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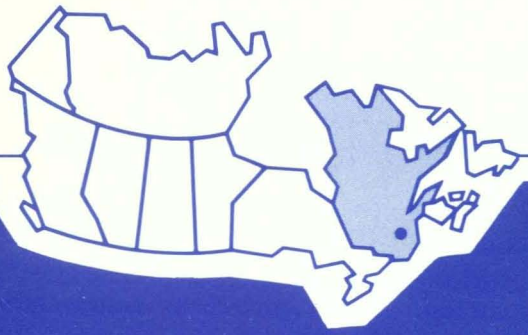
MIMOSOL

J. Beaulieu, A. Corriveau, and G. Daoust



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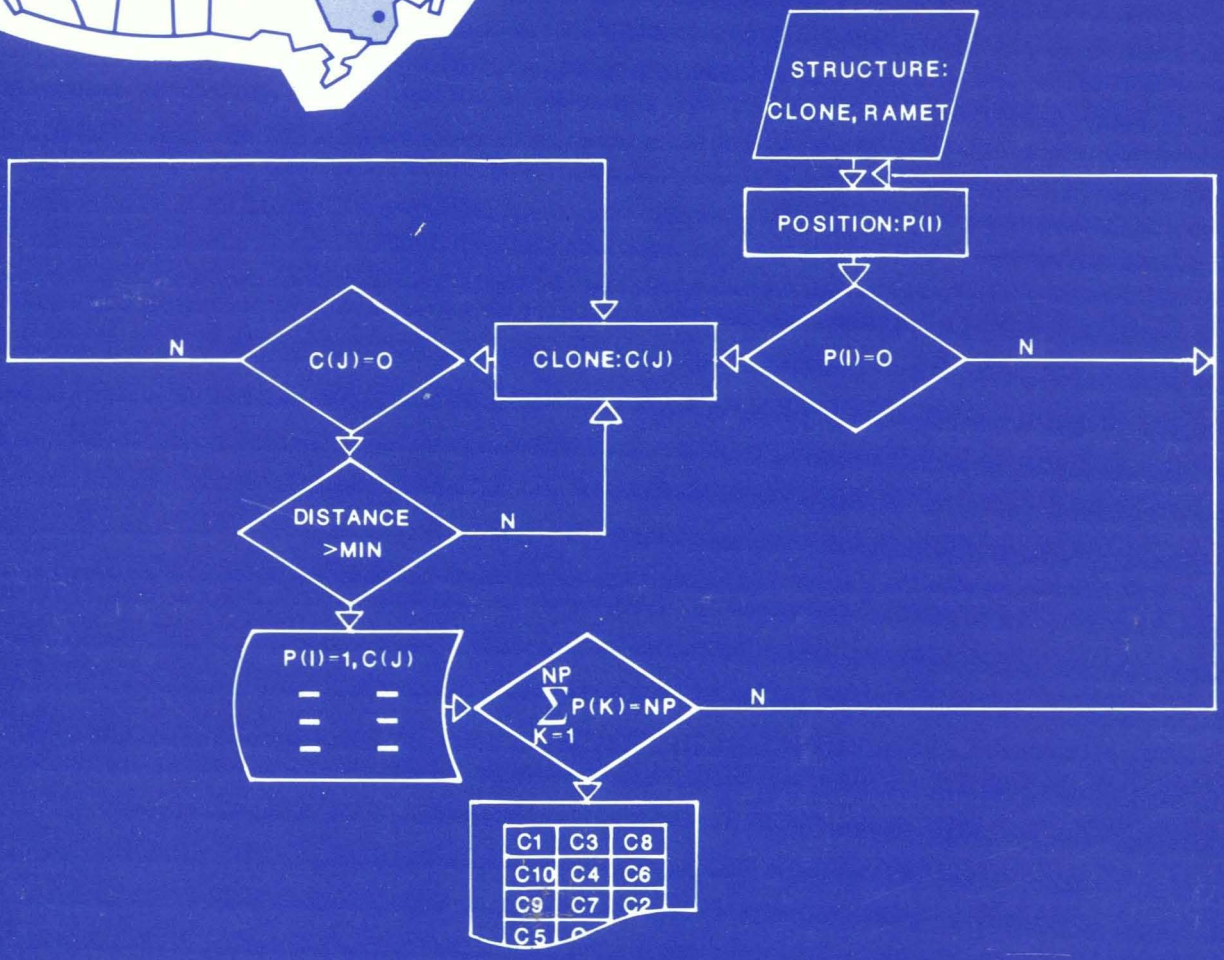

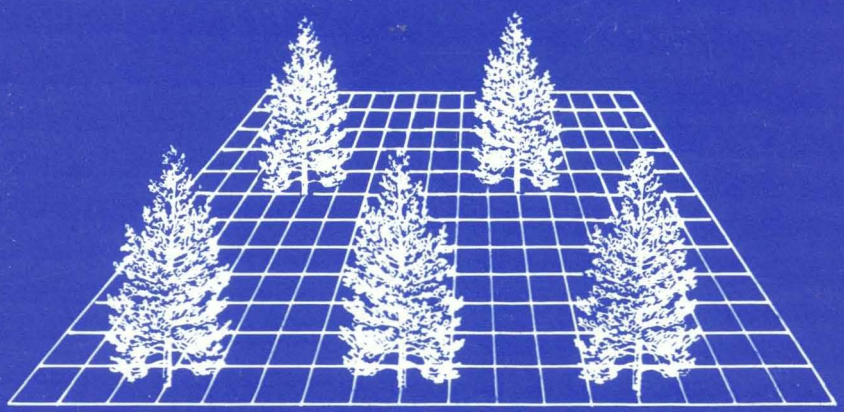

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MIMOSOL - Interactive computer program for minimum inbreeding and maximum outcrossing seed orchard layouts

J. Beaulieu, A. Corriveau, and G. Daoust

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ABSTRACT

MIMOSOL is an interactive computer program that will make the tree breeder's seed orchard design task considerably easier. The program will be very useful in the design of both clonal and seedling orchards. Orchard layouts can accommodate complete blocks of equal size or a single tenant.

The primary feature of the MIMOSOL program is that seed orchard layouts can be created minimizing inbreeding and favoring outcrossing, thus producing seed of better genetic quality. The program takes into account each individual's place in the hierarchy of a specific group and pre-established spacing constraints when the individual is positioned. The interactive nature of the MIMOSOL program makes it easy and attractive to use, even for people with limited computer experience.

Note: Copies of the MIMOSOL program may be obtained on request from the authors.

RÉSUMÉ

MIMOSOL est un programme informatique interactif qui facilitera considérablement la tâche de l'améliorateur forestier lors de la réalisation de plans de vergers à graines. Le programme MIMOSOL sera d'une grande utilité aussi bien lors de l'élaboration de plans de vergers à graines clonaux que de celle de plans de vergers à graines de semis. Les plans de vergers pourront être composés de blocs égaux complets ou être d'un seul tenant.

MIMOSOL a pour qualité première de permettre la réalisation de plans de vergers à graines dans lesquels l'inbreeding est minimisé et l'hétérofécondation favorisée, assurant ainsi une meilleure qualité génétique de la semence produite. Pour ce faire, MIMOSOL tient compte, lors du positionnement de chaque individu, de sa ligne hiérarchique d'appartenance à un groupe particulier ainsi que de contraintes d'espacement préétablies. Le caractère interactif du programme informatique MIMOSOL le rend accessible et attrayant, même pour celui que l'ordinateur rebute.

Note: Une copie du programme MIMOSOL peut être obtenue en en faisant la demande auprès des auteurs.

INTRODUCTION

For several years, cries of alarm have gone up across Canada from people concerned about the serious problem of unsatisfactory natural regeneration on harvested or burnt forest sites (Canadian Forestry Association 1977; Science Council of Canada 1983). One of the proposed means for correcting the situation is artificial regeneration, which depends on a suitable and sustained supply of quality seed. Accordingly, many seed orchards have been established. There are various approaches to orchard design (Giertych 1975; Bell and Fletcher 1978; Beaudoin and Desaulniers 1980; Nanson 1985), and layout selection is based on a number of criteria. The two main criteria are minimization of inbreeding and encouragement of outcrossing.

The MIMOSOL computer program was developed to meet these requirements by taking into account the variable family relationships between seed orchard members when assigning them positions within the orchard.

The program eliminates much of the difficulty of producing suitable seed orchard layouts without computer assistance. Because it is interactive, the program is easy to use even for people with limited computer experience.

METHODS

Types of seed orchard layouts

Two types of seed orchard layouts, for either clonal or seedling orchards, can be generated using the MIMOSOL program. The first type is for orchards made up of complete blocks of equal size. Each block contains only one representative of each group (clone or family). The number of blocks can be varied according to the user's needs.

The second type is for orchards in which a given number of individuals are assembled in a single block. In this type, the number of

individuals representing a given group (clone or family) can vary from one group to the next. The MIMOSOL program can be used to develop orchard layouts of this type when the tree breeder wishes to incorporate all available material (ramets or seedlings) into the orchard.

For seedling seed orchards, the family can be taken as the base component of the orchard and represented by a fixed number of full- or half-sibs occupying a given position in the orchard. This permits intra-family selection during subsequent genetic thinnings, after which a single representative of each family is retained at each position.

Positioning of individuals

The position to be occupied by a given individual in the orchard is initially chosen at random. The random choice is then conditioned by a number of constraints designed to minimize inbreeding and, at the same time, encourage outcrossing.

Inbreeding cannot be effectively controlled without knowledge of the family relationships between the individuals making up the orchard. Those with the closest links must be spaced the farthest apart, while those which are unrelated make good neighbors. The MIMOSOL program is able to take into account three hierarchical levels in addition to the level constituted by the block or blocks, including membership in a single clone or family, a single provenance or population, and a single provenance region. To minimize inbreeding, minimum spacing constraints are introduced based on family relationships between individuals. If family links are closer, minimum spacing constraints are stricter. Thus, individuals belonging to clones or families of a single population must be more widely spaced than individuals of different populations, even if they are from the same provenance area.

By limiting the number of times that two individuals of given pedigrees can occupy adjacent or close positions, it is possible to favor

outcrossing. The greater the number of different crosses we wish to obtain, the more we must limit the number of times a given neighborhood will occur i.e., individuals of given pedigrees, say x and y, will be neighbors or near neighbors since genetic exchanges vary as a function of the distance separating the individuals.

Assignment of priority to specific genotypes

Frequently in the design of seed orchards there is a wish to give priority to one or several genotypes by increasing their numerical representation. For example, if the tree breeder has a genotype or population of superior genetic quality, he will want to develop the orchard layout relying primarily on the superior material. The MIMOSOL program can take such considerations into account. To do so, it first positions any groups of preferred origin. When these groups have been positioned, a random distribution subjected to minimum spacing constraints is used again to allocate positions for the other members of the orchard.

PROGRAM DESCRIPTION

Machine independence

The MIMOSOL program is written in FORTRAN IV PLUS. It was developed and tested on a Digital Equipment Corporation PDP11/44 minicomputer belonging to the Canadian Forestry Service at Laurentian Forestry Centre. Since this computer has only limited central memory (64K), the permissible number of positions per block is limited. However, with greater computing power, the program could handle a much larger number of seed-bearers. This would simply involve changing the dimensions of certain matrices and increasing the size of the input-output buffer.

Flexibility

The MIMOSOL program is interactive. The user who runs it is asked, by means of a series of questions, to provide a number of parameter values and positive or negative answers. The questions refer to the various components described in the **Methods**.

To start, the user is asked to indicate the structure of the orchard or the hierarchy and the minimum spacing constraints associated with each level. The terms used to describe the structure are left to the discretion of the user, who can thus create a layout for a clonal orchard or a family orchard.

```
MIMOSOL > WHAT IS THE STRUCTURE OF THE SEED ORCHARD:
USER > POPULATION, FAMILY, INDIVIDUAL
```

In the example below, the user indicates to the computer that the orchard will be composed of a certain number of populations represented by families and that each family will in turn be represented by a given number of individuals equal to the number of blocks (Figure 1).

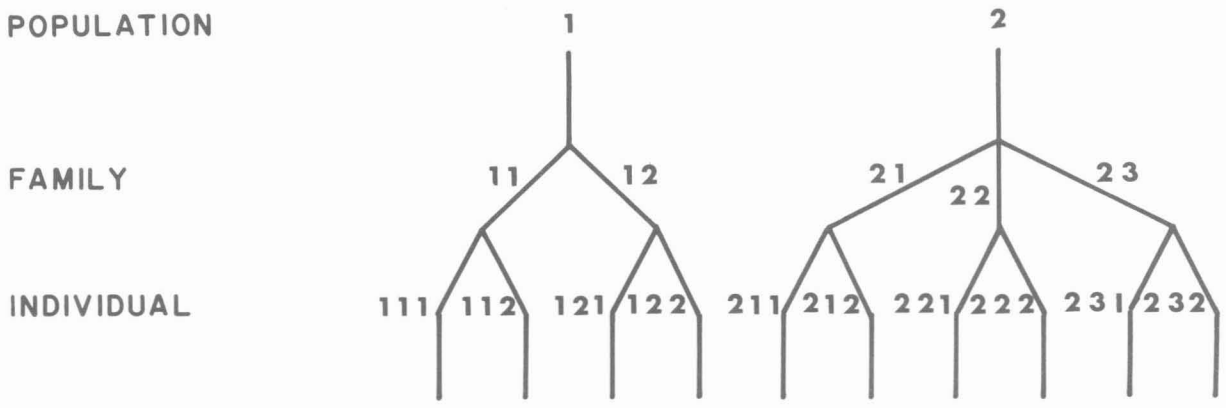


Figure 1. Orchard structure.

Depending on the structure provided, for each hierarchical level, the program asks the number of descending branches and the minimum spacing constraints (n orthogonal distances between adjacent positions) associated with them.

```
MIMOSOL > WHAT IS THE NUMBER OF:  POPULATION
USER > 2
MIMOSOL > IS THE NUMBER OF 'FAMIL' THE SAME FOR ALL 'POPUL'?
USER > NO
MIMOSOL > WHAT IS THE NUMBER OF 'FAMIL' IN 'POPUL' 1
USER > 2
MIMOSOL > WHAT IS THE NUMBER OF 'FAMIL' IN 'POPUL' 2
USER > 3
MIMOSOL > IS THE MINIMUM SPACING THE SAME FOR ALL 'POPUL'?
USER > YES
MIMOSOL > WHAT IS THIS SPACING?
USER > 3
MIMOSOL > WHAT IS THE NUMBER OF: INDIVIDUAL
USER > 2
MIMOSOL > IS THE MINIMUM SPACING THE SAME FOR ALL 'FAMIL'?
USER > YES
MIMOSOL > WHAT IS THIS SPACING?
USER > 4
```

In the above example, minimum spacing has been set at a single value for each branch descending from nodes at the same hierarchical level. However, this spacing can be varied. The minimum spacing specified at the question on populations also applies to individuals belonging to the same population but of different families. The minimum spacing stated at the question on families also applies to the individuals making up a given family and will apply between blocks in this example because the families are represented by only one individual per block.

Next, the user indicates whether he wishes to assign priority to certain groups with regard to positioning. This is done by simply entering the group numbers.

```
MIMOSOL > DO YOU WISH TO POSITION SOME 'POPUL' ON A PRIORITY BASIS?
USER > YES
MIMOSOL > HOW MANY 'POPUL' DO YOU WISH TO POSITION ON A PRIORITY BASIS,
          MAXIMUM OF 6?
USER > 1
MIMOSOL > LIST THE NUMBERS TO BE POSITIONED ON A PRIORITY BASIS
USER > 2
```

Then, the user is asked to indicate the physical size of the orchard. The first values sought are the number of rows (of trees) and the number of columns (individuals per row). The shape of the orchard must be rectangular (or square). Next, the number of rows occupied by a block and the distance between two adjacent orthogonal positions must be specified. The number of individuals per row within a block is calculated by the program.

```
MIMOSOL > WHAT IS THE NUMBER OF ROWS AND COLUMNS IN THE SEED ORCHARD?
USER > 2 5
MIMOSOL > WHAT IS THE NUMBER OF ROWS PER BLOCK AND THE DISTANCE BETWEEN
          'INDIV'?
USER > 2 4
```

As we mentioned in the **Methods**, the MIMOSOL program can also place constraints on neighborhoods to favor outcrossing. To do this, the user simply indicates the maximum number of times that two individuals of given pedigrees will be allowed to be immediate neighbors within the whole of the orchard.

```
MIMOSOL > DO YOU WISH TO FAVOR OUTCROSSING BY CONTROLLING NEIGHBORHOODS?
USER > YES
MIMOSOL > WHAT IS THE MAXIMUM NUMBER OF TIMES THAT TWO INDIVIDUALS OF
          GIVEN PEDIGREES CAN BE NEIGHBORS?
USER > 2
```

Finally, the user can indicate whether the program is authorized to position individuals without taking into account the minimum spacing constraints associated with the hierarchical levels. This may be desirable for the user who wishes to set high minimum spacing constraints for a majority of individuals to be positioned and is willing to drop all constraints for a small percentage of individuals.

```
MIMOSOL > WHAT PERCENTAGE OF THE NUMBER OF INDIVIDUALS MAKING UP A BLOCK
          MUST BE POSITIONED BEFORE SPACING CONSTRAINTS MAY BE NEGLECTED?
USER > 95
```

The resulting orchard layout may not be optimal if the constraints are dropped, but it may well be satisfactory. If the user studies the layout and finds it to be unsatisfactory, he can run the program again using less rigid minimum spacing constraints.

Maximum processing capability

The current upper limit for the MIMOSOL program is set at 900 positions per block. This limit is not absolute, however, and can be easily increased by making a few minor changes to the program.

SAMPLE APPLICATIONS

Example 1

Creation of complete-block seed orchard

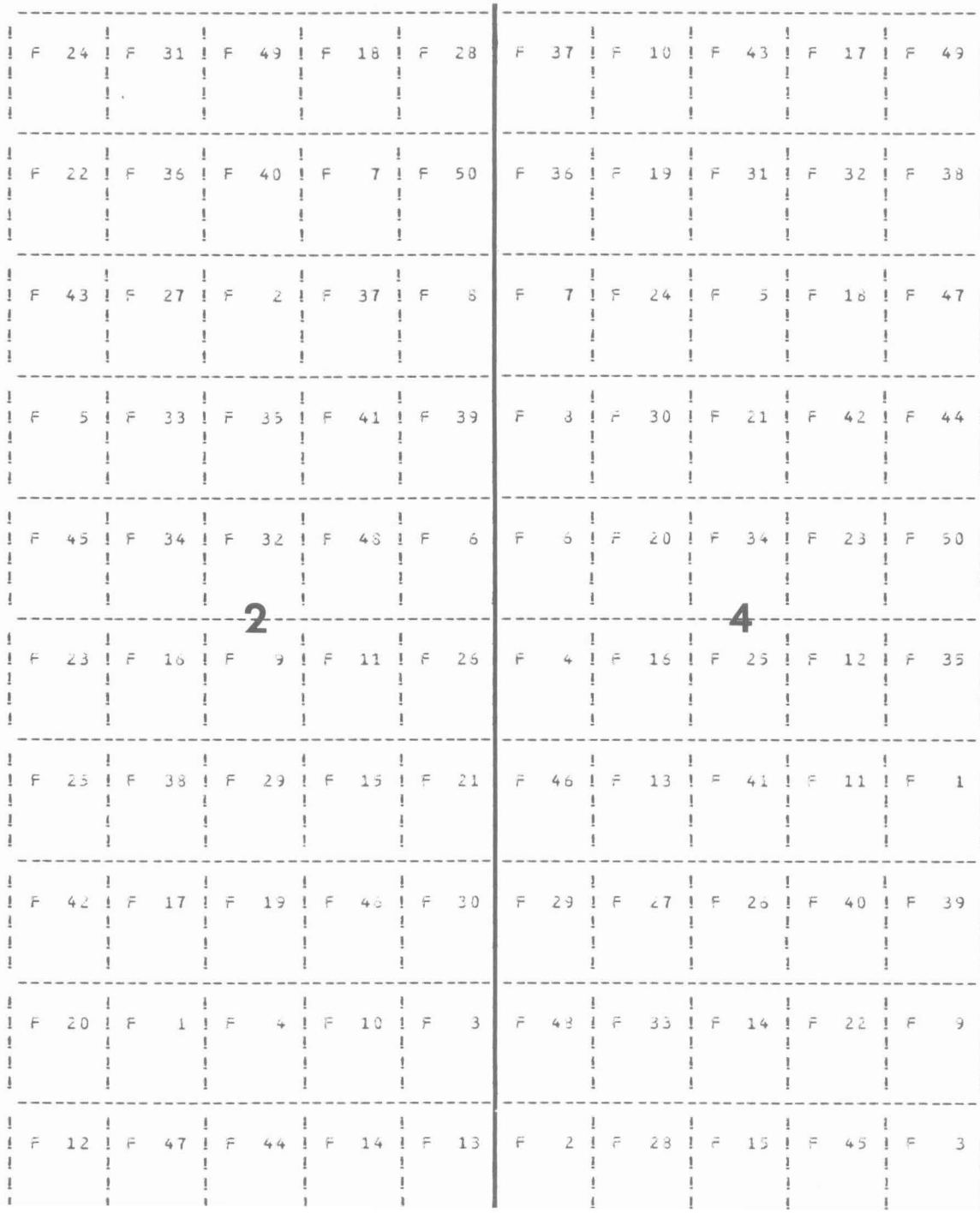
The seed orchard layout presented here is composed of four complete blocks, each containing one representative from 50 families. The spacing between individuals of the same family is at least three times the orthogonal distance between adjacent positions. However, these spacing constraints can be neglected once 95 percent of the individuals, or 48 out of 50, have been positioned in a block in accordance with the established constraints. Each block extends over 10 rows and 5 columns (individuals per row). Figure 2 shows how individuals are positioned in the orchard.

Example 2

Creation of a single-tenant seed orchard

In the following example, the orchard has a single tenant. It comprises 71 clones represented by varying numbers of ramets. The required minimum spacing between two ramets of the same clone is equal to three times the distance between adjacent orthogonal positions. To favor outcrossing, we have selected 3 as the number of times specific clones can be neighbors, for example clones 10 and 11. The orchard is composed of 18 rows and 20 columns, for a total of 360 ramets. To facilitate identification of clones, they were assigned numbers to permit generation of printouts like the one reproduced on pages 12 and 13. The layout of the single-tenant seed orchard is shown in Figure 3.

```
 @MIMOSOL
>;
>; THE MIMOSOL PROGRAM IS USED TO CREATE SEED ORCHARDS
>; WITH 2 TO 4 HIERARCHICAL LEVELS
>;
>; 1- SEED ORCHARD WITH 2 LEVELS
>; 2- SEED ORCHARD WITH 3 LEVELS
>; 3- SEED ORCHARD WITH 4 LEVELS
>;
>* PLEASE SELECT NUMBER OF LEVELS ? [S]: 2
>RUN ORC2
GIVE A NUMBER BETWEEN Ø AND 32767 :
15254
WHAT IS THE STRUCTURE OF THE SEED ORCHARD
USE A COMMA AS SEPARATOR :
FAMILIES,SEEDLINGS
WHAT IS THE NUMBER OF : FAMILIES
5Ø
WHAT IS THE NUMBER OF : SEEDLINGS
4
IS THE MINIMUM SPACING THE SAME FOR ALL  " FAMIL "?
YES
WHAT IS THIS SPACING ?
3.Ø
DO YOU WISH TO FAVOR OUTCROSSING BY CONTROLLING NEIGHBORHOOD ?
NO
GIVE THE NUMBER OF ROWS AND COLUMNS IN THE SEED ORCHARD :
2Ø 1Ø
WHAT IS THE NUMBER OF ROWS PER BLOCK AND THE DISTANCE BETWEEN " SEEDL " :
1Ø 5.Ø
WHAT PERCENTAGE OF THE INDIVIDUALS MAKING UP A BLOCK
UST BE POSITIONED BEFORE SPACING CONSTRAINTS
MAY BE NEGLECTED ?
95
```


F 24 F 31 F 49 F 18 F 28
F 22 F 36 F 40 F 7 F 50
F 43 F 27 F 2 F 37 F 8
F 5 F 33 F 35 F 41 F 39
F 45 F 34 F 32 F 48 F 6
2
F 23 F 16 F 9 F 11 F 26
F 25 F 38 F 29 F 15 F 21
F 42 F 17 F 19 F 46 F 30
F 20 F 1 F 4 F 10 F 3
F 12 F 47 F 44 F 14 F 13
F 37 F 10 F 43 F 17 F 49
F 36 F 19 F 31 F 32 F 38
F 7 F 24 F 5 F 18 F 47
F 8 F 30 F 21 F 42 F 44
F 6 F 20 F 34 F 23 F 50
4
F 4 F 16 F 25 F 12 F 35
F 46 F 13 F 41 F 11 F 1
F 29 F 27 F 26 F 40 F 39
F 48 F 33 F 14 F 22 F 9
F 2 F 28 F 15 F 45 F 3

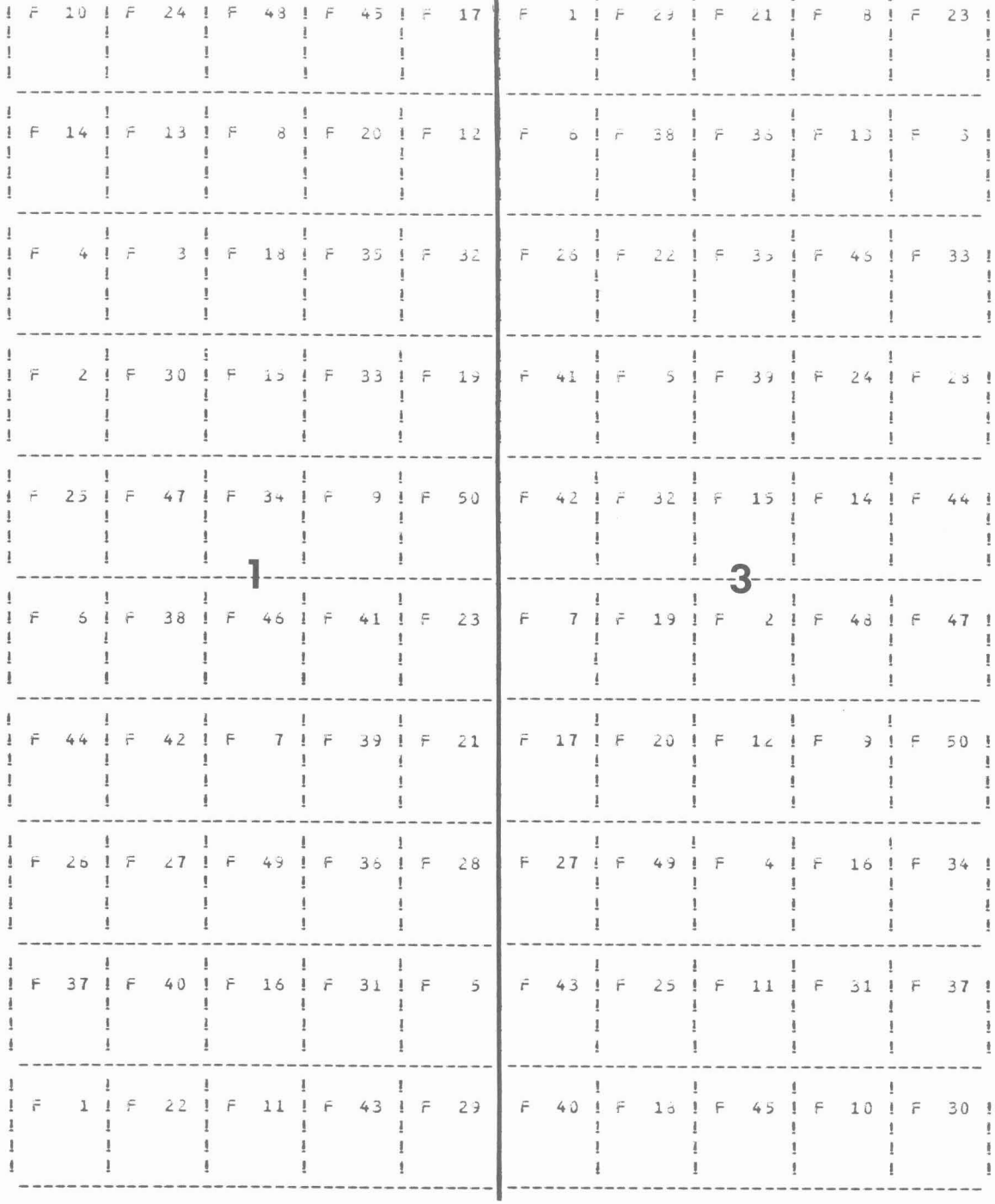


Figure 2. Schematic drawing of block layout within the orchard.

```
 @MIMOSOL
>;
>; THE MIMOSOL PROGRAM IS USED TO CREATE SEED ORCHARDS
>; WITH 2 TO 4 HIERARCHICAL LEVELS
>;
>; 1- SEED ORCHARD WITH 2 LEVELS
>; 2- SEED ORCHARD WITH 3 LEVELS
>; 3- SEED ORCHARD WITH 4 LEVELS
>;
>* PLEASE SELECT NUMBER OF LEVELS ? [S]: 3
>RUN ORC3
GIVE A NUMBER BETWEEN Ø AND 32767 :
6712
WHAT IS THE STRUCTURE OF THE SEED ORCHARD
USE A COMMA AS SEPARATOR :
CLONES,RAMETS,BLOCK
WHAT IS THE NUMBER OF : CLONES
71
IS THE NUMBER OF " RAMET " THE SAME FOR ALL " CLONE "
NO
WHAT IS THE NUMBER OF " RAMET " IN " CLONE "     1
6
WHAT IS THE NUMBER OF " RAMET " IN " CLONE "     2
1
WHAT IS THE NUMBER OF " RAMET " IN " CLONE "     3
3
WHAT IS THE NUMBER OF " RAMET " IN " CLONE "     4
4
WHAT IS THE NUMBER OF " RAMET " IN " CLONE "     5
6
WHAT IS THE NUMBER OF " RAMET " IN " CLONE "     6
6
WHAT IS THE NUMBER OF " RAMET " IN " CLONE "     7
1
WHAT IS THE NUMBER OF " RAMET " IN " CLONE "     8
6
WHAT IS THE NUMBER OF " RAMET " IN " CLONE "     9
3
WHAT IS THE NUMBER OF " RAMET " IN " CLONE "    1Ø
6
WHAT IS THE NUMBER OF " RAMET " IN " CLONE "    11
6
WHAT IS THE NUMBER OF " RAMET " IN " CLONE "    12
2
WHAT IS THE NUMBER OF " RAMET " IN " CLONE "    13
5
WHAT IS THE NUMBER OF " RAMET " IN " CLONE "    14
6
WHAT IS THE NUMBER OF " RAMET " IN " CLONE "    15
6
WHAT IS THE NUMBER OF " RAMET " IN " CLONE "    16
2
WHAT IS THE NUMBER OF " RAMET " IN " CLONE "    17
6
```

```
WHAT IS THE NUMBER OF " RAMET " IN " CLONE "   69
6
WHAT IS THE NUMBER OF " RAMET " IN " CLONE "   70
5
WHAT IS THE NUMBER OF " RAMET " IN " CLONE "   71
6
DATA IN MEMORY :
      6      1      3      4      6      6      1      6      3      6
      6      2      5      6      6      2      6      6      2      1
      6      4      3      4      1      6      6      6      6      6
      6      6      6      6      6      5      6      6      6      6
      6      4      6      6      6      6      6      6      6      6
      1      6      6      5      6      6      6      6      6      6
      6      3      6      5      6      6      6      2      6      5
      6
IS THIS OK ?
YES
IS THE MINIMUM SPACING THE SAME FOR ALL  " CLONE " ?
YES
WHAT IS THIS SPACING ?
3.Ø
WHAT IS THE NUMBER OF : BLOCK
1
IS THE MINIMUM SPACING THE SAME FOR ALL  " RAMET " ?
YES
WHAT IS THIS SPACING ?
3.Ø
DO YOU WISH TO POSITION SOME " CLONE " ON PRIORITY BASIS
NO
DO YOU WISH  TO FAVOR OUTCROSSING
BY CONTROLLING NEIGHBORHOOD ?
YES
WHAT IS THE MAXIMUM NUMBER OF TIMES THAT 2 INDIVIDUALS
OF GIVEN PEDIGREES CAN BE NEIGHBORS ?
3
GIVE THE NUMBER OF ROWS AND COLUMNS IN THE SEED ORCHARD :
18 2Ø
WHAT IS THE NUMBER OF ROWS PER BLOCK AND THE DISTANCE BETWEEN " RAMET " :
18 5.2
WHAT PERCENTAGE OF THE INDIVIDUALS MAKING UP A BLOCK
MUST BE POSITIONED BEFORE SPACING CONSTRAINTS
MAY BE NEGLECTED ?
1ØØ
```

BLOC : 1

14-	13-	13-	13-	14-	14-	13-	14-	14-	13-	14-	14-	14-	13-	14-	14-	14-	13-	14-	14-
387	797	769	807	305	474	789	310	378	855	347	308	471	806	342	320	382	833	487	313
14-	14-	14-	13-	14-	13-	14-	13-	14-	13-	14-	13-	14-	14-	14-	14-	14-	14-	14-	13-
349	312	468	824	342	817	393	820	390	817	380	774	502	337	305	302	310	393	312	809
14-	14-	14-	14-	13-	14-	14-	14-	14-	14-	14-	13-	14-	13-	14-	13-	14-	14-	14-	14-
488	364	496	325	855	381	480	355	471	500	377	820	487	797	327	771	308	471	502	314
14-	14-	14-	14-	13-	13-	13-	14-	14-	14-	14-	14-	14-	14-	14-	14-	14-	14-	13-	14-
321	394	393	487	841	822	833	347	321	339	349	302	387	474	500	322	344	321	816	347
13-	14-	14-	14-	13-	14-	14-	13-	14-	14-	13-	13-	14-	14-	14-	13-	14-	14-	13-	13-
833	314	347	327	842	377	394	797	310	320	842	783	378	320	335	817	487	474	472	837
13-	13-	14-	14-	14-	14-	14-	14-	14-	13-	13-	14-	13-	14-	13-	14-	13-	14-	14-	14-
837	809	307	472	344	390	468	335	465	771	784	337	769	384	472	393	822	472	496	308
14-	14-	13-	13-	14-	13-	13-	14-	14-	14-	13-	14-	14-	14-	14-	14-	13-	14-	14-	14-
320	333	783	806	474	809	472	381	384	342	817	322	313	381	312	325	774	384	468	312
14-	14-	14-	14-	14-	14-	14-	13-	13-	14-	14-	14-	14-	14-	13-	14-	13-	14-	14-	14-
308	465	468	339	322	382	301	842	837	480	487	496	364	347	820	302	783	471	313	305
14-	14-	14-	14-	13-	14-	14-	13-	13-	14-	14-	14-	14-	14-	14-	13-	14-	14-	14-	13-
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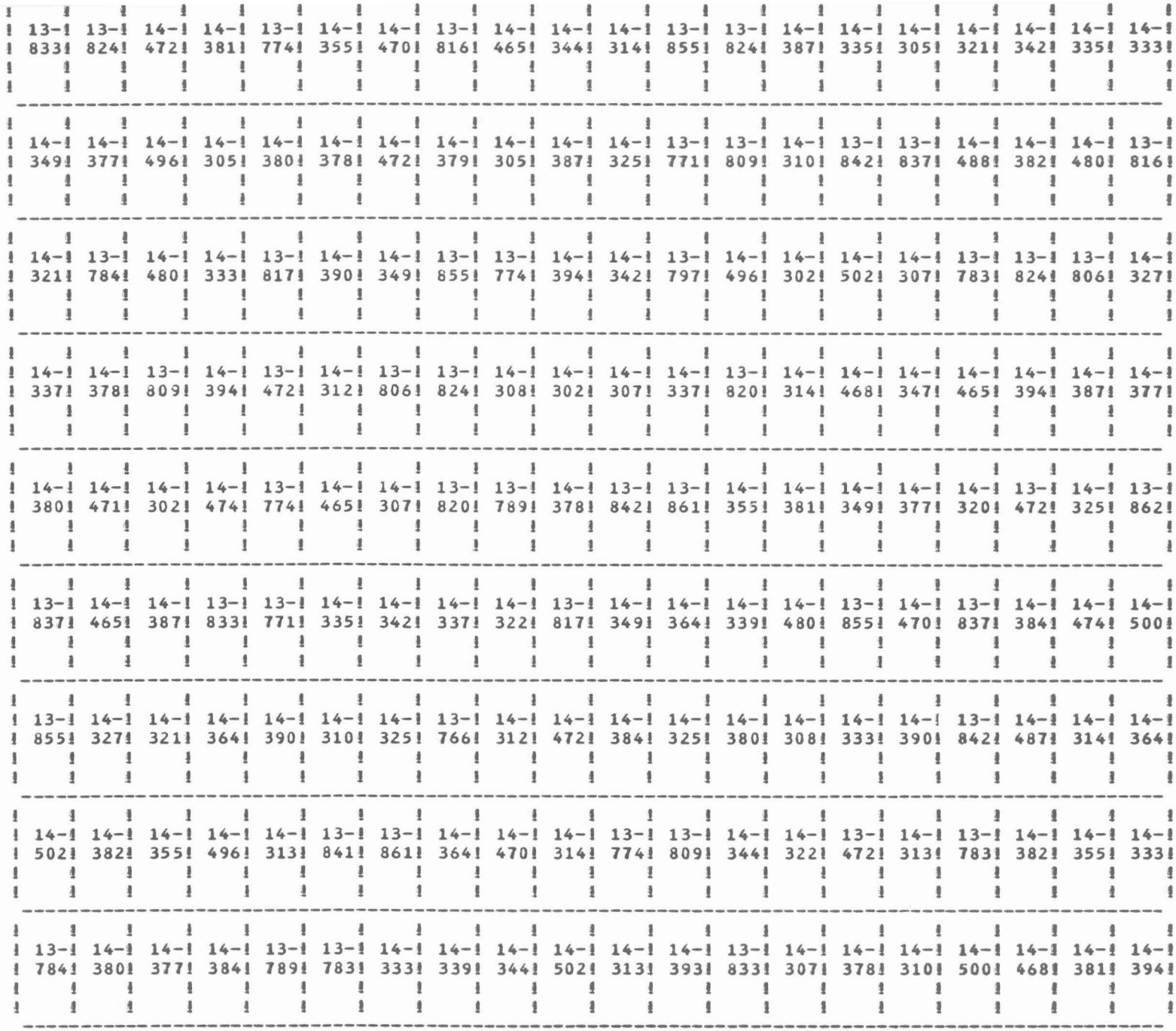

Figure 3. The layout of the single-tenant seed orchard.

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