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The feasibility of predicting the number of stems per tuber produced by potato seed stocks from measurements made before planting

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Summary

The number of stems per seed tuber produced by 17 seed stocks of cv. Record was determined in glasshouse and field experiments to assess the feasibility of predicting the number of stems produced in the field. Multiple regression analysis showed that seed tuber weight alone gave the most satisfactory fit to stems produced in the field, which was not improved by adding terms involving the number of stems produced in the glasshouse.

Quadratic relationships between the number of above-ground stems per tuber and tuber weight were most appropriate for each stock, with the fitted curves for individual stocks differing only in the constant term. However, there were significant rank correlation coefficients between the constant terms for relationships between field stems and tuber weight and glasshouse stems and tuber weight, suggesting that in other cultivars and seed stocks a predictive glasshouse test might still be useful.

Introduction

Potato growers change the number of seed tubers planted according to the tuber count (tubers/50 kg) of a seed stock, with little attention being paid to the ability of seed tubers to produce stems. The merit of using the stem as a unit of plant density in the potato crop was considered by Arthur (1892) and subsequently several workers (Reestman & De Wit, 1959; Bleasdale, 1965; Sharpe & Dent, 1968; Wurr, 1974; Lynch & Rowberry, 1977; Jarvis, 1977) have demonstrated relationships between tuber yield and stem density. In addition, there can be a considerable effect of stem density on the number of tubers per plant (Struik et al., 1990). Since seed tubers from different sources are known to produce different numbers of stems (Gill & Waister, 1988) more attention should be paid to the ability of seed stocks to produce stems.

While the number of stems per ha is now commonly accepted as the true unit of density, there is no system in use for predicting the number that will be produced in the field. Reestman & De Wit (1959) found that the number of stems per tuber was closely related to seed tuber surface area, while Bleasdale (1965) found a close relationship between the number of stems per tuber and the number of eyes per tuber. Wurr (1975) found that there were good linear relationships between the number of stems per tuber and the number of 'sproutlets' per tuber, yet such counts require experience and are not relevant to unsprouted seed. Wurr & Morris (1979), investigating more practical indicators of the number of stems per tuber, found linear relationships between the number of stems per seed tuber and tuber weight, although relationships varied with variety, season and seed storage regime.

In the experiments described here, the number of stems produced by seed stocks of the cv. Record were determined in a glasshouse test and the feasibility of using such data as a guide to the number of stems likely to be produced in the field was then assessed.

Materials and methods

In 1988 and 1989 respectively, eight and nine certified seed stocks of cv. Record were divided into eleven 10-g weight grades, the smallest being 20 – 30 g and the largest 120 – 130 g. In all experiments, each tuber was individually numbered and weighed and the three major axes were measured. Seed was kept prior to planting in an ambient temperature seed store with artificial fluorescent lighting. All seed stocks had minimal sprout growth when delivered and were therefore of similar physiological age. In each experiment, treatments were all combinations of the eleven weight ranges and the available seed stocks. In glasshouse experiments during 1988 and 1989, tubers were planted 11 cm deep into Levington M3 compost contained in plastic trays 60 cm long, 14 cm deep and 14 cm wide. Each tray contained ten tubers. Each treatment was represented by two replicates of five tubers, two plots being allocated to each planting tray. In 1988, because delivery of seed was delayed, tubers were planted on 4 May and harvested on 2 June, while in 1989, tubers were planted on 16 March and harvested on 18 April. The experiments were conducted at glasshouse ambient temperatures, with the vents opening at 25 °C. In 1988, the field experiment was planted on 27 April and harvested on 22 June, while in 1989 it was planted on 11 May and harvested on 6 July. Each treatment in the field experiments had two replicates of ten tubers, arranged in a randomized block design.

All field experiments were planted at Cambridge University Farm on a gravelly loam soil of the Milton Association. Fertilizer applied was 136 kg N, 60 kg P, 170 kg K and 36 kg Mg/ha in 1988, and 126 kg N, 55 kg P, 104 kg K and 76 kg Mg/ha in 1989. The within-row tuber spacing was 38 cm, with a row width of 71 cm. Tubers were planted to a depth of 12 – 16 cm from the top of the tuber, and harvesting occurred after the onset of tuber initiation. At harvest in all experiments, numbers of main and above-ground stems were recorded.

Results and discussion

Analyses were based on the mean data from the individual seed tubers pooling both replicates of five tubers in the glasshouse experiments and ten tubers in the field experiments. Wurr & Morris (1979) showed that relationships between the number of stems per tuber and tuber weight accounted for more of the variation in numbers of stems than relationships using tuber shape or sprout measurements. Initial analyses here (Table 1) showed that correlation coefficients between stems and seed tuber weight were always as great or greater than those between stems and tuber length, width, breadth and volume (calculated as the volume of an ellipsoid) and

Table 1. The correlation coefficients between the number of stems per tuber (main and above-ground) and various tuber characters (df 180) for glasshouse and field data.

Stems	Length	Width	Breadth	Volume	Weight
Glasshouse					
Main	0.49	0.55	0.54	0.52	0.57
Above-ground	0.63	0.68	0.67	0.66	0.70
Field					
Main	0.82	0.84	0.82	0.84	0.84
Above-ground	0.91	0.91	0.90	0.92	0.92

consequently only relationships using tuber weight are presented.

Table 1 also shows that the correlation coefficients between stems and tuber weight were greater with above-ground stems than with mainstems. This confirms the findings of Allen & Wurr (1973) and Lynch & Rowberry (1977) that above-ground stems act as a satisfactory unit of density, and it is not necessary to distinguish between mainstems and above-ground stems. Furthermore, analyses of our data showed that similar results were obtained whether using mainstems or above-ground stems. Therefore, in order to simplify the results, the analyses presented here are restricted to above-ground stems. Multiple regression analysis was then used to determine which variable would be the best predictor of the number of stems per tuber in the field. Terms included in the model were seed tuber weight and linear and quadratic terms in the number of stems in the glasshouse. The results in Table 2 show that seed tuber weight alone gave the most satisfactory fit, which was not improved by adding in terms involving the number of glasshouse stems. This suggests that with these cv. Record seed stocks a glasshouse test is unlikely to directly predict the number of stems produced in the field. However, the relationship between stems and tuber weight will still have practical value and so linear and quadratic models relating stems (y) to tuber weight (x) were fitted using data from all 17 seed stocks in both 1988 and 1989. Both Svensson (1966) and Gill & Waister (1987) reported a linear relationship between the number of stems per tuber and tuber weight. However, here a quadratic model: $y = ax^2 + bx + c_i$, where $i = 1 \ldots 17$ seed stocks, was found to be significantly better than the linear model. A similar quadratic relationship was also used by Hagman (1973). This quadratic relationship shows that for cv. Record the

Table 2. The total mean square and the residual mean squares resulting from fitting various terms in the model relating the number of stems to tuber weight.

	df	Total mean square
	181	0.7788
		Residual mean square
Fitting tuber weight	180	0.1251
Adding glasshouse stems	179	0.1240
Adding glasshouse stems^2	178	0.1253

Table 3. The total mean square and the residual mean squares resulting from fitting linear and quadratic terms in the models relating the number of stems (y) to tuber weight (x), where $i = 1 \ldots$ number of seed stocks.

	df	Glasshouse above-ground stems	Field above-ground stems
Total mean square	183	0.9114	0.7844
Residual mean square fitting			
$y = bx + c$	182	0.4640	0.1250
$y = bx + c_i$	166	0.2053	0.1128
$y = ax^2 + bx + c$	181	0.4590	0.1201
$y = ax^2 + bx + c_i$	165	0.1997	0.1069

relationship between stems and tuber weight showed some curvature, with lines differing only in the constant term c_i for individual seed stocks. Table 3 shows the residual mean squares from fitting the models described. The difference in the constant term fitted for separate seed stocks demonstrates that the smaller the seed used, the greater the effects of stocks on stem densities in the field. This is because in practice small seed tubers are planted at a higher density than large seed tubers and therefore the potential for variation in stem density per ha will be greater with small than with large seed tubers.

Figure 1 shows a scatter plot of data from all seed stocks and the fitted lines and data for the stocks with the extreme and central values of the constant term c_i for stems in the glasshouse (c_{gi}) (Figs 1a and b) and in the field (c_{fi}) (Figs 1c and d). The scatter plots show much greater spread than the fitted lines yet these data do not appear atypical since both Svensson (1966) and Hagman (1973) found that relationships between the number of stems per tuber and tuber weight only accounted for a small proportion of the total variance. They concluded that factors other than seed tuber weight were also important. The fitted lines indicate a range of about 1.6 stems per tuber between extreme seedlots at the same tuber weight in the glasshouse and 0.5 stems per tuber in the field. The latter suggests that there would be little need for predictions to discriminate between the number of stems per tuber for those individual stocks used here and that numbers of stems per tuber could be predicted reasonably accurately with a single relationship using tuber weight.

In contrast to these findings, Gill & Waister (1988) found with cv. Désirée that the number of stems per tuber from tubers of equal weight but different seed stocks could vary from 3.4 to 6.0. In such circumstances a predictive technique would be useful and the results here may indicate a possible method. Spearman rank correlation coefficients were calculated between the constant terms for the relationships involving field stems and tuber weight (c_{fi}) and glasshouse stems and tuber weight (c_{gi}). There was a significant correlation (0.62 with $n = 17$) between the c_{fi} and c_{gi} values, suggesting (Fig. 2) that a glasshouse test for a seed stock could be used to give an indication of the c value in the field. This would then enable the tuber planting

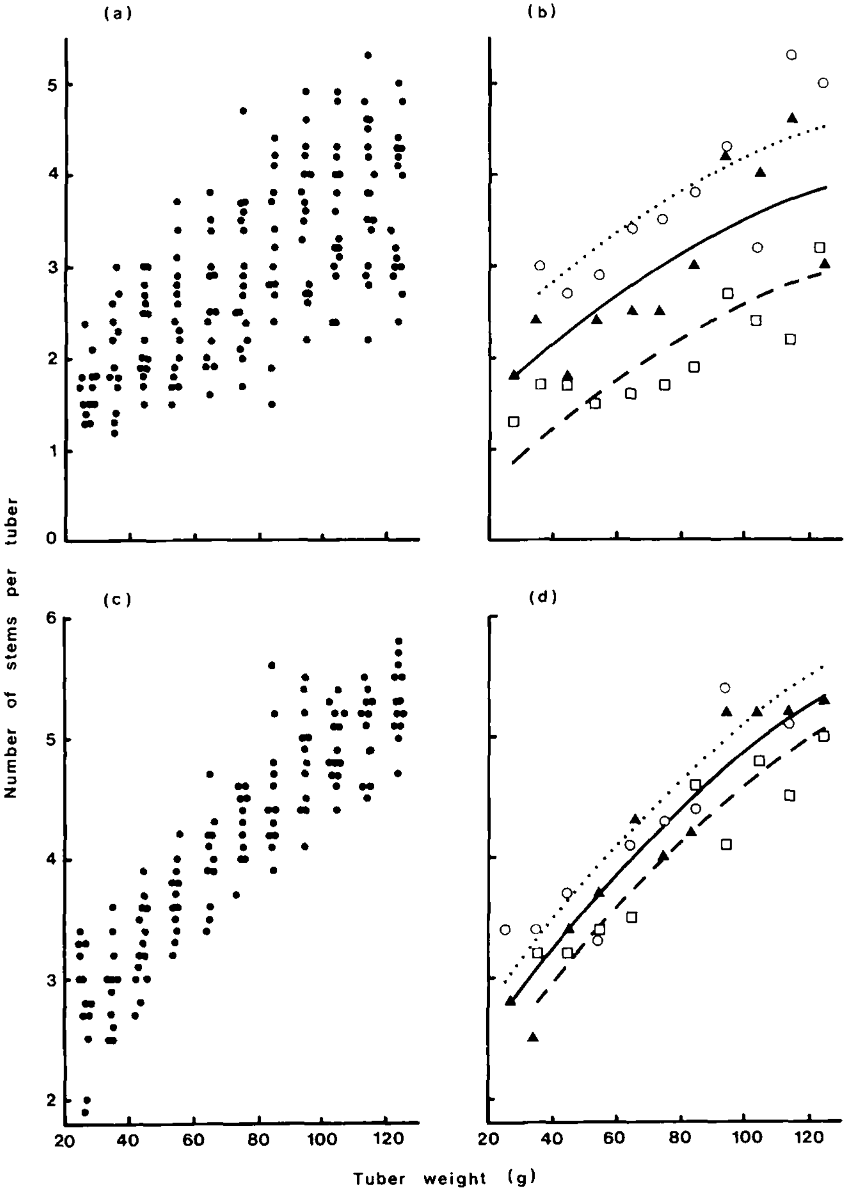

Fig. 1. Scatter plots of the number of stems per tuber against tuber weight for (a) all 17 seed stocks in the glasshouse experiments, (b) the central and extreme fitted lines in the glasshouse experiments, (c) all 17 seed stocks in the field experiments and (d) the central and extreme fitted lines in the field experiments.

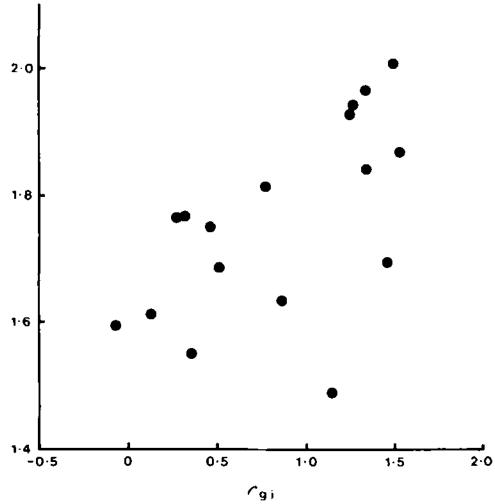

Fig. 2. A scatter plot of the c_{fi} parameters for the quadratic relationships between the number of stems per tuber and tuber weight in the field experiments against the c_{gi} parameters for the quadratic relationships between the number of stems per tuber and tuber weight in the glasshouse experiments.

density to be adjusted to optimise the stem density. In practice a glasshouse test would need to be conducted on a test seed stock (t) separated into at least four weight grades and a quadratic curve, $y = ax^2 + bx + c_{gt}$, fitted through the data. The value of c_{gt} from the glasshouse test would then be ranked relative to the known values of c_{gi} from previous glasshouse tests. It is suggested that this ranking could then be applied to previously determined c_{fi} values for field-grown stocks to estimate a c_{ft} value for field stems in the test stock. With the values of a and b fixed as found here, the number of stems to be produced by tubers of any weight could then be estimated.

We know that the number of stems produced can be affected by the length of the sprouting period (Allen et al., 1979; O'Brien et al., 1983), and a predictive technique applied after sprout development had taken place, but before planting, would be able to take some of this into account. It would need more controlled environmental conditions than those used here and would need to take account of the date of dormancy break of the seed stock and the time of planting the ware crop (Cho, 1981).

If such a technique to predict the number of stems per tuber before planting is developed it will be possible to adjust the seed tuber spacing to get closer to the optimum stem density required for any seed tuber weight and hence give better control of tuber size. It will also improve the efficiency of seed handling, ensuring that only seed which is required is moved to the field. Such predictive work is futuristic, yet technically-aware growers have recently expressed a need for information on the number of stems per tuber, and so it is unlikely to be regarded as unrealistic.

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