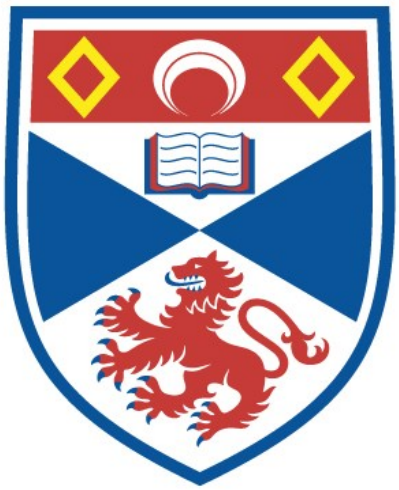
University of St Andrews



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APPLICATIONS OF COMPUTER GRAPHICS

TO

PLANT SCIENCE

by

Colin R. Norton B.Sc,M.Sc,Ph.D,M.I.Biol.

A thesis submitted to The University of St.Andrews
for the degree of Master of Science.
Department of Computational Science, 1979.

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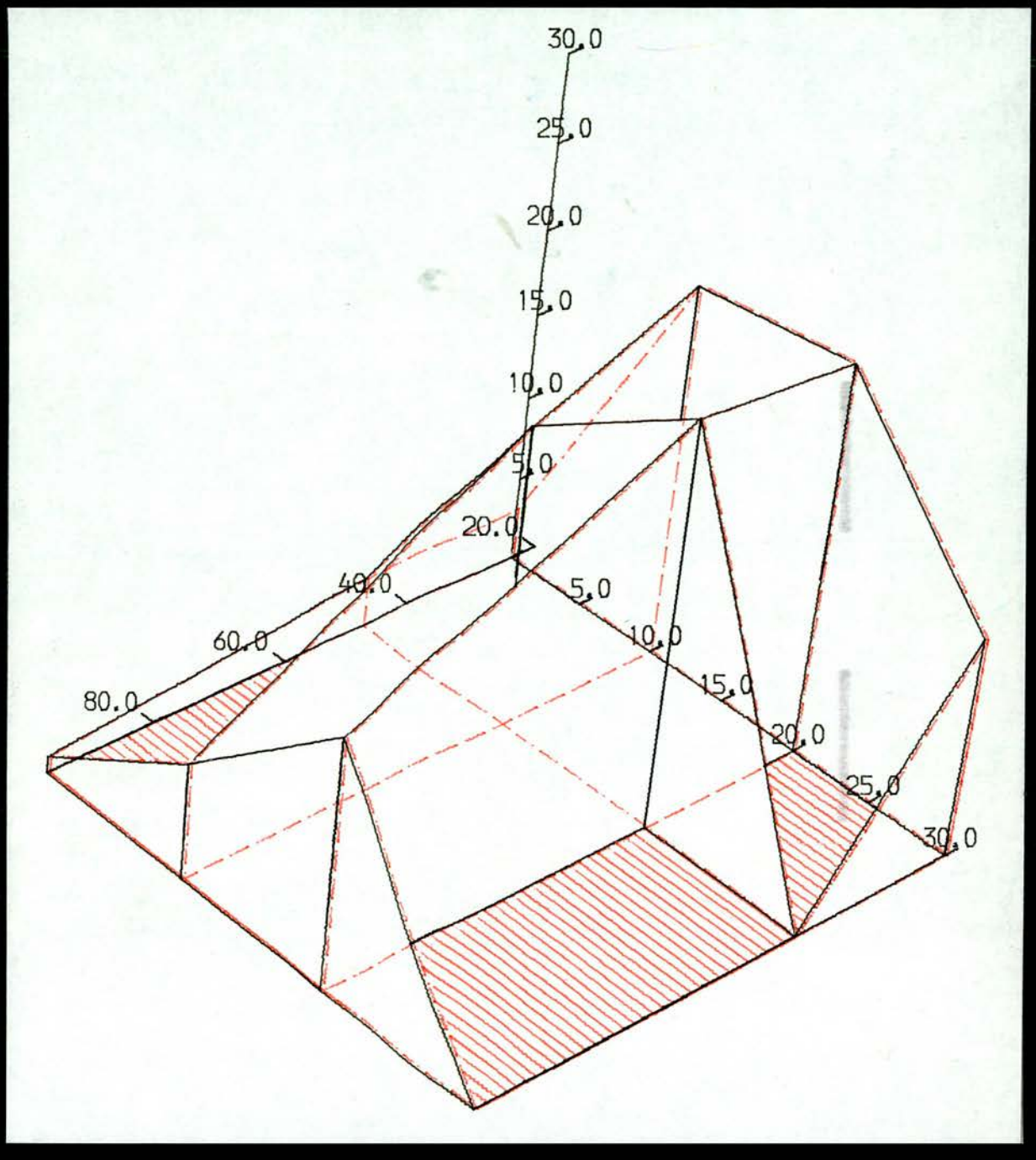
Frontispiece

The Three-dimensional Plotting of Data


30.0
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30.0

DECLARATION

I hereby declare that the following thesis is based upon work done by me, that the thesis is my own composition and that it has not previously been presented for a higher degree.

The research was carried out in the Department of Computational Science of The University of St.Andrews under the supervision of Professor Cole.

CERTIFICATE

I hereby certify that Colin R. Norton has been engaged upon research for a minimum of three terms under my supervision and that he is qualified to submit the accompanying thesis in application for the degree of Master of Science.

ACKNOWLEDGEMENTS

Generous thanks are given to the following three people :-

1. Professor A.J. Cole for his enthusiastic tutoring, friendship and his generous help in supervising this project;

2. Professor R.M. Cormack for stimulating an interest in statistical/computational techniques and his continued support of my work;

3. John Henderson for a great many hours of help debugging programs and solving other hardware and software problems.

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SECTION I

THEORETICAL CONSIDERATIONS

CHAPTER 1

INTRODUCTION

1.1 Biological Research

It has recently been suggested that more has been done for experimental biology by R.A.Fisher (e.g. Fisher, 1925) than by any other person this century (Heath,1976). This is remarkable for Fisher's contribution has been in the field of data interpretation.

A brief outline of the types of biological experimentation will give an insight into the data interpretation problem.

1.2 Types of Biological Science

a) Observational Science

Early biologists favoured observational science where an event was observed in the 'wild' or 'natural' population. A hypothesis is then constituted on which a prediction can be based. Further observations then follow, which may support or disprove the hypothesis. Additional literature review may then be used as further evidence.

In observational science there are experiments, which are provided by nature. They are therefore not designed to test a specific hypothesis and are rarely conclusive.

b) Experimental Science

This heading encompasses most current biological research work. The common link here is the observation of events in the 'natural' population which itself stimulates interest in the problem and provides a basis for constructing a hypothesis. This may then be subjected to rigorous analysis.

1.3 Problems of Data Interpretation

Rigorous analyses of data often do not immediately impart their critical information to the biologist. There is a particularly strong argument in favour of a visual representation of data for many applications. This should not replace but complement formal analysis.

1.4 Why a Graphics Package?

Computer use by different departments at St.Andrews University confirms that the exact sciences account for most computer time used (Tables 1.1 and 1.2). Of the experimental sciences, biologists use little central processor unit time. This is not a result of non-applicability to biology, but is probably in part due to lack of knowledge in computational technique. Few biologists are familiar with a programming language.

In biological research a number of specific forms of analysis or data presentation are frequently

used, the majority of which can be provided as pre-programmed packages. Packages of this type are appealing to the biologist since the data is not transformed in any way.

This thesis describes two packages which have been specifically developed with the above points in mind. In the context of St.Andrews University, these packages fit in with the available software as pre-programmed data presentation packages.

At present, there is a statistical package available, which is user interactive via a video terminal (RAX statistical system). This does not extend to a video-graphics system; graphics may be produced using an off-line plotter for which there are a number of software routines (or plotting commands). It is necessary to be familiar with a programming language to use this facility (A User's Guide to Ghost; Graph Plotting in Algol W).

A non-language package is not available locally although it would provide a positive contribution to biological sciences.

The current packages are designed to yield output to illustrate biological data for scientific articles.

Table 1.1

Percentage use of 360/44 computer systems by department (at St.Andrews University) 1976-1977

(Extract from University of St.Andrews Computing Laboratory Annual Report 1976-1977)

DEPARTMENT	MFT	RAX	O.S.	TOTAL
SCIENCE FACULTY				
Astronomy	16.32	4.70	0.27	8.49
Biochemistry	0.06	0.20	-	0.06
Botany	0.01	0.04	-	0.01
Chemistry	9.36	4.97	96.44	42.17
Computational Science	9.23	56.44	0.08	12.51
Geography	0.38	0.22	-	0.21
Geology	0.55	1.40	-	0.46
Mathematics (Applied)	14.49	7.30	-	7.89
Mathematics (Pure)	0.86	2.03	-	0.70
Mathematics (Statistics)	3.59	1.48	-	1.91
Physics	3.74	1.55	-	1.99
Theoretical Physics	5.18	2.32	-	2.78
Physiology	0.68	0.23	-	0.36
Psychology	-	0.23	-	0.03
Zoology	-	0.03	-	0.00
	64.45	83.41	96.77	79.57
ARTS FACULTY				
Archaeology	0.02	0.02	-	0.01
Economics	0.10	0.72	-	0.15
Maritime Archaeology	0.02	-	-	0.01
Mediaeval History	0.46	0.00	-	0.22
Moral Philosophy	0.28	0.44	-	0.20
	0.88	1.18	-	0.59
SERVICES				
Computing Laboratory	12.08	13.55	3.21	8.89
Gatty Marine	0.46	0.45	-	0.28
Information Systems	19.35	1.56	-	0.36
Non ISU Administration	0.15	0.09	-	0.08
Library	2.61	0.02	-	1.24
	34.65	15.67	3.21	19.85

Table 1.2

Percentage use of terminals by department (at St.Andrews University) 1976-1977

(Extract from University of St.Andrews Computing Laboratory Annual Report 1976-1977)

DEPARTMENT	Jobs run from terminals	Terminal connect time	Costed units of all terminal jobs
SCIENCE FACULTY			
Astronomy	3.32	3.61	2.91
Biochemistry	0.24	0.59	0.26
Botany	0.03	0.09	0.05
Chemistry	6.19	8.52	5.55
Computational Science	62.08	59.98	61.76
Geography	0.17	0.34	0.18
Geology	0.85	1.60	1.28
Mathematics (Applied)	4.77	4.26	7.84
Mathematics (Pure)	1.91	2.12	2.24
Mathematics (Statistics)	0.57	1.63	1.15
Physics	2.26	1.96	1.69
Theoretical Physics	3.21	2.59	2.75
Physiology	0.35	0.37	0.26
Psychology	0.10	0.58	0.32
Zoology	0.05	0.04	0.04
ARTS FACULTY			
Archaeology	0.00	0.00	0.00
Economics	0.46	1.32	0.82
Maritime Archaeology	-	-	-
Mediaeval History	-	-	-
Moral Philosophy	0.62	0.44	0.43
SERVICES			
Computing Laboratory	11.18	7.77	8.47
Gatty Marine	0.50	0.57	0.55
Information Systems	1.12	1.60	1.44
Non ISU Administration	0.02	0.01	0.01
Library	0.00	0.02	0.01

CHAPTER 2

PRELIMINARY CONSIDERATIONS IN A GRAPHICS PACKAGE

2.1 Other Packages Available

A large number of statistical packages have been developed for applications use. An explanatory classification follows -

a) Subroutine sets or programs for use by the advanced programmer

b) Data manipulation, editing or storage programs

c) Statistical packages for the non-programmer.

Most packages are of the type described in a) (Schucany and Minton, 1972), while neither a) nor b) is relevant to the aims of this work. Comparatively few packages are available for the non-programmer especially to produce graphics (although some probably do exist which have not been documented).

Some of the more widely used pre-programmed packages include

MAQUEST - a system for processing questionaires,

STAT 3600 - a general package for statistics,

OMNITAB II - numerical analysis, statistical analysis,

STAT SYSTEM/1130 - factorial analysis

STAT-PACK - statistics, especially regression,

SPSS - very large collection of statistics software (27,000 lines of code) includes descriptive

statistics, correlation, analysis of variance, scatter diagrams, and is very widely used in biological research.

Usually, these packages are accessed using prepared software (punched cards, magnetic or paper tape etc.). More packages are now becoming available which are interactive time sharing systems using a video terminal. Developments in this area are likely to increase although full core capability and hard copy are often required for complex plots.

No package has been found by the author which solves similar problems to those tackled here, but the locally available RAX statistical system is a pre-programmed package capable of producing

1. scatter diagrams
2. histograms
3. line plots

as well as a number of other non-graphical analyses.

2.2 A Graphics Package for Biology

Factorial analysis of appropriately designed experiments is one of the most valuable tools for data evaluation in horticulture, as well as other branches of biology. However, numerous attempts have been made to represent data in a graphical manner but tedious manual plotting has been necessary.

Examination of Figures 2.1 to 2.5 using a hand lens suggests that none of these pictures was computer drawn since the lines are continuous rather than finely broken.

The most significant contribution in a package of this type would be the ability to plot and view three-dimensional models of data. Also, the facility for standard two-dimensional graphs may be included since the majority of data sets may be represented in this way.

2.3 Illustrations taken from the literature

Figures 2.1 to 2.5 are representative examples of biological illustration taken from the literature. These were studied in order to note desirable features for inclusion in the current package. (However, the biological significance of these diagrams may not be apparent out of context.)

Figure 2.1

Three-dimensional illustration of a 4x4 data matrix

(taken from Street, H.E., 1969)

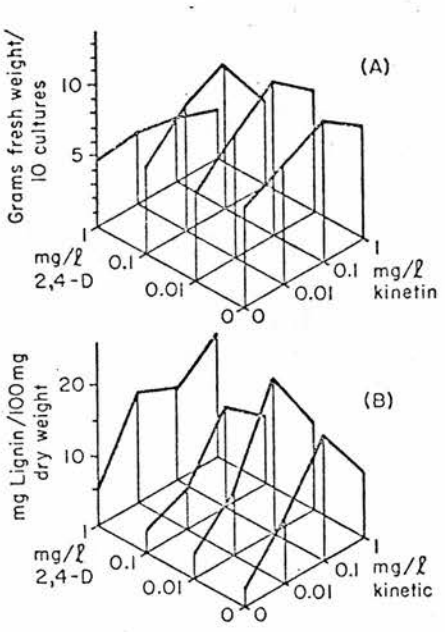


Figure 2.2

Three-dimensional representation of a 6x7 matrix with non-linear axis intervals

(from Das, Patau and Skoog, 1956)

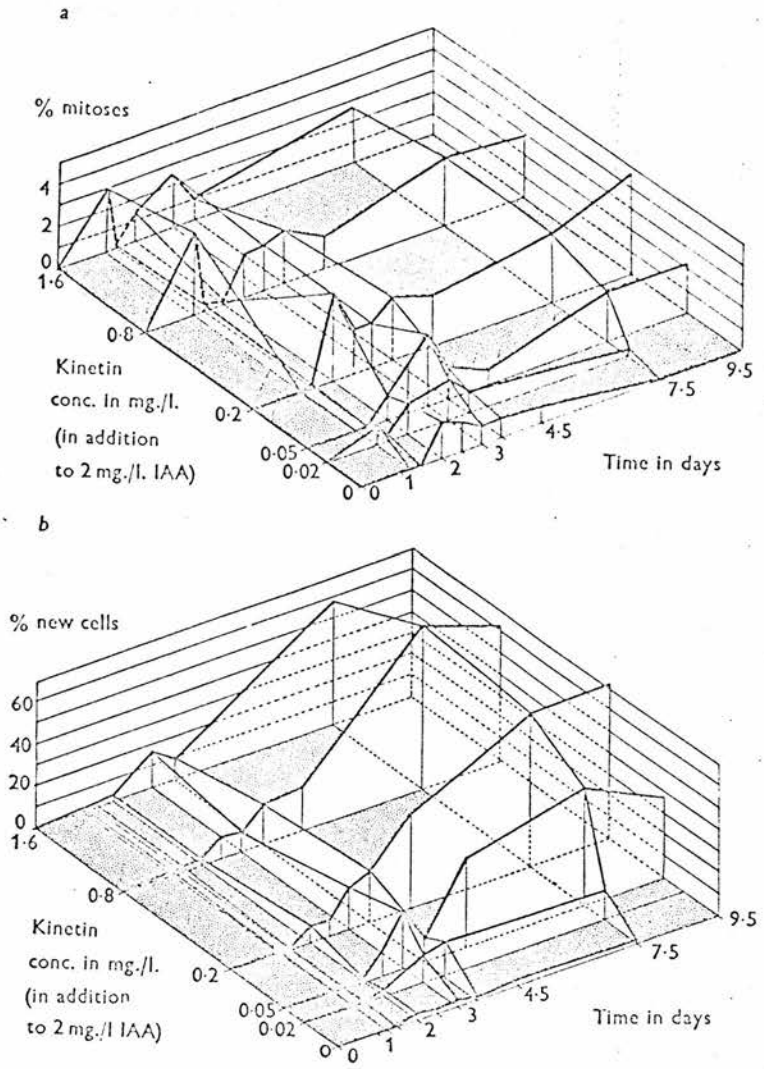


Figure 2.3

A 6x7 data matrix using linear scaling

(from Gray, 1977)

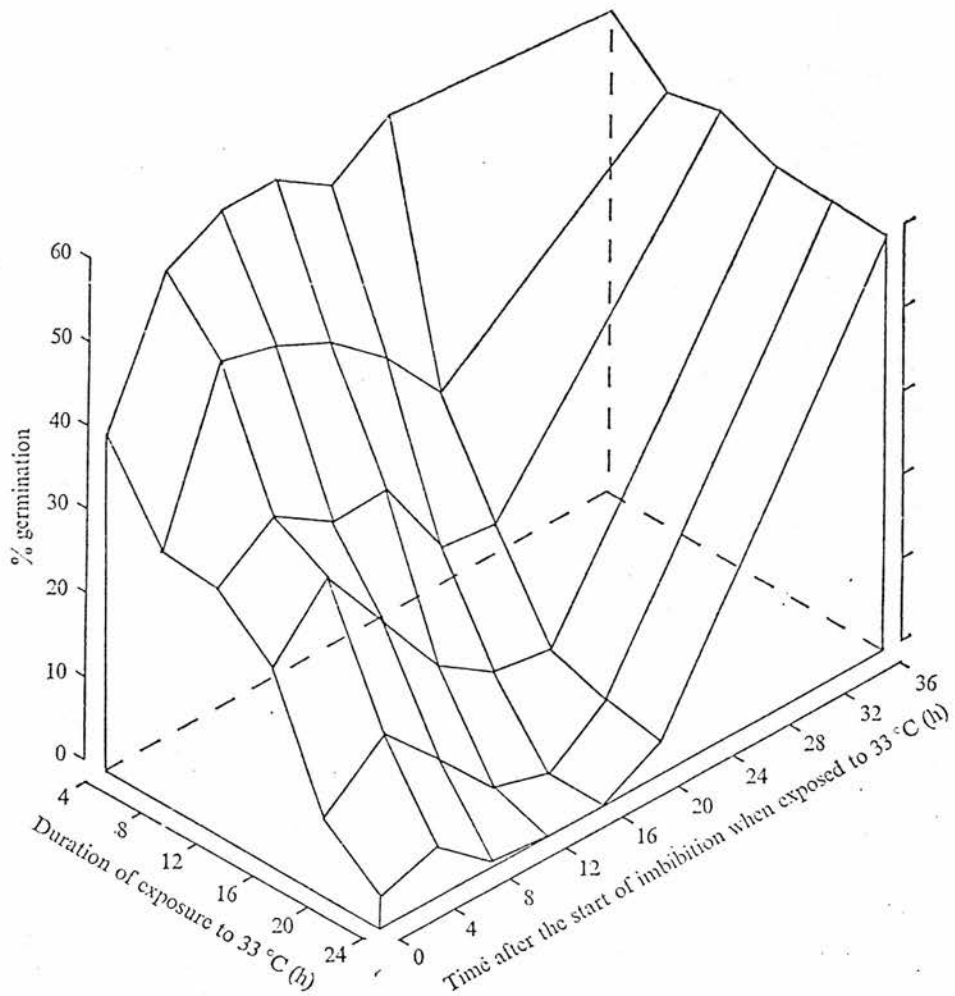


Figure 2.4

A regular 4x4 data grid in three dimensions

(from Wareing and Phillips, 1971)

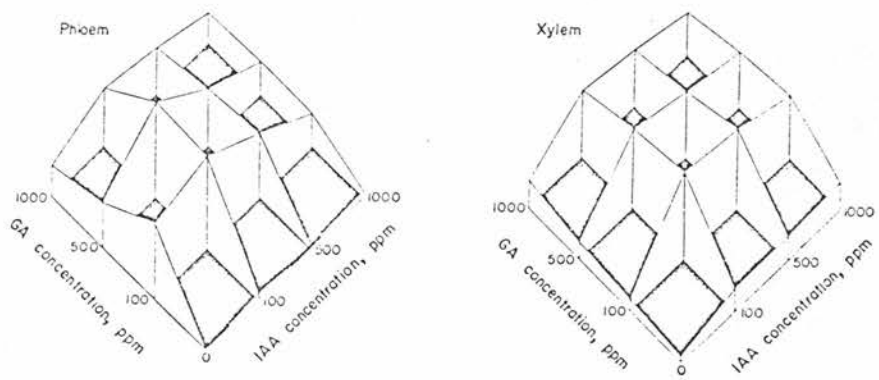
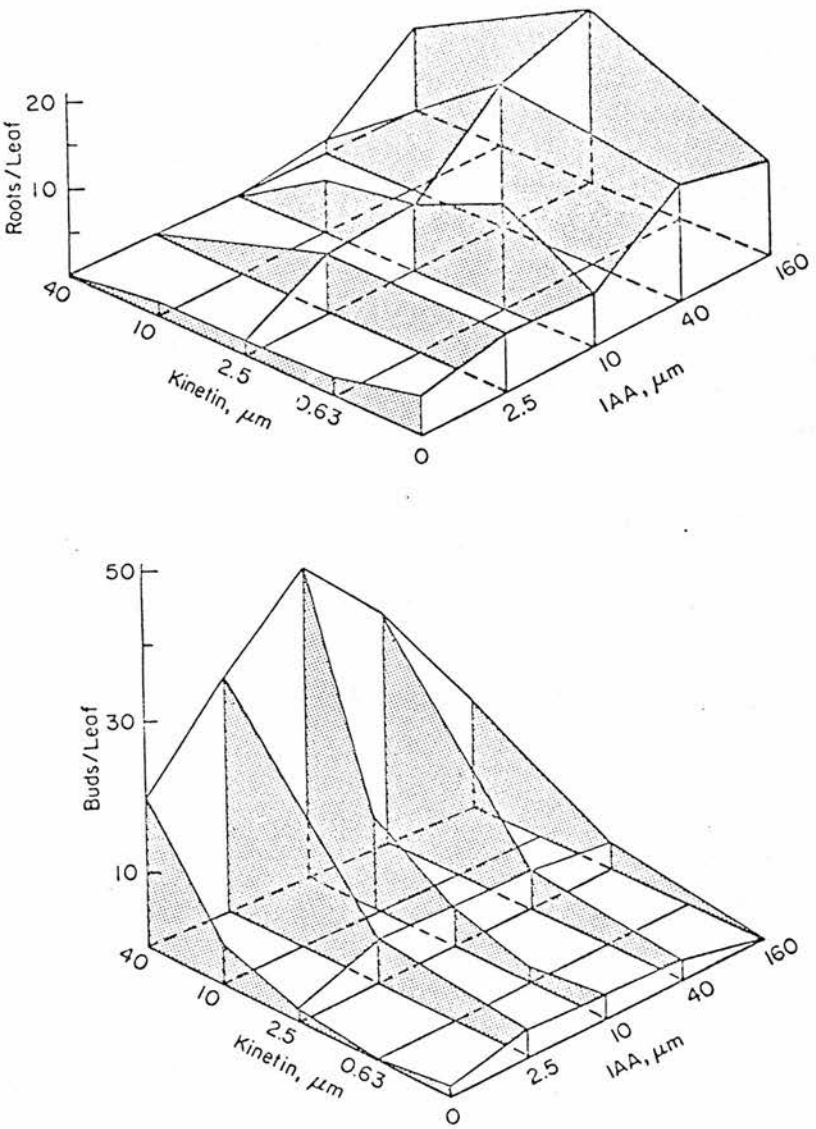


Figure 2.5

Logarithmic data transformation of a 5x5 data grid

(from Hartmann and Kester, 1968)



CHAPTER 3

PREPARATION OF THE PACKAGE

3.1 Plotting Facilities Available Locally

The pre-programmed package currently presented has been implemented as an extension of the facilities available at St.Andrews University. A brief resumé of these facilities follows in order to isolate the contribution of this package in perspective.
(User manuals are included in Sections II and III of this thesis.)

3.2 Hardware

An abbreviated list of relevant hardware available follows :-

IBM 360/44 computer

PLOTTER (The Computer Instrumentation Ltd. 6011 Off-line digital plotter)

The plotter is of the "delta mode" type and is capable of :-

1. framing and scaling
2. point to point plotting
3. character plotting
4. geometric figure plotting
5. pen changes (choice of two)
6. user override of "delta mode" facility

3.3 Software

For comparative purposes, other plotting software available locally is described.

3.31 The Playtime System

This system was developed within the Department of Computational Science at St.Andrews and is written in Algol W for use with the 6011 plotter described above. A picture is declared and described within a specially structured block. Within this description the following facilities are available :-

1. Definition of ranges for axes
2. Move to a point or join to a point
3. Plot or print the picture
4. Choice of execution flow summary
5. Insert a copy or offset a copy
6. Specified rotation of output (whole or part picture)
7. Mirror image reflection
8. Text plotting
9. Drawing of borders, graticules, axes, polygons
10. Selection of pen, broken or full lines
11. Superimposition
12. Curve drawing

(Graph Plotting in Algol W - The Playtime System, 1975)

The Playtime System incorporates several new features. For example, it is written in the context of Algol W, copying and offset copying are incorporated and

pictures may be rotated or given as a mirror image reflection.

3.32 The Graffiti Plotting System

Again, this system was developed in the same department as a logical development of the Algol W Playtime system. However, several important additions have been incorporated. The most important of these are :-

1. Three-dimensional plotting
2. The use of indefinite dimensions for logical space picture description, so that a box may be specified to plot only part of a three-dimensional picture
3. Hidden line plots

(The Graffiti Plotting System, 1977)

In use, both the Playtime and Graffiti plotting systems require the user to program for his application using the language Algol W.

3.33 Ghost

The Ghost system at St.Andrews is based upon the U.K.A.E.A. Culham system called Ghost (1) (Larkin, 1967). The system comprises a number of plotting commands as subroutines which may be called from other programs.

The main features allow for :-

1. Diagnostic routines
2. Plotter on/off

3. Pen choice
4. Frame advance and count
5. Choice of plotter space units and size
6. Choice of paper size
7. Choice of compression ratio
8. Point and join line drawing
9. Broken or full lines
10. Boxes and borders for plots
11. Histogram drawing
12. Plotting points
13. Curve drawing (various)
14. Circle, elipse, parabola, hyperbola, arc drawing
15. Rotation and expansion
16. Choice of character set, size, rotation, and location of characters
17. Character positioning
18. Number plotting
19. String plots
20. Graticule and axis drawing

In the case of this package, the user must program in Fortran IV to call each subroutine when a plotter command is required. Thus it is necessary to call subroutines for plotter turn-on, page sizes, character sizes, character sets etc. prior to point and join commands for line drawing.
(see also - A User's Guide to Ghost, 1973)

3.34 Extensions to Ghost

a) Line printer output of plots is now possible for rapid assesment of output but since character size variation, line drawing and accurate point plots are not possible, only rough plots are given. (Software Memo No.010 University of St.Andrews, Balch,1976).

b) Three-dimensional Plotting and Contouring. A set of subroutines has been added to the Ghost libraries for three-dimensional plotting. The subroutines allow for the following possibilities :-

1. Setting up three-dimensional space, centre and viewpoint of a three-dimensional object
2. Automatic scaling of three-dimensional space into two dimensions
3. Isometric and perspective plotting
4. Point, drawing, box, etc. but in three dimensions
5. Axis, graticule and grid drawing in three dimensions

(Software Memo No.009, Balch,1976)

c) Hidden Line Plotting.

This package has not hitherto been available. While it was written by Balch as an extension to Ghost, part of the present work involved the setting up of this package and editing a manual for it.

The main facilities are as follows :-

1. Definition of areas as window or opaque during plotting, i.e. subsequent areas will / will not plot over them
2. Definition of and ignoring areas when called

This is an extension to Ghost which allows the user to define areas of the plotter paper inside or outside of which the pen may not draw. There are at least two job steps using Hide. The first of these is the user's program containing the plotting commands. These do not write directly on to the plotting tape but write a simplified set of commands on to a disk. The next job step is the line hiding program which reads from the disk and calculates which lines to plot prior to writing instructions on to the plotter tape. (Hide - a line hiding package, 1979)

3.4 Software development for the present package

Sections II and III describe the use of two packages. The first (Section II)-'Grapha - A pre-programmed graphics package for the applied sciences'- is used for two-dimensional or three-dimensional graphical plots. Several special features have been introduced. The programs are entirely pre-programmed, so that it is only necessary to enter the data in the correct format (see User Manual Sections II and III)

in order to produce graphical output.

It is possible to fit a number of small plots into one page of output with or without spaces between plots. Several different types of plot may be produced in a single job run because the program has been designed to recycle without limit (other than user time limit). A wide choice of type of plot with various forms of text and annotation is possible e.g. multiple plots on one frame with labels for each plot appended below.

Most of the Ghost subroutines may be accessed in order to substitute values e.g. broken line mark space ratio, italics, page formats, character sizes.

The second package-'Hide - a package for three-dimensional graph plotting, including shading and hidden line calculation (a pre-programmed package)' - is similar in concept to the first package. This package allows for three-dimensional data plotting with hidden line omission and base shading (where visible from the viewpoint). Because of the size of this program and its higher C.P.U. time demands, it has been separated into a separate package. (Two-dimensional plots have been omitted from this package.)

In the development of these packages, a number of computational problems were encountered, the

solution for which is described in 3.41, 3.42 and 3.43.

3.41 Choice of programming language

Although programming using only the C.I.L. plotter commands (3.2) could have been used, the use of prepared packages avoids duplication of material. A choice between Algol W and Fortran based packages was therefore made.

It was thought desirable to program in Algol W, and therefore, packages based on this language should be more appropriate. However, Fortran (Ghost) commands were used for two reasons :-

1. the general flexibility of the Ghost packages available at St.Andrews
2. the Graffiti Plotting System (3.32) was not available until the greater part of this project was completed.

In order to use mixed language programming, the Fortran subroutines were made to behave like Algol W procedures. The number of Fortran Ghost routines could not exceed 32 because of system limitations, and therefore, several short Fortran programs were compiled external to the main program. Each of these external programs was given a Fortran subroutine name. For example, an externally compiled Fortran program called

SUBROUTINE SETUP (values for setup parameters)

could be accessed by the following declaration at the start of the main Algol W program -

```
Procedure plottersetup (values for setup parameters);
    Fortran "setup"
```

Where required in the program, a call -

```
plottersetup (values for setup parameters);
```

automatically invoked the external program.

The packages developed exceeded the full core capacity of the 360/44 Computer which necessitated a similar external compilation of several Algol W procedures, since program overlaying is not possible in Algol W.

3.42 System choice for the project (hardware)

The IBM 360/44 computer was used to prepare control tapes which could be plotted, off-line, at any time on the CIL plotter. As the plotter packages were only available through the 44MFT operating system (44MFT Guide to System Use,1976) and not through the RAX video terminal system, 44MFT has been used throughout, while the full core (rather than time sharing) requirement was necessary to avoid compiler overflow. (At least 186 K of the available 200 K is required.)

3.43 Some software refinements used in the program

a) Level of access to program (see Sections II and III for method use of package)

In order to write a program which is both simple

to use and versatile for more advanced applications, several conditional steps have been incorporated into the packages. The conditions, and thus the variables for user entry, are set using a readcard statement. Readcard reads a single card (80 characters) as a string. An example could read as follows :-

```
begin
    Readcard (sentence);
    if sentence = "help" then predeclared variables
    else readon (A, B, C, D, E)
end;
```

In this way, data entry can be limited by minimal requests for user information. If the user enters "two-dimensional help", for example, a number of parameters will be set automatically. In this way -

1. one data set for analysis will be assumed
2. a two-dimensional plot is specified
3. titles will be omitted
4. axis lengths will be based on minimum and maximum data values
5. picture size will be set to a pre-determined value (suitable for A4 size paper)

Alternatively, if the single word "help" is entered on the first card, then greater user manipulation is allowed, with a number of parameters still being pre-set.

Table 3.1a

Plot type table for package Grapha (Section II)

2.1 two dimensional graph

2.2 two dimensional graph with titles overlaid

2.3 two dimensional graph with sub-titles (at foot of page of graphs)

2.4 two dimensional graph with axes (large markings) around the edge of the page only and titles

2.21 or 2.41 as for 2.2 or 2.4 but titles are overlaid on graph in such a manner that overlay of the plot is minimised

****

3.1 three dimensional graph

3.2 three dimensional graph with titles overlaid

3.3 three dimensional graph with sub-titles at foot of page

3.4 three dimensional graph with titles overlaid and large axis markings

****

4.1 three dimensional graph with dotted base lines

4.2 three dimensional graph with dotted base lines and title

4.3 Three dimensional graph with dotted base lines and subtitles

4.4 three dimensional graph with dotted base lines and titles with large axis markings

****

Table 3.1a continued

5.1 three dimensional graphs produced as stereo pairs

5.2 three dimensional graphs produced as stereo pairs with titles

5.3 three dimensional graphs produced as stereo pairs with sub-titles

5.4 three dimensional graphs produced as stereo pairs with titles and large axis markings

****

Table 3.1b

Plot type table for package Hide (Section III)

6.1 three dimensional graph with hidden lines omitted

6.2 three dimensional graph with hidden lines omitted with titles

6.3 three dimensional graph with hidden lines omitted with sub-titles

6.4 three dimensional graph with hidden lines omitted and including titles and large axis markings

****

7.1 three dimensional graph with hidden lines dotted

7.2 three dimensional graph with hidden lines dotted and titles

7.3 three dimensional graph with hidden lines dotted and sub-titles

7.4 three dimensional graph with hidden lines dotted and titles and large axis markings

****

8.1 three dimensional graph with hidden lines omitted and base shaded

8.2 three dimensional graph with hidden lines omitted, base shaded and titles

8.3 three dimensional graph with hidden lines omitted, base shaded and sub-titles

Table 3.1b continued

8.4 three dimensional graph with hidden lines omitted, base shaded, title and large axis markings

****

9.1 to 11.3 similar to 6.1 to 8.3 but a stereo option is given

****

12.1 to 17.3 similar to 6.1 to 12.3 but the whole of the base of the figure is shaded regardless of viewpoint

****

If a blank card is entered at this point, then maximum user manipulation is possible.

b) Plot and title type selection

To simplify data entry, the type of plot chosen has been given a numeric value (not necessary for the user to enter in all cases, see Sections II and III). This numeric value indicates both the type of plot and the type of title to be given. These are tabulated in Tables 3.1a and 3.1b to illustrate the possibilities using the packages. Section II covers options 2.1 to 5.4 in this table while Section III covers options 6.1 to 17.3.

For simple plots, the plot type is pre-programmed into the package and will not need to be selected by the user (see User Manuals Sections II and III).

As an example of plot type, 4.2 (a three-dimensional graph with dotted base lines and a title) requires a program of the type -

```
if plotype>=2 and plotype<3 then
    begin  comment this block sets up values
           for arrays etc. for 2D plots;
           :
    end
else
    if plotype>=3 then
        begin  comment 3D bounds set up;
               :
        end;
```

```
        .
        .
        .
    case ((round (plotype))-2) of
            begin comment logical variable for 3D type
                  :
            end;  :
        .
        .
        .
    titletype := round ((plotype-(truncate(plotype)))*10);
    if titletype>=0 and titletype<=3 then
            begin comment logical variables assigned
                  for titles
                  :
            end;
```

c) Graph title location

A further programming refinement has been introduced for two-dimensional plots. The title may be overwritten on to the graph, or appended at the base of a page of graphs. However, an option (integrated title) when specified, scans graph data values once to the left and once to the right, to find both the smallest and the largest data values :-

```
maxremembered := 1;
minremembered := p;
comment p = last value in data array;
for k := 2 until p do
if C (1,maxremembered)< C (1,K) then
```

```
C (1,maxremembered) := C (1,K);
for K := p-1 step -1 until 1 do
if C (1,minremembered)> C (1,K) then
C (1,minremembered) := C (1,K);
comment array C contains data values for 2D plot
-restricted to one dimensional array;
```

Thus comparison of these values with their limits (axis minimum and maximum values) selects the larger interval for title location.

d) Array declarations

A further programming problem arose in the declaration of different numbers and sizes of arrays for two-dimensional or three-dimensional plots within the same program as it was necessary to read all data values into arrays whether for two or three dimensional plotting. To make the arrays in scope, for the plotting routines, the declarations have been made identical for two and three dimensional plots. An initial value for the number of points and the number of graphs is read in to define these arrays.

If arrays are declared -

```
real array A (1::px + 2);
real array B (1::py + 2);
real array C (1::px + 2, 1::py +2);
```

then for two-dimensional arrays where p = number of points

if px := -1

and py := p-2

then we have

real array A (1::1); - no array required, no space allocated

real array B (1::p); - array for x axis values (horizontal)

real array C (1::1, 1::p); - one dimensional array for y values (vertical axis)

For three-dimensional arrays where px := number of points on x axis (horizontal axis 1) and py := number of points on y axis (horizontal axis 2), we have

real array A (1::px + 2); - array for x axis intervals with two extra memory locations for base values to facilitate plotting (base values usually = 0 or bottom of solid object).

real array B (1::py + 2); - as above but for y axis

real array C (1::px + 2, 1::py + 2); - array with two dimensions for all data values (values for top plane of solid object)

In this way, a single array declaration will suffice for the whole package.

e) Sequential plotting of planes for hidden line calculation

The method used for hidden plane plots requires some clarification.

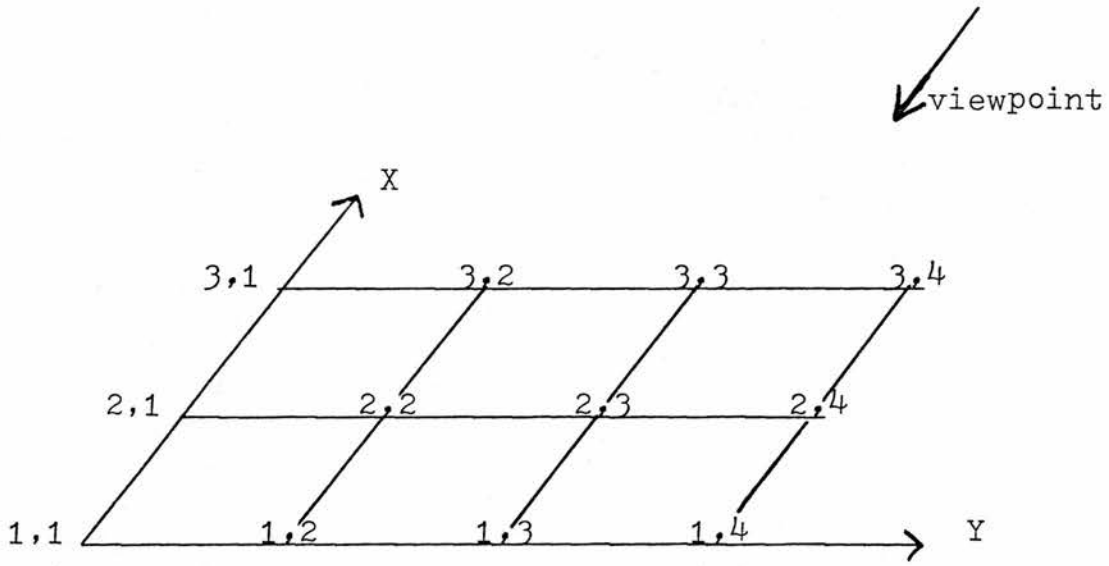
With respect to the viewpoint, each three-

dimensional plane was plotted one face at a time and then declared opaque to further plots. This was done as follows :-

```
Procedure opaqueplot;
    begin comment draws each face sequentially starting
          from viewpoint and declaring each area
          opaque in the same order. Assume a grid
          as in Figure 3.1 for plotting, where
          px = no points on x axis (3) and py = no
          points on y axis (4);
          for V := px + py step -1 until 2 do
          for I := 1 until px do
          for J := 1 until py do
          if I + J = V then
               begin comment check for y boundary
                     condition;
                     if J-1  0 then
                     face (I, J, I, J-1);
                     comment check for x boundary
                     condition;
                     if I-1  0 then
                     face (I, J, I-1, J);
                     comment face is a procedure which
                     draws a plane and then declares
                     it opaque
               end
    end;
```

Figure 3.1

Two-dimensional representation of hidden face problem in three-dimensional data matrix



Notes : For a sequential plot of each plane from the viewpoint (each plane being declared opaque as plotted) the following order would be required :- (3,4), (2,4), (3,3), (1,4), (2,3), (3,2), (1,3), (2,2), (3,1), (1,2), (2,1), (1,1). A plot in both directions from each co-ordinate is required e.g. for 3,4 join to 3,3 and join 3,4 to 2,4. This figure represents the base of the object only - the program also has to plot the vertical dimension, but is omitted here for clarity.

Similarly, where base shading was required as visible from the viewpoint, a whole base shade was used, but the opaque areas were missed in the same way.

SECTION II

(CHAPTER 4)

A USER MANUAL FOR GRAPHA A PRE-PROGRAMMED GRAPHICS PACKAGE FOR THE APPLIED SCIENCES

CONTENTS OF GRAPHA

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NOTES ON USE OF GRAPHA

1. For two dimensional plotting, turn to 2.1 for a first-time plot.

   For three dimensional plotting, turn to 3.1 for a first-time plot.

2. Sections 2.2, 2.3 are more complex in use but give greater user control over two dimensional plots.

   Similarly, Sections 3.2 and 3.3 give greater user control over three dimensional plots.

3. Where hidden line calculation is required, use manual for Hide (only after initial plots using this manual).

4. Check assembled data against Tables 4 to 8.

5. Three dimensional data conventions are given in Table 2.

1. A User Manual for Grapha - a Pre-Programmed Graphics Package

This manual describes the use of the package GRAPHA which produces both two and three dimensional graphical output. The most important feature of the package is the ease with which plots may be produced. No knowledge of computer use or of programming is required.

A description of the submission of data for this package follows, while at the end of this manual, data checklists may be found (Grapha Tables 4 to 7) which are useful for cross-checking the validity of the already assembled data cards. Attention is also drawn to Grapha Table 3 for additional options available for any type of plot, while Grapha Table 8 lists output messages with their meanings. An example is included for each main category of plot.

Reference is made in this text to three other manuals. These are

'A User's Guide to Ghost'

'Three-dimensional Plotting and Contouring'

'44MFT - Guide to System Use'.

Where reference to these manuals is useful for clarification, the appropriate item is noted. For example, Ghost = gargs means that the sub-routine

gargs is called as described in 'A User's Guide to Ghost'. Alternatively, Grapha Table 8 lists the parameters and output messages with their meanings.

The line printer output for each job includes a representation of the graphical output. This output will not be accurate, but only an approximation of the data.

When data has been prepared for analysis, advice should be sought from the programming advisory service on how to access the package (alternatively see Appendix).

2. Two-dimensional Plotting using Grapha

Three levels of entry to the two-dimensional plotting program are available. They differ in the degree of user control over the plots produced and therefore, in their ease of use. The level of entry is specified on the first card entered by the user.

Except where otherwise indicated, all entries should commence in column one of the data card. Where the instruction is set between quotation marks, then these will be omitted since they only serve here to indicate characters which are to be entered on the cards.

The three levels of entry are :-

a) "TWO-DIMENSIONAL HELP" (see Grapha User Manual 2.1) where the maximum number of variables is assigned automatically by the program. This produces only the bare essentials of a plot.

b) "HELP" (see Grapha User Manual 2.2) where greater user control is given e.g. to allow for page headings etc.

c) " " (see Grapha User Manual 2.3) A blank card is entered for complex plots where maximum user control is given over

output e.g. page size, type of characters may be specified.

It should be noted that for option a) the exact wording (including hyphen) should be given, otherwise option b) will be given by default.

Example of the use of TWO-DIMENSIONAL HELP option in Grapha

A typical extract of a laboratory record might read as follows :-

5.1.78 A comparison of the effect of temperature of seed presoaking on germination in rice

Cultivar - Oryza sativa L. cv. Oeiras

Duration of soaking - 48 hours

Temperature of soaking - 0, 10, 20, 30 degrees C

Number of seeds per batch - 30

Results

	0	10	20	30 °C
germination out of 30	12	23	23	29

To plot this data as a simple graph, the following method might be used :- Four points are to be plotted on one graph. The co-ordinates of these points are as follows - (0,12), (10,23), (20,23) and (30,29).

2.1 TWO-DIMENSIONAL HELP PLOTS

Card 1. "TWO-DIMENSIONAL HELP"

Card 2. number of points per graph (integer) e.g. 4
number of graphs in set (integer) (These graphs must be of the same type with only the data values changed.) At least one space must be left between these two values.
e.g. 1

Card 3. input of data in sequence :-

x1 (independent variable) then	y1 eg 0	12
x2	y2 eg 10	23
x3	y3 eg 20	23
xn	yn eg 30	29

These values may be integer(whole figures) or real (figures after decimal point) and must be spaced by at least one blank space.

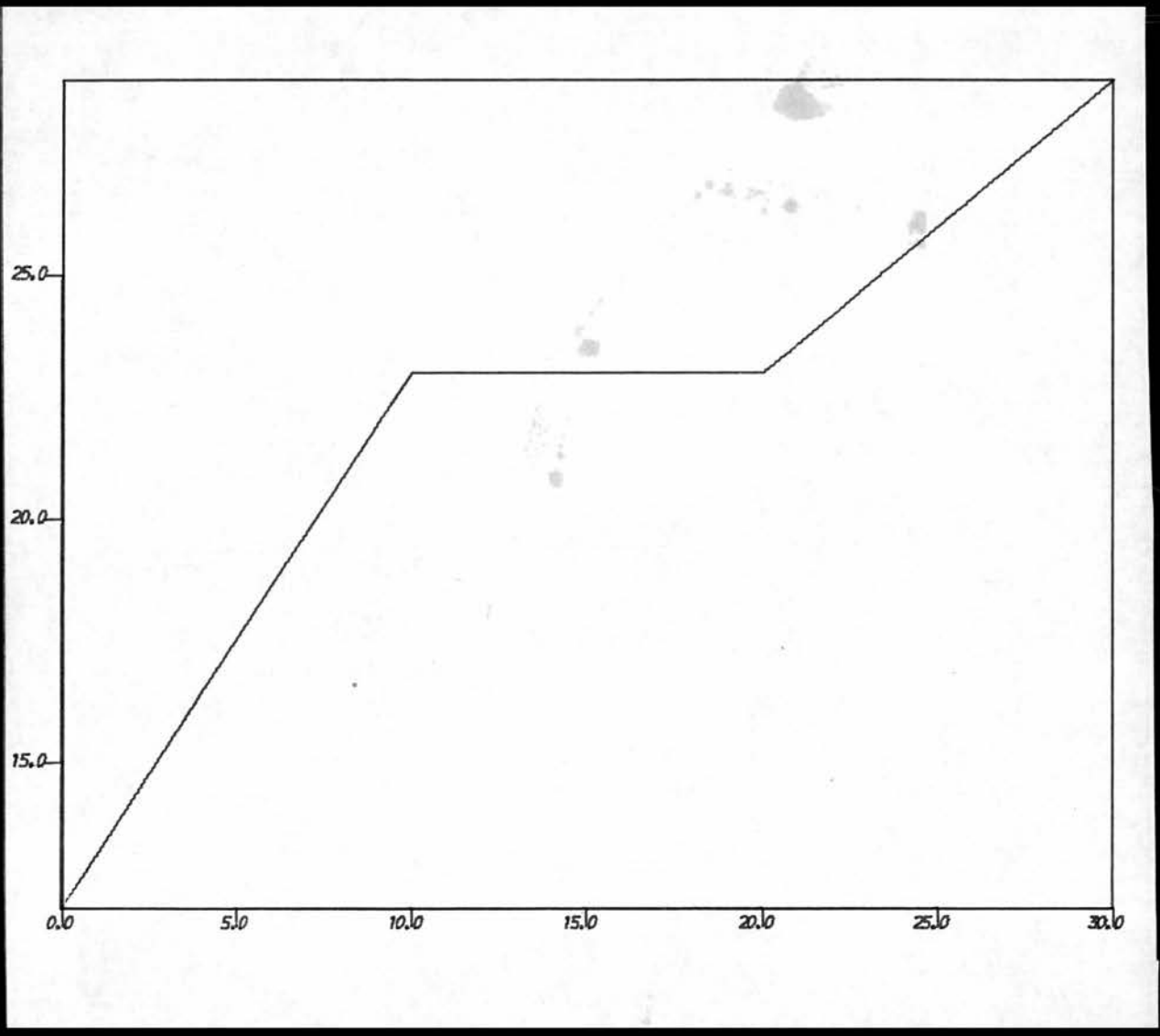
Cards 4. onwards. Repeat Card 3 for each data set (= data for one graph) in turn until the limit for the number of graphs in the set has been reached.

Example (compare with Figure 1)

```
TWO-DIMENSIONAL HELP
4   1
0   12   10   23   20   23   30   29
```

Grapha Figure 1.

A plot using the two-dimensional help option


25.0
20.0
15.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0

2.2 HELP PLOTS IN TWO DIMENSIONS

Card 1. "HELP" (or any other non-blank entry e.g. to act as a mnemonic for some purpose)

Card 2. Enter plot type (only the numeric value) selected from below :-

2.1 - plots without individual titles

2.2 - plots with individual titles

2.3 - plots with subtitle below graph

(Note that if more than one figure is given after the decimal point in option 2.2 e.g. 2.21, then the title is placed to minimise overlay of the graph. The second figure must not be 0.)

Card 3. number of points per graph (integer) e.g. 4

number of graphs in the set (integer) e.g. 2

If 1000 is entered, then a multiple plot (several lines) may be drawn. In this case, enter an integer for the number of lines and re-enter number of graphs.

The graphs in one set must be of the same type but with fresh data values.

Card 4. (optional) Enter "NO BORDERS" to omit frames from plots.

Card 5. (optional) Enter "NO AXES" to omit axes from plots.

Card 6. Enter a title for the page heading up to 80 characters long. Placing of the title elements may be improved, if necessary, by manipulating the position of the letters of this card suitably. Only one card is allowed for the page heading.
e.g. help plot with labelling

Card 7. Enter values for :-
x axis minimum value (integer or real) eg. 0
x axis maximum value eg. 30
y axis minimum value eg. 0
y axis maximum value eg. 30
(one space or more between each)
If a multiple plot, repeat Card 7. as necessary.

Card 8. Read individual graph title (one card only up to 80 characters). Only use in plot option 2.3 (see Card 2 above).
e.g. rice seeds soaked for 48 hours

Card 9. onwards. Input of data in sequence :-
x1 (independent variable) y1
x2 y2
xn yn
(at least one blank between each value)
e.g. 0 12 10 23 20 23 30 29
Repeat cards 8 and 9 until the number of graphs in the set has been reached.

Card 10. onwards. If a multiple plot has been selected, then enter text as follows :-

1) number of lines of explanatory text (integer)
2) a line of text (1 card) followed by x and y co-ordinates for start (real values)
3) repeat 2) until integer value in 1) has been reached

Note : Text is only appended to the last plot.

Example of the use of Grapha-help package

Laboratory book extract :-

The effect of temperature of pre-soaking on germination of rice seeds

Length of treatment : 48 or 96 hours

Temperature of soaking : 0, 10, 20 or 30 °C

Number of seeds per batch : 30

Results

Temp. of soak	0°C	10°C	20°C	30°C
germination out of 30 seeds after 48 hour soak	12	23	23	29
germination out of 30 seeds after 96 hour soak	24	22	27	21

Example of help plot

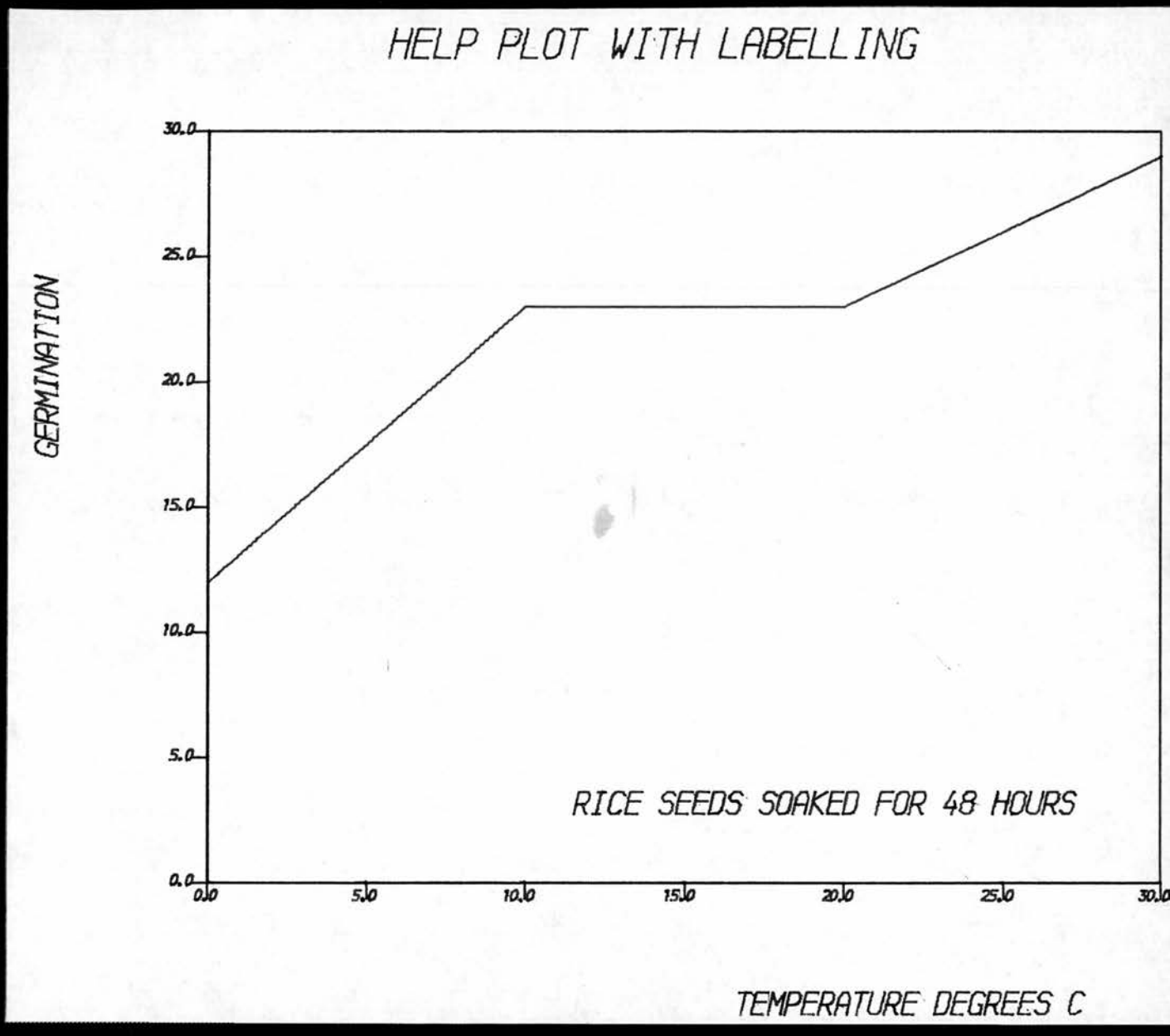
The results may be plotted as below :-

```
LABELS
POINTS                          } see Grapha Table 3
14  12  3  21                  } for explanation of
TEMPERATURE DEGREES C           } axis labelling
GERMINATION                     } (optional)
HELP
2.2
4  2
        HELP PLOT WITH LABELLING
0  30  0  30
RICE SEEDS SOAKED FOR 48 HOURS
0  12  10  23  20  23  30  29
RICE SEEDS SOAKED FOR 96 HOURS
0  24  10  22  20  27  30  21
```

(Compare with Grapha Figure 2)

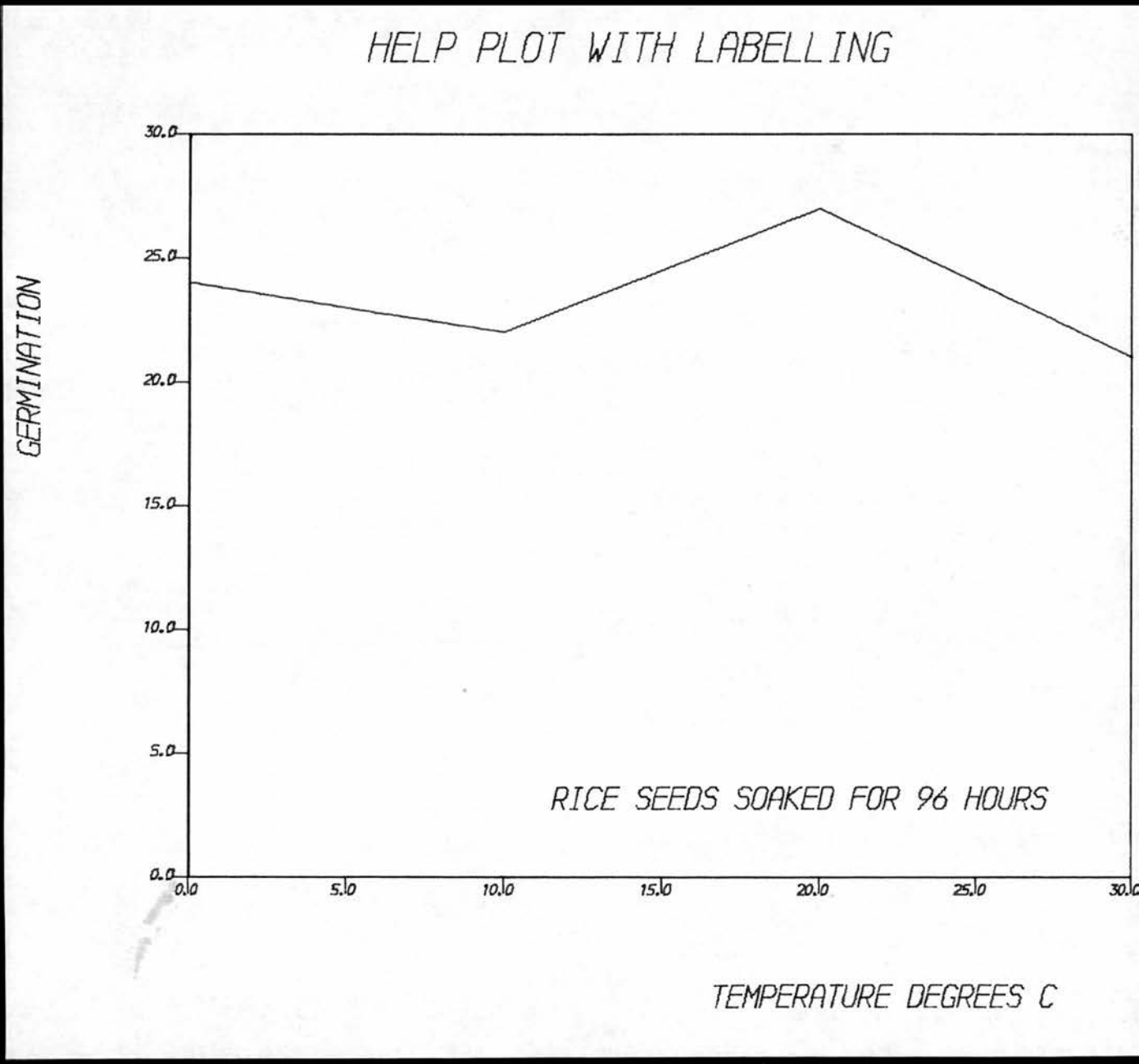
Grapha Figure 2a.

Two-dimensional plot with labelling run under Grapha help


HELP PLOT WITH LABELLING
GERMINATION
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
RICE SEEDS SOAKED FOR 48 HOURS
TEMPERATURE DEGREES C

Grapha Figure 2b.

Two-dimensional plot with labelling run under Grapha help


HELP PLOT WITH LABELLING
GERMINATION
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
RICE SEEDS SOAKED FOR 96 HOURS
TEMPERATURE DEGREES C

2.3 COMPLEX TWO-DIMENSIONAL PLOTS

If help plots do not provide the required degree of user control, then this option should be chosen.

Card 1. " " or blank card

Card 2. integer for number of types of graph to be plotted
This allows recycling of the program (limited by user time limit), in which case several different types of plot may be produced in one job. Note that Cards 1 and 2 are entered only at the start of fresh job and not in the recycling mode
e.g. 1

Card 3. Blank card

Card 4. Plot type. Enter a value for plot choice chosen from the plot type table (Grapha Table 1) with a value greater or equal to 2 but less than 3. If more than one decimal place is given (must be non-zero in the second place) in option 2.2, then the title is placed to minimise overlay of the graph plotted. Where subtitles are chosen, there is an arbitrary limit of 28 subtitles per page (otherwise the writing would be too

small to read). Titles in excess of this number will be omitted.

e.g. 2.2

Card 5. Points. Enter an integer value for the number of points per graph and an integer for the number of graphs in the current plot type category.

e.g. 4 1

If the number of graphs entered = 1000, then a multiple plot (several lines on one graph) can be drawn. An integer for the number of lines should then be entered followed by a new value for the number of graphs.

Card 6. If this card reads (optional card) -

"NO BORDERS"

then none will be given.

Card 7. If this card reads (optional card) -

"NO AXES"

then no axes (scale values) will be given on the plots produced.

Card 8. To specify sizes for plotter characters enter -

"SIZESTATED"

followed by values for each of the following - individual title height required (cms), point for start of title on X and on Y axes (horizontal and vertical axes respectively), size for main title letters and X and Y co-ordinates for start of main title.

(Note: co-ordinates relate to plotter paper size not dimensions within the box.)

e.g. sizestated 0.5 6 12.2 1 4 24

Card 9. Enter a page heading for output

e.g. "ITALIC LETTER OPTION"

Card 10. If

"BROKEN LINES"

is entered on this card then subsequent plots will be produced in broken line format. It is then necessary to enter values for the computation of mark-space ratio for which four integer values are required (new card). (See User's Guide to Ghost)

Card 11. If page size is to be set automatically, enter a blank card. Otherwise, enter a card reading

"PAGESIZE"

followed by values for the following :-

1. Underflow suppression - this should normally be set on (1) for the first plot but will fail if set on for subsequent passes (off=0)(Initio in 44MFT guide to System Use).

   e.g. 1

2. Initialise (Ibcint in 44MFT Guide) on = 1, off = 0 (set to 1 for first pass only).

   e.g. 1

3. Turn plotter on on initial pass (1).

   To turn off set 0 (Cilplt in Ghost).

   e.g. 1

4. Select units for plotting -

   1 = cms

   2 = mms

   3 = inches

   (Ghost = cms, mms, inches)

   e.g. 1

5. Select for italic or non-italic characters-

   1 = italic

   0 = non-italic characters

   (italic in Ghost)

   e.g. 0

6. Select for debugging option for return of plotter parameters (not normally required).

   1 = debug

   0 = no debugging

   (gargs in Ghost)

   e.g. 1

7. Select for character set -

   0 = Hollerith

   1 = upper case Roman

   2 = lower case Roman

   3 = upper case Greek

4 = lower case Greek

5 = Flexowriter case normal

6 = Flexowriter case shift

(Ghost = ctrset)

e.g. 2

8. Select for printing of frame number

1 = frame count

0 = no frame count

(Ghost = grend)

e.g. 1

9. Select for perspective control - irrelevant in two dimensional plots but enter either 0 or 1.

e.g. 0

All of the above values may be entered on one card with a gap between each. Nine integer values must be entered.

10. Enter values for page limits in cms. (i.e. overall size of page including margins etc.) as real or integer values for -

limits 1 (x minimum value) e.g. 0

limits 2 (x maximum value) e.g. 25

limits 3 (y minimum value) e.g. 4

limits 4 (y maximum value) e.g. 30

(Ghost = limits)

11. Enter value for actual space to be occupied by the plot in cms - (real or integer) -

Plotter space 1 (x axis minimum) e.g. 0

Plotter space 2 (x axis maximum) e.g. 20

Plotter space 3 (y axis minimum) e.g. 5

Plotter space 4 (y axis maximum) e.g. 25

(Ghost = pspace)

Card 12. Axis scale limits. Enter values for the mathematical size of the graph (i.e. minimum and maximum data scale values) -

x axis minimum data scale value e.g. 0

x axis maximum data scale value e.g. 30

y axis minimum data scale value e.g. 0

y axis maximum data scale value e.g. 30

(Ghost = mspace)

Card 13. Individual graph size. Enter x axis length in cms (real or integer). If x axis length is set greater than 200 then extra text may be entered on to each page of graphs and x axis length becomes equal to (x axis length - 200). If x axis length is set greater than 100, then an axis labelling option is given (one label each way for the whole page of graphs regardless of the number of graphs per page. An alternative option for individual

graph axis labelling is given in Grapha Table 3). (Labels for the X and Y axes (if just specified) are entered on two further cards. (Where values for x length of greater than 300 are encountered, then both options (text and axis labelling) will be given with graph lengt equal to the number of units over 300 after Card 14).) If x length is not an integer, then one graph per page is given.

e.g. 14

Card 14. Enter y axis length. If this value is not an integer, then the graphs will be blocked on to one page, within the limits defined, with a space left around each graph. This space will be defined by the value of the first decimal figure times 10.

If only one graph per page is required, then x length (Card 12) should be entered as a non-integer value, otherwise graphs will be blocked on to one page.

e.g. 12.2 (Enter X and Y axis labels on 2 further cards if specified under 13.)

Card 15. Heading for each graph. If an option from 2.2 to 2.4 (inclusive) was selected for plot type, then enter an individual graph heading up to 80 characters long (one card).

e.g. meteor seeds soaked for 48 hours

Card 16. onwards. Data for plot. Enter data in

sequence for current graph -

x1 (independent variable)	y1 (result)	(real or
x2	y2	integer)
xn	yn	

If a multiple graph has been selected, then repeat these cards for each line to be plotted.

Leave at least one gap between each data value.

e.g. 0 3 10 18 20 24 30 0

Other cards. Repeat Cards 15 and 16 for each data set.

Repeat all cards from this or other sections for the next plot type (if number of graph types originally entered allows).

Text cards. Where a multiple plot or text (x length greater than 200) has been specified, then enter -

1. The number of strings to be plotted (up to 80 characters each).
2. The line of text and its x and y co-ordinates for plotting (start of line). (2 cards)
3. Repeat text card 2 until the integer value specified in card 1 has been reached.

Example of two-dimensional blank or complex plot

(compare with Grapha Figure 3)

DEBUGGING INFORMATION

1

LABELS

POINTS

14 10 3 17

temperature degrees C

germination out of 30 seeds

→ see Grapha Table 3 for explanation of these options

2.2

4 1

SIZESTATED

0.5 6 12.2 1 4 24

italic letter option

PAGESIZE

1 1 1 1 1 1 2 1 0

0 25 4 30

0 20 5 25

0 30 0 30

14

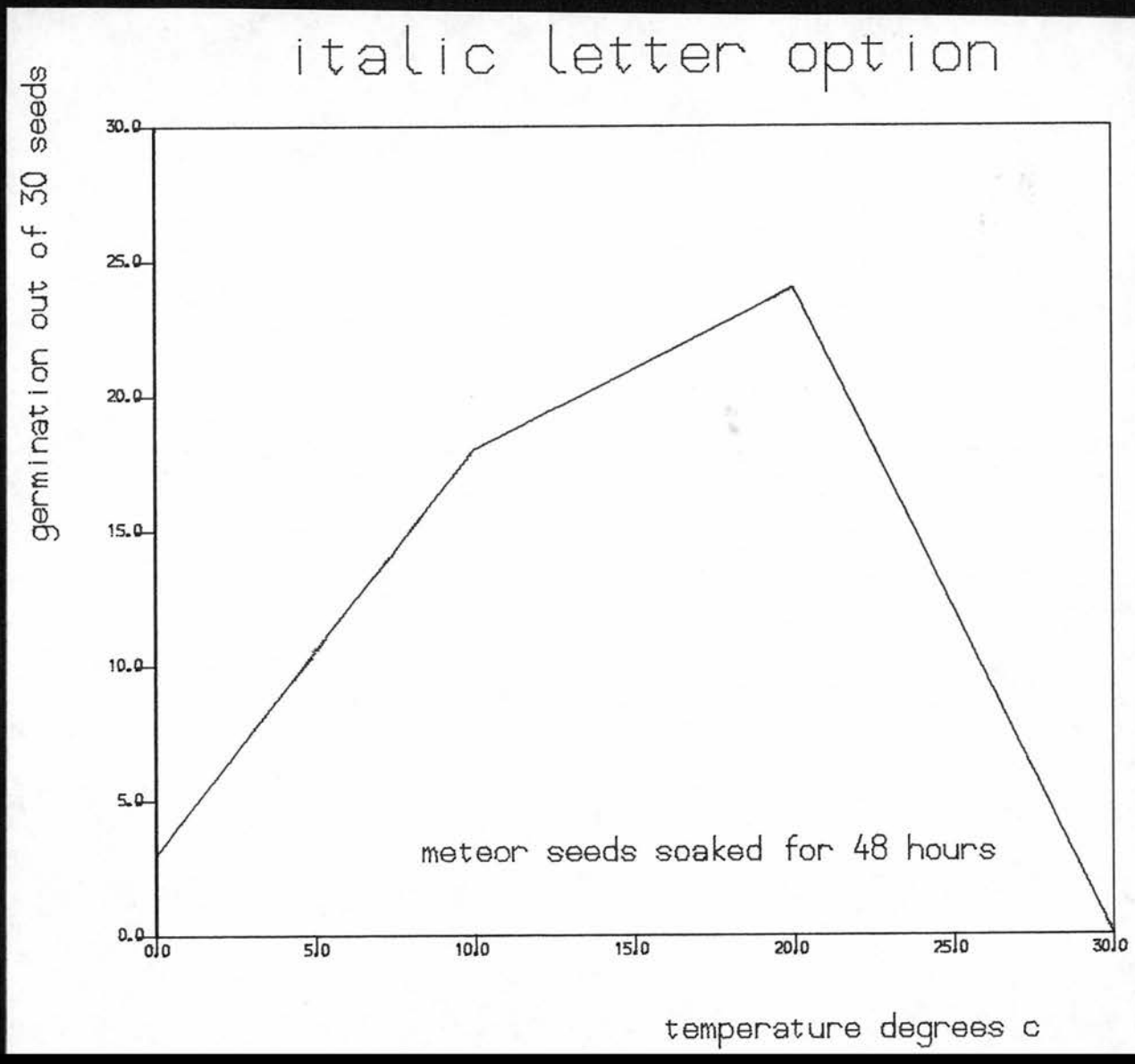
12.2

meteor seeds soaked for 48 hours

0 3 10 18 20 24 30 0

Grapha Figure 3.

Complex plot with italics run under Grapha


italic letter option
germination out of 30 seeds
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
meteor seeds soaked for 48 hours
temperature degrees c

3. Three-dimensional Plotting using Grapha

As with two-dimensional plotting, several levels of entry are possible for three-dimensional plotting, the levels differing in the extent of user control over output. Each level is accessed according to the initial card entered :-

a) "THREE-DIMENSIONAL HELP"

b) "HELP"

c) " " for complex plots

(no entry but a blank card must be substituted)

The exact wording must be given for a) while any other non-blank entry will give b) by default. Sections 3.2 and 3.3 should be ignored in the first attempt to use three-dimensional plotting.

3.1 THREE-DIMENSIONAL HELP PLOTS

This is the simplest plot form for three dimensional plots and therefore requires minimal user submitted information.

Card 1. Problem. Enter
"THREE-DIMENSIONAL HELP"

Card 2. Points. Enter integer value for number of data intervals on x axis and integer value for number of intervals on y axis. Enter integer value for number of graphs in set (each of these values must be separated by at least one blank space).
e.g. 3 4 1

Card 3. Data. Enter x axis interval values for data points (see Grapha Table 2 for data interval example).
e.g. 24 48 96
Enter y axis intervals (integer or real).
e.g. 0 10 20 30

Card 4. onwards. Data for vertical axis. Enter data values for each point in the grid as follows (see Grapha Table 2) -

x1 y1	x1 yn
x2 y1	x2 yn
xn y1	xn yn

e.g. 24 22 23 13

3 18 24 0

1 7 15 0

Note that this option only produces the bare essentials of a plot. It will be necessary to label the plot manually afterwards.

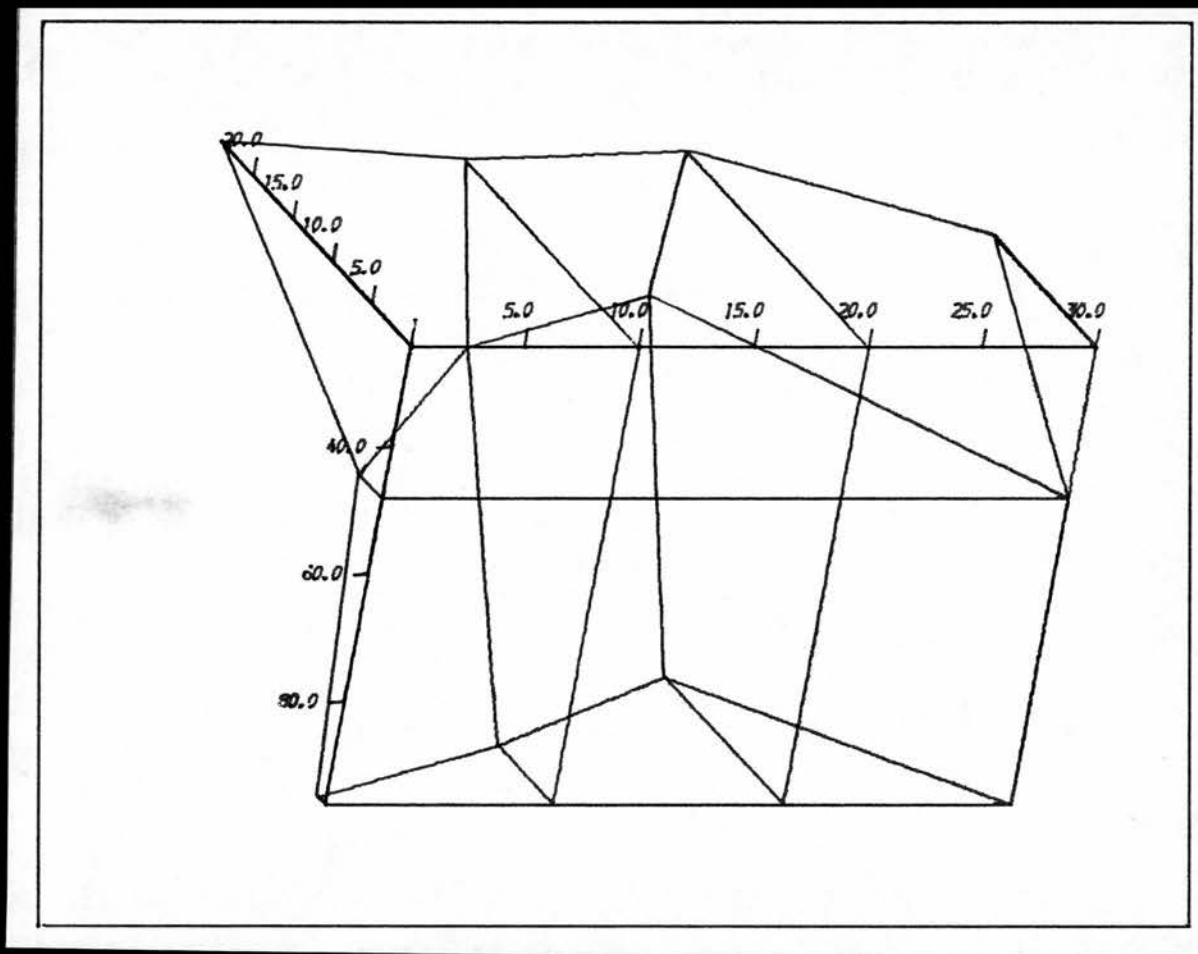
Example of the use of three-dimensional help Grapha plots

(compare with Figure 4)

```
THREE-DIMENSIONAL HELP
3  4  1
24  48  96
0  10  20  30
24  22  23  13
3  18  24  0
1  7  15  0
```

Grapha Figure 4.

Three-dimensional help plot run under Grapha


20.0
15.0
10.0
5.0
5.0
10.0
15.0
20.0
25.0
30.0
40.0
60.0
80.0

3.2 HELP PLOTS IN THREE DIMENSIONS UNDER GRAPHA

Card 1. Problems. Any non-blank entry
e.g."HELP"

Card 2. Plot type. Enter plot type chosen from plot type table (Grapha Table 1) i.e. value greater than 3 or equal to 3.
e.g. 4.2

Card 3. Points. Enter integer value for number of variables on x axis and an integer value for number of variables on y axis (see Grapha Table 2).
Enter integer value for number of graphs in set.
(At least one blank space must be left between each of these values.)
e.g. 3 4 1

Card 4. Page heading. Enter a string of up to 80 characters for the page heading. Otherwise enter a blank card.
e.g. help plot with titles

Card 5. Enter individual graph heading (string up to 80 characters) - can be used to enter additional information (if specified in plot type - Card 2).
e.g. X = hours, Y = degrees, Z = germination

Card 6. Mathematical space. Enter minimum and

maximum axis values for plot -

x axis minimum value

x axis maximum value

y axis minimum value

y axis maximum value

z axis minimum value

z axis maximum value

(Ghost = mspace)

e.g. 24 96 0 30 0 30

Card 7. Data intervals. Enter x axis data intervals and y axis data intervals (integer or real) (see Grapha Table 2)

e.g. 24 48 96

0 10 20 30

Card 8. Data. Enter data in x planes (integer or real) as follows -

x1 y1 -x1 yn

x2 y1 -x2 yn

xn y1 -xn yn

(see Grapha Table 2)

e.g. 3 22 23 13

3 18 24 0

1 7 15 0

Example of help plot (three-dimensional)

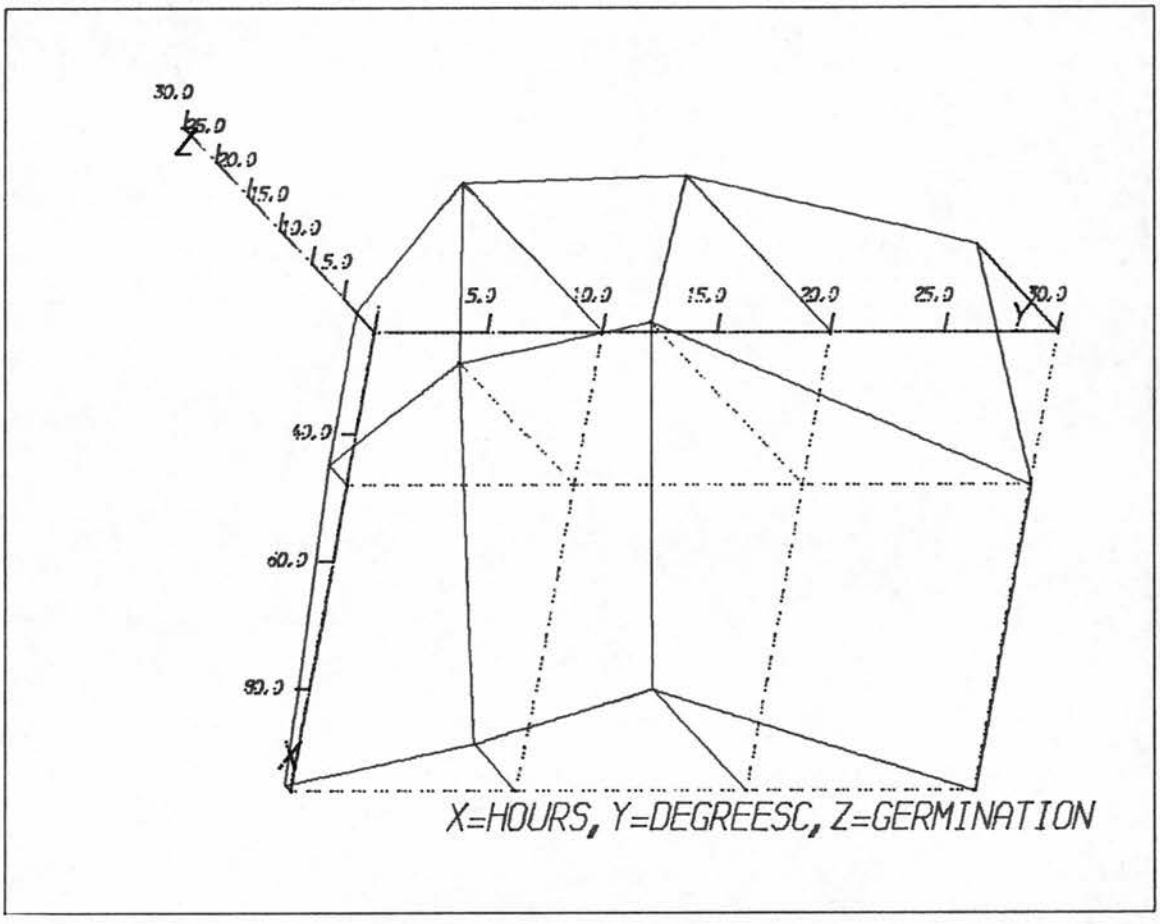
(compare with Grapha Figure 5)

```
HELP OPTION CHOSEN
4.2
3  4
1
HELP PLOT WITH TITLES
X = HOURS, Y = DEGREESC, Z = GERMINATION
24  96  0  30  0  30
24  48  96
0  10  20  30
3  22  23  13
3  18  24  0
1  7  15  0
```

Grapha Figure 5.

Help plot in three dimensions (Grapha)

HELP PLOT WITH TITLES



3.3 COMPLEX or " " (blank) PLOTS USING GRAPHA (THREE-DIMENSIONAL)

Card 1. Problem. Enter a blank card.

Card 2. Number of graph types. Enter number of types of graph to be plotted (integer value). This allows recycling of the program (limited by user time limit), in which case, all cards are repeated as in this list on subsequent passes with the exception that this card (2) will be omitted on subsequent passes. (Other plot types may be added to the job also.)

e.g. 1

Card 3. Blank card.

Card 4. Plot type. Enter a value for plot choice taken from the plot type table (Grapha Table 1) (value greater than or equal to 3). Note that where a plot type uses sub-titles, a limit of 28 per page is given.

e.g. 3.1

Card 5. Points. Enter an integer value for the number of points on the x axis and an integer value for the number of points on the y axis (see Grapha Table 2).

Enter an integer value for the number of

graphs in the set. (Each value must be separated by at least one blank space.)

e.g. 3 4 1

Card 6. Border omission. If this card reads -

"NO BORDERS"

then no frames will be given around the plots.

Card 7. Label size. If this card reads(optional) -

"SIZESTATED"

then enter values for each of the following -

1. individual title height (cms)(real or integer)
2. X axis value for start of title
3. Y axis value for start of title
4. height of main title letters
5. X axis value for start of main title
6. Y axis value for start of main title

Card 8. Page heading. Enter a page heading of up to 80 characters (or a blank card).

e.g. 3D plot with text

Card 9. Broken lines. If this card reads (optional) -

"BROKEN LINES"

the subsequent plots will be given in broken line format. It is then necessary to enter values for the mark space ratio. These four integer values should be entered on a new card.

e.g. broken lines

1 2 1 2

Card 10. (optional) To change the preset mark space ratio for plots normally using broken lines (other than those in 9 above), enter -

"BROKEN"

followed by four values for mark space ratio on another card (see User's Guide to Ghost).

Card 11. Page size. For automatic setting of page size, enter a blank card, otherwise enter -

"PAGESIZE"

followed by values for the following -

1. underflow suppression (1 = on, 0 = off)
2. initialize (1 = on, 0 = off)
3. plotter turn on (1 = on, 0 = off)
4. set plotter units (1 = cms, 2 = mms, 3 = inches)
5. italics (1 = on, 0 = off)
6. debugging (1 = on, 0 = off)
7. characterset (see User's Guide to Ghost)
8. framecount (1 = on, 0 = off)
9. perspective control (0 = perspective plot, 1 = isometric plot)
10. Enter values for page limits in cms (or as above)(limited by plotter paper size - see CIL Plotter Guide) as -

    limit 1 width-minimum value (real or integer)

    limit 2 width-maximum value " "

limit 3 height-minimum value (real or integer)

limit 4 height-maximum value " "

11. Enter values for plotter space (2D)

i.e. area actually available for graphical output (in cms or as above) as -

width 2D axis minimum value (real or integer)

" " " maximum " " "

height " " minimum " " "

" " " maximum " " "

e.g. blank card

Card 12. Enter values for mathematical space (2D).

For automatic scaling, enter

"0 0 0 0"

(see Three-dimensional Plotting and Contouring)

e.g. 0 0 0 0

Card 13. Individual graph size. Enter a value for graph width (real or integer). If width value is not an integer, then only one graph per page is given, otherwise graphs will be blocked on to one page.

If X axis length is greater than 200, then text may be entered on to each page of graphs and X axis length becomes equal to (x axis length -200).

If X axis length is greater than 100, then an axis labelling option is given for the whole page of graphs. (Labels for the x and

y axes respectively must then be entered on two further cards after Card 14.)

e.g. 207

Card 14. Enter y axis length or graph height. If y axis length is not an integer, then graphs will be blocked on to one page, within the limits defined, but a space will be left around each graph. This space will be defined by the value of the first decimal figure times 10.

e.g. 10 (Enter X and Y labels if specified on Card 13.)

Card 15. Individual graph heading. Enter an individual graph heading of up to 80 characters long if specified in plot type.

Card 16. Three-dimensional set up parameters.

Enter each of the following values :-

1. (optional) Enter -

   2000

   in order to plot data sets with different centres.

2. (optional) Enter -

   1000

   to append X, Y and Z to the respective axes for identification purposes.

3. Enter centre co-ordinates for object to be plotted.

   e.g. 1000

   0 0 0

Card 17. Three-dimensional plotter space. Enter estimated size for plotter space (in cms) for three-dimensional space as -

x minimum value (real or integer cms)
x maximum " "
y minimum " "
y maximum " "
z minimum " "
z maximum " "

(Ghost 3D = PSPC3D)

e.g. 5 20 5 20 5 20

Card 18. Mathematical space in three dimensions. Enter values as follows :-

x axis minimum value for scale (real or
x maximum integer)
y minimum "
y maximum "
z minimum "
z maximum "

e.g. 24 96 0 30 0 30

(Ghost 3D = MSPC3D)

Card 19. Data intervals. Enter x axis intervals (integer or real) (see Grapha Table 2). Enter y axis data intervals.

e.g. 24 48 96
0 10 20 30

Card 20. (several cards) Entry of data in x planes (see Grapha Table 2) -

x1 y1 -x1 yn

x2 y1 -x2 yn

xn y1 -xn yn

e.g. 3 22 23 13

3 18 24 0

1 7 15 0

Card 21. Viewpoints, axes and grids. Enter view 1 as follows -

1. If view 1 = 1000, then a set of standard views will be given and the program will terminate. (Some of these views may prove unsatisfactory, but at least one should prove useful for a given data set.)
2. If view 1 = 999, then axes (annotation also) will be omitted from all plots in the set.
3. If view 1 = 998, then readon integer values for XY, XZ, YZ where these represent planes for which a graticule will be drawn if a value of 1 is entered (e.g. 0 1 0 will highlight plane XZ by drawing a graticule in that plane).

   e.g. 998

   0 1 0

4. If view 1 = 997, then grids will be drawn, but axes omitted. Again, three integer values should be entered to indicate which planes are to be highlighted by graticule drawing.

5. Re-enter a value for view 1 if any of the above values have been entered (i.e. x co-ordinates of view point).
   e.g. 100

6. Enter values for views 2 and 3 (y and z co-ordinates of viewpoint chosen).
   e.g. 100 100

Card 22. Centres. If centre 1 was previously entered as 2000, then re-enter centres 1, 2 and 3 as in Card 14. The same options are available.

Card 23. Series of viewpoints. This program will continue to draw the same object from a number of view points. These may be entered as view 1, view 2 and view 3 as above (including options for selection of axes / grids). A value of greater than 1000 will terminate this part of the program. Alternatively, this part of the program may be terminated with a series of standard views by entering the value 1000 (in the last case i.e. view 1 greater than 1000 do not enter view 2 or 3).
e.g. 1001

Card 24. Repetitions. The whole series of cards may be repeated (except Card 2 for number of graph types) to the limit set by the number of graph types initially entered. Two and three dimensional plots may be mixed in a run.

Card 25. Text option (where x length is greater than 200). Text will be added to the last plot in the plot type section only. In this case enter :-

1. The number of strings (up to 80 characters) of text to be plotted (integer value).
   e.g. 3
2. Enter a line of text with x and y co-ordinates for the start of the line of text.
   e.g. X = hours of soaking
   5 12
3. Repeat line 2 until the integer value specified in 1 is reached.
   e.g. Y = temperature of soaking
   5 11
   Z = germination out of 30
   5 10

Example of complex three-dimensional plot using Grapha

(Compare with Grapha Figure 6)

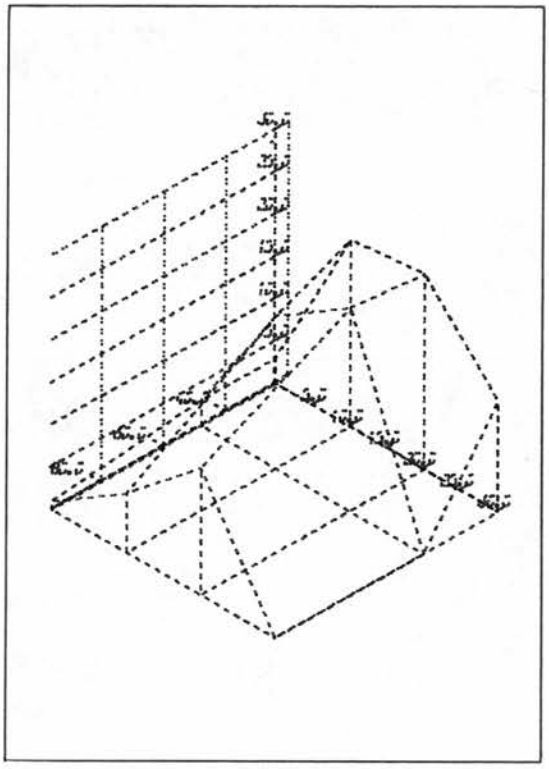
```
                .....(blank card)
1
                .....(blank card)
3.1
3  4  1
3D PLOT WITH TEXT
BROKEN LINES
1  2  1  2
                .....(blank card)
0  0  0  0
207
10
1000
0  0  0
5  20  5  20  5  20
24  96  0  30  0  30
24  48  96
0  10  20  30
3  22  23  13
3  18  24  0
1  7  15  0
998
0  1  0
100  100  100
```

```
1001
3
X = HOURS OF SOAKING
5  12
Y = TEMPERATURE OF SOAKING
5  11
Z = GERMINATION OUT OF 30
5  10
```

Grapha Figure 6.

Complex three-dimensional plot (Grapha)

3D PLOT WITH TEXT



X=HOURS OF SOAKING

Y=TEMPERATURE OF SOAKING

Z=GERMINATION OUT OF 30

Grapha Table 1

Plot Type Table for Plots using Grapha

2.1 two-dimensional graph

2.2 two-dimensional graph with titles overlaid

2.3 two-dimensional graph with sub-titles (at foot of page of graphs)

2.4 two-dimensional graph with axes(large markings) around the edge of the page only and titles

2.21 or 2.41 as for 2.2 or 2.4 but titles are overlaid on graph in such a manner that overlay of the plot is minimised

****

3.1 three-dimensional graph

3.2 three-dimensional graph with titles overlaid

3.3 three-dimensional graph with sub-titles at foot of page

****

4.1 three-dimensional graph with dotted base lines

4.2 three-dimensional graph with dotted base lines and titles

4.3 three-dimensional graph with dotted base lines and sub-titles

****

5.1 three-dimensional graphs produced as stereo pairs

5.2 three-dimensional graphs as stereo pairs with titles

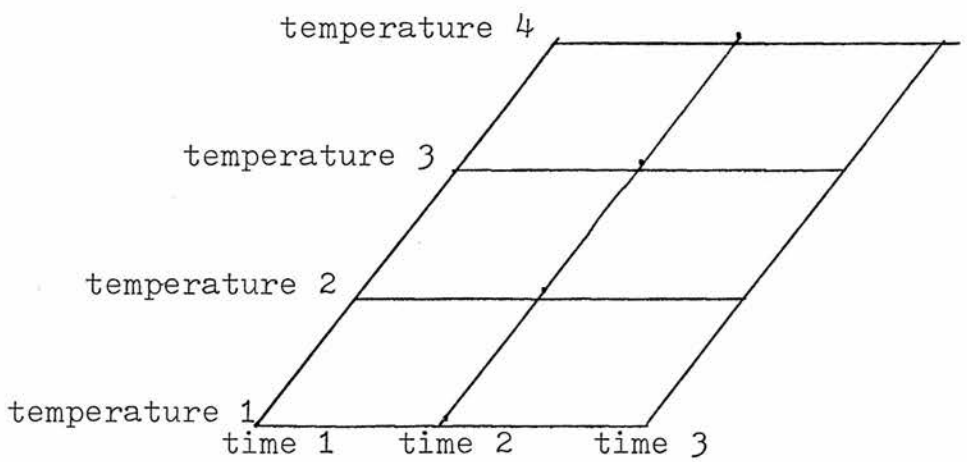
5.3 three-dimensional graphs with stereo pairs and sub-titles

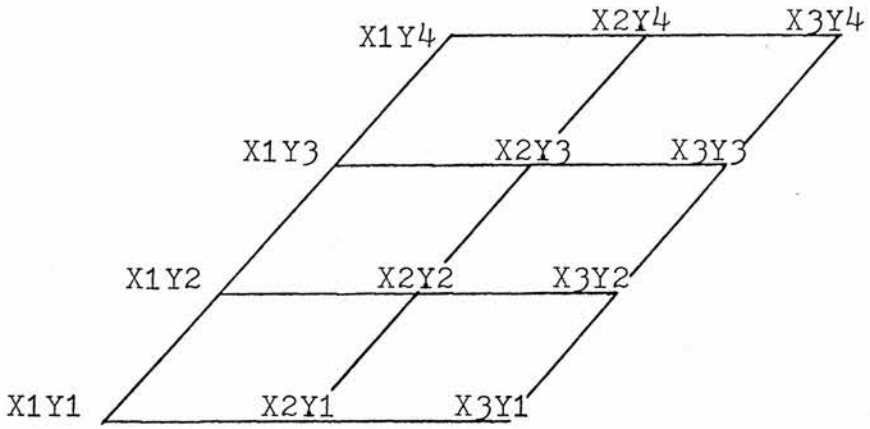
****

Grapha Table 2

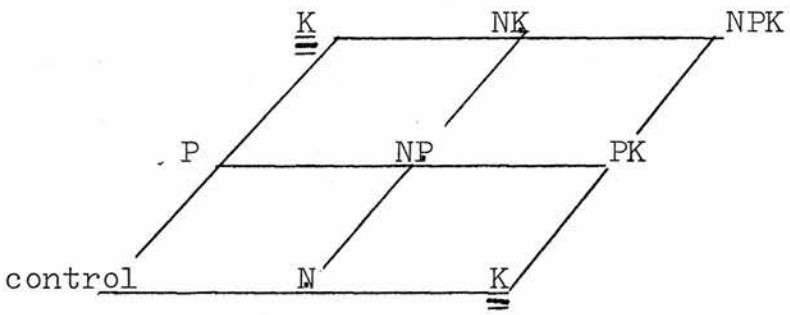
Conventions adopted for Three-dimensional Data Preparation

1. The two independent variables will be known as X and Y and will be represented by the two horizontal axes in a three space co-ordinate system. The vertical or Z axis will be the independent variable (or experimental result). It is recommended that, initially, the independent variables should be visualised as a two-dimensional co-ordinate grid. For example, imagine an experiment with four temperature treatments and three duration treatments. This might be represented as follows :-

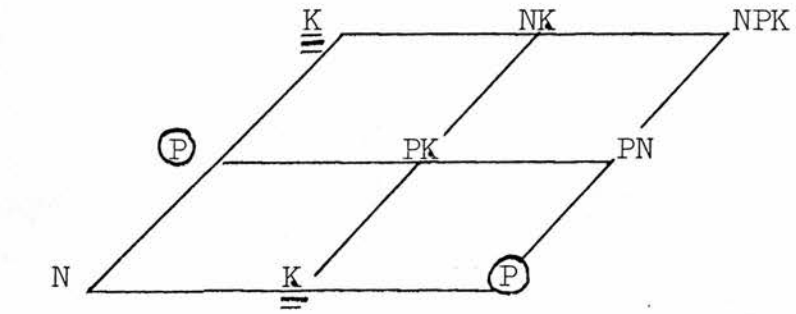




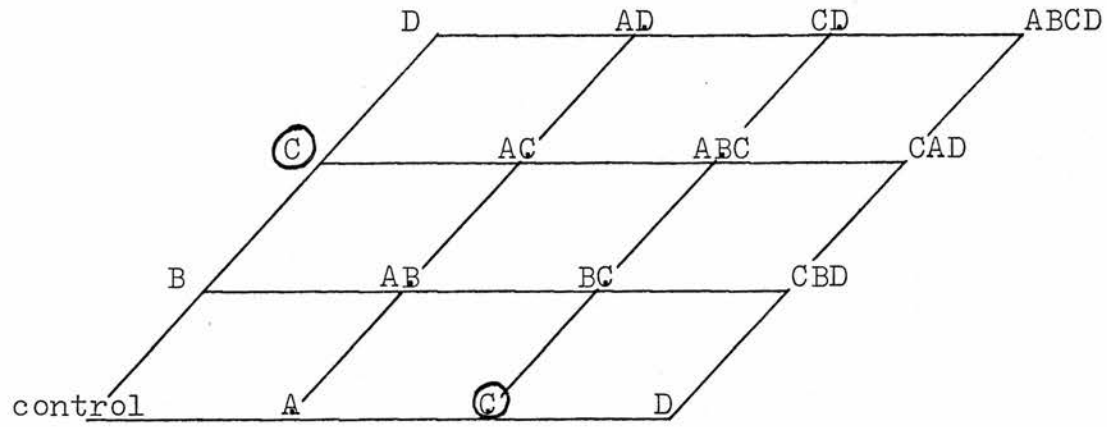
2. Any symmetrical data pattern may be represented in this way, while a non-symmetrical matrix may be made uniform by the substitution or repetition of values. In a fertilizer experiment, three fertilizers were used - nitrogen, potassium and phosphorus (abbreviated to N, P and K). These fertilizers were applied in all combinations. They could be represented as follows :-



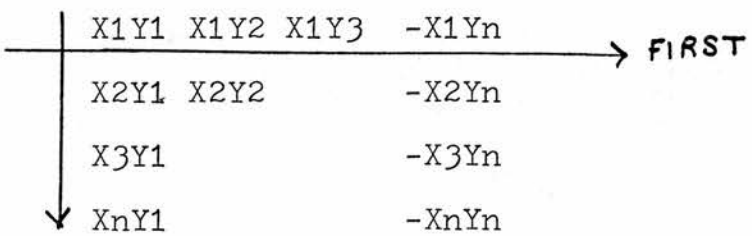
or



or

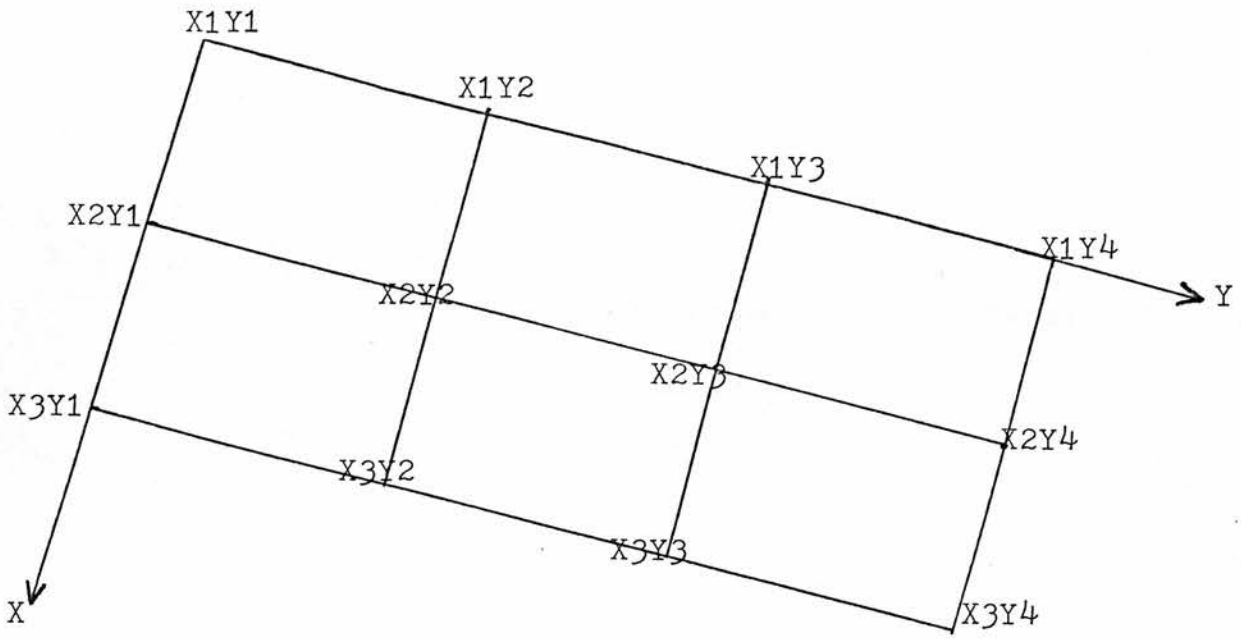


3. The data is then entered in order as



with a single data value (real or integer) for each co-ordinate pair.

4. Compare the following diagram with the data submitted -



X1Y1 = 4.2 X1Y2 = 3.5 X1Y3 =2.1 X1Y4 = 0.9

X2Y1 = 3.5 X2Y2 = 3.0 X2Y3 =1.8 X2Y4 = 0.7

X3Y1 = 3.0 X3Y2 = 2.0 X3Y3 =1.1 X3Y4 = 0.3

X4Y1 = 1.9 X4Y2 = 0.8 X4Y3 =0.7 X4Y4 = 0

Data entry sequence -

4.2 3.5 2.1 0.9

3.5 3.0 1.8 0.7

3.0 2.0 1.1 0.3

1.9 0.8 0.7 0

Grapha Table 3

Additional Facilities Available for All Grapha Plots: Debugging information, recycling of program for several types of plot and labelling of axes in plots

Any job may commence with one or more of the following conditional cards, provided that they are entered in the stated order if more than one condition is to be set.

a) DEBUGGING INFORMATION

The first card in the data set may read "DEBUGGING INFORMATION" in which case additional detail of plotter commands will be printed. This option should only be used when really necessary because many parameters internal to the program will be output, while their meaning will have little significance to the casual user.

b) A SET OF PLOT TYPES

Where a help option is chosen (blank options already include this option), recycling of the whole program may be given for a sequence of graphs of differing types. In this case, a blank card should be entered followed by a card with an integer value for the number of graphs to be produced. Any plot type may be subsequently selected.

c) AXIS LABELLING IN TWO-DIMENSIONAL PLOTS

A card reading "LABELS" should be entered in

order to access this option. Normally, axis labels will be plotted automatically at specific points, but this may be overridden by including a card reading "POINTS" followed on another card by four integer or real values for the x and y co-ordinates of the x axis label and y axis label respectively. In either case, two cards for the two axis labels should follow, firstly for the x and then for the y axis. Up to 80 characters are permitted but this will depend upon the size of the plot since long labels may exceed the plotting area. (For blank or complex plots, enter after number of graph types.)

Grapha Table 4

Key to Tables 5, 6 and 7

+	=	essential card
-	=	not to be included
+/-	=	optional
1*	=	one times
n*	=	n times
string or s	=	string of alphanumeric characters up to 80 units (i.e. one card)
integer or i	=	an integer value
real or r	=	a real value (i.e. with decimal point)
PURPOSE	=	need for card entry
NECESSARY	=	whether program will fail if supplied/not supplied
TYPE OF ENTRY	=	type of information called for by program
DEPENDENT CARDS	=	other cards which must be entered after first
OTHER NOTES	=	e.g. C1, C2, C3, V1, P1 etc. (see Table 8)
2D	=	two-dimensional
3D	=	three-dimensional

Grapha Table 5

Data Checklist for two and three dimensional plots using Grapha

List of cards

	PURPOSE	USE	NECESSARY	TYPE	ENTRY	NOTES
	Debug	any option	+/-	1*s	"DEBUGGING INFORMATION"	
	Complex plots		+	1*s	" "	Enter a blank card
	Number of graph types	blank plots	E+	1*s	"1*i"	This is the number of graph types in this job.
RESTART	Axes label	any option	+/-	1*s	"LABELS"	Can enter another card reading - "POINTS" followed by another with 4*r for xy co-ordinates for horizontal and vertical label position (otherwise axis label in preset position).
					"1*s"	X axis label
					"1*s"	Y axis label
First essential card for help plots	Problem		+	1*s	"TWO-DIMENSIONAL HELP" (A cards) "THREE-DIMENSIONAL HELP" (B cards) "STEREO HELP" (C cards) "HELP" (D cards) " " (E cards)	Enter using Grapha Table 6

Grapha Table 6

Data checklist

	PURPOSE	NECESSARY	TYPE	ENTRY	NOTES
	Type of plot	D+ E+	1*r	from Table 1	Selects type of plot required.
2D	Number of points	A+ D+	2*i	number of points per graph	If number of plots in set = 1000, then enter number of lines per graph then re-enter number of graphs.
2D	Number of plots	E+		number of plots in set	
3D	Number of points on X and Y axes	B+ C+ D+	3*i	number of intervals on X and Y axes,	A set = graphs all of same type with same axis intervals etc.
3D	Number of plots	E+		number of plots in set	
	Omit border	D+/- E+/-	1*s	"NO BORDERS"	
	Omit axes	D(if 2D)+/- E(if 2D)+/-	1*s	"NO AXES"	
	Title size	E+/-	1*s	"SIZESTATED"	Also enter 6*r for sizes
	Pageheading	D+ E+	1*s	" "	Enter blank card if no page heading

Grapha Table 6 continued

PURPOSE	NECESSARY	TYPE	ENTRY	NOTES
broken lines	E+/-	1*s	"BROKEN LINES" or "BROKEN"	Also enter 4*r for mark-space ratio.
page size	E+	1*s	"PAGESIZE"	If blank card placed here, do not enter plotter characters (next card).
plotter characters	E+	1*s		Enter 9*i 8*r to change plotter setup.
X axis value limits Y axis value limits	D(if 2D)+ E+	4*r		minimum and maximum axis markings for X and Y axes
plot size (cms)	E+		"1*r or i, 1*r or i"	First for plot width, second for height (cms). For text option add 200 to width. For label X and Y axes, add 100 to width (follow by 2*s for X and Y labels). For both, add 300 to width. If width value not an integer, then one graph per page given. If height not an integer, then space left around graphs.

Grapha Table 7

Data checklist (repeat until N)

	PURPOSE	NECESSARY	TYPE	ENTRY	NOTES
2D	Title (not main heading)	if specified	1*s	"title"	i.e. sub-title or individual title
	Data	A+ D+ E+	n*r	enter data as x,y co-ordinate pairs	If multiple graph, repeat.
	Text	E(if length greater than 200) + A+/- if D+/- multiple E+/- graphs on plot	1*i 1*s 2*r	"number of sentences" "sentences" X,Y co-ordinates	Repeat until "number of sentences"
3D	Title (not main heading)	if specified	1*s	"title"	i.e. subtitle or individual title
	Object centre	E+ E+	1*r 2*r	centre 1 centre 2, centre 3	2000 repeats centres, 1000 XYZ appended to axes. (Re-enter C_1 in either case.)
	Plotter setup	E+ D+E+	6*r 6*r	P1-P6 M1-M6	

Grapha Table 7 continued

PURPOSE	NECESSARY	TYPE	ENTRY	NOTES
Data	all plots		X axis data intervals Y axis data intervals Data in planes see Table 2.	
NEW VIEW				
3D Grids and axes	E+	1*r	999 998 997	no axes or grids grids and axes grids only no entry gives axes only If grids selected, then enter choice for XY,XZ,YZ where grid = 1 (e.g. 0 1 0 = XZ plane grid).
Views	E+	3*r	view 1 view 2 view 3	If view = 1000, then a set of standard views is given and view section of program terminates.
	E+/-	3*r	centre 1 centre 2 centre 3	If previous C1 = 2000, re-enter C1, C2, C3 for new centres. (2000 may be re-entered if required.)
To terminate	E+/-	1*r	V1	If = 1000, standard views are given, otherwise if greater than 1000 stops or go to NEW VIEW.
Text	E+ (if length is greater than 200)	1*i 1*s 2*r	"number of sentences" "sentences" X and Y coordinates for sentence	Repeat until "number of sentences".
GO TO RESTART IF NUMBER OF GRAPH TYPES PERMITS.				

Grapha Table 8

A list of output messages with their significance

A4	- A4 page size pre-set, either true or false
A (1 - PX)	- intervals for X axis data in 3D plots
Axeslabel	- selection of axis labelling, either true or false
axessi	- intervals for axis numbering plotted
B (1 - PY)	- horizontal axis data values if 2D plot, otherwise data intervals for Y axis data in 3D plots
Border	- frame plotted around the graph
Broken (1-4)	- broken line mark space ratio
C (1-3)	- or centre (1-3), centre co-ordinates for three-dimensional plot
C (1,1)-C(PX,PY)	- vertical axis data values if two-dimensional plot, otherwise data values for data matrix in three-dimensional plots
card	- a computer coded (punched card) entered by the user
char	- character in use
characterset	- the character set (number) selected
centre	- the centre of the object being plotted

crsize	- character size currently in use
ctrset	- the character set (number) selected
ctrang	- character rotation (radians)
debug	- numeric value for the debug option selected (0 = none, 1/11/21/31 = debug in use)
donotknow	- automatic selection of plotter parameters, either true or false
frame	- advances the plotter by one frame (new page)
framecount	- the number of the frame currently being plotted
full	- the plotter reverts to full lines after plotting broken lines
gap	- the value for a gap to be left between graphs where a number are blocked on to one page (or frame)
gargs	- debugging on (1) or off (0)
graphs	- two-dimensional plot selected
grend	- frame count option selected
help	- status of program, help either true or false
initial	- plotter initialised
initio	- plotter initialised
isome or isomet	- isometric plot selected
italic	- italic letters selected if equal to 0 otherwise non-italic letters given

label axes - labelling of axes given

largenumbers - overall axes for a page of graphs using large figures for annotation

length of X or Y axis selected - graph width and height respectively in use for the current plot (Note values greater than 200 indicate text is to be plotted.)

limits - limits beyond which plotting of graph or characters not possible

LS1-4 - values for page limits set

M1-6 - values for three-dimensional mathematical space in use

MS1-4 - two-dimensional mathematical space values in use

Mspace - mathematical space -two-dimensional

MSPC3D - mathematical space -three-dimensional

N - the number of graphs in the set

numberofgraphtypes - the number of graph types in the job submitted

overallaxes - axes around edge of page in lieu of individual axes for each graph on a blocked page

P - the number of points on a two-dimensional graph

P1-P6 - numeric values for plotter space in three dimensions

pagehead - page heading to be plotted, true or false

pagesize - page size parameters pre-selected or chosen by the user, either true or false

pen(X) - indicates pen currently in use by the plotter

plotlp - request for current frame to be plotted on the line printer

plotter - plotter in use

problems - type or level of access to plotting package

plotype - type of plot to be used, see plot type table (Grapha Table 1 or Hide Table2)

PS1-4 - plotter space in two dimensions

Pspace - plotter space in two dimensions

PSPC3D - plotter space in three dimensions

PX - points on X axis

PY - points on Y axis

set up parameters - values for state of plotter setting up parameters

stereo help - stereo help option selected, either true or false

subtitle - sub-titles required in plot

three-dimensional help - three-dimensional help plot to be given

titletype - type of title to be given
i.e. figure after decimal point
in plot type selected times 10

total number of frames - frame count for the number of frames plotted

two-dimensional help - two-dimensional help option in use, either true or false

underflow - suppression of underflow selected

units - units of measurement in use

V1-3 - viewpoint co-ordinates for three-dimensional plots

V4-7 - converted viewpoints for three-dimensional plots in stereo pairs

view - the view currently being plotted

Xlengths - the width of the current plot

Ylengths - the height of the current plot

****

REFERENCES

44MFT Guide to System Use. Tecnical Report. University of St.Andrews Computing Laboratory.

3D Plotting and Contouring. Software Memo 009, University of St.Andrews Computing Laboratory.

A User's Guide to Ghost. Technical Report CL/73/2. University of St.Andrews Computing Laboratory.

APPENDIX

The package is accessed in the following manner. Cards should be submitted which read as follows :-

```
passcard
job card
//SYSRDR ACCESS CLOPT(GRAPHA)
/*
     data submitted as described below
/*
/&
```

A description of the passcard and job card may be found elsewhere (44MFT Guide to System Use,1976), but a brief note is also included here. The passcard will normally be punched with the user ID and password (issued on registration at the computer unit). No blank spaces are permitted between any of the characters which must start in column one.

A job card is essential to every job and should be similar to the one shown below -

```
//IDNAME JOB ,T1P30
```

The IDNAME will not exceed 8 characters in total while the time and page limits are optional (if none are entered then a value for each will automatically be set, but this may not be sufficient for the job

in hand) where time and page limits are not entered, the comma should still be entered one space on from JOB. At present, convention dictates the use of orange cards for all of the above with the exception of the white passcard. The orange cards are termed job control language (JCL) cards, and are used to access both hardware (the central processing unit or CPU, tape units, disk drives etc.) and software (normally the medium carrying the program instructions e.g. tape, disk and cards).

It is necessary to indicate to the computer operators which units are required when these are not normally accessed automatically. Thus, the white passcard has sections requesting this information. In the current context, the following entries should be made :-

name

department

tick 44MFT (the system in which the program is available)

enter FULL CORE in the blank box (Because of the large storage requirement of this program, it will not run unless the whole CPU space is available for execution.)

the job name should be entered from the JOB card

Finally, it is necessary to tick the box marked plotter which indicates to the operators that

the plotter tape should be loaded.(This tape will carry all of the information for the graphical output to be plotted later.)

When a request for a plot is to be made, the job name, the date and time at which it was run should be submitted along with the request.

SECTION III

(CHAPTER 5)

A USER MANUAL FOR HIDE:
A PRE-PROGRAMMED PACKAGE
FOR THREE DIMENSIONAL GRAPH PLOTTING
INCLUDING SHADING AND HIDDEN LINE CALCULATION

CONTENTS OF HIDE

1. Shading and hidden line three-dimensional plots using the package Hide 126
2. Use of Hide three-dimensional help option 128
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NOTES ON USE OF HIDE

1. To use the line hiding option, consult Hide Manual Section 2 for a first time plot. Sections 3 and 4 require greater user manipulation but are more versatile.
2. Check assembled data against Tables 5 and 6.
3. Table 3 gives data conventions.
4. If the data has not been plotted using Grapha, then use Grapha first.

1. SHADING AND HIDDEN LINE THREE-DIMENSIONAL PLOTS USING THE PACKAGE HIDE

This package is similar to Grapha in concept (Norton, 1979) but also contains shading and line hiding routines. However, two-dimensional plots are not available in this package because of computer space considerations. HIDE should only be used where Grapha is unsuitable since central processor unit time (CPU time) is considerably increased when using the line hiding options. Other differences in use are listed in Hide Table 1.

Four levels of access to this program are available and these differ in their requirement for user submitted information. The three levels are known as :-

"THREE-DIMENSIONAL HELP"

"STEREO HELP"

"HELP"

" " blank or complex plots.

For a given plot, the lowest option in the list capable of producing the required output should be used. A description for use follows.

Hide Table 2 lists the types of plot which are available in help or blank plots (three-dimensional and stereo help automatically select a plot type).

Hide Table 3 shows the conventions used for data submission under Hide.

For clarification of certain parameters, the user is referred to"A User's Guide to Ghost","3D plotting and contouring", "44MFT - A Guide to System Use" and "Hide - a line hiding package". Where difficulty may be encountered, a note is appended, e.g. (Ghost = gargs) for a debug option. Alternatively, Hide Table 7 lists the significance of all the named parameters and output messages.

The attention of the user is drawn to the following tables found at the end of this manual -

a) Hide Table 4. Additional facilities available for all Hide plots
b) Hide Table 5. Key to Hide Table 6.
c) Hide Table 6. Data entry checklists.
d) Hide Table 7. List of output messages and their meanings.

A line printer representation of plots is also given along with output. The first of these does not include any hidden line calculation, while subsequent plots are only included to indicate to the user that a plot has been produced as they are not a good representation of the plot produced.

2. USE OF HIDE "THREE-DIMENSIONAL HELP" OPTION

Little user control is given but output requiring annotation is produced with minimal user information requests. To use this option, the first card should read -

Card 1. "THREE-DIMENSIONAL HELP"

Card 2. Enter the number of data intervals on the X and Y axes as integer values. Also enter the number of graphs in the set.

Card 3. Enter data intervals for X and for Y axes

e.g 24 48 96

0 10 20 30

Card 4. Entry of data in grids (see Hide Table 3) -

X1Y1 -X1Yn

X2Y1 -X2Yn

X3Y1 -XnYn

e.g. 24 22 23 13

3 18 24 0

1 7 15 0

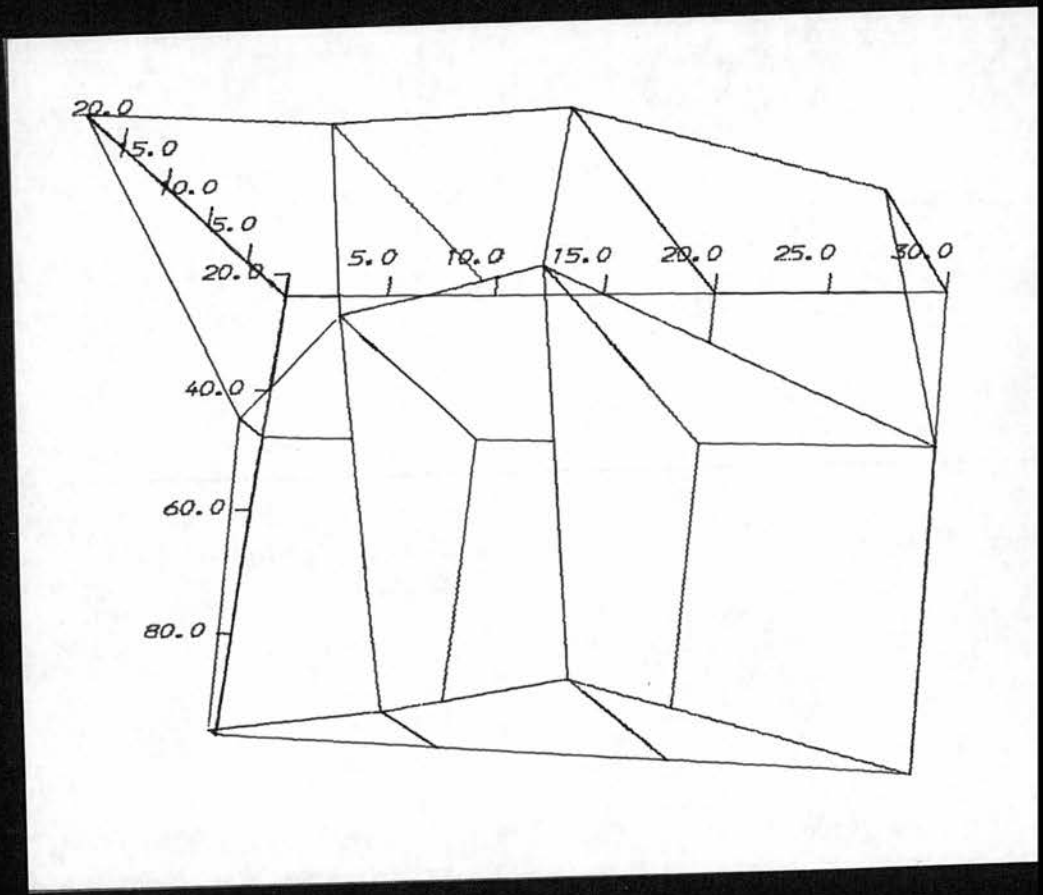
Card 5. onwards. Repeat Card 3 to number of graphs in set.

Example of data entry for Hide three-dimensional help

```
THREE-DIMENSIONAL HELP
3  4  1
24  48  96
0  10  20  30
24  22  23  13
3  18  24  0
1  7  15  0
```

Hide Figure 1.

Three-dimensional help plot with hidden lines omitted


20.0
15.0
10.0
5.0
20.0
5.0
10.0
15.0
20.0
25.0
30.0
40.0
60.0
80.0

3. USE OF HIDE-HELP PACKAGE

Card 1. A card to indicate help status should be entered initially.

e.g. HELP

Card 2. A numeric value for plot type should be entered (chosen from Hide Table 2).

e.g. 8.1

Card 3. Enter number of data intervals (see Hide Table 3) on both X and Y axes (two integer values).

e.g. 3 4

Enter number of graphs in set (all of the same plot type)(integer value).

e.g. 1

Card 4. Page heading. Enter a string of up to 80 characters for the page heading, otherwise enter a blank card.

e.g. RICE HELP

Card 5. Enter an individual title if specified in plot type.

Card 6. Enter maximum and minimum axis values for plot (6 real values) -

x axis minimum value x axis maximum value

y " " " y " " "

z " " " z " " "

e.g. 24 96 0 30 0 30

Card 7. The data intervals for the two-dimensional lattice forming the base of the plot should be entered (see Hide Table 3).

x1 x2 -xn e.g. 24 48 96

y1 y2 -yn e.g. 0 10 20 30

Card 8 onwards. Data. Enter data in X planes (integer or real) in order (see Hide Table 3) as -

x1 y1 x1 y2 --x1 yn

x2 y1 --x2 yn

xn y1 --xn yn

e.g. 22 23 23 29

12 23 23 29

24 22 27 21

Example of Hide-help

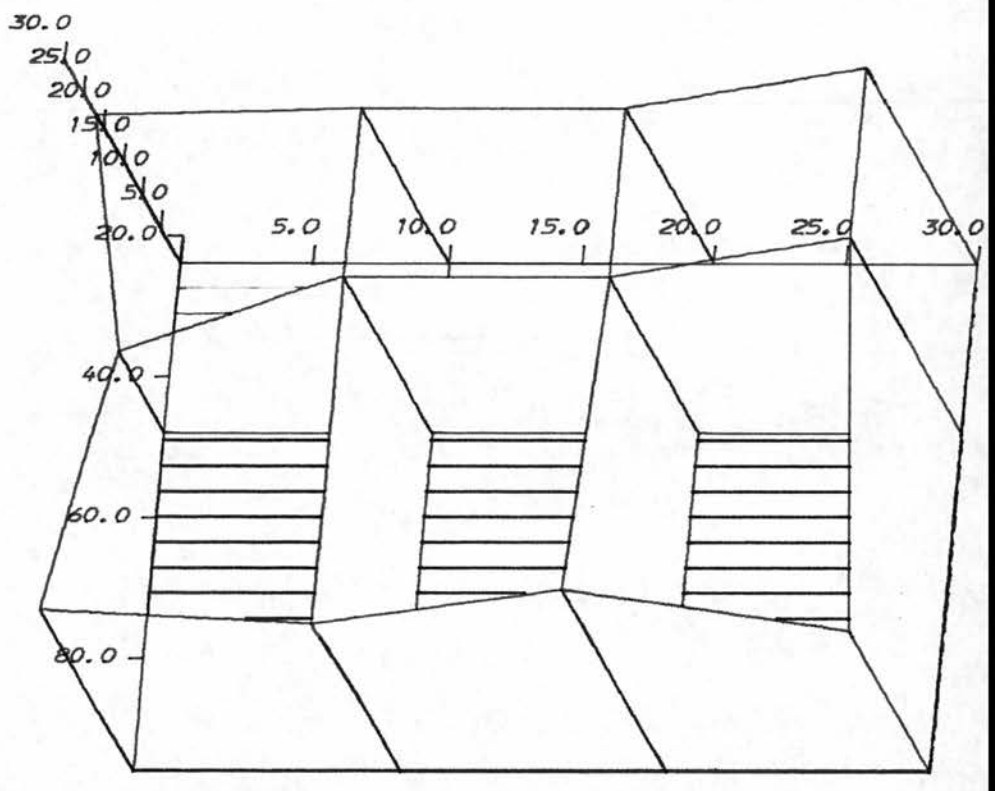
(Compare with Hide Figure 2)

```
HELP
8.1
3  4  1
RICE HELP
24  96  0  30  0  30
24  48  96
 0  10  20  30
22  23  23  29
12  23  23  29
24  22  27  21
```

Hide Figure 2.

A help plot using Hide

RICE HELP



4. HIDE COMPLEX PLOTS

Card 1. Several debugging options are available in Hide but only a limited debug output will be given unless the first card reads :- "DEBUGGING INFORMATION". In normal use, this option should not be required, while careful thought should be given before requesting a debug option since the output becomes excessive. (A further override and other debug options are available later in this program.) e.g. debugging information

Card 2. Blank card. This selects for complex plots eg blank card

Card 3. Enter an integer value for the number of types of plot in the current job.
e.g. 1

Card 4. Blank card. This sets the program to complex plot (recycling mode). e.g. blank card

Card 5. To set the type of plot, a value must be selected from Hide Table 2 and entered here (one real value).
e.g. 7.1

Card 6. Enter the number of data intervals on the X axis and the number of data intervals on the Y axis (two integer values) and the number of graphs in the set (one integer

value).

e.g. 5 4 1

Card 7. (optional) To pre-set character size, a card should be entered as follows :-

7a) "SIZESTATED"

followed by real values for each of the following (six real values) :-

7b)individual title size (centimetres);

X and Y co-ordinates for start of individual title ;

main title size;

X and Y co-ordinates for start of main title.

Card 8. Enter a line of text (or a blank card) for a page heading.

e.g. plot type 7.1 (hidden broken lines)

Card 9. (optional) For a plot made up of broken lines throughout, enter :-

9a) "BROKEN LINES"

or for a plot where the size of broken lines e.g. hidden lines is to be specified, enter :-

"BROKEN".

e.g. broken

9b) In either case, enter four real values for mark space ratio intervals.

e.g. 1 2 1 2

Card 10. For control over page size, plotter characters etc., enter "PAGESIZE", otherwise enter a blank card.

e.g. blank card

1. If "PAGESIZE" is entered, then enter nine integer values for :-

   underflow suppression

   initialize plotter

   turn plotter on/off

   units for plotting

   italic / non-italic characters

   debugging

   character set

   printing of frame number

   perspective control

   A full description of these can be found in "A User Manual for Grapha - a pre-programmed graphics package for the applied sciences". The value 1 will turn each of these parameters on, while the value 0 turns them off.

   Note that underflow suppression and plotter initialization should only be turned on once otherwise the job will fail.

   There are two major differences from Grapha.

   a) Perspective control allows for isometric

(1) or perspective (0)plots.

b) Additional debugging facilities are available. A value of 1, 11, 21, or 31 may be entered. The higher values give more information but since output becomes excessive, it is not recommended that these options are used. However, where they are selected, the output is normally self-explanatory (see Hide Table 7).

2. If "PAGESIZE"is entered above, then enter :-

four real values for page limits

width minimum value

width maximum value

height minimum value

height maximum value

(Ghost = limits)

3. If "PAGESIZE" is entered above, then enter four real values for two-dimensional graph space :-

width minimum value

width maximum value

height minimum value

height maximum value

(Ghost = pspace)

Card 11. For axis marking limits in two dimensions,

enter four values for mathematical space.
If in doubt, enter "0 0 0 0", otherwise
refer to "3D Plotting and Contouring".
(Ghost = mspace)
e.g. 0 0 0 0

Card 12. Graph width may be specified by entering a value (in centimetres). If text is required on the plot itself, add 200 to the width value. If this text is to be manipulated from two to three dimensions, add a further 300 to this value e.g. 200 + 300 + 10 = 510.
a) e.g. 210
b) enter graph height in centimetres
e.g. 10

Card 13. If an individual title has been specified in the plot type chosen, then enter the title here.
e.g. INDIVIDUAL TITLE

Card 14. (optional) Several object centres for a given plot are possible. Enter "2000" to use this facility.

Card 15. (optional) Axes may have a large letter X, Y or Z appended appropriately for identification purposes. Enter "1000" to use this facility.
e.g. 1000

Card 16. (optional) Alternating isometric and perspective plots may be given by entering

"999".

Card 17. Enter values for the object centre as three real values.

e.g. 3 2 10

Card 18. Enter graph plot size in three-dimensional space as follows :-

X minimum value (cms)(real or integer)
X maximum value "
Y minimum value "
Y maximum value "
Z minimum value "
Z maximum value "

(Ghost 3D = PSPC3D)

e.g. 5 15 5 15 5 15

Card 19. (optional) Where the pre-set shade density is unsatisfactory, another value may be substituted as follows. Enter "1001" and a value for density. e.g. "50".

Card 20. Enter axis limits for three-dimensional space as follows :-

X minimum axis marking
X maximum " "
Y minimum " "
Y maximum " "
Z minimum " "
Z maximum " "

(Ghost 3D = MSPC3D)

e.g. 1 5 1 4 0 20

Card 21. Enter number of data values on X axis (integer).

Enter number of data values on Y axis. "

(Hide Table 3)

e.g. 1 2 3 4 5

1 2 3 4

Card 22. Enter data grid as described in Hide Table 3 as follows :-

X1Y1 X1Y2 .....X1Yn

X2Y1 X2Y2 .....X2Yn

XnY1 XnY2 .....XnYn

Any number of new cards may be used.

e.g. 1 2 3 4

5 6 7 8

9 10 11 12

13 14 15 16

17 18 19 20

NEW VIEW

Card 23. (optional) Enter "999" if neither grids nor axes are required on the plot. Enter "998" if grids and axes are required followed by three integers. If any of the three integers = 1, then a grid will be drawn for that plane, viz. XY, XZ, YZ.

Enter "997.5" for axes to be drawn only where visible from the viewpoint (then

enter "100 100 100").

Enter "997" for grids to be drawn followed by three integer values as above.

Axes only given by default.

Card 24. Enter viewpoint co-ordinates (X, Y and Z)- V_1, V_2, V_3 (real values).

e.g. 10 10 50

Card 25. If centre 1 = 2000 (on last entry), then re-enter values for C.

If C_1 = 2000 again this option becomes available for the next plot.

If C_1 = 1000, then X, Y and Z will be appended to each axis for identification purposes.

If C_1 = 999, then alternating isometric and perspective plots will be given.

Several of the above values may be entered if they are entered in order of decreasing value. Enter three real values for centre.

Card 26. If a value greater than 500 was entered on Card 12 (width of graph), then text and text manipulation will be given. The following must be entered :-

1) either a value of zero or text as in Card 27 (text below plot).
2) character size for text on plot
3) number of lines of text on plot

4) read a line of text

5) enter "0 0"

6) enter X and Y co-ordinates in two-dimensional space for transformation to three-dimensional space

7) enter transformation values where

X = XT(1) * x + XT(2) * y + XT(3)

Y = YT(1) * x + YT(2) * y + YT(3)

Z = ZT(1) * x + ZT(2) * y + ZT(3)

as three real values for

XT(1-3)

as three real values for

YT(1-3)

as three real values for

ZT(1-3)

Card 27. If width was specified as more than 200 but less than 300, then enter text as follows (unless directed from Card 26) :-

1) Enter integer value for number of lines

e.g. 6.

2) Enter a line of text followed by real values for the X and Y co-ordinates for the start of this line of text.

e.g. any number of lines of text desiredfor example

5 14

3) Repeat 2) until the integer value entered

in 1) is reached.

Card 28. If stereo, repeat Cards 26 and /or 27.

Card 29. Enter a value greater than 1000 to stop the program or enter a value of 1000 to give a series of standard views of the object; otherwise return to NEW VIEW.
e.g. 1001

Example of use of Hide complex plot

(Compare with Hide Figure 3)

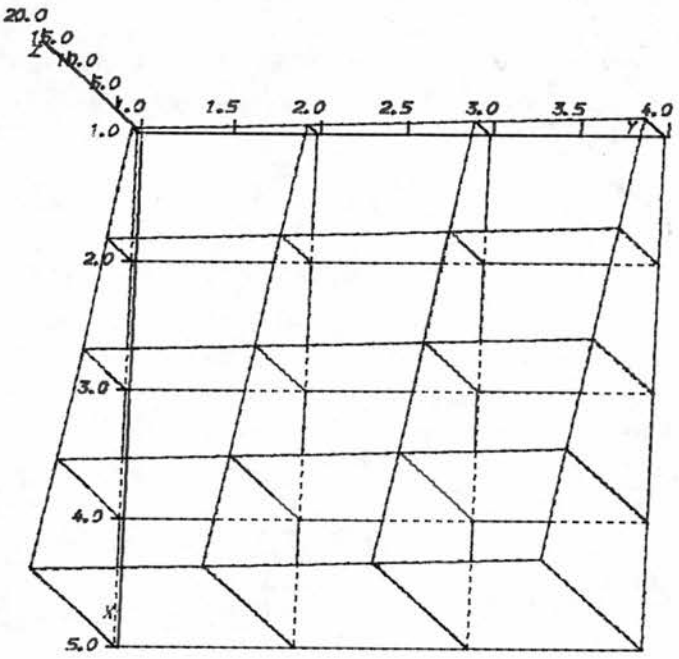
```
DEBUGGING INFORMATION

1

7.1
5  4  1
PLOT TYPE 7.1 (HIDDEN BROKEN LINES)
BROKEN
1  2  1  2

0  0  0  0
210  10
1000
3  2  10
5  15  5  15  5  15
1  5  1  4  0  20
1  2  3  4  5
1  2  3  4
1  2  3  4
5  6  7  8
9  10  11  12
13  14  15  16
17  18  19  20
```

```
10  10  50
6
 ANY NUMBER OF LINES OF TEXT DESIRED FOR EXAMPLE
5  14
 A LIST OF AXIS ANNOTATION MAY BE ENTERED AS FOLLOWS
5  13.3
 X = ONE HORIZONTAL AXIS, IN THIS CASE HOURS OF SOAKING
5  12.6
 Y = OTHER HORIZONTAL AXIS, HERE TAKEN AS TEMPERATURE OF
                                                    SOAKING
5  11.9
 Z = VERTICAL AXIS OR INDEPENDENT VARIABLE, IN THIS CASE
                                          GERMINATION OUT OF 30
5  11.2
 SEEDS.
5  10.5
1001
```

Hide Figure 3.

A complex plot using the hidden line package (Hide)

PLOT TYPE 7.1 (HIDDEN BROKEN LINES)



ANY NUMBER OF LINES OF TEXT DESIRED FOR EXAMPLE

A LIST OF XIS ANNOTATION MAY BE ENTERED AS FOLLOWS

X = ONE HORIZONTAL AXIS, IN THIS CASE HOURS OF SOAKING.

Y = OTHER HORIZONTAL AXIS, HERE TAKEN AS TEMPERATURE OF SOAKING.

Z = VERTICAL AXIS OR INDEPENDENT VARIABLE IN THIS CASE GERMINATION OUT OF 30 SEEDS.

Hide Table 1.

Major differences between HIDE and GRAPHA packages

1. Where a line hiding option is chosen, only one graph per page will be given regardless of graph size chosen. (That is to allow for the memory requirements for the hidden line points.)
2. It is recommended that the output from any job should be restricted to one graph because the plotter tape is produced in two separate stages. This means that an error in graph 7, for example, will cause graph 1 to fail on its second stage of computation - thus the whole job will fail.
3. In general, three-dimensional data prepared for Grapha will run under Hide although size of output may vary.
4. A number of additional plot types are available - see Hide Table 2.
5. Shading and shading density are under user control.
6. Character plotting in three-dimensional space is also available with rotational characters.
7. A pre-set for alternating isometric and perspective plots is available.
8. Access to the package is similar to Grapha i.e.

   passcard

   job card

```
//SYSRDR ACCESS CLOPT(HIDE)
/*
   data submitted as described below
/*
/*
/&
```

Note the addition of an additional /* before the termination card (/&). This card executes the line hiding part of the program.

Hide Table 2.

Plot type table for plots using Hide

3.1 three-dimensional graph

3.2 three-dimensional graph with titles overlaid

3.3 three-dimensional graph with sub-titles at foot of page

3.4 three-dimensional plot with titles overlaid and large axis markings

****

4.1 three-dimensional graph with dotted base lines

4.2 three-dimensional graph with dotted base lines and title

4.3 three-dimensional graph with dotted base lines and sub-titles

4.4 three-dimensional graph with dotted base lines and titles and large axis markings

****

5.1 three-dimensional graphs produced as stereo pairs

5.2 three-dimensional graphs produced as stereo pairs with titles

5.3 three-dimensional graphs produced as stereo pairs with sub-titles

5.4 three-dimensional graphs produced as stereo pairs with titles and large axis markings

****

6.1 three-dimensional graph with hidden lines omitted

6.2 three-dimensional graph with hidden lines omitted and with titles

6.3 three-dimensional graph with hidden lines omitted and with sub-titles

6.4 three-dimensional graph with hidden lines omitted and including titles and large axis markings

****

7.1 three-dimensional graphs with hidden lines dotted

7.2 three-dimensional graphs with hidden lines dotted and titles

7.3 three-dimensional graphs with hidden lines dotted and subtitl

7.4 three-dimensional graphs with hidden lines dotted and titles and large axis markings

****

8.1 three-dimensional graph with hidden lines omitted and base shaded

8.2 three-dimensional graph with hidden lines omitted, base shaded and titles

8.3 three-dimensional graph with hidden lines omitted, base shaded and subtitles

8.4 three-dimensional graph with hidden lines omitted, base shaded, title and large axis markings

****

9.1 to 11.3 similar to 6.1 to 8.3 but a stereo option is given

****

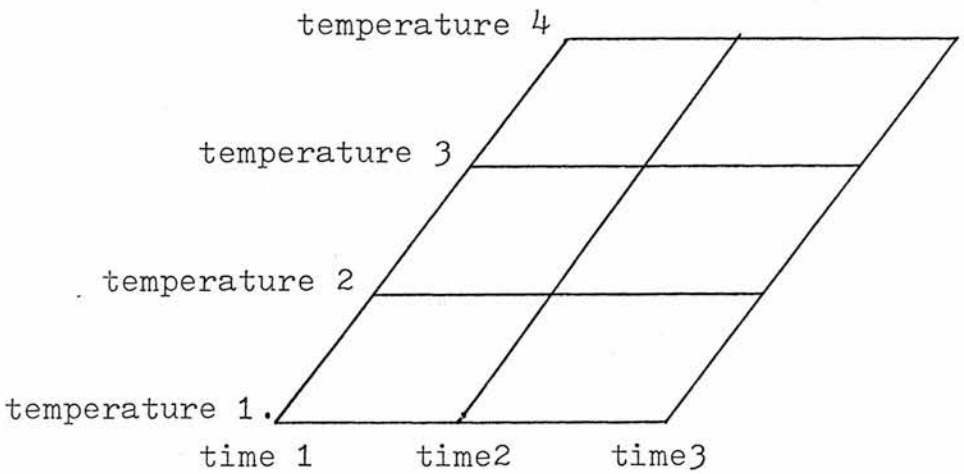
12.1 to 17.3 similar to 6.1 to 12.3 but the whole of the base of the figure is shaded regardless of viewpoint

****

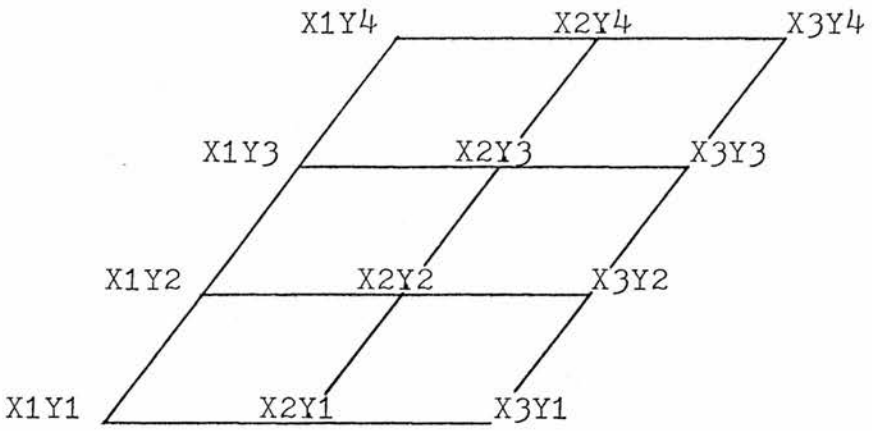
Hide Table 3.

Conventions adopted for three-dimensional data preparation

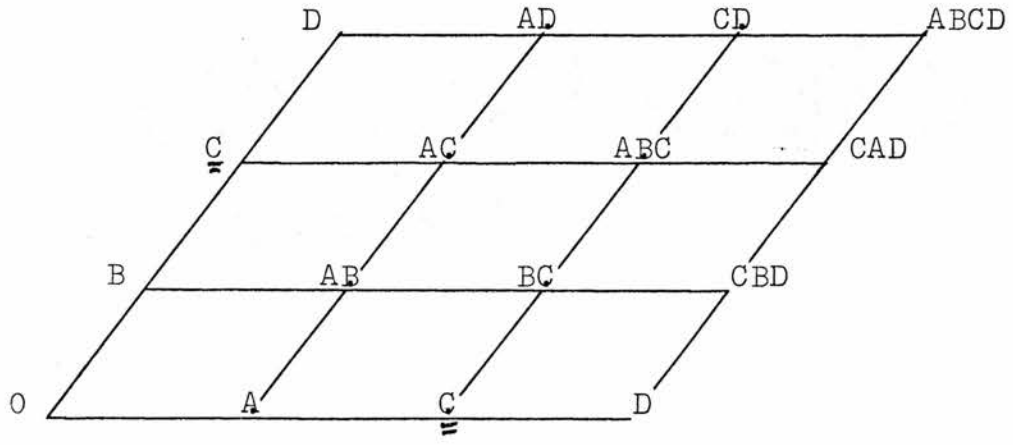
1. The two independent variables will be known as as X and Y and will be represented by the two horizontal axes in a three space co-ordinate system. The vertical or Z axis will be the dependent variable (or experimental result). It is recommended that, initially, the independent variables should be visualised as a two-dimensional co-ordinate grid. For example, an experiment with four temperature treatments and three duration treatments might be represented as follows :-



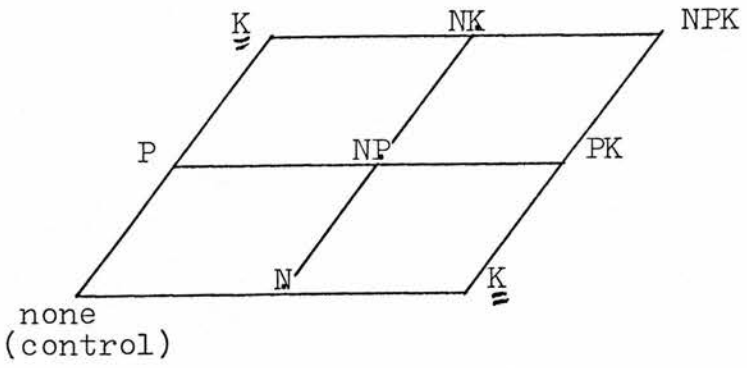
or



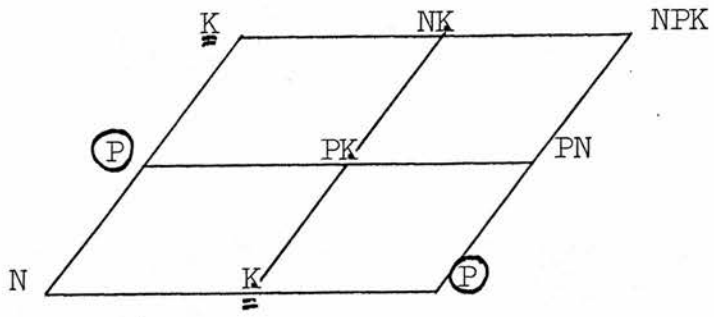
2. Any symmetrical data pattern may be represented in this way, while a non-symmetrical matrix may be made uniform by the substitution or repetition of values. In a fertilizer experiment, three fertilizers were used - nitrogen, potassium and phosphorus (abbreviated to N, P and K). These fertilizers were applied in all combinations. They could be represented as follows :-



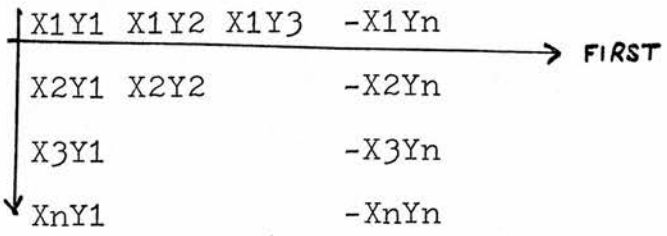
or



or

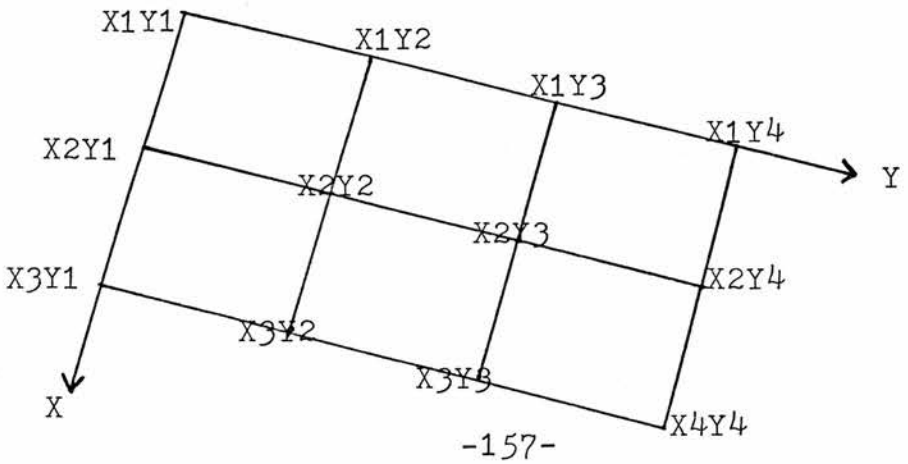


3. The data is then entered in order as :-



with a single data value (real or integer) for each co-ordinate pair.

4. Compare the following diagram with the data submitted -



X1Y1 = 4.2 X1Y2 = 3.5 X1Y3 = 2.1 X1Y4 = 0.9

X2Y1 = 3.5 X2Y2 = 3.0 X2Y3 = 1.8 X2Y4 = 0.7

X3Y1 = 3.0 X3Y2 = 2.0 X3Y3 = 1.1 X3Y4 = 0.3

X4Y1 = 1.9 X4Y2 = 0.8 X4Y3 = 0.7 X4Y4 = 0

Data entry sequence -

4.2 3.5 2.1 0.9

3.5 3.0 1.8 0.7

3.0 2.0 1.1 0.3

1.9 0.8 0.7 0

5. Data intervals. These are integer values for the number of points for which there are data values. This means the number of intervals on the X and on the Y axes. In the previous example, the integer values would be 3 and 4.

Hide Table 4

Additional facilities available for all Hide plots

Debugging information and recycling of the program

Any job may commence with one or more of the following conditional cards, provided that they are entered in the stated order if more than one condition is to be set.

a) DEBUGGING INFORMATION

The first card in the data set may read "DEBUGGING INFORMATION" in which case additional detail of plotter commands will be printed. This option should only be used when really necessary because many parameters internal to the program will be output, while their meaning will have little significance to the casual user.

b) A SET OF PLOT TYPES

Where a help option is chosen (blank options already include this option), recycling of the whole program may be given for a sequence of graphs of differing types. In this case, a blank card should be entered followed by a card with an integer value for the number of types of graph to be produced. Any plot type may be subsequently selected.

Hide Table 5

Key to Hide Table 6

+	= essential to include
-	= not to be included
+/-	= optional
1*	= one times
n*	= n times
string or s	= string of alphanumeric characters up to 80 units (i.e. one card)
integer or i	= an integer value
real or r	= a real value (i.e. with decimal points)
PURPOSE	= need for card entry
CONDITION	none = can be used for any option blank = blank or complex plot help = "help"or "three-dimensional help" or "stereo help"
NECESSARY	= whether program will fail if supplied/ not supplied
TYPE OF ENTRY	= type of information called for by program
DEPENDENT CARDS	= other cards which must be entered after first
OTHER NOTES	= e.g. C1, C2, C3, V1, P1 etc. see abbreviations list

Hide Table 6.

Data checklist for Hide plots (with hidden lines)

PURPOSE	CONDITION	NECESSARY	TYPE	ENTRY	NOTES
Debug	none	+/-	1*s	"DEBUGGING INFORMATION"	
Complex plots		+	1*s	" "	Enter a blank card.
Number of graph types	blank plots	+	1*s	"1*i"	Enter number of graph types.
Problem	all	+	1*s	"THREE-DIMENSIONAL HELP" "STEREO HELP" "HELP" " "	
Plotype	help or blank plots	+	1*r	"value taken from table"	
Points on X and Y axes	all	+	2*i	"number points X axis" "number points Y axis"	
Graphs in set (one plotype)	all	+	1*i	"number graphs in set"	

RESTART

Hide Table 6 continued

PURPOSE	CONDITION	NECESSARY	TYPE	ENTRY	NOTES
Omit frame	help or blank plot	+/-	1*s	"NO BORDERS"	optional
Character size option	help or blank plot	+/-	1*s 6*i	"SIZESTATED" "individual title size, X,Y co-ordinates for start, main title size, X,Y co-ordinates"	optional
Page heading	help or blank plots	+	1*s	"PAGEHEADING"	may be blank
Broken line setting	blank plots	+/-	1*s 4*r	"BROKEN LINES" or "BROKEN" "mark-space ratio values"	optional - whole plot broken lines optional - part broken line plots
Pagesize	blank plots	+	1*s 9*i and 4*i and 4*r	" " or "if anything"	then enter - for plotter characters etc. for limits and pspace
2D scale space	blank plots	+	4*r	"Mspace"	

Hide Table 6 continued

PURPOSE	CONDITION	NECESSARY	TYPE	ENTRY	NOTES
Text and graph width	blank plots	+	1*r		If greater than 300 sets for transformation of text on plot (width becomes width -300). If greater than 200 text option given (width = width -200). Values may be additive.
Graph height	blank plots	+	1*r		
Individual title entry	if specified in plot type	+	1*s	"title"	
Several centre plots	blank plots	+/-	1*r	"2000"	several plots of same data with different centres
Axis labelling	blank plots	+/-	1*r	"1000"	X, Y and Z appended to ends of appropriate axes
Isometric and perspective plots (alternating)	blank plots	+/-	1*r	"999"	gives two plots of each data set (isometric and perspective plots)
Centre for plotted data	blank plots	+	3*r	"centre 1-3"	

Hide Table 6 continued

PURPOSE	CONDITION	NECESSARY	TYPE	ENTRY	NOTES
3D plotting space (cms)	blank plots	+	6*r	"pspace3D 1-6"	
Shade density	help or blank plots	+/-	1*r	"1001"	then enter density of shading 1*r
3D axis marking	help or blank plots	+	6*r	"mspace3D 1-6"	
Data	all plots			X axis data intervals Y axis data intervals	
Data grids				X plane 1 as X1Y1 to X1Yn X plane 2 as X2Y1 to X2Yn until X plane n as XnY1 to XnYn	
NEW VIEW Axes and grids (optional)	blank plots	+/-	1*r	"999" "998" "997.5" "997"	No grids or axes Grids and axes Axes partly hidden if behind planes plotted Grids only No entry gives axes only
Grid plane	if "998" or "997" entered on previous card	+	3*i	e.g. "0 1 0"	Grids drawn where 1 given thus XY,XZ,YZ planes

Hide Table 6 continued

	PURPOSE	CONDITION	NECESSARY	TYPE	ENTRY	NOTES
	Axis hide	if "997.5" entered on previous card	+	3*1	"100 100 100"	
	Viewpoint	blank plots	+	3*r	"view 1-3"	
only if 2000 entered earlier	Several centre plot	if several centre entered on earlier card i.e."2000"	+	1*r	"2000"	several centre plot
only if 2000 entered earlier	X, Y and Z axis labels	if "2000" on previous card	+/-	1*r	"1000"	X, Y and Z axis labels
only if 2000 entered earlier	Isometric/ perspective plots	if "2000" or "1000" on previous card	+/-	1*r	"999"	alternating isometric and perspective plots
only if 2000 entered earlier	Centre	if "2000" or "1000" or "999" on previous card	+	3*r	"centres 1-3"	
	Transformed text overlay	if width greater than 300 on earlier card	+	1*r	"character size of transformed overlay"	

Hide Table 6 continued

PURPOSE	CONDITION	NECESSARY	TYPE	ENTRY	NOTES
Text entry	if width greater than 200 on earlier card	+	1*i 1*s 2*r	"number of lines of text" "string of text" "X, Y co-ordinates for text"	Repeat text and co-ordinates until number of lines of text reached. If X=0 then transform as below.
Repeat until number of lines of text reached					
Text size	if width = 100	+/-	1*i	enter character size and width	
Transform text to 3D	if X = 0 above	+	2*r	"points for title-to-base transformation on"	
			9*r	"XT(1-3), YT(1-3), ZT(1-3)"	see"3D Plotting and Contouring"
Note: if stereo, then repeat all of the above section.					
New view or stop or GO TO NEW VIEW	blank plots	+	1*r or 1*r	"1000" "1001"	standard views given then stops stops program
Recycle whole program	if number of graph types (where specified) not yet reached		THEN GO TO RESTART		

Hide Table 7

List of output messages with their meanings

(refer to manual "Grapha - a pre-programmed graphics package for the applied sciences" for messages not included here)

MESSAGE	SIGNIFICANCE
area X	- number of area of plot currently being handled [1]
CPU time	- central processor unit time used up to this point[1]
endar	- end of description or definition of current area[1]
ignall	- previous area definitions all ignored at this point[1]
ignore X	- previous definition of area X ignored[1]
normal	- return line hiding package to normal state[1]
notrn	- return two to three dimensional character transformation to normal state[2]
opaque X	- area X has been defined as opaque to further plotting[1]
sumopq	- all defined areas become opaque as one opaque area[1]
trnfrm	- transformation of two dimensional characters for three-dimensional plotting[2]
vector	- listing of vectors used in plot (e.g. the lines used in shading)[1]

1. "Hide - a line hiding package"
2. "3D plotting and contouring using Ghost"

REFERENCES

44Mft Guide to System Use. Technical Report. The University of St.Andrews Computing Laboratory.

Hide - a line hiding package. The University of St. Andrews Computing Laboratory Report.

Norton, C.R. 1979 A User Manual for Grapha - a pre-programmed graphics package for the applied sciences. The University of St. Andrews Computing Laboratory.

3D Plotting and Contouring. 1976 Software Memo 009, The University of St.Andrews Computing Laboratory.

A User's Guide to Ghost. Technical Report CL/73/2 The University of St.Andrews Computing Laboratory.

SECTION IV

THE GRAPH PLOTTING PACKAGES IN USE

CHAPTER 6

THE VERSATILITY OF THE PACKAGES

This chapter includes a number of figures illustrating the nature of output possible using the packages described. The figures produced are based, in the main, on biological experimentation by the author.

6.1 Two-dimensional graphs

An interesting feature of this package is the ability to block a number of graphs on to one page. Figures used to demark axes may be enlarged and plotted on the edge of the page only (Figure 6.01) and in combination with title integration for minimal overlay of the graphs (Figure 6.02). A series of titles (suba notation) may be appended at the foot of the page (Figure 6.03).

Alternatively, it may be desirable to block a number of figures on to one page while leaving a specified gap around each plot (Figure 6.04).

It is often useful to plot several graphs on to one output field. In this case, up to four graphs may be plotted using different plot formats (solid or broken lines, black or red colouration)(Figure 6.05).

Figure 6.01

Example of blocking of graphs on to one page using large axis markings (Grapha)

(Data for plot in Appendix Table 1)

SOAKING INJURY IN SEEDS

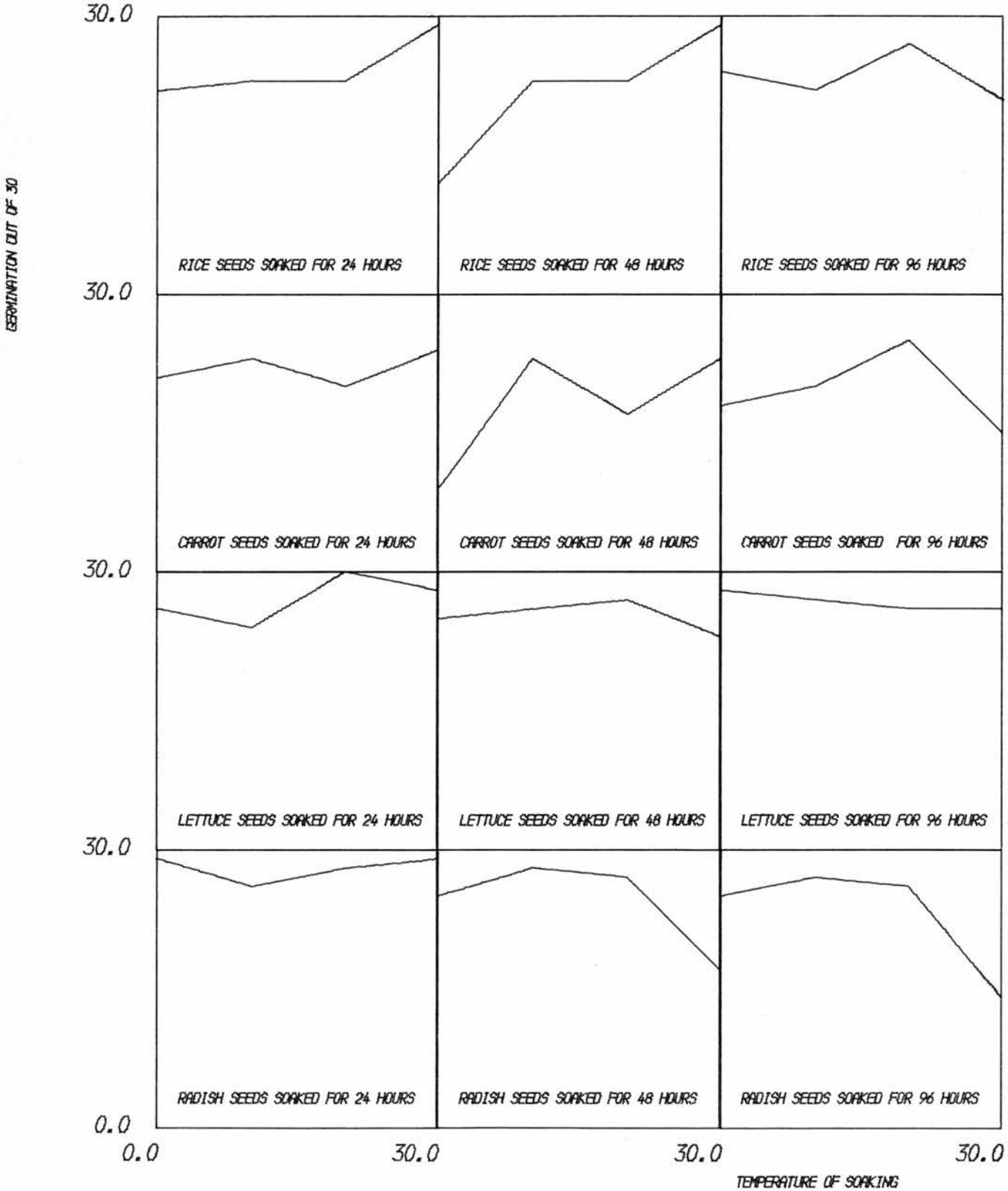
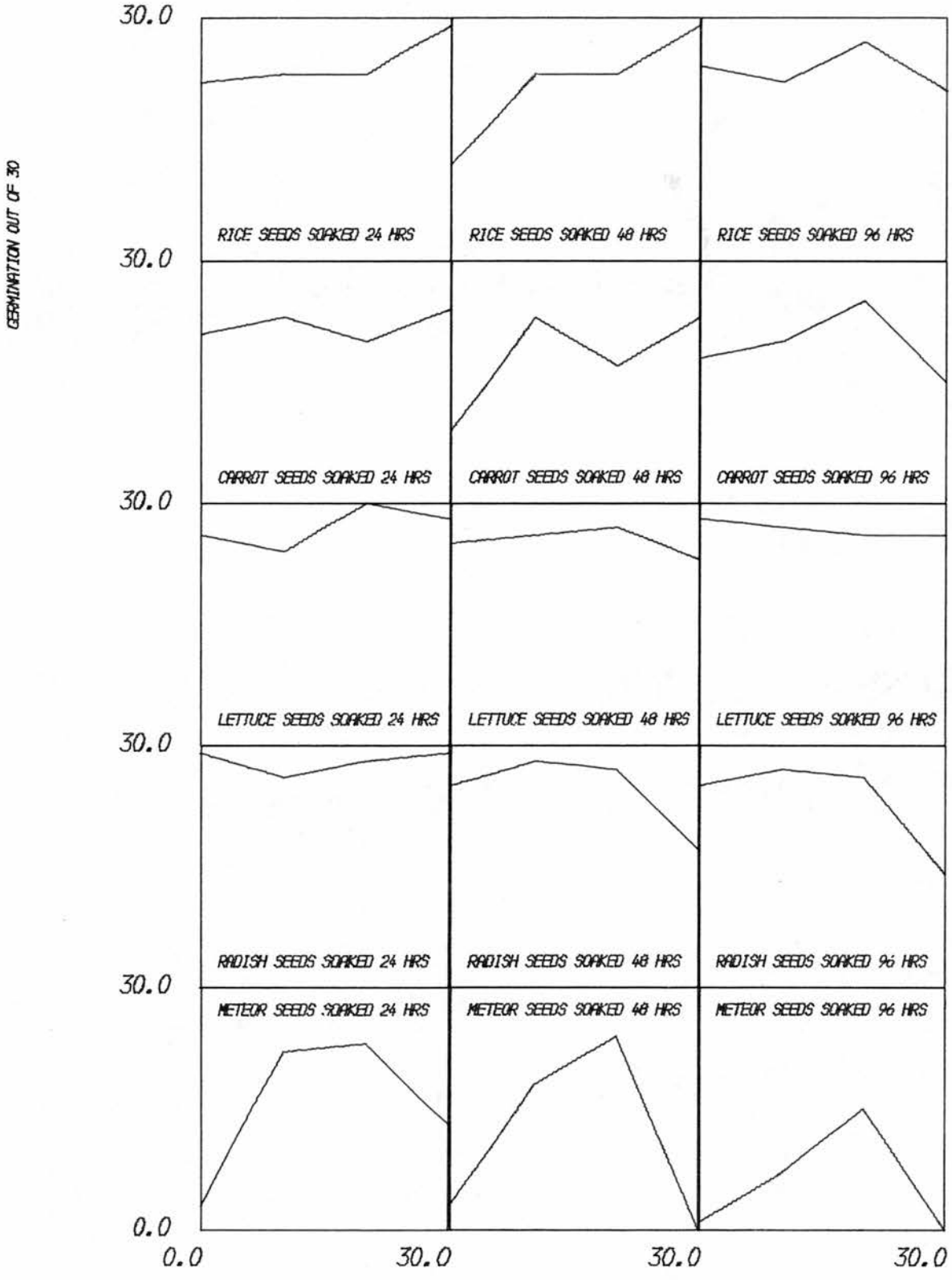


Figure 6.02

Use of integrated title option for minimal graph overlay by title (Grapha)

(Data for plot in Appendix Table 2)

PLOT TYPE 2.21



(Data for plot in Appendix Table 2.)

Figure 6.03

The sub-title option for a page of graphs (Grapha)

(Data for plot in Appendix Table 3)

Figure 6.03

The sub-title option for a page of graphs (Grapha)

(Data for plot in Appendix Table 3)

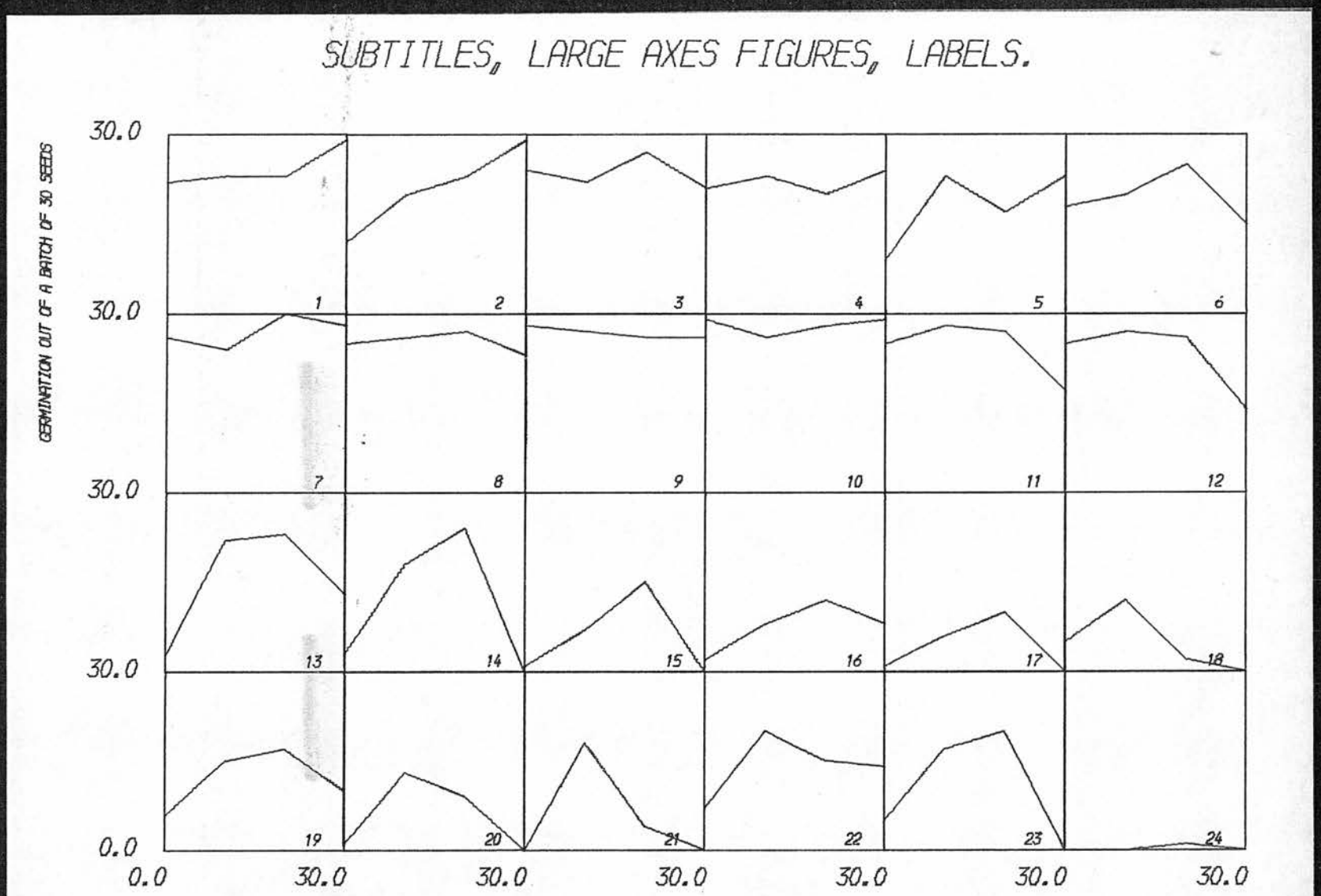


Figure 6.04

The spacing of graphs on a single page (Grapha)

(Data in Appendix Table 4)

spaces

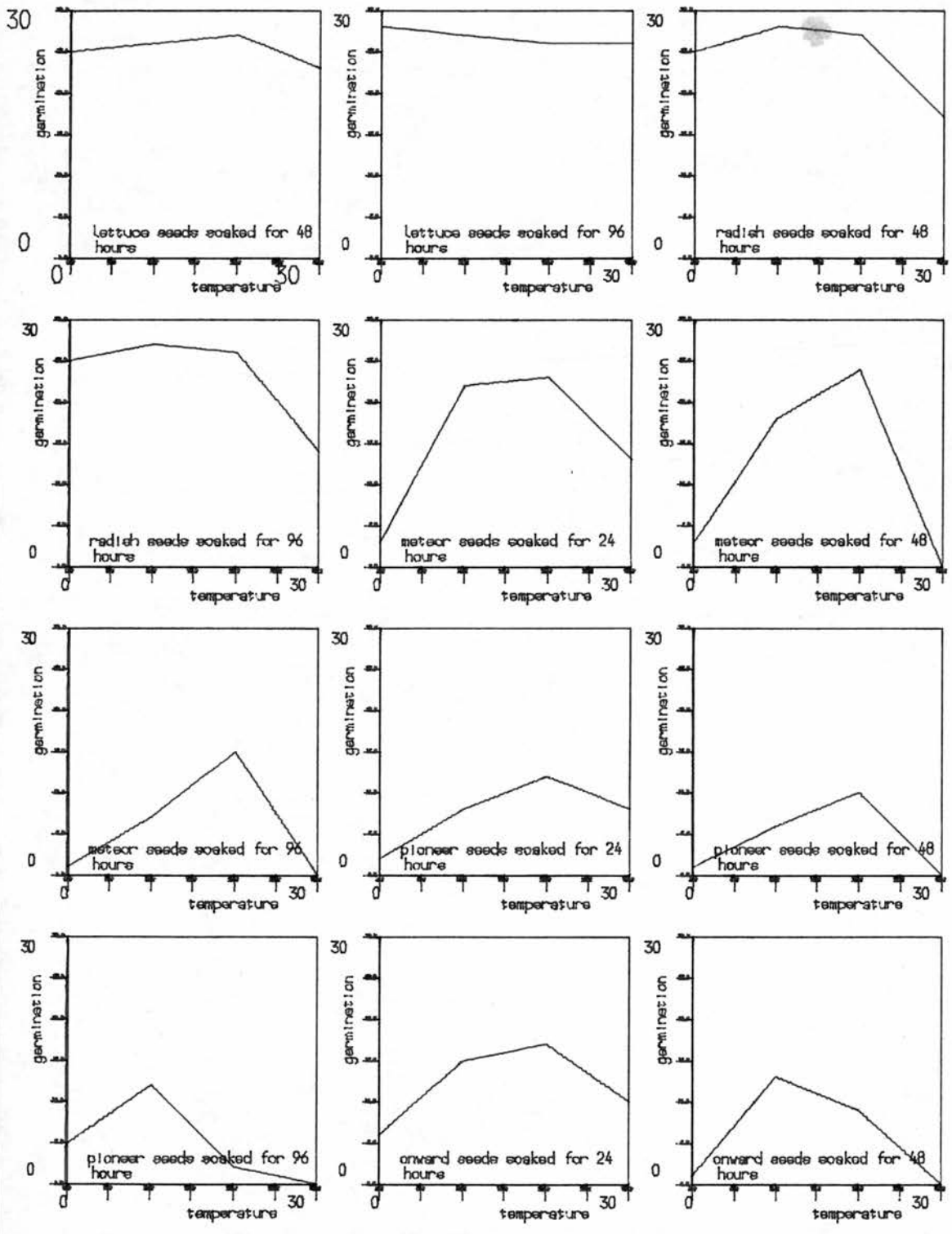
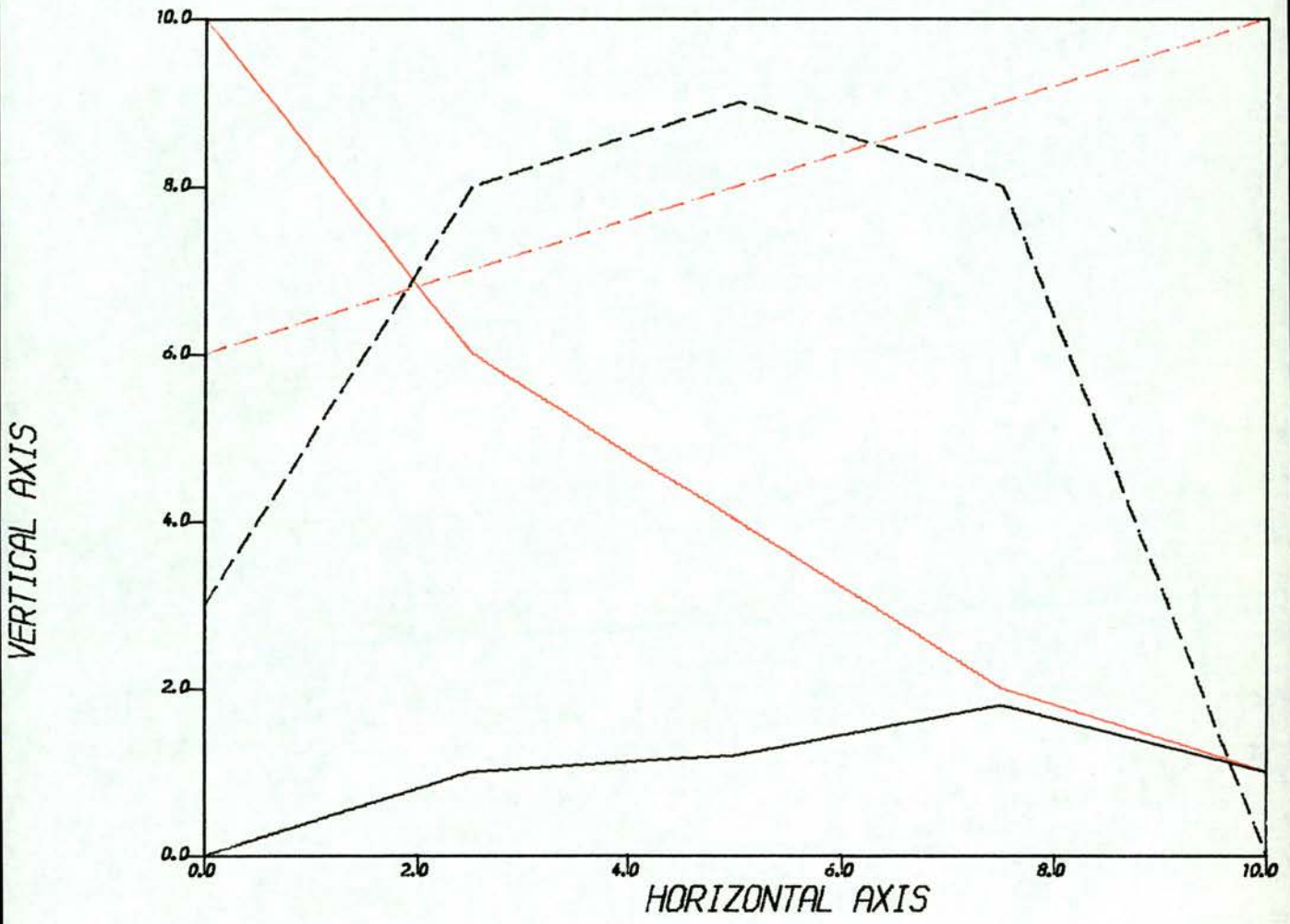

30
germination
0
lettuce seeds soaked for 48 hours
0
30
temperature
lettuce seeds soaked for 96 hours
radish seeds soaked for 48 hours
radish seeds soaked for 96 hours
meteor seeds soaked for 24 hours
meteor seeds soaked for 48 hours
meteor seeds soaked for 96 hours
pioneer seeds soaked for 24 hours
pioneer seeds soaked for 48 hours
pioneer seeds soaked for 96 hours
onward seeds soaked for 24 hours
onward seeds soaked for 48 hours

Figure 6.05

Multiple graph plotting on one output field (Grapha)

(Data for plot in Appendix Table 5)

SUPERIMPOSED GRAPH OPTION



BLACK LINE = GRAPH 1.

BLACK BROKEN LINE = GRAPH 2.

RED LINE = GRAPH 3.

RED BROKEN LINE = GRAPH 4.

6.2 Three-dimensional graphs

The relief of data plots may be heightened by using a broken line option for the base (comparatively economical of CPU time), while specification of a different pen colour will produce better relief (Figure 6.08).

Examples of the use of hidden line plots, base shading and dotted hidden lines are shown in Figures 6.07 to 6.10.

6.3 Stereo plots

Using the above techniques, 'apparent' depth may sometimes be difficult to visualise. However, the production of stereo pairs is straightforward using this package. A viewpoint separation similar to that of human eyes (6.5 cm) is calculated equally to either side of the user specified viewpoint (Figure 6.11).

Viewing of stereo pairs is possible using a pocket stereoscope. However, plotter inaccuracy (Figure 6.12) suggests that photographic reduction of stereo pairs is more feasible. Figures 6.13 and 6.14 illustrate larger scale stereo plots.

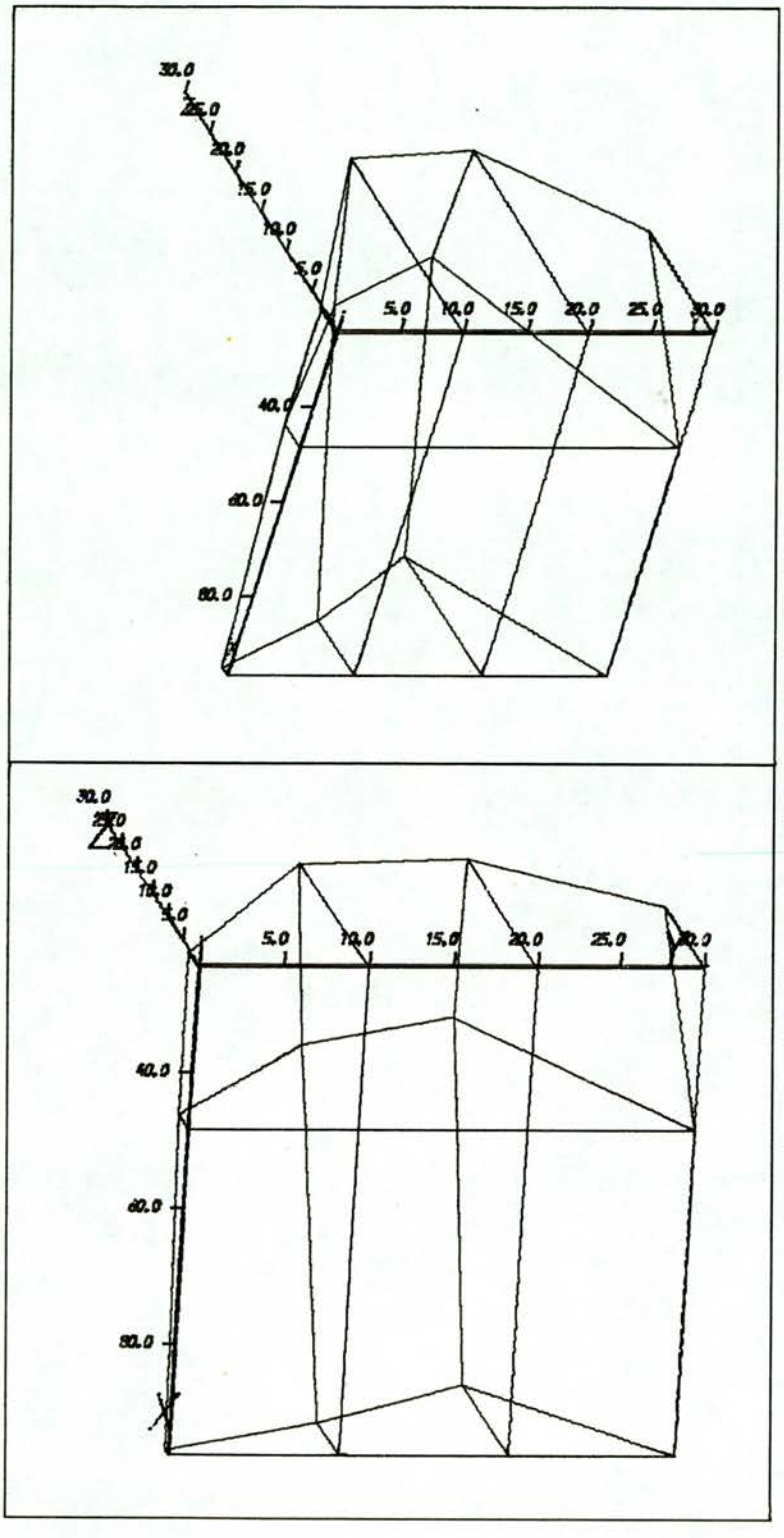
6.4 Mixed plots

Either package may be used to run a series of mixed plots, limited only by user time limit.

Figure 6.06

The use of alternative viewpoints for a three dimensional plot (Grapha)

3D PLOT OPTION



X= NUMBER OF HOURS OF SOAKING

Y= TEMPERATURE OF SOAKING

Z= GERMINATION OUT OF 30

Figure 6.07

Plotting without hidden lines (Hide)

(Data in Appendix Table 6)

PLOT 6.1 USING HELP OPTION

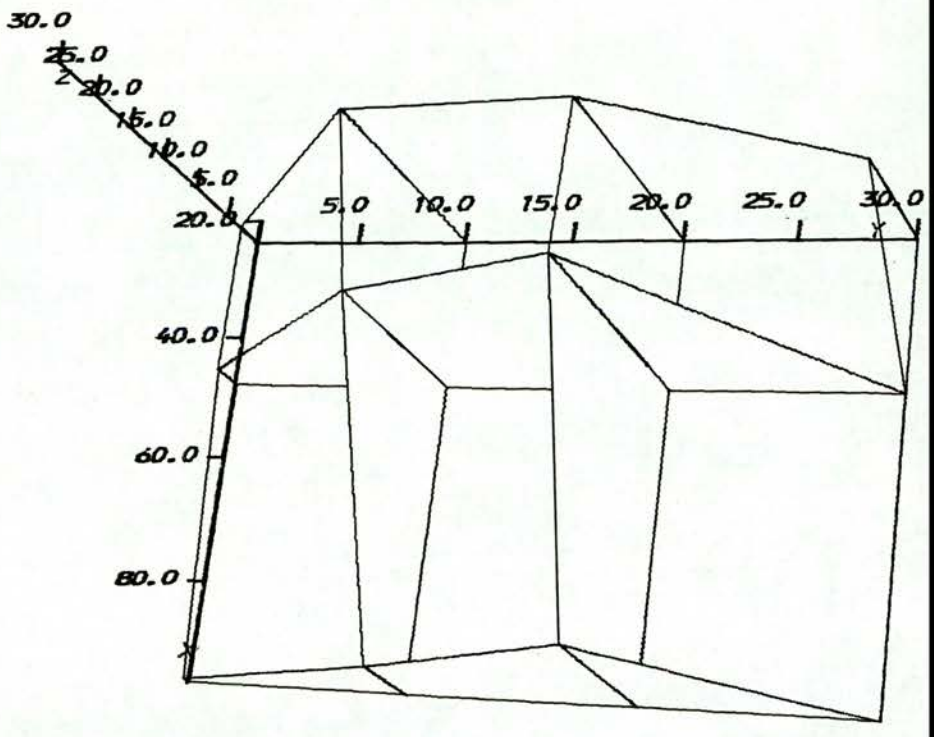
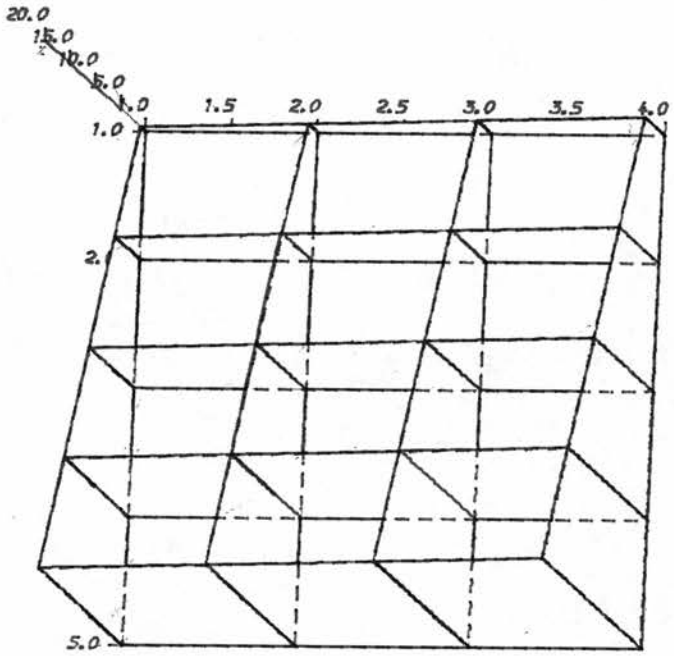


Figure 6.08

The use of broken hidden lines and a text option (Hide)

(Data in Appendix Table 7)

PLOT TYPE 7.1 (DOTTED LINES).



INDIVIDUAL TITLE

X = X AXIS LABEL.

Y = Y AXIS LABEL.

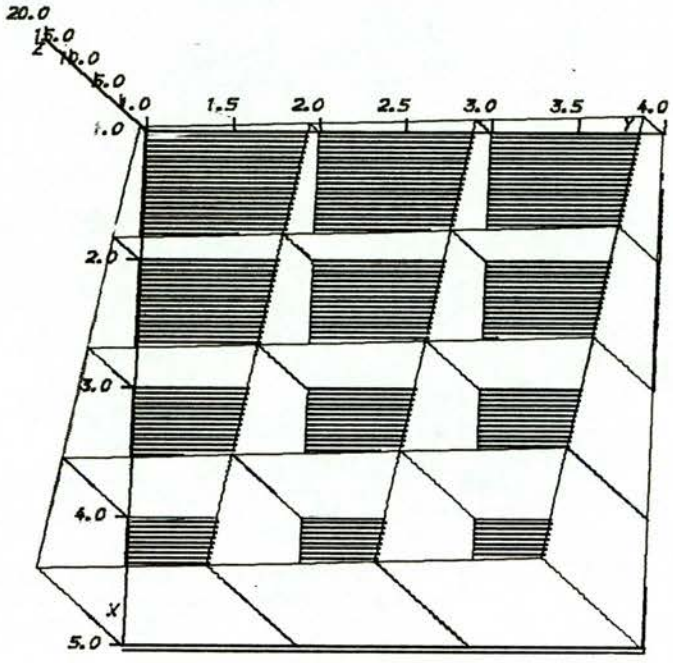
Z = Z AXIS LABEL

Figure 6.09

The use of a base shading option (Hide)

(Data in Appendix Table 8)

PLOT TYPE 8.3 WITH TEXT



1 HIDDEN LINES OMITTED

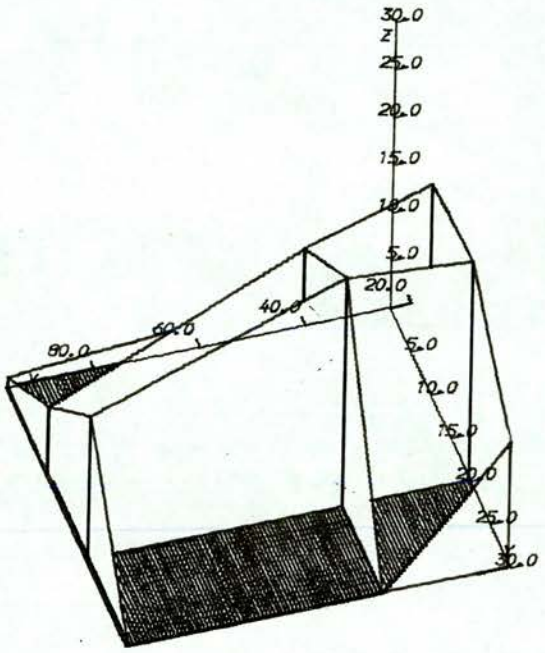
CNHIDE PACKAGE WITH TEXT

Figure 6.10

Oblique viewpoint and base shading in use (Hide)

(Data in Appendix Table 9)

3D PLOT OPTION



X= NUMBER OF HOURS OF SOAKING

Y= TEMPERATURE OF SOAKING

Z= GERMINATION OUT OF 30

Figure 6.11

Calculation of stereo viewpoints

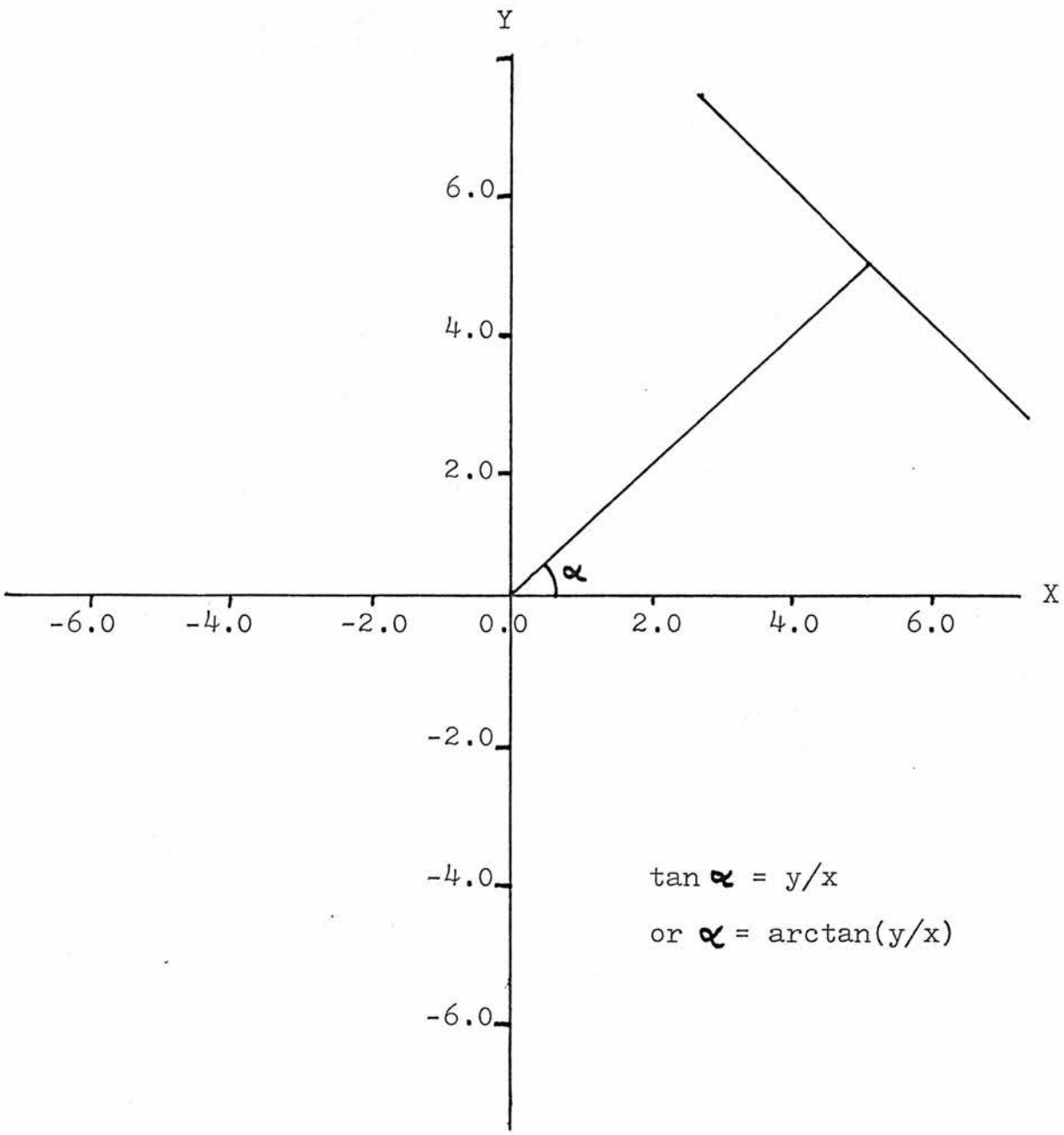
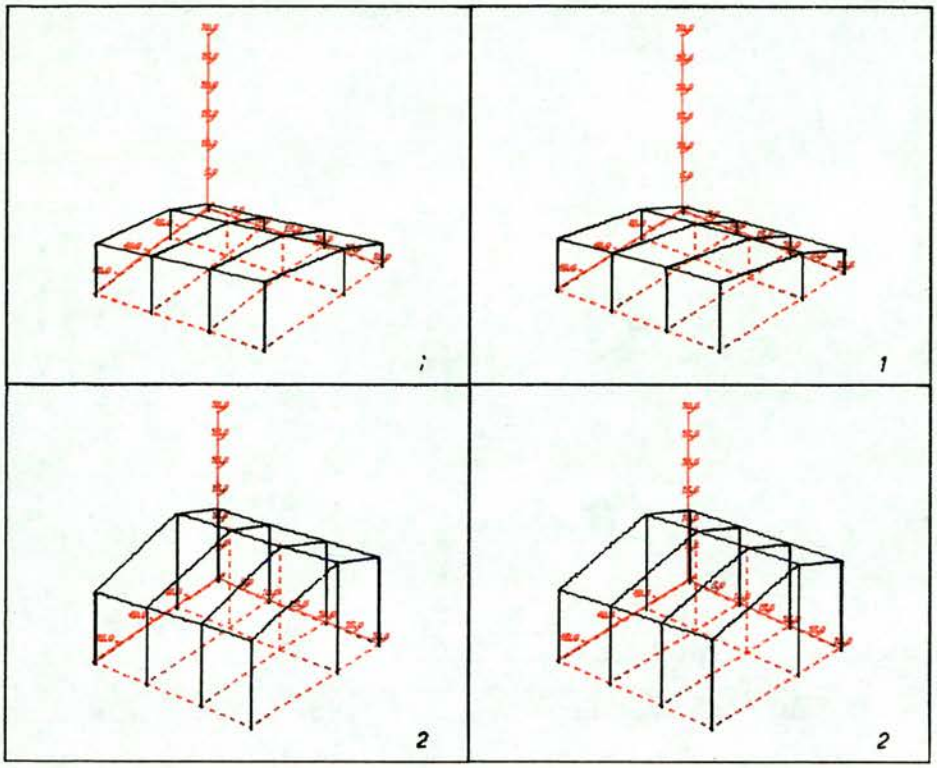


Figure 6.12

Plotter inaccuracy for small stereo plots (Grapha)

SUBTITLE OPTION

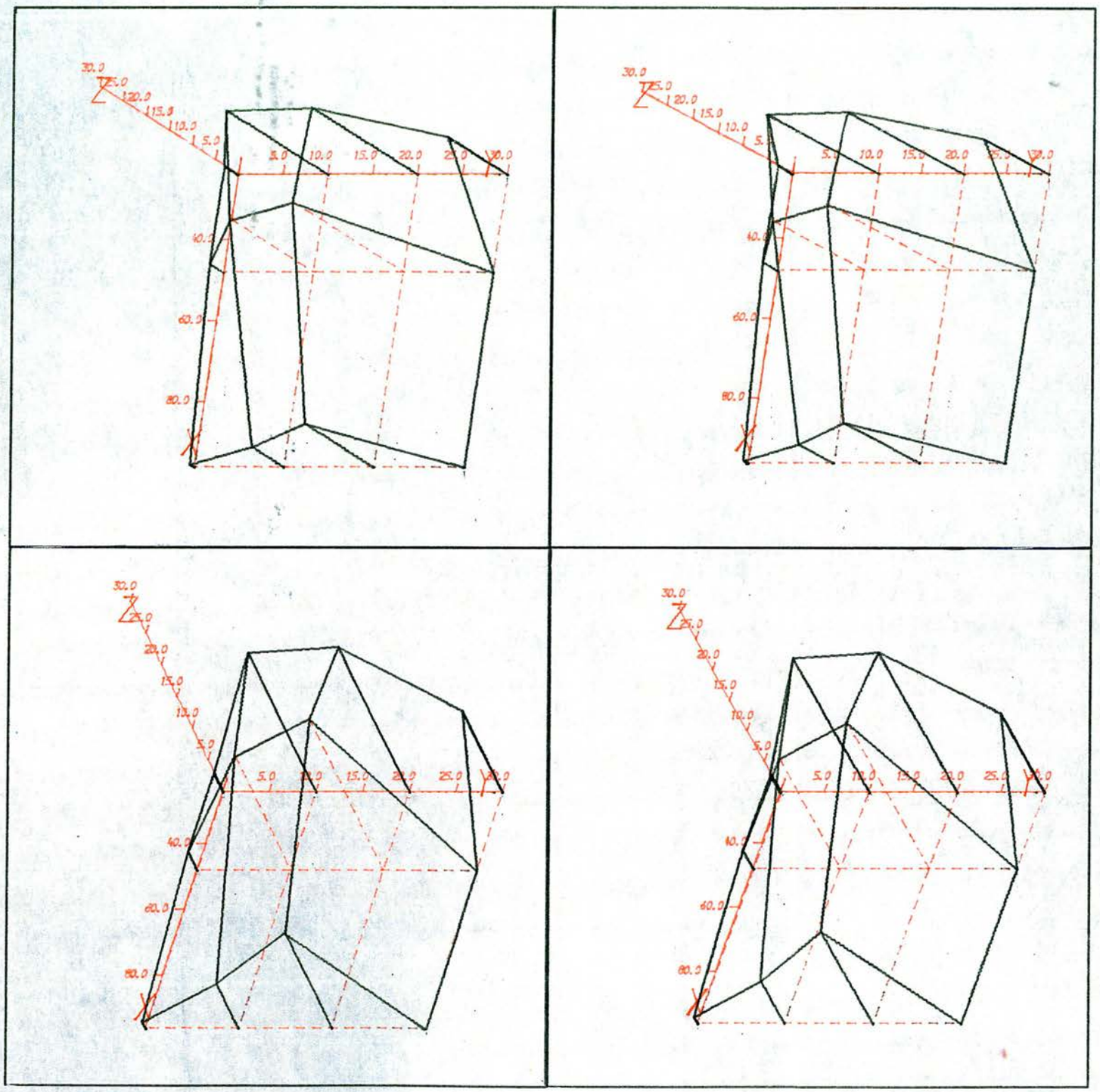


1 STEREO WITH SUBTITLES A.

Figure 6.13

Stereo pairs produced under Grapha

3 DIMENSIONAL BLOCK DIAGRAMS IN STEREO PAIRS.



X= HOURS OF SOAKING

Y= TEMPERATURE OF SOAKING

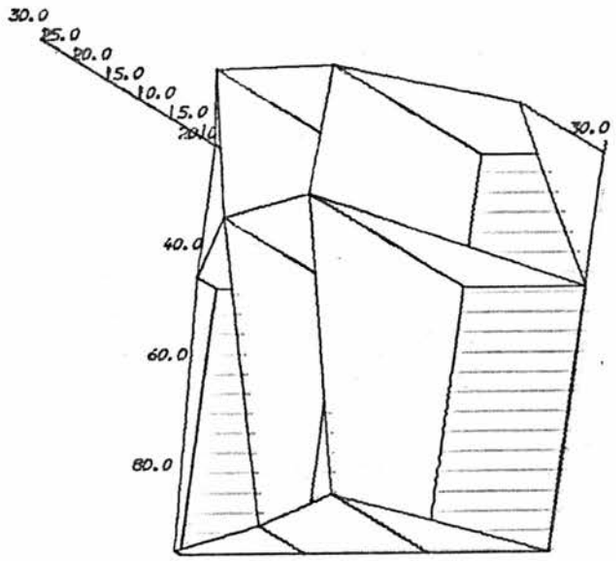
Z= GERMINATION OUT OF 30 SEEDS

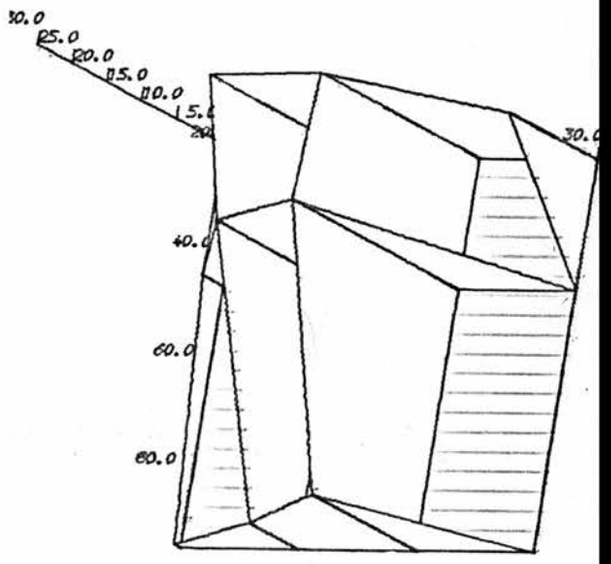
Figure 6.14

Stereo pairs produced under Hide

(Data in Appendix Table 10)

STEREO PAIRS OF 3D BLOCK DIAGRAMS.





X= HOURS OF SOAKING

Y= TEMPERATURE OF SOAKING

Z= GERMINATION OUT OF 30 SEEDS

6.5 Coloured plots

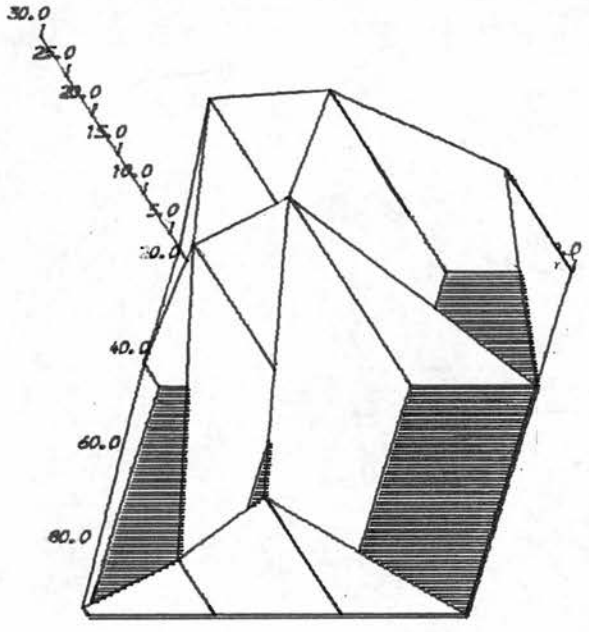
Specification of coloured inks for the plotter will automatically produce coloured plots. Figures 6.15 and 6.16 show the same plot in colour and in black and white. Figure 6.17 shows hidden axis marking with a red base shading, while Figure 6.18 shows the use of a coloured grid option.

Figure 6.15

Comparison of black and white with colour (Figure 6.16) plot (Hide)

(Data in Appendix Table 9)

3D PLOT OPTION



X= NUMBER OF HOURS OF SOAKING

Y= TEMPERATURE OF SOAKING

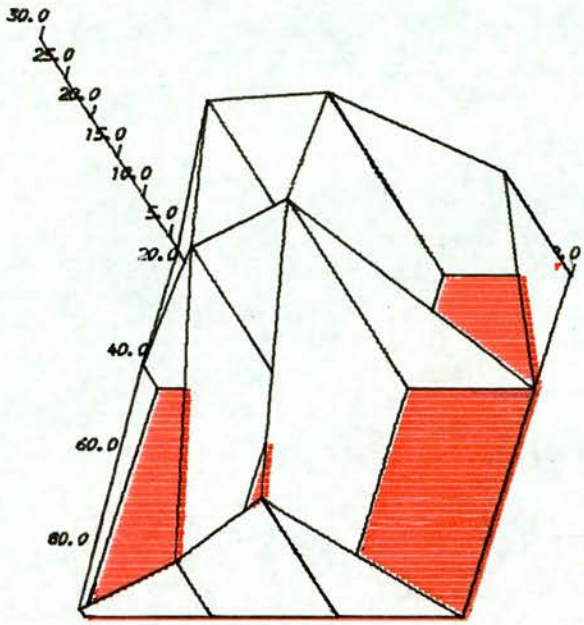
Z= GERMINATION OUT OF 30

Figure 6.16

Colour version of Figure 6.15 (Hide)

(Data in Appendix Table 9)

3D PLOT OPTION



X= NUMBER OF HOURS OF SOAKING

Y= TEMPERATURE OF SOAKING

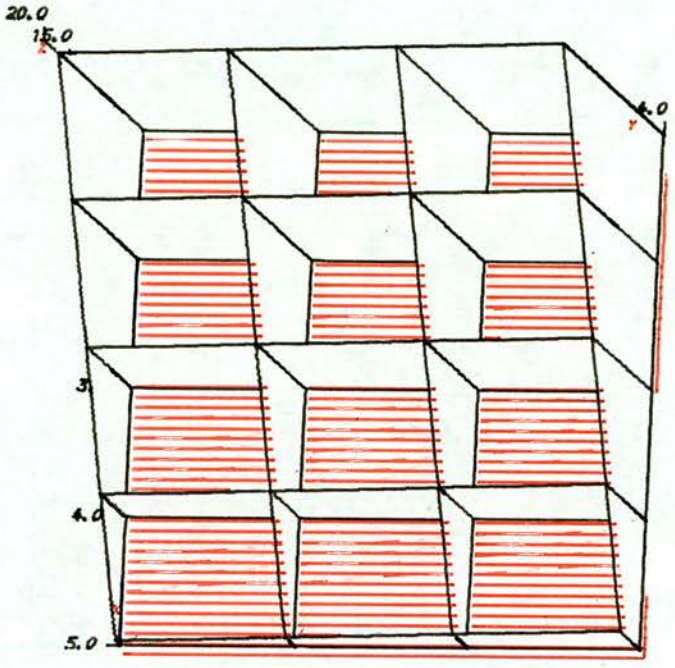
Z= GERMINATION OUT OF 30

Figure 6.17

Hidden axis marking and red base shading under Hide

(Data in Appendix Table 11)

PLOT TYPE 12.3 (SUBTITLES GIVEN).

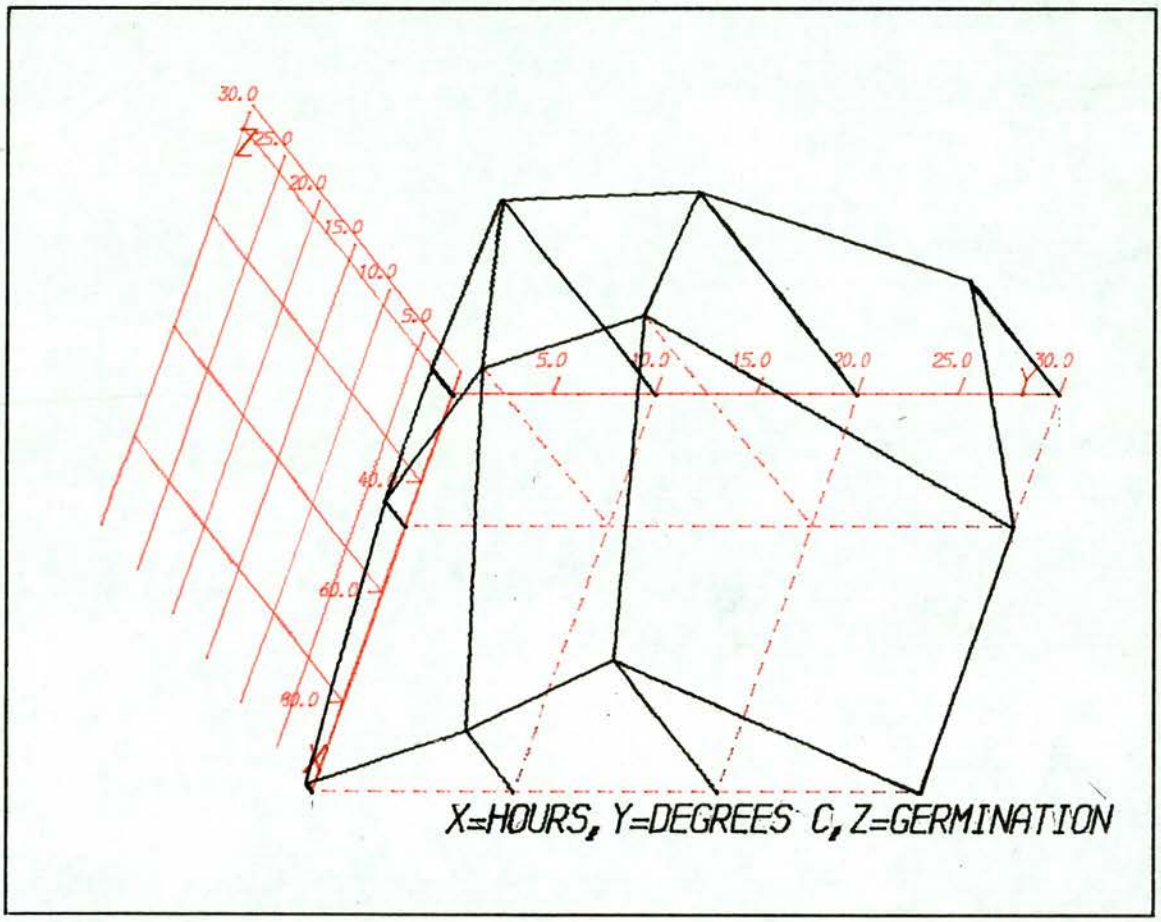


X=LABEL 1, Y=LABEL2, Z=LABEL3

Figure 6.18

The use of a coloured grid option (Grapha)

HELP PLOT WITH TITLES



CHAPTER 7

CONCLUSION TO THESIS

These packages have been instituted for use by non-programmers, but it may be argued, in view of the complex and varied nature of the plots possible, that the simple nature of the package has been lost. However, the first time user is able to use only those parts of the manual appropriate to his plot. The more advanced user may wish to make slight changes to the plot produced, without resorting to non pre-programmed plotting. It was therefore thought desirable to include as many options in the package as possible.

A number of plots have been produced by a biological user with no prior knowledge of programming or of computer usage. The first plot produced (using only the manual enclosed for guidance) is shown in Figure 7.01. Subsequent plots by the same user are given in Figures 7.02 to 7.04.

Data assembly for a simple plot (Figure 7.01) took approximately 15 minutes while card punching (demonstration given) took a similar length of time.

A cost-time analysis has also been produced (in relation to operation costs for the computational part of this work) for these packages. Table 7.1

Figure 7.01

A user produced plot (Grapha)

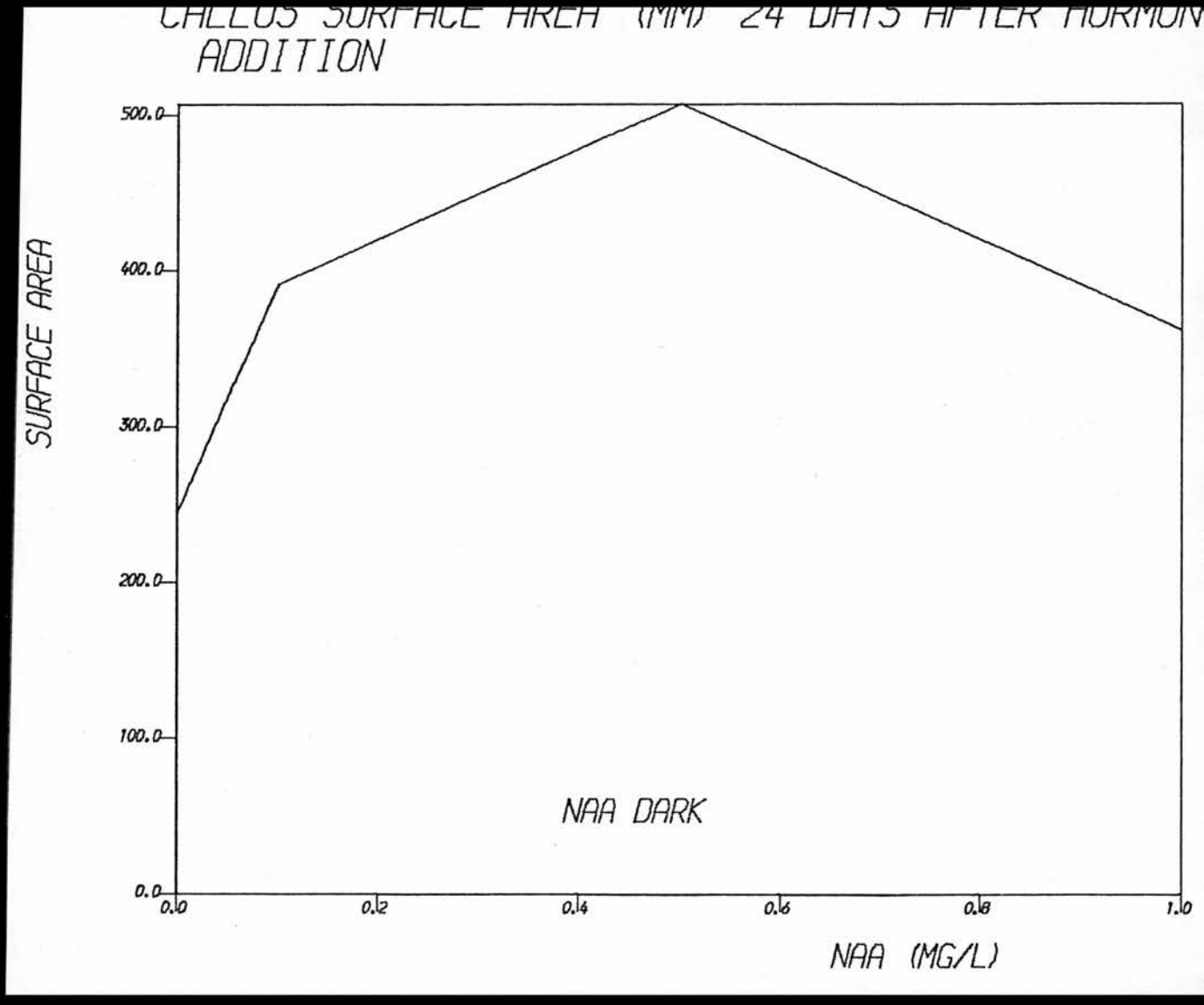

CALLUS SURFACE AREA (MM) 24 DAYS AFTER HORMON
ADDITION
SURFACE AREA
500.0
400.0
300.0
200.0
100.0
0.0
0.10
0.12
0.14
0.16
0.18
1.10
NAA DARK
NAA (MG/L)

Figure 7.02

A user produced three-dimensional plot (Grapha)

HORMONES AND CALLUS GROWTH RATE (2, 4-D AND KINETIN)

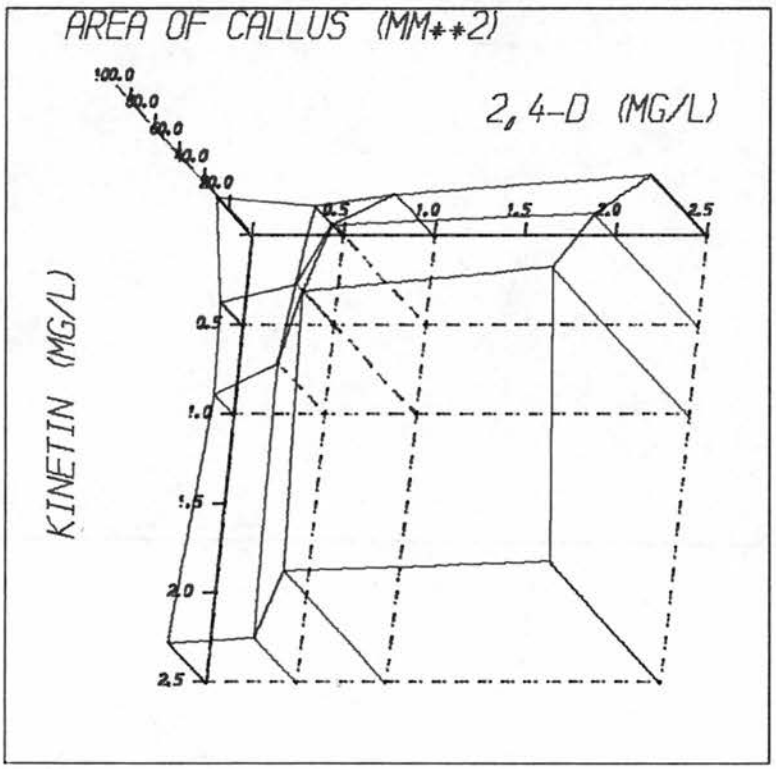


Figure 7.03

A user produced spaced plot (Grapha)

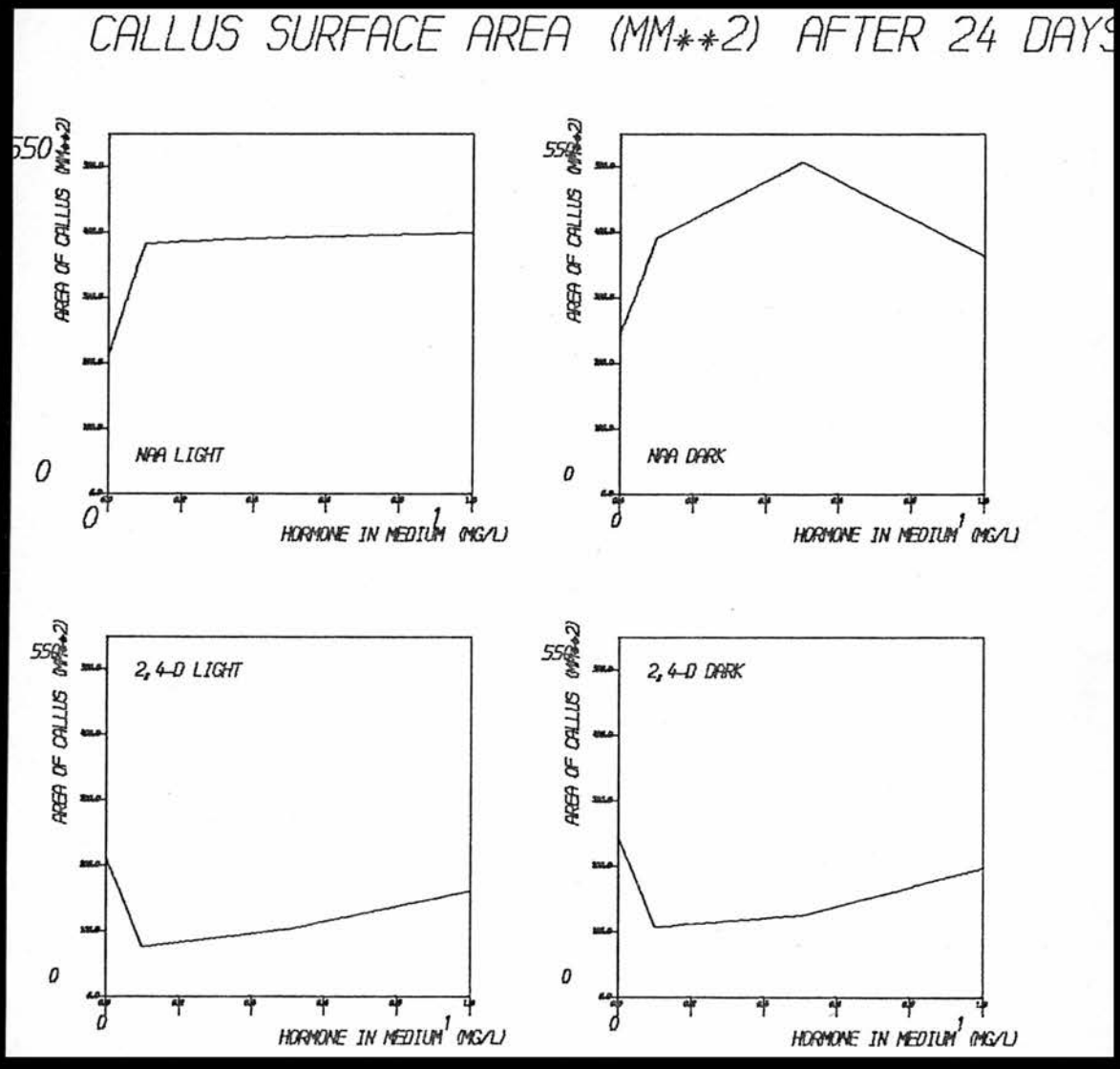
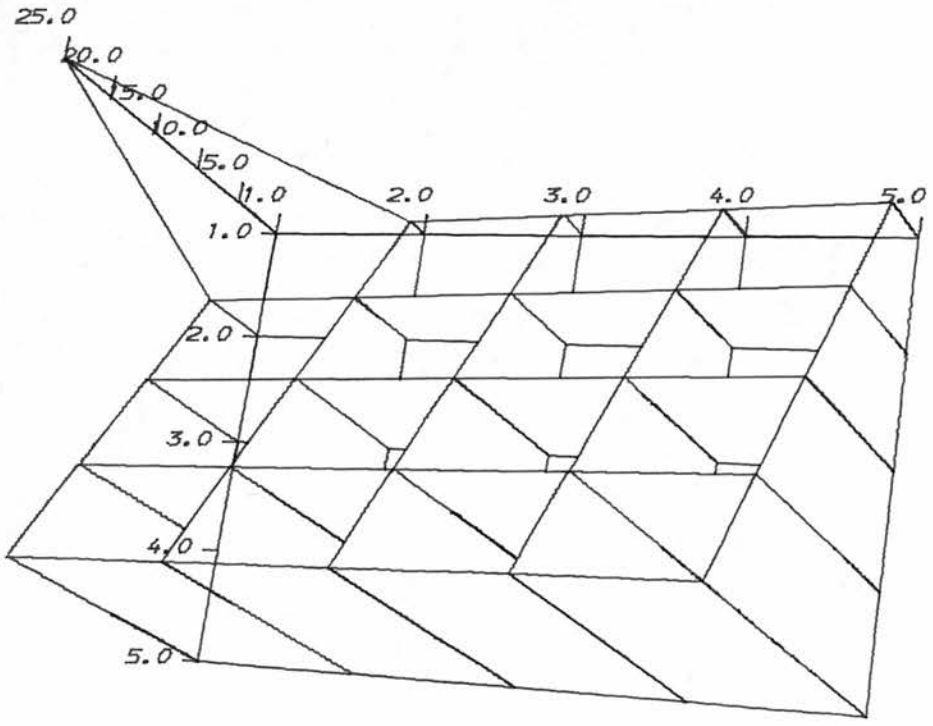

CALLUS SURFACE AREA (MM**2) AFTER 24 DAYS
550
AREA OF CALLUS (MM**2)
0
NAA LIGHT
0
1
HORMONE IN MEDIUM (MG/L)
550
AREA OF CALLUS (MM**2)
0
NAA DARK
0
1
HORMONE IN MEDIUM (MG/L)
550
AREA OF CALLUS (MM**2)
2,4-D LIGHT
0
0
1
HORMONE IN MEDIUM (MG/L)
550
AREA OF CALLUS (MM**2)
2,4-D DARK
0
0
1
HORMONE IN MEDIUM (MG/L)

Figure 7.04

A user produced hidden line plot (Hide)


25.0
20.0
15.0
10.0
5.0
1.0
2.0
3.0
4.0
5.0
1.0
2.0
3.0
4.0
5.0

lists the relative costs (based on the St.Andrews University Computing Laboratory costing system) and computer requirements for the figures used in this thesis run under Grapha. Table 7.2 lists similar information for plots run under Hide.

From these tables, it may be seen that almost any job run under Grapha mounts only insignificant costs. However, line hiding options rapidly multiply costs quite dramatically. Since plots of this type are very difficult to produce manually, this cost is thought to be justifiable.

Table 7.1

Cost-time analysis for plots using Grapha

Type of plot	Number of plots	Lines of text/ page	Matrix size	Debug option	CPU time used	Pages	Cost
GRAPHA							
Fig.1	1	0	4 points	-	0.06	5	21p
Fig.2	2	4	4 points	-	0.15	7	35p
Fig.3	1	4	4 points	+	0.10	6	26p
Fig.4	1(3)	0	4*3	-	0.13	9	35p
Fig.5	1(3)	2	4*3	-	0.26	9	50p
Fig.6	1	4	4*3	-	0.10	5	26p
CHAPTER 6							
Fig.6.01	3(27)	15	4 points	-	0.47	19	88p
Fig.6.02	2(27)	18	4 points	-	0.37	16	72p
Fig.6.03	2(27)	27	4 points	+	0.48	28	1.00
Fig.6.04	2(19)	37	4 points	-	1.19	14	1.19
Fig.6.05	1	7	5*4	-	0.10	5	26p
Fig.6.06	1(2)	4	3*4	-	0.14	5	32p
Fig.6.12	1	4	3*4	-	0.18	6	36p
Fig.6.13	1	4	3*4	-	0.26	5	44p
Fig.6.18	1(3)	2	4*3	-	0.29	9	52p
CHAPTER 7							
Fig.7.01	4	2	4 points	-	0.26	12	53p
Fig.7.02	3	0	4*4	-	0.18	9	40p
Fig.7.03	1(4)	13	4 points	-	0.19	6	37p

Table 7.2

Cost-time analysis for plots using Hide

Type of plot	Number of plots	Lines of text/ page	Matrix size	Debug option	CPU time used	Pages	Cost
HIDE							
Fig.1	4	0	4*3	-	2.06	13	2.17
Fig.2	4	1	4*3	-	5.41	13	4.84
Fig.3	1	7	4*5	-	1.20	7	1.63
CHAPTER 6							
Fig.6.07	4	1	3*4	-	2.06	13	2.35
Fig.6.08	1	5	4*5	+(21)	1.56	38	2.25
Fig.6.09	1	3	4*5	+(21)	3.36	45	3.51
Fig.6.10	2	4	4*3	+(21)	6.51	87	6.56
Fig.6.14	1	4	4*3	-	3.28	9	3.03
Fig.6.15	2	4	4*3	+(21)	6.51	87	6.56
Fig.6.16	1	2	5*4	+(21)	6.51	87	6.56
Fig.6.17	1	2	5*4	+(21)	2.51	40	2.88
CHAPTER 7							
Fig.7.04	4	0	5*5	-	5.55	14	4.91

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APPENDIX

Appendix Table 1.

Data used for Figure 6.01

(Note : Figure 6.01 includes the first 12 plots of a 27 plot series)

```
                .....(blank card)
1
LABELS
POINTS
13  5  2.93  19
                        TEMPERATURE OF SOAKING
              GERMINATION OUT OF 30
2.4
4  27
          SOAKING INJURY IN SEEDS
                .....(blank card)
0  30  0  30
5
5
RICE SEEDS SOAKED FOR 24 HOURS
0  22  10  23  20  23  30  29
RICE SEEDS SOAKED FOR 48 HOURS
0  12  10  23  20  23  30  29
RICE SEEDS SOAKED FOR 96 HOURS
0  24  10  22  20  27  30  21
CARROT SEEDS SOAKED FOR 24 HOURS
0  21  10  23  20  20  30  24
CARROT SEEDS SOAKED FOR 48 HOURS
0  9  10  23  20  17  30  23
CARROT SEEDS SOAKED FOR 96 HOURS
```

0 18 10 20 20 25 30 15

LETTUCE SEEDS SOAKED FOR 24 HOURS

0 26 10 24 20 30 30 28

LETTUCE SEEDS SOAKED FOR 48 HOURS

0 25 10 26 20 27 30 23

LETTUCE SEEDS SOAKED FOR 96 HOURS

0 28 10 27 20 26 30 26

RADISH SEEDS SOAKED FOR 24 HOURS

0 29 10 26 20 28 30 29

RADISH SEEDS SOAKED FOR 48 HOURS

0 25 10 28 20 27 30 17

RADISH SEEDS SOAKED FOR 96 HOURS

0 25 10 27 20 26 30 14

METEOR SEEDS SOAKED FOR 24 HOURS

0 3 10 22 20 23 30 13

METEOR SEEDS SOAKED FOR 48 HOURS

0 3 10 18 20 24 30 0

METEOR SEEDS SOAKED FOR 96 HOURS

0 1 10 7 20 15 30 0

PIONEER SEEDS SOAKED FOR 24 HOURS

0 2 10 8 20 12 30 8

PIONEER SEEDS SOAKED FOR 48 HOURS

0 1 10 6 20 10 30 0

PIONEER SEEDS SOAKED FOR 96 HOURS

0 5 10 12 20 2 30 0

ONWARD SEEDS SOAKED FOR 24 HOURS

0 6 10 15 20 17 30 10

ONWARD SEEDS SOAKED FOR 48 HOURS

0 1 10 13 20 9 30 0

ONWARD SEEDS SOAKED FOR 96 HOURS

0 0 10 18 20 4 30 0

GLADSTONE SEEDS SOAKED FOR 24 HOURS

0 7 10 20 20 15 30 14

GLADSTONE SEEDS SOAKED FOR 48 HOURS

0 5 10 17 20 20 30 0

GLADSTONE SEEDS SOAKED FOR 96 HOURS

0 0 10 0 20 1 30 0

BBEAN SEEDS SOAKED FOR 24 HOURS

0 7 10 13 20 4 30 12

BBEAN SEEDS SOAKED FOR 48 HOURS

0 10 10 14 20 1 30 1

BBEAN SEEDS SOAKED FOR 96 HOURS

0 6 10 3 20 2 30 0

Appendix Table 2.

Data used for Figure 6.02

(Note - the first 15 graphs are included in Figure 6.02 out of a 27 plot series.)

```
LABELS
POINTS
14  2.4  2.5  21
TEMPERATURE OF SOAKING
GERMINATION OUT OF 30

2.41
4  27
      PLOT TYPE 2.21

0  30  0  30
4  4
RICE SEEDS SOAKED 24 HOURS
0  22  10  23  20  23  30  29
RICE SEEDS SOAKED 48 HOURS
0  12  10  23  20  23  30  29
RICE SEEDS SOAKED 96 HOURS
0  24  10  22  20  27  30  21
CARROT SEEDS SOAKED 24 HOURS
0  21  10  23  20  20  30  24
CARROT SEEDS SOAKED 48 HOURS
0  9  10  23  20  17  30  23
```

CARROT SEEDS SOAKED 96 HOURS

0 18 10 20 20 25 30 15

LETTUCE SEEDS SOAKED 24 HOURS

0 26 10 24 20 30 30 28

LETTUCE SEEDS SOAKED 48 HOURS

0 25 10 26 20 27 30 23

LETTUCE SEEDS SOAKED 96 HOURS

0 28 10 27 20 26 30 26

RADISH SEEDS SOAKED 24 HOURS

0 29 10 26 20 28 30 29

RADISH SEEDS SOAKED 48 HOURS

0 25 10 28 20 27 30 17

RADISH SEEDS SOAKED 96 HOURS

0 25 10 27 20 26 30 14

METEOR SEEDS SOAKED 24 HOURS

0 3 10 22 20 23 30 13

METEOR SEEDS SOAKED 48 HOURS

0 3 10 18 20 24 30 0

METEOR SEEDS SOAKED 96 HOURS

0 1 10 7 20 15 30 0

PIONEER SEEDS SOAKED 24 HOURS

0 2 10 8 20 12 30 8

PIONEER SEEDS SOAKED 48 HOURS

0 1 10 6 20 10 30 0

PIONEER SEEDS SOAKED 96 HOURS

0 5 10 12 20 2 30 0

ONWARD SEEDS SOAKED 24 HOURS

0 6 10 15 20 17 30 10

ONWARD SEEDS SOAKED 48 HOURS

0 1 10 13 20 9 30 0

ONWARD SEEDS SOAKED 96 HOURS

0 0 10 18 20 4 30 0

GLADSTONE SEEDS SOAKED 24 HOURS

0 7 10 20 20 15 30 14

GLADSTONE SEEDS SOAKED 48 HOURS

0 5 10 17 20 20 30 0

GLADSTONE SEEDS SOAKED 96 HOURS

0 0 10 0 20 1 30 0

BEAN SEEDS SOAKED 24 HOURS

0 7 10 13 20 4 30 12

BEAN SEEDS SOAKED 48 HOURS

0 10 10 14 20 1 30 1

BEAN SEEDS SOAKED 96 HOURS

0 6 10 3 20 2 30 0

Appendix Table 3

Data used to plot Figure 6.03

(first out of a series of 27 plots)

```
LABELS
POINTS
17  11.7  3  18
        TEMPERATURE OF SEED SOAKING DEGREES C
                GERMINATION OUT OF A BATCH OF 30 SEEDS

2.3
4
27
          SUBTITLES, LARGE AXES FIGURES, LABELS.
PAGESIZE
0  0  1  1  1  1  1  1  1
0  30  0  30
5  25  5  25
0  30  0  30
3  3
RICE SEEDS SOAKED FOR 24 HOURS
0  22  10  23  20  23  30  29
RICE SEEDS SOAKED FOR 48 HOURS
0  12  10  20  20  23  30  29
RICE SEEDS SOAKED FOR 96 HOURS
0  24  10  22  20  27  30  21
CARROT SEEDS SOAKED FOR 24 HOURS
0  21  10  23  20  20  30  24
```

CARROT SEEDS SOAKED FOR 48 HOURS

0 9 10 23 20 17 30 23

CARROT SEEDS SOAKED FOR 96 HOURS

0 18 10 20 20 30 15

LETTUCE SEEDS SOAKED FOR 24 HOURS

0 26 10 24 20 30 30 28

LETTUCE SEEDS SOAKED FOR 48 HOURS

0 25 10 26 20 27 30 23

LETTUCE SEEDS SOAKED FOR 96 HOURS

0 28 10 27 20 26 30 26

RADISH SEEDS SOAKED FOR 24 HOURS

0 29 10 26 20 28 30 29

RADISH SEEDS SOAKED FOR 48 HOURS

0 25 10 28 20 27 30 17

RADISH SEEDS SOAKED FOR 96 HOURS

0 25 10 27 20 26 30 14

METEOR SEEDS SOAKED FOR 24 HOURS

0 3 10 22 20 23 30 13

METEOR SEEDS SOAKED FOR 48 HOURS

0 3 10 18 20 24 30 0

METEOR SEEDS SOAKED FOR 96 HOURS

0 1 10 7 20 15 30 0

PIONEER SEEDS SOAKED FOR 24 HOURS

0 2 10 8 20 12 30 8

PIONEER SEEDS SOAKED FOR 48 HOURS

0 1 10 6 20 10 30 0

PIONEER SEEDS SOAKED FOR 96 HOURS

0 5 10 12 20 2 30 0

ONWARD SEEDS SOAKED FOR 24 HOURS

0 6 10 15 20 17 30 10

ONWARD SEEDS SOAKED FOR 48 HOURS

0 1 10 13 20 9 30 0

ONWARD SEEDS SOAKED FOR 96 HOURS

0 0 10 18 20 4 30 0

GLADSTONE SEEDS SOAKED FOR 24 HOURS

0 7 10 20 20 15 30 14

GLADSTONE SEEDS SOAKED FOR 48 HOURS

0 5 10 17 20 20 30 0

GLADSTONE SEEDS SOAKED FOR 96 HOURS

0 0 10 0 20 1 30 0

BROAD BEAN SEEDS SOAKED FOR 24 HOURS

0 7 10 13 20 4 30 12

BROAD BEAN SEEDS SOAKED FOR 48 HOURS

0 10 10 14 20 1 30 1

BROAD BEAN SEEDS SOAKED FOR 96 HOURS

0 6 10 3 20 2 30 0

Appendix Table 4

Data used to plot Figure 6.04

.....(blank card)

1

LABELS

temperature

germination

2.2

4

19

SPACES

0 30 0 30

4

4.1

lettuce seeds soaked for 48 hours

0 25 10 26 20 27 30 23

lettuce seeds soaked for 96 hours

0 28 10 27 20 26 30 26

radish seeds soaked for 48 hours

0 25 10 28 20 27 30 17

radish seeds soaked for 96 hours

0 25 10 27 20 26 30 14

meteor seeds soaked for 24 hours

0 3 10 22 20 23 30 13

meteor seeds soaked for 48 hours

0 3 10 18 20 24 30 0

meteor seeds soaked for 96 hours

0 1 10 7 20 15 30 0

pioneer seeds soaked for 24 hours

0 2 10 8 20 12 30 8

pioneer seeds soaked for 48 hours

0 1 10 6 20 10 30 0

pioneer seeds soaked for 96 hours

0 5 10 12 20 2 30 0

onward seeds soaked for 24 hours

0 6 10 15 20 17 30 10

onward seeds soaked for 48 hours

0 1 10 13 20 9 30 0

onward seeds soaked for 96 hours

0 0 10 18 20 4 30 0

gladstone seeds soaked for 24 hours

0 7 10 20 20 15 30 14

gladstone seeds soaked for 48 hours

0 5 10 17 20 20 30 0

gladstone seeds soaked for 96 hours

0 0 10 0 20 1 30 0

bean seeds soaked for 24 hours

0 7 10 13 20 4 30 12

bean seeds soaked for 48 hours

0 10 10 14 20 0 30 1

bean seeds soaked for 96 hours

0 6 10 3 20 2 30 0

Appendix Table 5

Data used for Figure 6.05

```
LABELS
POINTS
12  13.3  3  17
HORIZONTAL AXIS
VERTICAL AXIS
HELP
2.1
5
1000
4
1
SUPERIMPOSED GRAPH OPTION
0  10  0  10
0  0  2.5  1  5  1.25  7.5  1.75  10  1
0  3  2.5  8  5  9  7.5  8  10  0
0  10  2.5  6  5  4  7.5  2  10  1
0  6  2.5  7  5  8  7.5  9  10  10
4
BLACK LINE = GRAPH 1.
5.5  12
BLACK BROKEN LINE = GRAPH 2.
5.5  10
RED LINE = GRAPH 3.
5.5  8
RED BROKEN LINE = GRAPH 4.
5.5  6
```

Appendix Table 6

Data used for Figure 6.07

```
HELP
6.1
3  4  1
PLOT 6.1 USING HELP OPTION
24  96  0  30  0  30
24  48  96
0  10  20  30
3  22  23  13
3  18  24  0
1  7  15  0
```

Appendix Table 7

Data used for Figure 6.08

```
DEBUGGING INFORMATION

1

7.2
5  4  1
NO BORDERS
SIZESTATED
0.8  8  14  1.2  4  29
PLOT TYPE 7.1(DOTTED LINES).

0  0  0  0
210  10
INDIVIDUAL TITLE
1000
3  2  10
5  15  5  15  5  15
1001  30
1  5  1  4  0  20
1  2  3  4  5
1  2  3  4
1  2  3  4
5  6  7  8
```

```
9  10  11  12
13  14  15  16
17  18  19  20
997.5
100  100  100
10  10  50
3
X = X AXIS LABEL.
5.5  12
Y = Y AXIS LABEL.
5.5  10
Z = Z AXIS LABEL.
5.5  8
1001
```

Appendix Table 8

Data used in Figure 6.09

```
DEBUGGING INFORMATION

1

8.3
5  4  1
PLOT TYPE 8.3 WITH TEXT

0  0  0  0
210  10
HIDDEN LINES OMITTED
1000
3  2  10
5  15  5  15  5  15
1001  100
1  5  1  4  0  20
1  2  3  4  5
1  2  3  4
1  2  3  4
5  6  7  8
9  10  11  12
13  14  15  16
17  18  19  20
```

```
10  10  50
1
 CNHIDE PACKAGE WITH TEXT
5  10
1001
```

Appendix Table 9

Data used in Figures 6.10, 6.15, 6.16

Note that this program produces two plots and different pen colours may be specified for relief.

```
DEBUGGING INFORMATION

1

8.1
3
4
1
3D PLOT OPTION

0  0  0  0
210  10
1000
48  15  15
0  20  5  25  0  20
1001  100
24.0  96.0  0.0  30.0  0.0  30.0
24.0  48.0  96.0
0.0  10.0  20.0  30.0
3.0  22.0  23.0  13.0
3.0  18.0  24.0  0.0
```

```
1.0  7.0  15.0  0.0
997.5
100  100  100
100  60  90
3
X = NUMBER OF HOURS OF SOAKING
5.5  12.3
Y = TEMPERATURE OF SOAKING
5.5  11.4
Z = GERMINATION OUT OF 30
5.5  10.5
60  30  30
3
X = NUMBER OF HOURS OF SOAKING
5.5  12.3
Y = TEMPERATURE OF SOAKING
5.5  11.4
Z = GERMINATION OUT OF 30
5.5  10.5
1001
```

Appendix Table 10

Data used in Figure 6.13

```
          .....(blank card)
1

9.1
3  4  1
   STEREO PAIRS OF 3D BLOCK DIAGRAMS

0  0  0  0
210  10
1000
48  15  15
0  20  5  25  0  20
24  96  0  30  0  30
24  48  96
0  10  20  30
3  22  23  13
3  18  24  0
1  7  15  0
997.5
100  100  100
100 60  90
3
X = HOURS OF SOAKING
```

5.5 5.1

Y = TEMPERATURE OF SOAKING

5.5 4.2

Z = GERMINATION OUT OF 30 SEEDS

5.5 3.3

0

1001

Appendix Table 11

Data used for Figure 6.17

```
DEBUGGING INFORMATION

1

8.3
5  4  1
NO BORDERS
PLOT TYPE 12.3(SUBTITLES GIVEN).

0  0  0  0
10  10
X=LABEL 1,Y=LABEL2,Z=LABEL3
1000
3  2  10
5  15  5  15  5  15
1001  50
1  5  1. 4  0  20
1  2  3  4  5
1  2  3  4
1  2  3  4
17  18  19  20
13  14  15  16
9  10  11  12
```

```
5  6  7  8
1  2  3  4
997.5
100  100  100
10  10  50
1001
```