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The relationship between total yield, number of tubers and yield of large tubers in potato crops

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SUMMARY

Experiments were made over 2 years at two sites using three varieties to investigate the relationship between total yield, number of tubers > 1 cm and the yield of tubers in the 60–80 mm size range. Regression analysis revealed that yield of tubers in the 60–80 mm size range was a linear function of total yield and number of tubers > 1 cm. The effect of changes in tuber shape on this relationship is discussed.

INTRODUCTION

Many growers are interested in producing large tubers to market as 'bakers' because a substantial premium over ware (45–80 mm) tubers can be obtained. It has been suggested that tuber-size distribution is a function of total yield and number of tubers (Sands & Regel, 1983). Experiments were made in 1984 and 1985 to investigate the relationship between total yield (T), the number of tubers > 1 cm (N), and yield in the 60–80 mm size range (Y) which approximates to baking weight tubers.

MATERIALS AND METHODS

In both years, three varieties, Estima, Pentland Squire and Maris Piper, were planted at three within-row spacings, 20, 40 and 80 cm, in a randomized-block design with three replicates. The experiment was planted at the Cambridge University Farm (CUF) and at Lords Ground Farm (LF), near Swaffham Prior, Cambridgeshire. Details of the sites and the cultural conditions are given in Table 1. Harvests were dug by hand from June to late September and tubers were mechanically graded over square-mesh riddles. On each occasion T, N and Y were recorded. At the final harvest, 30 tubers from each variety × site combination were selected at random from the 60–70 and 70–80 mm size ranges and lengths of the three major axes and weight recorded. In 1984, similar measurements were recorded from 20 tubers of the variety Maris Piper randomly selected from the 50–60 mm size range from three other sites of differing soil type. In addition, records of T, N and Y were included in the analysis from other seed weight × within-row spacing

Table 1. *Site details and cultural conditions*

	Cambridge University Farm	Lords Ground Farm
Soil series ... (Hodge & Seale, 1966)	Milton (sandy clay loam)	Adventurers (fen peat)
Seed weight (g)	70–80	70–80
Row width (cm)	71	86
Planting date		
1984	18. iv	1. v
1985	23. iv	2. iv
Fertilizer (kg/ha)		
1984	150 N, 65 P, 192 K	165 N, 134 P, 250 K 50 Mg
1985	150 N, 65 P, 187 K, 41 Mg	50 N, 74 P 49 t sewage sludge/ha
Herbicide	Terbutryne + terbuthylazine	Metribuzin
Nematicide	None	Aldicarb
Irrigation (total amount in mm)	25	75

Table 2. *Relationship between* Y (*t/ha*), N (*'000s/ha*), *and* T (*t/ha*)

Group 1	Estima, Pentland Squire, Maris Piper at CUF and Pentland Squire at LF	$Y = -2.33 - 0.0378N + 0.866T$
Group 2	Estima at LF	$Y = -2.33 - 0.0480N + 0.866T$
Group 3	Maris Piper at LF	$Y = -2.33 - 0.0523N + 0.866T$

Table 3. *Individual tuber measurements*, 1984

		60–70 mm				70–80 mm			
		Length (mm)	Width (mm)	Depth (mm)	Weight (g)	Length (mm)	Width (mm)	Depth (mm)	Weight (g)
Estima	CUF	102	78	62	223	131	88	68	366
	LF	130	78	59	274	163	89	66	461
Pentland	CUF	93	76	62	210	117	87	73	344
Squire	LF	100	79	64	228	119	94	73	359
Maris Piper	CUF	102	77	59	222	116	89	66	341
	LF	128	78	58	284	152	89	67	422
S.E.		2·9	1·0	1·0	9·6	3·9	1·7	1·2	16·0

experiments using the three varieties in 1984 and Estima in 1985 at CUF.

RESULTS AND DISCUSSION

Regression analysis of the data revealed that Y was a simple linear function of N and T over the range tested, N from 200000 to 1200000 tubers/ha and T from 30 to 70 t/ha. Data points where $Y < 2.5$ t/ha were excluded as being of little practical interest. Initially, separate relationships were fitted for each variety × site × year combination. However, further analysis revealed that the data could be regarded as falling into three groups with no significant increase in the residual mean square. In this model, all the data from CUF with Pentland Squire from LF were regarded as one group, Estima from LF as a second group and Maris Piper from LF as a third group. The coefficient of multiple determination (r^2) was 0·88 and the regression coefficients (see Table 2) were significant.

This grouping of results and the greater Y for a given N and T of group 1 than groups 2 and 3 were at least partially caused by differences in tuber shape between groups. In Table 3, the length, width, depth and weight of tubers in 60–70 and 70–80 mm size ranges are shown for all variety × site combinations in 1984. Similar results were obtained in 1985. Clearly, tubers in group 1 shared similar shape characteristics while tubers in groups 2 and 3 were longer for a given width and depth which was reflected in their greater average weight. An estimate of the effect these differences in tuber shape might be expected to have on the size grading of the crop and hence on the relationship between Y, N and T was made (Table 4). The lower and upper individual tuber weights in the 60–80 mm size range were estimated for group 1 and group 2 with 3 from the mid-point between the mean tuber weights of the 60–70 and 70–80 mm size ranges and the mean tuber weights of the preceding and following 10 mm size ranges respectively. It was assumed that the distribution of yield with respect to tuber weight was approximately normal. Clearly, the difference in Y between group 1 and group 2 with 3 estimated from the change in grading due to tuber shape changes was similar to that estimated from the equations in Table 2. Thus, tuber shape changes may account for both the grouping of these results and for the greater Y at given N and T of group 1 over groups 2 and 3.

For the above relationships to be of practical use one must decide which equation to use on the basis of tuber shape and one must also have an estimate of N and T. To some degree, tuber shape is a varietal characteristic: the three varieties used here are classified as oval or short oval (National Institute of Agricultural Botany, 1986). However, it has been shown that the shape of two of the varieties was affected by site of production (Table 3). The roundest variety, Pentland Squire, was least affected by site of production, an effect also noted by Reust & Munster (1978). In Table 5, the effect of three sites of differing soil type on the shape characteristics of Maris Piper in the 50–60 mm size range is shown. Again, tubers from the fenland site were longer for a given width and depth while there was little difference between tubers from the other two sites. Further experiments are needed to determine

Table 4. *Estimated effect of tuber shape on* Y *(t/ha), final harvest,* 1984

Estimated mean of distribution of yield with respect to tuber weight (g)	130	
Estimated standard deviation (g)	165	
Number of tubers > 1 cm/ha	523000	
Total yield (t/ha)	60·4	
Estimated lower and upper tuber weights in 60–80 mm size range (g)		
Group 1	178	444
Group 2+3	220	527
Proportion of total yield represented by tubers of weight greater than (Powell, 1982)		
178 g	0·39	
220 g	0·29	
444 g	0·029	
527 g	0·008	
Proportion of total yield represented by tubers of weight between		
178 and 220 g	0·10	
444 and 527 g	0·021	
Yield (t/ha) of tubers whose weight lies between		
178 and 220 g	$0·10 \times 60·4 = 6·0$	
444 and 527 g	$0·021 \times 60·4 = 1·3$	
Y (group 1) − Y (group 2+3)	$6·0 - 1·3 = 4·7$	
Y (group 1) − Y (group 2+3) from substituting $N = 523$ and $T = 60·4$ into equations in Table 1	$30·2 - 23·7 = 6·5$	

Table 5. *Effect of site on shape of Maris Piper*, 1984

Site	Soil type	Length (mm)	Width (mm)	Depth (mm)	Weight (g)
Stretham, Cambs.	Fen peat	82	60	45	159
Holbeach, Lincs.	Silt	66	57	45	121
Terling, Essex	Loam	70	56	48	135
S.E.		2·1	0·8	0·7	5·2

whether this is a general effect of fenland sites with some varieties. Soil type has previously been reported as affecting tuber shape (Neumann, 1925; Reust & Munster, 1978). In the former study, sandy soils produced the shortest tubers while heavier soils produced elongated tubers, whereas in the latter study, the reverse was reported. Other factors are known to influence tuber shape e.g. soil temperature (Yamaguchi. Timm & Spurr, 1964; Epstein, 1966), fertilizer (Neumann, 1925; Wohrmann, 1966), seed physiological age (Reust & Munster, 1978) and growth substances (Al-Rawi, 1981; Weis & Schoenemann, 1985), but their influence under U.K. field conditions is poorly understood.

From the equations in Table 2, a high yield of large tubers can be produced with a high total yield and a large number of tubers or a low total yield and a small number of tubers. Thus, using the equation for group 1, 20 t/ha of 60–80 mm tubers could be produced with a total yield of 65 t/ha and 898000 tubers/ha or a total yield of 35 t/ha and 211000 tubers/ha. Clearly, the lower the likely total yield, the more critical it is to restrict the number of tubers.

To some extent the number of tubers is under the control of the grower through varietal choice and seed rate. Unless yields are expected to be very high a variety such as Maris Piper which tends to set many tubers (rating 7, National Institute of Agricultural Botany, 1986) is less likely to be

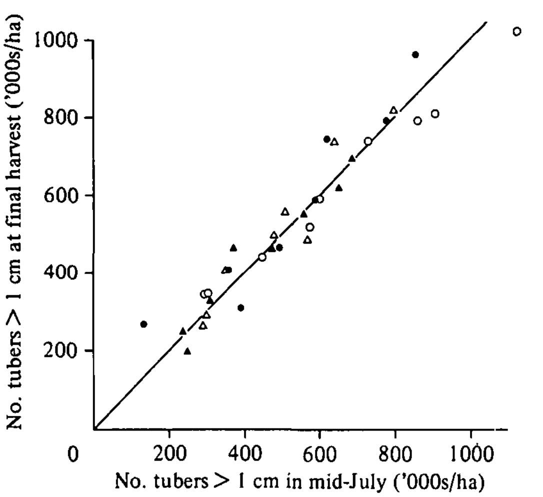

Fig. 1. Number of tubers > 1 cm in mid-July and at final harvest. ○, CUF; △, LF; closed symbols, 1984; open symbols, 1985; solid line, $y = x$.

suitable for the production of large tubers than a variety like Pentland Squire (rating 3, National Institute of Agricultural Botany, 1986). It is undoubtedly possible to reduce the number of tubers by reducing the seed rate but eventually this will also reduce total yield. Until it is possible to predict the relationship between seed rate and the number of tubers and seed rate and total yield for any particular crop, the net effect on the yield of large tubers will inevitably remain unpredictable.

N cannot be predicted with any accuracy, but could be estimated from field samples taken in mid-July after the end of tuber initiation. The number of tubers > 1 cm remains relatively constant from this time as shown in Fig. 1. *T* could be estimated using one of the many models of tuber growth available (Sands, Hackett & Nix, 1979; MacKerron & Waister, 1985) or growers might just make a most optimistic and most pessimistic estimate based on their own experience. The 95% confidence limits for *Y* are $\pm 6{\cdot}2$ t/ha at mean *N* and *T*. These limits are quite wide and thus reduce the usefulness of the relationships for predictive purposes. However, the best way of estimating the yield of 60–80 mm tubers, direct field sampling, is also subject to variation. In these experiments, the 95% confidence limits of the yield of 60–80 mm tubers were never less than $\pm 6{\cdot}2$ t/ha at final harvest with a sample size of 10 m of row length replicated three times. Thus, without very large field samples the accuracy of direct sampling of this grade is low.

CONCLUSIONS

The yield of large tubers is linearly related to total yield and the number of tubers but where tubers are graded by size, the relationship will vary with tuber shape. The main mechanisms available to growers for altering the number of tubers are varietal choice and seed rate but these are also likely to alter total yield with an unpredictable net effect. The number of tubers can be estimated from field samples in mid-July, and by using these linear relationships it should be possible to identify those crops most likely and least likely to give a reasonable yield of large tubers and those most likely to benefit from an extended growing season or from early burning off.

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