

**To modify SPACING to improve  
its predictions, appearance and  
extend its application  
to red beet.**

**Final Report FV 124a**

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competition, variation, marketable yield, size  
grade, root diameter, red beet, beetroot

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Date project completed: 31 March 1995

## Relevance to growers and practical application

### Application

A model developed with MAFF funding that predicts the seeding rates in each row to eliminate edge effects and maximizes yield in specified diameter grades of carrots had been encoded in software called SPACING. Many changes to SPACING have now been made. Great attention has been given to making the prompts for information to be as clear and unambiguous as possible. SPACING can now accommodate more complex row spacing systems, and can be used for red beet and carrots.

### Summary

Edge effects are well known in carrot and red beet crops grown on bed systems, and contribute to undesirable root-to-root size variation. Such edge effects can be eliminated by increasing the within-row seeding rate in the outer rows with respect to that in the inner rows. The extent of this differential in seeding rate depends on the row spacing system, duration of growth, overall plant density and target diameter grade. A competition model developed with MAFF funding at HRI, Wellesbourne can calculate the weight of roots, taking all these factors into account. This model was used as a basis for SPACING, which was developed solely for carrots. This development was funded by HDC as project FV 124. SPACING also used the relationship between diameter and weight, and assumptions about the distributions of individual root weights in a population to predict the seeding rate to maximise the yield of carrots in target diameter grades.

The objective of the new project (FV 124a) was to modify SPACING to allow it to make predictions for red beet, improve its appearance and use a more recent version of the competition model. This would involve supplying the parameters for the competition and shape models for red beet, and supplying a relationship between mean weight and variation in weight about the mean from existing red beet data.

Growers were shown the software at initial preparatory stage and when near completion. These presentations were done in collaboration with staff from HUSAT at Loughborough University. Also, Kevin Bailey of Stanhay Webb was asked whether the row spacing systems that SPACING accommodates are sufficiently general for commercial application. Most of the software rewriting was done by Data Semantics, but important contributions were made by Richard Reader of the HRI Biometrics Department. Richard Reader also developed new algorithms to perform integration to calculate yields in diameter grades. Analysis of the variation data in red beet and re-fitting of the revised spacing algorithm was done by Laurence Benjamin.

The new version of SPACING will be provided to users on a floppy disc, and will be accompanied by new documentation.

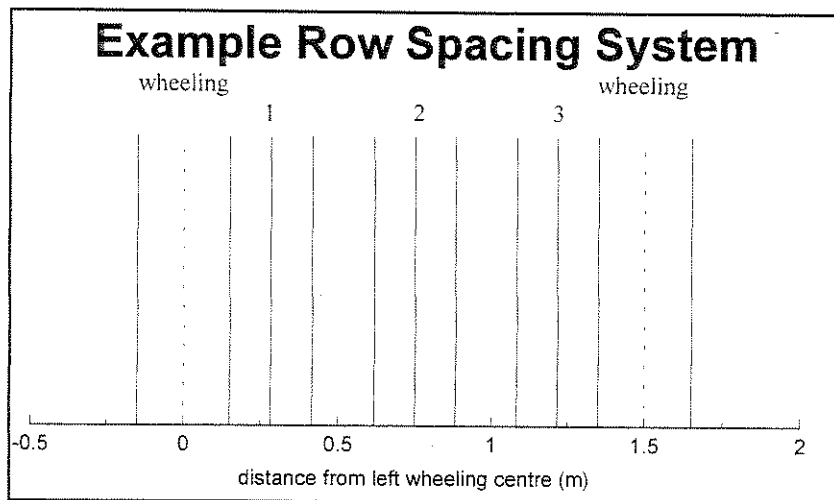
SPACING allows the user to evaluate different row spacing systems, by comparing the expected yields and financial returns for different diameter grades of carrots or red beet and durations of growth. For each row spacing system, the seeding rate in inner and outer rows is stipulated to give maximum yield in a target diameter grade.

The parameters of the competition model were estimated by fitting to a wide

range of experimental treatments found in 19 sets of data from five carrot spacing experiments and to 17 red beet data sets from 6 MAFF funded experiments conducted at HRI, Wellesbourne, UK. The parameters of the relationship between root fresh weights and diameter are based on the results of two carrot and three red beet MAFF funded experiments conducted at HRI, Wellesbourne, (Benjamin and Sutherland, 1989). The predicted frequency distributions of weights were based on the assumption that the weights of roots plus a constant are log normally distributed. The mean of this distribution is proportional to the log of the mean weight, and the constant is inversely proportional to the mean weight. For carrots, the standard deviation is a constant, whereas in red beet this value is inversely proportional to the log of the mean weight. For carrots, this relationship held true over 10 data sets ranging in age and density. For red beet the relationship was established for three cultivars sown at target densities from 60 to 240 plants m<sup>-2</sup> and harvested between 56 and 200 days.

Evaluating different row spacing systems will allow growers to target their within-row spacings more precisely to ensure maximum yield of roots in marketable size grades.

Here is an example row spacing system. The bed is 1.5 m wide (wheeling centre-to-wheeling centre). Within the



bed there are three groups of coulters. The distance between the groups across a wheeling is 0.3 m, (outer row to outer row). The distance from group centre-to-centre within a bed is 0.3 m. The distance from coulters centre-to-centre within each group is 0.133 m. The coulters are 0.05m wide and each sows a triple line. Below is the spacing report produced by SPACING for this row system. The red beet are to be grown for 140 days and the greatest yield is to be in the 40-45 mm grade.

The report listed below is displayed on the terminal screen when SPACING has completed its calculations. A printed version is available by the menu system, and a file in ASCII format is produced on disc containing the report of the latest run of SPACING. This is useful if one should need to produce a report for recommended seeding rates.

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Plant Spacing Report  
Spacing Model - Prediction for Red Beet

SPECIFIED

Crop Duration : 140 (days)  
 Tractor Wheel Setting : 1.50 (m)  
 Diameter Chosen : 45 - 50 (mm)  
  
 Number of groups between wheelings : 3  
 Number of coulters in a group : 3  
 Number of lines per coulters : 3  
  
 Distance between groups : 0.30 (m)  
 Distance between coulters : 0.13 (m)  
 Coulters width : 0.050 (m)  
  
 % Germination : 140%  
 Field Factor : 0.85  
 Seed Costs (per 1000000, 50000 or kg) : £5.00  
 Fixed area costs : £2500.00  
 Expected yield loss : 5.00%

SPACING PREDICTS

Seeds/Metre of row

Rows adjacent to wheeling : 36.95/m  
 Rows adjacent to gaps between groups : 11.65/m  
 Rows adjacent to gaps between coulters : 6.56/m  
 Rows sown by middle of triple line coulters : 3.04/m  
  
 Number of seeds sown : 1510230/ha  
 Final stand achieved : 1797174/ha  
 Total yield of all grades : 61 t/ha

Diameter mm	Yield t/ha	Yield % of total	Value £/tonne	Total Value £
25 - 40	14.00	22.87	85.00	1189.96
40 - 45	7.18	11.73	80.00	574.38
45 - 50	7.29	11.90	80.00	582.90
50 - 55	6.78	11.07	80.00	542.12
55 - 60	5.90	9.63	80.00	471.88
60 - 65	4.88	7.97	80.00	390.52
65 - 75	6.89	11.25	50.00	344.52
75 +	8.31	13.58	20.00	166.23

Total seed costs : £151/ha  
 Total nett income for field : £1611

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To achieve the maximum yield in the 40-45 mm diameter range, the seeding rate in the two lines (or rows) next to the wheelings should be  $37.0 \text{ m}^{-1}$ , for the other lines on the edge of the groups it should be  $11.7 \text{ m}^{-1}$ , for the other lines sown on the edge of the coulter the seeding rate is  $6.5 \text{ m}^{-1}$  and the lines sown by the middle of the coulter is  $3.0 \text{ m}^{-1}$ .

The effect of different durations of growth, price structures and costs can be evaluated by rerunning SPACING with these attributes altered. Every item of listed on the above report can be altered in SPACING's menus and SPACING takes only a few seconds to run, depending on the capacity of the PC. Note, that for red beet, the % germination allows for multigerm cultivars, in which germination rates can exceed 100%.

## Improvement to SPACING

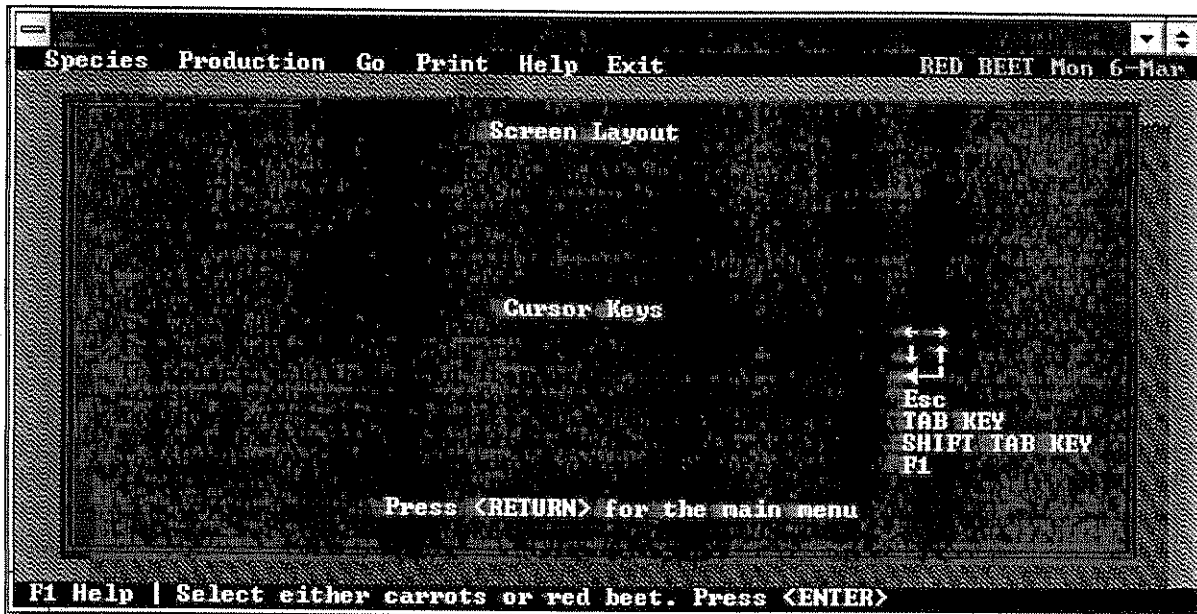
### Introduction

The following changes to SPACING were made:-

- i) The spacing algorithm was based on Benjamin and Sutherland (1992), rather than on Sutherland and Benjamin (1987).
- ii) Predictions were allowed for red beet or carrots.
- iii) The number of possible row spacing systems was expanded. In the new version, the distance between groups of coulters across a wheeling can be different to the distance between groups of coulters within the area straddled by the tractor wheel base.
- iv) The help menu includes diagrams to make the distances to be supplied by the user more clear.
- v) The information requested is closer to the way growers consider row spacing systems. For example, SPACING requests information on the coulter width, distance between coulters, between coulter groups and the width of the tractor wheel base. The distance between coulter groups across a wheeling is calculated by SPACING. Formerly, this distance across the wheelings had to be supplied to SPACING, which entailed the user having to do several calculations.
- vi) Financial information was split off into a separate form, as this information is not essential for the predictions made by SPACING. Formerly, its close integration into the forms on spatial patterns implied that accurate financial information, which is difficult to obtain, was crucial for accurate predictions.
- vii) The number of grades and their limits for red beet had to be presented in a special new form, to replace the one for carrots.
- viii) The final report was condensed to give all the relevant information on one page.

### The New Appearance of SPACING

Most of the old features of SPACING have changed. On starting, the screen displays the HRI, HDC and MAFF logos, not just that of HRI. The licence agreement is no longer listed on start up, but is an item under help. The next screen describes how the user moves around the menu system of SPACING, and is shown below:- There are now six menu items at the top of the page, **Species, Production, Go, Print Help and Exit.**

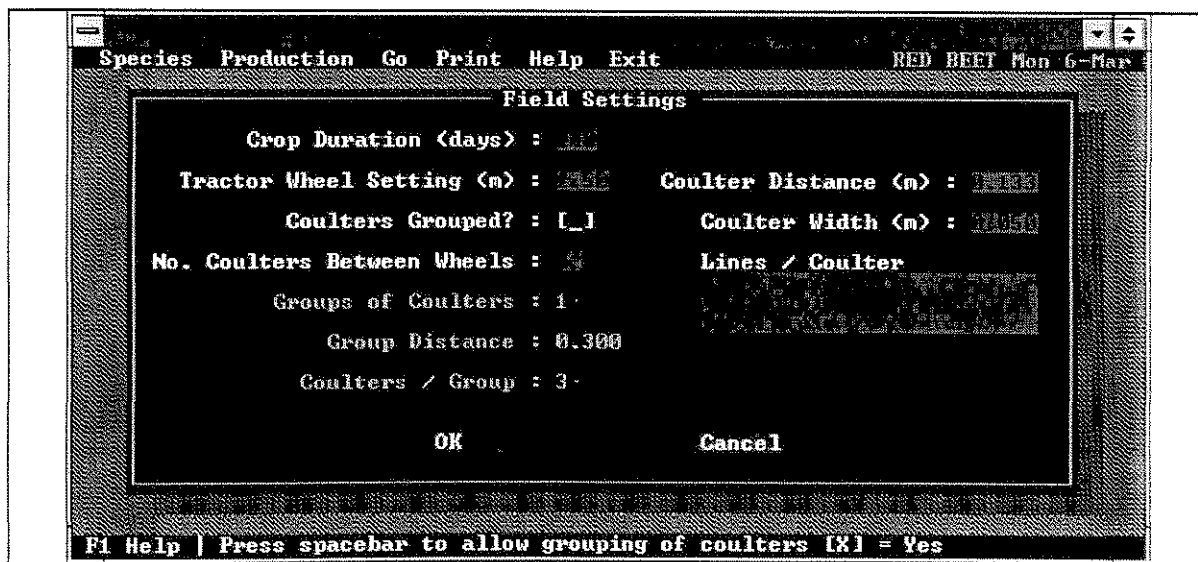


'Species' is a new form and simply lists the names carrots or red beet. The currently selected species is displayed on the top right-hand side, along with the date.

The 'Production' form has been simplified to have only three items. These are 'Field Settings', 'Target Sizes' and 'Financial'.

The 'Field Settings' form is shown below

Many changes have been made to this form. Previously, sowing and harvest dates were requested. This gave the incorrect impression that SPACING allowed for



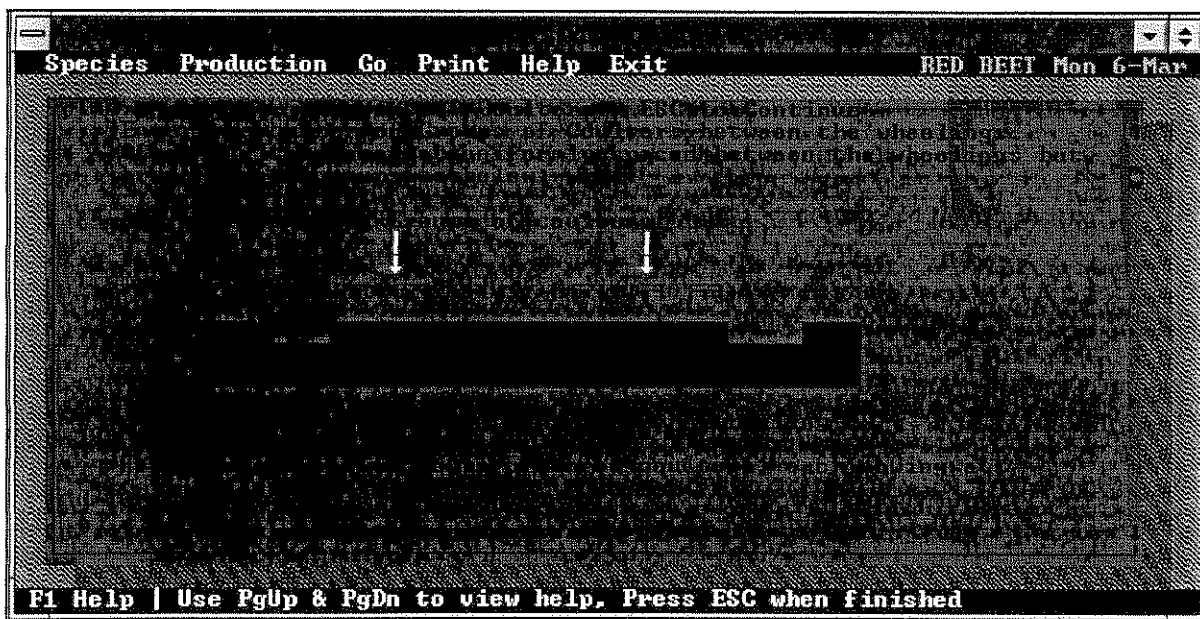
climatic conditions. The simpler request for the number of growing days is made. The F1 help advises that days before 1st March or after 15 October should not be included in the growing days. The intention is to improve SPACING further to allow for a dependence on climatic conditions.

'Tractor Wheel Setting' is the distance between the wheelings. This had been

called bed width. The term 'bed' is simpler, but led to confusion, as some growers thought of a bed as a group of rows, and hence there could be several beds between the tractor wheelings. Discussion with growers revealed that carrot growers felt that tractor wheel setting should exclude any compacted soil in the wheelings, especially if using a raised bed. However, the red beet growers felt that excluding the wheelings would ignore the additional radiation available to plants on edge rows. I think this is a matter that can be left to the discretion of the user. The advice given in the F1 help is to exclude the width of the wheelings when growing carrots, but to include this space when growing red beet, especially in row spacing systems sown with a seed drill that may sow several 'tractor widths' simultaneously, giving little soil compaction in the many wheelings.

The 'Coulters Grouped?' question asks if there is grouping of coulters. Asking this question allows for information to be targeted to specific row spacing systems. The above illustration displays the form when the answer is no. Note that the appearance of the three questions about groups of coulters is different to the rest of the form. This is because these questions are not relevant in this situation, and hence are not accessible. When the answer is yes, then the line asking how many coulters there are between the wheels is not accessible, and the three questions about grouping are displayed fully.

The 'No of coulters between the wheelings' simply asks how many coulters



there are between the wheelings, when there is no grouping of coulters.

'Groups of Coulters' asks how many groups of coulters there are between the wheelings.

Above is the appearance of the help screen, which can be obtained by pressing the F1 help, if the user is not clear about what is being asked. This is typical of many new picture screens accessible from the help.

'Group Distance' is the distance between the groups, from centre-to-centre. This distance is not allowed to vary between groups.

'Coulters / Group' is the number of coulters in each group. Again, this number

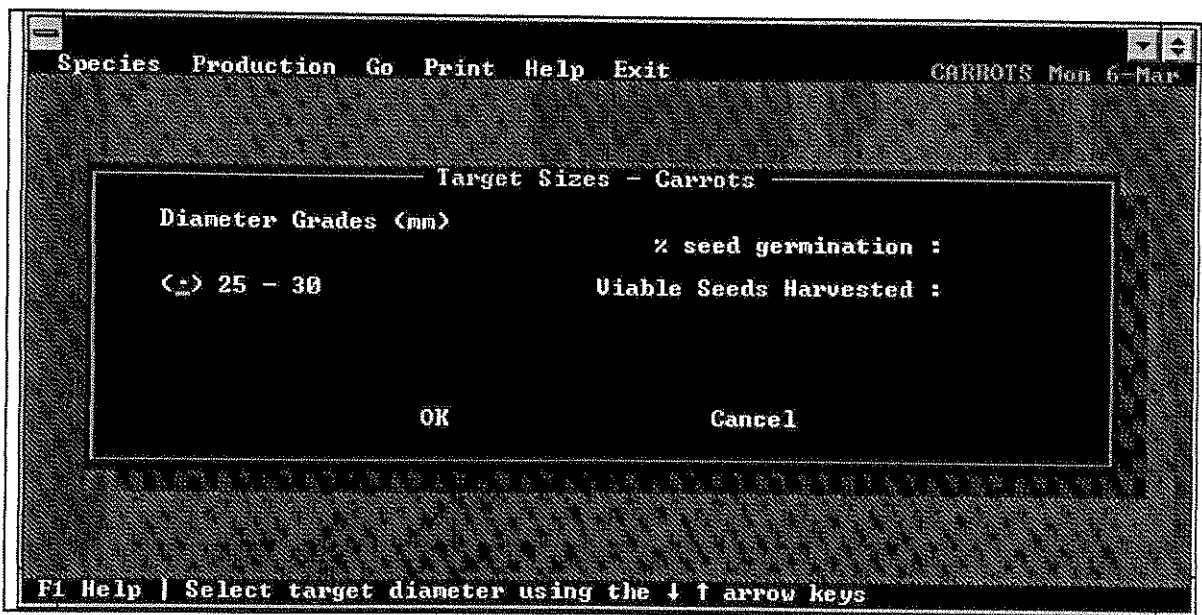
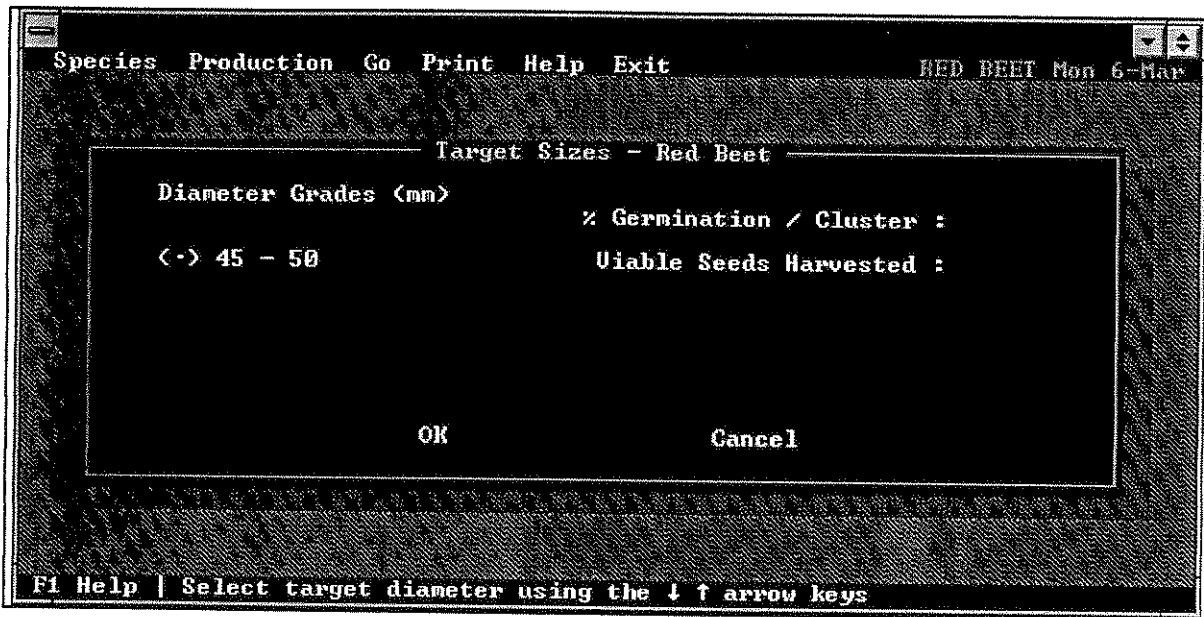
is not allowed to vary between groups.

'Coulter Distance' is the distance between coulters, from centre-to-centre. This distance is not allowed to be less than 0.1 m.

'Coulter Width' is the width of the coulter, and sets the distance between 'lines', when each coulter sows two or three lines. This distance must be between 0.02 and 0.20 m.

'Lines / Coulter' is the number of lines sown by each coulter. This is a radio button dialogue box as coulters can sow only one, two or three lines.

The 'Target Sizes' form allows the user to specify a single diameter grade. SPACING will predict the seeding rates to maximize yield in that grade. There are different numbers of grades and grade limits for carrots and red beet. These grades





were established after discussion with growers. Also, the germination details are different between the two species, to reflect the difference in seed types. The maximum percentage germination is allowed to exceed 100 for red beet, but not for carrots.

'Viable Seeds Harvested' was called a field factor in the earlier version. However, this can be confused with the proportion of seeds that are present shortly after seeding emergence is complete. This may not be the same as the numbers of plants harvested.

The 'Financial Form' is not essential for making spacing predictions but allows some financial implications of the predicted spacings to be evaluated.

The Fixed area costs box allows the user to provide an estimate of those costs of production that are determined on a per unit area basis. Here a single figure is entered to include the total cost of land rental, fertilizer and spreading, chemicals and

Diameter	Grades (mm)	Value (£/tonne)
25	- 40	85.00
40	- 45	
45	- 50	
50	- 55	
55	- 60	
60	- 65	
65	- 75	
75	+	

Fixed Area Costs (£) :                      Fixed Yield Costs (%) :

Seed Costs (£)                                      1000 seed weight (g) : 1.0

OK                                      Cancel

F1 Help | Enter the value of the current diameter

application, irrigation water and application, land preparation, drilling, lifting and grading. The income from each grade, and the total income from the field will have these fixed area costs deducted.

The Fixed Yield Costs box allows the user to enter the percentage of the yield lost during lifting and packhouse operations. Also, the user should include the estimated percentage losses due to forking, splitting and disease. The yield of each grade will be deducted by this percentage, and the financial return will take this yield loss into account.

The Seed Costs box allows the user to select whether seeds are purchased per million, per 50,000 or by weight. If the method of payment is by weight, then the seed weight box must have an accurate figure entered. If payment is by number, then the 1000 seed weight box cannot be accessed.

Prediction, are made by selecting Go in the main menu and a report file will be generated on the screen. Even on some now old XT PCs, SPACING takes only about a minute to run. On the more standard 486 PCs, SPACING completes its calculations

in less than a second. A report containing the above information is generated on disc in an ASCII file called SPACING.REP,. This can be printed off, or more simply, the above report can be printed using the menu system within SPACING. The typical contents of this file are shown above in the summary. The output for when no grouping of rows occurs is simpler than for this example, as there are fewer numbers of different row types. SPACING has been written to detect whether rows are grouped and present the appropriate form of final report.

When running SPACING, further help and background information are available via the help menu. The user can select an Introduction, Guide to SPACING, a description of the Features and Assumptions of the software, there is also a contact name at HRI and finally the Licence can be viewed.

Red beet growers expressed the strong wish that SPACING be used on a trial basis in commercial conditions before it is marketed widely.

### Conclusion

The modified version of SPACING now allows it to be fitted to red beet data and to most possible row spacing systems. Many modifications have been made to its appearance, and the use of pictures in the help should greatly improve its ease of use.

### References

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