# PLANT POPULATIONS AND ROW WIDTHS FOR DIPLOID SUGAR-BEET VARIETIES

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## SUMMARY

The aim of this work was to see whether the introduction of diploid varieties, with their more erect leaf growth, would require any adjustment of the traditional plant spacing and row width recommendations for sugar beet.

Five trials were carried out in 1996-98 in which the diploid variety Celt was sown at three row widths: 51, 56 and 61 cm. At each row width, seed spacings were adjusted to give four plant densities between 30,000 and 89,000 plants/ha.

In four of the trials, field establishment was between 75 and 90%. In these trials, there was a slight increase in sugar yield with population up to 75,000 plants/ha, and little or no change above this level. There was a slight increase in extractability at higher populations, but not sufficient to have a significant effect on extractable sugar yield.

In one trial where plant establishment was reduced by very cold weather, yield and sugar content continued to increase up to the highest plant count of 65,000 plants/ha.

Over the five trials, there were no yield or quality differences between 51- and 56-cm rows. There was a reduction of 3.5% in extractable sugar yield in 61-cm rows, though this reached statistical significance in only one trial.

Taking into account the high emergence that is normally achieved with diploid varieties, these results suggest that no change should be made to the seed spacings currently recommended for triploid varieties. For those using 61-cm rows, a small yield increase could probably be achieved by reducing row width.

## INTRODUCTION

Since the earliest days of sugar beet production, the target plant stand has been at least 76,000 evenly spaced plants per ha (30,000 plants/acre) in row widths of 56-61cm (22-24 inches). Changes such as sowing to a stand, monogerm seed and big yield increases have not led to any changes in these recommendations. The introduction of diploid varieties, whose more erect leaf growth might be expected

to affect the interception of solar radiation, makes a re-examination of plant stand requirements timely.

In Irish experiments with triploid varieties in 1977-79, plant populations were varied by adjusting the seed spacing. In trials where the plant establishment was over 70%, the effect of population on extractable sugar yield was small over a range from 50,000 to 95,000 plants/ha (20-36,000 plants/acre) (1). Also the yield from the optimum sown-to-a-stand plant count in these trials was within 2% of the yield from plots carefully singled to 76,000 plants/ha, which suggests little room for further improvement.

In one Irish triploid trial in which the plant establishment was about 60%, the effect of plant count on yield was more substantial, and the difference between the optimum population and the singled treatment rose to 7% (1).

In other countries, a model based on a review of Dutch and German trials suggests an optimum of about 90,000 plants/ha, though the yield difference between 75,000 and 90,000 plants/ha suggested by the model is no more than about 1% (2). Danish trials have shown yield changes of less than 3% between 65,000 and 115,000 plants/ha, with a suggested optimum count of 90,000 plants/ha (3). On the other hand, French trials at various sites indicate optimum populations from 86,000 to 144,000 plants/ha, with occasional substantial yield reductions at counts below 80,000 plants/ha (4).

Traditional recommended plant densities in the UK have been about 80-100,000 plants/ha, and recent trials suggest that this is also adequate for diploids (5, 6). In four trials carried out by the Agricultural Development Department of Irish Sugar plc with three diploid varieties (Aztec, Celt and Zulu) in 1994-95, seed spacings from 15 to 22.5 cm (6 to 9 inches) were used at three row widths (51, 56 and 61 cm), giving plant densities from 63,000 to 125,000 plants/ha. The only consistent effect in the trials was an increase of extractability with plant population. The Irish Sugar trials also gave an indication that the response of other diploid varieties to changes in plant count was similar to that of Celt (7).

In contrast with trial results, surveys of the relationships between husbandry practices and yields delivered by growers have always shown a more pronounced relationship between plant count and delivered yield (8, 9, 10).

Recommended row widths for sugar beet in most EU countries are 45 to 50 cm (18 to 20 inches). French trials have shown no yield difference between 45 and 50 cm rows (11). UK trial results concur with this, but also indicate some yield reduction at 55 cm (5). In Oak Park trials with triploid varieties, row widths from 45 to 61 cm (18 to 24 inches) all gave similar yields, as long as the seed spacing was adjusted to give comparable plant populations (1).

The 1977 An Foras Taluntais survey showed a tendency for delivered yield to increase with row width, at least up to widths of 58 cm (23 inches). Regression analysis showed this result to be significant, i.e. it was not produced by other factors (e.g. drill or flat sowing) which might have an association with row width (9). The increase in delivered yield in wider rows may be partly explained by a reduction in harvest losses in wider rows; this is suggested by a 1977-79 field loss survey (12). Reduced damage to leaves and roots by inter-row traffic may also play a part.

## METHODS

Five trials were carried out in which plant densities and row widths were compared using the diploid variety Celt. Three row widths (51, 56 and 61 cm) were included. At each row width, seed spacing was varied so that four seed counts were sown. In the first two trials, these were 50,000, 66,000, 83,000 and 100,000 seeds/ha; in the remainder, the two higher figures were increased to 93,000 and 113,000 seeds/ha. On the assumption of 90% establishment, the aim was to achieve plant populations in the range from 45,000 to 102,000 plants/ha (18,000 to 40,000 plants/acre). The seed spacings to achieve these densities are shown in Table 1.

The trial site locations in each year were as follows:

1996 Ballycarney, Co. Carlow
1997 Oak Park, Carlow
1998 Oak Park, Carlow
1998 Ballycarney, Co. Wexford
1999 Mallow, Co. Cork

**Table 1:** Row widths and seed spacings in trials

| Seeds/ha x $10^3$ | 50 | 66 | 83 | 93 | 100 | 113 |
|---|---|---|---|---|---|---|
| Plants/ha @ 90% est. x $10^3$ | 45 | 60 | 75 | 84 | 90 | 102 |
| Row width (cm) | Seed spacing (cm) | | | | | |
| 51 | 39.2 | 29 | 23.5 | 21.0 | 19.6 | 17.3 |
| 56 | 35.7 | 27 | 21.4 | 19.1 | 17.8 | 15.7 |
| 61 | 32.8 | 25 | 19.7 | 17.5 | 16.3 | 14.4 |

The trial crops were sown on the flat in late March to April. Each plot consisted of five rows 11 metres long, of which three rows were harvested and weighed. Six replications were included in a split-plot design. Pesticides were applied by a sprayer travelling on headlands at right angles to the rows, so there was no wheel traffic through the plots between sowing and harvesting. The plots were harvested with a single-row Armer harvester adapted for plot harvesting.

# RESULTS

There were no significant interactive effects of plant population and row width on yield or quality in any of the trials, so their effects are presented separately in this report.

## Plant population

Tables 2 to 6 give the results of the five trials, in four of which the emergence was between 85 and 90%.

**Table 2:** Effect of plant population on yield, sugar content and extractability, Carlow 1996

| Plant count (pl/ha x $10^3$) | 45 | 60 | 70 | 85 | SE | F-test |
|---|---|---|---|---|---|---|
| Root yield (t/ha) | 59.7 | 60.7 | 62.6 | 61.7 | 1.91 | NS |
| Sugar content (%) | 18.1 | 18.4 | 18.6 | 18.6 | 0.13 | *** |
| Sugar yield (t/ha) | 10.80 | 11.17 | 11.64 | 11.48 | 0.37 | NS |
| Extractability (%) | 93.4 | 94.2 | 94.6 | 95.0 | 0.28 | *** |
| Ext. sugar yield (t/ha) | 10.13 | 10.51 | 11.02 | 10.92 | 0.36 | NS |

**Table 3:** Effect of plant population on yield, sugar content and extractability, Oak Park 1997

| Plant count (pl/ha x $10^3$) | 45 | 60 | 70 | 85 | SE | F-test |
|---|---|---|---|---|---|---|
| Root yield (t/ha) | 68.7 | 67.5 | 68.7 | 69.1 | 2.03 | NS |
| Sugar content (%) | 16.61 | 16.74 | 16.65 | 16.75 | 0.22 | NS |
| Sugar yield (t/ha) | 11.40 | 11.27 | 11.42 | 11.54 | 0.25 | NS |
| Extractability (%) | 92.97 | 93.37 | 93.28 | 93.39 | 0.49 | NS |
| Ext. sugar yield (t/ha) | 10.60 | 10.51 | 10.65 | 10.78 | 0.22 | NS |

**Table 4:** Effect of plant population on yield, sugar content and extractability, Oak Park 1998

| Plant count (pl/ha x$10^3$) | 29.6 | 39.1 | 52.6 | 65.0 | SE | F-test |
|---|---|---|---|---|---|---|
| Root yield (t/ha) | 49.1 | 51.7 | 55.8 | 57.9 | 1.38 | *** |
| Sugar content (%) | 16.8 | 17.3 | 17.3 | 17.4 | 0.11 | *** |
| Sugar yield (t/ha) | 8.25 | 8.92 | 9.64 | 10.10 | 0.25 | *** |
| Extractability (%) | 93.6 | 94.2 | 94.4 | 94.5 | 0.17 | ** |
| Ext. sugar yield (t/ha) | 7.73 | 8.40 | 9.11 | 9.54 | 0.24 | *** |

**Table 5:** Effect of plant population on yield, sugar content and extractability, Wexford 1998

| Plant count (pl/ha x$10^3$) | 38.9 | 52.2 | 69.7 | 88.2 | SE | F-test |
|---|---|---|---|---|---|---|
| Root yield (t/ha) | 62.9 | 63.8 | 65.2 | 62.9 | 1.27 | NS |
| Sugar content (%) | 17.2 | 17.3 | 17.4 | 17.4 | 0.08 | NS |
| Sugar yield (t/ha) | 10.75 | 11.00 | 11.36 | 10.93 | 0.19 | NS |
| Extractability (%) | 93.6 | 94.2 | 94.4 | 94.7 | 0.17 | *** |
| Ext. sugar yield (t/ha) | 10.07 | 10.37 | 10.73 | 10.36 | 0.17 | NS |

**Table 6:** Effect of plant population on yield, sugar content and extractability, Cork 1998

| Plant count (pl/ha x$10^3$) | 39.4 | 56.7 | 68.9 | 89.0 | SE | F-test |
|---|---|---|---|---|---|---|
| Root yield (t/ha) | 66.4 | 70.2 | 69.1 | 70.4 | 1.19 | NS |
| Sugar content (%) | 16.7 | 16.8 | 16.9 | 16.8 | 0.11 | NS |
| Sugar yield (t/ha) | 11.10 | 11.80 | 11.70 | 11.86 | 0.19 | * |
| Extractability (%) | 93.2 | 93.9 | 94.3 | 94.6 | 0.18 | *** |
| Ext. sugar yield (t/ha) | 10.31 | 11.09 | 11.03 | 11.22 | 0.20 | * |

In the 1996 trial, sugar content and extractability were significantly increased at the higher counts, and the resultant increase in extractable sugar yield fell just short of statistical significance. In 1997, there was very little effect of population on either yield or quality.

The Oak Park 1998 trial was sown on March 31. The seed had germinated but not emerged by April 10, a night of sub-zero temperatures and high winds, as a result of which emergence was reduced to about 58%. Final plant counts were from 30,000 to 65,000 plants/ha (12,000 to 26,000 plants/acre). The low plant counts had a significant effect on root and sugar yields, as well as sugar content and extractability.

There was a significant increase in extractability with plant count in each of the other 1998 trials (Tables 5, 6). In the Mallow trial, there was also a significant effect on sugar yield, mainly due to a low yield at the lowest plant count (39,000 plants/ha, Table 6).

## Row width

In the 1996 and 1997 trials, there was a fall in root yield in the widest rows in each year, which was highly significant in 1997 (Tables 7, 8). In 1996 this did not translate into a significant effect on sugar yield (Table 7), but in the 1997 trial there was a highly significant reduction in sugar yield (Table 8). There were no significant effects of row width in any of the 1998 trials (Tables 9-11).

**Table 7:** Effect of row width on yield and quality, Carlow 1996

| Row width (m) | 0.51 | 0.56 | 0.61 | SE | F-test |
|---|---|---|---|---|---|
| Root yield (t/ha) | 62.3 | 62.4 | 58.8 | 1.65 | NS |
| Sugar content (%) | 18.4 | 18.4 | 18.5 | 0.11 | NS |
| Sugar yield (t/ha) | 11.49 | 11.50 | 10.85 | 0.32 | NS |
| Extractability (%) | 94.2 | 94.6 | 94.1 | 0.24 | NS |
| Ext. sugar yield (t/ha) | 10.83 | 10.89 | 10.22 | 0.31 | NS |

**Table 8:** Effect of row width on yield and quality, Oak Park 1997

| Row width (m) | 0.51 | 0.56 | 0.61 | SE | F-test |
|---|---|---|---|---|---|
| Root yield (t/ha) | 70.8 | 70.2 | 64.6 | 1.76 | .*** |
| Sugar content (%) | 16.62 | 16.59 | 16.86 | 0.19 | NS |
| Sugar yield (t/ha) | 11.74 | 11.61 | 10.87 | 0.22 | *** |
| Extractability (%) | 93.03 | 93.04 | 93.71 | 0.42 | NS |
| Ext. sugar yield (t/ha) | 10.92 | 10.80 | 10.18 | 0.19 | *** |

**Table 9:** Effect of row width on yield, sugar content and extractability, Oak Park 1998

| Row width (m) | 0.51 | 0.56 | 0.61 | SE | F-test |
|---|---|---|---|---|---|
| Root yield (t/ha) | 55.0 | 54.4 | 51.5 | 1.19 | NS |
| Sugar content (%) | 17.1 | 17.3 | 17.1 | 0.10 | NS |
| Sugar yield (t/ha) | 9.41 | 9.45 | 8.82 | 0.21 | NS |
| Extractability (%) | 94.1 | 94.5 | 94.0 | 0.15 | NS |
| Ext. sugar yield (t/ha) | 8.86 | 8.93 | 8.30 | 0.24 | NS |

**Table 10:** Effect of row width yield, sugar content and extractability, Wexford 1998

| Row width (m) | 0.51 | 0.56 | 0.61 | SE | F-test |
|---|---|---|---|---|---|
| Root yield (t/ha) | 63.2 | 64.5 | 63.4 | 1.10 | NS |
| Sugar content (%) | 17.4 | 17.3 | 17.3 | 0.09 | NS |
| Sugar yield (t/ha) | 10.94 | 11.16 | 10.96 | 0.16 | NS |
| Extractability (%) | 94.2 | 94.3 | 94.2 | 0.15 | NS |
| Ext. sugar yield (t/ha) | 10.30 | 10.52 | 10.33 | 0.15 | NS |

**Table 11:** Effect of row width on yield, sugar content and extractability, Cork 1998

| Row width (m) | 0.51 | 0.56 | 0.61 | SE | F-test |
|---|---|---|---|---|---|
| Root yield (t/ha) | 67.6 | 70.3 | 69.2 | 1.03 | NS |
| Sugar content (%) | 17.0 | 16.7 | 16.8 | 0.10 | NS |
| Sugar yield (t/ha) | 11.5 | 11.7 | 11.6 | 0.16 | NS |
| Extractability (%) | 94.4 | 93.8 | 93.9 | 0.16 | NS |
| Ext. sugar yield (t/ha) | 10.83 | 10.85 | 10.92 | 0.17 | NS |

# DISCUSSION

## Plant population

The results of the five trials were combined by expressing all yield and quality parameters as percentages of the value at 70,000 plants/ha for that trial. The mean sugar yield increased with population up to about 75,000 plants/ha, with little or no increase above that level (Fig. 1).

Extractability continued to increase at higher plant counts, but this had little effect on the trend of extractable sugar yield, which was similar to that of total sugar (Figs. 2, 3). From a processing viewpoint, the higher extractabilities at increased populations would bring a small additional benefit, and might be seen as a justification for a higher target plant population. However, the additional benefit at counts above 75,000 plants/ha appears to be small (Fig. 2). UK trials support this view (6).

From a grower viewpoint, the possibility of increasing sugar content might be seen as an advantage, even if there were no increase in sugar yield. Here again, however, there is very little evidence of any increase in sugar content at populations above 75,000 plants/ha.

There are a number of other factors which might have a bearing on the selection of a target plant population. Some effects on harvest losses and soil tare might be expected, and an effect on sugar loss in storage is a possibility. Another concern would be the commonly-held belief that high populations suffer more from drought stress in dry periods.

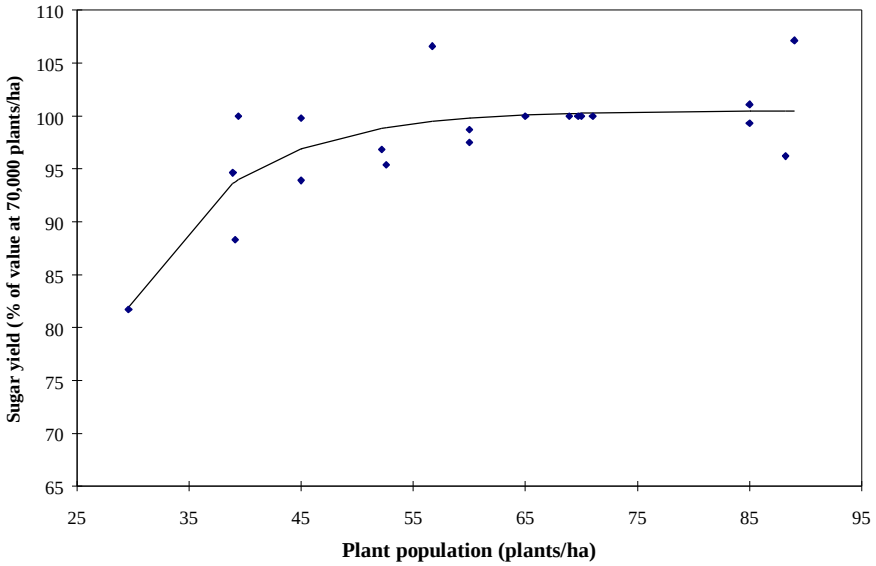


**Fig. 1**: Effect of plant population on sugar yield (58.2% of variance accounted for)

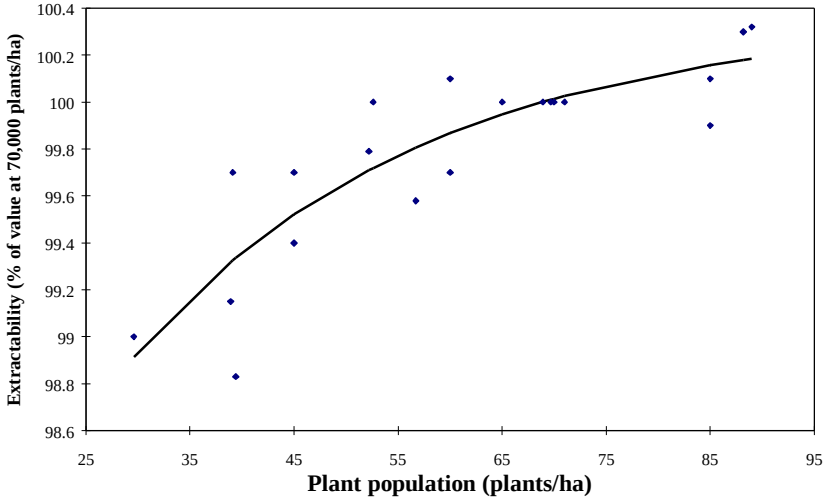


**Fig. 2**: Effect of plant population on sugar extractability (71.8% of variance accounted for)

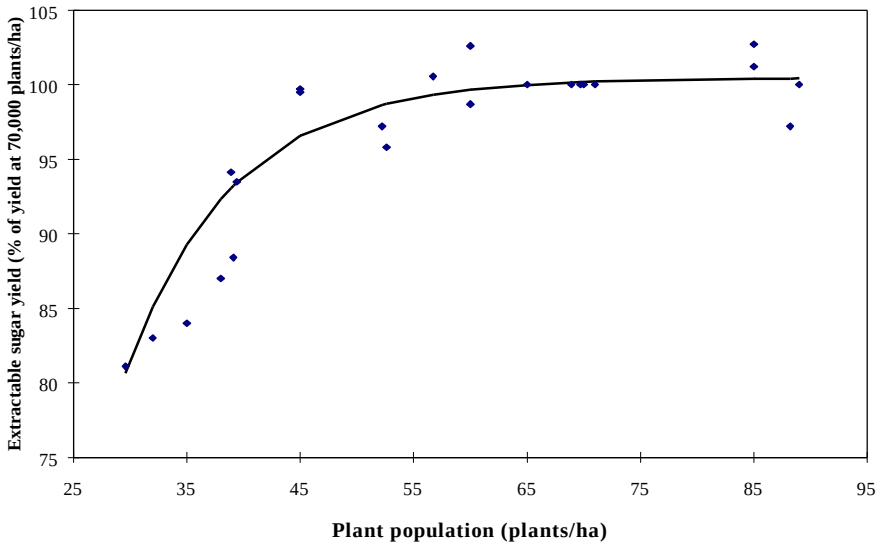


**Fig. 3:** Effect of plant count on extractable sugar yield (82.1% of variance accounted for)

***Harvest losses***

In an Irish survey of on-farm harvest losses in 1977-79, a relationship between losses and plant count emerged as in Table 12 (12). UK trials have given similar results (5,6).

**Table 12:** Field losses vs. plant population

| Plant count (thousands/ha) | <60 | 60 - 70 | 70 - 80 | >80 |
|---|---|---|---|---|
| Harvest loss (t/ha) | 3.3 | 2.6 | 2.4 | 3.3 |

A slight increase in losses was found at the lowest (due to gaps and variable root sizes) and highest (due to small roots) plant counts. The differences were small, but they might caution against the selection of a very high target plant population.

***Drought stress***

There is a common perception that on light land low plant counts suffer less from drought stress. This is presumably based on the observation of more wilting in dense stands.

The results of irrigation trials on light land in Oak Park in 1979-82 would suggest that this observation does not carry through into effects on yield (13). In 1979 and 1981, irrigation increased yields by about 33%, or 2 t/ha of sugar. Even in these conditions, counts of 65,000 and 85,000 plants/ha still gave similar yields when the crop was not irrigated (Table 13). One UK trial in 1995 showed a small reduction in yield in dry conditions when the population was increased to 120,000 plants/ha (5). Within a normal plant count range, however, the possibility of drought stress should not influence the selection of a target plant population.

**Table 13:** Response of sugar beet to irrigation at two plant populations

| Plant count (plants/ha) | Irrigated | | Unirrigated | | Response | |
|---|---|---|---|---|---|---|
| | 60,000 | 85,000 | 60,000 | 85,000 | 60,000 | 85,000 |
| Year | Extractable sugar yield (t/ha) | | | | | |
| 1979 | 7.7 | 8.1 | 5.9 | 6.0 | 1.8 | 2.1 |
| 1981 | 8.6 | 8.6 | 5.7 | 6.5 | 2.9 | 2.1 |
| 1982 | 10.0 | 10.2 | 8.9 | 8.7 | 1.1 | 1.5 |

***Storability of beet***

It is possible that the amount of sugar lost in pre-delivery storage might be affected by plant population. The heat generated by the beet, or respiration rate, is a good measure of its propensity to lose sugar in storage. The respiration rate of beet from three plant population trials was measured to look for differences in storability (14).

In these trials, two conflicting factors affected the respiration rate:

(i) The greater surface/volume ratio of the smaller roots would cause them to respire more freely.

(ii) The higher extractability and lower impurity levels of these roots would tend to reduce respiration.

There were considerable differences in respiration rate between sites, and the highest rates coincided with the lowest yields. However, within each site there was very little difference in the heat generation or sugar loss as a result of the changes in plant density (Table 14).

**Table 14:** Effect of plant population on extractability, extractable sugar yield and respiration rate

| Site + year | | Plant count (plants/ha x 1000) | | |
|---|---|---|---|---|
| | | 60 | 87 | 112 |
| Tuam | Extractability (%) | 84.6 | 85.1 | 85.7 |
| 1977 | Ext. sugar (t/ha) | 5.48 | 5.56 | 5.45 |
| | Respiration rate (mg $O_2$/kg h) | 6.28 | 5.97 | 6.22 |
| | Av. root size (kg) | 1.12 | 0.74 | 0.56 |
| Athy | Extractability (%) | 93.3 | 93.9 | 93.9 |
| 1977 | Ext. sugar (t/ha) | 7.92 | 7.91 | 7.55 |
| | Respiration rate (mg $O_2$/kg h) | 4.08 | 4.21 | 4.25 |
| | Av. root size (kg) | 1.10 | 0.83 | 0.61 |
| Knocktopher | Extractability (%) | 91.8 | 92.5 | 92.6 |
| 1978 | Ext. sugar (t/ha) | 5.35 | 6.33 | 6.66 |
| | Respiration rate (mg $O_2$/kg h) | 5.22 | 4.93 | 4.74 |
| | Av. root size (kg) | 0.77 | 0.69 | 0.59 |

***Soil tare***

Although there is no Irish data to relate soil tare to plant population, there are indications from other countries that high plant counts consistently lead to increased soil tare. In Brooms Barn trials from 1991 to 1995, beet plots sown to achieve target counts of 60,000 to 120,000 plants/ha gave soil tares immediately after harvest of 7.2 to 11.6% (5). This represents a tare increase of 1% for an increase of 15,000 plants/ha in plant count. French trials suggest that soil tare increases by 1% for a population increase of 10,000 plants/ha (15). The present cost to the grower of a 1% increase in soil tare is small, but as waste management regulations become more stringent the cost to the industry will become substantial.

***Seed cost***

If a seed cost of £60 per 100,000 seeds is assumed, the cost of each additional 10,000 plants/ha, at an emergence of 85%, would be about £7/ha. Clearly this should not influence the selection of a target plant population.

***Conclusion***

If the target plant population were increased, say from 75,000 to 90,000 plants/ha, the cost of extra seed and soil tare would have to be balanced by the increase in sugar extractability and the added security when plant establishment is very low. These costs and benefits would be small and would almost balance out.

### Row width

When the results of the five trials were combined, extractable sugar yields were the same for 51- and 56-cm rows, and 3.5% lower in the 61-cm rows (Table 15). Although it reached significance in only one of five trials, it is likely that there is a slight yield reduction associated with the use of 61-cm rows.

**Table 15:** Relationship between extractable sugar yield and row width (mean of five trials, 1996-98)

| Row width (m) | 0.51 | 0.56 | 0.61 |
|---|---|---|---|
| Root yield (t/ha) | 63.79 | 64.08 | 61.51 |
| Sugar content (%) | 17.31 | 17.26 | 17.30 |
| Sugar yield (t/ha) | 11.01 | 11.03 | 10.62 |
| Extractability (%) | 93.99 | 93.97 | 93.96 |
| Ext. sugar yield (t/ha) | 10.36 | 10.35 | 10.00 |

## CONCLUSIONS

The results of these trials indicate that the plant population requirement for maximum yield of extractable sugar is the same for diploid and triploid varieties, in spite of the more erect leaf growth and apparently less effective radiation interception of the diploids. A count of at least 75,000 plants/ha (30,000 plants/acre) is required for maximum yield, and increases above this level bring little or no further benefit. The aim should be to use a combination of row width

and seed spacing that guarantees the achievement of the target plant count even at the lowest expected level of plant establishment.

The trials suggest that yields are slightly lower in 61-cm rows than at reduced widths. In practice, anyone reducing row width should ensure that this does not lead to more wheel damage to the crop or higher harvest losses, otherwise some of the potential yield increase may not be reflected in delivered yield.

Once the row width has been selected, a seed spacing within the row should then be chosen to give a plant population of at least 75,000 plants/ha at the lowest plant establishment that is considered likely to occur. For example, if a minimum establishment of 70% is assumed, then at least 107,000 seeds/ha should be sown. In 56-cm (22-in) rows, this would require a seed spacing of 16.5 cm (6.5 in). In 51-cm (20-in) rows the corresponding seed spacing is 18.3 cm (7.2 in).

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