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Computer organised orchard layouts (COOL) based on the permutated neighbourhood design concept

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Summary

COOL is a computer program which produces seed orchard layouts based on the permutated neighbourhood design concept. The program is flexible, coping with irregular areas, up to 100 clones, varying numbers of ramets per clone, and hybrid orchards. It is easy to use, being controlled by a set of English command words, and can be operated without specialised statistical or computing knowledge. The use of COOL should eliminate much of the hard work involved in designing seed orchards.

Key words: seed production, seed orchard design, tree breeding.

Zusammenfassung

Für die Planung und Anlage von Samenplantagen wird ein Computerprogramm (COOL) vorgestellt, mit dem viele Schwierigkeiten bei der Erstellung von Samenplantagen behoben werden können. COOL ist einfach zu handhaben und vielseitig anwendbar. Anlagepläne können auch für unregelmäßig geformte Flächen und für unterschiedlich große Klongruppen konstruiert werden.

Introduction

The first clonal seed orchard in Britain was planted in 1952. Several orchards of various species have been planted since then using a range of designs (FAULKNER 1965). In this early period clonal components of the orchards had not been properly tested and the area of individual orchards was generally less than one hectare. Breeding Programmes for the main commercial species have now developed to the stage where most selected trees are in half-sib progeny tests an a nurnber of sites. Selection ob clones is based on a full consideration of data from these tests including a detailed analysis of any family X site interaction (JOHNSTONE and SAMUEL 1978).

New clonal seed orchards of the 1.5 generation type (WEIR and ZOBEL 1975) are being established and before embarking on this programme of orchards a set of basic rules was established.

1. On the basis of past experience, and, to keep the breeding population at an acceptable size in order to minimise problems of relatednoss, the number of clones in any orchard should be between 30 and 50. This number can be reduced by thinning as more information becomes available general and specific combining ability, proportions of male and female flowers, dates of flowering and self-fertility levels.

2. The minimum area of an orchard should be four hectares (KOSKI 1975) to ensure satisfactory cross-pollination within the orchard.

3. Spacing should be related to the expected shape and development of the crowns for the species and the expected year of the first commercial cone crops.

4. Risk of self-pollinaticm should be minimised.

5. Theoretically all possible crosses should occur with similar frequency to obtain panmixis.

6. For ease of layout, management and the use of machinery for ground cover coatrol, planting should be based on a square or rectangular grid system.

Several types of design have been suggested in the past such as, shifting-clone design (MALAC 1962) or a modification of it as used in the southern states of Arnerica; cyclic balanced incomplete block designs (FREEMAN 1967; DYSON and FREEMAN 1968); most orchards however use simple randomised designs (GIERTYCH 1975).

GIERTYCH (1975) considered a range of orchard designs and concluded that most tree breeders require minimal self-pollination and good panmixis from their designs. Several designs fulfill these two objectives to a greater or lesser degree but when other factors are considered a permutated neighbourhood design is the most suitable. In commercial orchards factors such as, compariscm of clones or the division of an orchard into replicates for experimentation, are unimportant. The permutated neighbourhood design has not been widely used because it is difficult to coastruct without the aid of a computer, particularly when orchards are extensive and/or have mixtures of clones which are not evenly represented.

LA BASTIDE (1967) developed a computer program for permutated neighbourhood designs which allows all cross-combinations to occur with approximately equal frequency and minimal selfing. However, the program is too rigid and requires the orchard to be rectangular and have equal numbers of ramets per clone.

Experience in Britain shows that prime seed orchard sites are difficult to obtain and are often irregular in shape. In addition the number of ramets available for each clone may not be constant due to varied grafting success, though in some cases varying numbers of ramets may be desirable due to imbalance in flower production between clones. An orchard design was required to take these factors into account and LA BASTIDE having demonstrated the possibility of producing permutated neighbourhood designs by computer, it was decided to develop a similar but more flexible program.

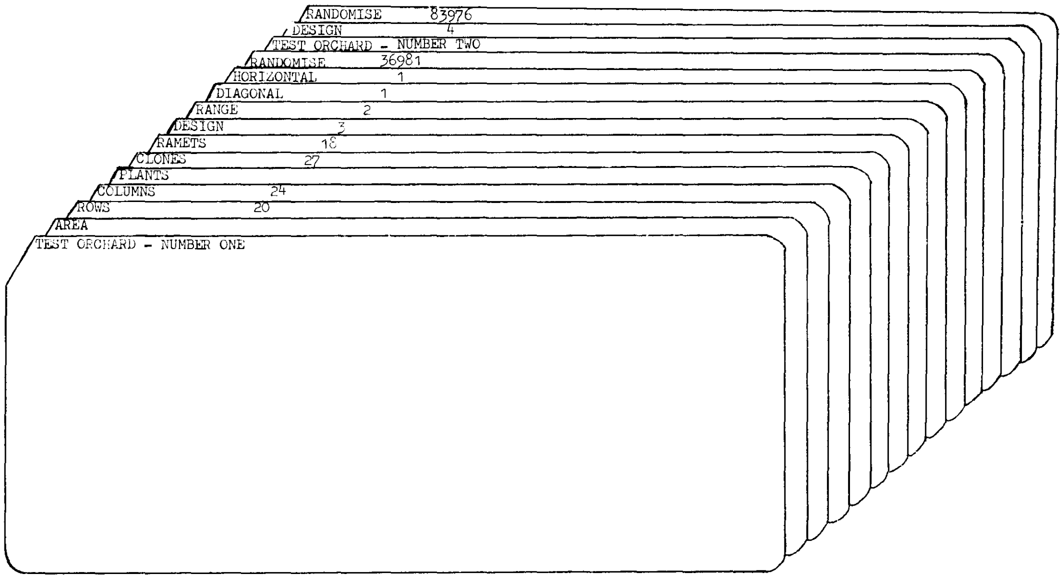

Figure 1. — An example of input showing the command structure and format. In this case the program will generate two orchards, the second of which will differ from the first in that it is a 'Design Type' 4 instead of 'Type' 3 but the other constraints remain the same.

Seed Orchard Design Program

The orchard design program (COOL) has been written with the following general considerations in mind: machine independence; simplicity of input and operation; flexibility.

Machine independence

The program is written in Fortran which is widely available. Minor changes may be required for some of the dialects.

Simplicity of input and operation

COOL is controlled by a series of English command words which are written in a standard format. Default values are provided; the program will run even if commands are omitted.

COOL can design more than one orchard in one run and commands set in earlier runs will retain their value unless reset. This allows the breeder to experiment by changing the design criteria one at a time without having to re-input all the basic data.

If a solution is impossible within the initial constraints which have been set, the program will reduce the constraints and contine running. In this case an explanatory message appears in the output. This method of running may be useful for designing large orchards which then become infinitely expandable. Designs which are complex either in shape or composition require more complex input, which again is done by standardised formats, not too complex for the breeder to use. An example of the simplicity of the input is given in *Figure 1*.

Flexibility

The input commands (as shown in *Figure 1)* are at two levels. At the first level there are three commands *area, plants* and *design* which have sub-commands which further specify the users requirements.

The command *area* controls the size and shape of the orchard. It has three sub-commands *rows* and *columns* which define the dimensions of a rectangular orchard and *irregular* which is used for non-rectangular areas.

The command *plants* has two sub-commands *clones* and *ramets* which control the orchard composition.

Design introduces six sub-commands namely *range, diagonal, horizontal* or *vertical, hybrid, mechanical* and *neighbours*. It is also used to specify 'Design Type'; this specifies the number of rings by which the selected clone is isolated and whithin which no other ramet of the same clone *can* occur (see *Figure 2)*.

The sub-command *range* is complex in its operation but it can be used to even-out the distribution of clones throughout the orchard or to give weightings to individual clones. Its use may allow the program to find a solution in cases where it had failed previously.

Diagonal and *horizontal/vertical* are used to specify the number of times two clones can occur in the same immediate positions relative to each other.

Hybrid provides for the design of hybrid orchards of two separate parent groupings. *Mechanical* provides for mechanical thinning of the orchard when it is necesary to keep the composition constant. *Neighbours* provide a table of counts of neighbours in horizontal, vertical or diagonal

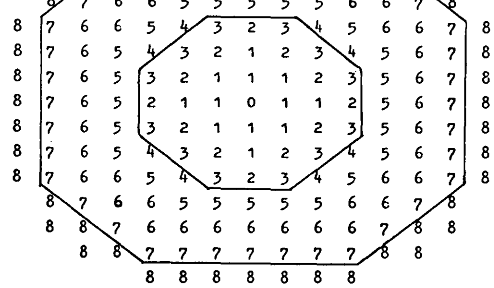

Figure 2. — Each ramet of clone '0' is separated from other ramets of '0' by the ring of integers $\leqslant$ the 'Design Type'. The lines in the figure represent the isolation achieved by 'Design Type' 3 (inner ring) and 'Design Type' 7 (outer ring). In 'Design Type' 3 positions occupied by digits $\geqslant$ 4 could be occupied by clone '0'.

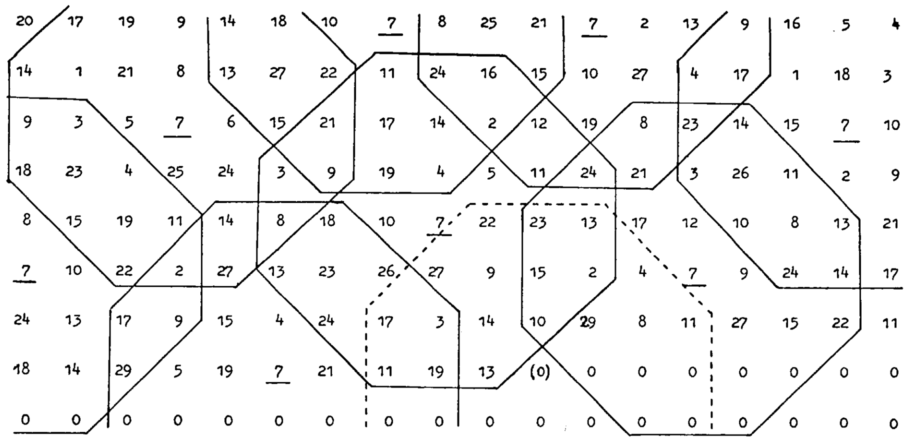

Figure 3. — Example of a 29 clone orchard with variable number of ramets using Design Type 3.

positions. The last command *randomise* is used to initiate the design of the orchard. The value which is read on the *randomise* card is used as a starting value for a random number generator. Providing the other commands are unaltered the same starting value will always produce the same orchard layout.

How COOL Works

An example of a section of an orchard of 29 clones with different numbers of ramets per clone and with an isolation achieved by a design of 'Type' 3 is shown in *Figure 3.*

The design has been left incomplete to show how the program selects the next clone (0) in the orchard. First the program scans those clones within the 'Design Type' boundary (dotted line), clones 22 — 13; 27 — 4; 17 — 11; 11 — 13 and rejects these. Second it scans a table of counts of the remaining clones (1, 5, 6, 7, 12, 16, 18, 20, 21, 24, 25, 26, 28) occurring in horizontal, vertical or diagonal directions with the immediate neighbours 14, 10, 29 and 13 and rejects any clones which already occur the maximum number of permitted times. Third it generates a random number which is used to select a particular clone from those remaining. This selection is weighted in favour of those clones which have most plants left. In this particular case the computer chose clone 7 for the next available position.

Conclusions

Several orchards have now been satisfactorily designed and planted. These include orchards of one or two species with both rectangular and irregular shapes. Although the program was not designed to produce exact solutions several exact solutions have been obtained.

COOL has proved flexible and easy to use, furthermore, there may be design considerations apart from those listed which could be added, for example, the facility to expand an existing established orchard.

The multiple design capability is extremely useful at the initial planning stage. Several designs can be run at the same time and the resulting plans compared.

COOL obviates the difficulties of manually produced designs, eliminates most of the risk of clerical errors and reduces the cost of design work. The computer cost of designing two orchards of 24 × 20 planting positions with 27 clones was less than one pound sterling. Central processor time on an I.C.L. 4/75 was 60 seconds. A 5,600 plant irregular seedling seed orchard took 168 seconds to compute on an IBM 360 at a cost of £ 3.

Additional to the design program COOL is a second program which translates the output from COOL into actual clone numbers and lists the planting co-ordinates of each ramet by clone number. Field managers have experienced no difficulties in using these layouts for setting out the orchards.

A COOL User's Manual describing the program, the commands with full program listing, examples of input and corresponding output is available on request.

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