# Seed rates for the new sugar regime

---

**BBRO Project 06/05 Final Report**

**Broom's Barn and British Sugar**
**26/5/2009**

# Seed rates for the new sugar regime

# BBRO Project 06/05
# Final Report

## Executive Summary


1. Eleven experiments testing seed rates and sugar beet yields were made on loamy sand, sandy loam, sandy clay loam and silty clay loam soils between 2006 and 2008. All experiments were harvested by machine. Population densities ranged from 55 to 145 thousand plants per hectare.
2. There was never a significant adjusted yield response to changes in plant population density, although there were tendencies for sugar concentrations and dirt tares to increase as density was increased. Sodium, potassium and amino N concentrations in the beet tended to decrease with increased density. There was no tendency for top tare to change.
3. Bleasdale and Nelder's (1960) model was fitted to the yield and plant density data from each experiment, and was then inverted to estimate the adjusted yield at a range of densities. The value of these yields was calculated, assuming that each adjusted tonne was worth £26. The seed cost at each density was calculated assuming 60 or 80% seedling establishment and seed priced at £150/unit. These data were then combined to calculate the net return for each population at each site.
4. Net return was at 97% of its maximum value over a wide range of population densities. At 10 of the 11 sites, ***80,000 plants per hectare was an appropriate target population density:*** 100,000 plants per hectare was too high a target at 3 of these 10 sites. The penalty from having more plants than this target was always small, but that from having fewer plants could sometimes be large. The target density was not affected by establishment percentage, soil texture or the yield of the site.
5. Despite recent increases in seed prices, falls in beet prices and changes to harvest techniques, there is no need to radically revise the plant population targets for the sugar beet crop in England.
6. Surveys of population, seedling establishment and yield in about 1600 fields from 2004 to 2008 showed that there was a tendency for fields with less than 80,000 plants per hectare to produce less than 70 t/ha, while fields with more than this target tended to yield more than 70t/ha. Whether or not the target of 80,000 plants per hectare was achieved seemed to be mostly associated with variations in seedling establishment percentage, and not seed rate or soil type.
7. Staff from Broom's Barn and British Sugar will consider how best to research methods to reliably improve establishment and prepare a research proposal for consideration in 2010.

## Objectives

1. To determine, on the major soil types, the effects of three in-row seed spacings on plant uniformity, yield and beet quality at two seedling establishment percentages on large strip plots to allow the costs and benefits at the commercial scale to be evaluated.

2. To compare, the effects of the same treatments as in Objective 1 on yield and beet quality using 50 and 60 cm rows using standard experimental plots on a sandy soil.

3. To use recent British Sugar plc survey data from commercial fields to determine the distributions of seed rates and plant population densities in commercial sugar-beet fields and thus pinpoint the risks that might arise from any changes to current practice and identify any improvements that may be needed.

4. To combine information from the experimental and survey work to produce new recommendations for the most cost-effective seed spacings for the new sugar regime.

## Introduction

The last experiments on the effects of plant population density on the performance of UK sugar-beet crops on which much of our current advice is based were done over 30 years ago (Hull & Jaggard 1971) and last reassessed nearly 20 years ago (Jaggard 1990). The main conclusion was that the optimum plant population density for maximum yield was 65,000 plants/ha on good soils increasing to about 85,000 plants/ha on poor soils. Although yields were not improved at higher than optimal densities, sugar content and beet quality (amino-N, potassium and sodium contents) were improved. Very high densities increased dirt tare. The few experiments done since (primarily those funded by the SBREC and done by British Sugar plc and Broom's Barn between 1989 and 1996 to examine interactions between variety, spacing and plant population density) largely confirm these basic findings, and show that beet grown at high densities were more uniform in size with fewer harvesting losses (Bee & Jaggard 1996). Other work on crown size and frost physiology shows that high planting densities decrease crown height and beet water content suggesting that such beet should be less susceptible to frost damage (PJ Jarvis, unpublished).

Since the last re-assessment, both the quality and the price of the treated seed have increased. Today, seed costs represent, on average, one third of the variable costs of beet production and will increase in relevance under the new sugar regime.  Because of this, there is a need to reassess the yield responses of modern varieties to seed spacing on different soil types to determine the new optima, and assess the risks that yield will be lost if too few seeds are sown. The context for this needed to be widened to make an overall economic assessment of the benefits of different seed rates on the individual elements of beet production, beet harvesting, beet transport and beet processing. This series of experiments, conducted across a range of soil types and three seasons, by British Sugar and Broom's Barn, have provided the information to make this re-assessment.

## Experimental Methods

### British Sugar's experiments

British Sugar plc contracted to establish commercial-scale trials on a sandy loam, a sandy clay loam and a silty clay loam in each of the project's three years. The experiments tested factorial combinations of three in-row seed spacings (12.5, 20 and 25cm) and two establishment percentages (achieved by sowing standard pelleted seed or standard seed mixed with 20% blank pellets) on 50 cm rows. The seeds were Advantage treated and the pellets included a neonicotinoid insecticide. The experiments were laid out as large strip trials using 12-row wide by 100-200m long plots (the actual length depending on the size of the field) arranged in four randomised blocks. This meant the crop could be grown and harvested using conventional commercial practices. Each treatment strip was entirely harvested with a commercial 6-row machine operated by the grower or contractor and the surface and breakage harvesting losses estimated. Agronomic details are given in Table 1.

Yields were determined in the field by weighing every trailer load lifted from each strip on coupled weigh cells. Four standard, factory-bucket samples of beet were taken from each trailer and delivered to the Wissington factory tarehouse for measurement of dirt tare, crown tare, percentage sugar and the amino-N, potassium and sodium impurities. The data was analysed using GENSTAT.

In 2008, British Sugar staff conducted two additional experiments. In one, the comparison of commercial and adulterated seed was replaced by a comparison of Advantage and XBeet seed treatments. In the other, there was no comparison of commercial and adulterated seed, instead there were 6 seed spacing treatments ranging from 10 to 22.5 cm.

### Broom's Barn's experiments

Standard, small-plot factorial experiments were established by Broom's Barn on sandy sites to compare responses to 15, 20 and 25 cm seed spacings and the above establishment percentages on 50 and 60 cm rows. Rows 60 cm apart were only used in the first experiment. The experiments were lifted with a plot harvester, and yield and beet quality were measured at Broom's Barn. The treatments were replicated four times in the first year and six times thereafter. The seed treatments were the same as in the first six experiments conducted by British Sugar and agronomic details are in Table 1.

### Population density models

Yield and plant population density data from the strip trials and standard plot experiments were analysed by fitting a plant population/yield model (Bleasdale & Nelder 1960):

$$\frac{1}{W^{\theta}} = \alpha + \beta P$$

In which $W$ is the adjusted weight per plant, $P$ is the population density per hectare, $\alpha$ and $\beta$ are constants. The value of $\theta$ was fixed at 0.9 on the basis of analyses of previous sugar beet experiments (Jaggard 1979). The model was used to calculate the plant population density that produced a near-maximum economic return, taking account of the value of the beet and the current cost of seed. These analyses were used to determine the target seed spacing for each major soil group.

### Survey data

Data from the field surveys conducted in 2004-08 by British Sugar on seed spacing and plant population density was collated and analysed to estimate seedling establishment percentages and plant populations that are achieved on the most important soil textures used to grow the national crop.

## Results

### Experiments

In 2007 British Sugar staff started experiments on sandy loam and silty clay loam soils, as originally planned. Seedling establishment on these sites was so poor and variable that the experiments were abandoned. Additional experiments were carried out in their place in 2008.

The treatment using 60cm rows at Risby in 2006 was intended to test the appropriate seed spacing for wide rows, which may have been needed for providing frost protection to late harvested beet. At the end of 2006 it became clear that this treatment was not needed, so future experiments concentrated on 50cm row spacing. The results in this report for the 2006 experiment conducted by Broom's Barn are the results for 50cm row spacing only.

The populations, yields and some assessments of crop and harvest quality are shown in Tables 2 – 5 and a scatter diagram of adjusted yield and plant population density is presented in Fig. 1. There were no significant differences in adjusted yield between treatments when the standard ANOVA test was applied. There was a general tendency for sugar concentration to increase and for sodium, potassium and amino N impurity concentrations to decrease with increased population density, although these tendencies were seldom significant. Nevertheless, these tendencies are in line with previous research. There was also a tendency for dirt tare to increase with increasing population density, but once again this effect was small and not always present. There was no consistent effect of population density on top tare or on root breakage. However, increased density did lead to a small increase in surface losses of beet at harvest.

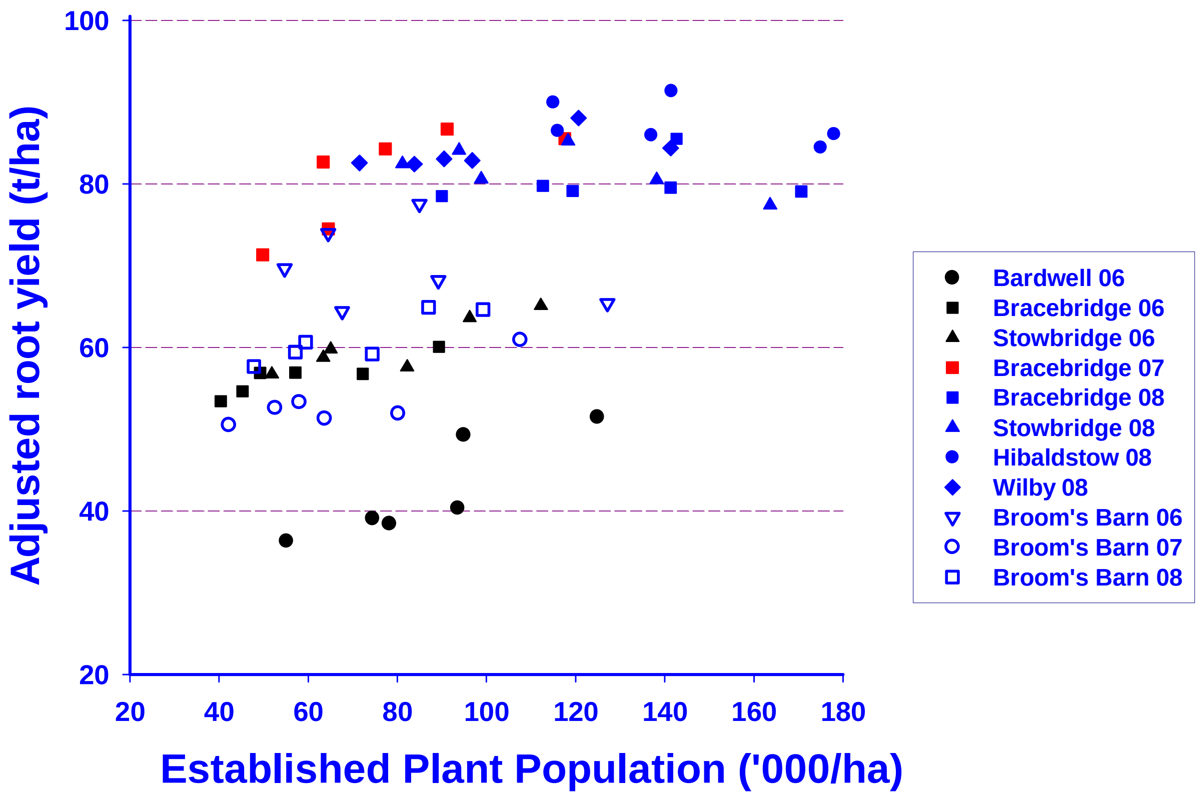


**Fig. 1.** ***Scatter diagram of the yields and population densities in the 11 experiments.***

The adjusted yield data from each experiment was described by the equation of Bleasdale & Nelder (1960). The value for θ was set at 0.9 on the basis of previous use of the equation (Jaggard 1979). The term controls the shape of the dense population part of the relationship, but it has no control over the density at which maximum yield is achieved. There was almost no difference in the population/yield relations for the two seedling establishment treatments at any site, so the model was fitted jointly to all available data points for a site.

The same was true for the Advantage and XBeet treatments at the Hibaldstow site in 2008.

The model accounted for >95% of the variance in the adjusted yield in 10 of the 11 experiments (Table 6). In the 11th experiment it accounted for *c*. 72% of the variance. The model was inverted to estimate yields at increments of 10,000 plants/ha, and the value of this yield determined, assuming a beet price of £26/t. The net margin was then calculated assuming either 60 or 80% seedling establishment to determine the amount of seed needed: the seed price was assumed to be £150/unit. The population density range that produced 97% or more of the maximum net return at 80% establishment is shown in Fig. 2. These population ranges were often very large (Fig. 2) because the yield/density relationship showed little change over a large part of the yield response curve There was almost no difference between 60 and 80% establishment in the population range that produced the near-maximum return.

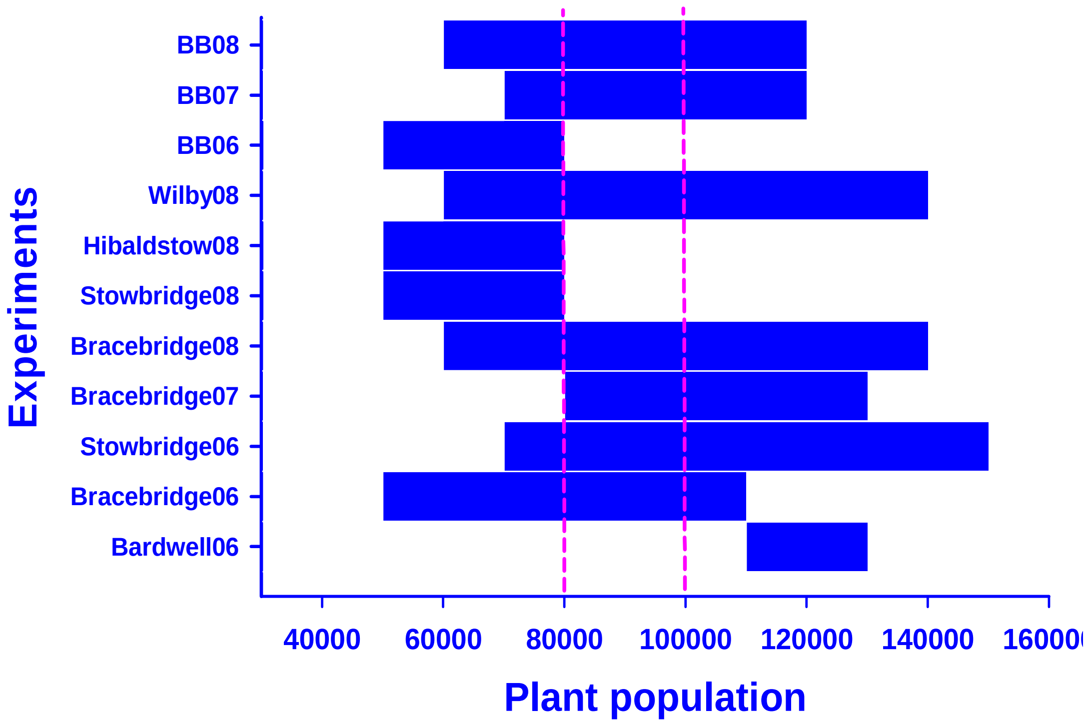


**Fig. 2.** ***The population range (per hectare) that produced 97% or more of the maximum net return at each experimental site.***

Figure 2 shows that a density of 80,000 plants per hectare was an appropriate target for 10 of the 11 sites, and that a target of 100,000 plants/ha would be appropriate at only 7 of the 11 sites. Unlike some previous studies, there was no evidence that sandy soils needed more plants than more fertile soils. Nor was there much evidence that low yield sites needed denser stands of plants than the most productive sites.

### Surveys

Data from 5 years of the British Sugar survey (approximately 2450 fields) are shown in Fig. 3. The plant populations of these fields were categorized as having more or less than 80,000 plants/ha (i.e. having broadly adequate or inadequate numbers of plants). There were no indications that inadequate population densities were associated with soil type, sowing date or seed rate. The major overriding factor that determined whether or not the plant stand was adequate was clearly the seedling establishment percentage - many fields had establishment percentages lower than 70% which is the minimum needed for successful drilling-to-a-stand (Jaggard, 1979). It is important to remember that the survey's plant populations are the average of 10 counts taken across the whole field. This implies that many fields with populations not far in excess of 80,000 will have parts of the field with an inadequate plant stand. The survey data was associated with the sample dig data for the same fields. This showed that fields with average populations of >80,000 plants per hectare were more likely to have yields of >70t/ha than fields with < 80,000 plants per hectare (Fig. 4).

## Conclusions

The 11 experiments in this study have shown that sugar-beet growers should aim to achieve 80,000 plants per hectare. There is no significant yield loss if this target is exceeded when seedling establishment is unexpectedly good, but if populations fall well short of the target there is risk of yield losses on some sites. The soil type and expected level of yield does not affect the target plant population. Dense plant stands had a tendency to have a larger dirt tare than sparse stands, but this difference was not sufficient (seldom more than 1% dirt tare) to shift the target density, especially as some of the soil would fall off the roots during cleaning and loading.

Grower's success or otherwise in achieving an adequate plant population does not seem to be linked to soil texture type, sowing date or seed rate, but is very dependent upon to seedling establishment they are manage to achieve. This is clearly a topic that needs further research to find the causes and solutions to the problem, and this is illustrated by the observation that, despite our best efforts, two of our trials failed through poor establishment. Staff from Broom's Barn and British Sugar will jointly investigate possible approaches to this research and produce a proposal for consideration in 2010.

## References

Bee P & Jaggard K (1996) Plant populations for today's conditions. *British Sugar Beet Review* **64** (**3**), 28-30.

Bleasdale JKA & Nelder JA (1960) *Nature* **188**,342.

Hull R & Jaggard KW (1971) Recent developments in the establishment of sugar-beet stands. *Field Crop Abstracts* **24** 381-390.

Jaggard KW (1979) *Effects of plant distribution on the yield of sugar beet*. PhD Thesis, Nottingham University

Jaggard KW (1990) Are there too many beet in our fields? *British Sugar Beet Review* **58,** 6-9.

## Table 1. *Agronomic details of the 2006-08 seed rate experiments*

| Year | Location | Soil type | Treatments | Variety | Drilling date | Harvest date |
|---|---|---|---|---|---|---|
| | **British Sugar** | | | | | |
| 2006 | Bardwell | Sandy loam | 12.5, 20.0 & 25 cm seed spacing; ± 20% dead seed | Bobcat | 31 March | |
| | Bracebridge | Sandy clay loam | 12.5, 20.0 & 25 cm seed spacing; ± 20% dead seed | Dominika | 7 April | 12 October |
| | Stowbridge | Silty clay loam | 12.5, 20.0 & 25 cm seed spacing; ± 20% dead seed | Salvador | 31 March | 19 September |
| 2007 | Bracebridge | Sandy clay loam | 12.5, 20.0 & 25 cm seed spacing; ± 20% dead seed | | | 19 November |
| 2008 | Wilby | Loamy sand | 10.0, 12.5, 15.0, 17.5, 20.0 & 22.5 cm seed spacing | Goya | 5 April | 15 January |
| | Bracebridge | Sandy clay loam | 10.0, 12.5 & 15.0 cm seed spacing; ± 20% dead seed | Trinita | 15 April | 9 November |
| | Hibaldstow | Sandy clay loam | 10.0, 12.5 & 15.0 cm seed spacing; Advantage vs Xbeet seed | Trinita | 10 April | 30 October |
| | Stowbridge | Silty clay loam | 10.0, 12.5, 15.0 & 17.5 cm seed spacing; 15.0 & 17.5 cm seed spacing ± 20% dead seed | Trinita | 2 April | 15 October |
| | **Broom's Barn** | | | | | |
| 2006 | Risby | Loamy sand | 15, 20 & 25cm seed spacing: ± 20% dead seed | Bobcat | 7 April | 21 November |
| 2007 | Cavenham | Loamy sand | 15, 20 & 25cm seed spacing: ± 20% dead seed | Anemona | 28 March | 22 November |
| 2008 | Cavenham | Loamy sand | 15, 20 & 25cm seed spacing: ± 20% dead seed | Goya | 9 April | 13 November |

## Table 2. Plant population density at harvest (thousands/ha).

| Year | Site | Treatments | | | | | |
|---|---|---|---|---|---|---|---|
| | | **25** | **20** | **12.5** | **25 + dead** | **20 + dead** | **12.5 + dead** |
| 2006 | Bardwell | 78.2 | 94.9 | 124.9 | 55.1 | 74.4 | 93.6 |
| | Bracebridge | 45.3 | 57.1 | 89.3 | 40.4 | 49.2 | 72.2 |
| | Stowbridge | 63.4 | 82.2 | 112.2 | 51.9 | 65.1 | 96.2 |
| 2007 | Bracebridge | 63.4 | 77.3 | 117.6 | 49.8 | 64.5 | 91.2 |
| | | **22.5** | **20** | **17.5** | **15** | **12.5** | **10** |
| 2008 | Wilby | 71.5 | 83.8 | 90.5 | 96.8 | 120.7 | 141.3 |
| | | **15** | **12.5** | **10** | **15 + dead** | **12.5 + dead** | **10 + dead** |
| | Bracebridge | 119.3 | 142.7 | 170.7 | 90 | 112.7 | 141.3 |
| | | **15 Adv** | **12.5 Adv** | **10 Adv** | **15 XB** | **12.5 XB** | **10 XB** |
| | Hibaldstow | 115 | 137 | 178 | 116 | 141.5 | 175 |
| | | **17.5** | **15** | **12.5** | **10** | **17.5 + D** | **15 + D** |
| | Stowbridge | 118.3 | 138.2 | 163.7 | 81.2 | 93.8 | 98.8 |
| | | **25** | **20** | **15** | **25 + dead** | **20 + dead** | **15 + dead** |
| 2006 | Risby | 68 | 85 | 127 | 55 | 65 | 89 |
| 2007 | Cavenham | 58 | 64 | 108 | 42 | 53 | 80 |
| 2008 | Cavenham | 59 | 74 | 99 | 48 | 57 | 87 |

## Table 3. Adjusted root yield (t/ha)

| Year | Site | Treatments | | | | | |
|---|---|---|---|---|---|---|---|
| | | 25 | 20 | 12.5 | 25 + dead | 20 + dead | 12.5 + dead |
| 2006 | Bardwell | 38.5 | 49.3 | 51.5 | 36.3 | 39.1 | 40.4 |
| | Bracebridge | 54.6 | 56.9 | 60.1 | 53.4 | 56.9 | 56.8 |
| | Stowbridge | 58.8 | 57.6 | 65.1 | 56.7 | 59.8 | 63.6 |
| 2007 | Bracebridge | 82.7 | 84.3 | 85.5 | 71.3 | 74.5 | 86.7 |
| | | 22.5 | 20 | 17.5 | 15 | 12.5 | 10 |
| 2008 | Wilby | 82.6 | 82.4 | 83.1 | 82.9 | 88.1 | 84.4 |
| | | 15 | 12.5 | 10 | 15 + dead | 12.5 + dead | 10 + dead |
| | Bracebridge | 79.1 | 85.5 | 79.1 | 78.5 | 79.8 | 79.6 |
| | | 15 Adv | 12.5 Adv | 10 Adv | 15 XB | 12.5 XB | 10 XB |
| | Hibaldstow | 89.9 | 85.9 | 86.1 | 86.5 | 91.3 | 84.5 |
| | | 17.5 | 15 | 12.5 | 10 | 17.5 + D | 15 + D |
| | Stowbridge | 80.6 | 85.2 | 80.5 | 77.4 | 82.5 | 84.1 |
| | | 25 | 20 | 15 | 25 + dead | 20 + dead | 15 + dead |
| 2006 | Risby | 64.4 | 77.6 | 65.4 | 69.7 | 74 | 68.2 |
| 2007 | Cavenham | 53.3 | 51.3 | 60.9 | 50.5 | 52.6 | 51.9 |
| 2008 | Cavenham | 60.7 | 59.2 | 64.6 | 57.7 | 59.4 | 64.9 |

## Table 4. Sugar concentration (%)

| Year | Site | Treatments | | | | | |
|---|---|---|---|---|---|---|---|
| | | 25 | 20 | 12.5 | 25 + dead | 20 + dead | 12.5 + dead |
| 2006 | Bardwell | 15.64 | 15.9 | 16.03 | 15.86 | 15.8 | 15.77 |
| | Bracebridge | 17.22 | 17.43 | 17.38 | 17.19 | 17.35 | 17.59 |
| | Stowbridge | 14.62 | 15.06 | 15.37 | 14.74 | 14.83 | 15.1 |
| 2007 | Bracebridge | 19.53 | 19.62 | 19.73 | 19.25 | 19.76 | 19.64 |
| | | 22.5 | 20 | 17.5 | 15 | 12.5 | 10 |
| 2008 | Wilby | 17.7 | 17.54 | 17.43 | 17.33 | 17.3 | 17.22 |
| | | 15 | 12.5 | 10 | 15 + dead | 12.5 + dead | 10 + dead |
| | Bracebridge | 17.71 | 17.96 | 17.87 | 18.06 | 17.85 | 17.89 |
| | | 15 Adv | 12.5 Adv | 10 Adv | 15 XB | 12.5 XB | 10 XB |
| | Hibaldstow | 19.2 | 19.06 | 19.18 | 19.32 | 19.36 | 19.14 |
| | | 17.5 | 15 | 12.5 | 10 | 17.5 + D | 15 + D |
| | Stowbridge | 19.29 | 19.3 | 19.24 | 19.09 | 19.19 | 19.15 |
| | | 25 | 20 | 15 | 25 + dead | 20 + dead | 15 + dead |
| 2006 | Risby | 16.49 | 16.51 | 16.83 | 16.68 | 16.66 | 16.5 |
| 2007 | Cavenham | 17.07 | 17.09 | 17.18 | 16.91 | 16.95 | 17.21 |
| 2008 | Cavenham | 17.37 | 17.53 | 17.44 | 17.45 | 17.55 | 17.4 |

## Table 5. Dirt tare (%)

| Year | Site | Treatments | | | | | |
|---|---|---|---|---|---|---|---|
| | | 25 | 20 | 12.5 | 25 + dead | 20 + dead | 12.5 + dead |
| 2006 | Bardwell | 4.9 | 6.6 | 8.2 | 4.7 | 5.4 | 5.4 |
| | Bracebridge | 2.9 | 3.3 | 3.8 | 2.5 | 2.9 | 4 |
| | Stowbridge | 1.8 | 3.1 | 4 | 2.1 | 5 | 2.5 |
| 2007 | Bracebridge | 9.5 | 10.1 | 11.4 | 7.6 | 8.6 | 11.4 |
| | | 22.5 | 20 | 17.5 | 15 | 12.5 | 10 |
| 2008 | Wilby | 3.4 | 2.8 | 3.9 | 4 | 3.8 | 5.8 |
| | | 15 | 12.5 | 10 | 15 + dead | 12.5 + dead | 10 + dead |
| | Bracebridge | 10.3 | 9.4 | 11.6 | 13.7 | 9.3 | 10.7 |
| | | 15 Adv | 12.5 Adv | 10 Adv | 15 XB | 12.5 XB | 10 XB |
| | Hibaldstow | 10.5 | 13.5 | 12.5 | 12.9 | 10.4 | 12.4 |
| | | 17.5 | 15 | 12.5 | 10 | 17.5 + D | 15 + D |
| | Stowbridge | 13.8 | 12.9 | 15.7 | 15.5 | 12 | 10.8 |
| | | 25 | 20 | 15 | 25 + dead | 20 + dead | 15 + dead |
| 2006 | Risby | 2.6 | 1.9 | 1.7 | 3 | 1.9 | 2.9 |
| 2007 | Cavenham | 2.1 | 1.8 | 2.3 | 1.9 | 2.1 | 1.9 |
| 2008 | Cavenham | 1.4 | 1.3 | 3 | 1.2 | 2.2 | 1.9 |

**Table 6.** ***Variance in adjusted yield accounted for by the model.***

| Trial site/year | Variance accounted for (%) ($R^2$) | Data points |
|---|---|---|
| Bardwell06 | 72.4 | 6 |
| Bracebridge06 | 99.4 | 6 |
| Stowbridge06 | 97.4 | 6 |
| Bracebridge07 | 97.1 | 6 |
| Bracebridge08 | 97.3 | 6 |
| Stowbridge08 | 98.9 | 6 |
| Hibaldstow08 | 98.2 | 6 |
| Wilby08 | 99.1 | 6 |
| BB06 | 95.6 | 6 |
| BB07 | 95.1 | 6 |
| BB08 | 98.4 | 6 |

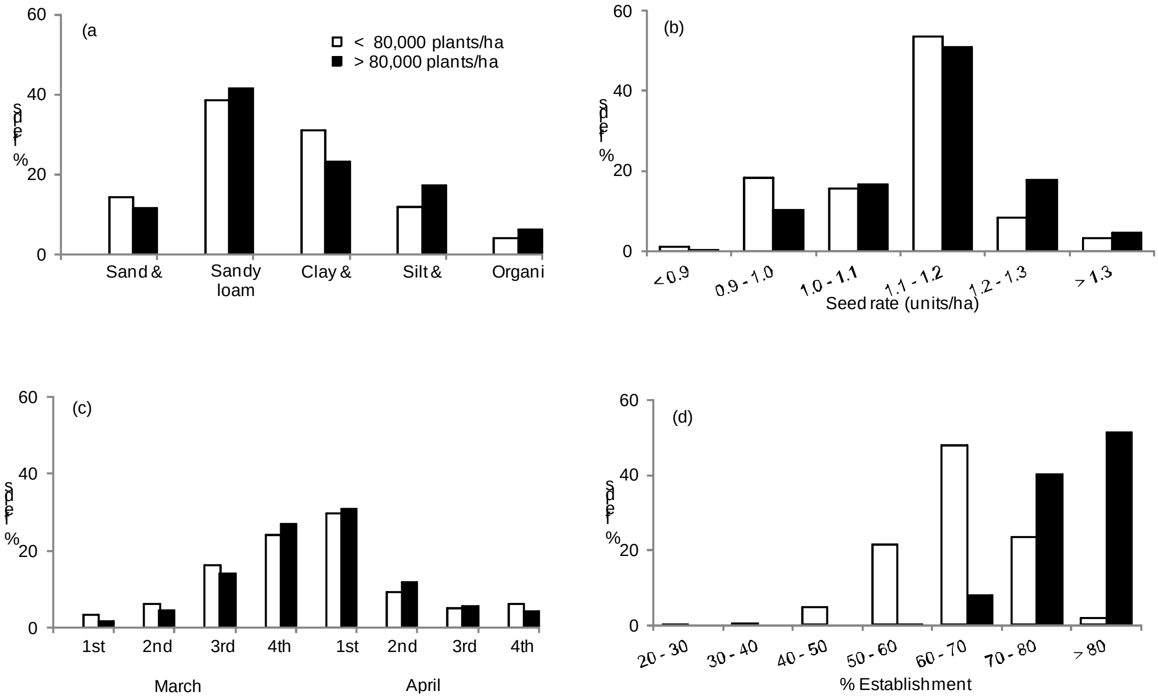


**Fig. 3.** ***Categorisation of fields with below and above optimal plant populations according to (a) soil type, (b) seed rate, (c) drilling date and (d) plant establishment. (British Sugar plc field surveys 2004-08)***

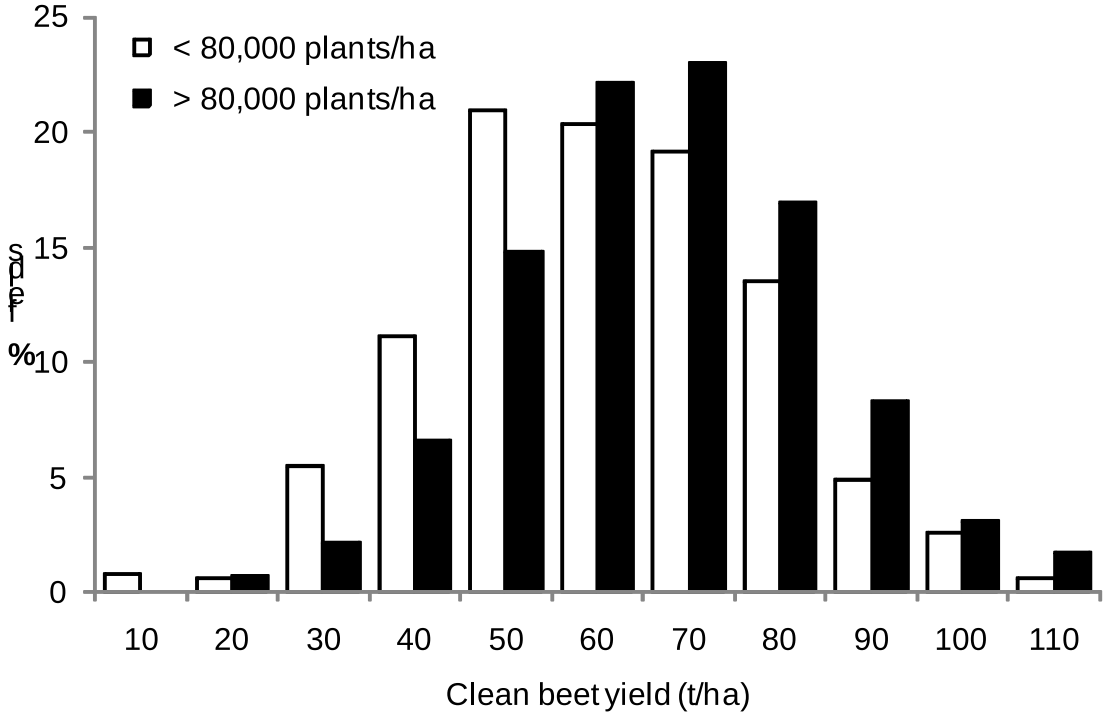


**Fig 4.** ***Categorization of clean beet yield (t/ha) in survey fields (2004-07) by plant population density.***