUF recommended population. At the final sampling on 8 October (120 DAE) the total tuber yields were nearly identical in both the standard and modified areas and averaged 68.2 t/ha. Numerically, the NIAB-CUF comparison had a larger yield > 45 mm but had a smaller proportion of tubers > 90 mm in length. The counts per 10 kg were similar for both comparisons and averaged 59. The tuber dry matter concentration was 21.4 and 19.8 % in the McCain and NIAB-CUF comparisons, respectively.

Figure 11. Comparison of standard (McCain) with modified (NIAB-CUF) plant populations for Markies grown at Mercer's Wind Pump field.

Grower:	James Daw	James Daw
Field name:	Mercers Wind Pump	Mercers Wind Pump
Unique ID:	DAW12013130	DAW12013131
Part Field Name:	35-45 Standard	35-45 Modified
Variety:	Markies	Markies
Intended yield:	50 t/ha	50 t/ha
Intended use:	French-fries	French-fries
Planting date (start):	7 May	7 May
Date of 50 % emergence:	10 Jun	10 Jun
Total N applied:	170 kg N/ha	170 kg N/ha
Seed size:	35-45 mm	35-45 mm
Seed count:	853 per 50 kg	853 per 50 kg
Planned density:	31.2 000/ha	25.5 000/ha
Planned spacing:	35.0 cm	42.9 cm
Achieved density:	36.0 000/ha	26.4 000/ha
Achieved spacing:	30.4 cm	41.4 cm



Yield Samples (S.E. in italics)

		35-45 Standard			35-45 Modified	
		23 Jul	8 Oct		23 Jul	8 Oct
Plants (000/ha)		32.8	39.2		28.3	24.6
		2.58	*1.75*		*0.91*	*1.75*
Stems (000/ha)		121.2	101.2		123.9	103.9
		5.02	*8.20*		*6.49*	*9.93*
Stems/plant		3.7	2.6		4.4	4.2
		0.27	*0.19*		*0.18*	*0.12*
Tubers (000/ha)	> 10 mm	519	513	> 10 mm	550	526
		50.3	*28.2*		*14.0*	*53.6*
Tubers (000/ha)	> 40 mm	121	372	> 40 mm	151	385
		12.6	*22.7*		*11.0*	*28.5*
Tuber yield (t/ha)	> 10 mm	17.8	68.2	> 10 mm	20.5	68.1
		1.31	*2.23*		*0.90*	*4.57*
Tuber yield (t/ha)	> 45 mm	3.1	57.5	> 45 mm	4.1	61.8
		0.43	*1.71*		*0.69*	*3.91*
Tuber yield (%)	> 90 mm		66.6	> 90 mm		50.6
			2.59			*0.79*
DM (%)		13.0	21.4		11.9	19.8
		0.41	*0.19*		*0.14*	*0.23*
Mean tuber size (mm)		38.7	54.9		39.4	56.6
		0.24	*0.64*		*0.56*	*0.80*

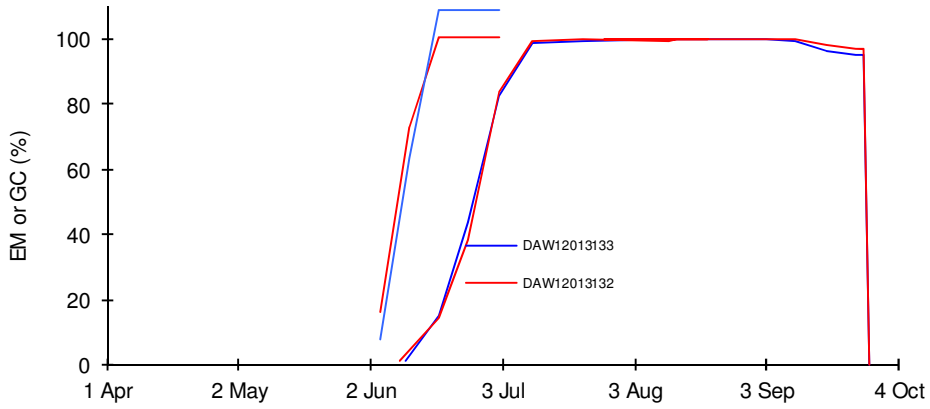
On average, the larger stock of Russet Burbank reached 50 % plant emergence on *c.* 10 June. When averaged over both samplings, the achieved plant population were similar to those intended (Figure 12). For both the McCain and NIAB-CUF comparisons the mainstem population was larger at the first harvest than at the second and, when averaged over both samplings, the mainstem population was 95 700/ha and 100 300 in the McCain and NIAB-CUF areas, respectively. The larger stem population in the NIAB-CUF comparison was mainly due to a larger number of stems produced per plant. At the final sampling on 8 October, the total tuber population was numerically larger in the NIAB-CUF area than in the McCain area, but both estimates of total tuber population were associated with large standard errors. Since both comparisons had similar stem populations, the pattern of ground cover development, persistence and senescence was also very similar. In consequence, the McCain and NIAB-CUF crops should have absorbed similar amounts of solar radiation and had similar yield potentials. Between the first and second sampling, average, total tuber yield increased from 17.1 t/ha to 64.0 t/ha. Once the errors associated with these measurements are taken into account, there was little difference in tuber yield. At the final sampling, the mean tuber size was 55.0 and 54.7 mm in the McCain and NIAB-CUF areas respectively. The yield > 45 mm and the proportion of tubers > 90 mm in length were numerically larger in the modified (NIAB-CUF) area however, when compared to the standard errors, the differences between the means were small. At the final sampling the tuber DM concentration was numerically larger in the crop grown at the intended McCain plant population but the difference was small. Due to the similarity in stem and total tuber populations this comparison will be excluded from the summary tables.

Both comparisons planted using the smaller stock of Russet Burbank emerged on 9 May (33 DAP) and for both the McCain and NIAB-CUF comparisons the achieved plant population was close to that originally planned (Figure 13). When averaged over both sampling occasions, the mean stem populations for the McCain and NIAB-CUF comparisons were 110 800 and 85 200/ha, respectively. At the final sampling, the total tuber population also differed by 76 000/ha. Despite having a smaller stem population, the crop grown using the NIAB-CUF recommendation produced a ground cover curve that was very similar to that produced in the McCain area. Numerically, the total tuber yield was larger in the McCain comparison than in the NIAB-CUF (68.2 compared with 61.9 t/ha, respectively) as was the yield > 45 mm (57.5 and 52.2 t/ha, respectively) but these estimates were associated with large standard error (particularly for the NIAB-CUF comparison) and the differences are unlikely to be real. Despite having a numerically smaller total and ware

yield, the NIAB-CUF crop had a similar proportion of yield > 90 mm in diameter but a numerically smaller count (58 compared with 54 per 10 kg).

Figure 12. Comparison of standard (McCain) with modified (NIAB-CUF) plant populations for Russet Burbank grown at Mercer's Wind Pump field.

Grower:	James Daw	James Daw
Field name:	Mercers Wind Pump	Mercers Wind Pump
Unique ID:	DAW12013133	DAW12013132
Part Field Name:	40-50 Standard	40-50 Modified
Variety:	Russet Burbank	Russet Burbank
Intended yield:	50 t/ha	50 t/ha
Intended use:	French-fries	French-fries
Planting date (start):	7 May	7 May
Date of 50 % emergence:	10 Jun	9 Jun
Total N applied:	200 kg N/ha	200 kg N/ha
Seed size:	40-50 mm	40-50 mm
Seed count:	640 per 50 kg	640 per 50 kg
Planned density:	28.0 000/ha	25.0 000/ha
Planned spacing:	39.0 cm	43.8 cm
Achieved density:	27.3 000/ha	24.6 000/ha
Achieved spacing:	40.0 cm	44.4 cm

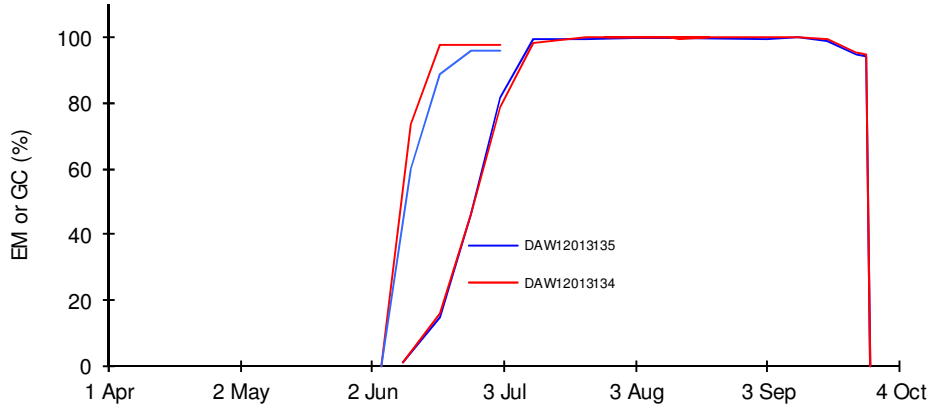


Yield Samples (S.E. in italics)

		40-50 Standard			40-50 Modified	
		23 Jul	8 Oct		23 Jul	8 Oct
Plants (000/ha)		26.4	28.3		27.3	21.9
		1.75	*0.91*		*2.35*	*1.49*
Stems (000/ha)		106.6	84.8		123.0	77.5
		10.35	*7.04*		*15.56*	*7.35*
Stems/plant		4.1	3.0		4.5	3.5
		0.32	*0.17*		*0.39*	*0.14*
Tubers (000/ha)	> 10 mm	467	484	> 10 mm	452	506
		31.5	*61.3*		*40.5*	*62.6*
Tubers (000/ha)	> 40 mm	90	311	> 40 mm	89	355
		13.0	*44.3*		*6.7*	*32.8*
Tuber yield (t/ha)	> 10 mm	17.4	61.9	> 10 mm	16.8	66.1
		0.44	*6.65*		*1.02*	*3.42*
Tuber yield (t/ha)	> 45 mm	2.6	52.3	> 45 mm	2.5	55.7
		0.80	*6.52*		*0.31*	*2.56*
Tuber yield (%)	> 90 mm		68.0	> 90 mm		69.0
			7.17			*4.39*
DM (%)		14.5	19.5		14.0	18.8
		0.09	*0.41*		*0.09*	*0.40*
Mean tuber size (mm)		37.9	55.0		37.9	54.7
		1.05	*1.39*		*0.27*	*1.23*

Figure 13. Comparison of standard (McCain) with modified (NIAB-CUF) plant populations for Russet Burbank grown at Mercer's Wind Pump field.

Grower:	James Daw	James Daw
Field name:	Mercers Wind Pump	Mercers Wind Pump
Unique ID:	DAW12013135	DAW12013134
Part Field Name:	30-40 Standard	30-40 Modified
Variety:	Russet Burbank	Russet Burbank
Intended yield:	50 t/ha	50 t/ha
Intended use:	French-fries	French-fries
Planting date (start):	7 May	7 May
Date of 50 % emergence:	9 Jun	9 Jun
Total N applied:	200 kg N/ha	200 kg N/ha
Seed size:	30-40 mm	30-40 mm
Seed count:	1235 per 50 kg	1235 per 50 kg
Planned density:	36.5 000/ha	31.8 000/ha
Planned spacing:	30.0 cm	34.4 cm
Achieved density:	37.4 000/ha	31.4 000/ha
Achieved spacing:	29.3 cm	34.8 cm



Yield Samples (S.E. in italics)

		30-40 Standard			30-40 Modified	
		23 Jul	8 Oct		23 Jul	8 Oct
Plants (000/ha)		35.5	39.2		31.9	31.0
		1.75	*1.75*		*1.75*	*1.05*
Stems (000/ha)		120.3	101.2		98.4	72.0
		11.04	*8.20*		*3.65*	*6.02*
Stems/plant		3.4	2.6		3.1	2.3
		0.16	*0.19*		*0.26*	*0.25*
Tubers (000/ha)	> 10 mm	445	513	> 10 mm	394	437
		32.5	*28.2*		*29.3*	*29.3*
Tubers (000/ha)	> 40 mm	104	372	> 40 mm	108	303
		12.8	*22.7*		*11.6*	*17.8*
Tuber yield (t/ha)	> 10 mm	18.0	68.2	> 10 mm	17.1	61.9
		0.90	*2.23*		*0.67*	*6.08*
Tuber yield (t/ha)	> 45 mm	2.9	57.5	> 45 mm	2.8	52.2
		0.52	*1.71*		*0.72*	*7.18*
Tuber yield (%)	> 90 mm		66.6	> 90 mm		66.5
			2.59			*4.96*
DM (%)		15.1	21.4		15.0	20.8
		0.27	*0.19*		*0.13*	*0.56*
Mean tuber size (mm)		38.8	54.9		39.0	56.5
		0.59	*0.64*		*0.74*	*1.96*

Internal Defects in Russet Burbank and Markies

Once grading, yield assessments and tuber dry matter measurements were complete all remaining tubers > 90 mm in length were first assessed for the presence of misshapes and then for internal defects (internal rust spot and hollow heart) by cutting each tuber in half along the long-axis and scoring the severity of any defects according to the scheme shown in Appendix 2 (Table 16). In 2013, internal defects were generally more severe for the Russet Burbank crops grown by B&C Farming than for the crops of Markies and Russet Burbank grown by James Daw (Table 7). On average, crops grown using the NIAB-CUF spacings had a larger mean tuber size than use grown using McCain recommendations (55.1 ± 0.65 mm compared with 53.8 ±0.80 mm, respectively). Despite this, there was no evidence that the larger tubers resulting from use of NIAB-CUF recommendations were more likely to have internal damage. For example, the percentage of tubers without internal damage averaged 81 ± 7.6 for the NIAB-CUF crops compared with 82 ± 8.2 for the McCain crops.

Summary of effect of modified plant populations on Russet Burbank 2011-2013

In total there were 18 comparisons of McCain and NIAB-CUF seed rate recommendations for Russet Burbank between 2011 and 2013. In addition there were seven "grower" comparisons which tested intermediate plant populations or populations larger than the McCain recommendations but these are excluded from this analysis. Of the 18 comparisons of McCain and NIAB-CUF plant populations, five were omitted because the achieved plant populations were too dissimilar to those intended or the differences in achieved plant populations between the McCain and CUF comparisons were too small. For reference, the complete data are shown in Table 8 whereas the valid data are shown in Table 9. When the data were restricted to valid comparisons only, the average, intended McCain and NIAB-CUF plant populations differed by *c* 10 700 plants/ha. However, the achieved plant populations differed by only 6 600 plant/ha. On average, the NIAB-CUF comparisons used 0.23 t/ha less seed than the McCain comparisons and analysis by paired 'T' test showed that this difference was statistically significant. Numerically, the average total tuber population was smaller for the NIAB-CUF than the McCain comparison (455 000/ha compared with 500 000/ha) however this difference was too small to be statistically significant. The total tuber yield was 2.5 t/ha larger in the crops grown with the McCain plant population than those grown using the NIAB-CUF recommendation, but this difference was too small to be statistically significant. It is of interest that the intended yield for these crops was typically 48 to 50 t/ha and the average total yield for both comparisons was 62.4 t/ha. The ware yield

(> 45 mm) was similar for both comparisons as were the proportion of yield > 90 mm in length and the tuber count of the ware crop. For both comparisons, tuber dry matter concentration averaged 23.5 % and differed little between either the McCain or NIAB-CUF regime.

A concern with using reduced seed rates for the production of Russet Burbank is that the resulting increase in mean tuber size would be associated with an increase in internal defects such as internal rust spot and hollow heart. For all 18 comparisons the mean tuber size for the McCain crops was 53.5 ± 0.85 mm compared with 54.3 ± 0.74 mm for the NIAB-CUF crops. The effects of different intended plant population on the proportion of tubers with no defect, the proportion with internal rust spot and the proportion with hollow heart are shown in Figure 14*a*, *b* and *c*, respectively. The data shown that the incidence of internal defects varied widely between seasons (crop grown in 2011, 2012 and 2013 had stock number starting with 50, 60 and 70 000, respectively), However, there was no evidence that reductions in plant populations were consistently associated with changes in internal defects.

In summary, the Russet Burbank comparisons show that the modest reductions in seed rate associated with the NIAB-CUF recommendations have no significant effect on total or ware yield, tuber count, tuber dry matter or the incidence of internal defects.

Table 7. Severity of internal rust spot (IRS) and hollow heart (HH) found within Russet Burbank and Markies crops grown by B&C Farming, Norfolk and James Daw, Staffordshire. For description of how internal defects were quantified see Appendix 2

	Field Name	Stock number	Variety	Spacing	Intended spacing (cm)	Achieved mean tuber size (mm)	Percentage of tubers with no internal defects	Percentage of tubers with IRS in categories 1-3	Percentage of tubers with HH in categories 4-6
DAW12013130	Wind Pump	74885	Markies	McCain	35.0	54.9 ± 0.64	100.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00
DAW12013131	Wind Pump	74885	Markies	NIAB-CUF	42.9	56.6 ± 0.80	96.0 ± 1.46	1.9 ± 1.11	2.1 ± 1.26
DAW12013135	Wind Pump	71106	Russet Burbank	McCain	30.0	54.9 ± 0.64	87.9 ± 1.95	8.9 ± 1.64	3.2 ± 1.23
DAW12013134	Wind Pump	71106	Russet Burbank	NIAB-CUF	34.4	56.5 ± 1.96	90.7 ± 1.26	8.3 ± 0.87	1.0 ± 1.00
DAW12013133	Wind Pump	71106	Russet Burbank	McCain	39.0	55.0 ± 1.39	91.3 ± 3.00	7.6 ± 2.56	1.1 ± 1.14
DAW12013132	Wind Pump	71106	Russet Burbank	NIAB-CUF	43.8	54.7 ± 1.23	88.7 ± 3.53	11.3 ± 3.53	0.0 ± 0.00
BCF12013210	Booton 31	71971	Russet Burbank	B&C	26.0	52.9 ± 0.23	56.0 ± 8.13	30.3 ± 4.90	14.6 ± 3.44
BCF12013211	Booton 31	71971	Russet Burbank	NIAB-CUF	33.8	53.1 ± 0.91	53.7 ± 3.77	34.7 ± 3.40	9.9 ± 0.81
BCF12013212	Booton 31	71971	Russet Burbank	McCain	27.4	53.4 ± 0.71	52.3 ± 2.19	41.4 ± 4.06	6.3 ± 2.72
BCF12013213	Medlers Reservoir	71971	Russet Burbank	B&C	26.0	48.8 ± 0.50	78.7 ± 6.99	14.7 ± 2.92	6.6 ± 4.35
BCF12013214	Medlers Reservoir	71971	Russet Burbank	NIAB-CUF	33.8	54.7 ± 1.05	75.4 ± 5.09	17.8 ± 5.39	6.8 ± 2.29
BCF12013215	Medlers Reservoir	71971	Russet Burbank	McCain	27.4	50.8 ± 0.90	76.9 ± 4.68	16.9 ± 2.67	4.4 ± 1.58

Table 8. Effect of McCain or NIAB-CUF intended plant populations on achieved plant populations, seed rates and components of yield for all Russet Burbank seed rate comparisons, 2011-2013

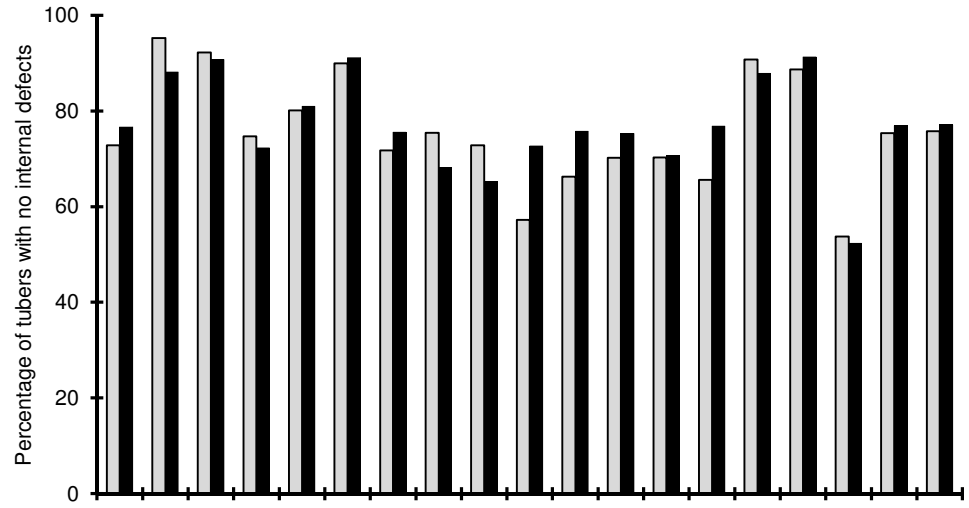
	Intended plant population (000/ha)	Achieved plant population (000/ha)	Achieved seed rate (t/ha)	Achieved total tuber population (000/ha)	Achieved total tuber yield (t/ha)	Tuber DM concentration (%)	Achieved mean tuber size (mm)	Achieved tuber yield > 45 mm (t/ha)	Achieved tuber yield > 90 mm (%)	Achieved tuber count (No/10 kg)
McCain (n=18)	48.0 ± 2.88	44.7 ± 2.48	1.49 ± 0.057	494 ± 13.6	63.1 ± 1.84	23.6 ± 0.42	53.5 ± 0.85	51.9 ± 2.61	59 ± 2.4	64 ± 2.3
NIAB-CUF (n=18)	37.6 ± 1.97	39.4 2.16	1.31 ± 0.048	467 ± 13.9	61.7 ± 1.39	23.3 ± 0.44	54.3 ± 0.74	52.1 ± 2.02	61 ± 2.4	62 ± 2.4
Difference in means (n=18)	10.4 ± 3.48	5.3 ± 3.29	0.18 ± 0.075	27 ± 19.5	1.4 ±2.31	0.3 ± 0.61	0.8 ± 1.12	0.1 ± 3.31	2 ± 3.4	2 3.3
Probability difference is significant	0.005	0.113	0.021	0.172	0.547	0.624	0.462	0.968	0.593	0.658

Table 9. Effect of McCain or NIAB-CUF intended plant populations on achieved plant populations, seed rates and components of yield for valid Russet Burbank seed rate comparisons, 2011-2013

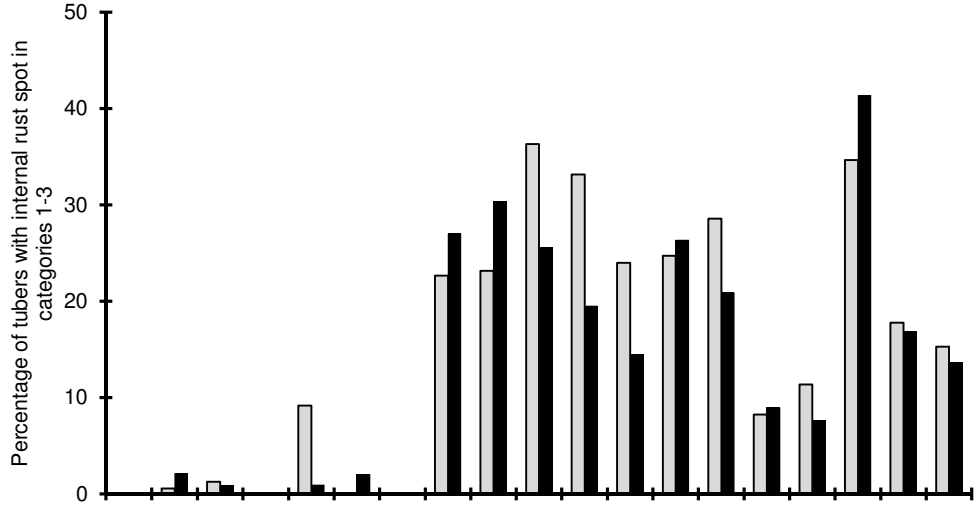
	Intended plant population (000/ha)	Achieved plant population (000/ha)	Achieved seed rate (t/ha)	Achieved total tuber population (000/ha)	Achieved total tuber yield (t/ha)	Tuber DM concentration (%)	Achieved mean tuber size (mm)	Achieved tuber yield > 45 mm (t/ha)	Achieved tuber yield > 90 mm (%)	Achieved tuber count (No/10 kg)
McCain (n=13)	46.4 ± 3.77	44.6 ± 3.37	1.57 ± 0.067	500 ± 17.8	63.6 ± 2.54	23.4 ± 0.52	53.8 ± 1.05	52.8 ±3.49	57 ±2.5	65 ± 3.0
NIAB-CUF (n=13)	35.7 ± 2.32	38.0 ± 2.74	1.34 ± 0.062	455 ± 16.6	61.1 ± 1.78	23.1 ± 0.59	54.9 ± 0.90	52.4 ± 2.55	60 ±2.7	62 ± 3.3
Difference in means (n=13)	10.7 4.43	6.6 ± 4.34	0.23 ± 0.091	45 ± 24.3	2.5 ± 3.10	0.2 ± 0.78	1.1 ± 1.38	0.4 ± 4.32	3 3.7	3 4.5
Probability difference is significant	0.023	0.140	0.018	0.078	0.429	0.763	0.419	0.924	0.409	0.560

Figure 14. Effect of NIAB-CUF (grey bars) or McCain (black bars) plant populations on internal defects in 2011-2013. Number on x-axis are seed stock numbers. See text for details of categories. The mean tuber size for NIAB-CUF crops was 54.3 ± 0.74 mm compared with 53.5 ± 0.85 mm for crops grown with McCain recommended plant populations.

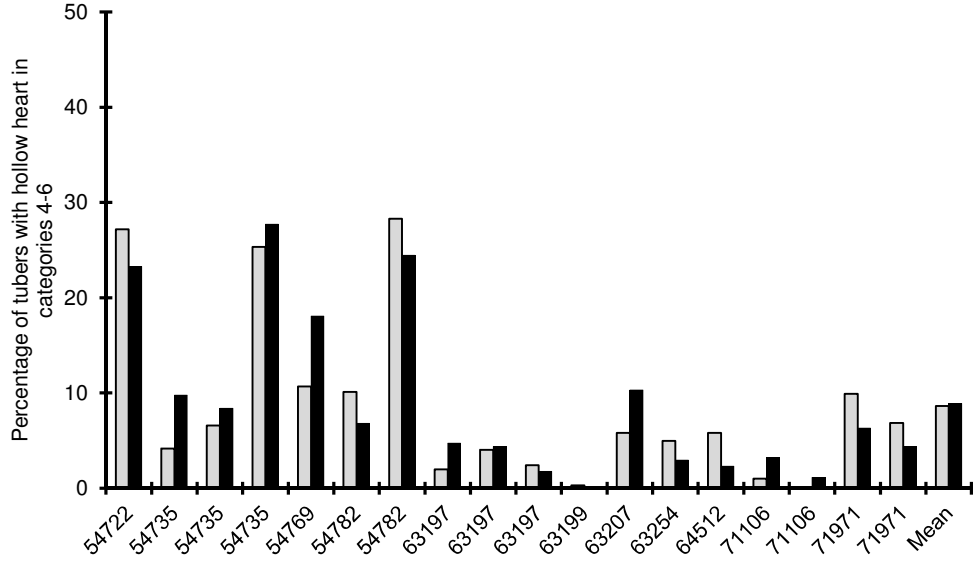
(*a*)



(*b*)



(*c*)



Economic Analysis of Standard and Modified Agronomies

In previous reports and publications the effects of the contrasting agronomies (standard and improved) were quantified in terms of average, total (> 10 mm) and ware (> 40 mm) yields or by simple economic assessment where ware-size tubers had a uniform value of £120/t and potato seed and nitrogen fertilizer cost £250/t and £0.90/kg, respectively. However, in many commercial contracts potatoes are not valued uniformly and assuming a uniform value for ware sized tuber may obscure the real benefits of devising seed rates to maximise yields in the most valuable grades. To overcome this problem the sample data from 2007 to 2013 were reanalysed to make better estimates of true crop value. This was done by fitting a normal, un-weighted distribution to the graded yields for each plot and using the estimates of mean tuber size (mu) and its standard deviation (sigma) to calculate the proportion of the total yield in the five grades shown in Table 10. The total crop value was then calculated by summing the value in each grade. The cost of the seed (£300/t) and nitrogen fertilizer used (£0.90/kg) to produce this crops was then subtracted to calculate the margin of production over seed and N costs. Whilst this analysis is more sophisticated than shown in earlier reports the pricing structure ignores any bonuses paid for tuber dry matter content, freedom from defects etc. Furthermore, the values of potatoes sold on the free-market are volatile and the absolute benefit of any particular agronomy will be difficult to determine. Some comparisons of N rates were omitted from this analysis due to erratic crop emergence, the effects of PCN or a failure to apply the intended amount of N to either the standard or improved crops. Paired comparisons of N application rates were only included in the analysis if the 'standard' and 'improved' crops had similar plant populations (within 10 % of each other). However, comparisons of seed rates were only included if the achieved standard and modified seed rates were within 10 % of those intended and the achieved and modified seed rates differed by more than 10 %. A paired 'T' test was then used to determine whether, on average, the improved agronomies resulted in a statistically significant increase in crop value.

Table 10. Potato pricing structure for different sectors of the UK potato industry and used to estimate whole crop value

	Diameter	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5
Processing 1	Lower (mm)	0	35	40	65	90
	Upper (mm)	35	40	65	90	200
	Value (£/t)	0	25	110	110	25
Processing 2	Lower (mm)	0	35	40	53	75
	Upper (mm)	35	40	53	75	200
	Value (£/t)	0	25	110	110	25
Baking Potatoes	Lower (mm)	0	35	45	65	85
	Upper (mm)	35	45	65	85	200
	Value (£/t)	0	25	100	150	25
General Ware	Lower (mm)	0	35	45	65	85
	Upper (mm)	35	45	65	85	200
	Value (£/t)	0	25	150	100	25
Salad Potatoes	Lower (mm)	0	20	28	35	41
	Upper (mm)	20	28	35	41	200
	Value (£/t)	0	260	220	100	60

In total, there were 25 valid comparisons that compared standard with reduced N application rates and the average reduction in N application rate was 33 kg N/ha (Table 11*a*). On average, reducing the N application rate was associated with a small increase in the tuber population > 10 mm but, when assessed using a paired 'T'-test, this increase was not statistically significant. On average, reducing the N application rate from 202 to 169 kg N/ha was associated with a statistically significant increase in yield from 55.4 to 58.8 t/ha. The economic analysis showed that, on average, due to the reduction in N usage and the increase in marketable yield there was a statistically significant increase in crop value of £460/ha when less N had been applied. The increase in margin was partly due to the savings in N fertilizer (*c*. £30/ha) but a much larger component was due to the increase in marketable yield as a direct result of an increase in total yield. Whilst we do not have conclusive proof, this increase in yield is consistent with modest reductions in N input having relatively little effect on canopy persistence, radiation absorption and total dry matter production but having significant effects on the partitioning of dry matter allocation between haulm and tubers.

In total there were 39 valid comparisons of standard and reduced seed rates Table 11*b*. The most common reason for paired comparisons to be omitted from the analysis was too large a difference between achieved and intended plant populations or too small a difference between the achieved plant populations in the standard and reduced seed rate crops. For the

valid comparisons the average reduction in seed rate was from 2.50 to 2.05 t/ha. Reducing the seed rate, reduced the total tuber population from 546 000 to 490 000/ha and this effect was highly significant. However, average total tuber FW yields were almost identical when grown using the standard or reduced seed rates. Economically, crops produced using the reduced seed rates had a larger margin over seed and N costs than the standard crops. The increase (£223/ha) was statistically significant and was due in part to a reduced seed cost (on average £138/ha) and an increase in marketable yield (*c*. £85/ha). The effects of reduced seed rate on the increase in crop value are relatively small and this may be a consequence of our data-set being dominated by processing or ware varieties where crop value is primarily driven by yield > 40 mm and where over-size tubers have some value albeit at stock-feed prices. If the data set included a large proportion of salad potato crops then the effects of seed rates on crop value should be more noticeable. Similarly, an agronomy that allowed a grower to produce early-season baker crops before their competitors would also emphasise the importance of optimised seed rates.

Table 11. Summary showing average effects of (*a*) reduced nitrogen application rates and (*b*) reduced seed rates on total tuber population and yield and margin over seed and nitrogen cost. Data from Grower Collaboration project 2007-2013. Seed has been valued at £300/t and N at £0.90/kg. For further details see text

(*a*)	Nitrogen application rate (kg N/ha)	Tuber population > 10 mm at final sampling (000/ha)	Tuber yield > 10 mm at final sampling (t/ha)	Margin over seed and nitrogen costs (£/ha)
Mean of standard crops (n=25)	202	495 ± 20.9	55.4 ± 2.36	4911 ± 362
Mean of improved crops (n=25)	169	520 ± 21.6	58.8 ± 2.53	5371 ± 387
Mean difference	33	25 ± 14.6	3.4 ± 1.52	460 ± 186
Probability difference is significant		P = 0.096	P = 0.034	P = 0.021

(*b*)	Seed rate (t/ha)	Tuber population > 10 mm at final sampling (000/ha)	Tuber yield > 10 mm at final sampling (t/ha)	Margin over seed and nitrogen costs (£/ha)
Mean of standard crops (n=39)	2.50	546 ± 27.6	56.7 ± 1.56	4871 ± 186
Mean of improved crops (n=39)	2.05	490 ± 23.2	56.8 ± 1.45	5095 ± 162
Mean difference	0.46	56 ± 11.2	0.1 ± 0.90	223 ± 104
Probability difference is significant		P < 0.001	P = 0.911	P = 0.039

Appendix 1

Table 12. Summary of all N rate comparison data (N rate decreased) collected in Potato Council/NIAB-CUF Grower Collaboration Project R295 2007-2013. Yield data are hand-dug-samples taken about the time of defoliation

Year	Grower	Field	Variety	Standard N rate (kg N/ha)	Modified N rate (kg N/ha)	Change in N rate (kg N/ha)	Standard yield > 10 mm (t/ha)	Modified yield > 10 mm (t/ha)	Change in yield > 10 mm (t/ha)	Standard yield > 40 mm (t/ha)	Modified yield > 40 mm (t/ha)	Change in yield > 40 mm (t/ha)
Invalid comparisons												
2008	Strawson Farming†	Bower 8	Hermes	193	169	-24	66.2	60.6	-5.6	63.8	58.2	-5.6
2008	Mease Valley Potatoes‡	MFL B	Russet Burbank	200	160	-40	69.1	52.8	-16.3	64.5	46.8	-17.7
2010	RS Cockerill Ltd#	Field 16	Hermes	175	140	-35	55.8	51.6	-4.3	52.5	48.6	-3.9
2011	Co-operative Farms*	Pasture 116	Maris Piper	200	175	-25	61.0	62.8	1.8	59.7	61.3	1.6
Valid comparisons												
2007	Mease Valley Potatoes	Upper Trent	Russet Burbank	220	165	-55	59.5	67.6	8.1	56.4	64.1	7.7
2007	NNPG	Market Style	Saturna	240	175	-65	40.2	51.0	10.8	29.9	36.4	6.5
2008	AH Worth & Co	Field 13	Maris Piper	180	140	-40	56.0	50.9	-5.1	53.3	47.9	-5.3
2008	NNPG	Malthouse	Saturna	240	180	-60	45.2	48.6	3.4	42.1	45.4	3.3
2008	NNPG	Horseshoes	Hermes	224	175	-49	50.4	53.6	3.2	47.4	50.9	3.6
2009	AH Worth & Co	F38	Maris Piper	180	155	-25	71.4	72.6	1.1	69.8	70.7	0.9
2009	Mease Valley Potatoes	Curborough	Markies	150	130	-20	56.4	55.7	-0.7	51.7	50.9	-0.9
2009	Mease Valley Potatoes	Deercote Barn	Maris Piper	220	200	-20	64.5	54.4	-10.1	59.9	48.6	-11.3
2009	Strawson Farming	Wood 10	Hermes	210	185	-25	37.6	44.0	6.4	35.3	41.4	6.1
2009	Strawson Farming	Godfrey 13	Saturna	220	195	-25	63.1	58.9	-4.2	60.5	55.9	-4.6
2009	NNPG	Bakers 27	Saturna	240	180	-60	48.8	52.0	3.2	46.4	49.4	3.1
2009	NNPG	Long Lions	Hermes	191	181	-10	57.0	61.0	4.0	54.7	58.1	3.4
2010	Co-operative Farms	3/5/7/ B	Estima	230	205	-25	35.9	43.1	7.2	33.8	39.7	5.9
2010	Branston Potatoes	Pit Field	Desiree	140	120	-20	74.3	75.8	1.5	70.7	72.2	1.6
2010	AH Worth & Co	Field 26/27	Marfona	180	150	-30	54.8	60.9	6.1	53.4	59.5	6.0
2010	AH Worth & Co	JEP28	Melody	180	155	-25	44.2	46.5	2.3	40.1	41.3	1.2
2010	RS Cockerill Ltd	Field 35	Saturna	230	195	-35	47.2	39.2	-8.0	43.4	36.6	-6.8

Table 12. (continued)

Year	Grower	Field	Variety	Standard N rate (kg N/ha)	Modified N rate (kg N/ha)	Change in N rate (kg N/ha)	Standard yield > 10 mm (t/ha)	Modified yield > 10 mm (t/ha)	Change in yield > 10 mm (t/ha)	Standard yield > 40 mm (t/ha)	Modified yield > 40 mm (t/ha)	Change in yield > 40 mm (t/ha)
2010	RS Cockerill Ltd	Field 18	Hermes	225	185	-40	65.4	65.9	0.5	62.9	63.8	0.8
2011	RS Cockerill Ltd	Field 11	Hermes	220	190	-30	61.9	80.7	18.8	59.9	77.8	17.9
2011	RS Cockerill Ltd	Stanwick Wall	Saturna	175	160	-15	66.7	72.1	5.4	64.6	70.4	5.7
2011	Co-operative Farms	Pasture 116	Maris Piper	200	175	-25	63.9	68.3	4.4	62.2	66.8	4.6
2012	Co-operative Farms	Field 34	Melody	190	150	-40	62.8	71.0	8.2	57.7	67.1	9.4
2012	Co-operative Farms	Field 38	Harmony	190	140	-50	50.3	62.7	12.4	47.5	60.2	12.7
2012	RS Cockerill Ltd	Richardson	VR808	210	180	-30	37.2	36.3	-0.9	30.4	30.0	-0.4
2013	Frederick Hiam Ltd	Hill Farm 5	Vivaldi	180	160	-20	57.3	73.7	16.5	52.9	70.9	18.0
			Average (n=29)	201	168	-33	56.0	55.4	2.4	52.7	54.9	2.2

Not included in summaries because: †, N application rate smaller than intended; ‡, crop severely affected by potato cyst nematode; #, large difference in dates of emergence of standard and modified crops and *, plant populations different to those intended.

Table 13. Summary of all N rate comparison data (N rate increased) collected in Potato Council/NIAB-CUF Grower Collaboration Project R295 2007-2013. Yield data are hand-dug-samples taken about the time of defoliation. NB These comparison were done for the interest of growers and were not application rate suggested by NIAB-CUF

Year	Grower	Field	Variety	Standard N rate (kg N/ha)	Modified N rate (kg N/ha)	Change in N rate (kg N/ha)	Standard yield > 10 mm (t/ha)	Modified yield > 10 mm (t/ha)	Change in yield > 10 mm (t/ha)	Standard yield > 40 mm (t/ha)	Modified yield > 40 mm (t/ha)	Change in yield > 40 mm (t/ha)
2012	RS Cockerill Ltd	Richardson	VR808	210	240	30	37.2	32.1	-5.1	30.4	27.1	-3.3
2013	Frederick Hiam	Hill Farm 5	Vivaldi	180	200	20	57.3	65.7	8.5	52.9	63.0	10.1

Table 14. Summary of all seed rate comparison data (seed rate increased) collected in Potato Council/NIAB-CUF Grower Collaboration Project R295 2007-2012. Yield data are hand-dug-samples taken about the time of defoliation

Year	Grower	Field	Variety	Standard seed rate (t/ha)	Modified seed rate (t/ha)	Change in seed rate (t/ha)	Standard yield > 10 mm (t/ha)	Modified yield > 10 mm (t/ha)	Change in yield > 10 mm (t/ha)	Standard yield > 40 mm (t/ha)	Modified yield > 40 mm (t/ha)	Change in yield > 40 mm (t/ha)
2011	SWAG†	Big Mead	Sante	2.30	2.52	0.23	43.9	45.3	1.5	41.2	42.4	1.2
2007	Mease Valley Potatoes	Thorpe 41	Saturna	1.37	1.60	0.23	54.2	50.1	-4.1	51.8	46.1	-5.8
2007	Strawson Farming	Godfrey Blyth	Saturna	2.42	2.72	0.30	69.0	72.4	3.4	67.4	70.7	3.3
2009	NNPG	Bakers 27	Saturna	1.77	2.02	0.25	48.8	54.2	5.4	46.4	50.0	3.7
			Average (n=4)	1.96	2.21	0.25	54.0	55.5	1.5	51.7	52.3	0.6

Not included in summaries because: †achieved seed rates different to those intended.

Table 15. Summary of all seed rate comparison data (seed rate decreased) collected in Potato Council/NIAB-CUF Grower Collaboration Project R295 2007-2012. Yield data are hand-dug-samples taken about the time of defoliation

Year	Grower	Field	Variety	Standard seed rate (t/ha)	Modified seed rate (t/ha)	Change in seed rate (t/ha)	Standard yield > 10 mm (t/ha)	Modified yield > 10 mm (t/ha)	Change in yield > 10 mm (t/ha)	Standard yield > 40 mm (t/ha)	Modified yield > 40 mm (t/ha)	Change in yield > 40 mm (t/ha)
Invalid comparisons												
2008	A H Worth & Co†	Field 69	Estima	2.33	1.85	-0.48	59.0	59.6	0.6	56.5	56.1	-0.5
2008	A H Worth & Co†	Field 69	Estima	3.00	2.59	-0.41	59.2	69.8	10.6	56.1	67.1	10.9
2008	Strawson Farming†	Hoggard 6	Saturna	2.54	2.18	-0.36	67.6	60.1	-7.5	62.6	56.5	-6.1
2008	NNPG†	Millfield	Hermes	4.57	1.87	-2.70	53.9	59.4	5.6	49.0	56.6	7.5
2009	A H Worth & Co†	JEP44	Estima	2.43	2.17	-0.26	60.1	55.2	-4.9	58.7	54.0	-4.7
2009	Mease Valley Potatoes†	Marsh Barn	Lady Rosetta	1.71	1.40	-0.30	57.6	51.1	-6.5	52.3	48.5	-3.8
2009	Strawson Farming†	S. Wood 14	Hermes	3.14	2.87	-0.27	42.3	39.1	-3.1	38.7	36.1	-2.5
2009	NNPG†	Long Lions	Hermes	3.04	2.40	-0.64	57.0	62.2	5.2	54.7	59.6	4.9
2010	A H Worth & Co†	Field 26/27	Marfona	2.97	2.67	-0.30	54.8	63.3	8.5	53.4	62.2	8.7
2010	RS Cockerill Ltd†	Field 35	Saturna	2.36	2.28	-0.09	47.2	44.4	-2.8	43.4	40.8	-2.6
2011	SWAG†	Big Mead	Sante	2.30	2.07	-0.23	43.9	53.1	9.2	41.2	51.1	9.9
2011	B&C Farming Ltd†	Grove Farm 89	Russet Burbank	1.49	1.05	-0.44	61.6	65.3	3.7	55.8	59.6	3.8
2012	B&C Farming Ltd†	Fengate	Russet Burbank	1.50	1.33	-0.18	62.1	57.6	-4.5	55.0	53.0	-2.0
2012	B&C Farming Ltd†	Fengate	Russet Burbank	1.50	1.29	-0.22	58.3	59.4	1.1	51.4	52.9	1.5
2012	Branston Ltd††	DB3	Estima	3.05	2.66	-0.39	48.5	29.9	-18.6	41.6	18.9	-22.7
2013	James Daw	Wind Pump	Markies	1.83	1.49	-0.34	68.2	68.1	-0.1	64.0	64.6	0.6
2013	James Daw	Wind Pump	Russet Burbank	2.19	1.95	-0.24	61.9	66.1	4.1	57.1	61.9	4.8
2013	B&C Farming Ltd	Booton 31	Russet Burbank	1.44	1.16	-0.27	63.6	68.8	5.2	59.7	64.3	4.6
Valid comparisons												
2007	Mease Valley Potatoes	Ellis B	Hermes	2.89	2.44	-0.44	64.4	75.8	11.4	60.5	71.9	11.4
2007	Mease Valley Potatoes	Thorpe 41	Saturna	2.94	2.44	-0.51	58.8	51.4	-7.4	56.0	46.5	-9.5
2007	Strawson Farming	K. Narborough	Saturna	2.30	2.11	-0.20	51.0	49.8	-1.1	48.2	47.8	-0.4
2007	Strawson Farming	S. Creake	Hermes	3.43	2.46	-0.97	47.5	46.8	-0.7	46.9	46.4	-0.5

Table 15. (continued)

Year	Grower	Field	Variety	Standard seed rate (t/ha)	Modified seed rate (t/ha)	Change in seed rate (t/ha)	Standard yield > 10 mm (t/ha)	Modified yield > 10 mm (t/ha)	Change in yield > 10 mm (t/ha)	Standard yield > 40 mm (t/ha)	Modified yield > 40 mm (t/ha)	Change in yield > 40 mm (t/ha)
2007	Strawson Farming	B. Carburton	Hermes	4.39	2.81	-1.58	55.5	58.6	3.1	52.3	56.7	4.3
2007	NNPG	45 acres	Saturna	2.56	2.15	-0.42	68.7	62.8	-5.9	64.7	59.9	-4.8
2007	NNPG	Wrights	Hermes	3.07	2.16	-0.91	49.8	54.0	4.2	45.5	51.0	5.5
2008	A H Worth & Co	Field 13	Maris Piper	1.54	1.13	-0.41	64.4	56.0	-8.4	59.9	53.3	-6.7
2008	Strawson Farming	Bower 8	Hermes	4.47	2.50	-1.96	66.2	57.9	-8.3	63.8	56.2	-7.6
2008	Strawson Farming	Godfrey 8	Saturna	2.45	2.17	-0.29	50.6	52.0	1.5	46.8	48.5	1.6
2008	NNPG	Millfield	Hermes	4.57	2.96	-1.61	53.9	59.3	5.5	49.0	56.8	7.7
2008	NNPG	Horseshoes	Hermes	2.59	2.09	-0.49	50.4	53.6	3.2	47.4	51.7	4.3
2008	NNPG	Malthouse	Saturna	2.02	1.61	-0.41	45.2	43.3	-1.9	42.1	41.3	-0.8
2008	Mease Valley Potatoes	Bowling Alley	Lady Rosetta	3.27	2.98	-0.29	66.9	64.7	-2.1	62.2	60.9	-1.2
2008	Mease Valley Potatoes	P. Quarry	Hermes	3.89	2.53	-1.36	57.8	55.0	-2.8	51.8	49.9	-1.9
2009	A H Worth & Co	JEP44	Estima	3.42	2.89	-0.54	67.8	66.2	-1.6	65.8	65.1	-0.7
2009	Mease Valley Potatoes	Marsh Barn	Lady Rosetta	2.37	1.80	-0.57	54.5	52.2	-2.3	46.2	48.5	2.3
2009	Strawson Farming	S. Wood 14	Hermes	3.14	2.27	-0.86	42.3	39.6	-2.6	38.7	37.5	-1.1
2009	NNPG	Bakers 55	Hermes	3.05	2.40	-0.66	56.6	58.2	1.6	52.1	55.8	3.7
2010	Cooperative Farms	3/5/7/ B	Estima	2.80	2.36	-0.44	35.9	39.5	3.6	33.8	38.0	4.2
2010	Branston Potatoes Ltd	Hall Field	King Edward	2.14	1.88	-0.27	67.2	66.0	-1.1	60.6	61.3	0.7
2010	RS Cockerill Ltd	Field 16	Hermes	3.45	2.56	-0.89	55.8	58.4	2.6	52.5	55.8	3.2
2010	RS Cockerill Ltd	Field 18	Hermes	3.14	2.35	-0.79	57.1	65.4	8.3	55.6	62.9	7.3
2011	Branston Potatoes Ltd	Nocton 2	Maris Piper	1.76	1.51	-0.25	71.2	68.3	-2.9	69.3	67.0	-2.3
2011	RS Cockerill Ltd	Field 11	Hermes	3.70	2.65	-1.05	61.9	73.5	11.6	59.9	72.1	12.1
2011	Co-operative Farms	Pasture 116	Maris Piper	2.40	2.08	-0.32	63.9	61.0	-2.9	62.2	59.7	-2.5
2011	Co-operative Farms	Pasture 116	Maris Piper	2.40	2.08	-0.32	68.3	62.8	-5.5	66.8	61.3	-5.5
2011	Tame Valley Potatoes	29 Acre	Russet Burbank	1.73	1.43	-0.30	71.5	66.4	-5.1	67.7	63.5	-4.2
2011	Tame Valley Potatoes	29 Acre	Russet Burbank	1.83	1.51	-0.32	65.0	60.4	-4.5	57.8	55.0	-2.9

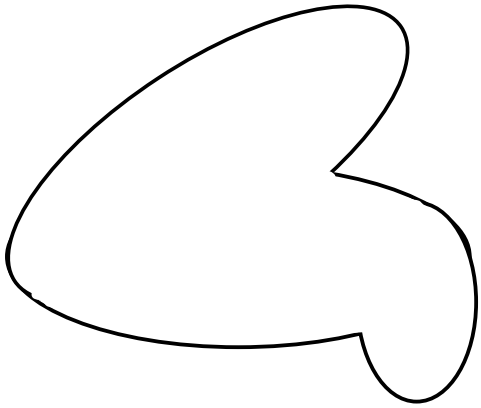
Table 15. (continued)

Year	Grower	Field	Variety	Standard seed rate (t/ha)	Modified seed rate (t/ha)	Change in seed rate (t/ha)	Standard yield > 10 mm (t/ha)	Modified yield > 10 mm (t/ha)	Change in yield > 10 mm (t/ha)	Standard yield > 40 mm (t/ha)	Modified yield > 40 mm (t/ha)	Change in yield > 40 mm (t/ha)
2011	B&C Farming Ltd	Grove Farm 91	Russet Burbank	1.49	1.05	-0.44	75.6	67.1	-8.5	70.0	62.4	-7.6
2011	B&C Farming Ltd	Grove Farm-91	Russet Burbank	1.47	1.01	-0.46	72.4	66.5	-5.9	65.0	59.8	-5.2
2011	B&C Farming Ltd	Medler Melton	Russet Burbank	1.49	1.05	-0.44	59.8	57.3	-2.5	51.0	50.2	-0.8
2011	B&C Farming Ltd	Medler Melton	Russet Burbank	1.47	1.01	-0.46	58.5	61.3	2.8	48.6	54.8	6.2
2012	Co-operative Farn	Field 38/02	Harmony	3.09	2.71	-0.38	50.3	61.0	10.7	47.5	58.4	10.9
2012	Cockerills	Richardson	VR808	1.92	1.49	-0.43	37.2	35.6	-1.6	30.4	31.3	0.8
2012	James Daw	Green Lane	Markies	1.98	1.66	-0.31	43.1	54.4	11.3	40.1	52.4	12.2
2012	James Daw	Green Lane	Russet Burbank	1.71	1.40	-0.31	41.4	46.4	5.0	35.2	40.5	5.3
2012	B&C Farming	Grove Farm 82	Russet Burbank	1.50	1.29	-0.22	72.5	69.9	-2.7	68.0	66.0	-2.0
2012	B&C Farming	Fengate	Russet Burbank	1.53	1.25	-0.27	63.6	65.2	1.6	58.8	59.5	0.8
2012	B&C Farming	Fengate	Russet Burbank	1.74	1.15	-0.59	64.0	59.5	-4.5	55.5	55.2	-0.4
2012	B&C Farming	Medler C. Hall	Russet Burbank	1.50	1.29	-0.22	61.4	57.4	-4.1	54.1	50.5	-3.6
2013	3Ms	Angel Hill	Maris Peer	5.04	3.93	-1.10	43.8	43.5	-0.3	19.5	24.6	5.1
2013	James Daw	Wind Pump	Russet Burbank	2.85	2.48	-0.36	68.2	61.9	-6.3	64.0	57.8	-6.2
2013	B&C Farming	Medlers Res.	Russet Burbank	1.44	1.16	-0.27	54.6	54.2	-0.3	50.4	51.1	0.8
			Average (n=62)	2.54	1.99	-0.54	57.8	57.6	-0.2	53.2	53.9	0.7

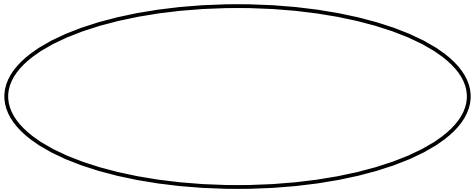
Not included in summaries because: †achieved seed rates different to those intended; ††variable crop due to blight.

Appendix 2.

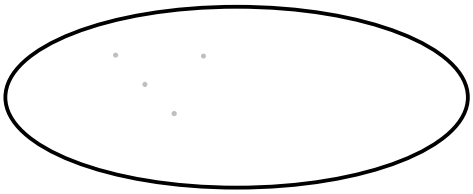
Table 16. Scheme used to assess internal defects in Markies and Russet Burbank. Assessments are made on tubers > 90 mm in length. The number of mis-shapes and dolls are first recorded then all tubers are then cut in half length-ways and assessed for defects.



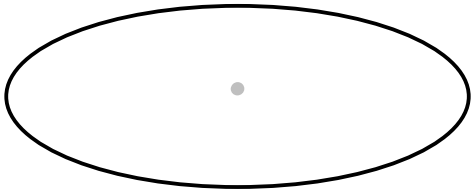
Number of dolls & mis-shapes in sample



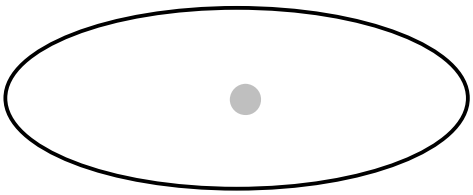
0. No internal discolouration on cut surface



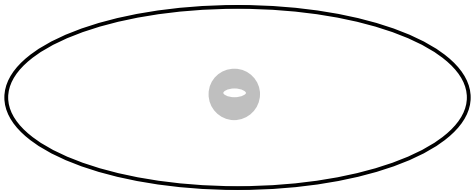
1. Slight speckling



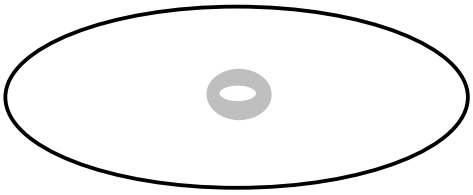
2. Obvious staining . Spots are c. 2-3 mm



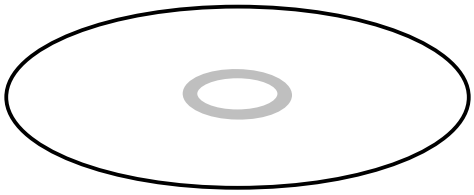
3. Large, 4-5 mm or multiple spots



4. First sign of hollowness at centre of tuber



5. Hollowness at centre of tuber *c*. 5 mm



6. Hollowness at centre of tuber *c.* 10 mm