Genstat®

Graphics

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VSNi

A Guide to Genstat® Graphics
(22^{nd} Edition)

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Genstat is developed by VSN International Ltd, in collaboration with practising statisticians at Rothamsted and other organisations in Britain, Australia, New Zealand and The Netherlands.

Published by: VSN International, 2 Amberside, Wood Lane,
Hemel Hempstead, Hertfordshire HP2 4TP, UK
E-mail: info@genstat.co.uk
Website: http://www.genstat.co.uk/

First published 2017, for Genstat *for Windows* 19th Edition
This edition published 2022, for Genstat *for Windows* 22^{nd} Edition

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Introduction

Graphics are a key component of statistical analysis, enabling data to be visualized and summarized. An essential tool in exploratory data analysis, graphs are useful for checking and examining data, allowing unusual observations, such as outliers or typographical errors, to be identified and (where possible) corrected. Furthermore, the use of graphs to explore data can help guide the selection of an appropriate statistical model and reveal relationships between variables. Following a statistical analysis, graphs provide an effective tool for conveying information on the results of analysis in a compact and easily accessible format.

This guide is designed to introduce you to Genstat's suite of graphical tools, and enable you to use them correctly and effectively. Focusing on the menu interface, and using a set of examples that demonstrate the range of graphs available, the first two chapters provide an overview of Genstat graphics. The latter chapters are designed to provide more experienced users with the skills to create more advanced graphs using the Genstat command language.

Chapter 1 provides an overview of the Genstat graphics system and the Genstat Graphics Wizard, which guides users through the process of creating high-resolution graphs appropriate to their needs. High-resolution graphs are drawn in the Genstat *Graphics Viewer*, a program that runs independently of Genstat. The functionality of the *Graphics Viewer* is described, including how to edit and save graphical output. The overall look and feel of high-resolution graphical output is controlled by the *Graphics Environment*. The chapter demonstrates how the appearance of a graph changes according to which built-in environment is active, and how to modify, save and activate a *Graphics Environment*.

Chapter 2 gives four case-studies; a bar chart, a line plot, a 3D scatter plot and a trellis plot. Using these exemplars, the functionality of the Graphics menu and the *Graphics Viewer* is demonstrated.

Chapter 3 provides an introduction to the generation of high-resolution graphics via the command language. The command language accommodates greater functionality than the menu interface, enabling more advanced graphics to be created. The chapter focuses on the directive `DGRAPH`, for drawing high-resolution graphs containing points, lines or shaded polygons, and the directive `FRAME`, `PEN`, `XAXIS`, `YAXIS` and `ZAXIS`, for modifying the *Graphics Environment*.

Further examples of using the command language to produce high-resolution graphics are provided in Chapter 4. These examples showcase the breadth of graphics possible in Genstat.

Chapter 5 provides appendices listing Genstat’s graphical directives, procedures, pre-defined colours, pre-defined symbols and pre-defined line styles.

1 Overview of Genstat graphics

To help users generate high-resolution graphs appropriate to their needs, Genstat offers a Graphics Wizard. High-resolution graphs are then drawn in the *Graphics Viewer*, a program that runs independently of Genstat for display, editing and saving graphical output. Graphical output can be saved as a *Genstat Meta File* (file extension `.gmf`), a special file format that enables a graph to be re-loaded into the *Graphics Viewer* at a later date.

The overall look and feel of the graphical output is controlled by the *Graphics Environment*. The default *Graphics Environment* is designed to be appropriate for the most common types of graph. To obtain more control over the appearance of your graphical output, you can change the *Graphics Environment*.

In this chapter you will learn how to:

- generate a graph using the Graphics Wizard (Section 1.1)
- use the *Graphics Viewer*, including how to view, edit and save a graph (Section 1.2)
- save graphical output as a *Genstat Meta File* and open it in the *Graphics Viewer* at a later date (Section 1.2.4.1)
- make changes to the global settings of the *Graphics Viewer* (Section 1.2.5)
- create, save and activate a *Graphics Environment* (Section 1.2.4)

1.1 Genstat Graphics Wizard

Prior to analysis, it is often helpful to explore the data using graphical displays. Graphs can be used to examine the structure of the data, identify unusual observations, such as outliers or typographical errors, and/or to display the distribution of the data. Similarly, graphs are useful post analysis for visualizing and summarizing the results. Many types of graph can be accessed directly as options of the Graphics menu (see Chapter 2). Alternatively, Genstat provides a Graphics Wizard to help you select an appropriate graph.

In this section we demonstrate use of the Graphics Wizard using the Sulphur.gsh data set, collected in 1990 to investigate changing levels of air pollution. The data set comprises two variates and two factors each containing 114 values: the amount of sulphur in the air each day (variate, Sulphur), the strength (variate, Windsp) and direction (factor, Winddir) of the wind and a factor Rain indicating whether or not it had rained. To load the data, click on File on the menu bar and select the Open Example Data Sets... option (Figure 1.1). This launches the Example Data Sets menu (Figure 1.2), where we select Sulphur.gsh.

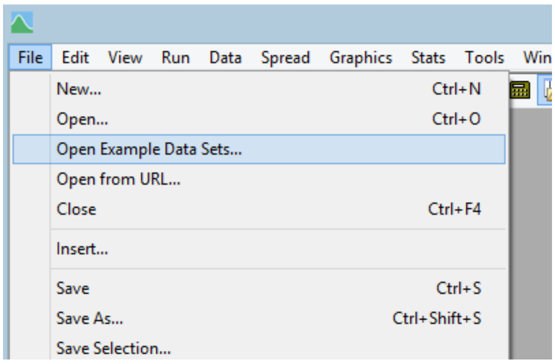
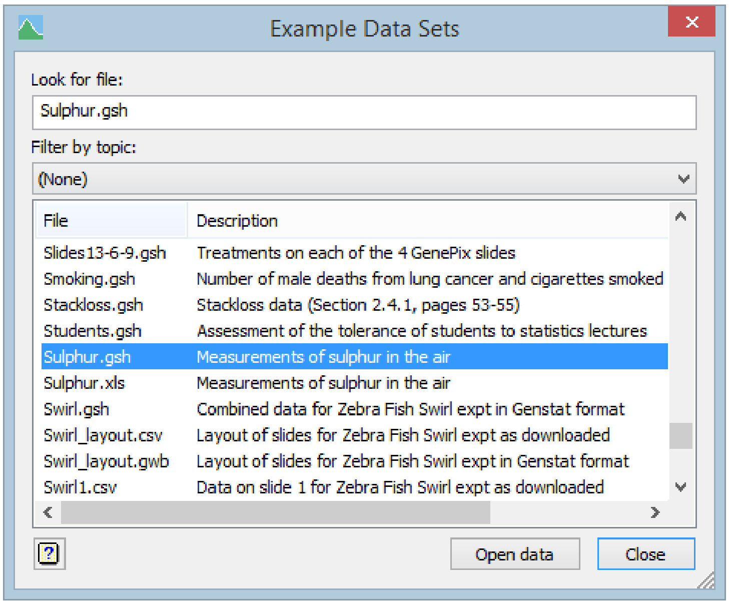


Figure 1.1: Loading a Genstat example data set.



Look for file: Sulphur.gsh

Filter by topic: (None)

File	Description
Slides13-6-9.gsh	Treatments on each of the 4 GenePix slides
Smoking.gsh	Number of male deaths from lung cancer and cigarettes smoked
Stackloss.gsh	Stackloss data (Section 2.4.1, pages 53-55)
Students.gsh	Assessment of the tolerance of students to statistics lectures
Sulphur.gsh	Measurements of sulphur in the air
Sulphur.xls	Measurements of sulphur in the air
Swirl.gsh	Combined data for Zebra Fish Swirl expt in Genstat format
Swirl_layout.csv	Layout of slides for Zebra Fish Swirl expt as downloaded
Swirl_layout.gwb	Layout of slides for Zebra Fish Swirl expt in Genstat format
Swirl1.csv	Data on slide 1 for Zebra Fish Swirl expt as downloaded

Figure 1.2: Opening Sulphur.gsh using the Example Data Sets menu.

To access the Graphics Wizard, from the menu select Graphics | Create Graph (Figure 1.3). This opens the Choose Graph menu (Figure 1.4), designed to help you select a graph appropriate for the type of data structures that you have available. The top pane, What is the form of the data?, lists common categories used to describe the data. When you select an item in this pane, the list of graphs provided for that particular type of data is displayed in the second pane, Select the type of graph:. (In Table 1-1 the graphs corresponding to each form of data are listed.) To further assist in selecting an appropriate graphic, clicking on an item in the Select the type of graph: pane produces an example graph with a short description. We'll use the Graphics Wizard to investigate the distribution of sulphur measurements (Single variate) using a 2D Histogram (see Figure 1.4).

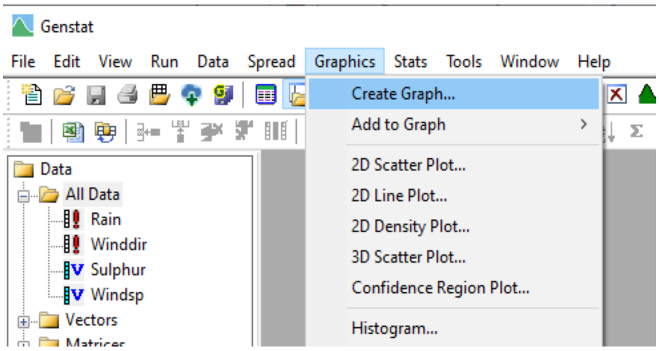


Figure 1.3: Opening the Graphics Wizard.

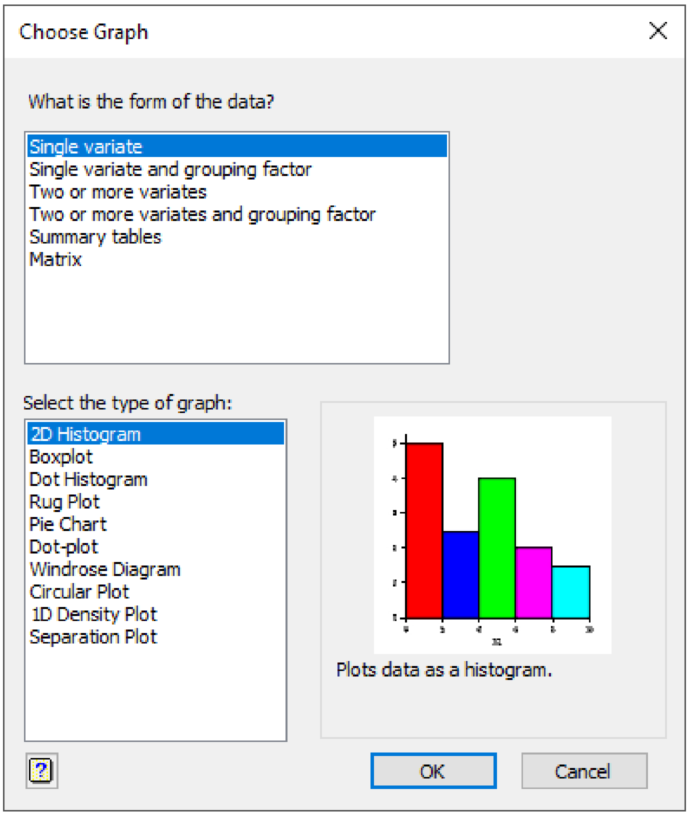


Figure 1.4: Choose Graph menu of the Graphics Wizard.

Table 1-1: Data type with corresponding graphs offered by the Graphics Wizard.

	Single variate	Single variate and grouping factor	Two or more variates	Two or more variates and grouping factor	Summary tables	Matrix
2D Scatter Plot		✓	✓	✓		
3D Scatter Plot			✓	✓		
Confidence Region Plot			✓	✓		
2D Line Plot		✓	✓	✓		
2D Line & Scatter Plot		✓	✓	✓		
2D Histogram	✓	✓	✓	✓		
3D Histogram						✓
Dot Histogram	✓	✓	✓	✓		
Bar Chart					✓	
Two-way Bar Chart					✓	
Plot Table					✓	
Boxplot	✓	✓	✓	✓		
Dot-plot	✓	✓	✓	✓		
Bland-Altman Plot			✓			
Separation Plot	✓	✓	✓	✓		
Rug Plot	✓	✓	✓	✓		
Pie Chart	✓				✓	
1D Density Plot	✓	✓	✓			
2D Density Plot			✓			
Contour Plot						✓
Surface Plot						✓
Shade Plot						✓
Image Plot						✓
Scatter Plot Matrix			✓	✓		
Trellis Plot			✓	✓		
Windrose Diagram	✓					
Circular Plot	✓		✓			
Polar Plot			✓	✓		
Spider-web / Star Plot				✓	✓	
Separation Plot	✓	✓	✓	✓		✓

Clicking the OK button opens the menu corresponding to the chosen graphic, here 2D Histogram (see Figure 1.5). Each menu has a similar structure comprising a Data tab and an Options tab, and where relevant tabs for Error bars, Lines and Symbols, Key, X-Axis, Y-Axis, Z-Axis and Frame. Although the fields within each tab are customized to the chosen graphic, the essential function is the same:

- Data tab: specifies the data for plotting;
- Options tab: controls the appearance of the graph (e.g. providing a title);
- Error bars tab: used to add error bars to the graph (for an example, see Section 2.1.2);
- Lines and Symbols tab: controls the colour and style of the plotted lines and/or symbols (for an example, see Section 1.1.2);
- Key tab: controls the appearance and contents of the key (for an example, see Section 2.2.2);
- X-Axis, Y-Axis, Z-Axis tabs: used to set the attributes of the axes to control the appearance of the graph (e.g. specifying lower and upper axes limits; for an example, see Section 1.1.1);
- Frame tab: used to set the attributes of the frame in which the graph is displayed (see Section 1.1.3).

In the bottom right-hand corner of the Graphics menu are three buttons (see Figure 1.5): Run produces the graph, Cancel closes the graphics menu, and Defaults returns the options to their default settings. In the bottom left-hand corner are four action icons:

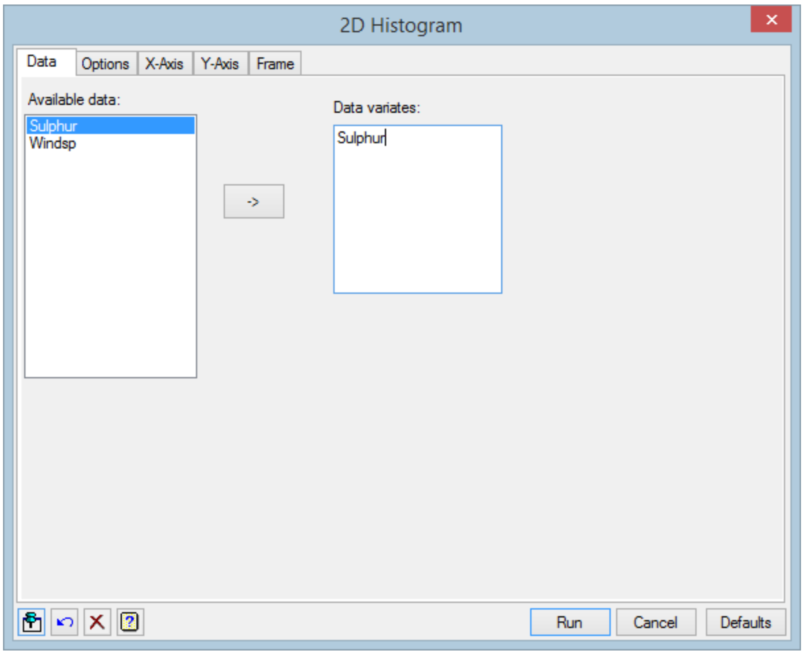
📌 **Pin** The Pin icon controls whether the menu remains open after the Run button is clicked. When the pin is down (📌), the menu is kept open. This allows you to try different settings, until you get the graph you want, without having to reopen the Graphics menu and reset all the fields. When the pin is sideways (📌 , the default), the menu will close after the Run button is clicked.

↶ **Restore** The Restore icon restores the input field settings used previously.

✕ **Clear** The Clear icon clears the input fields.

? **Help** The Help icon launches the help documentation for the Graphics menu.

The 2D Histogram menu opens on the Data tab, where we enter the data to be plotted (Figure 1.5). To create a histogram of the sulphur measurements, select `Sulphur` from within the Available data: list. Click the arrow (or double mouse-click) to place it into the Data variates: field.

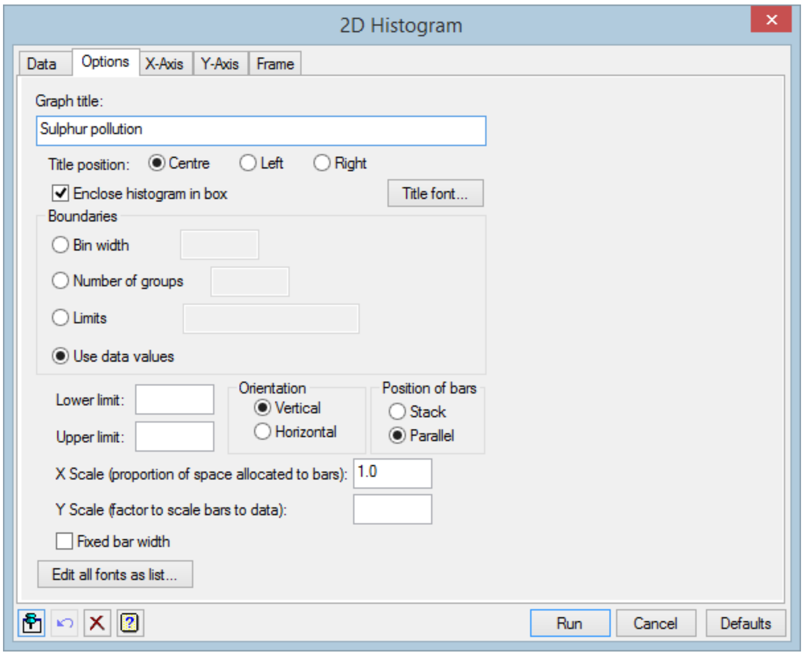


Available data:
Sulphur
Windsp

Data variates:
Sulphur

Figure 1.5: Using the 2D Histogram menu to create a histogram of Sulphur.

Additional options and settings can be set in the Options, X-Axis, Y-Axis and Frame tabs. Help documentation is provided for each tab. To access the help, click the help icon (?) located in the bottom left corner of each tab. We'll provide a title for the histogram by entering `Sulphur pollution` into the Graph Title: field of the Options tab (Figure 1.6).



Graph title: Sulphur pollution

Title position: ● Centre ○ Left ○ Right

☑ Enclose histogram in box

Boundaries

○ Bin width

○ Number of groups

○ Limits

● Use data values

Lower limit:

Upper limit:

Orientation: ● Vertical ○ Horizontal

Position of bars: ○ Stack ● Parallel

X Scale (proportion of space allocated to bars): 1.0

Y Scale (factor to scale bars to data):

□ Fixed bar width

Figure 1.6: Options tab of the 2D Histogram menu.

Clicking the Run button produces the histogram shown in Figure 1.7, giving the number of observations in successive equal-width categories of the Sulphur scale. Clearly Sulphur has a skewed distribution: there are many days with little or no sulphur in the air, and then decreasing numbers in successive categories with more and more sulphur.

Many statistical studies are concerned not just with a single variate, but with the relationships between variables. For example, with the sulphur air pollution data it is natural to investigate questions such as "*Is there any effect of wind speed on the sulphur level?*"

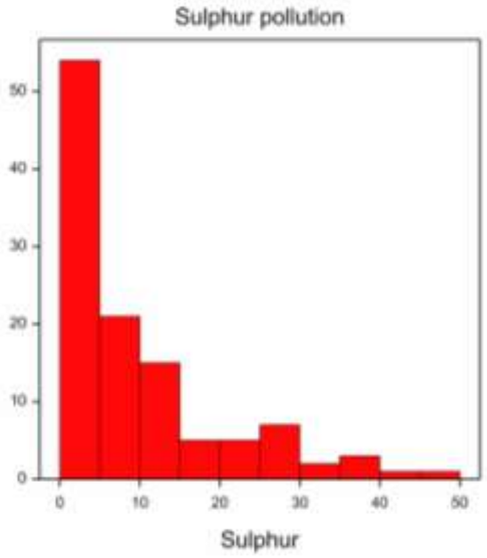
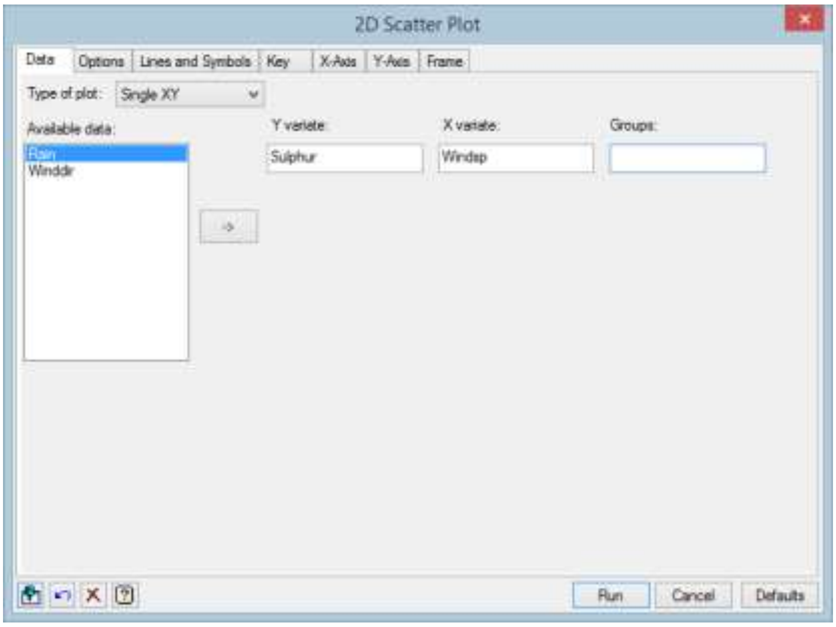


Figure 1.7: Histogram of the variate Sulphur.

Scatter plots are a useful tool for investigating the relationship between variates. To produce a scatter plot, from the menu select Graphics | Create Graph then select Two or more variates. In the Select the type of graph: field select 2D Scatter Plot. Clicking OK opens the 2D Scatter Plot menu on the Data tab, shown in Figure 1.8. As we wish to plot the sulphur levels against the wind speeds, select Sulphur as the Y variate: and Windsp as the X variate:.



Type of plot: Single XY

Available data:
Rain
Winddir

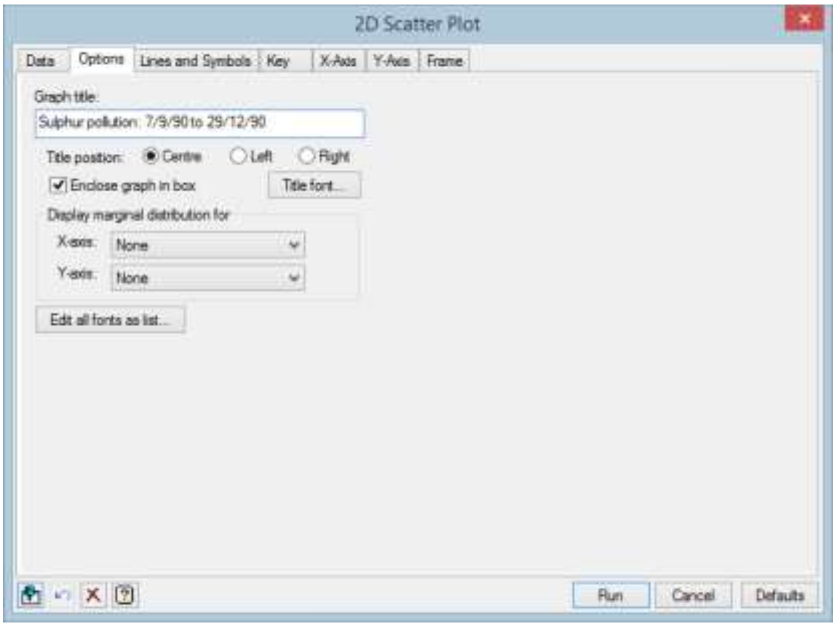
Y variate: Sulphur

X variate: Windsp

Groups:

Figure 1.8: Using the 2D Scatter Plot menu to create a scatter plot of Sulphur against Windsp.

In the Options tab, shown in Figure 1.9, we’ll enter a title for the plot in the Graph title: field. Clicking on Run produces the graph shown in Figure 1.10.



Graph title: Sulphur pollution: 7/9/90 to 29/12/90

Title position: ● Centre ○ Left ○ Right

☑ Enclose graph in box

Display marginal distribution for

X-axis: None

Y-axis: None

Figure 1.9: Options tab of the 2D Scatter Plot menu.

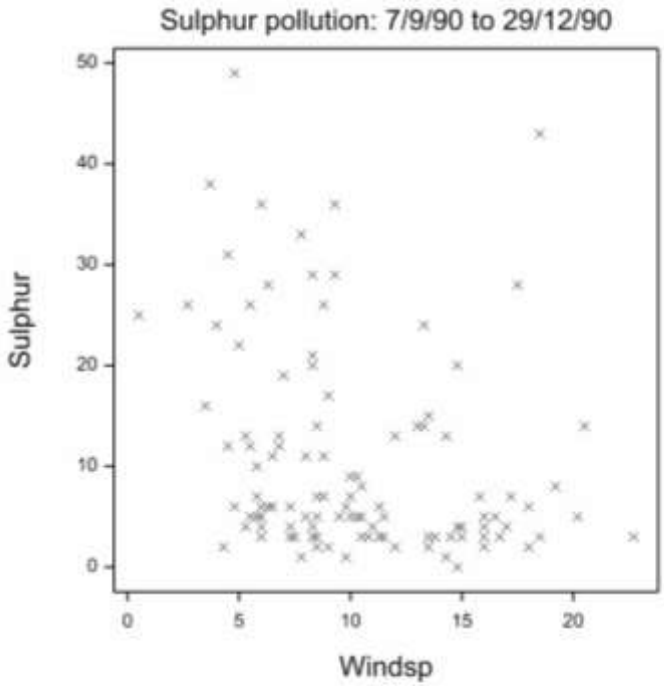


Figure 1.10: Scatter plot of Sulphur against Windsp.

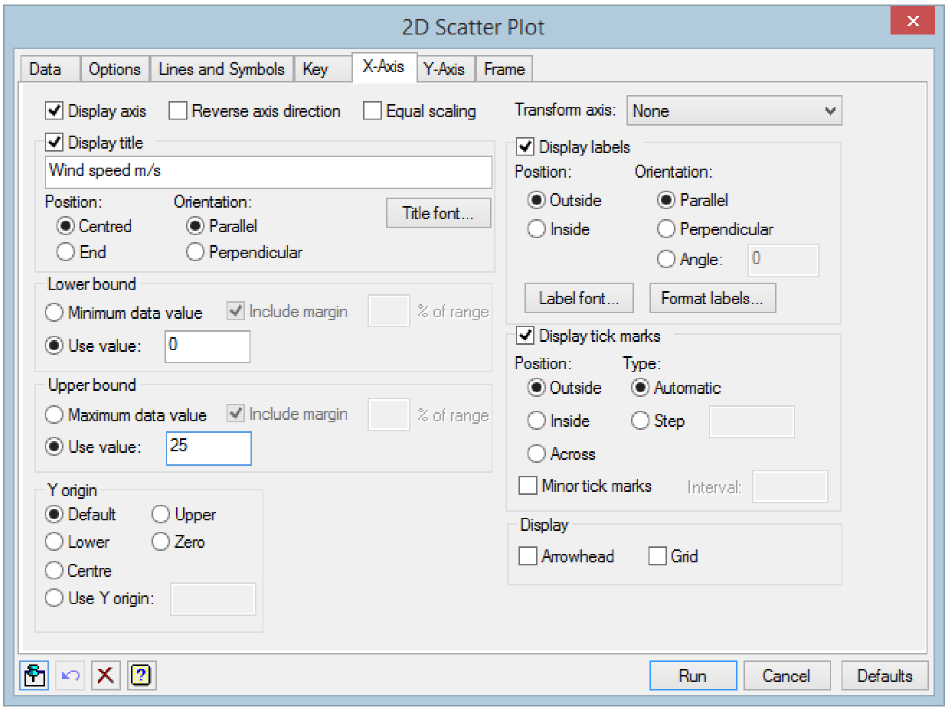
1.1.1 Modifying axis attributes

Many of the graphics menus contain axis tabs allowing you to modify the different axes (x, y, z). Here, you can set various axis attributes such as a title, a lower limit, an upper limit, tick mark positions and the origin position (i.e., values on the x-, y- or z-axis through which the axis is drawn).

To illustrate the axis tabs, from the menu select Graphics | Create Graph and again select the Two or more variates option with 2D Scatter Plot as the type of graph. On the Data tab, select `Sulphur` as the Y variate: and `Windsp` as the X variate:, as before.

The X-Axis tab is shown in Figure 1.11. Detailed help information on all options is available by clicking on the help icon (?). To improve the plot (shown in Figure 1.10), we'll change the x-axis title by selecting the Display title option and entering `Wind speed m/s` into the space provided. Furthermore, using the Lower bound and Upper bound panes we'll set the lower and upper x-axis bounds to 0 and 25, respectively.

Clicking on the Y-Axis tab produces an identical menu to the X-Axis tab. Select the Display title option and enter the title `Sulphur microg/m~^{3}`. The string `~^{3}` is a special typesetting command to make 3 a superscript (for more information on typesetting, refer to Section 4.2.1).



2D Scatter Plot

Data | Options | Lines and Symbols | Key | X-Axis | Y-Axis | Frame

☑ Display axis ☐ Reverse axis direction ☐ Equal scaling

Transform axis: None

☑ Display title

Wind speed m/s

Position: ● Centred ○ End

Orientation: ● Parallel ○ Perpendicular

Title font...

Lower bound

○ Minimum data value ☑ Include margin % of range

● Use value: 0

Upper bound

○ Maximum data value ☑ Include margin % of range

● Use value: 25

Y origin

● Default ○ Upper

○ Lower ○ Zero

○ Centre

○ Use Y origin:

☑ Display labels

Position: ● Outside ○ Inside

Orientation: ● Parallel ○ Perpendicular ○ Angle: 0

Label font... Format labels...

☑ Display tick marks

Position: ● Outside ○ Inside ○ Across

Type: ● Automatic ○ Step

☐ Minor tick marks Interval:

Display

☐ Arrowhead ☐ Grid

Run Cancel Defaults

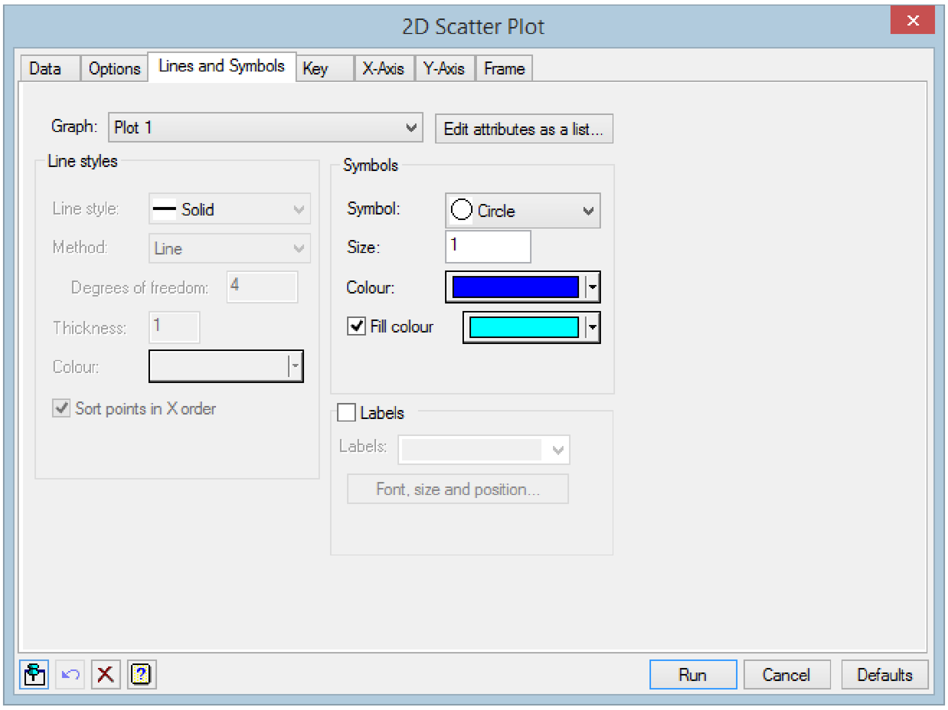
Figure 1.11: X-Axis tab of the 2D Scatter Plot menu.

1.1.2 Modifying lines and/or symbols

The Graphics menus for line, scatter and polar plots also contain a Lines and Symbols tab. This allows you to set the style and colour of the graph's lines and/or symbols. The Lines and Symbols tab for a scatter plot is shown in Figure 1.12.

In the Graph: field we specify the series for which the line and/or symbol attributes are to be set. If groups had been specified on the Data tab (see Figure 1.8), then these would be shown in the Graph: field list. For example, had we entered the factor `Winddir` in the Groups: field of the 2D Scatter Plot menu, then a list of 8 series (corresponding to the 8 levels of `Winddir`) would appear under the Graph: field. The first series in the list corresponds to the first ordinal value of the grouping factor and so on (i.e. Plot 1 – Group 1 = `E`, Plot 2 – Group 2 = `N`, Plot 3 – Group 3 = `NE`, …, Plot 8 – Group 8 = `W`). You can set line and symbol attributes for each different level of the group (i.e. series) by toggling through the list in the Graph: field.

As there is only one series in our current example (scatter plot of `Sulphur` against `Windsp`) the Graph: list contains only Plot 1. To improve the plot (shown in Figure 1.10), we'll change the symbols to dark blue circles with light blue fill: choose ○ Circle in the Symbols: field, and use the Colour: and Fill colour list boxes to specify the desired colours (see Figure 1.12).



Graph: Plot 1

Line style: Solid

Method: Line

Degrees of freedom: 4

Thickness: 1

Colour:

☑ Sort points in X order

Symbol: ○ Circle

Size: 1

Colour:

☑ Fill colour

□ Labels

Labels:

Figure 1.12: Using the Lines and Symbols tab to change the symbols to dark blue circles with light blue fill.

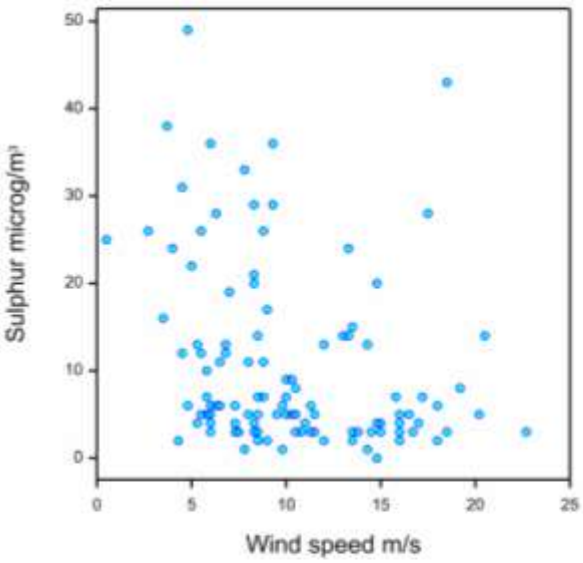
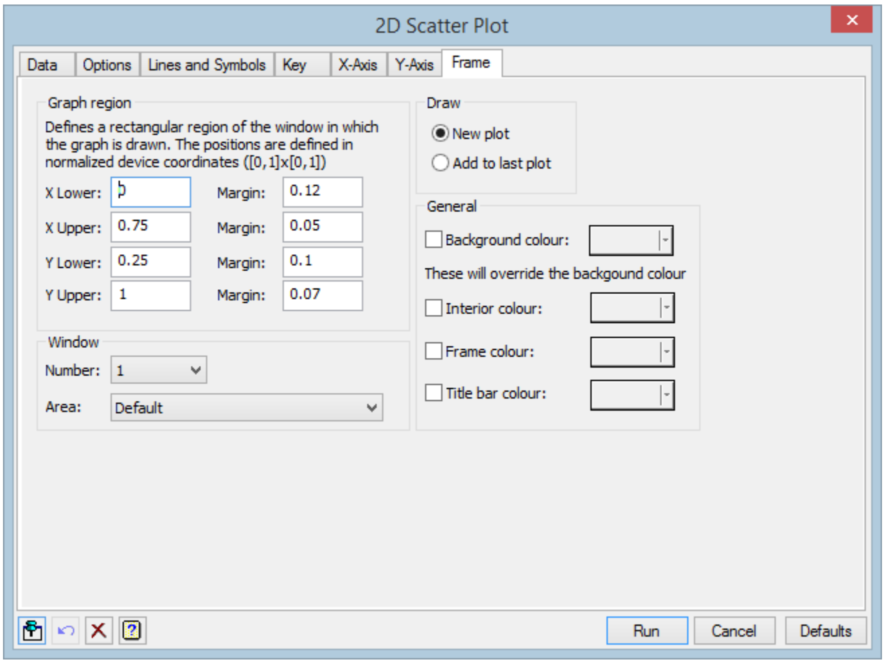


Figure 1.13: Improved scatter plot of `Sulphur` against `Windsp`.

Clicking on Run produces the graph shown in Figure 1.13, where the points are now represented by filled circles and the axes are titled. Modifications to this graph, for example adding a forgotten title, can still be made using *Editor* mode of the *Graphics Viewer* (see Section 1.2.2).

1.1.3 Modifying the frame

The Frame tab (Figure 1.14) allows you to control the position of the plot within the graphics *frame* (see Section 2.1.5 for further information). Each graph is plotted into one of the *windows* in the frame. Here, we are plotting into window 1 using its default position. This is defined to use the top 3/4 of the frame. (Window 2, which is used if you include a key on the graph, uses the lower 1/4 of the frame.). The Draw radio buttons allow you to put extra graphs onto an existing frame (i.e. superimpose a new plot onto the current graph)



Graph region

Defines a rectangular region of the window in which the graph is drawn. The positions are defined in normalized device coordinates ([0,1]x[0,1])

X Lower: 0 Margin: 0.12

X Upper: 0.75 Margin: 0.05

Y Lower: 0.25 Margin: 0.1

Y Upper: 1 Margin: 0.07

Window

Number: 1

Area: Default

Draw

● New plot

○ Add to last plot

General

□ Background colour:

These will override the backgound colour

□ Interior colour:

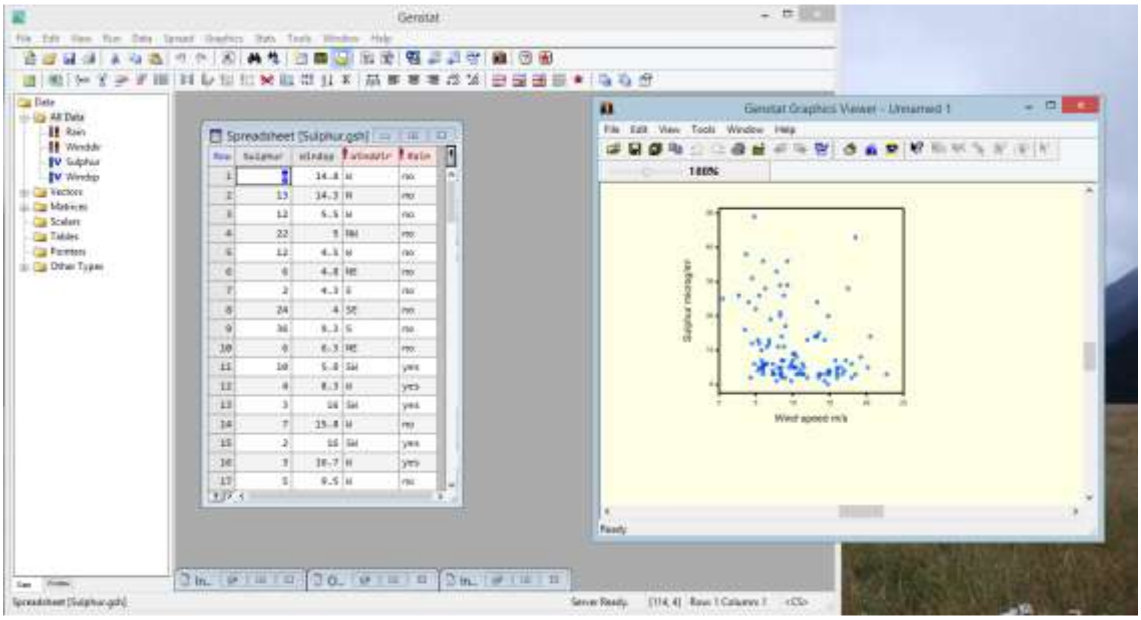
□ Frame colour:

□ Title bar colour:

Figure 1.14: The Frame tab of the 2D Scatter Plot menu.

1.2 Genstat Graphics Viewer

By default the graphical output is drawn in the Graphics Viewer, a program that runs independently of Genstat (see Figure 1.15). This starts automatically when a graph is generated, and you can switch between Genstat and the Graphics Viewer at any time. To bring the Graphics Viewer to the front of the display click the Graphics button (📊) on the toolbar:


Genstat
File Edit View Run Data Spread Graphics Stats Tools Window Help
Data
All Data
Rain
Winddir
Sulphur
Windsp
Vectors
Matrices
Scalars
Tables
Pointers
Other Types
Spreadsheet [Sulphur.gsh]
Genstat Graphics Viewer - Unnamed 1
File Edit View Tools Window Help
100%
Sulphur microg/m3
Wind speed m/s
Ready
Spreadsheet [Sulphur.gsh]
Server Ready

Row	Sulphur	Windsp	Winddir	Rain
1	[illegible]	14.4	W	no
2	13	14.3	N	no
3	12	5.5	W	no
4	22	5	NW	no
5	12	4.5	W	no
6	6	4.8	NE	no
7	2	4.3	E	no
8	24	4	SE	no
9	36	6.3	S	no
10	8	6.3	NE	no
11	10	5.8	SW	yes
12	4	8.3	W	yes
13	3	16	SW	yes
14	7	15.8	W	no
15	2	16	SW	yes
16	3	10.7	N	yes
17	5	9.5	W	no

Figure 1.15: Genstat (left window) and Graphics Viewer (right window).

Images in the Graphics Viewer are produced in a vector format which is scaled to fit the current size of the Graphics Viewer window. This means that the full resolution of the image can be maintained if the window is resized or printed. Genstat's graphics format also includes extensive meta-information about the graph and the data contained within it, allowing many aspects to be edited interactively on the screen.

The Graphics Viewer operates in three modes – Viewer, Editor and Child. We describe each of these modes in turn.

1.2.1 Viewer mode

The Viewer mode is the default display for the Graphics Viewer (see Figure 1.16). When graphs are received from Genstat or opened via the File menu they will be displayed in Viewer mode. In this mode you can zoom the graph, view data information on different points, add a title and save the graph to other graphics formats, such as Enhanced Windows Metafile, Bitmap, JPEG, PostScript, or PNG.

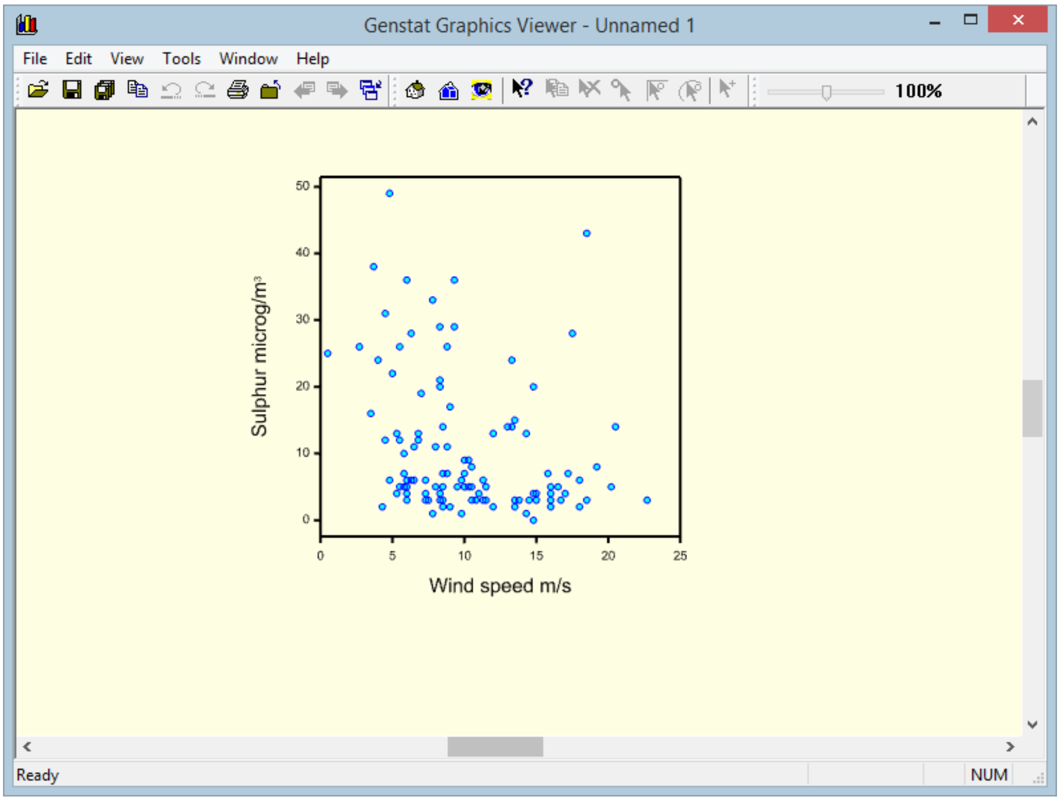
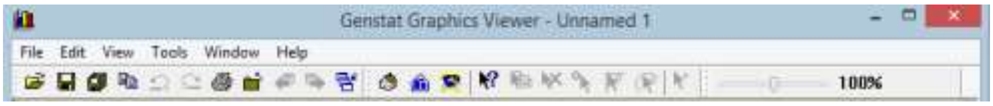

Genstat Graphics Viewer - Unnamed 1
File Edit View Tools Window Help
100%
Sulphur microg/m³
50
40
30
20
10
0
0
5
10
15
20
25
Wind speed m/s
Ready
NUM

Figure 1.16: *Graphics Viewer* in *Viewer* mode.

The *Graphics Viewer* displays a single graph (or a single composite plot, such as a trellis plot) at any one time. However, it also maintains a list of graphs as they are generated within Genstat. It is easy to switch the display between the current graph and another by selecting the name of the desired graph from the Window menu; or, by using the Previous (⇦) or Next (⇨) arrows on the toolbar.

The *Viewer* mode has its own bars, as you can see in Figure 1.16 and reproduced below:

Title bar
Menu bar
Toolbar


Genstat Graphics Viewer - Unnamed 1
File Edit View Tools Window Help
100%

If the graph has been given a title, this will appear in the title bar. Since Figure 1.16 is untitled a default name, `Unnamed 1`, appears on the title bar. You can readily add a title in *Viewer* mode using the Edit | Main Title... menu.

Hovering the mouse over a button on the toolbar will cause a tooltip containing the button's name to appear. We briefly describe the function of each button below:

Buttons on the standard toolbar

	Open	Opens a previously saved *Genstat Meta File* (extension `.gmf`), a private file format that enables Genstat graphs to be re-loaded into the *Graphics Viewer* (see Section 1.2.4.1).
	Save	Saves the active graph (see Section 1.2.4).
	Save All	Saves all graphs listed in the *Graphics Viewer* (see Section 1.2.4).
	Copy	Copies the active graph to the Clipboard.
	Undo	Undoes changes made to the graph in *Editor* mode (see Section 1.2.2).
	Redo	Redoes an undone change that was made to the graph in *Editor* mode (see Section 1.2.2).
	Print	Prints the graph to your selected device.
	Close	Closes the graph, removing it from the *Graphics Viewer*.
	Previous	Switches the display to the previous graph listed in the *Graphics Viewer*.
	Next	Switches the display to the next graph listed in the *Graphics Viewer*.
	List	Opens a menu window that lists the graphs available for display by the *Graphics Viewer*. Using this menu, you can select which graph to display using the Activate button, or close one or more graphs using the Close Window(s) button.

Buttons on the graphics toolbar

	Home	Returns the graph to the home position. Scroll bars on the bottom and right-hand side of the *Graphics Viewer* window (see Figure 1.16) allow you to alter the horizontal and vertical position of the graph on your screen. The zoom slider on the toolbar, 100%, enables you to alter its size. Clicking on the Home button returns the graph to its "*home*" position and size.
	Set Home	Resets the home position to the currently displayed position and size of the graph.
	Show All	Changes the zoom to make the entire graph visible.
	Data Info	Provides information about a plotted data point. Clicking on the Data Info button changes the cursor to an arrow with a question

mark. Hovering this cursor over a point in the graph makes information about that point appear. See Figure 1.17.

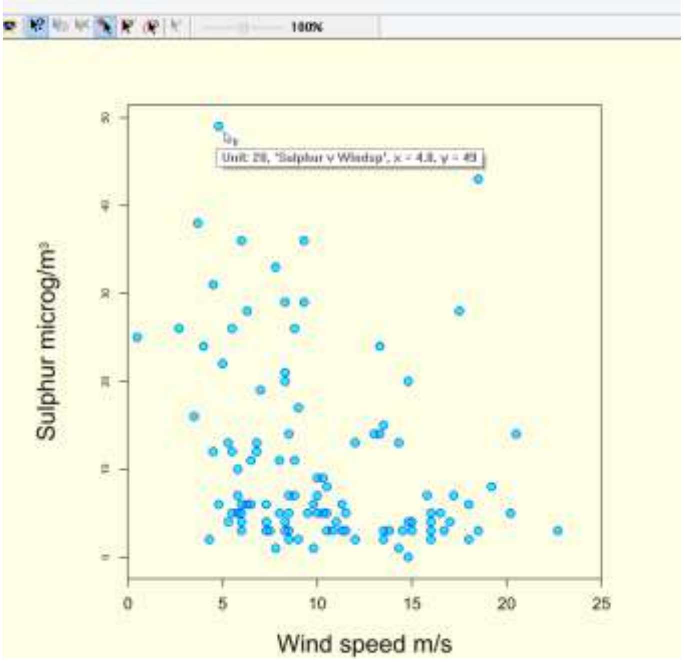


Figure 1.17: Using the Data Info button to elicit information on a data point.

You can change what information is displayed on the screen using the Tools | Options… | Data Information… menu. By default the label, unit number, description and coordinates of the selected point are displayed.

	Point Selection	Selects a data point. Clicking on a data point selects that point. Clicking a second time will remove it from the selection. Each selected point is highlighted (see Figure 1.18, where five data points have been selected). Information on the selected data points can be copied to the Clipboard using the Copy Data button. The Point Selection button becomes available only when the Data Info button is activated.

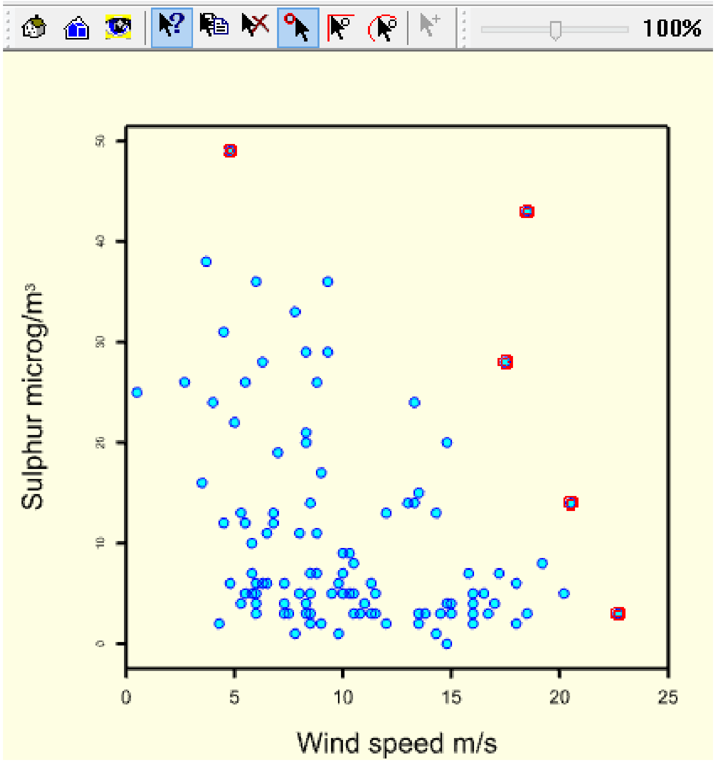


Figure 1.18: Five data points (outlined in red) selected using Point Selection.

	Rectangle Selection	Selects points within a rectangular region on the graph. To define the region, click on a corner of your desired rectangular region, hold down the left mouse button and drag to draw a rectangle. Release the mouse button to complete the rectangle. Points falling inside this region are selected. The Rectangle Selection button becomes available only when the Data Info button is activated.
	Polygon Selection	Selects points within a polygon on the graph. To define, sequentially click on the corners of your desired polygon, using a right-click to specify the last corner. The Polygon Selection button becomes available only when the Data Info button is activated.
	Copy Data	Copies information on data points selected using the Point Selection, Rectangle Selection and/or Polygon Selection buttons to the Clipboard. You can change what information is copied using the Tools | Options… | Data Information… menu.
	Clear Selection	Clears the selection of data points.
	Hot Choice	A special button that allows you to toggle the visibility of "*hot components*" in a graph. See Section 4.2.13.

1.2.2 Editor mode

Modifications to a graph, for example adding a forgotten title, can be made by invoking *Editor* mode. To do this either:

- double-click on the graph; or,
- select Edit Graph from the Edit menu.

The window title and background colour will change to indicate the new mode, as shown in Figure 1.19.

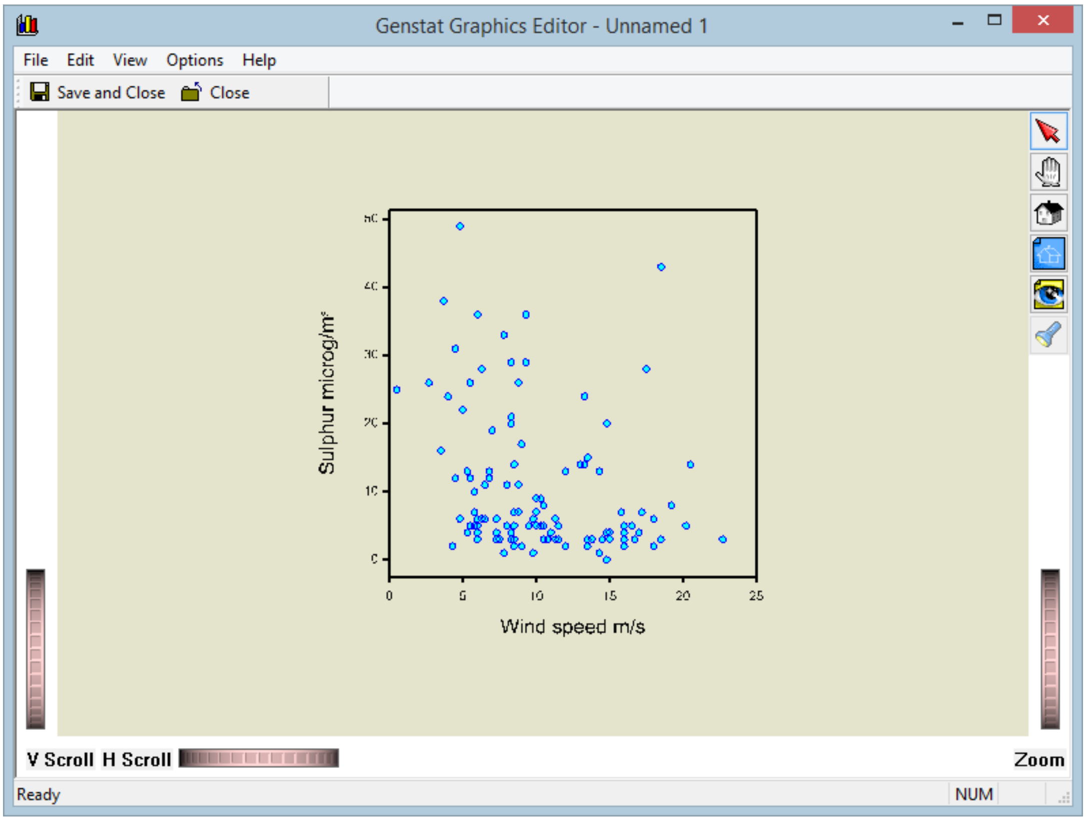
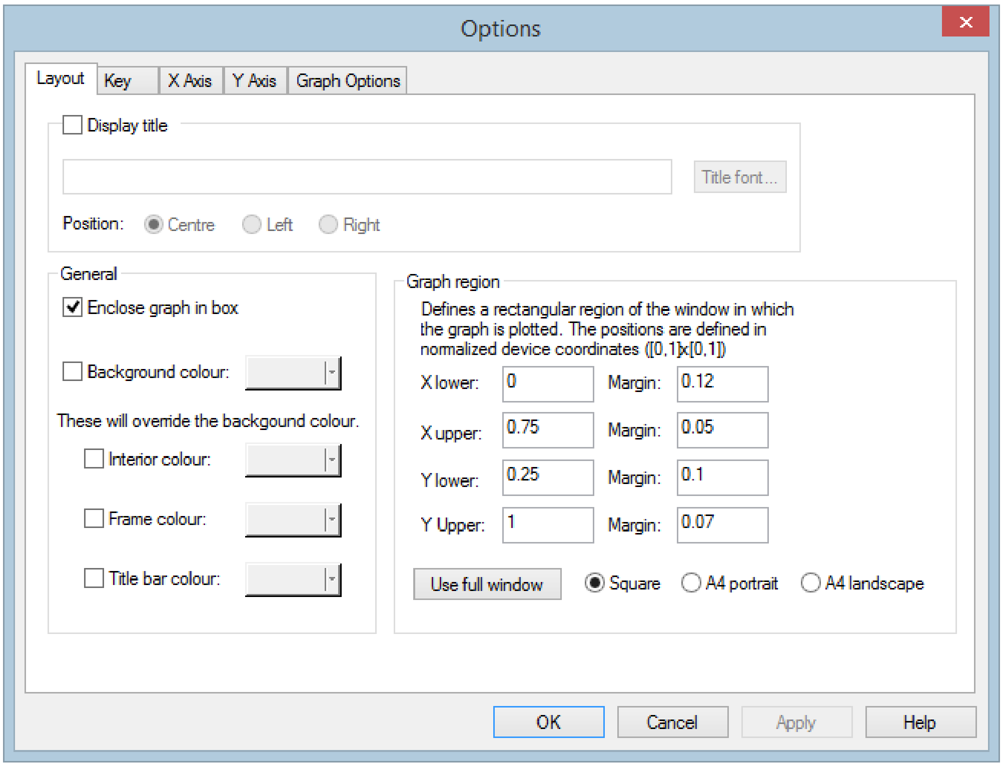


Figure 1.19: *Graphics Viewer* in *Editor* mode.

When you change to *Editor* mode, the Options menu automatically opens (If closed, the Options menu can be re-opened by double-clicking on the graph or by selecting one of the options under Edit on the menu bar.) This menu consists of several tabs where graphical settings can be changed The fields within each tab are customized to each graph type. Full documentation on all Options can be found within the Genstat Help System (accessed via the Help button).

The Options menu for the scatter plot of `Sulphur` against `Windsp` is shown in Figure 1.20. Changes to the layout of the graph can be made via the Layout tab. For example, here you can edit (or disable) the graph's title and control the background colours. You can edit the appearance (e.g. font and position) of the key or legend via the Key tab. The axis tabs (here X Axis and Y Axis) enable you to alter the settings of the axes attributes, such as the lower and upper bounds. Additional options to control the display (e.g. the colour of the plotted points) are accessed via the last tab, Graph Options. (This tab is labelled Histogram Options for Histograms, Pie Chart Options for pie charts, and so on.)



Options

Layout | Key | X Axis | Y Axis | Graph Options

□ Display title

Title font...

Position: ● Centre ○ Left ○ Right

General

☑ Enclose graph in box

□ Background colour:

These will override the backgound colour.

□ Interior colour:

□ Frame colour:

□ Title bar colour:

Graph region

Defines a rectangular region of the window in which the graph is plotted. The positions are defined in normalized device coordinates ([0,1]x[0,1])

X lower:	0	Margin:	0.12
X upper:	0.75	Margin:	0.05
Y lower:	0.25	Margin:	0.1
Y Upper:	1	Margin:	0.07

Use full window ● Square ○ A4 portrait ○ A4 landscape

OK Cancel Apply Help

Figure 1.20: Options menu within Editor mode of the Graphics Viewer for a scatter plot.

In the upper right corner of the Editor mode window you'll find the buttons shown in Figure 1.21. The functions of these buttons are:

- Select/Pick button: enables you to select an object in the graph to manipulate (by double-clicking on the chosen object). For example, clicking on a point in the graph (of Figure 1.19) launches the Graph Options, in which you can edit the appearance of the plotted points. When the Select/Pick button is active, the cursor is an arrow (↖).

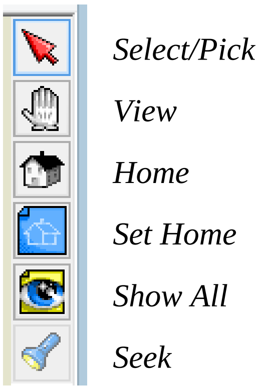


Figure 1.21: Buttons in Editor mode.

- View button: enables you to alter the position and size of the graph on your screen. For two-dimensional graphs, such as scatter plots, hold the left mouse button and drag to zoom. For three-dimensional graphs, hold the left mouse button and drag to rotate. To change the position of the graph hold the scroll-wheel and drag the plot. When the View button is active, the cursor will change to an upright arrow (↑).

  You can also use the thumbwheels to adjust the position and size of the graph. For two-dimensional graphs, the thumbwheels (V Scroll, H Scroll) in the lower left-hand corner (see Figure 1.19) can be used to move the graph horizontally (H Scroll) or vertically (V Scroll). For three-dimensional plots these are replaced by RotX and RotY, which rotate the graph around the x- and y-axes, respectively (see Section 2.3). The Zoom thumbwheel in the lower right-hand corner (see Figure 1.19) enlarges/shrinks the graph. To move a thumbwheel, click down on the thumbwheel button and drag your mouse left/right or up/down as appropriate.

- Home button: returns the graph to its home position.

- Set Home button: resets the home position to the current position and size of the graph.

- Show All button: changes the zoom to make the entire graph visible.

- Seek button: "*centres*" the graph. When the Seek button is activated, the cursor changes to a crosshair (+). Clicking on the graph will move that point to the centre of the display. For three-dimensional plots, this also sets the centre point for rotation.

For three-dimensional graphs, a further 3 buttons become available: the projection buttons XYZ (see Section 2.3). The Z button rotates the graph to align the view to the z-axis, providing a top-down view along the z-axis. Clicking the Z button again will toggle the view between aligning the view with the z-axis in the positive and negative directions. The X and Y buttons perform the same function relative to the x- and y-axes, respectively.

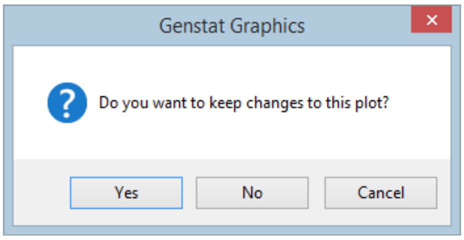
For composite graphs containing two or more individual components within a single display, such as trellis plots, the position/zoom controls operate on the entire display, whilst the built-in editor operates on individual component plots (for further details, see Section 2.4).

Once you've made the desired changes to the graph, return to *Viewer* mode either by:

- selecting File | Save and Close on the menu bar; or,
- by clicking the Save and Close button on the toolbar.

(The Undo (↶) and Redo (↷) buttons on the *Graphics Viewer* toolbar will enable you to undo, then redo, any changes.)

Alternatively, if you wish to discard your changes before returning to *Viewer* mode, select File | Close on the menu bar (or click the Close button on the toolbar). A prompt (see Figure 1.22) will appear asking you whether you want to keep the changes you've made to the graph. To discard the changes, click the No button. Selecting Yes will retain the changes. Clicking Cancel will return you to *Editor* mode.



Do you want to keep changes to this plot?

Figure 1.22: Options for retaining or discarding changes made to a graph in *Editor* mode.

1.2.3 Child mode

The *Graphics Viewer* displays only a single graph (or single composite plot) at a time. The *Child* mode allows you to view several plots at once. From the *Graphics Viewer*, you can open any graph in a new instance of the *Child Viewer* by right-clicking on the graph and selecting Display in Child Viewer from the pop-up menu (Figure 1.23). The window title and background colour will change to indicate the new mode.

In the *Child Viewer* you cannot edit the graph or open other graphs. However, you can still print, save and interact with the graph as in the main *Graphics Viewer*.

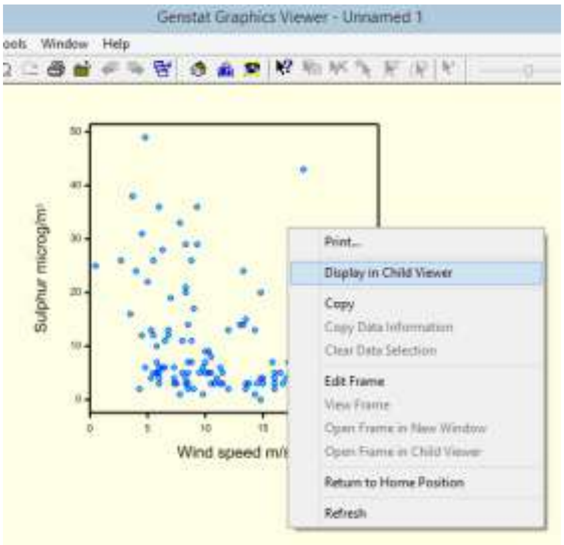


Figure 1.23: Opening a graph in a new instance of the *Child Viewer*.

1.2.4 Saving Genstat graphics

1.2.4.1 Genstat Meta Files

Individual displays can be saved as a *Genstat Meta File* (extension `.gmf`). This is a private file format that saves the graph and additional information, so that the graph can be redisplayed or edited on another occasion using the *Graphics Viewer*. In *Viewer* mode, to save a graph as a *Genstat Meta File* either:

- select File | Save (or File | Save As…) on the menu bar; or,
- click the Save button on the toolbar (💾),

and then choose Genstat Meta Files (*gmf) in the Save as type: field.

Multiple graphs can be easily saved via File | Save All, or the Save All button (💾).

Previously saved .gmf files can be opened in the *Graphics Viewer* (from Genstat or the *Graphics Viewer*) via:

- File | Open … on the menu bar; or,
- the Open button on the toolbar (📂).

Note, it is not possible for graphics saved in other formats to be (re)opened in the *Graphics Viewer*.

1.2.4.2 Other formats

The contents of the *Graphics Window* can also be saved to files in standard graphics formats: Encapsulated PostScript (.ps), Windows Enhanced Meta Files (.emf), JPEG (.jpg), TIFF (.tif), Portable Network Graphics (.png), Bitmaps (.bmp) and Portable Document Format (.pdf). Simply select your desired format in the Save as type: field. When saving a graph as points, the.png file format is recommended (as opposed to .jpg, .tif or .bmp) since the file size is smaller and .png files don't suffer from information loss as.jpg files do.

When saving a graph to a .jpg, .tif .png or.bmp file, the resolution and amount of white space bordering the graph can be controlled using the *Graphics Viewer* options (Tools | Options | Saving Files, see Section 1.2.5). The resolution and orientation of .pdf files can also be specified.

1.2.4.3 Saving Genstat commands

In this chapter we've used Genstat menus to create graphs. However, the menus themselves operate by generating Genstat commands which you can see recorded in the *Input Log* window. (In Genstat, to bring the *Input Log* window to the top select Window | Input Log.) Genstat commands can be saved as .gen files that can be used to re-generate the graph at a later date, or edited to modify the graph if desired. Within the *Graphics Viewer*, you can save the Genstat commands that produce the active graph by:

- choosing File | Save (or File | Save As…) on the menu bar; or,
- clicking the Save button on the toolbar (💾),

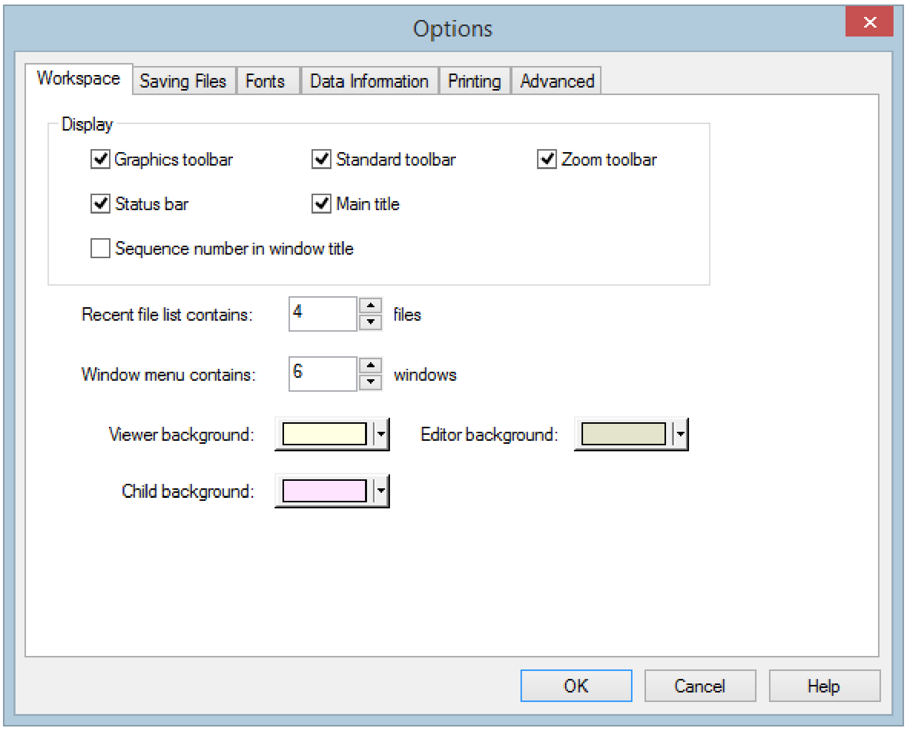
and then selecting Genstat Command Files (*.gen) in the Save as type: field.

Using Genstat's command language unlocks the full power of the Genstat graphics. We illustrate the use of commands in Chapter 3.

1.2.5 Global Graphics Viewer options

From *Viewer* (and *Child*) mode, you can set global options for the *Graphics Viewer*. Select Tools | Options… to launch the Options menu for the *Graphics Viewer* (Figure 1.24). The menu comprises six tabs with the following functions:

- Workspace tab (Figure 1.24): controls the appearance and settings of the *Graphics Viewer*. For example, from the Workspace tab you can specify the toolbars to display and the background colours used for distinguishing between the *Viewer*, *Editor* and *Child* modes.



Options

Workspace | Saving Files | Fonts | Data Information | Printing | Advanced

Display

☑ Graphics toolbar ☑ Standard toolbar ☑ Zoom toolbar

☑ Status bar ☑ Main title

☐ Sequence number in window title

Recent file list contains: 4 files

Window menu contains: 6 windows

Viewer background: 🟨 Editor background: ▨

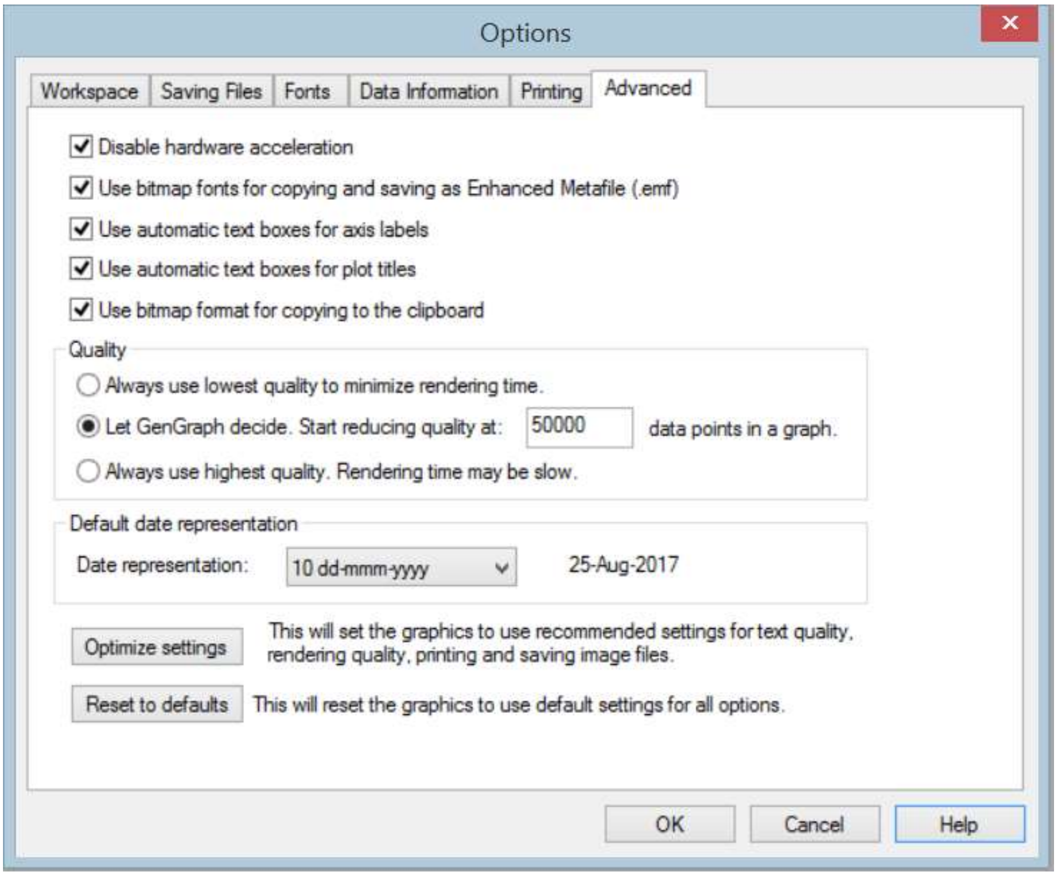
Child background: 🟪

OK | Cancel | Help

Figure 1.24: Options menu of the *Graphics Viewer*.

- Saving Files tab: provides options and settings to control how graphics are saved (see Section 1.2.4).
- Fonts tab: enables you to set the default font used by Genstat for textual output, including titles and axes labels.
- Data Information tab: controls the type of information on a data point that is displayed on the screen (by) or copied to the Clipboard (by).
- Printing tab: provides options and settings to control how graphics are printed.
- Advanced tab (Figure 1.25): provides options to override certain default settings in cases where problems arise because of incompatibilities with Windows, other software or device drivers. Note that the Use automatic text boxes for axis labels option is

automatically selected by default. This option forces the axis labels to fit into non-overlapping text boxes, the width of which are determined by the distance between tick marks. Axis labels therefore may not appear in the size specified when this option is selected. You may wish to deselect the Use automatic text boxes for axis labels option in order to freely resize the labels (see Section 2.1.1.1 and Figure 2.8 for an example), however this often results in overlapping axis labels. Likewise, the Use automatic text boxes for plot titles option is automatically selected by default. This forces the plot's title to fit into a text box based on the width of the plot. Therefore, when this option is selected, the plot title may not appear in the size specified.



☑ Disable hardware acceleration

☑ Use bitmap fonts for copying and saving as Enhanced Metafile (.emf)

☑ Use automatic text boxes for axis labels

☑ Use automatic text boxes for plot titles

☑ Use bitmap format for copying to the clipboard

Quality

○ Always use lowest quality to minimize rendering time.

● Let GenGraph decide. Start reducing quality at: 50000 data points in a graph.

○ Always use highest quality. Rendering time may be slow.

Default date representation

Date representation: 10 dd-mmm-yyyy 25-Aug-2017

Optimize settings — This will set the graphics to use recommended settings for text quality, rendering quality, printing and saving image files.

Reset to defaults — This will reset the graphics to use default settings for all options.

Figure 1.25: Advanced tab of the Options menu for the *Graphics Viewer*.

At the bottom of each tab are three buttons: OK accepts the changes made to the options, Cancel discards the changes made to the options and Help launches the help documentation.

1.2.5.1 Resetting options to higher resolution settings

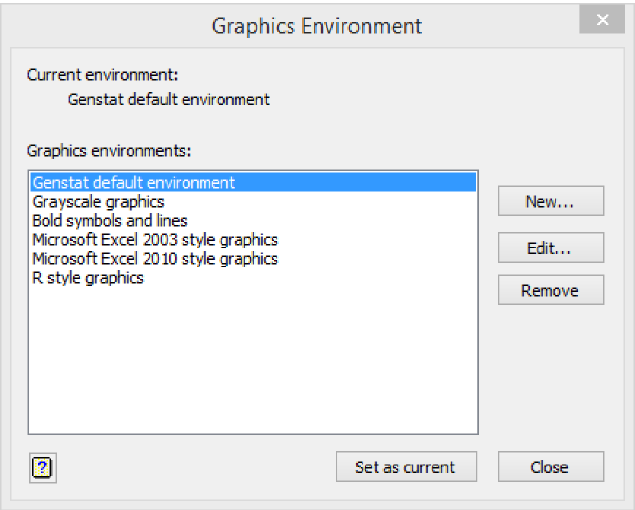
Versions of Genstat prior to the 17th edition used lower resolution settings that optimised the output from standard printers available at the time. More modern printers are capable of higher resolution output, typically 600 dpi or greater. If you have successively upgraded Genstat from earlier versions you will have imported your old print and save file settings from those versions; to increase the resolution of your saved or printed graphs, follow these steps.

1. In the *Graphics Viewer* select Tools | Options then click the Advanced tab (Figure 1.25).
2. Click Optimize settings to let Genstat choose recommended settings for text quality, rendering quality, printing and saving image files.

1.3 Graphics Environment

The appearance of graphical output in Genstat is controlled by the *Graphics Environment*. The *Graphics Environment* specifies how graphs are to be produced, controlling aspects such as whether the graph is enclosed in a box, how the key is displayed, and the colours used for plotting. Genstat provides *Graphics Environments* to suit different tastes and situations. Alternatively, you can design your own (see Sections 1.3.1 and 1.3.2). *Graphics Environments* are saved in a special file format with extension `.ggd` (see Section 1.3.3).

To see the choices of *Graphics Environments* available, from the menu select Tools | Graphics environments…. This opens the Graphics Environment menu shown in Figure 1.26. Your currently selected environment will be highlighted.



Current environment:
Genstat default environment

Graphics environments:
Genstat default environment
Grayscale graphics
Bold symbols and lines
Microsoft Excel 2003 style graphics
Microsoft Excel 2010 style graphics
R style graphics

Figure 1.26: Graphics Environment menu accessed via Tools | Graphics environments….

The Graphics environments: pane lists all of the available *Graphics Environments* (i.e. `.ggd` files stored in the graphics subfolder of the Genstat add-ins folder; see Section 1.3.3). Genstat provides several built-in *Graphics Environments*, including the Genstat Default Environment, designed to be appropriate for many different types of graph. The default environment was used to create the graphs presented earlier in this chapter. Environments for creating graphs in the style of Excel and R are also provided.

To activate a different *Graphics Environment*, highlight the desired environment in the Graphics environments: pane then click the Set as current button. This will not only activate the selected *Graphics Environment* in the current session but will continue to use it each time Genstat is re-started (until another environment is activated).

To show how the appearance of the graph changes according to which built-in *Graphics Environment* is currently active, let's re-create the two graphs in Section 1.1 (Figure 1.27: histogram of `Sulphur` and Figure 1.28: scatter plot of `Sulphur` against `Windsp`) under the six built-in *Graphics Environments*.

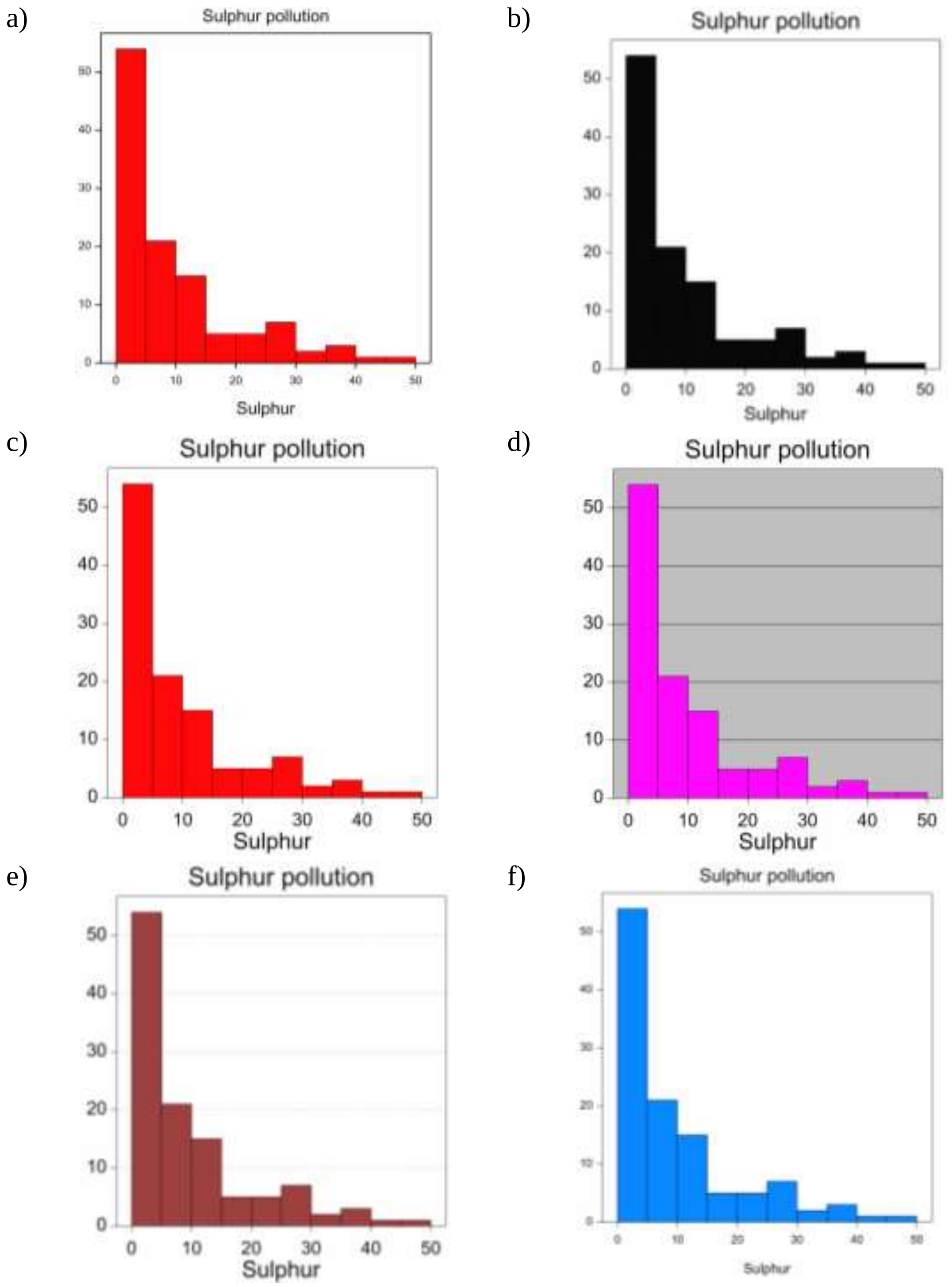


Figure 1.27: Histogram of `Sulphur` created under the six built-in *Graphics Environments*; a) Genstat Default Environment (*cf* Figure 1.7 of Section 1.1), b) Grayscale graphics, c) Bold symbols and lines, d) Microsoft Excel 2003 style graphics, e) Microsoft Excel 2010 style graphics, f) R style graphics.

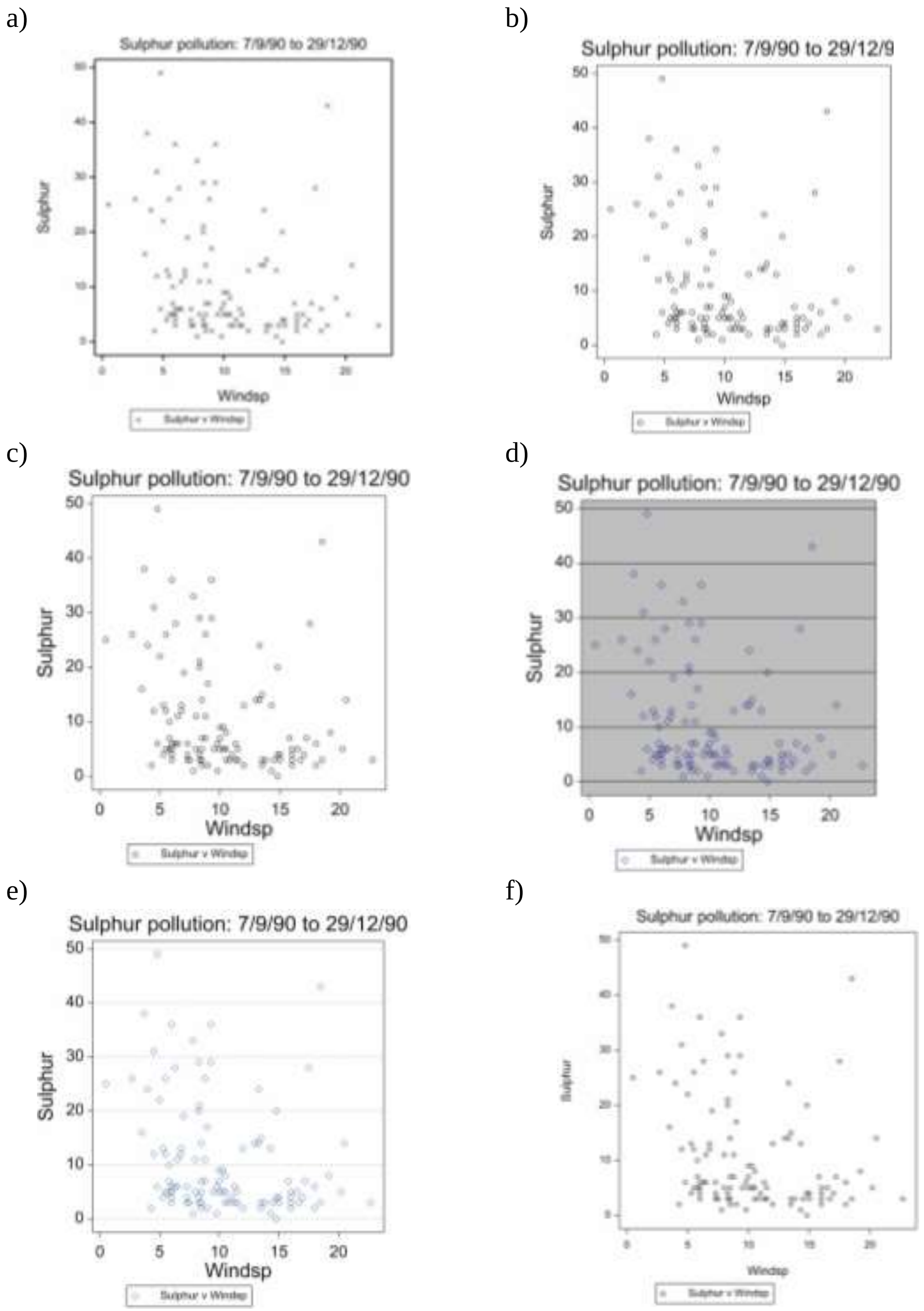


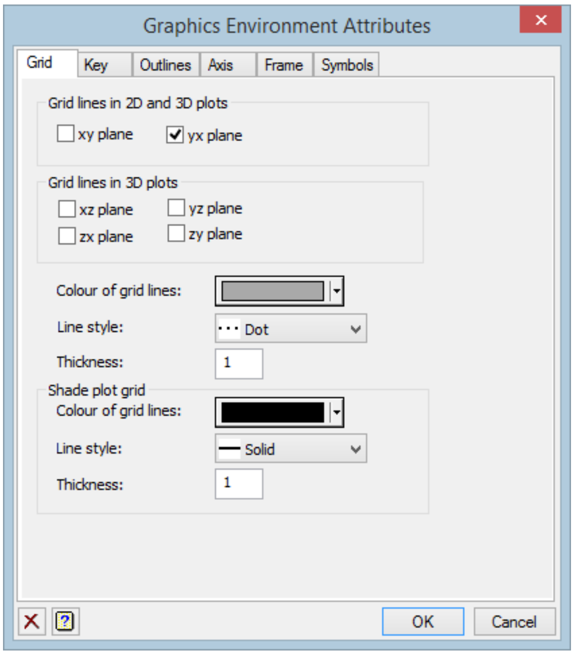
Figure 1.28: Scatter plot of `Sulphur` against `Windsp` created under the six built-in *Graphics Environments*; a) Genstat Default Environment (*cf* Figure 1.10 of Section 1.1) , b) Grayscale graphics, c) Bold symbols and lines, d) Microsoft Excel 2003 style graphics, e) Microsoft Excel 2010 style graphics, f) R style graphics.

1.3.1 Editing an existing Graphics Environment

You can modify an existing *Graphics Environment* (but not the Genstat Default Environment) by clicking on the Edit... button in the Graphics Environment menu (Figure 1.26). This opens the Graphics Environment Attributes menu, shown in Figure 1.29, comprising six tabs used to control:

- Grid tab: aspects of grid lines, such as their colours and presence;
- Key tab: aspects of the key such as the font and colour;
- Outlines tab: outlines of graphs such as histograms, bar charts and pie charts;
- Axis tab: aspects of axes such as fonts and colours for titles and labels;
- Frame tab: aspects of the frame such as the title font and colour;
- Symbols tab: aspects of the pens used to display the symbol, such as colours and symbol size.

The Grid tab, populated with the settings of the built-in *Graphics Environment* Microsoft Excel 2010 style graphics, is shown in Figure 1.29. The options in the Grid lines in 2D and 3D plots and Grid lines in 3D plots panes control whether or not grid lines are drawn in a particular direction. For example, the selection of yx plane draws grid lines in the yx plane running from the y-axis (i.e., parallel to the x-axis). Here you can also control the colour, line style and thickness of the grid lines used by the *Graphics Environment*.



Grid lines in 2D and 3D plots

□ xy plane ☑ yx plane

Grid lines in 3D plots

□ xz plane □ yz plane

□ zx plane □ zy plane

Colour of grid lines:

Line style: Dot

Thickness: 1

Shade plot grid

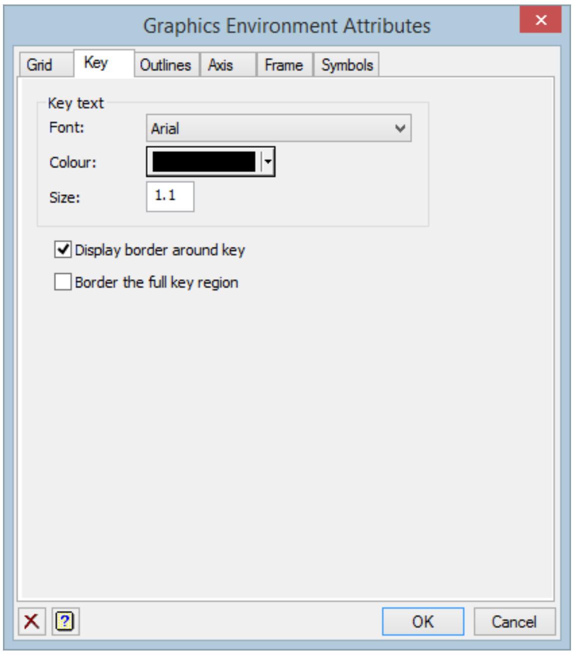
Colour of grid lines: ■

Line style: Solid

Thickness: 1

Figure 1.29: Grid tab of the Graphics Environment Attributes menu, launch by clicking on the Edit button on the Graphics Environment menu. The tab is populated with the settings of the built-in *Graphics Environment* Microsoft Excel 2010 style graphics.

Figure 1.30 shows the Key tab populated with the settings of the built-in *Graphics Environment* Microsoft Excel 2010 style graphics. Here you can set the font style, colour and size (relative to the default font size) of the key used by *Graphics Environment*. Options are also provided for displaying a border around the key. If Border the full key region is selected, the box around the key is drawn using the full region that the key is placed in. For example, if the key is placed in Window 2, then the box will be drawn around the border of Window 2.

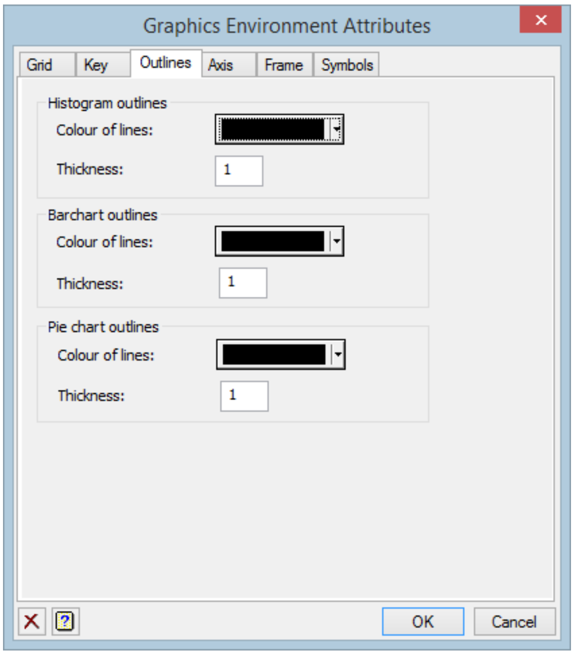


Key text
Font: Arial
Colour: ■
Size: 1.1

☑ Display border around key
□ Border the full key region

Figure 1.30: Key tab populated with the settings of the *Graphics Environment* Microsoft Excel 2010 style graphics.

The Outlines tab, populated with the Microsoft Excel 2010 style graphics settings, is shown in Figure 1.31. It comprises three panes where you can set the outline colour and thickness for histograms, bar charts and pie charts.



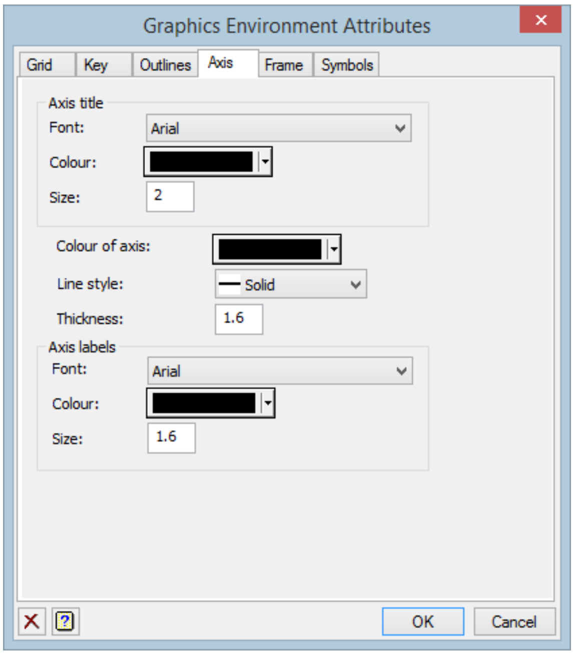
Histogram outlines
Colour of lines: ■
Thickness: 1

Barchart outlines
Colour of lines: ■
Thickness: 1

Pie chart outlines
Colour of lines: ■
Thickness: 1

Figure 1.31: Outlines tab populated with the settings of the *Graphics Environment* Microsoft Excel 2010 style graphics.

The Axis tab (populated with the Microsoft Excel 2010 style graphics settings) is shown in Figure 1.32. Here you can set the font style, colour and size (relative to the default font size) of the axes titles and labels, used by *Graphics Environment*. You can also set the colour, style and thickness of the axes lines.



Graphics Environment Attributes

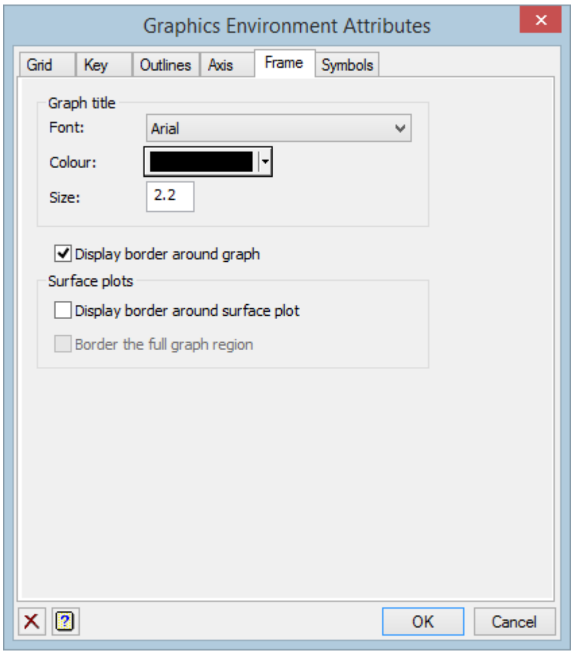
Axis title
Font: Arial
Colour: ■
Size: 2

Colour of axis: ■
Line style: Solid
Thickness: 1.6

Axis labels
Font: Arial
Colour: ■
Size: 1.6

Figure 1.32: Axis tab populated with the settings of the *Graphics Environment* Microsoft Excel 2010 style graphics.

The Frame tab (populated with the Microsoft Excel 2010 style graphics settings) is shown in Figure 1.33. Here you can set the font style, colour and size (relative to the default font size) of the graph title. You can also control whether or not the *Graphics Environment* draws a bounding box around the graphs. For surface plots, when Border the full graph region is selected a box is drawn around the full region the surface plot is drawn in. For example, if the surface plot is drawn in Window 5, then the box will be drawn around the border of Window 5.



Graphics Environment Attributes

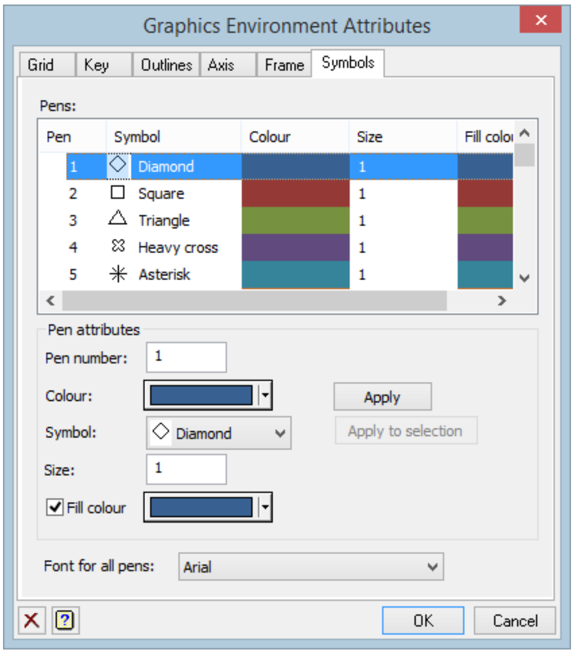
Graph title
Font: Arial
Colour: ■
Size: 2.2

☑ Display border around graph

Surface plots
☐ Display border around surface plot
☐ Border the full graph region

Figure 1.33: Frame tab populated with the settings of the *Graphics Environment* Microsoft Excel 2010 style graphics.

Figure 1.34 shows the Symbols tab populated with the settings of the *Graphics Environment* Microsoft Excel 2010 style graphics. The Pens: pane lists the available pens within Genstat and their associated symbol attributes. You can select a pen in the Pens: pane and alter its attributes (colour, symbol, symbol size, and fill colour) by changing the various settings in the Pen attributes pane. Click Apply to apply the changes to the selected pen. To change several pens simultaneously, simply select multiple pens in the Pens: pane (hold the Ctrl button down whilst selecting the pens), make the desired changes in the Pen attributes pane and click Apply to selection. This opens a dialog box asking you to confirm what settings in the selection to change.



Pens:

Pen	Symbol	Colour	Size	Fill colou
1	◇ Diamond		1	
2	□ Square		1	
3	△ Triangle		1	
4	Heavy cross		1	
5	✳ Asterisk		1	

Pen attributes

Pen number: 1

Colour:

Symbol: ◇ Diamond

Size: 1

☑ Fill colour

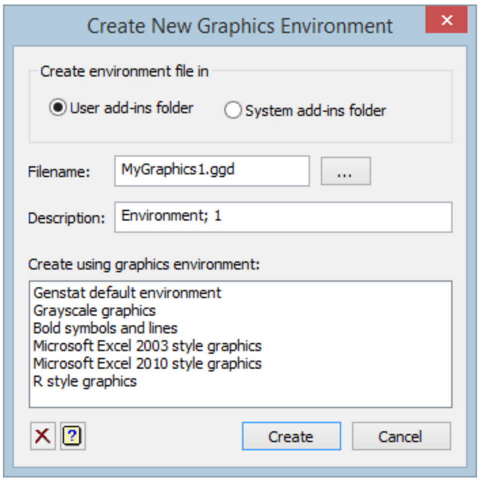
Font for all pens: Arial

Figure 1.34: Symbols tab populated with the settings of the *Graphics Environment* Microsoft Excel 2010 style graphics.

After editing the tabs, click the OK button. This will permanently save your changes to the *Graphics Environment*.

1.3.2 Creating a new Graphics Environment

Rather than modifying an existing built-in *Graphics Environment*, it might be preferable to create a new one. You can design your own *Graphics Environment* by clicking on the New... button on the Graphics Environment menu (Figure 1.26). This opens the Create New Graphics Environment menu (Figure 1.35).



Create environment file in

● User add-ins folder ○ System add-ins folder

Filename: MyGraphics1.ggd

Description: Environment; 1

Create using graphics environment:

Genstat default environment
Grayscale graphics
Bold symbols and lines
Microsoft Excel 2003 style graphics
Microsoft Excel 2010 style graphics
R style graphics

Figure 1.35: Menu for creating a new *Graphics Environment*.

New *Graphics Environments* are saved as `.ggd` files in the Genstat add-ins folder (see Section 1.3.3). The two options of the Create environment file in pane specify whether the *Graphics Environment* file will be saved within the system or user add-in folder. To make the

Graphics Environment file available system wide, i.e. to all users with access to Genstat on a network server or on a local machine, the file must be placed in the system add-in folder. Alternatively, to make the *Graphics Environment* file available only to the current user, the file must be placed within the user add-in folder. (The location of the user add-in folder is set on the Tools | Option | General tab.)

The Filename: field lets you specify a filename. Save the file using the extension `.ggd`. In the Description: field you can specify a description of your new *Graphics Environment*. This description will be displayed in the list of *Graphics Environments* on the Graphics Environment menu (see Figure 1.26).

The Create using graphics environment: pane lists all of the available *Graphics Environments.* You must select one of these to initially create your new *Graphics Environment*.

Clicking the Create button launches the Graphics Environment Attributes menu (see Figure 1.29). The tabs of this menu will be populated with the settings of the *Graphics Environment* you chose in the Create using graphics environment: pane. Modify these settings then click OK to create your new *Graphics Environments* (see Section 1.3.1). The description of your newly created *Graphics Environment* will now appear in the list of *Graphics Environments* on the Graphics Environment menu (see Figure 1.26). (Note, you can delete a selected *Graphics Environment* and its associated file from the add-ins folder by clicking on the Remove button in the Graphics Environment menu.)

1.3.3 Graphics Environment files

A *Graphics Environment* is created by a `.ggd` file that contains commands specifying exactly how a graph is to be produced. It controls aspects like whether or not boxes are drawn around the plots, how the key is displayed, and the styles and the colours of outlines for graphs such as histograms or shade plots. The *Graphics Environment* files (`.ggd`) are located in a subfolder of the add-ins folder called “*graphics*”. There are two types of add-in folders: system and user. *Graphics Environment* files that are available system wide, i.e. to all users that have access to Genstat on a network server or on a local machine, are located in the graphics subfolder of the system add-in folder called “*AddIns within the Genstat installation*”. Alternatively, *Graphics Environment* files available only to the current user are located in the user add-in folder. The location of the user add-in folder is controlled via the General tab within the Tool | Options menu: the default file path is C:\Program Files\Gen19Ed\AddIns.

2 Genstat Graphics menu

Many different types of graph can be accessed directly as options of the Graphics menu found on the menu bar (see Figure 1.3). Selecting a graph will launch a window containing its menu, designed to guide you through the creation of your chosen graphic. The menus of all graphs have a similar structure comprising a Data tab and an Options tab, and where relevant tabs for Error bars, Lines and Symbols, Key, Axis, X-Axis, Y-Axis, Z-Axis and Frame. To demonstrate how to generate and customize a graph using the Graphics menu, this chapter presents four case-studies: a bar chart (Section 2.1), a line plot (Section 2.2), a 3D scatter plot (Section 2.3) and a trellis plot (Section 2.4). For each case study, the menu options are described in detail. We also explore how to use *Editor* mode in the *Graphics Viewer* to modify the graph.

The Graphics menu also provides functionality to add text, reference lines and arrows to an existing graph open in the *Graphics Viewer*. In Section 2.5, we illustrate how to add these additional features to a graph.

Comprehensive help for all of the graphics menus is readily available by clicking on the help icon, ?, located at the bottom left-hand corner of the menu window.

All graphs illustrated in this chapter are generated using the Genstat Default Environment.

In this chapter you will learn:

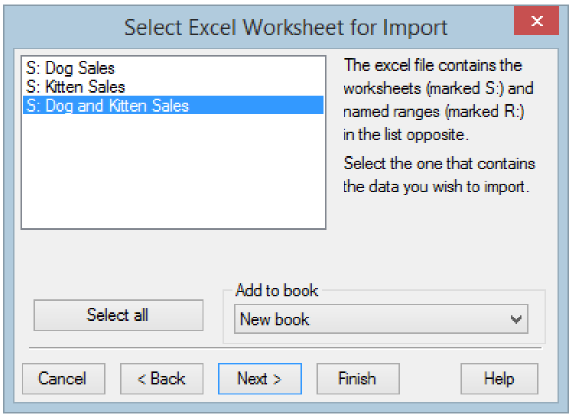
- how to create a graph using the Graphics menu
- how to add text, reference lines and arrows to a graph
- the functionality of the Data, Options, Error bars, Lines and Symbols, Key, Axis, X-Axis, Y-Axis, Z-Axis and Frame tabs

2.1 Case study: bar chart

A bar chart provides a graphical representation of a table. For example, a bar chart might present product sales in different cities, or sales of different types of products. Bar charts differ from histograms in that the x-axis is not divided into a set of contiguous intervals (as in Figure 1.7), but rather the bars are located at equal intervals along the x-axis. Also, the table need not contain counts, but may contain any numerical values, for example profits (and losses), or yields of a crop.

Bar charts with either one or two classifying factors can be plotted using the Graphics | Bar Chart... menu. In the following subsections, we'll describe the functionality of the Bar Chart menu's six tabs using the example data set `Toysales.xls` for illustration.

The excel file `Toysales.xls` contains yearly sale data on toy dogs and toy kittens from a business with shops in four cities. The worksheet, `Dog and Kitten Sales`, contains the number of toy dogs and kittens sold (`SoldDog` and `SoldKitten`, respectively), and the price of these per unit (`CostDog` and `CostKitten`, respectively) for each shop (`City`) over three years (`Year`). To load the worksheet, click on File | Open Example Data Sets..., then select `Toysales.xls`. Clicking the Open data button launches the Select Excel Worksheet for Import menu where we select the worksheet `Dog and Kitten Sales` Figure 2.2. Click Finish and the spreadsheet shown in Figure 2.2 will be loaded.



Select Excel Worksheet for Import

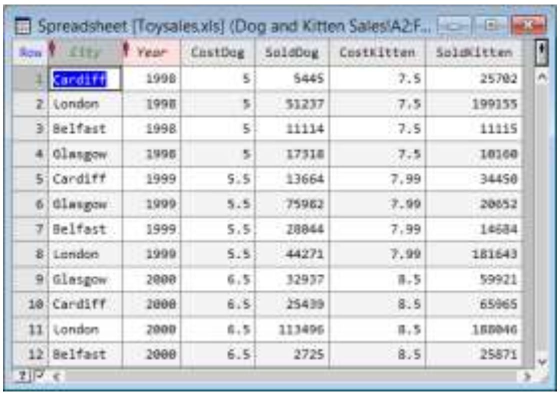
S: Dog Sales
S: Kitten Sales
S: Dog and Kitten Sales

The excel file contains the worksheets (marked S:) and named ranges (marked R:) in the list opposite.

Select the one that contains the data you wish to import.

Add to book: New book

Figure 2.2: Selecting the worksheet `Dog and Kitten Sales` of Excel file `Toysales.xls` to import.



Spreadsheet [Toysales.xls] (Dog and Kitten Sales!A2:F...

Row	City	Year	CostDog	SoldDog	CostKitten	SoldKitten
1	Cardiff	1998	5	5445	7.5	25702
2	London	1998	5	51237	7.5	199155
3	Belfast	1998	5	11114	7.5	11115
4	Glasgow	1998	5	17318	7.5	10160
5	Cardiff	1999	5.5	13664	7.99	34450
6	Glasgow	1999	5.5	75982	7.99	20652
7	Belfast	1999	5.5	28844	7.99	14684
8	London	1999	5.5	44271	7.99	181643
9	Glasgow	2000	6.5	32937	8.5	59921
10	Cardiff	2000	6.5	25439	8.5	65965
11	London	2000	6.5	113496	8.5	188046
12	Belfast	2000	6.5	2725	8.5	25871

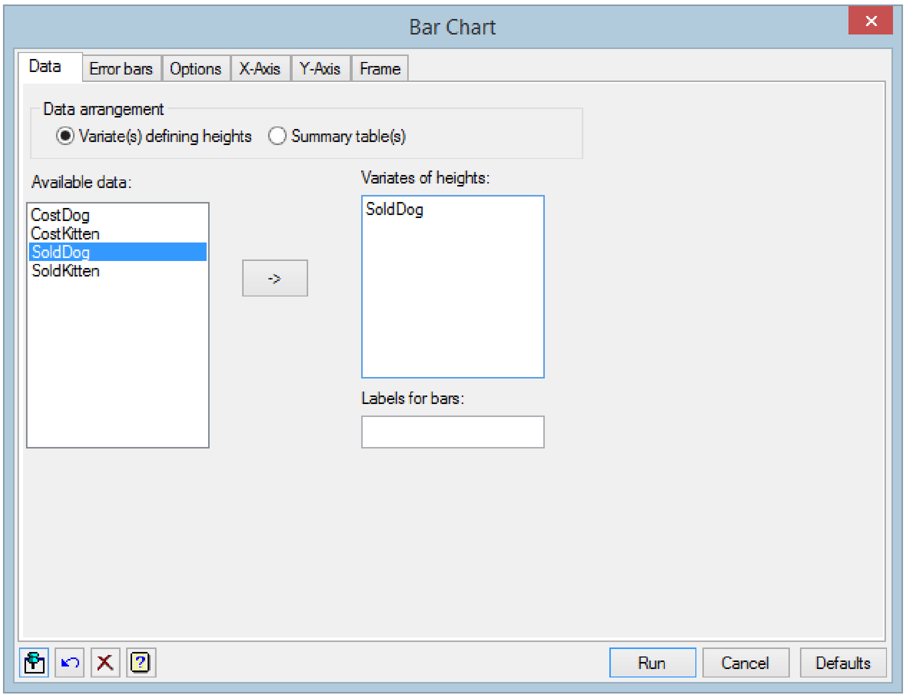
Figure 2.2: Spreadsheet of the toy dog and toy kitten yearly sale data (`Toysales.xls`).

2.1.1 Data tab

The Graphics | Bar Chart... menu opens in the Data tab, used for specifying the data to plot (Figure 2.3). The data can be supplied as a Variate(s) defining heights or as a Summary table(s). A *single bar chart* is plotted when a one-way table of data or a variate defining the bar heights is supplied. Alternatively, several bar charts are plotted on the same graph if a list of one-way tables (classified by the same factor), a list of variates, or a two-way table is supplied. Examples of these different scenarios are provided below.

2.1.1.1 Data supplied as a variate(s)

To form a bar chart from data supplied as a variate(s), select Variate(s) defining heights in the Data arrangement pane (Figure 2.3). The variates available for plotting are listed in the Available data: field. The toy data contains four variates (CostDog, CostKitten, SoldDog and SoldKitten). We'll begin by plotting the number of toy dogs sold (SoldDog) in each year at the four cities in a *single bar chart*. Select SoldDog and click on the arrow (or alternatively double-click on SoldDog) to move it into the input field, Variates of heights:, where the variates for plotting are specified. The Labels for bars: field lets you specify a text structure for labelling the bars. As no text structures have yet been defined, the Available data: field is empty when the Labels for bars: field is selected.



Data arrangement
● Variate(s) defining heights ○ Summary table(s)

Available data:
CostDog
CostKitten
SoldDog
SoldKitten

Variates of heights:
SoldDog

Labels for bars:

Figure 2.3: Data tab settings for drawing a bar chart of the number of toy dogs sold (SoldDog).

Once the data have been supplied, you can draw the bar chart graph by clicking the Run button. The resulting bar chart is shown in Figure 2.4. Alternatively, additional options and axes settings can be set in the other tabs (as described in the subsections that follow).

The bar chart comprises 12 bars, labelled 1, 2, …, 12 corresponding to the rows of data in Figure 2.2. Note, that although the data is ordered by Year, the ordering of City within Year is inconsistent. To aid interpretation of the bar chart, we shall label the bars and order them by Year and City within Year.

To create a text structure for labelling the bars, click on the Spreadsheet window (Figure 2.2) then select Spread | Calculate | Combine Text…. This opens the Combine/Concatenate Text Columns menu where we'll combine the Year and City columns to create a new text structure, RowLabels (refer to Figure 2.5).

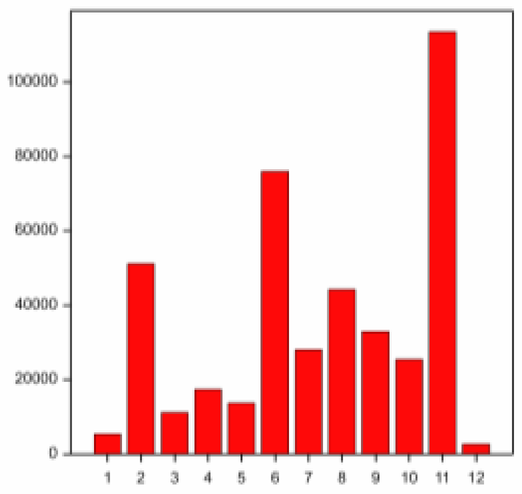
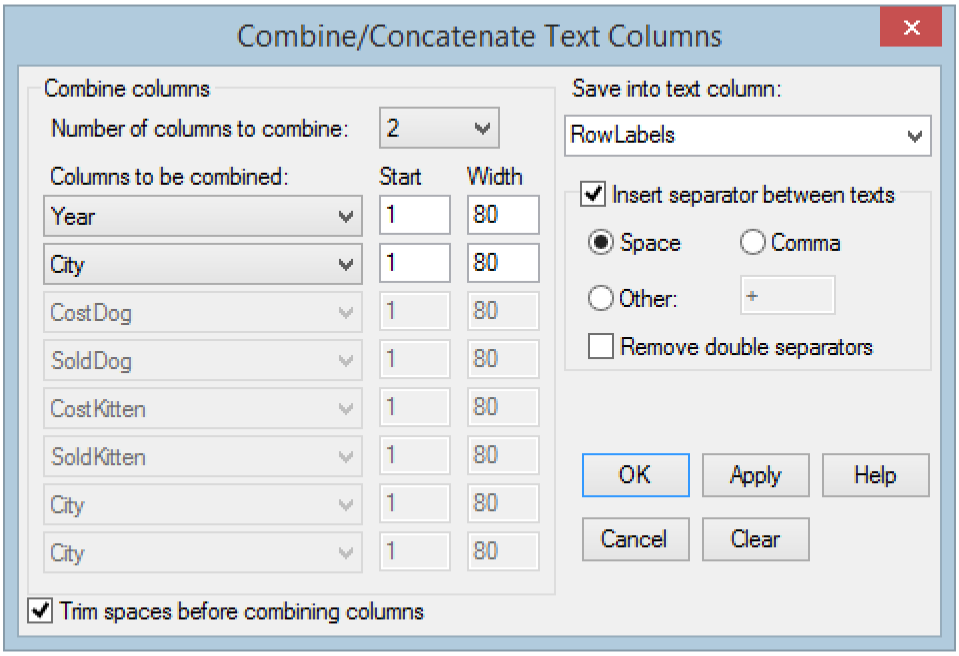


Figure 2.4: Bar chart of the number of toy dogs sold (SoldDog).



Combine/Concatenate Text Columns

Combine columns

Number of columns to combine: 2

Columns to be combined:	Start	Width
Year	1	80
City	1	80
CostDog	1	80
SoldDog	1	80
CostKitten	1	80
SoldKitten	1	80
City	1	80
City	1	80

☑ Trim spaces before combining columns

Save into text column: RowLabels

☑ Insert separator between texts

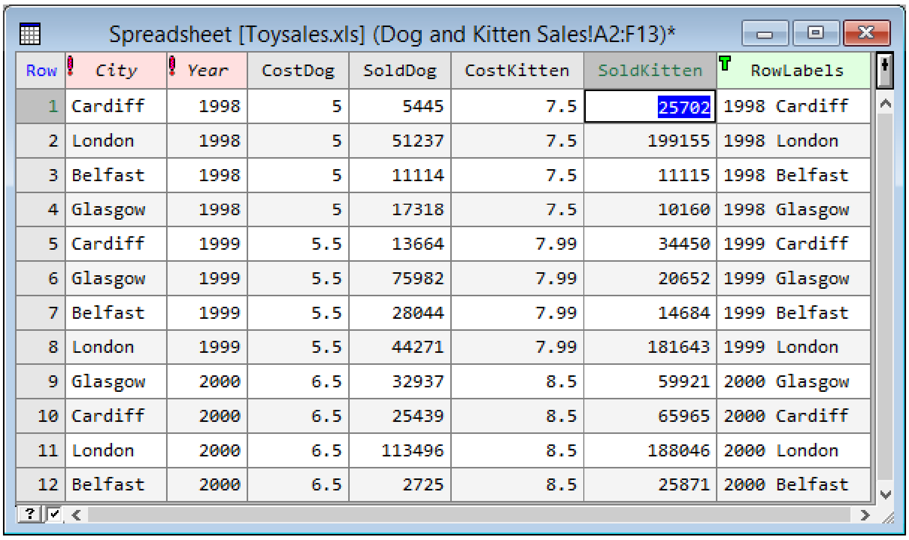
● Space ○ Comma

○ Other: +

☐ Remove double separators

Figure 2.5: Combine/Concatenate Text Columns menu settings used to create a new text structure, from the Year and City columns of Figure 2.2, to label the bars of Figure 2.4.

Next, to ensure the bars are consistently ordered, click on the Spreadsheet window then select Spread | Sort…. This opens the Sort on Column values menu where we select RowLabels in the Sort on column: field. Click OK and the rows of data are now ordered by RowLabels (i.e. Year and City within Year) (see Figure 2.6).



Spreadsheet [Toysales.xls] (Dog and Kitten Sales!A2:F13)*

Row	City	Year	CostDog	SoldDog	CostKitten	SoldKitten	RowLabels
1	Cardiff	1998	5	5445	7.5	25702	1998 Cardiff
2	London	1998	5	51237	7.5	199155	1998 London
3	Belfast	1998	5	11114	7.5	11115	1998 Belfast
4	Glasgow	1998	5	17318	7.5	10160	1998 Glasgow
5	Cardiff	1999	5.5	13664	7.99	34450	1999 Cardiff
6	Glasgow	1999	5.5	75982	7.99	20652	1999 Glasgow
7	Belfast	1999	5.5	28044	7.99	14684	1999 Belfast
8	London	1999	5.5	44271	7.99	181643	1999 London
9	Glasgow	2000	6.5	32937	8.5	59921	2000 Glasgow
10	Cardiff	2000	6.5	25439	8.5	65965	2000 Cardiff
11	London	2000	6.5	113496	8.5	188046	2000 London
12	Belfast	2000	6.5	2725	8.5	25871	2000 Belfast

Figure 2.6: Spreadsheet of the toy dog and toy kitten yearly sale data (`Toysales.xls`), with text column `RowLabels` added and data ordered by `Year` and `City` within `Year`.

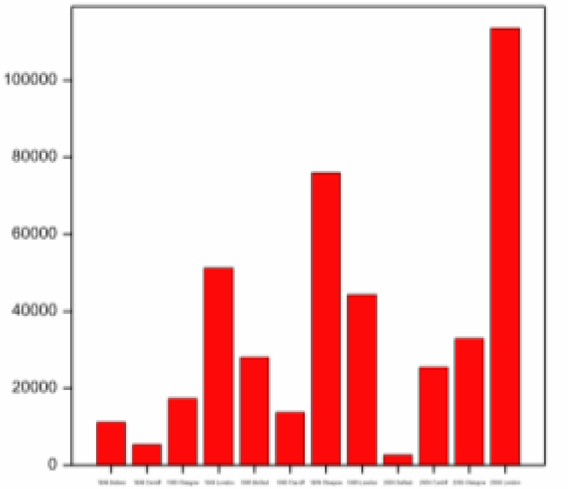


Figure 2.7: Bar chart of the number of toy dogs sold (`SoldDog`) with bar labels (`RowLabels`).

We will now redraw the bar chart in Figure 2.4 but include bar labels by entering `RowLabels` into the Labels for bars: field (see Figure 2.3). The resulting bar chart is shown in Figure 2.7.

The bar labels are illegibly small as the axis labels are forced to fit into non-overlapping text boxes by default. The width of these text boxes are determined by the distance between tick marks (see Section 1.2.5, Advanced options). To make them legible, we will edit their settings in the *Graphics Viewer* (see Section 1.2). Invoke *Editor* mode, for example by double-clicking on the graph. Once in *Editor* mode, open the X Axis tab of the Options window, for example by choosing the X Axis option under Edit on the menu bar. In the Display labels pane, we set the Direction: to Perpendicular, so that the labels are orientated to run perpendicular to the x-axis. To increase the font size, click on the Label font... button and increase the Size: to `10` in the Font window. Click OK to close the Font window. Click Apply to apply the changes to the bar labels. (In order to freely resize the font, ensure that Use automatic text boxes for axis labels is unselected in the Advanced tab of the global *Graphics Viewer* Options menu (see Section 1.2.5).)

To further enhance the bar chart, we'll also add a title to the y-axis. In the Y Axis tab, select Display title and enter the text "`Number of Toy Dogs Sold`". Click Apply to add the y-axis title.

Finally, we'll colour the individual bars according to the city: green = `Belfast`, red = `Cardiff`, blue = `Glasgow` and white = `London`. Open the Barchart Options tab of the Options menu. Select a bar using the Bar: field (bars are labelled numerically by row number, i.e. bar 1 = `1998 Belfast`, bar 2 = `1998 Cardiff`, ..., bar 12 = `2000 London`) and pick the required colour in the Bar Colour: dropdown menu. Ensure sure Apply colour to all bars is not selected then click Apply to change the colour of the selected bar. Repeat to appropriately colour all bars.

Click OK then Save and Close, to make the requested changes and exit *Editor* mode. The resulting graph is shown in Figure 2.8.

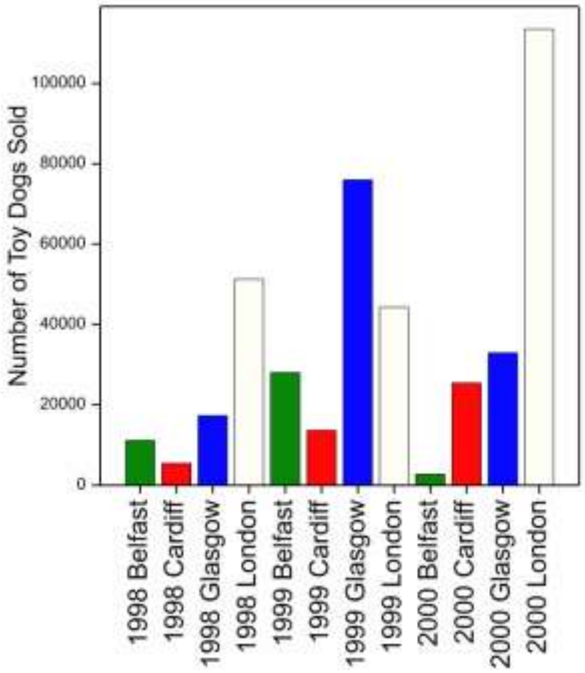
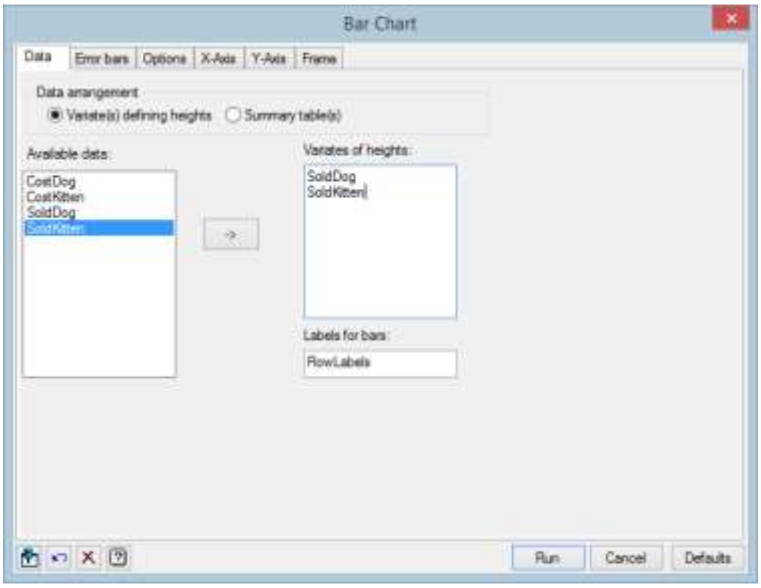


Figure 2.8: Bar chart of the number of toy dogs sold (`SoldDog`) having edited the bar labels (`RowLabels`) to make them legible, added a y-axis title and coloured the bars according to the `City`.

We can also plot *several bar charts* on the same graph, for example both the number of toy dogs and toy kittens sold (`SoldDog` and `SoldKitten`, respectively), by entering multiple variates into the Variates of heights: field of the Data tab (see Figure 2.9). However, if several variates are supplied they must contain the same number of values.



Bar Chart

Data | Error bars | Options | X-Axis | Y-Axis | Frame

Data arrangement

● Variate(s) defining heights ○ Summary table(s)

Available data:

CostDog
CostKitten
SoldDog
SoldKitten

Variates of heights:

SoldDog
SoldKitten

Labels for bars:

RowLabels

Figure 2.9: Data tab settings for drawing a bar chart with two variates: the number of toy dogs sold (SoldDog) and the number of toy kittens sold (SoldKitten).

A bar chart of both the SoldDog and SoldKitten variates is shown in Figure 2.10. As above, the bar labels have been edited in the *Graphics Viewer* to make them legible. Furthermore, to avoid overlap with the bar labels, the key has been moved to the top left by opening the Key tab on the Options menu (when in *Editor* mode) and setting the X Position: to 0.5 and the Y Position: to 1 in the Key Region pane (see Figure 2.11). We've also opted to remove the box around the key by deselecting Display Border:.

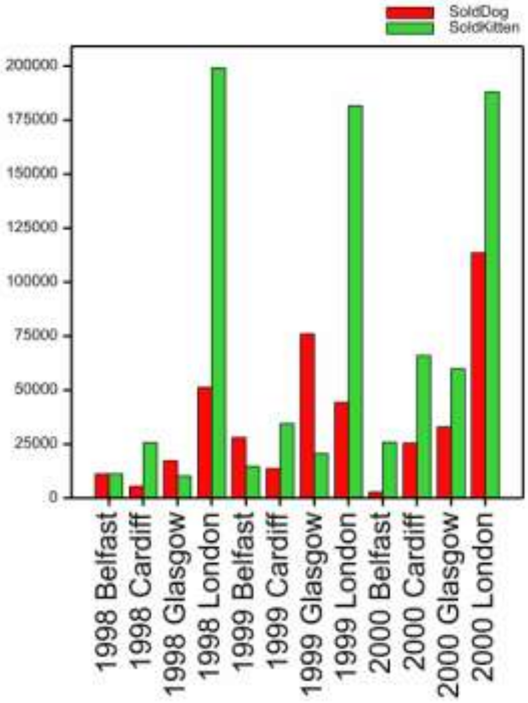
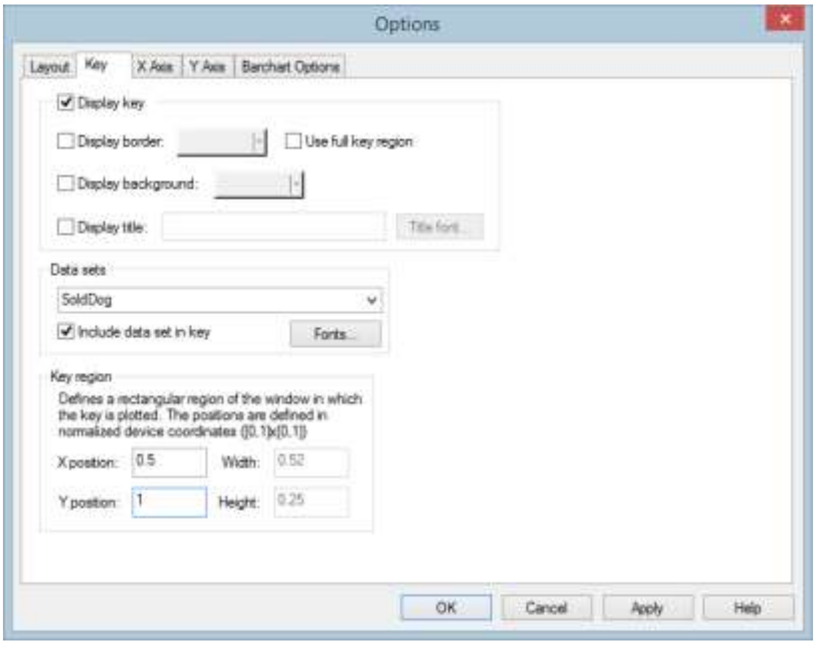


Figure 2.10: Bar chart with two variates defining bar heights: SoldDog and SoldKitten. The bar labels (RowLabels) have been edited to make them legible, and the key moved to avoid overlap.



☑ Display key

☐ Display border:

☐ Use full key region

☐ Display background:

☐ Display title:

Data sets

SoldDog

☑ Include data set in key

Key region

Defines a rectangular region of the window in which the key is plotted. The positions are defined in normalized device coordinates ([0,1]x[0,1])

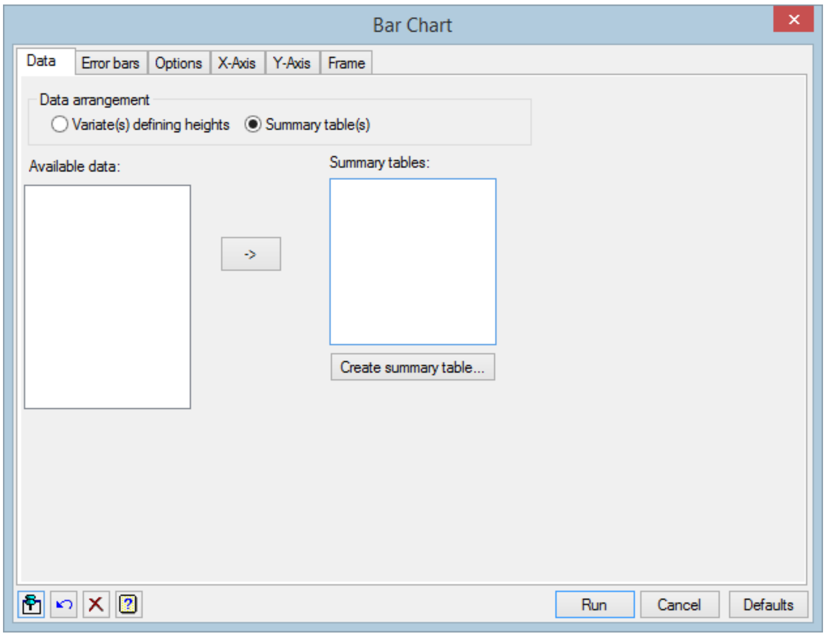
X position: 0.5 Width: 0.52

Y position: 1 Height: 0.25

Figure 2.11: Settings of the Key tab of the Options menu used to change the position of the key (in *Editor* mode).

2.1.1.2 Data supplied as a summary table(s)

One-way and two-way summary tables, whose entries contains the heights for each bar, can also be used to generate bar charts. To form a bar chart from data supplied as a table, select Summary tables(s) in the Data arrangement pane (Figure 2.12).

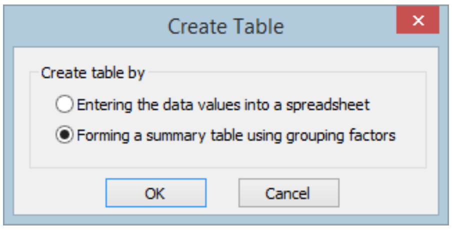


Data arrangement

○ Variate(s) defining heights ● Summary table(s)

Figure 2.12: Fields of the Data tab when Summary table(s) is selected.

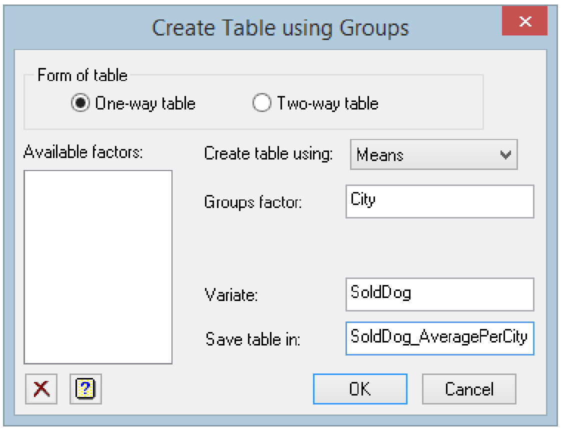
All summary tables available for plotting will be listed in the Available data: field. As our session doesn't yet contain any one- or two-way tables we click the Create summary table... button to form one. This opens a dialog box (Figure 2.13) offering two options for creating tables with 1 or 2 classifying factors: Entering the data values into a spreadsheet or Forming a summary table using grouping factors. We can use the grouping factors Year and/or City to form a summary table.



○ Entering the data values into a spreadsheet
● Forming a summary table using grouping factors

Figure 2.13: Create Table dialog box with the two options for creating a one- or a two-way summary table.

Select Forming a summary table using grouping factors and click OK to open the Create Table using Groups menu (Figure 2.14) First, let's create a summary table giving the average number of toy dogs sold per year in each of the four cities. To do this, form a One-way table of the Variate: SoldDog by the Groups factor: City. The Create table using: dropdown provides a list of the statistics that can be used to summarize the groups. Here, we select the statistic Means, so that the summary table contains the average number of toy dogs sold per year for each city. Finally, the Save table in: field lets us specify a name for our table. We save the table as SoldDog_AveragePerCity. Clicking OK will form the table and return us to the Data tab of the Bar Chart menu (Figure 2.12). Our table, SoldDog_AveragePerCity, now appears in the Available data: field.

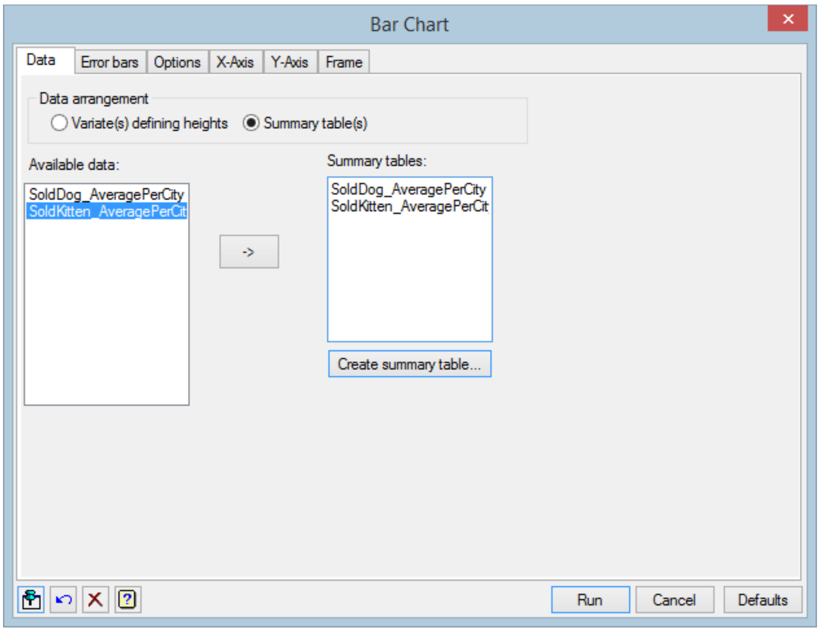


Form of table: ● One-way table ○ Two-way table
Create table using: Means
Groups factor: City
Variate: SoldDog
Save table in: SoldDog_AveragePerCity

Figure 2.14: Settings of the Create Table using Groups menu used to create SoldDog_AveragePerCity, a one-way table containing the average number of toy dogs sold per year in each city.

Repeat using the Variate: SoldKitten to create a summary table giving the average number of toy kittens sold per year in each city. Save this table as SoldKitten_AveragePerCity.

In the input field, Summary tables:, the tables for plotting are specified. You can supply one or more one-way tables or a single two-way table. If several one-way tables are supplied, they must all be classified by the same factor. Here, we select our newly created one-way tables, SoldDog_AveragePerCity and SoldKitten_AveragePerCity, both of which are classified by the factor City (Figure 2.15). Click Run to produce the graph shown in Figure 2.16.



Data arrangement
○ Variate(s) defining heights ● Summary table(s)

Available data:
SoldDog_AveragePerCity
SoldKitten_AveragePerCit

Summary tables:
SoldDog_AveragePerCity
SoldKitten_AveragePerCit

Figure 2.15: Data tab settings for creating a bar chart from two one-way tables (SoldDog_AveragePerCity and SoldKitten_AveragePerCity), which respectively describe the average number of toy dogs and toy kittens sold per year in each of the four cities.

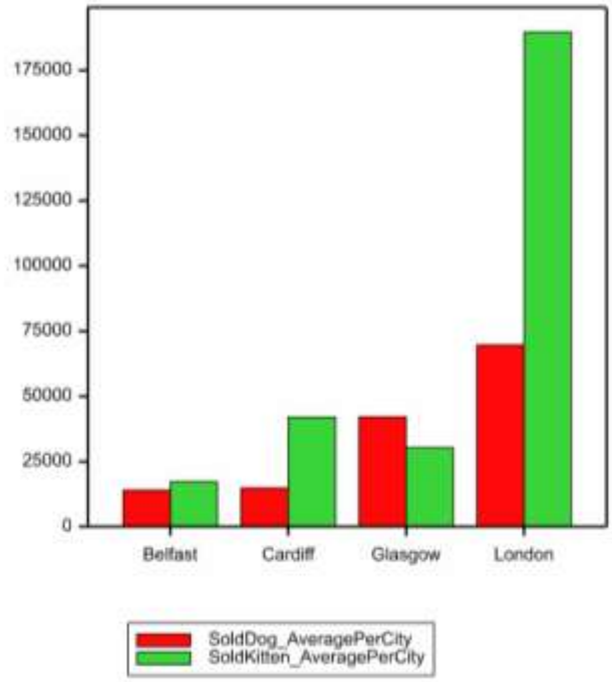


Figure 2.16: Bar chart describing the average number of toy dogs and toy kittens sold per year in four cities.

Finally, we demonstrate the creation of a bar-chart from a two-way table. After selecting Summary tables(s) in the Data arrangement pane of the Bar Chart menu (Figure 2.15), click the Create summary table… button. In the dialog box choose Forming a summary table using grouping factors and click OK to open the Create Table using Groups menu (Figure 2.13). We will use the grouping factors `Year` and `City` to rearrange the toy dog sales data (see Figure 2.6) into a two-way table. (As in this example there is no replication at the `Year` by `City` level, setting the Create table using: field to Totals or Means simply rearranges the original data from long-format into a two-way table). The factor supplied in the Groups factor 1: field defines the colour of the bars, whereas the factor supplied in the Groups factor 2: field defines the grouping of bars on the x-axis. The bar charts produced with Groups factor 1: `City` and Groups factor 2: `Year`, and vice versa, are given in Figure 2.17a and b, respectively.

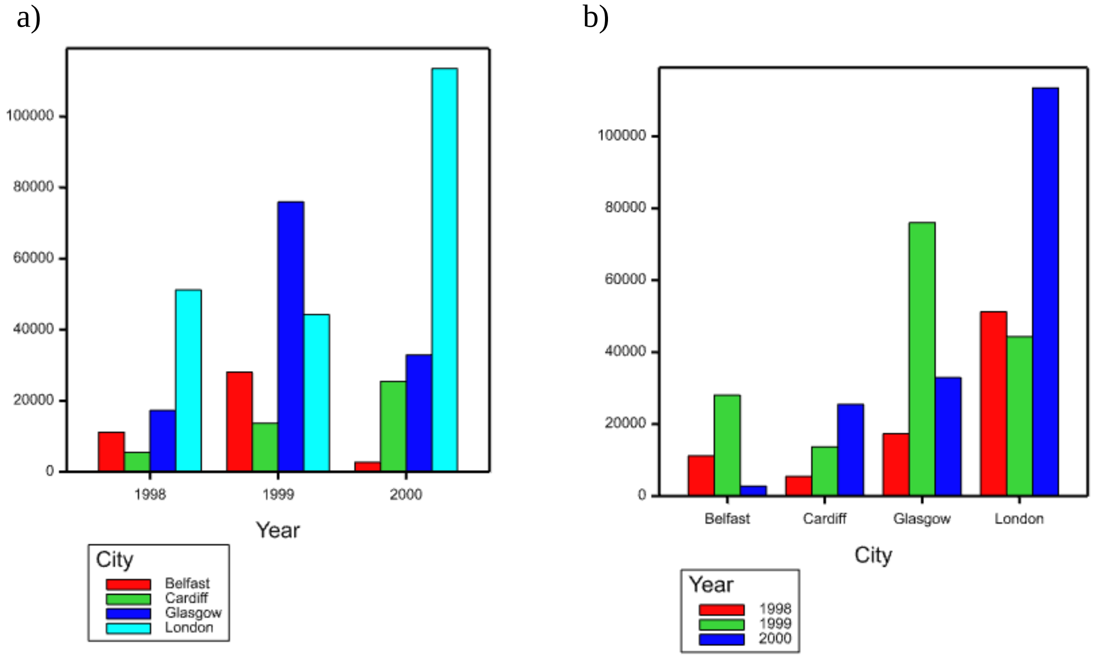
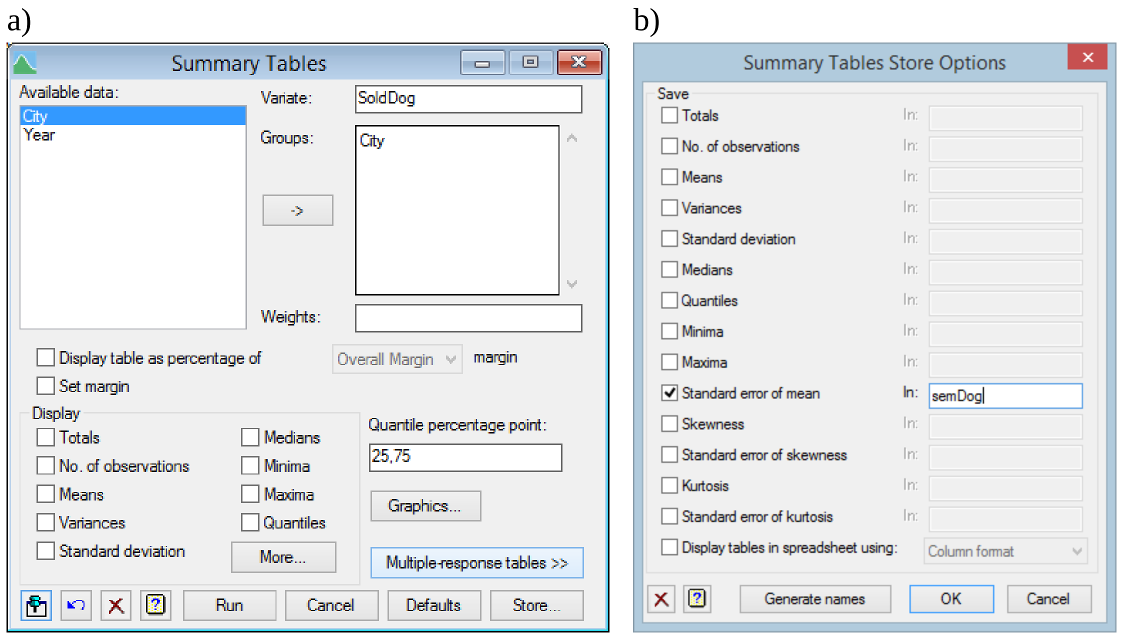


Figure 2.17: Bar chart of the `SoldDog` variable rearranged into a two-way table. a) Groups factor 1: `City` and Groups factor 2: `Year`, b) Groups factor 1: `Year` and Groups factor 2: `City`.

2.1.2 Error bars tab

The Error bars tab, which can be used to include error bars on the bar chart, becomes available after the data has been supplied within the Data tab (Section 2.1.1). Each error bar takes the form of a horizontal line joined by a vertical line at the specified height both above and below the bar. The heights for the error bars must be supplied using the same type of data structures that were used in the Data tab menu. For example, if the data were supplied in variates defining the heights (as in Section 2.1.1.1) then the heights of the error bars must also be supplied using variates.

We will add standard error of the mean (SEM) error bars to Figure 2.16 – a bar chart describing the average number of toy dogs and toy kittens sold per year in each of the four cities. However, in order to do so we must first calculate the SEMs of the plotted means. In Genstat, this is readily achieved using the Stats | Summary Statistics | Summary tables… menu (Figure 2.18a). To calculate the SEM of the average number of toy dogs sold per year, set the Variate: field to `SoldDog` and the Groups: field to `City`. Click the Store… button to open the Summary Tables Store Options menu (Figure 2.18b), enabling us to save the SEMs in a table. Select Standard Error of Mean. The In: field provides a space to name the table of SEMs. We'll store them in `semDog`. Repeat for `SoldKitten`, and save the SEMs in a table named `semKitten`.

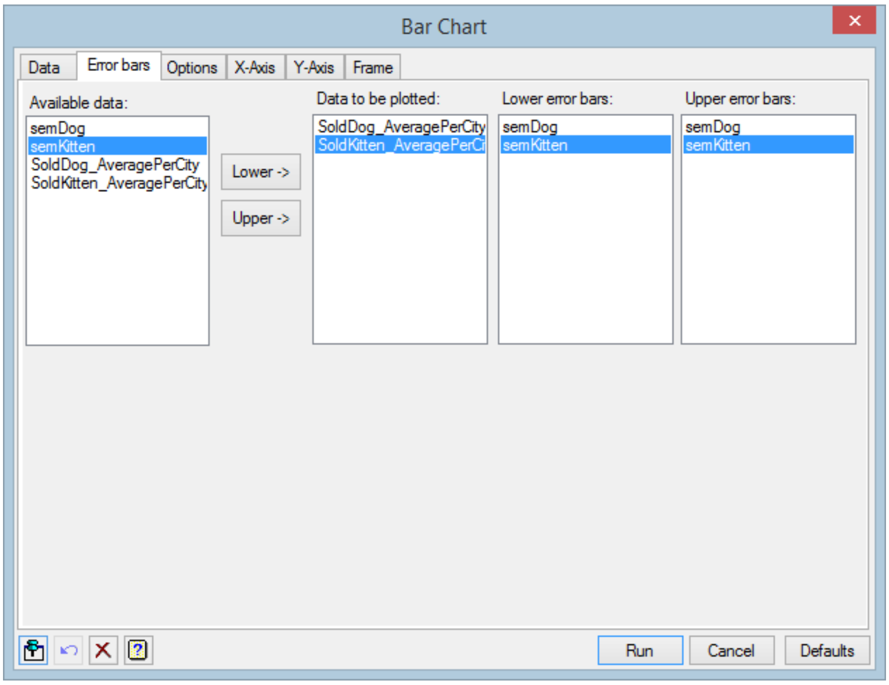


Variate: SoldDog
Groups: City
Weights:
Quantile percentage point: 25,75

☑ Standard error of mean In: semDog

Figure 2.18: Using the Summary Table menu to a) calculate and b) save a table, `semDog`, containing the standard error of the average number of toy dogs sold per year for each of the four cities.

In the Error bars tab (Figure 2.19), the height of the lower and upper error bars are specified in the Lower error bars: and Upper error bars: fields, respectively. Using the settings shown in Figure 2.19, +/- SEM bars are added to Figure 2.16. The resulting graph is shown in Figure 2.20. Note, if Lower error bars: are not specified, the error bars are assumed to have the same heights below and above the bars (for our example, once again resulting in Figure 2.20).



Available data:
- semDog
- semKitten
- SoldDog_AveragePerCity
- SoldKitten_AveragePerCity

Data to be plotted:
- SoldDog_AveragePerCity
- SoldKitten_AveragePerCi

Lower error bars:
- semDog
- semKitten

Upper error bars:
- semDog
- semKitten

Figure 2.19: Error bars tab: adding +/- SEM bars to Figure 2.16.

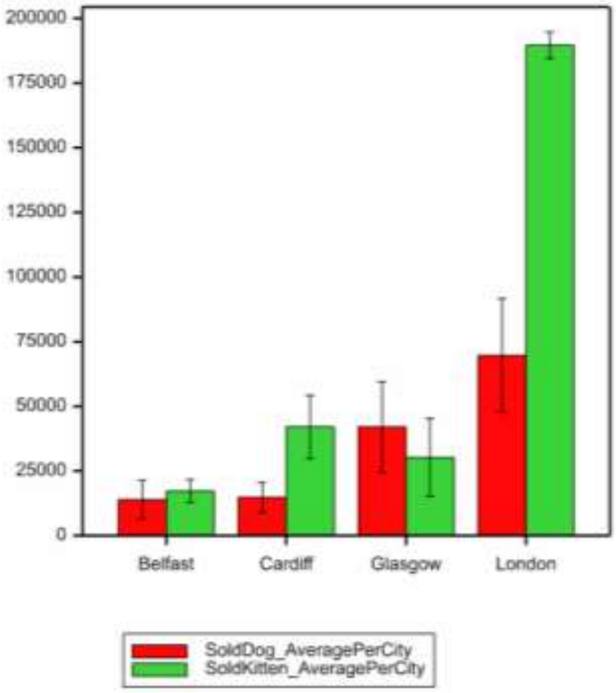


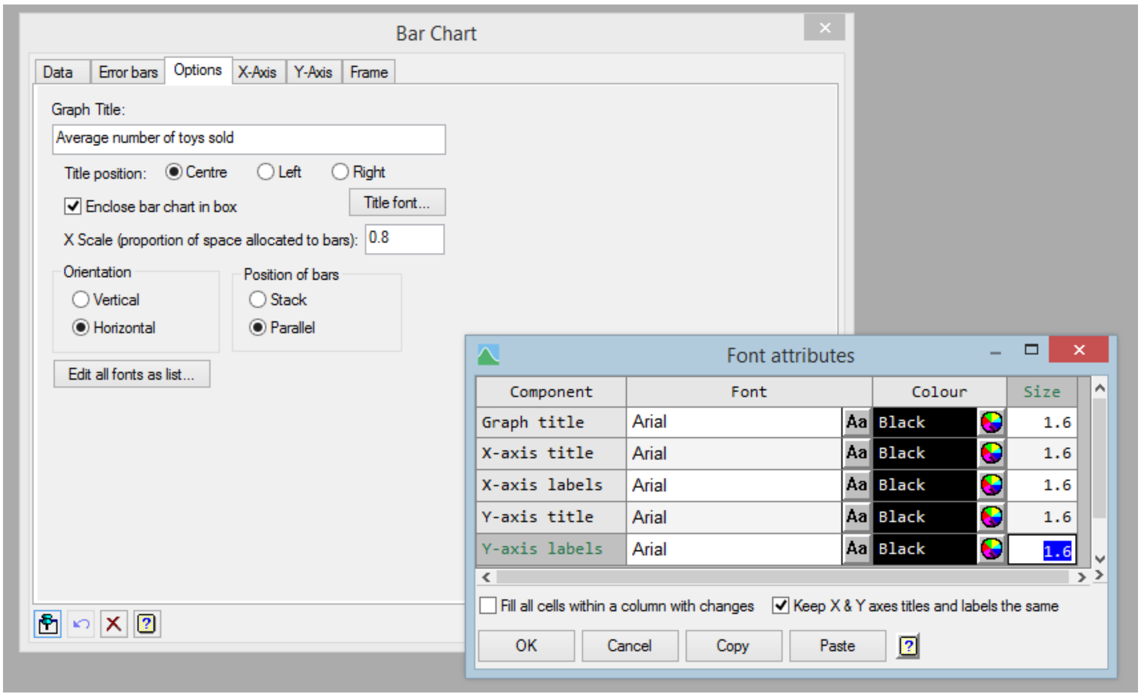
Figure 2.20: Bar chart describing the average number of toy dogs and toy kittens sold per year in the four cities. Errors bars denote +/-SEM.

2.1.3 Options tab

The Options tab allows you to set attributes that control the appearance of a bar chart (Figure 2.21). The Graph Title: field lets you enter a title for your graph. If Enclose bar chart in box is selected, a box is drawn around the graph. You can control the gap between bars using the X scale (proportion of space allocated to bars): setting. Here, the proportion of the space along the x-axis that each bar occupies is specified (default = `0.8`). Increase this value to reduce the gap (a setting `1` forces the bars to be contiguous); decrease this value to increase the gap. The Orientation pane allows you to specify the orientation of the bars as either Vertical (the default) or Horizontal. For multiple bar charts, such as Figure 2.20, the Position of bars pane allows you to select between Parallel (the default) or Stacked bars.

The Title font... button opens a menu where you can change the font attributes (style, colour and size) of the graph's title. Alternatively, the Edit all fonts as list... button opens the Font attributes menu in which you can specify the font attributes of all titles and labels (Figure 2.21).

For illustration, we'll re-plot the graph of Figure 2.20, using the Options tab to add a title, remove the enclosing box, draw horizontally stacked bars and, using the Edit all fonts as list...| Font attributes menu, increase the size of the x-axis labels. See Figure 2.21. The resulting bar chart is shown in Figure 2.22.



Graph Title: Average number of toys sold

Title position: ● Centre ○ Left ○ Right

☑ Enclose bar chart in box

X Scale (proportion of space allocated to bars): 0.8

Orientation: ○ Vertical ● Horizontal

Position of bars: ○ Stack ● Parallel

Component	Font	Colour	Size
Graph title	Arial	Black	1.6
X-axis title	Arial	Black	1.6
X-axis labels	Arial	Black	1.6
Y-axis title	Arial	Black	1.6
Y-axis labels	Arial	Black	1.6

□ Fill all cells within a column with changes ☑ Keep X & Y axes titles and labels the same

Figure 2.21: Settings of the Options tab used for adding a title, removing the enclosing box, and re-plotting Figure 2.20 with horizontally stacked bars.

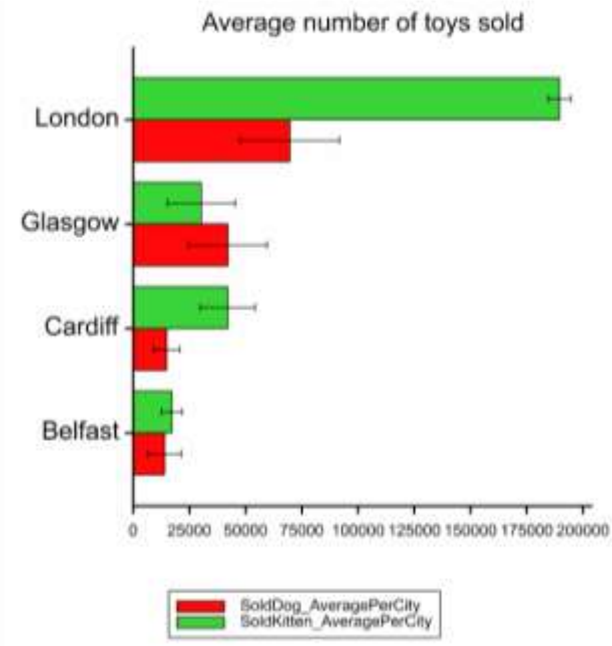


Figure 2.22: Re-plotting Figure 2.20 using the Options tab settings given in Figure 2.21.

2.1.4 X-Axis and Y-Axis tabs

The X-Axis and Y-Axis tabs provide control over the appearance of the bar chart's x- and y-axes, respectively. The Y-Axis tab of the Bar Chart menu is shown in Figure 2.23. The X-Axis tab is similar, albeit with a subset of the fields, since not all the functionality is required to control a bar chart's x-axis (i.e. there is no need to set lower and upper bounds on a bar chart's x-axis).

The visibility of the axis is controlled using Display axis. Deselecting Display axis will hide the axis. Selecting Reverse axis direction will reverse the direction the axis runs (i.e. from upper to lower, instead of the default lower to upper).

The Display title field lets you enter an axis title. You can control the appearance of the title using the Position: and Orientation: radio buttons, and using the font menu launched by clicking on the Title font… button.

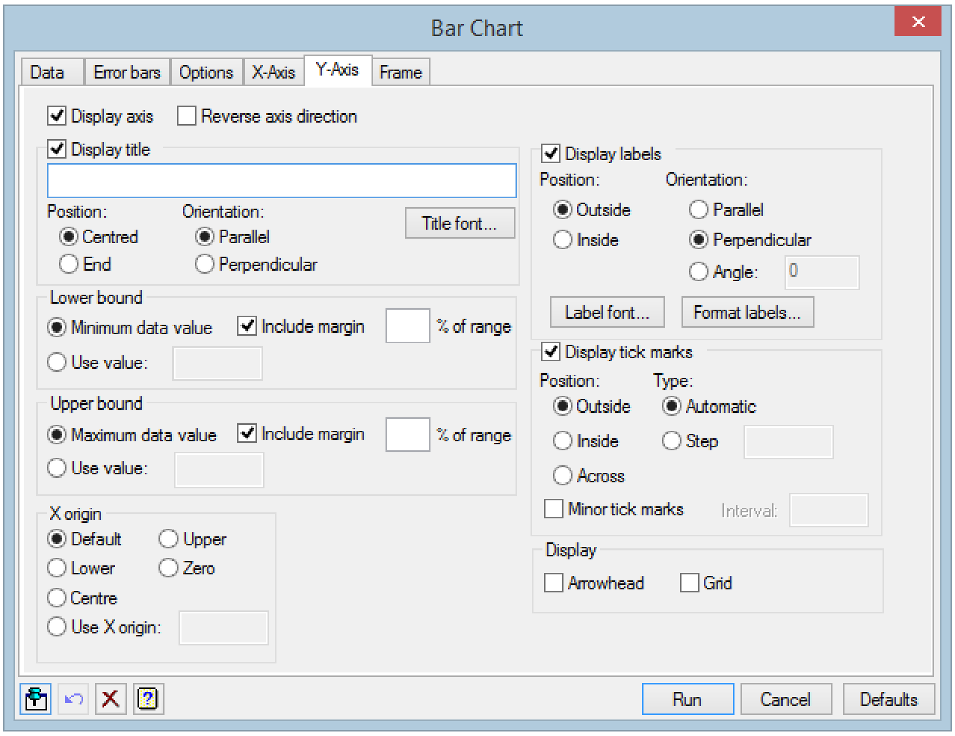
The lower bound of the axis is set within the Lower bound pane. You can either supply a lower bound, by selecting Use value: and entering a number into the space provided, or request that a bound based on the minimum data value is used, by selecting Minimum data value. In the latter case, by selecting Include margin and entering a value into the % of range field, you can control the size of margin between the lower value of the axis and the minimum data value. Similarly, the upper bound can be set using the fields within the Upper bound pane.

The X origin pane is used to specify the position of the origin on the x-axis. By default, the lower bound of the x-axis is used, so that the axis is drawn at the bottom of the plot. However, you can use the radio buttons to put the origin at either the Upper, Lower, Centre, or Zero value on the x-axis, or at a specified value by selecting Use X origin: and entering a number. Note, if the origin specified is outside the axis bounds, then the upper or lower bound is automatically adjusted to include it.

The Display labels option controls whether or not the axis labels are displayed. If selected, the appearance of the labels can be controlled using the Position: radio buttons, the Orientation: radio buttons, the Edit font for y-axis label menu (launched by clicking Label font…) and the Format Label Options menu (launched by clicking Format labels…).

The Display tick marks option controls whether or not tick marks are displayed. If selected, you can control the positioning and type of tick marks using the options provided. If Minor tick marks is selected, you can specify the number of minor tick marks to draw between each of the (major) tick marks.

In the Display pane you can select whether an arrowhead will appear at the end of the axis and whether grid lines are drawn.



☑ Display axis ☐ Reverse axis direction

☑ Display title

Position: ● Centred ○ End

Orientation: ● Parallel ○ Perpendicular

Lower bound: ● Minimum data value ☑ Include margin % of range ○ Use value:

Upper bound: ● Maximum data value ☑ Include margin % of range ○ Use value:

X origin: ● Default ○ Upper ○ Lower ○ Zero ○ Centre ○ Use X origin:

☑ Display labels

Position: ● Outside ○ Inside

Orientation: ○ Parallel ● Perpendicular ○ Angle: 0

☑ Display tick marks

Position: ● Outside ○ Inside ○ Across

Type: ● Automatic ○ Step

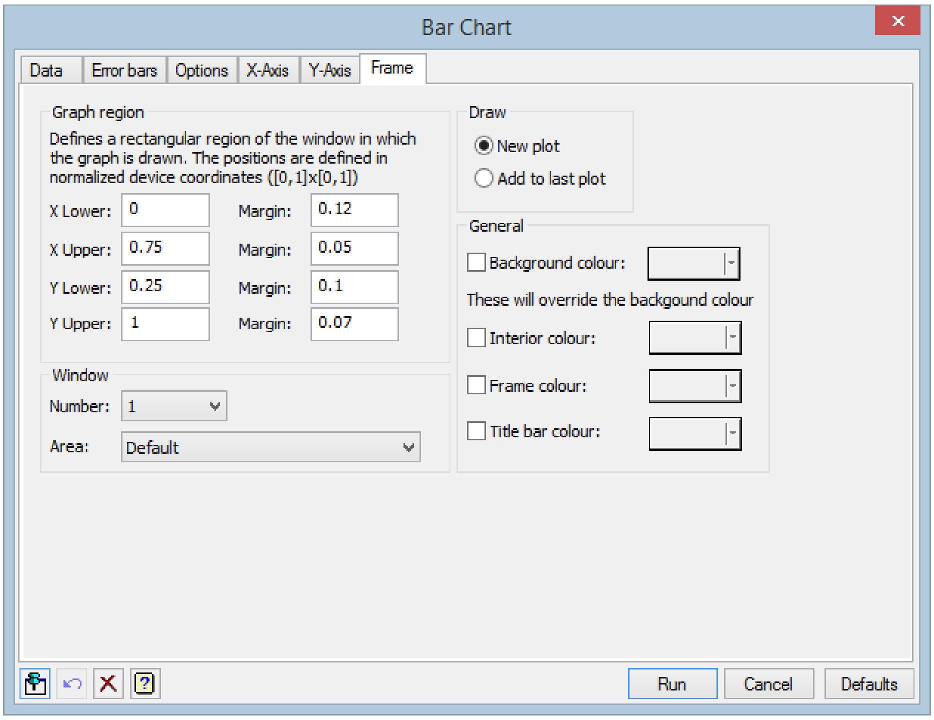
☐ Minor tick marks Interval:

Display: ☐ Arrowhead ☐ Grid

Figure 2.23: Y-Axis tab of the Bar Chart menu.

2.1.5 Frame tab

The Frame tab sets the attributes of the *frame* that the bar chart is displayed within. The graph is plotted into one of the numbered *windows* in the *frame* (by default, Window 1). Each *window* is a rectangular area of the screen which is defined using normalized device coordinates (NDC). The Graph region pane is used to define the area of the *window*, along with margins for titles, axis labels, etc. The default settings of the Graph region, corresponding to Window 1, are shown in Figure 2.24.



Bar Chart

Graph region

Defines a rectangular region of the window in which the graph is drawn. The positions are defined in normalized device coordinates ([0,1]x[0,1])

X Lower: 0 Margin: 0.12

X Upper: 0.75 Margin: 0.05

Y Lower: 0.25 Margin: 0.1

Y Upper: 1 Margin: 0.07

Window

Number: 1

Area: Default

Draw

● New plot

○ Add to last plot

General

□ Background colour:

These will override the backgound colour

□ Interior colour:

□ Frame colour:

□ Title bar colour:

Figure 2.24: Frame tab of the Bar Chart menu.

Alternatively, the Window pane allows you to define the *window* in which the bar chart is plotted. You can either select a *window* Number: or a position within the frame using the list provided in the Area: dropdown menu. When a *window* Number: or Area: is selected the positions and margins will change within the Graph region pane corresponding to the position of the selected *window* within the *frame*. You can change these settings to alter the size and position of the region.

The Draw radio buttons control whether a new plot is created in the *Graphics Viewer*, or whether the bar chart is superimposed onto the last plot drawn.

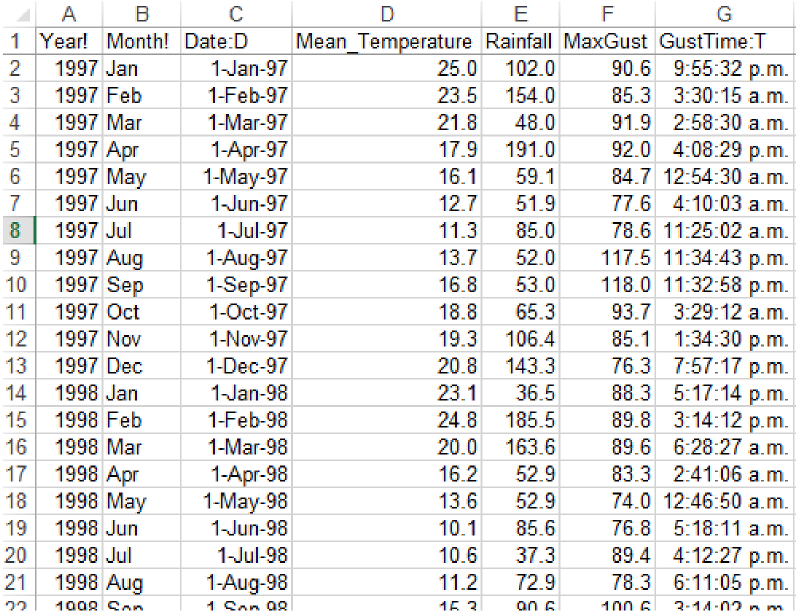
In the General pane you can specify colours for the window: either a global Background colour:, or separate colours for the interior of the window (where the data is plotted), the frame of the window (the region outside the interior) and the title bar of the window.

2.2 Case study: 2D line plot

Line plots (also known as line charts) are used to graph two variables as a series of data points connected by line segments. This allows the local change from point to point to be seen, in addition to the global trend. Line plots are very similar to scatter plots, the key differences being: i) lines connect adjacent data points, and ii) the independent variable can be ordinal as well as continuous.

Line plots, with either single or multiple X and Y variables, can be created using the Graphics | 2D Line Plot... menu. In the following subsections, the functionality of the 2D Line Plot menu is described. The example data set DiptonWeather.xls is used for illustration.

The Excel file DiptonWeather.xls contains monthly meteorological data from Dipton, New Zealand, collect from January 1997 to December 2012 (Figure 2.25). The data set comprises three continuous variables; the monthly mean of the daily maximum temperatures (Mean_Temperature), the total monthly rainfall (Rainfall) and the maximum wind speed for the month (MaxGust). The time of the day the maximum wind gust was recorded is stored as a time variate, GustTime (the suffix :T in the column title marks this column as time). The year and month the meteorological information was collected is stored in factors Year and Month (marked by the suffix !), respectively. The date of collection is stored in the date variate, Date (the suffix :D marks this column as a date).



	A	B	C	D	E	F	G
1	Year!	Month!	Date:D	Mean_Temperature	Rainfall	MaxGust	GustTime:T
2	1997	Jan	1-Jan-97	25.0	102.0	90.6	9:55:32 p.m.
3	1997	Feb	1-Feb-97	23.5	154.0	85.3	3:30:15 a.m.
4	1997	Mar	1-Mar-97	21.8	48.0	91.9	2:58:30 a.m.
5	1997	Apr	1-Apr-97	17.9	191.0	92.0	4:08:29 p.m.
6	1997	May	1-May-97	16.1	59.1	84.7	12:54:30 a.m.
7	1997	Jun	1-Jun-97	12.7	51.9	77.6	4:10:03 a.m.
8	1997	Jul	1-Jul-97	11.3	85.0	78.6	11:25:02 a.m.
9	1997	Aug	1-Aug-97	13.7	52.0	117.5	11:34:43 p.m.
10	1997	Sep	1-Sep-97	16.8	53.0	118.0	11:32:58 p.m.
11	1997	Oct	1-Oct-97	18.8	65.3	93.7	3:29:12 a.m.
12	1997	Nov	1-Nov-97	19.3	106.4	85.1	1:34:30 p.m.
13	1997	Dec	1-Dec-97	20.8	143.3	76.3	7:57:17 p.m.
14	1998	Jan	1-Jan-98	23.1	36.5	88.3	5:17:14 p.m.
15	1998	Feb	1-Feb-98	24.8	185.5	89.8	3:14:12 p.m.
16	1998	Mar	1-Mar-98	20.0	163.6	89.6	6:28:27 a.m.
17	1998	Apr	1-Apr-98	16.2	52.9	83.3	2:41:06 a.m.
18	1998	May	1-May-98	13.6	52.9	74.0	12:46:50 a.m.
19	1998	Jun	1-Jun-98	10.1	85.6	76.8	5:18:11 a.m.
20	1998	Jul	1-Jul-98	10.6	37.3	89.4	4:12:27 p.m.
21	1998	Aug	1-Aug-98	11.2	72.9	78.3	6:11:05 p.m.
22	1998	Sep	1-Sep-98	15.3	90.6	100.6	3:14:02 p.m.

Figure 2.25: Segment of the Excel file DiptonWeather.xls.

To load the Dipton weather data, click on File | Open Example Data Sets…, and then select DiptonWeather.xls.

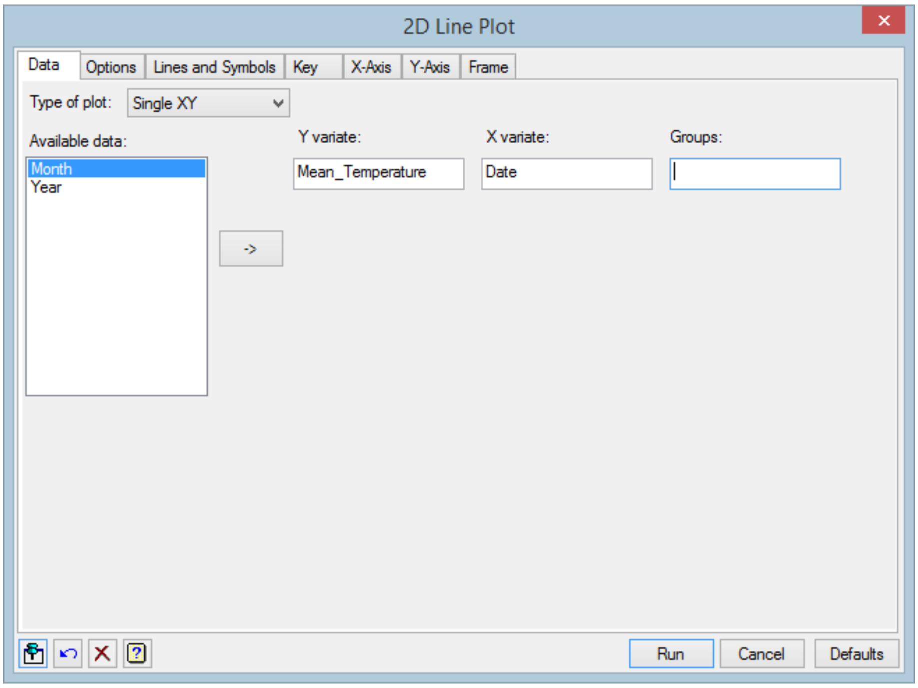
2.2.1 Data tab

The Graphics | 2D Line Plot… menu opens in the Data tab, used to supply the data to plot (Figure 2.26). The menu accommodates four types of plot, listed in the Type of plot: field;

- Single XY – used for plotting a single Y variable against a single X variable. For example, Mean_Temperature against Date (see Figure 2.27).
- Multiple X – used for plotting a single Y variable against multiple X variables in the same graph. For example, we might be interested in plotting Mean_Temperature against both Rainfall and MaxGust in a single graph.
- Multiple Y – used for plotting multiple Y variables against the same X variable in a single graph. For example, Mean_Temperature and Rainfall against Date.
- Paired XY – used when plotting multiple X and Y variables in the same graph. Here, each Y variate is paired with an X variate. For example, suppose we also had monthly rainfall data recorded in the nearby towns of Tuatapere and Gore. For each town, the pair of X (date) and Y (rainfall) variables can be plotted, as a separate line, in a single graph.

For all plot types, there are three input fields: the Y variate: and X variate: fields, where the Y and X variate(s) for plotting are specified, and the Groups: field where a factor(s) can be specified so that different groups are plotted as separate lines (on the same graph). The Available data: field lists all the available data structures appropriate to the current input field. The contents will change as you move from one field to the next. Double-click on a name (or click on the arrow button) to copy it into the current input field.

We'll begin by plotting Mean_Temperature against Date (see Figure 2.26). Click Run to create the plot using the default Options, Lines and Symbols, Key, X-Axis, Y-Axis and Frame settings (Figure 2.27a).



Type of plot: Single XY

Available data: Month, Year

Y variate: Mean_Temperature

X variate: Date

Groups:

Figure 2.26: Data tab of the 2D Line Plot menu, for a Single XY line plot of Mean_Temperature against Date.

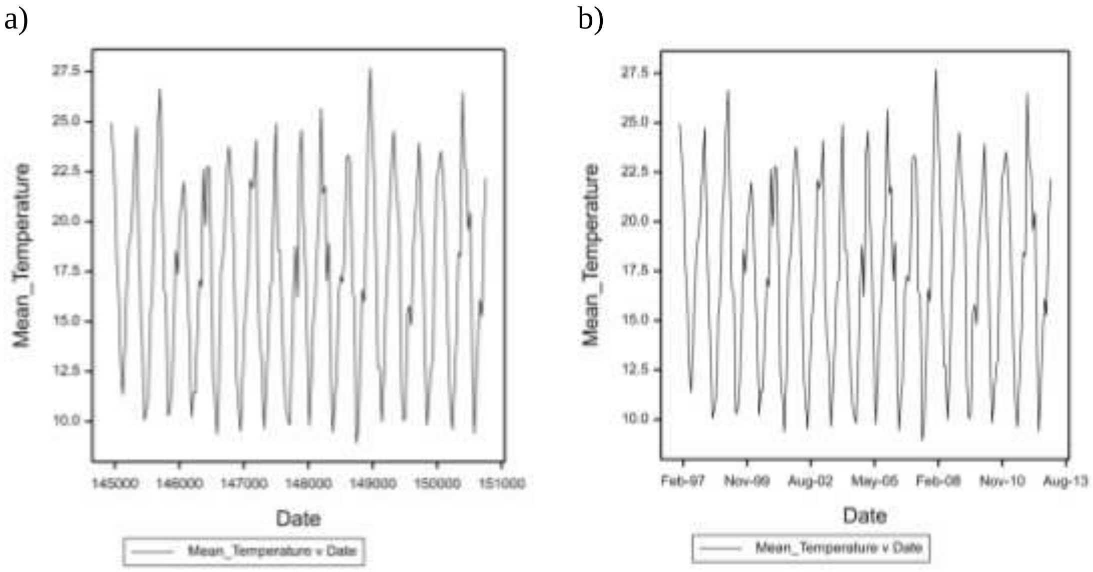
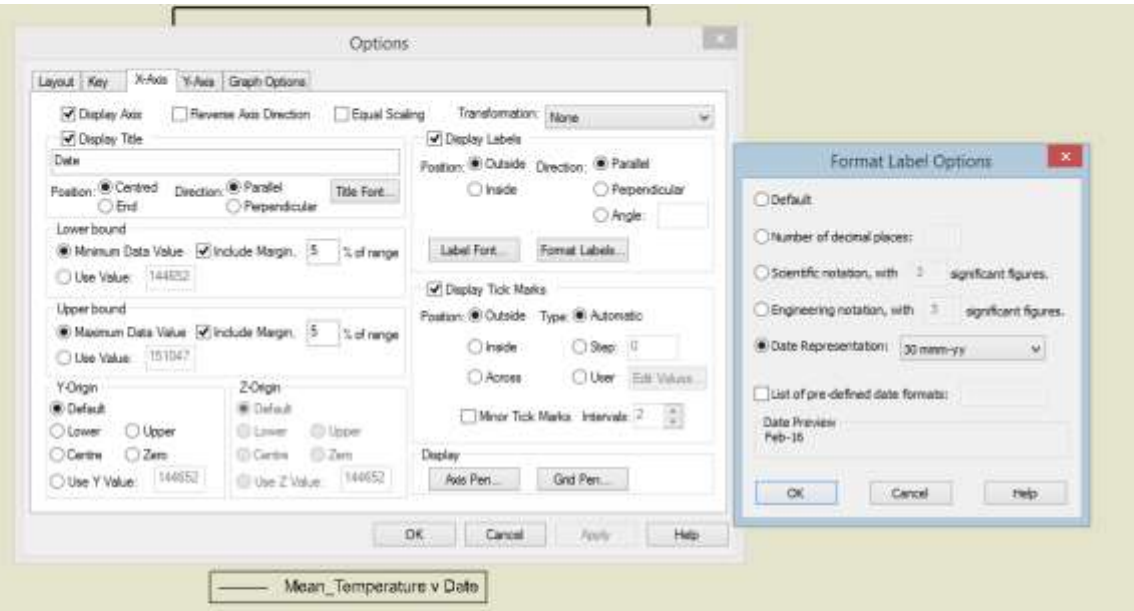


Figure 2.27: Line plot of Mean_Temperature against Date, with a) default settings and b) formatted date labels.

The x-axis labels for Date (a variate stored as a date) are given as the number of days since 1 January 1900 (refer to *A Guide to the Genstat Spreadsheet* for more information). We can change the format of these labels, say to *mmm-yy*, in *Editor* mode of the *Graphics Viewer* (see Section 1.2). Invoke *Editor* mode by double-clicking on the plot, then open the X-Axis tab. Click the Format Labels… button to launch the Format Label Options menu (Figure 2.28). In this menu select Date Representation:. This allows you to choose your desired format for Date in the dropdown list. The modified graph is shown in Figure 2.27b.



☑ Display Axis ☐ Reverse Axis Direction ☐ Equal Scaling Transformation: None

☑ Display Title: Date

Position: ● Centred ○ End Direction: ● Parallel ○ Perpendicular

Lower bound: ● Minimum Data Value ☑ Include Margin: 5 % of range ○ Use Value: 144652

Upper bound: ● Maximum Data Value ☑ Include Margin: 5 % of range ○ Use Value: 151047

Y-Origin: ● Default ○ Lower ○ Upper ○ Centre ○ Zero ○ Use Y Value: 144652

Z-Origin: ● Default ○ Lower ○ Upper ○ Centre ○ Zero ○ Use Z Value: 144652

☑ Display Labels Position: ● Outside ○ Inside Direction: ● Parallel ○ Perpendicular ○ Angle:

☑ Display Tick Marks Position: ● Outside ○ Inside ○ Across Type: ● Automatic ○ Step: 0 ○ User

☐ Minor Tick Marks Intervals: 2

Display

○ Default

○ Number of decimal places:

○ Scientific notation, with 3 significant figures.

○ Engineering notation, with 3 significant figures.

● Date Representation: 30 mmm-yy

☐ List of pre-defined date formats:

Date Preview: Feb-16

Figure 2.28: Using *Editor* mode to change the format of the x-axis Date labels.

To better visualize the annual trend, next we'll plot Mean_Temperature against Month separately for each Year. To do this we set the Y variate: to Mean_Temperature, the X variate: to Month, and in the Groups: field we enter Year. The resulting graph is shown in Figure 2.29. Each year of data is represented by a differently coloured line. By default a key is displayed, in which the factor labels for Year have been used to describe the different data series. Notice though how the key has been truncated at 2007, such that the labels for 2008 to 2012 are missing. This has occurred because the key, at its current location, cannot fit onto an A4 page. In the next section, Section 2.2.2, we demonstrate

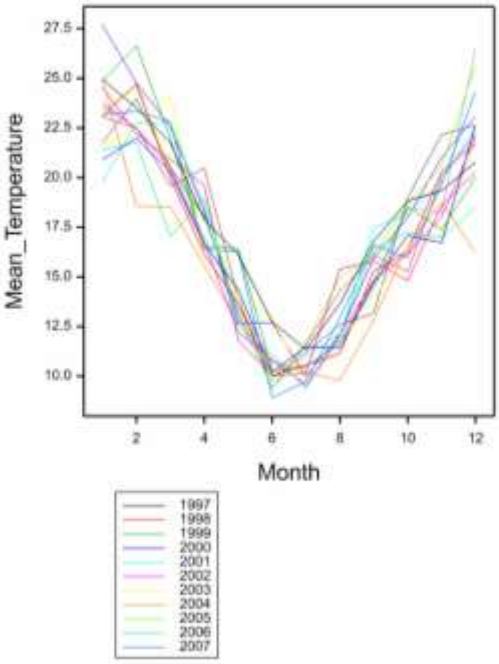
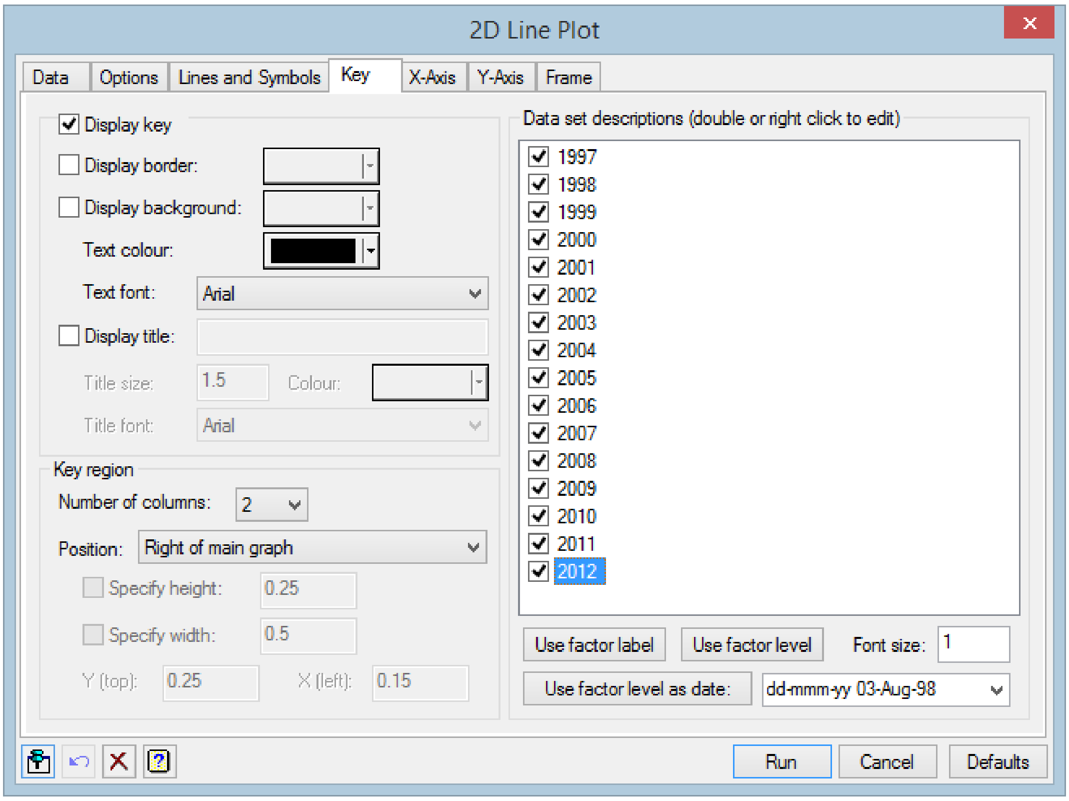


Figure 2.29: Annual trend in Mean_Temperature for 1997 to 2012.

how to alter the position of the key, using the Key tab menu, to avoid this truncation.

2.2.2 Key tab

The Key tab menu (Figure 2.30) controls the display and contents of the key. To include a key, select Display key. This will activate the other fields in the tab in which you can define the appearance and contents of the key.



☑ Display key
□ Display border:
□ Display background:
Text colour: ■
Text font: Arial
□ Display title:
Title size: 1.5 Colour:
Title font: Arial

Key region
Number of columns: 2
Position: Right of main graph
□ Specify height: 0.25
□ Specify width: 0.5
Y (top): 0.25 X (left): 0.15

Data set descriptions (double or right click to edit)
☑ 1997
☑ 1998
☑ 1999
☑ 2000
☑ 2001
☑ 2002
☑ 2003
☑ 2004
☑ 2005
☑ 2006
☑ 2007
☑ 2008
☑ 2009
☑ 2010
☑ 2011
☑ 2012

Font size: 1
Use factor level as date: dd-mmm-yy 03-Aug-98

Figure 2.30: Key tab of the 2D Line Plot menu.

The text displayed by key, to describe each series plotted, can be changed using the fields in the right-hand pane of the Key tab (see Figure 2.30). Under Data set descriptions a list giving the key *descriptions* for each data series is shown. In our example, this corresponds to the 16 years of Dipton Weather data. By default, Genstat automatically generates the key from the variates plotted and/or the group labels (as in the current example). You can change the text displayed in the key by double-clicking on an item in the list then typing into the field. Alternatively, right clicking on an item allows it to be edited, cleared, set to its default value, set to its factor label, or set to its factor level. To simultaneously edit multiple items, select them using the keyboard Shift or Ctrl keys. (Selected items are highlighted.) The right mouse menu or the buttons (Use factor label, Use factor level, or Use factor level as date:) can then be used to simultaneously edit the selected items. If groups have been provided (in the Groups: field of the Data tab) clicking the Use factor label button sets the key descriptions of the currently selected items to use the factor labels. (If the factor does not have labels, then the levels will be used). Similarly, clicking Use factor level sets the key descriptions to use the factor levels. The Use factor level as date button sets the currently selected items to use the factor level displayed as a date. The date format used is specified in the dropdown list to the right of this button. The size of the font used for displaying the descriptions in the key is set in the Font size: field. You can remove items from the key by unselecting the check boxes in the list.

You can change the appearance of the key using the fields in the left-hand pane of the Key tab. Using the Display border: tick box and dropdown list you can control whether a border is drawn around the key in the specified colour. Likewise you can control whether the background of the key is filled, with a specified colour using Display background:. The Text colour: and Text font: dropdowns enable you to set the colour and style of the key’s font, respectively.

To display a title above the key, select Display title: and enter text into the space provided. The key's title will be displayed using the font specified in the Title font: dropdown list, with the colour selected in the Colour: field. The size of the font is controlled by the Title size: field. This is a positive number (smaller than 100), specifying a value by which the default font size is multiplied.

The position and size of the key is set in the Key region pane. Using the Position: dropdown list you can select the location of the key on the plot. By default the key is displayed below the graph. The Specify height: and Specify width: fields, controlling the size of the key in device coordinates, are activated when a non-default position is selected. These default to values large enough to accommodate the descriptions in the key. However, if values are provided and i) insufficient height is allowed for, the description list will be truncated, or ii) insufficient width is allowed for, the key descriptions will be shrunk. When Position is set to Given, the Y (top) and X (left) fields are enabled. These fields define the position of the top left corner of the key in device coordinates. The Number of columns dropdown list specifies how many columns the key is displayed in. (Note: the options available in the Position: dropdown list are determined by whether the key is displayed in one or more columns)

We redraw the plot in Figure 2.29 such that a key with 2 columns is displayed, without a border, to the right of the main graph, using the settings given in Figure 2.30. See Figure 2.31for the resulting graph.

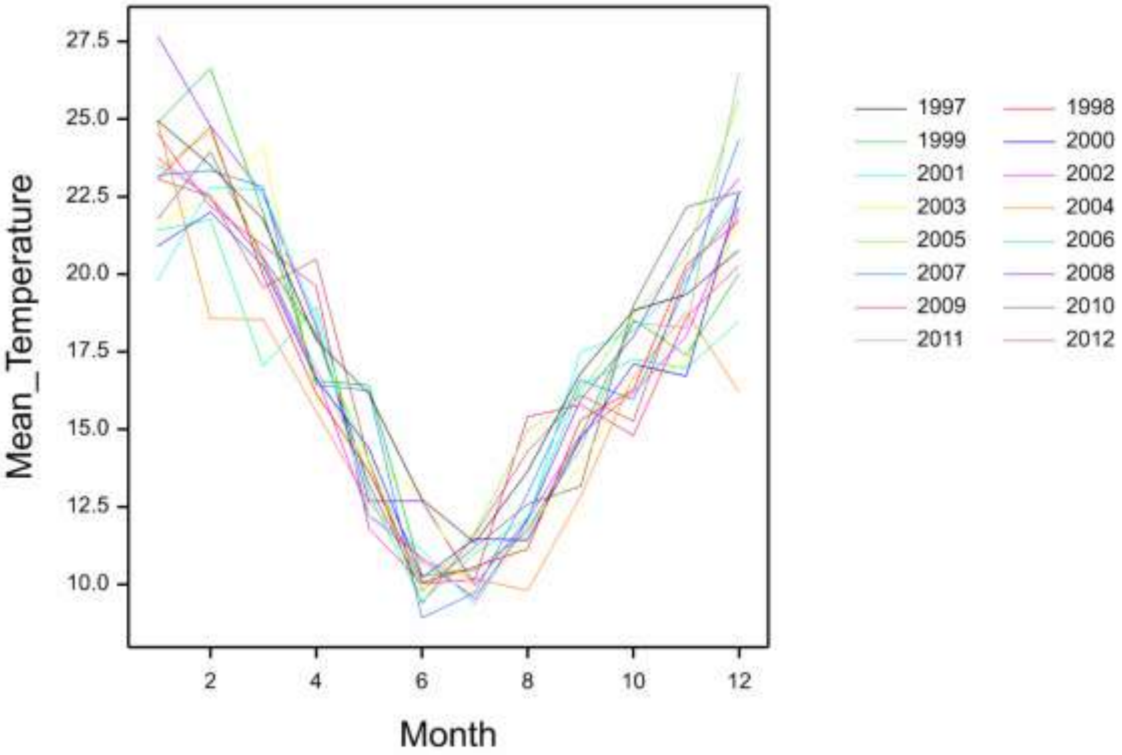
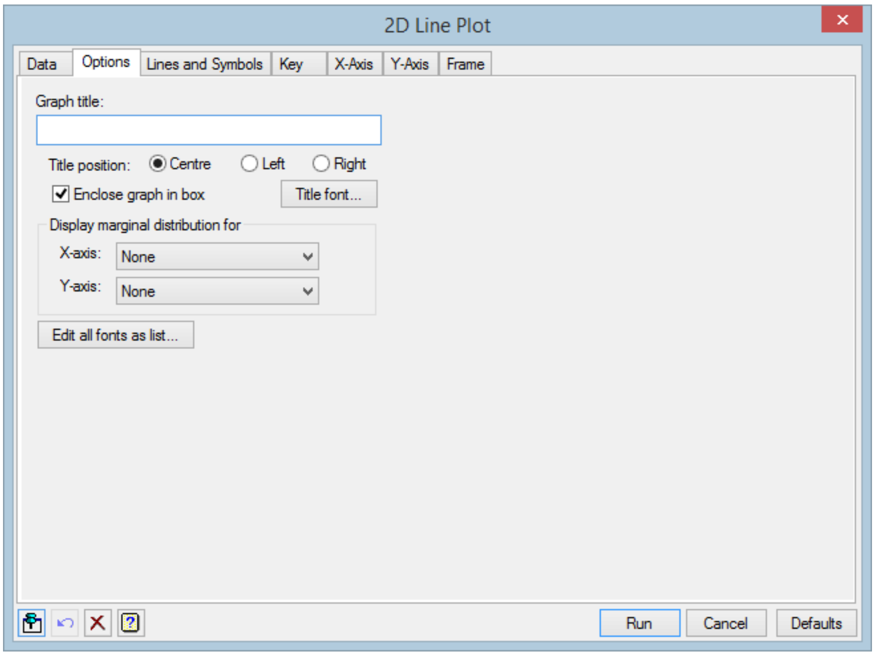


Figure 2.31: Annual trend in `Mean_Temperature` for 1997 to 2012. Key position modified using the Key tab settings shown in Figure 2.30.

2.2.3 Options tab

The Options tab allows you to set attributes that control the appearance of the line plot (Figure 2.32).



Graph title:

Title position: ● Centre ○ Left ○ Right

☑ Enclose graph in box

Display marginal distribution for

X-axis: None

Y-axis: None

Figure 2.32: Options tab of the 2D Line Plot menu.

A title for the line plot can be specified in the Graph title: field. Set the title position by selecting either the Centre, Left or Right radio buttons. To set the font for the title, click on the Title font... button to launch the Edit font for plot title menu, or, alternatively, click the Edit all fonts as list... button to open the Font attributes menu (see Figure 2.21).

You can choose whether or not to draw a box around the graph using the Enclose graph in box option.

For a Single XY line plot, the Display marginal distribution for pane is available. This provides the option of plotting a Histogram, Rug plot or Boxplot of the X variable and/or Y variable along their respective axes (see Figure 2.33). By default, no marginal distributions are plotted. To illustrate, in Figure 2.33 the marginal distribution of `Mean_Temperature` is displayed as a a) Histogram, b) Rug plot and c) Boxplot on the line plot against `Date`.

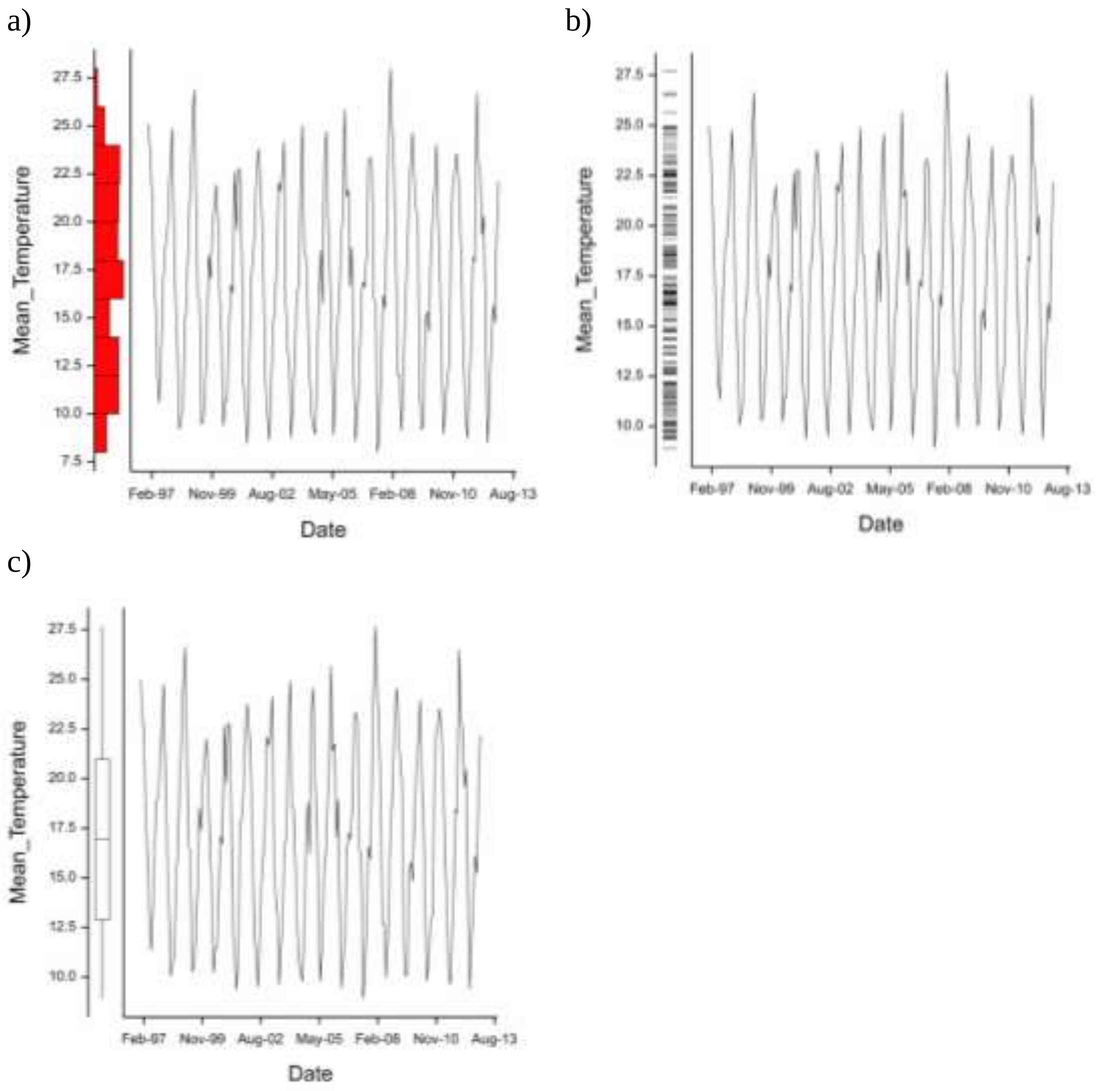
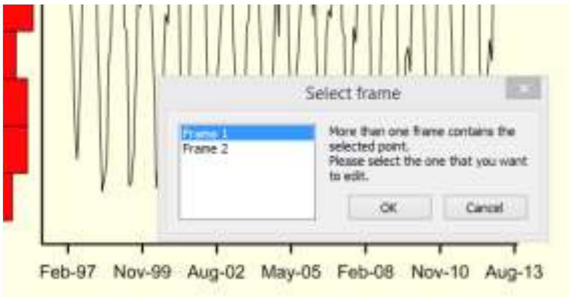


Figure 2.33: Line plot of `Mean_Temperature` against `Date`, displaying marginal distribution of `Mean_Temperature` as a a) Histogram, b) Rug plot and c) Boxplot.

The line plot and the graph of the marginal distribution are plotted in separate frames: the line plot, by default, in *Frame 1* and the marginal distribution in *Frame 2*. You can modify the features of either graph by invoking *Editor* mode and selecting the appropriate frame in the Select frame dialog box (Figure 2.34).

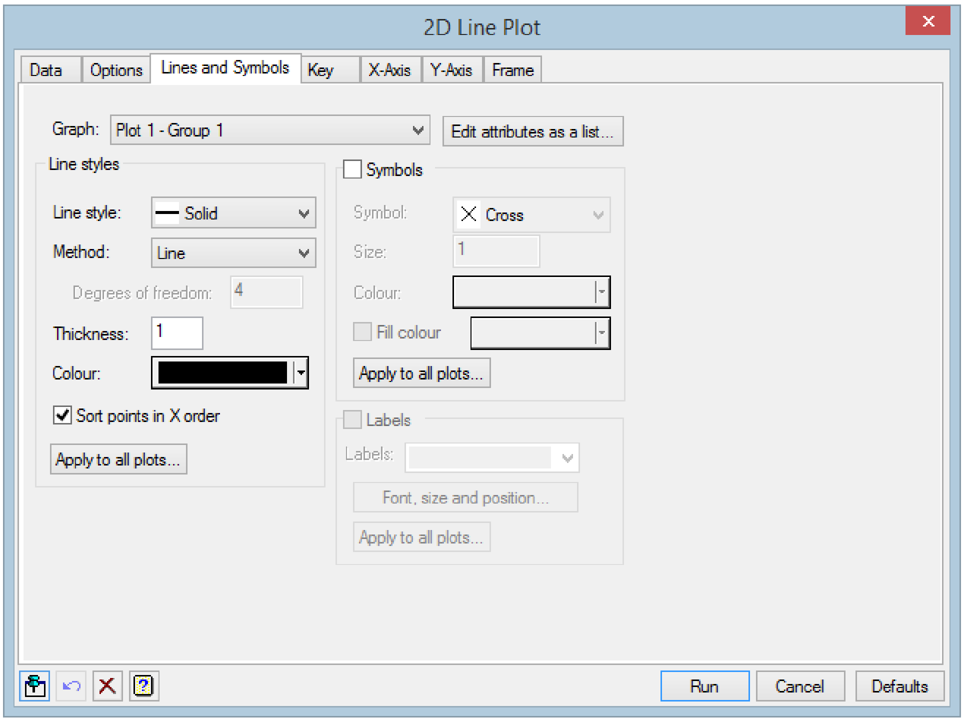


More than one frame contains the selected point.
Please select the one that you want to edit.

Figure 2.34: Selecting frame of Figure 2.33a to edit in *Editor* mode.

2.2.4 Lines and Symbols tab

The Lines and Symbols tab allows you to control the appearance of the plotted data points (Figure 2.35). This tab becomes available after the data has been supplied within the Data tab. By default, for a line plot the data points are connected using solid lines, and symbols aren't displayed.



Graph: Plot 1 - Group 1

Line styles

Line style: Solid

Method: Line

Degrees of freedom: 4

Thickness: 1

Colour:

☑ Sort points in X order

□ Symbols

Symbol: Cross

Size: 1

Colour:

□ Fill colour

□ Labels

Labels:

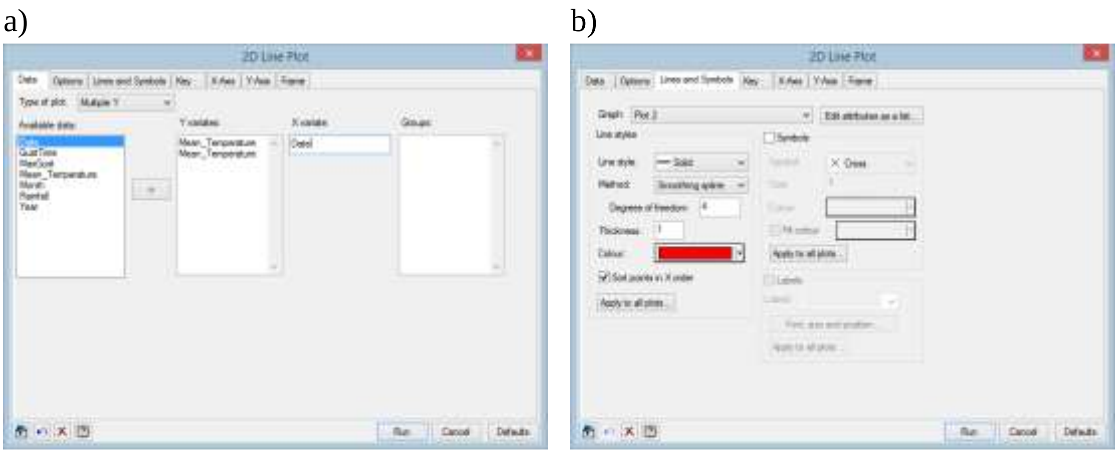
Figure 2.35: Lines and Symbols tab of the 2D Line Plot menu.

In the Graph: field we specify the series for which the line and/or symbol attributes are to be set. Note: if groups have been specified on the Data tab menu, these will be listed in the Graph: field. The "*plot*" for each group (i.e. series on the graph) is represented by its ordinal value. For more information, refer to Section 1.1.2.

Within the Line styles pane you can set the style, thickness and colour of the plotted line. In addition, using the Method: dropdown list, you can specify how the lines connecting the data points are drawn. The default method, Line, connects the data points using straight lines. The methods Monotonic, Closed Curve or Open Curve connect the data points using smooth curves. (For more information on these methods, refer to the help documentation accessible by clicking on the help icon, ?.) The Smoothing Spline setting plots a spline fitted through the data points. By default four degrees of freedom are used, however, you can change this by supplying another value in the Degrees of freedom: field.

To add a smoothing spline to Figure 2.27b we could either:

- first create the plot of Figure 2.27b, then use the Add to last plot option of the Frame tab to superimpose a plot of Mean_Temperature against Date with the Smoothing Spline setting, or;
- set Type of plot: to Multiple Y (or PairedXY) in the Data tab, then request two plots of Mean_Temperature against Date (see Figure 2.36a). The Graph: field in the Lines and Symbols tab will now list two plots (*Plot 1* and *Plot 2*). For one, set the method to Line, and for the other to Smoothing Spline. For example, using the settings shown in Figure 2.36b, series *Plot 2* is plotted as a smoothing spline, with four degrees of freedom, using a solid red line. The resulting plot is shown in Figure 2.37.



a)
Type of plot: Multiple Y
Y-Variates: Mean_Temperature, Mean_Temperature
X-Variate: Date

b)
Graph: Plot 2
Line style: Solid
Method: Smoothing spline
Degrees of freedom: 4
Thickness: 1
Colour: 🟥
☑ Sort points in X order
□ Symbols
Symbol: Cross
Size: 1
□ Labels

Figure 2.36: Adding a red smoothing spline to a line plot of Mean_Temperature against Date; a) Data tab and b) Lines and Symbols tab.

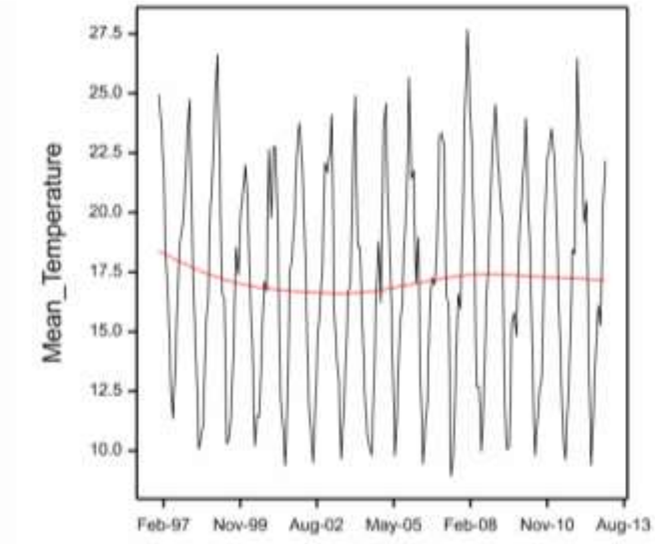
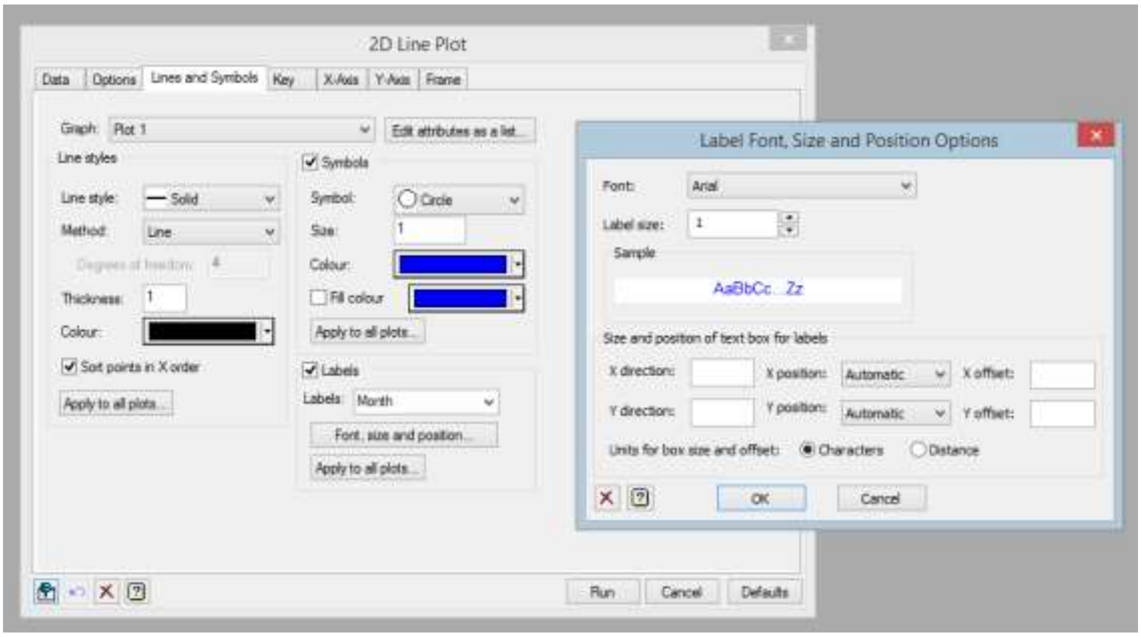


Figure 2.37: Line plot of Mean_Temperature against Date. Superimposed in red is the fitted smoothing spline (with 4 degrees of freedom).

Also within the Line styles pane is the option to Sort points in X order. When selected (the default), the data will be sorted so the x-variates are in ascending order prior to plotting. This may be necessary to ensure the correct appearance of the plotted line, for example a fitted regression line, regardless of the order in which data are recorded or stored.

For line plots, by default symbols aren't displayed. However, checking Symbols will activate the fields in the Symbols pane, to plot symbols in the style, size and colour specified. Also activated is the Labels pane. If selected, this allows points to be labelled within the graph. The attributes of the labels can be specified in the Label Font, Size and Position Options menu launched by clicking on Font, size and position… (For more information on this menu, refer to the help documentation accessible by clicking on the help icon, ?.) To illustrate, symbols (blue unfilled circles) labelled by `Month` are added to Figure 2.37 using the settings shown in Figure 2.38. The resulting graph is shown in Figure 2.39.



Graph: Plot 1

Line styles

Line style: — Solid

Method: Line

Degrees of freedom: 4

Thickness: 1

Colour: ■

☑ Sort points in X order

☑ Symbols

Symbol: ○ Circle

Size: 1

Colour: ■

□ Fill colour ■

☑ Labels

Labels: Month

Font: Arial

Label size: 1

Size and position of text box for labels

X direction: X position: Automatic X offset:

Y direction: Y position: Automatic Y offset:

Units for box size and offset: ● Characters ○ Distance

Figure 2.38: Adding symbols with `Month` labels to Figure 2.37.

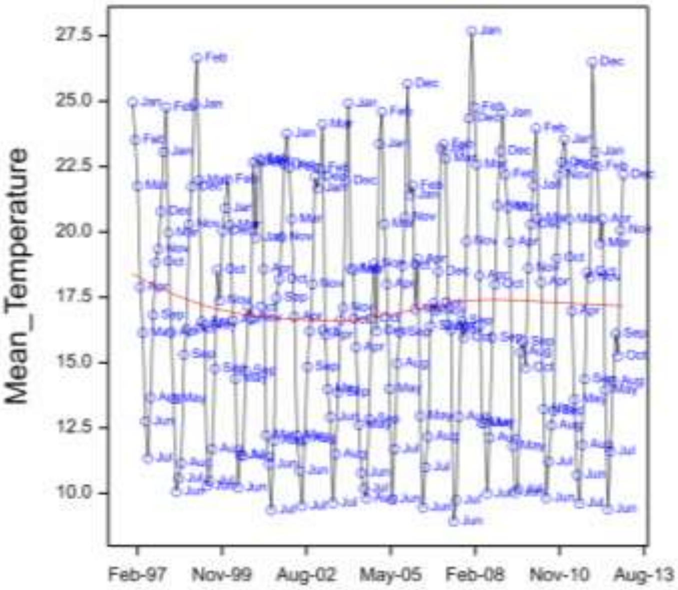
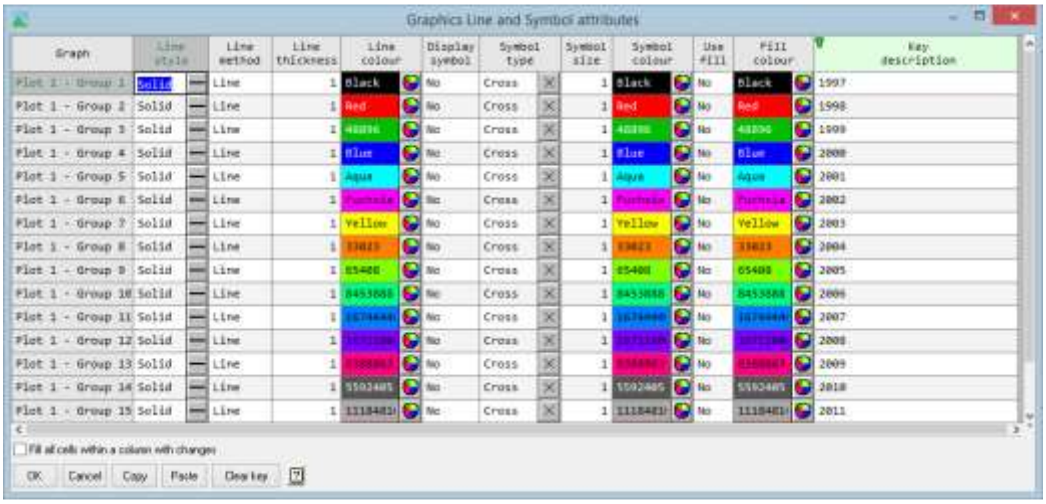


Figure 2.39: Addition of symbols, labelled by Month, to Figure 2.37 using the settings shown in Figure 2.38.

Rather than editing each series listed in the Graph: field separately, multiple series can be edited at once by clicking on the Edit attributes as a list... button. This opens a Graphics Line and Symbol attributes spreadsheet, enabling you to edit the line and symbol attributes of all series simultaneously. To demonstrate, we'll open the Graphics Line and Symbol attributes spreadsheet associated with Figure 2.31, a plot of Mean_Temperature against Month with separate series for each Year. (In the Data tab set the Y variate: to Mean_Temperature, the X variate: to Month, and the Groups: field to Year.) The Graphics Line and Symbol attributes spreadsheet for this graph comprises 15 rows, one for each series (Figure 2.40).



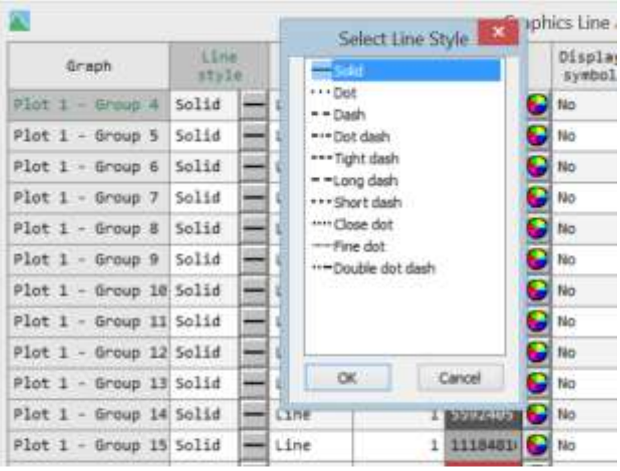
Graph	Line style	Line method	Line thickness	Line colour	Display symbol	Symbol type	Symbol size	Symbol colour	Use fill	Fill colour	Key description
Plot 1 - Group 1	Solid	Line	1	Black	No	Cross	1	Black	No	Black	1997
Plot 1 - Group 2	Solid	Line	1	Red	No	Cross	1	Red	No	Red	1998
Plot 1 - Group 3	Solid	Line	1	48896	No	Cross	1	48896	No	48896	1999
Plot 1 - Group 4	Solid	Line	1	Blue	No	Cross	1	Blue	No	Blue	2000
Plot 1 - Group 5	Solid	Line	1	Aqua	No	Cross	1	Aqua	No	Aqua	2001
Plot 1 - Group 6	Solid	Line	1	Fuchsia	No	Cross	1	Fuchsia	No	Fuchsia	2002
Plot 1 - Group 7	Solid	Line	1	Yellow	No	Cross	1	Yellow	No	Yellow	2003
Plot 1 - Group 8	Solid	Line	1	33023	No	Cross	1	33023	No	33023	2004
Plot 1 - Group 9	Solid	Line	1	65408	No	Cross	1	65408	No	65408	2005
Plot 1 - Group 10	Solid	Line	1	8453888	No	Cross	1	8453888	No	8453888	2006
Plot 1 - Group 11	Solid	Line	1	16744448	No	Cross	1	16744448	No	16744448	2007
Plot 1 - Group 12	Solid	Line	1	[illegible]	No	Cross	1	[illegible]	No	[illegible]	2008
Plot 1 - Group 13	Solid	Line	1	[illegible]	No	Cross	1	[illegible]	No	[illegible]	2009
Plot 1 - Group 14	Solid	Line	1	5592405	No	Cross	1	5592405	No	5592405	2010
Plot 1 - Group 15	Solid	Line	1	1118481	No	Cross	1	1118481	No	1118481	2011

☐ Fill all cells within a column with changes

OK Cancel Copy Paste Clear key

Figure 2.40: Graphics Line and Symbol attributes spreadsheet populated with the settings of the 15 series in Figure 2.31.

The settings for each series are displayed within the rows of the Graphics Line and Symbol attributes spreadsheet. You can edit these by typing directly into the cell, or (where relevant) by launching a dialog. For example, the *Line style* column specifies the line styles used when plotting each series. The style is shown in the icon on the right of the cell. A new line style can be selected by clicking this icon or by double-clicking the cell. This will open a dialog where you can select a line style from a list (see Figure 2.41). Alternatively, line styles can be specified by typing the first few letters of the word that uniquely identifies the style or by using numerical values representing a line style in the Genstat command language. (For more information, refer to the help, .)



Graph	Line style	Display symbol
Plot 1 - Group 4	Solid	No
Plot 1 - Group 5	Solid	No
Plot 1 - Group 6	Solid	No
Plot 1 - Group 7	Solid	No
Plot 1 - Group 8	Solid	No
Plot 1 - Group 9	Solid	No
Plot 1 - Group 10	Solid	No
Plot 1 - Group 11	Solid	No
Plot 1 - Group 12	Solid	No
Plot 1 - Group 13	Solid	No
Plot 1 - Group 14	Solid	No
Plot 1 - Group 15	Solid	No

Figure 2.41: Line style dialog.

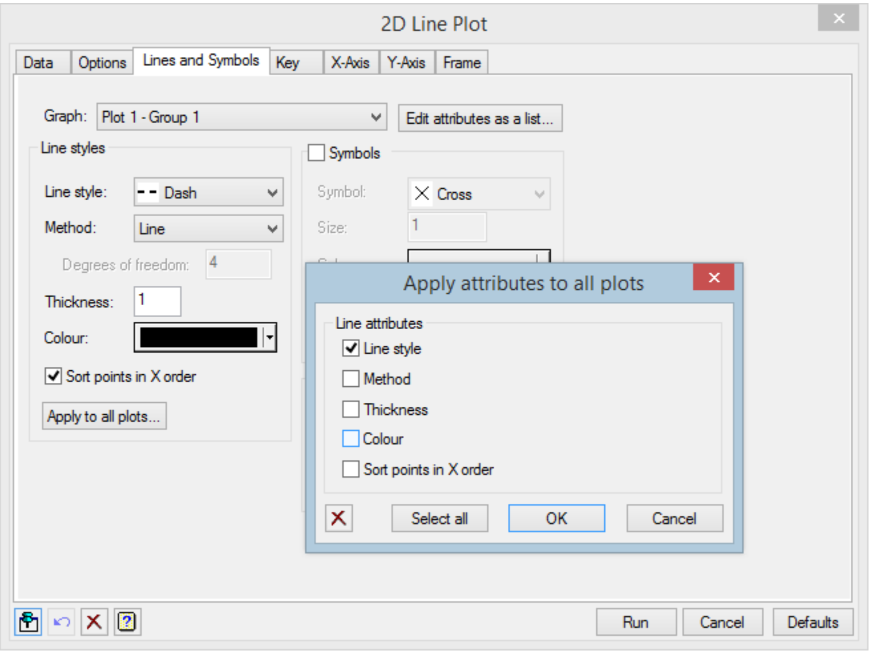
Should you wish to impose the same change to all cells within a column, select Fill all cells within a column with changes prior to making the change. For example, to draw each series as a dashed line, select Fill all cells within a column with changes before changing the line style to Dash in one of the cells in the *Line style* column. This will populate the change down the entire column.

Copying and pasting in the Graphics Line and Symbol attributes spreadsheet behaves as for any other Genstat spreadsheets. For example, if you have set the *Line colour* column and you want the symbols to be the same colour, you could click on the *Line colour* heading to select that column, press Ctrl+C to copy the colours to the clipboard, then click on the *Symbol colour* heading and press Ctrl+V to paste them into the column.

In the bottom left-hand corner of the Graphics Line and Symbol attributes spreadsheet are five action buttons, plus the help icon.

- OK saves the changes and closes the spreadsheet.
- Cancel closes the spreadsheet without saving the changes.
- Copy copies the selected spreadsheet cells to the clipboard.
- Paste pastes the contents of the clipboard into the spreadsheet.
- Clear key clears the contents in the *Key description* column.

The three Apply to all plots… buttons (located on the Lines and Symbols tab, see Figure 2.35) may also be used to simultaneously make changes to multiple series. These buttons launch a menu in which you can specify which Lines/Symbols/Labels attributes of the current series (i.e. that selected in the Graph: field) are applied to all series. For example, to draw each series as a dashed line, we could set the Line style: field to Dash for the first series (Plot 1 – Group 1) then click the Apply to all plots… button in the Line styles pane. This will launch the Apply attributes to all plots menu, where we select Line style to apply the dashed line style to all series (see Figure 2.42).



Graph: Plot 1 - Group 1

Line style: - - Dash

Method: Line

Degrees of freedom: 4

Thickness: 1

Colour: ■

☑ Sort points in X order

□ Symbols

Symbol: ✕ Cross

Size: 1

☑ Line style

□ Method

□ Thickness

□ Colour

□ Sort points in X order

Figure 2.42: Using the Apply attributes to all plots menu to set the line style for all series to that defined by Plot 1 – Group 1 (i.e. the series currently selected in the Graph: field).

Note: The Apply to all plots… button within the Symbols pane launches an Apply attributes to all plots menu with fields specific to symbol attributes. Likewise, the Apply to all plots… button within the Labels pane launches an Apply attributes to all plots menu with fields specific to label attributes.

2.2.5 X-Axis and Y-Axis tabs

The X-Axis and Y-Axis tabs allow you to control the appearance of the line plot's x- and y-axis, respectively. These tabs are largely the same as those previously described for the Bar Chart menu (Refer to Section 2.1.4). However, unlike the Bar Chart menu, the X-Axis tab for 2D line plots contains the same functionality as the Y-Axis tab. In addition, the X-Axis and Y-Axis tabs offer the:

- Equal scaling option. When selected the x- and y-axes are scaled identically.
- Transform axis: dropdown menu. This allows you to select a transformation to scale the axis. The tick marks are still defined and labelled according to the original scale, but their physical positions on the graph are transformed. For example, if you selected Log (base 10), the physical distance between 1 and 10 would be the same as the distance between 10 and 100.

2.2.6 Frame tab

The Frame tab sets the attributes of the *frame* that the line plot is displayed in. This tab is the same as that previously described for the Bar Chart menu. Refer to Section 2.1.5.

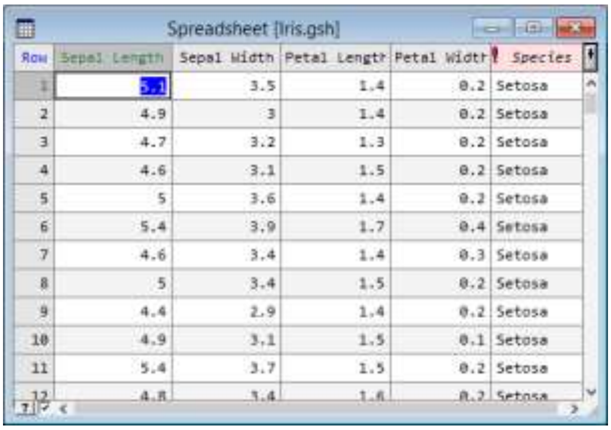
2.2.7 2D scatter plots

The menu used for creating 2D scatter plots is the same as that described for 2D line plots. However, by default the data points are plotted using symbols without connecting lines (for example, Figure 1.10).

2.3 Case study: 3D scatter plot

A 3D scatter plot can be used to visualize the relationship between three continuous variables. The data points are plotted on three axes (x, y, z): typically the predictor variables are plotted on the x- and y-axes and the response variable on the z-axis. 3D scatter plots with either one or more X, Y and/or Z variables can be plotted using the Graphics | 3D Scatter Plot… menu. In the following subsections, we'll first illustrate the use of the 3D Scatter Plot menu and then we'll demonstrate *Editor* mode of the *Graphics Viewer*, which looks slightly different for 3D graphs than for 2D graphs.

Throughout this section, the classic Fisher's iris data set is used for illustration. The data consists of measurements of sepal lengths and widths (`Sepal_Length`, `Sepal_Width`), and petal lengths and widths (`Petal_Length`, `Petal_Width`) from iris plants belonging to three different species (factor `Species`). The data are



Spreadsheet [Iris.gsh]

Row	Sepal Length	Sepal Width	Petal Length	Petal Width	Species
1	5.1	3.5	1.4	0.2	Setosa
2	4.9	3	1.4	0.2	Setosa
3	4.7	3.2	1.3	0.2	Setosa
4	4.6	3.1	1.5	0.2	Setosa
5	5	3.6	1.4	0.2	Setosa
6	5.4	3.9	1.7	0.4	Setosa
7	4.6	3.4	1.4	0.3	Setosa
8	5	3.4	1.5	0.2	Setosa
9	4.4	2.9	1.4	0.2	Setosa
10	4.9	3.1	1.5	0.1	Setosa
11	5.4	3.7	1.5	0.2	Setosa
12	4.8	3.4	1.6	0.2	Setosa

Figure 2.43: Segment of Fisher's iris data set, `Iris.gsh`.

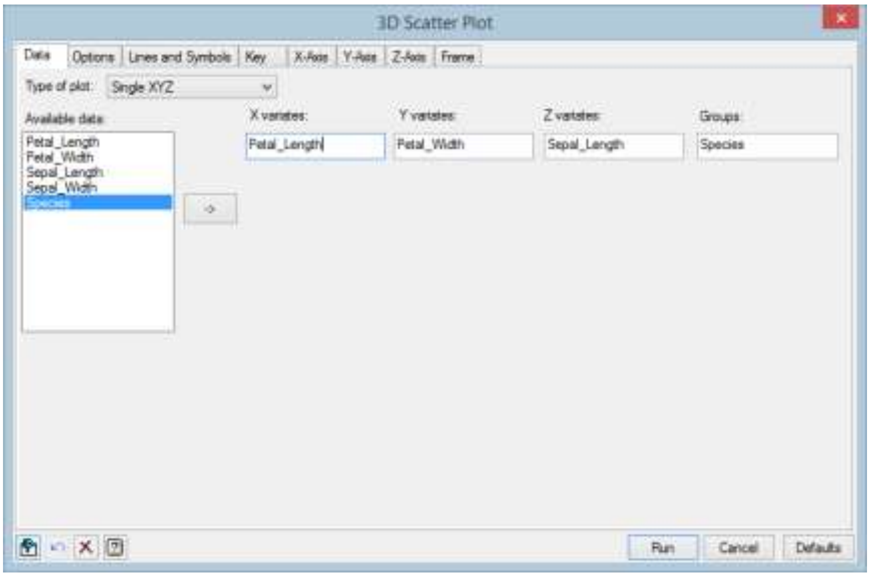
available in the Genstat spreadsheet `Iris.gsh` (Figure 2.43).

2.3.1 Menu

The 3D Scatter Plot menu is very similar to the 2D line plot menu, previously described in Section 2.2, but with additional fields and options to accommodate the third axis.

The 3D Scatter Plot... menu opens in the Data tab, where the data for plotting is supplied (Figure 2.44). In the Type of plot: field you can specify how the data is formatted. You can select a combination of single, multiple or paired X, Y and Z variables, or triplet X, Y, Z variables. When an item in the Type of plot: field is selected, the length of the four data input fields (Y variates:, X variates:, Z variates: and Groups:) will change accordingly. The Available data: field lists all the available data structures appropriate to the current input field. The contents will change as you move from one field to the next.

Figure 2.44 gives the Data tab menu settings used to create a three-dimensional scatter plot of petal length, petal width and sepal length, in which the plotted points are coloured by iris species.



Type of plot: Single XYZ

Available data:
Petal_Length
Petal_Width
Sepal_Length
Sepal_Width
Species

X variates: Petal_Length

Y variates: Petal_Width

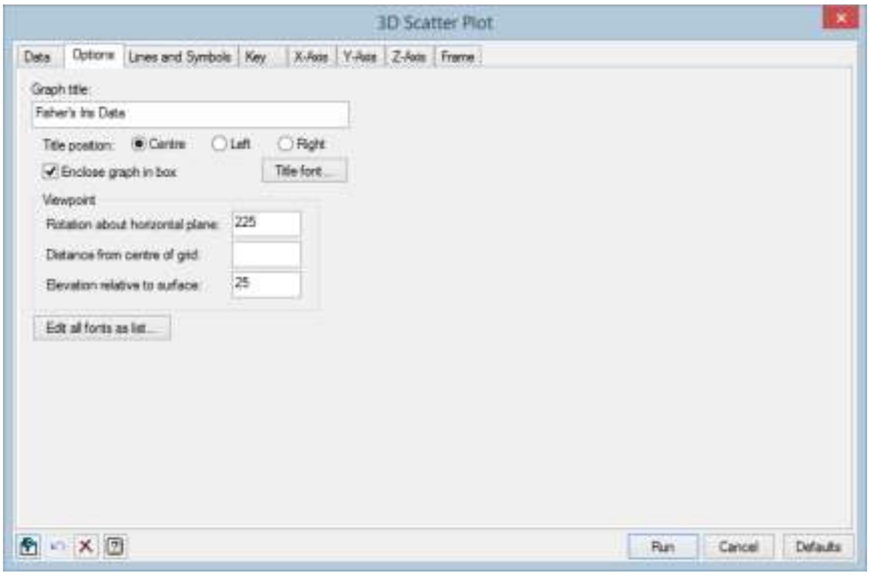
Z variates: Sepal_Length

Groups: Species

Figure 2.44: Data tab of the 3D Scatter Plot menu. Field settings for creating a three-dimensional scatter plot of the petal length, petal width and sepal length data, where the data points are coloured by iris species.

After selecting the data for plotting you can draw the graph by clicking on the Run button. Alternatively, additional options and axis settings can be set by clicking on the Options, Lines and Symbols, Key, X-Axis, Y-Axis, Z-Axis and Frame tabs.

In Figure 2.45 the Options tab is shown. It contains a Viewpoint pane, where you can specify the position of the viewpoint (in terms of *rotation*, *elevation* and *distance*), and thus the orientation of the three-dimensional graph. *Rotation* and *elevation* are specified in degrees, and the *distance* in the same units as the y-axis. Altering the *rotation* value in the Rotation about horizontal plane: field will change the azimuth, in effect, rotating the plot in the horizontal plane about the z-axis. The setting of the Distance from the centre of grid: field determines the position of the viewpoint in the horizontal plane (by default, the *distance* is set to 25 times the number of y points in the grid). The *elevation* of the viewpoint can be altered in the Elevation relative to surface: field. In general the default Viewpoint pane settings, chosen to produce a reasonable display in most situations, will suffice. We'll retain the viewpoint defaults, and in the Graph title: field enter a title, `Fisher's Iris Data`, for our graph.



Graph title: Fisher's Iris Data

Title position: ● Centre ○ Left ○ Right

☑ Enclose graph in box

Viewpoint

Rotation about horizontal plane: 225

Distance from centre of grid:

Elevation relative to surface: 25

Figure 2.45: Options tab of the 3D Scatter Plot menu.

The Lines and Symbols tab allows you to control the appearance of the plotted data points (refer to Section 2.2.4). By default, the data is plotted using the sphere symbol and will be coloured by group if a factor has been supplied in the Groups: field on the Data tab.

The Key tab controls the display and contents of the key (refer to Section 2.2.2). The X-Axis, Y-Axis and Z-Axis tabs allow you to control the appearance of the plot's x-, y- and z-axis, respectively (refer to Section 2.1.4). The Frame tab sets the attributes of the *frame* that the plot is displayed in (refer to Section 2.1.5). We'll retain the default settings.

Click Run to draw the three-dimensional scatter plot shown in Figure 2.46.

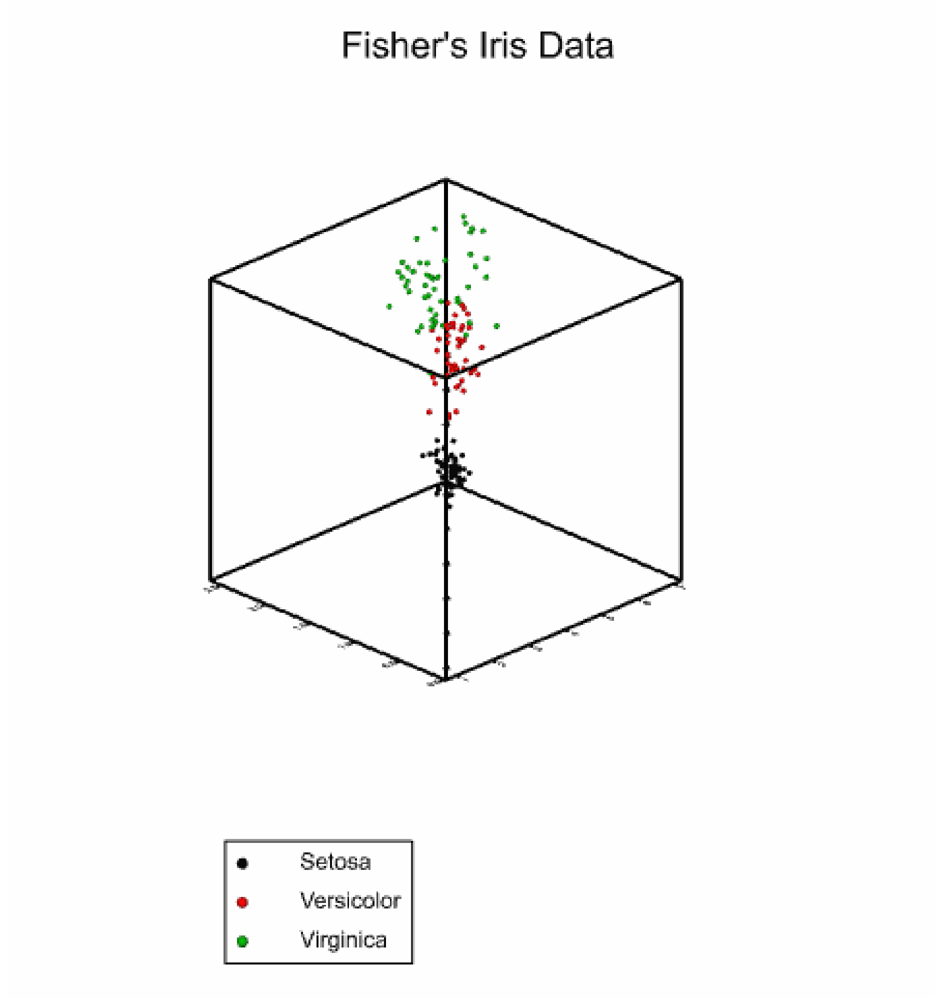
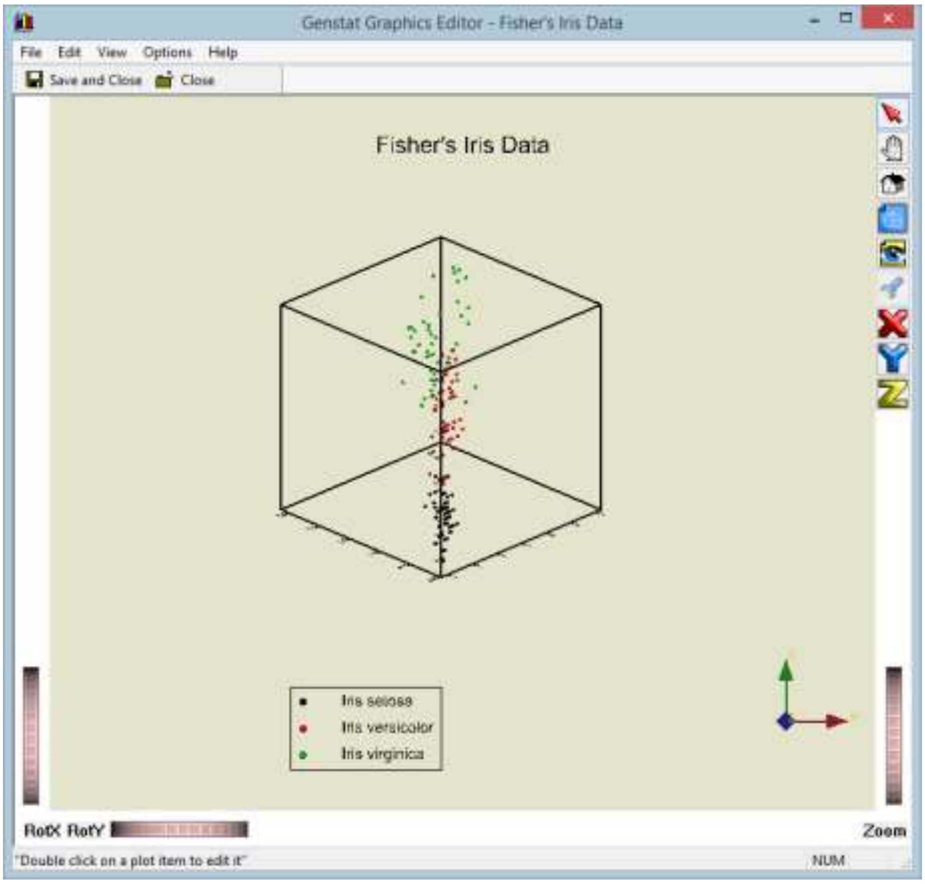


Figure 2.46: Three-dimensional scatter plot of the Iris data, coloured by species.

2.3.2 Graphics Viewer

To accommodate the extra dimension, *Editor* mode of the *Graphics Viewer* is different for three-dimensional graphs than for two-dimensional graphs. Now, instead of moving the graph horizontally and vertically, the graph can be rotated about the x- and y-axes using the RotX and RotY rollers located in the lower left-hand corner (Figure 2.47; also see Section 1.2.2). The View button (🖐) enables you to rotate the plot in a direction other than about the x- or y-axis. To use this, click the View button and left mouse-click on the figure without releasing the button. Move the mouse to rotate the plot. Should you release the left mouse button whilst still moving the mouse, the plot will keep rotating. To stop the rotation, click with the left mouse button. The arrows in the lower right corner depict the orientation and direction of the x-, y- and z-axes.



"Double click on a plot item to edit it"

Figure 2.47: *Editor* mode of the *Graphics Viewer* for a three-dimensional plot.

The projection buttons (XYZ) can be used to project the graph into the y-z plane, the x-z plane and the x-y plane, respectively (Figure 2.48; also see Section 1.2.2)

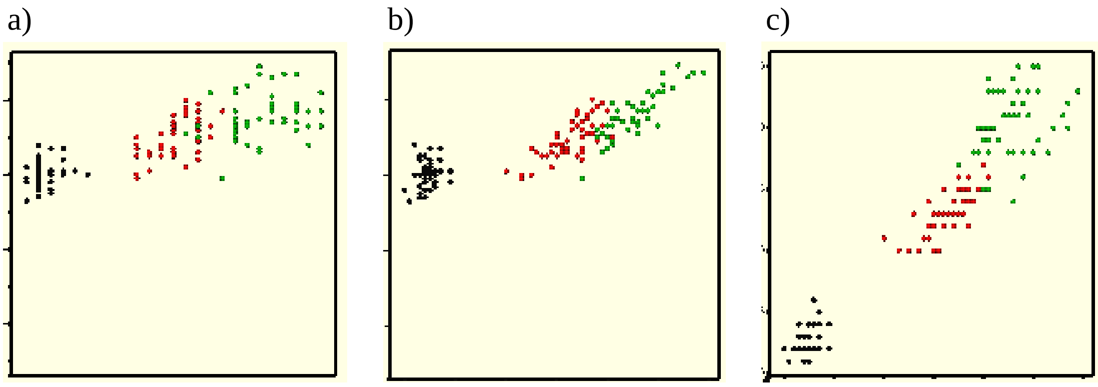


Figure 2.48: Using projection buttons to project the graph into the a) y-z plane, b) x-z plane and c) x-y plane.

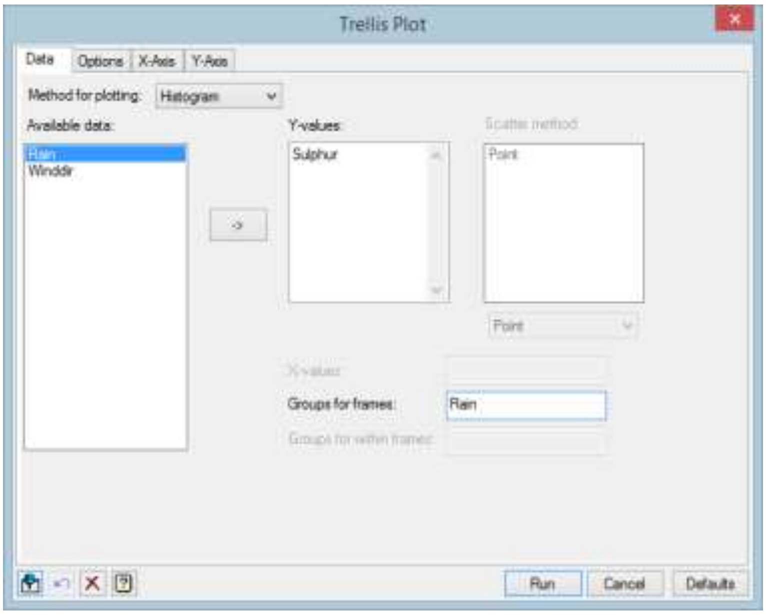
2.4 Case study: trellis plot

A trellis plot is a rectangular array of graphs, each representing a particular subset of the data. In Genstat, you can draw a trellis of histograms, boxplots or scatter plots. Trellis plots provide a powerful tool for displaying a variable, or the relationship between variables, compactly in one graphic whilst distinguishing between different subsets of the data.

Trellis plots can be created using the Graphics | Trellis Plot... menu. In the following sections, we'll describe the functionality of the Trellis Plot menu and demonstrate how to modify features of a trellis plot using *Editor* mode of the *Graphics Viewer*. Throughout this section the Sulphur.gsh data set, previously described in Section 1.1, is used for illustration.

2.4.1 Menu

The Graphics | Trellis Plot... menu comprises four tabs: Data, Options, X-Axis and Y-Axis. The menu opens in the Data tab, where the type of plot is specified and the data for plotting is supplied (Figure 2.49). The Method for plotting: field offers three options: Scatter Plot, Histogram, Boxplot. Here you can set, the type of plot to appear in each frame of the trellis i.e. the graph drawn for each subset of data. Depending on the choice of plotting method the fields within the Data tab become available or are greyed out.



Method for plotting: Histogram

Y-values: Sulphur

Groups for frames: Rain

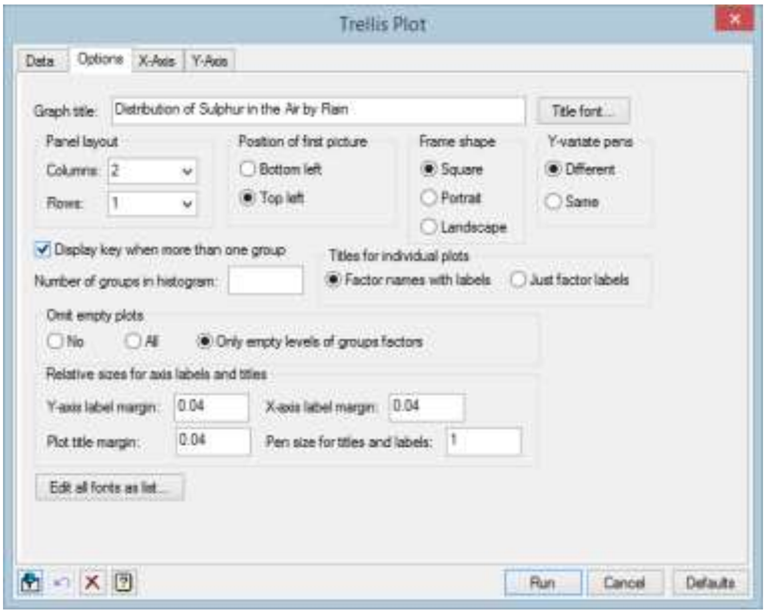
Figure 2.49: Data tab for creating a trellis plot of Sulphur histograms conditional on Rain.

We'll demonstrate all three types of trellis, but to begin with let's investigate the distribution of sulphur measurements (Sulphur) conditional on whether or not it had rained (Rain). To do so, we set the Method for plotting: to Histogram. Two input fields are active: Y-values: and Groups for frames: (see Figure 2.49). In the Y-values: field we specify the data for plotting, Sulphur. Entering more than one variate into this field will create a trellis plot containing jointly graphed histograms for each variate (*cf* Figure 2.10). The factor defining how the data is to be subsetted into the separate plots (or frames) is specified in the Groups for frames: field. In this example, Rain.

In the Options tab we can enter a title for the graph, specify the fonts used for the titles and labels, control the arrangement of the plots (frames) within the trellis (Panel Layout pane), choose to hide or display the key and, for histograms, specify the number of groups used to define the boundaries of the histogram bars (Figure 2.50). Let's provide the trellis plot with the title Distribution of Sulphur in the Air by Rain.

By default, the graphs in a trellis plot are arranged so that the area of the page used for plotting is maximized, with up to 64 graphs per page (8 by 8). However, the number of Columns: and Rows: in the rectangular array of graphs can be explicitly set. The graphs corresponding to the subsets of data are drawn left to right, ordered according to their ordinal level, starting by default in the top-left corner. The Position of first picture radio buttons allow you to change this setting so that first graph appears in the bottom-left corner. For the current example, the subsetting factor, Rain, has two levels (1=No, 2=Yes). By default the two histograms will be arranged in a 2 row by 1 column array, with the No rain histogram appearing at the top. To plot the histograms side-by-side, set the number in Columns: to 2 and the number in Rows: to 1 (see Figure 2.50).

Genstat selects the number of groups defining the boundaries of the histogram bars automatically. However, you can use the Number of groups in histogram: option to specify a particular number of groups. The groups are then defined by intervals of equal width, spanning the range of values of the variate. We'll retain the default.



Trellis Plot

Data | Options | X-Axis | Y-Axis

Graph title: Distribution of Sulphur in the Air by Rain [Title font...]

Panel layout
Columns: 2
Rows: 1

Position of first picture
○ Bottom left
● Top left

Frame shape
● Square
○ Portrait
○ Landscape

Y-variate pens
● Different
○ Same

☑ Display key when more than one group

Number of groups in histogram:

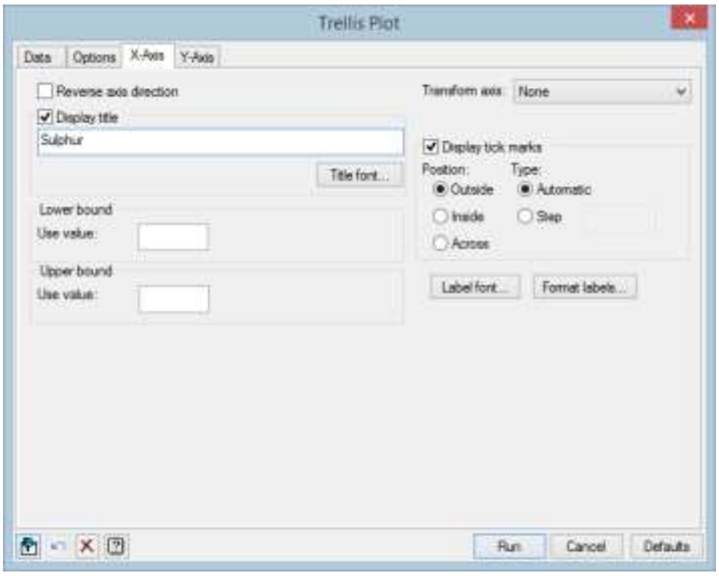
Titles for individual plots
● Factor names with labels ○ Just factor labels

Omit empty plots
○ No ○ All ● Only empty levels of groups factors

Relative sizes for axis labels and titles
Y-axis label margin: 0.04 X-axis label margin: 0.04
Plot title margin: 0.04 Pen size for titles and labels: 1

Figure 2.50: Options tab for creating a trellis plot of `Sulphur` histograms conditional on `Rain`, with plots arranged in a single row.

In the X-Axis and Y-Axis tabs you can set attributes to control the appearance of the x- and y-axis, respectively (Figure 2.51). The fields, which are the same in both of these tabs, can be used to specify an overall axis title, to transform or reverse the axis, and to set the axis bounds and tick marks for all the graphs in the trellis plot. Let's provide the x-axis with the title `Sulphur`, and the y-axis with the title `Frequency`.



Trellis Plot

Data | Options | X-Axis | Y-Axis

□ Reverse axis direction

Transform axis: None

☑ Display title
Sulphur

Lower bound
Use value:

Upper bound
Use value:

☑ Display tick marks
Position:
● Outside
○ Inside
○ Across
Type:
● Automatic
○ Step

Figure 2.51: X-Axis tab of the Trellis Plot menu.

Click the Run button to produce the trellis plot shown in Figure 2.52. A separate histogram has been drawn for each of the two levels of Rain. From the histograms we observe that higher sulphur measurements in the air are recorded on days without rain compared to days with rain, as to be expected.

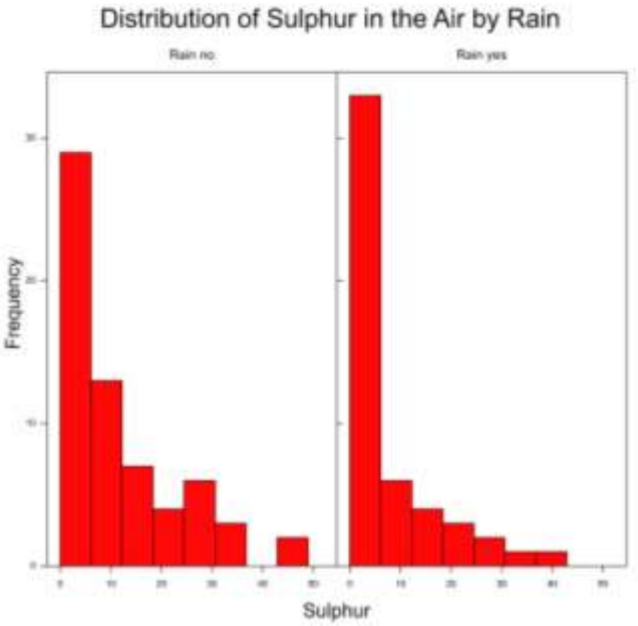
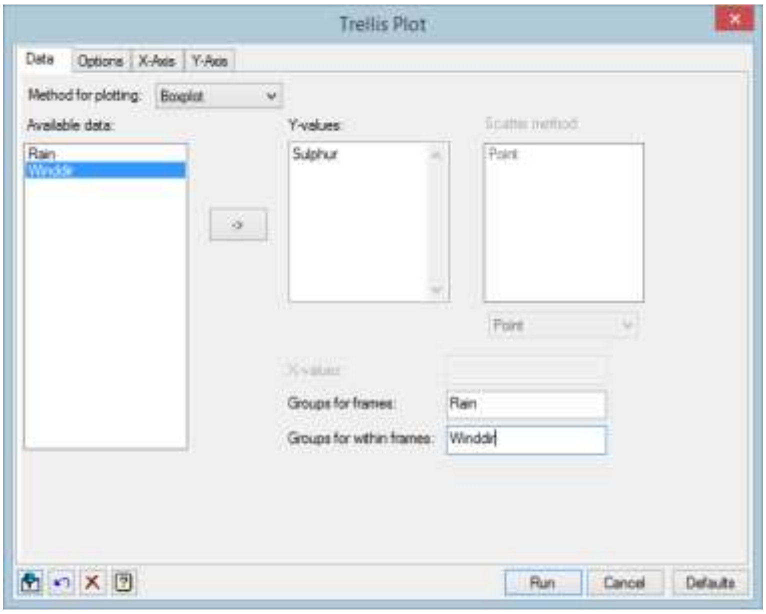


Figure 2.52: Trellis plot of sulphur measurement (Sulphur) histograms conditional on whether or not it had rained (Rain).

Boxplots provide an alternative tool for examining the distribution of a variate. To create a trellis plot of boxplots, on the Data tab select Boxplot in the Method for plotting: field. In addition to the Y-values: and Groups for frames: input fields, the Groups for within frames: field is active (Figure 2.53). Like the Groups for frames: field, this field can be used to specify a factor for subsetting the data. However, whereas the Groups for frames: field determines the subsetting of data into separate graphs, the Groups for within frames: field controls the subsetting of data within a graph (i.e. frame). That is, for boxplots a separate box is drawn for each level of the factor within the frame.

If multiple y-variates are supplied in the Y-values: field then boxplots are drawn for each y-variate within each frame. However, if you supply multiple y-variates you cannot then subset the data using the Groups for within frames: field.

Using a boxplot trellis plot, let's investigate the distribution of sulphur measurements (Sulphur) conditional on both rain (Rain) and wind direction (Winddir). In the Groups for frames: field enter Rain, to create separate graphs according to whether or not it rained. Within each graph, draw separate boxplots for each wind direction by entering Winddir into the Groups for within frames field (see Figure 2.53). As described above, the Options, X-Axis and Y-Axis tabs provide additional options for controlling the appearance of a trellis plot. On the Options tab we'll enter a title for our graph, Distribution of Sulphur in the Air by Rain and Wind Direction. On the Y-Axis tab enter a y-axis title, Sulphur microg/m~^{3}. Click Run to create the trellis plot in Figure 2.54.



Method for plotting: Boxplot

Available data: Rain, Winddir

Y-values: Sulphur

Groups for frames: Rain

Groups for within frames: Winddir

Figure 2.53: Data tab for creating a trellis of Sulphur boxplots conditional on both Rain and Winddir.

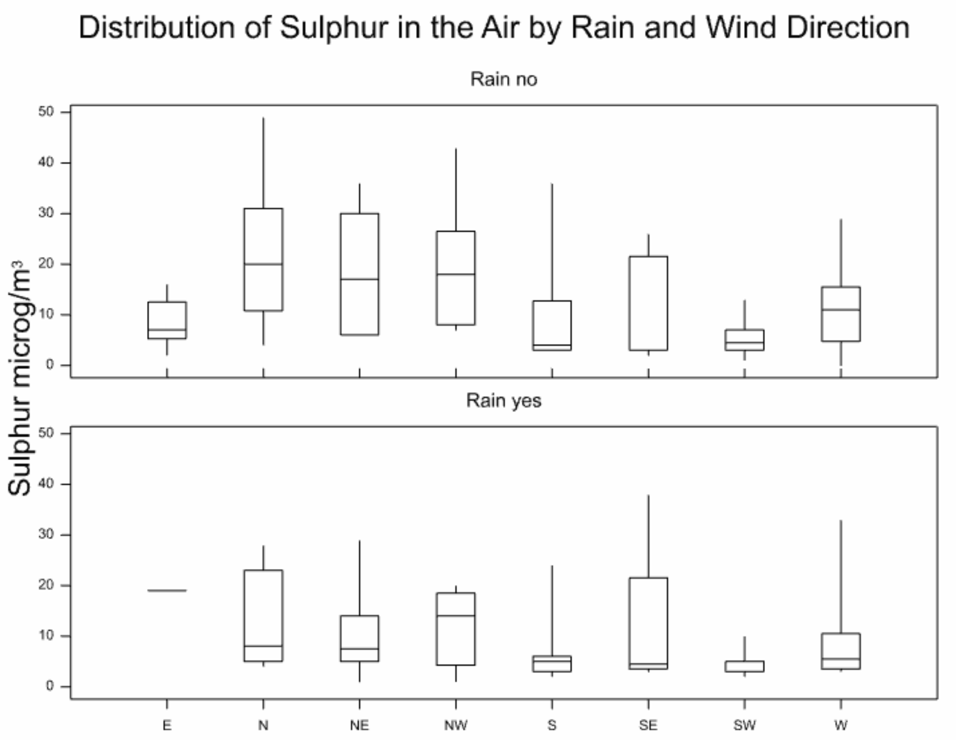
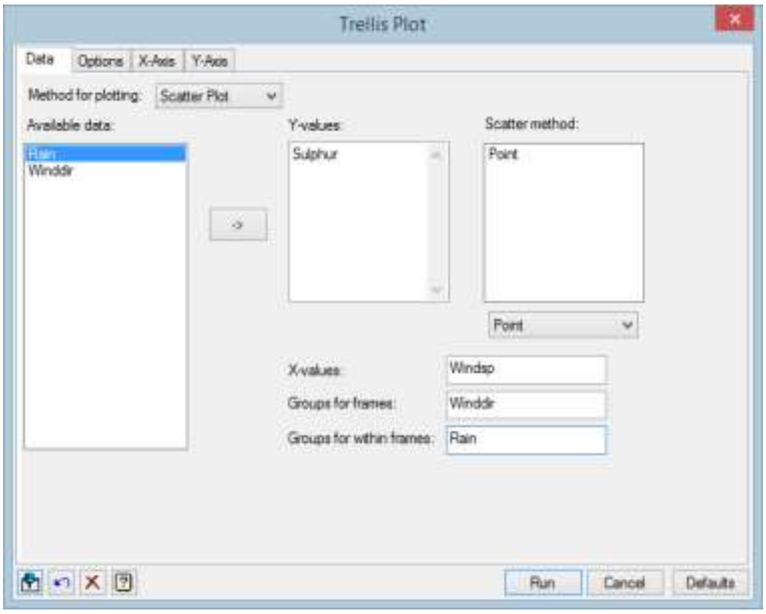


Figure 2.54: Trellis of sulphur measurement boxplots (Sulphur) conditional on both whether or not it had rained (Rain) and the wind direction (Winddir).

Trellis plots can also be used to explore the relationship between variables that are conditional on subsetting factors by setting the Method for plotting: field on the Data tab to Scatter Plot. This activates all input fields on the Data tab menu (see Figure 2.55).

Genstat's trellis accommodates both single and multiple y-variate scatter plots, enabling different series to be plotted within each graph. For each series, you can specify how the data points are to be drawn in the Scatter method: field. Using the dropdown list below the Scatter method: field, you can choose from Point, Line, Mean, Median or Spline. (You can change the Scatter method: field by double-clicking on the variate in this list and selecting a new method in the dropdown.) When either mean (or median) is selected, a line is drawn to connect the mean (or median) at each x-value. If spline is selected, then this will be drawn using 4 df.

To examine the relationship between sulphur level and wind speed, separately for each wind direction and according to whether it had rained or not, create a trellis of scatter plots using the Data tab settings given in Figure 2.55. This draws separate `Sulphur` against `Windsp` scatter plots for each level of the factor `Winddir`, in which points are coloured according to the level of the `Rain` factor (Figure 2.56). For most wind direction by rain subsets, it is unclear what the relationship between sulphur level and wind speed is, in part because the data at this level is sparse.



Method for plotting: Scatter Plot

Available data:
Rain
Winddir

Y-values:
Sulphur

Scatter method:
Point

Point

X-values: Windsp

Groups for frames: Winddir

Groups for within frames: Rain

Figure 2.55 Trellis plot of `Sulphur` against `Windsp`, subsetted by `Winddir`. Points within each scatter plot are coloured according to the level of `Rain`.

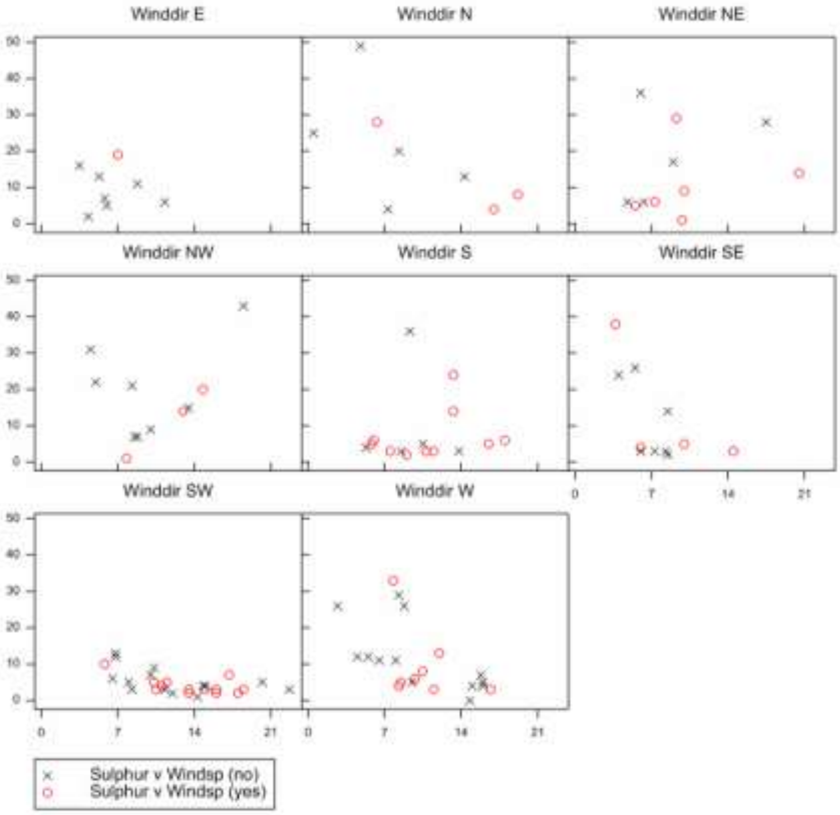
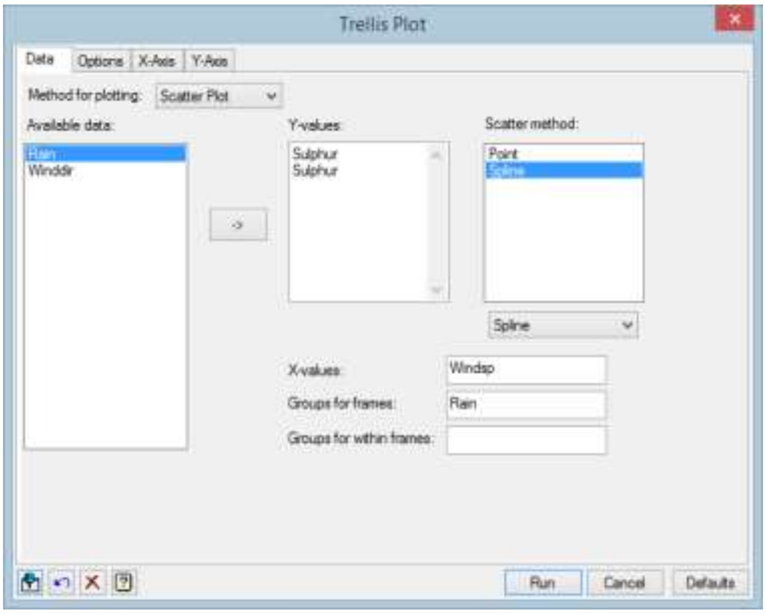


Figure 2.56: Trellis of scatter plots created using the Data tab settings in Figure 2.55. The data points are coloured according to whether it had rained (red) or not (black).

Let's simplify the subsetting to only Rain. Use the Data tab settings shown in Figure 2.57 to create separate scatter plots of Sulphur against Windsp according to whether it had rained or not. We'll enter Sulphur into the Y-values: field twice so that within each scatter plot we can request that both points and a spline are drawn.

The Sulphur.gsh data set contains a missing Windsp value on row 31. This will affect how the spline is drawn – separate splines will be fitted to the data before (rows 1 to 30) and after (rows 32 to 114) this missing value. To overcome this, before fitting the trellis plot we restrict the data to exclude row 31. Select row 31, and from the menu select Spread | Restrict/Filter | Selected Rows | Set as Exclude rows. Alternatively, Spread | Restrict/Filter | Exclude rows with Missing values to exclude any data row containing a missing value.

The resulting trellis plot (having restricted the data to exclude row 31 before plotting) is shown in Figure 2.58.


Trellis Plot

Method for plotting: Scatter Plot

Available data:
Rain
Winddir

Y-values:
Sulphur
Sulphur

Scatter method:
Point
Spline

Spline

X-values: Windsp

Groups for frames: Rain

Groups for within frames:

Figure 2.57: Data tab settings for drawing scatter plots of `Sulphur` against `Windsp` conditional on `Rain`. Data is drawn as both points and splines. Row 31, with missing `Windsp`, was restricted out before plotting.

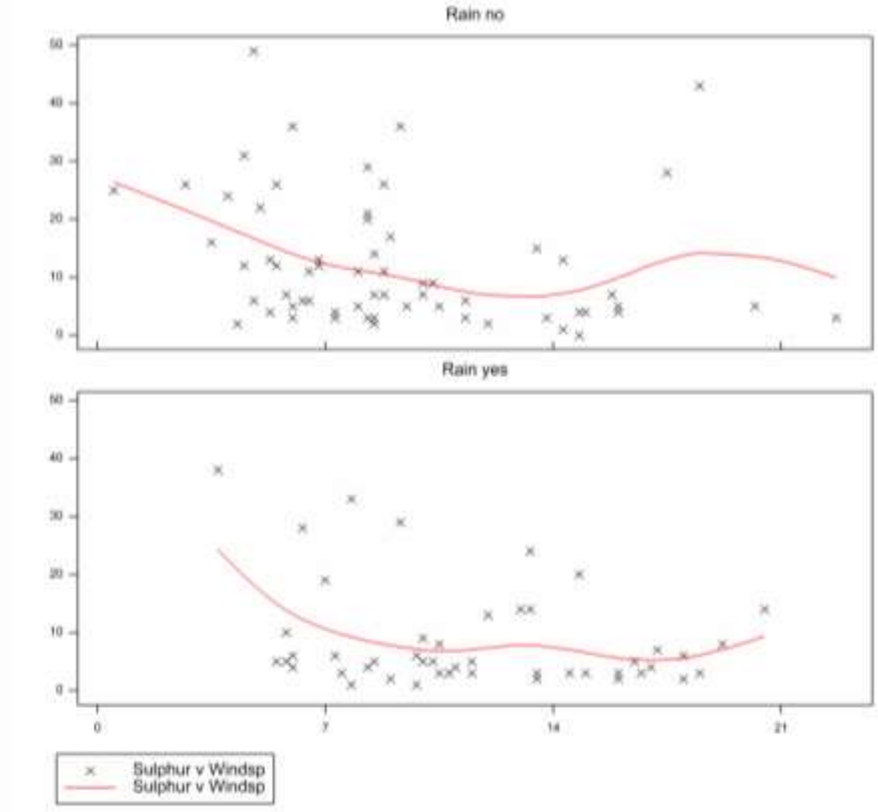


Figure 2.58: Trellis of scatter plots created using the Data tab settings in Figure 2.57, having first restricted the data set to exclude the row with the missing `Windsp` value (row 31).

2.4.2 Graphics Viewer

For graphs containing two or more individual frames within a single display, such as trellis plots, the zoom and scroll controls in *Viewer* mode operate on the entire display, whilst the built-in *Editor* operates on the individual component plots. To edit an individual plot, double-click on the plot to launch it in *Editor* mode.

To demonstrate, let's modify Figure 2.58 so that the points in the second plot (Rain= yes) are coloured blue. Double-click on the second scatter plot to open it in *Editor* mode (see left pane of Figure 2.59). Using *Editor* mode, this scatter plot can now be modified in the standard way (refer to Section 1.2.2). Open the Graph Options tab and change the colour of the symbols in the first series to blue (see right pane of Figure 2.59). Click Apply, OK, then Save and Close to accept the change.

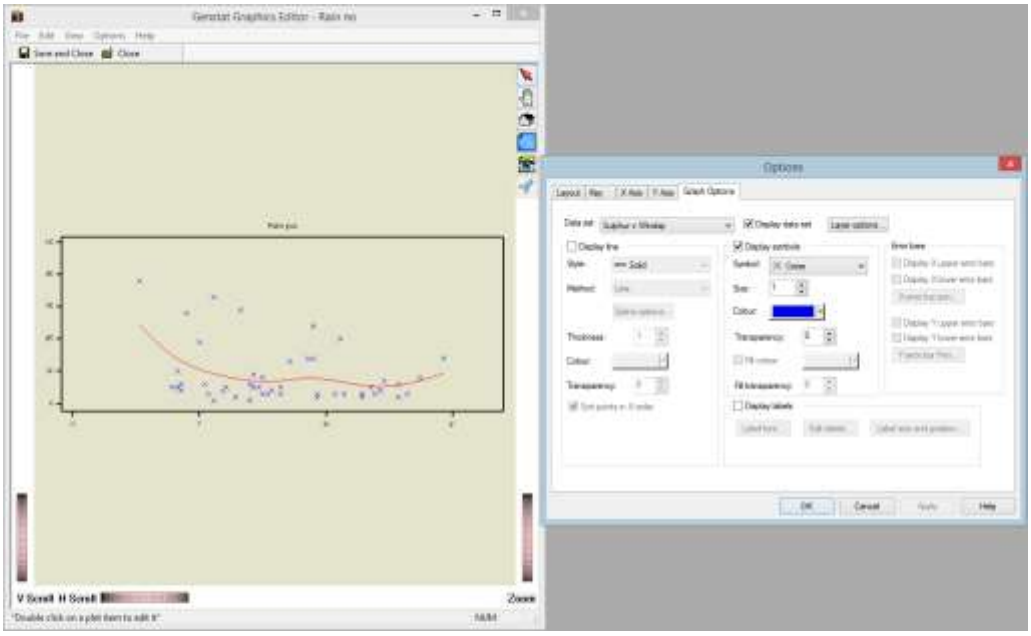


Figure 2.59: Using *Editor* mode to change the colour of the points in the second scatter plot of Figure 2.58 to blue.

2.5 Adding additional features to a graph

The Graphics | Add to Graph menu options (Figure 2.60) provide functionality to add additional features to an existing graph open in the *Graphics Viewer*, such as text, horizontal or vertical reference lines, arrows and error bars. In the following subsections, we

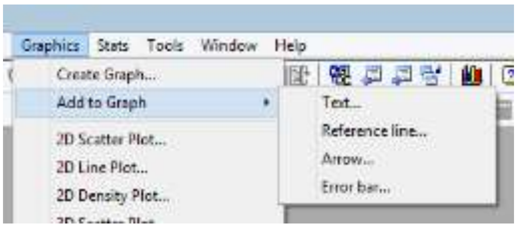


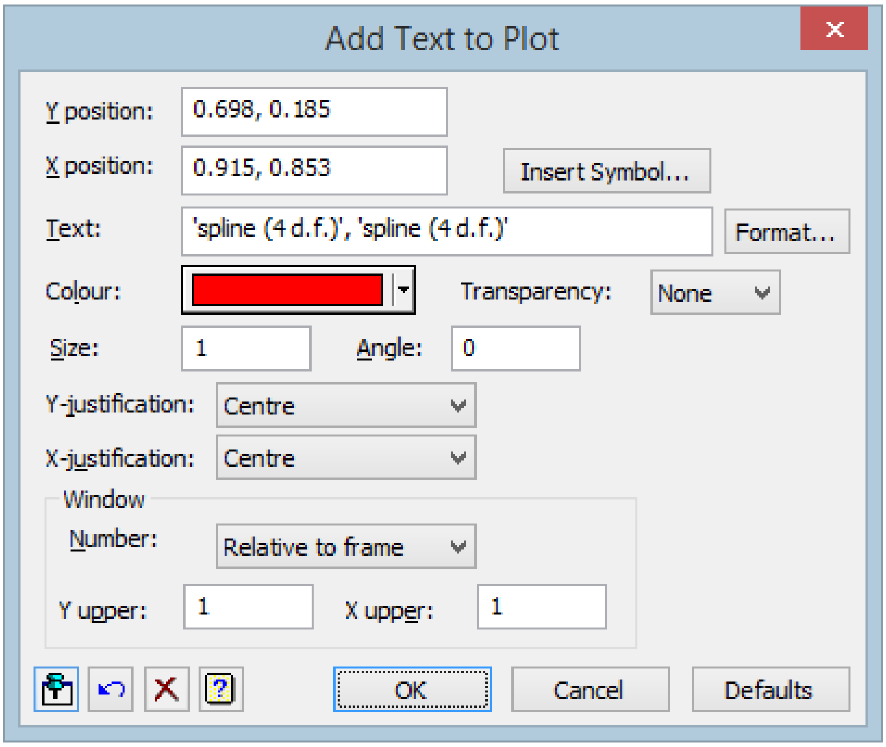
Figure 2.60: Accessing the Add to Graph menu options.

demonstrate how to add features to the figures created previously.

Note, if multiple graphs are open in the *Graphics Viewer*, the features will be added to the most recently created graph. Also note, features cannot be added to a previously saved *Genstat Meta File*.

2.5.1 Adding text to an existing graph

To add some text to an existing graph open in the *Graphics Viewer*, from the menu bar select Graphics | Add to Graph | Text.... This opens the Add Text to Plot menu shown in Figure 2.61.



Y position: 0.698, 0.185
X position: 0.915, 0.853
Text: 'spline (4 d.f.)', 'spline (4 d.f.)'
Colour: 🟥
Transparency: None
Size: 1
Angle: 0
Y-justification: Centre
X-justification: Centre
Window
Number: Relative to frame
Y upper: 1
X upper: 1

Figure 2.61: Add Text to Plot menu. The menu is populated with the settings for adding text labels to Figure 2.58 that produce Figure 2.62.

The Y position: and X position: fields specify the position to place the text. This can be a number, a list of numbers separated by spaces or commas, or the name of a variate or scalar structure existing in Genstat. Note, the length of the variates or lists of numbers supplied in the Y position: and X position: fields must be the same. The Window Number: dropdown list specifies which window to add the text to. If the option Relative to frame is selected, the Y and X positions are relative to the frame (whose maximum X and Y limits are provided in the Y upper: and X upper: fields). For example, if the X and Y upper boundaries are 1, then a value of 0.5 for the X and Y positions will position the text at the centre of the graph. If a window number is used, the Y and X positions are relative to the data currently displayed in that graph.

The text is supplied in the Text: field. If more than one line of one text is to be inserted, you can specify a list of strings separated by spaces (e.g. `‵a′ ‵b′ ‵c′`) or commas (e.g. `‵a′,‵b′,‵c′`), or a text structure containing several lines. The number of lines of text must be the same as the number of X (and Y) positions. Strings that contain spaces or commas must be contained in single quotes (e.g. `'Group 1','Group 2'`). If you need to use a quote in a quoted text, this should be doubled (e.g. `'tomorrow''s location'`). Typesetting commands (see Section 4.2.1) can be used to add special characters and formatting to the text. This is aided by the Insert Symbol… and Format… buttons. The Insert Symbol… button opens a dialog box allowing you to add Greek and mathematical symbols or line breaks, into the Text: field. The Format… button opens a dialog box allowing you to format the text (bold, italic, subscript, superscript) entered in the Text: field. If only part of the text is selected, only that selection will be formatted.

The Colour: dropdown list allows you to select the colour of the text, and apply transparency using the Transparency: dropdown list. The larger the value of Transparency:, the more the existing graph will show through the text; selecting None means nothing on the graph will show through the text. In the Size: field, set the amount by which the standard text size is to be multiplied (e.g. a value of 2 will produce text double the standard size). In the Angle: field you can set the orientation of the text. An angle of 0 places the text horizontally, 90 places the text vertically and 180 flips the text so that it appears upside down. The Y-justification: dropdown list determines how the text is to be placed relative to the values supplied in the Y position: field (below Y position, centred around Y position, or below Y position). Similarly, the X-justification: dropdown list determines how the text is to be placed relative to the values supplied in the X position: field (left of X position, centred around X position, or right of X position).

To demonstrate, let’s add red text labels, `‵spline (4 d.f.)′`, to each spline in Figure 2.58. In the *Graphics Viewer* it is easy to determine the X and Y positions of a point relative to either the frame or plot coordinates. In *Viewer* mode, hover the mouse cursor over the location where you wish to add the text. The coordinates of this point are displayed in the bottom right-hand corner of the *Viewer* window. The first set corresponds to the Y and X positions relative to the data displayed in the graph, and the second set relative to the frame. Using the settings shown in Figure 2.61, labels are added to the trellis in Figure 2.58 giving Figure 2.62.

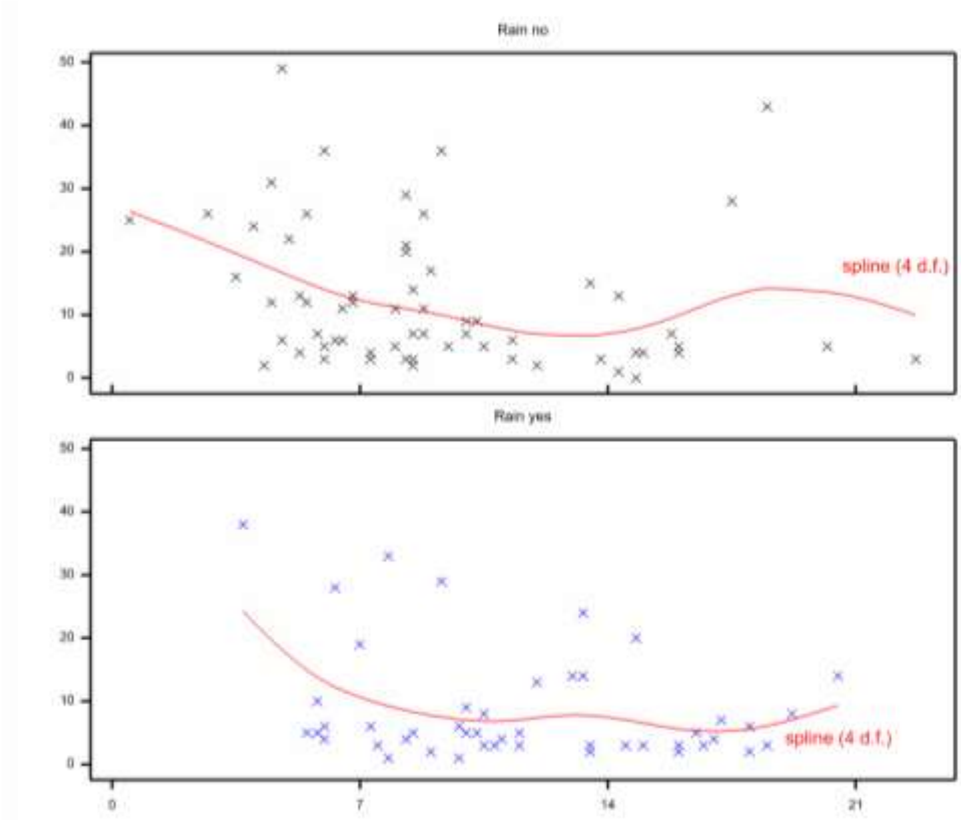


Figure 2.62: Figure 2.58 with text labels added.

2.5.2 Adding a reference line to an existing graph

The Add Reference Line to Plot menu, shown in Figure 2.63, is accessed by selecting Graphics | Add to Graph | Reference line... on the menu bar. This menu allows you to add a horizontal or vertical reference line, as specified by the Orientation radio buttons, to an existing graph open in the *Graphics Viewer*. Note, reference lines cannot be added to all plots; e.g. trellis plots, 3D plots, stem and leaf plots or scatter plot matrices. The position the reference line is to be plotted is specified in the Position: field. If the Orientation is Horizontal, this represents the Y value for the line. Conversely, if the Orientation is Vertical, this represents the X value for the line.

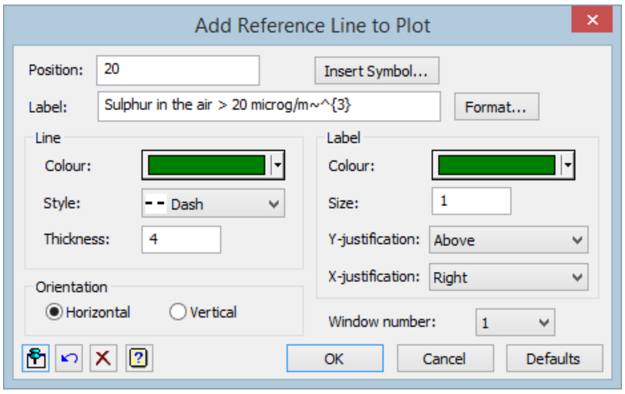
The Line pane offers fields for specifying the colour, style and thickness of the plotted reference line. The value supplied in the Thickness: field sets the amount to multiply the standard thickness of the plotted line by (where 1 represents the standard thickness).

You can enter a label for the reference line in the Label: field. As with adding text to a graph (Section 2.5.1), you can use typesetting commands (see Section 4.2.1) to add special characters and formatting to the label. Use the Insert Symbol... and Format...

buttons to add special characters and font formatting. The colour, size and justification of the label can be controlled using the fields in the Label pane.

The Window number: dropdown list defines the window you are adding the reference line to.

To demonstrate, we'll add a horizontal reference line to the scatter plot of `Sulphur` against `Windsp` (*cf* Figure 1.13) to indicate when sulphur in the air exceeds 20 microg/m^3. We'll plot the reference line using a thick, green, dashed-line, and add a green label above it: "`Sulphur in the air > 20 microg/m3`". The Add Reference Line to Plot menu settings are given in Figure 2.63, and the graph in Figure 2.64.



Position: 20

Label: Sulphur in the air > 20 microg/m~^{3}

Line

Colour: 🟩

Style: -- Dash

Thickness: 4

Label

Colour: 🟩

Size: 1

Y-justification: Above

X-justification: Right

Orientation

● Horizontal ○ Vertical

Window number: 1

Figure 2.63: Add Reference Line to Plot menu. The menu is populated with the settings that provide the reference line in Figure 2.64.

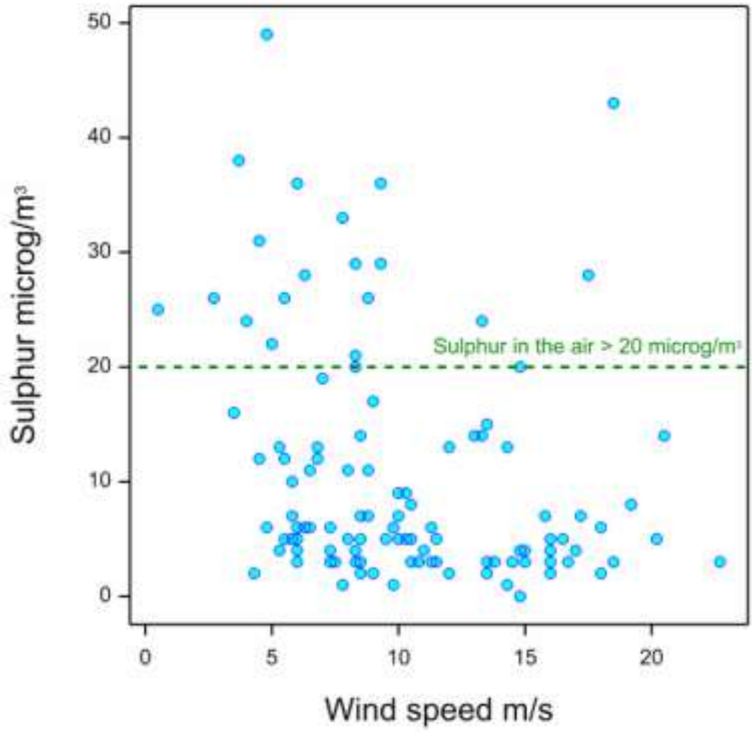
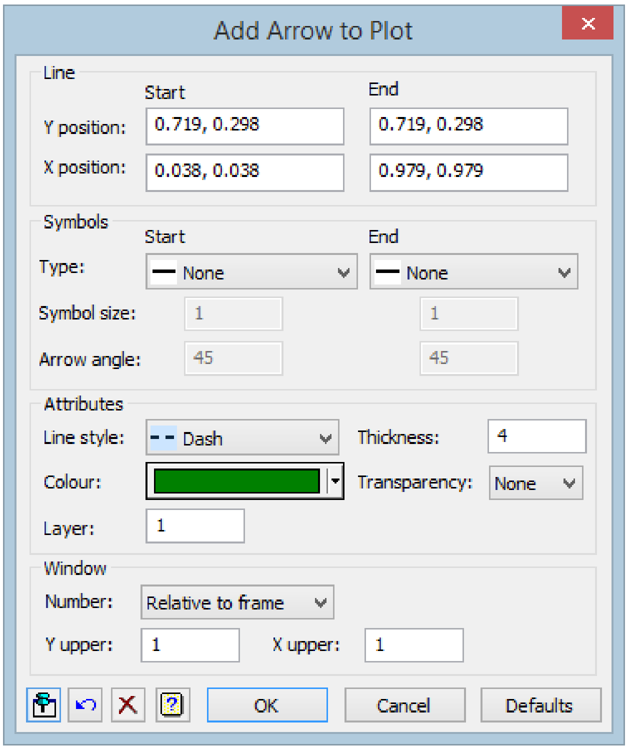


Figure 2.64: Horizontal reference line, at 20 microg/m^3, added to a scatter plot of `Sulphur` against `Windsp`.

2.5.3 Adding an arrow to an existing graph

The Add Arrow to Plot menu, shown in Figure 2.65, is accessed by selecting Graphics | Add to Graph | Arrow... on the menu bar. This menu allows you to add arrows (or lines if the Start and End styles are set to None) to an existing graph open in the *Graphics Viewer*.



Add Arrow to Plot

Line

	Start	End
Y position:	0.719, 0.298	0.719, 0.298
X position:	0.038, 0.038	0.979, 0.979

Symbols

	Start	End
Type:	None	None
Symbol size:	1	1
Arrow angle:	45	45

Attributes

Line style:	Dash	Thickness:	4
Colour:	🟩	Transparency:	None
Layer:	1		

Window

Number:	Relative to frame		
Y upper:	1	X upper:	1

Figure 2.65: Add Arrow to Plot menu. The menu is populated with the settings to draw the reference line in Figure 2.66.

The Start and End position of the arrow is defined using the Y position: and X position: fields. These can be either entered directly as a number, a list of numbers separated by spaces or commas, or as the name of a variate or scalar structure existing in Genstat. The list or variate lengths must all be the same. The Number: dropdown list in the Window pane specifies which window to add the arrow to. If the option Relative to frame is selected, the Start and End Y and X positions are relative to the frame (whose maximum X and Y limits are provided in the Y upper: and X upper: fields). If a window number is used, the Start and End Y and X positions are relative to the data currently displayed in that graph.

In the Symbols pane you can set the style at the start and end of the arrow. In the Type: dropdown list you can choose between an Open arrowhead, Filled arrowhead, Circle or None. You can change the size of the arrow head, relative to the standard size by altering the value in the Symbol size: field (e.g. a value 2 will result in arrowheads twice the standard size). The angle (in degrees) of the arrow head is controlled using the Arrow angle: field.

Setting the angle to a value greater than 180 (e.g. 315) reverses the direction of the arrowhead. The angle must be between 0 and 360.

The Attributes pane specifies the style, thickness, colour and transparency of the arrow's line. Using the Layer: field you can control whether the arrows overlie the data points, and how different sets of arrows overlay each other. A large value will force the arrows to overlie previous layers in the plot, and a value less than the existing layers will display arrows underneath these in the plot. For example, if we were to plot a set of arrows in layer 1 and another set in layer 2, the second set would overlie the first set.

We will use the Add Arrow to Plot menu to add a reference line at 20 microg/m^3 to the trellis of scatter plots given in Figure 2.62. Using the *Graphics Viewer* to establish the required start and end positions relative to the frame, green arrow lines (without arrow heads) are added to both scatter plots using the menu settings shown in Figure 2.65. The trellis plot, with arrows added, is shown in Figure 2.66.

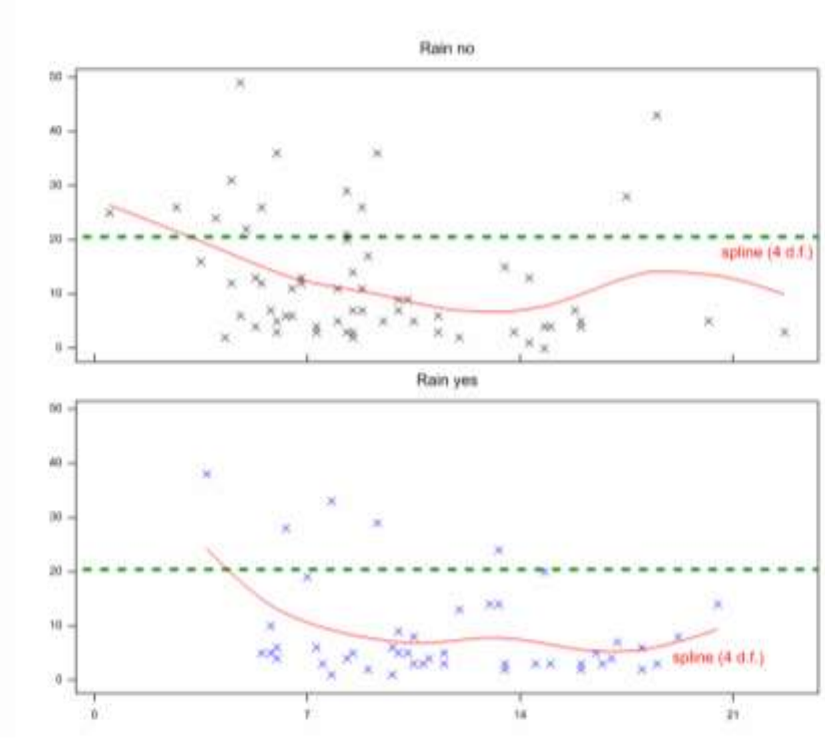
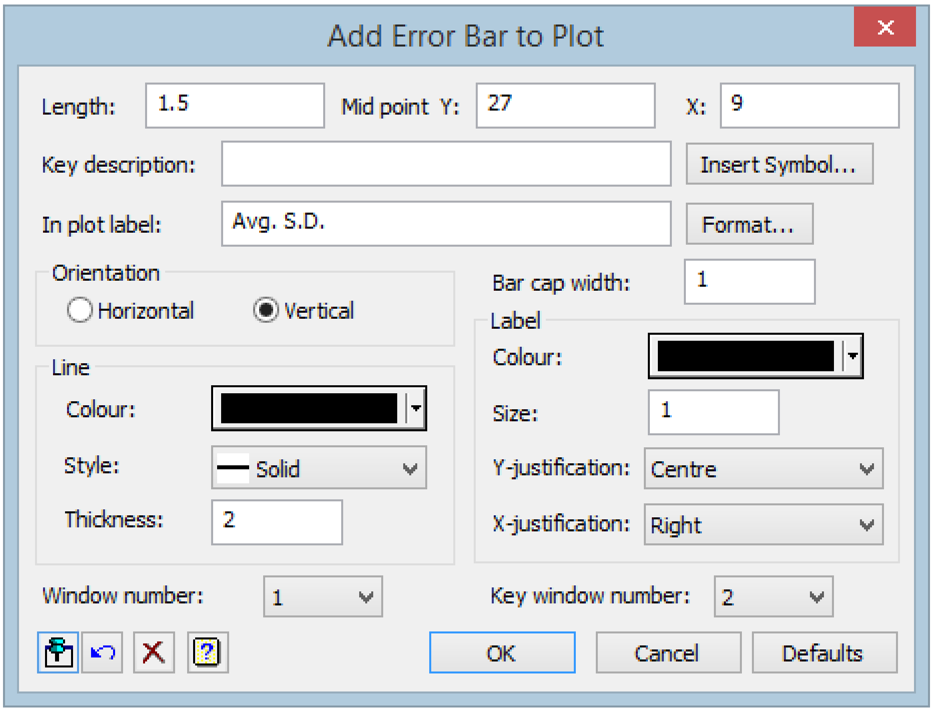


Figure 2.66: Figure 2.62 with arrows, representing a reference line at 20 microg/m^3, added.

2.5.4 Adding error bars to an existing graph

To open the Add Error Bar to Plot menu, shown in Figure 2.67, select Graphics | Add to Graph | Error bar… on the menu bar. This menu allows you to add error bars to an existing graph open in the *Graphics Viewer*.



Length: 1.5
Mid point Y: 27
X: 9
Key description:
In plot label: Avg. S.D.
Orientation
○ Horizontal ● Vertical
Line
Colour: ■
Style: Solid
Thickness: 2
Bar cap width: 1
Label
Colour: ■
Size: 1
Y-justification: Centre
X-justification: Right
Window number: 1
Key window number: 2

Figure 2.67: Add Error Bar to Plot menu. The menu is populated with the settings used to draw an error bar on Figure 2.31 to produce Figure 2.68.

You must specify the length of the error bars to be plotted in the Length: field. (All other menu fields are optional). The Window number: field specifies which window the error bars are to be added to.

The error bars can be drawn either vertically (the default) or horizontally, and this is set in the Orientation pane. You can control where the error bars are plotted using the Mid point Y: and X: fields.

The appearance of the error bars (line colour, style and thickness) can be changed in the Line pane, and the width of the bar cap in the Bar cap width: field.

In the Key description: field you can supply annotation on the error bars for the graph's key. The key's window is specified in the Key window number: field. You can also supply labels to plot alongside the error bars in the In plot label: field. The Label pane controls the colour, size and position of the labels. Symbols can be inserted into these two text fields using the Insert Symbol... button, and the text formatting controlled using the Format... button.

To illustrate, we'll add error bars to Figure 2.31. The standard deviations of Mean_Temperature for each month, Jan to Dec, are 1.9, 1.8, 1.8, 1.4, 1.5, 1.2, 0.8, 1.5, 1.3, 1.3, 1.6, 2.5, respectively. (Note: you can use the Stats | Summary Statistics | Summary Tables... menu to calculate and save these.) The average of these monthly standard deviations is 1.5. Let's add an error bar to Figure 2.31 representing this average standard deviation and label it "Avg. S.D.". To plot the average standard deviation in the top right of the graph, set the Length: field to 1.5, the Mid point Y: field to 27, the X: field 9, and the In plot label: field to Avg. S.D. (see Figure 2.67). In addition, we'll make the error bar slightly bolder in appearance by setting the Thickness: field to 2. The plot, with labelled error bar, is shown in Figure 2.68.

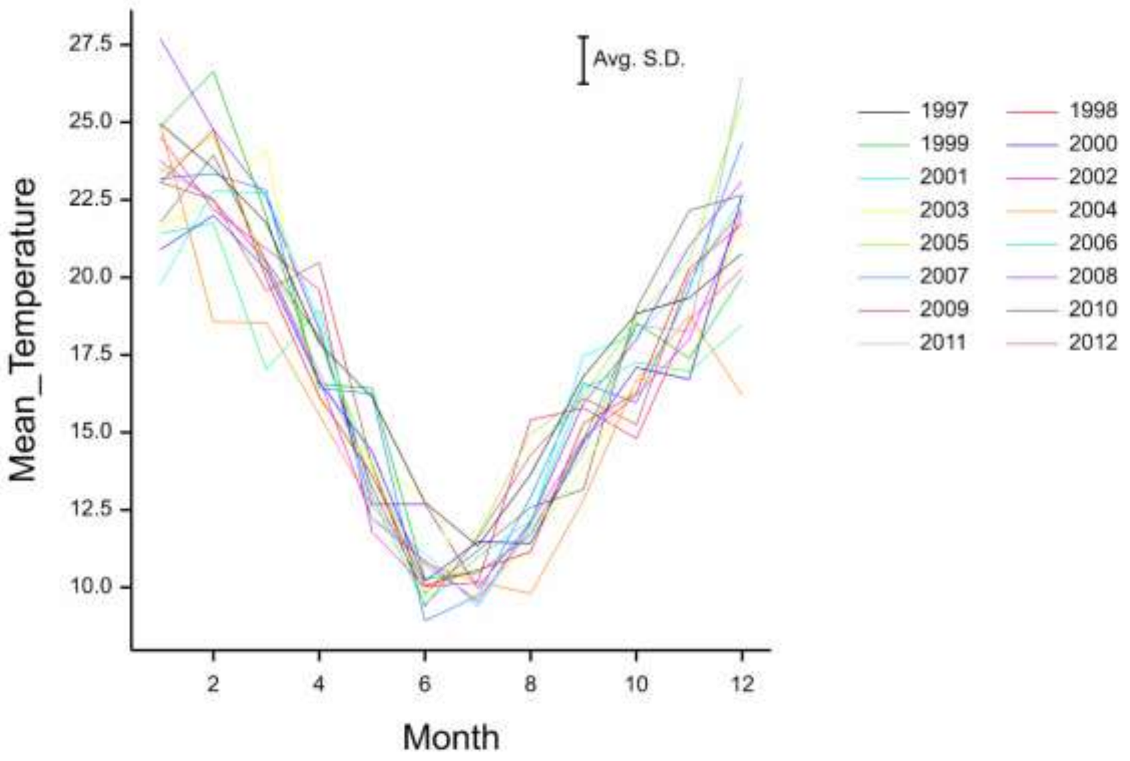
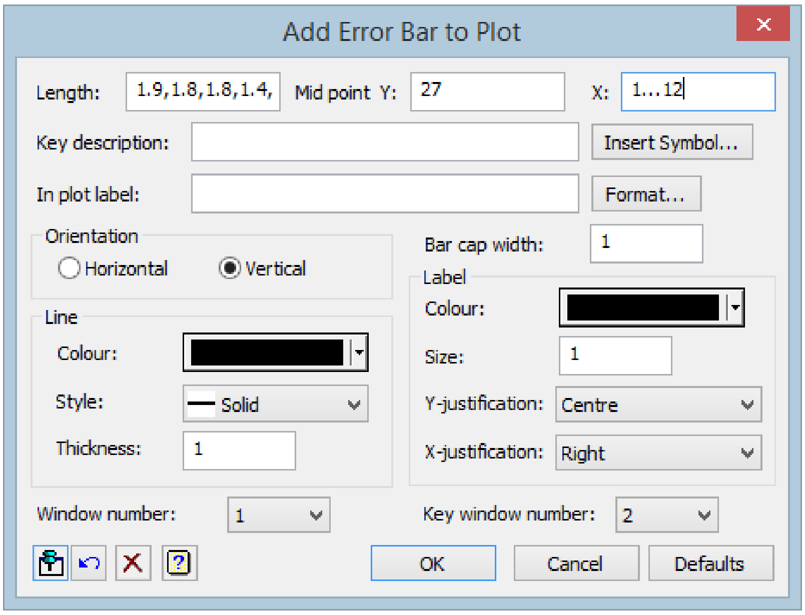


Figure 2.68: Figure 2.31 with an error bar added. The Add Error Bar to Plot menu settings used to produce this plot are shown in Figure 2.67.

Instead of adding a single average standard deviation, let's add to Figure 2.31 a series of error bars representing the standard deviation of mean temperature for each month. You can use the Undo (⟲) button on the *Graphics Viewer* toolbar to remove the error bar we added previously. To plot the standard deviations for each month at the top of the graph enter the monthly standard deviations, separated by commas, into the Length: field (i.e. 1.9,1.8,1.8,1.4,1.5,1.2,0.8,1.5,1.3,1.3,1.6,2.5), set the Mid point Y: field to 27, and set the X: field to 1…12 (see Figure 2.69). The resulting plot is shown in Figure 2.70.



Add Error Bar to Plot

Length: 1.9,1.8,1.8,1.4, Mid point Y: 27 X: 1...12

Key description:

In plot label:

Orientation
○ Horizontal ● Vertical

Bar cap width: 1

Line
Colour: ■
Style: Solid
Thickness: 1

Label
Colour: ■
Size: 1
Y-justification: Centre
X-justification: Right

Window number: 1

Key window number: 2

Figure 2.69: Add Error Bar to Plot menu. The menu is populated with the settings used to draw standard deviation bars on Figure 2.31 to produce Figure 2.70.

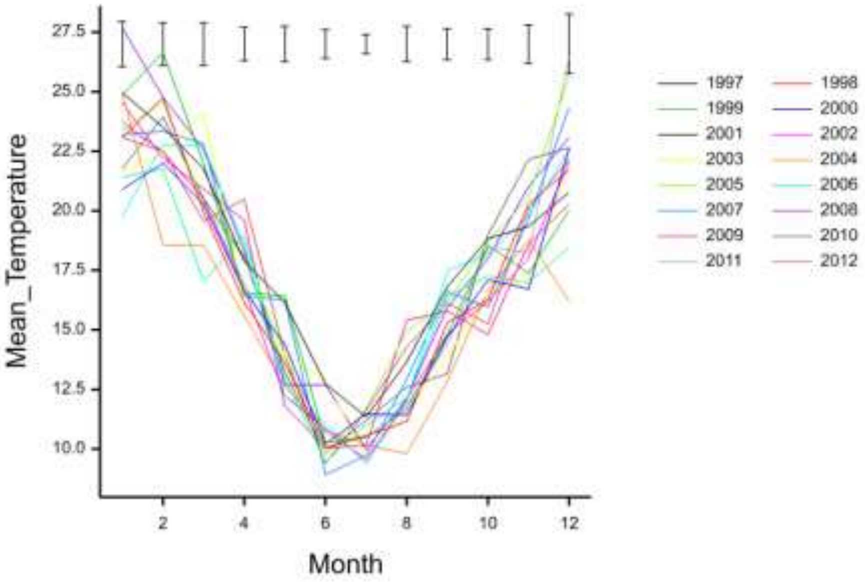


Figure 2.70: Figure 2.31 with error bars representing the standard deviation of monthly mean temperature added.

3 Genstat commands for high-resolution graphics

In the previous chapters we demonstrated the use of the menu interface to generate high-resolution graphics. However, graphs can also be created using commands in the Genstat language. (Note, use of the menus will generate commands in the *Input Log* window that can be used to reproduce the graph at a later date, or edited to modify the graph. See Section 1.2.4.3.) The command language accommodates greater functionality than the menu interface enabling more advanced and complex graphics to be created. We begin this chapter with a brief guide on how to write and run commands in Genstat (Section 3.1). To learn more about unlocking the full power of the Genstat command language, refer to *An Introduction to the Genstat Command Language*, which you can access from the menu bar by selecting Help | Genstat Guides. A list of Genstat's graphical directives and procedures is provided in Appendix 5.1.

In this chapter, we use the DGRAPH directive to introduce the generation of high-resolution graphics via the command language. We illustrate the use of the FRAME directive for defining the position and appearance of the plotting window, the PEN directive for specifying the colours, fonts and symbols used to draw the plot, the XAXIS, YAXIS and ZAXIS directives for determining how the axes are drawn, and the DEVICE directive for selecting what graphical device is used to generate the output. We also show how the current settings of the graphics environment can be saved using DSAVE and later reloaded using DLOAD.

Fisher's iris data set is used for illustration throughout this chapter. The data, available in the Genstat spreadsheet Iris.gsh, consists of sepal lengths (Sepal_Length), sepal widths (Sepal_Width), petal lengths (Petal_Length) and petal widths (Petal_Width) of iris plants belonging to three different species (factor Species). Fisher's iris data set can be loaded by running the command:

```
SPLOAD '%GENDIR%/Data/Iris.gsh'
```

In this chapter you will learn how to:

- execute commands in Genstat (Section 3.1)
- produce a high-resolution scatter plot or line graph using the DGRAPH directive (Section 3.2)
- specify the position and appearance of the plotting window using the FRAME directive (Section 3.3)

- specify the attributes of the graphical *pens* (such as colour, font and symbol) used for plotting using the `PEN` directive (Section 3.4)
- specify how the x-, y- and z-axes are drawn using the `XAXIS`, `YAXIS` and `ZAXIS` directives, respectively (Section 3.5)
- switch between graphical devices using the `DEVICE` directive (Section 3.6)
- load and save a *Graphics Environment* using the directives `DSAVE` and `DLOAD`, respectively (Section 3.7)

3.1 Writing and running Genstat commands

This section provides a basic introduction on how to write and run commands (or '*statements*') in Genstat. For a more detailed explanation refer to *An Introduction to the Genstat Command Language*, which you can access from the menu bar by selecting Help | Genstat Guides.

Genstat offers a comprehensive system of menus providing all the standard (and many non-standard) analyses and graphs. The menus define analyses and graphs by writing *programs* in Genstat's command language. These commands are then written to the Input Log, providing a complete audit trail. However, you can write your own programs to do something new or non-standard, to save time and/or to automate repetitive tasks. Genstat programs can be typed into any text window and then executed using the Run menu bar (or appropriate shortcut key). The output generated by the program will then appear in the Output window, and any high-resolution graphics in the *Graphics Viewer*.

There are two types of commands in Genstat: *directives* are the basic commands of the Genstat language while *procedures* are extensions of the language, using programs written in the Genstat language itself. All Genstat commands have a common form of syntax:

```
    statement-name [ option-settings ] parameter-settings :
```

where the *statement-name* gives the name of the directive or procedure that is to be used, the *parameters* specify parallel lists of arguments for the directive or procedure, and the *options* specify settings that apply to all the (parallel) sets of parameters. Parameter settings are separated from one another by semicolons (;). Option settings are enclosed in square brackets, and are also separated from one another by semicolons. (If no option settings are given, the square brackets can be omitted.) For example, the command below calls the DGRAPH directive, with parameters Y and X set to Sepal_Length and Sepal_Width, respectively, and the WINDOW option set to 1.

```
DGRAPH [WINDOW=1] Y=Sepal_Length; X=Sepal_Width
```

Nearly all options, and some parameters, have default values, chosen to be those required most often. Therefore, all of the options and parameters don't always need to be set. Furthermore, the names of directives, procedures, options and parameters can be given in lower- or upper-case (or a mixture of both), and can always be abbreviated to four characters. (Names of options and parameters can often be abbreviated to fewer than four characters. See *An Introduction to the Genstat Command Language* to learn more.) For example, the command above could be written as:

```
DGRAPH [Wind=1] y=Sepal_Length; x=Sepal_Width
```

Throughout this guide, each command is written on a separate line. However, if you wish to provide several commands on the same line, you must use the terminating colon (:). For example:

```
PEN NUMBER=1; COLOUR='red': DGRAPH Y=Sepal_Length; X=Sepal_Width
```

Conversely, to continue a command onto the next line, you must end the line with a continuation symbol \. For example:

```
DGRAPH [KEYWINDOW=12; KEYDESCRIPTION='Iris species'] \
  Y=Sepal_Length; X=Sepal_Width; PEN=Species; \
  DESCRIPTION=!T(Setosa,Versicolour,Virginica)
```

Notice that in the examples above different colours have been used to identify the various components of the command. For example, the names of the commands are in blue. This is *syntax highlighting*, which can be turned on or off by checking or unchecking Syntax Highlighting in the Tools menu bar.

To write a program in Genstat, open a new text window. This is done by clicking File | New in the menu bar then selecting Text Window. Click OK to open a new text window. You can then write the commands in this text window using the usual keys for typing and deleting characters.

The Run menu bar (or the appropriate shortcut key) is used to execute commands (see Figure 3.1). For example, to run the entire program, select Submit Window, or alternatively you can use the shortcut key Ctrl+W. A single line of the program can be executed by placing the cursor on the line then selecting Run | Submit Line, or alternatively by using the shortcut key Ctrl+L.

You can save the contents of a text window using Save or Save As in the File menu. Existing Genstat programs can be loaded into a new text window using the File | Open menu.

Note: The Run and File menu always operate on the currently active window, so ensure that the desired window is active by clicking on the title bar before using these menus.

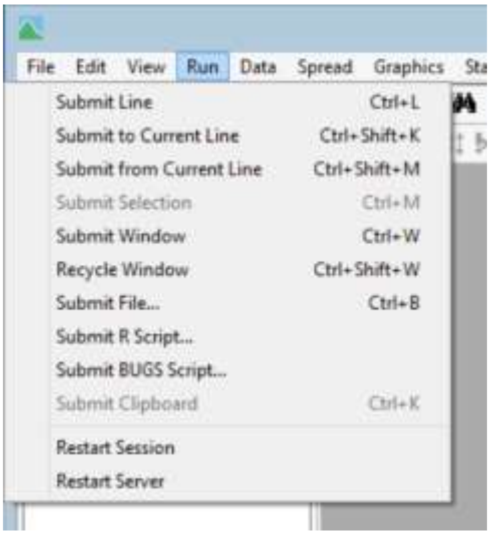


Figure 3.1:The Run menu bar.

3.2 DGRAPH directive

The DGRAPH directive draws high-resolution scatter plots and line graphs. The options and parameters controlling DGRAPH are briefly described in Table 3-1. Full documentation, containing a more detailed explanation, is provided within the Genstat Help System () – also see in *Genstat Reference Manual (Part 2 for Directives)* accessible via Help | Reference Manual | Directives….

Table 3-1: Options and parameters of DGRAPH.

Options	
TITLE = *text*	Provides a title for the graph. Default *.
WINDOW = *scalar*	Defines the window, within the plotting area, in which the graph is drawn. By default this is window 1. Note, the position and appearance of the plotting windows can be set using the FRAME directive (see Section 3.3).
KEYWINDOW = *scalar*	Specifies the window in which the key appears. By default this is window 2. Setting KEYWINDOW=0 suppresses the key.
SCREEN = *string token*	Specifies whether to clear the screen before plotting (the default) or to continue plotting on the old screen (keep, resize).
KEYDESCRIPTION = *text*	Provides a title for the key. Default *.
ENDACTION = *string token*	Controls whether Genstat pauses (pause) or continues (continue) after completing the plot.
HOTMENU = *matrices*	Defines sets of "hot" components for the user to select as shown or hidden by a menu in the *Graphics Viewer*. (see Section 4.2.13).
HOTCHOICE = *string token*	Specifies whether one or several "hot" components can be displayed at a time. By default this is several.
Parameters	
Y = *identifiers*	Y coordinates of the points to be plotted.
X = *identifiers*	X coordinates of the points to be plotted.
PEN = *scalars, variates* or *factors*	Pen associated with each pair of Y and X. By default, pen 1 is used for the first pair, pen 2 for the second, and so on. Pen attributes, such as colour, font, symbols and labels, can be set using the PEN directive (see Section 3.4).
DESCRIPTION = *texts*	Provides labels for the key.

YLOWER = *identifiers*
YUPPER = *identifiers*
	Enables vertical bars to be included in the plot by setting the YLOWER and YUPPER parameters to variates defining the lower and upper values for the error bar to be drawn at each point.

XLOWER = *identifiers*
XUPPER = *identifiers*
	Enables horizontal bars to be included in the plot by setting the XLOWER and XUPPER parameters to variates defining the lower and upper values for the error bar to be drawn at each point.

YBARPEN = *scalars, variates* or *factors*	Specifies the pen to be used for the vertical bars, with the default pen set to -11.
XBARPEN = *scalars, variates* or *factors*	Specifies the pen to be used for the horizontal bars, with the default pen set to -11.
LAYER = *scalars*	Defines the “layer” on which the data are plotted.
UNITNUMBERS = *identifiers*	Specifies the unit numbers to be used when points are selected in the *Graphics Viewer* (see Section 1.2.1). By default the actual unit numbers of the values in the X and Y structures are used.
DISPLAY = *string tokens*	Specifies whether components of the graph (specified by pairs of Y and X) should be shown (show) or hidden (hide) in the initial graph displayed by the *Graphics Viewer*. Default show.
HOTCOMPONENT = *scalars*	Allows components of the graph (specified by pairs of Y and X settings) to be defined as "hot" components that can be shown or hidden through their association with "hot" points or using a menu in the *Graphics Viewer*.
HOTDEFINITION = *matrices*	Supplies a matrix with a row for each "hot" point, and a column for each type of "hot" component. The elements of the matrix specify the "hot" components to be associated with each "hot" point, using the numbers defined by the HOTCOMPONENT parameter.

In the simplest use of DGRAPH you just need to specify the y and x coordinates of the points to be plotted using the Y and X parameters, respectively. For example, the command

```
DGRAPH Y=Sepal_Length; X=Sepal_Width
```

will plot the values of Sepal_Length against the values of Sepal_Width to generate the graph shown in Figure 3.2a (see Section 3.1 for more information on how to execute commands in Genstat). Multiple pairs of Y and X structures may also be supplied. These are processed in parallel. For example, the command

```
DGRAPH Y=Sepal_Length,Petal_Length; X=Sepal_Width,Petal_Width
```

generates a graph containing plots of Sepal_Length against Sepal_Width and Petal_Length against Petal_Width (see Figure 3.2b).

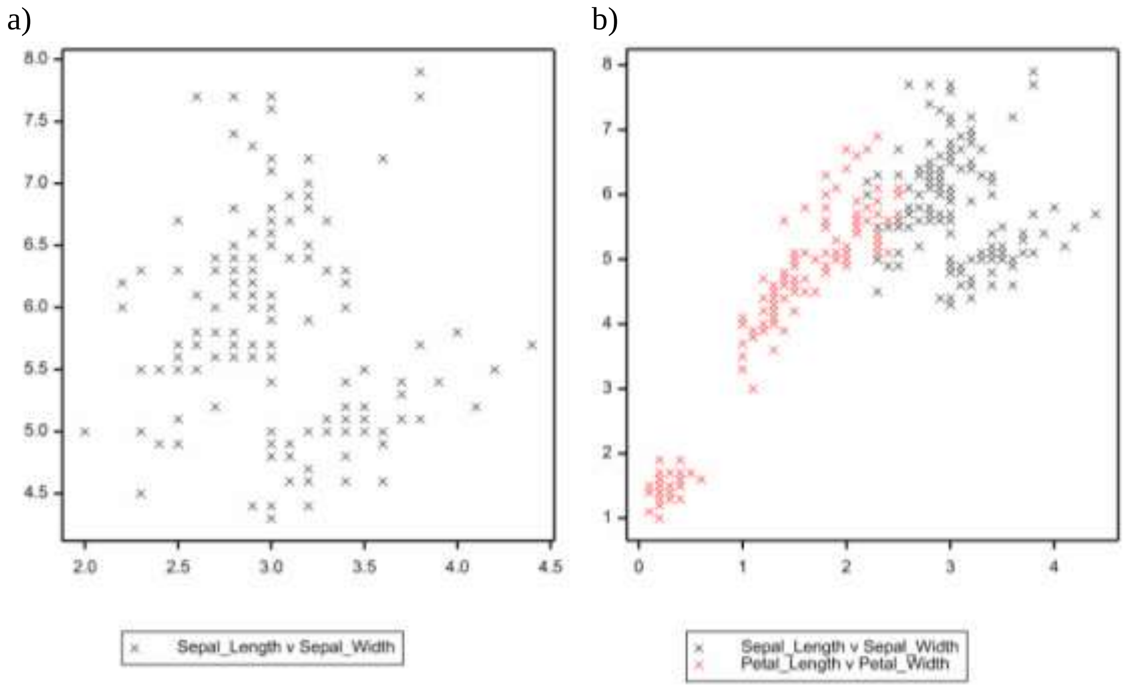


Figure 3.2: High-resolution graphs generated using DGRAPH. a) Scatter plot with a single pair of Y and X structures, b) Scatter plot with two pairs of Y and X structures.

Each pair of Y and X structures has an associated graphical *pen*, specified by the PEN parameter. By default pen 1 is used for the first pair, pen 2 for the second, and so on. The type of graph that is produced (scatter or line) and the appearance of the plotted data (colour, font, symbol-type, labels, etc.,) are determined by the pens. In Section 3.4 we demonstrate how to change the appearance of the graph by modifying the attributes of the pens (using the PEN directive). The default pens and pen attributes (under the Genstat Default *Graphics Environment*, see Section 1.3) were used to produce the plots in Figure 3.2. Here, pen 1 plots black crosses and pen 2 plots red crosses. We can, for example, reproduce Figure 3.2a but with the data plotted as red crosses by setting the PEN parameter to 2, i.e.

```
DGRAPH Y=Sepal_Length; X=Sepal_Width; PEN=2
```

produces Figure 3.3a.

The PEN parameter can also be set to a variate or factor, allowing different pens to be used to plot different subsets of the data. For example, the statement

```
DGRAPH Y=Sepal_Length; X=Sepal_Width; PEN=Species
```

will plot the data corresponding to each level of `Species` using a different pen (as shown in Figure 3.3b).

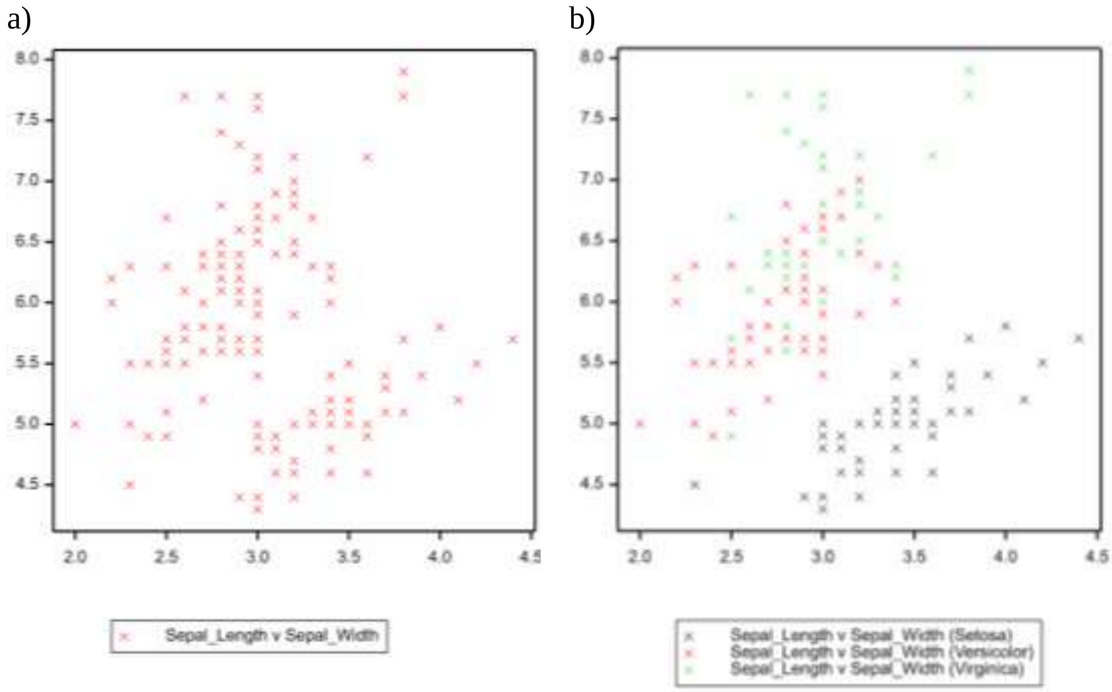


Figure 3.3: Using the `PEN` parameter to modify the appearance of the plotted data. a) `PEN` set to a scalar: data plotted as red crosses by setting `PEN=2`, b) `PEN` set to a factor: data for each iris species plotted using a different pen by setting `PEN=Species`.

By default, a key is printed. The key contains a line of information for each pair of `Y` and `X` structures, written with the associated pen. The labels for the key are formed automatically, however you can provide your own using the `DESCRIPTION` parameter. You can also specify a title for the key using the `KEYDESCRIPTION` option. The *window* in which the key is plotted can be specified the `KEYWINDOW` option. By default the key is plotted in window 2, the lower 1/4 of the graphics *frame*. Setting `KEYWINDOW=0` suppresses the key. The following command modifies the default key of Figure 3.3b to plot it in window 12, display a title, and use supplied labels. The resulting graph is shown in Figure 3.4.

```
DGRAPH [KEYWINDOW=12; KEYDESCRIPTION='Iris species'] \
  Y=Sepal_Length; X=Sepal_Width; PEN=Species; \
  DESCRIPTION=!T(Setosa,Versicolour,Virginica)
```

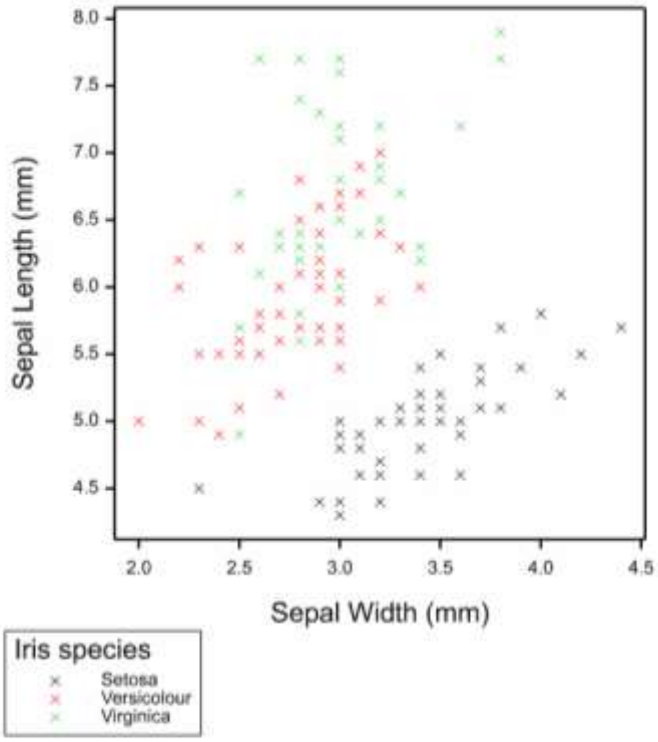


Figure 3.4: Modification of the key in Figure 3.3b using the KEYWINDOW option, KEYDESCRIPTION option and DESCRIPTION parameter of DGRAPH.

The TITLE option can be used to provide a title for the graph. Typesetting commands can be used to include Greek, mathematical or special symbols in the title and to control the text formatting. Further information on typesetting is provided in Section 4.2.1.

The appearance, including titles, of the x- and y-axes are controlled by the XAXIS and YAXIS directives, respectively (refer to Section 3.5).

Additional DGRAPH options and parameters enable the plotting window to be changed, error bars to be added, graphs to be superimposed, hot components to be defined and unit numbers to be supplied. Refer to Table 3-1 for more information.

There are many aspects to producing a graph that we may wish to control. However, it is not feasible to allow all of these to be specified via the options or parameters of DGRAPH (or likewise, other graphical directives and procedures): the syntax would become very complicated, and you'd need to specify all the relevant settings every time DGRAPH was called. Instead Genstat provides additional directives that define the *Graphics Environment*. Each time DGRAPH is called, it accesses the relevant information in the *Graphics Environment* to determine how to construct the graph. In the following sections we examine four directives that define the *Graphics Environment*:

- FRAME: defines the position and appearance of the plotting window (Section 3.3)
- PEN: defines the attributes of the graphical *pens* (Section 3.4)
- XAXIS, YAXIS and ZAXIS: defines how the x-, y- and z-axes are drawn, respectively (Section 3.5)
- DEVICE: specifies graphics device (Section 3.6).

3.3 FRAME directive

All graphical output is drawn in individual graphics *windows*. A window is a rectangular area of the screen. The position and size of the window is defined in terms of its lower and upper bounds in the vertical (y) and horizontal (x) directions using a data-independent coordinate system that ranges from 0.0 to 1.0 in each direction. Altogether there are 256 windows, numbered from 1 up to 256. Windows are independent of one another, and on most devices they are allowed to overlap or contain other windows, enabling complex graphical displays to be generated.

When producing a graphic you can either use the default windows defined by Genstat, or you can use the FRAME directive to define the position and appearance of your own windows. The options and parameters controlling FRAME are briefly described in Table 3-2. For a more comprehensive description, refer to the Genstat Help (▤). A suite of example graphs demonstrating the various option and parameter settings of FRAME is provided in Section 3.3.1.

Table 3-2: Options and parameters of FRAME.

Options	
GRID= *string tokens*	Specifies what grid lines are to be drawn (xy, xz, yx, yz, zx, zy). For example, the setting xy requests lines in the xy plane running from the x-axis (that is, parallel to the y-axis). Default *.
BOXFRAME = *string tokens*	Specifies whether or not a box is drawn around the entire frame (include, omit). Default omit.
BACKGROUND = *scalars* or *texts*	Specifies the colour to be used for the background of the whole frame.
RESET = *string token*	Specifies whether to reset the window definition to the default values (yes, no). Default no.
Parameters	
WINDOW = *scalars*	Numbers of the windows to be redefined. You can define up to 256 windows, numbered from 1 to 256.

YLOWER = *scalars*	Lower y device coordinate for each window.
YUPPER = *scalars*	Upper y device coordinate for each window.
XLOWER = *scalars*	Lower x device coordinate for each window.
XUPPER = *scalars*	Upper x device coordinate for each window.
YMLOWER = *scalars*	Size of bottom margin (for x-axis labels).
YMUPPER = *scalars*	Size of upper margin (for overall title).
XMLOWER = *scalars*	Size of left-hand margin (for y-axis labels).
XMUPPER = *scalars*	Size of right-hand margin.
BACKGROUND = *scalars* or *texts*	Specifies the colour to be used for the background in each window.
BOX = *string tokens*	Specifies whether or not a box is drawn around the plotted graphic (include, omit). Default include.
BOXSURFACE = *string tokens*	For a surface plot, specifies whether a full box enclosing the whole graph, a bounded box enclosing just the surface, or no box is drawn. Default omit.
BOXKEY = *string tokens*	Specifies whether a full box, a bounded box, or no box be drawn around each key. Default omit.
PENTITLE= *scalars*	Pen to use to write the overall title. Default -5.
PENKEY = *scalars*	Pen to use for the key. Default -6.
PENGRID = *scalars*	Pen to use to draw the grid lines. Default -4.
SCALING = *string tokens*	Specifies how to scale the axis in each window (xyequal, xzequal, yzequal, xyzequal). For example, the xyequal setting ensures that the x and y axes are scaled identically,
TPOSITION = *string tokens*	Position of title (right, left, center, centre). Default centre.
CINTERIOR = *scalars* or *texts*	Specifies the colour to be used for the interior of each window.
CFRAME = *scalars* or *texts*	Specifies the colour to be used for the frame of each window.
CTITLE = *scalars* or *texts*	Specifies the colour to be used for the title bar of each window.
AXES = *identifiers* or *pointers*	Additional oblique axes, defined by the AXIS directive (see Section 4.2.7), to include in each window.
SAVE = *pointers*	Saves the current FRAME settings.

When you use the FRAME directive, any aspects of the windows that you do not specify explicitly retain the values that they had immediately before the FRAME statement. Alternatively, specifying the option RESET=yes will reset all these aspects to the default values. In the example below, we redefine the plotting window of the graphic in Figure 3.4, window 1, such that:

- the x and y grid lines are displayed, using the `GRID` option
- the box enclosing the graphic is omitted, using the `BOX` parameter
- interior of the plot is coloured light yellow, using the `CINTERIOR` parameter

using the commands:

```
FRAME [GRID=xy,yx] WINDOW=1; BOX=omit; CINTERIOR='lightyellow'
DGRAPH [KEYWINDOW=12; KEYDESCRIPTION='Sepal Length v Width'] \
  Y=Sepal_Length; X=Sepal_Width; PEN=Species; \
  DESCRIPTION=!T(Setosa,Versicolour,Virginica)
```

The resulting graph is shown in Figure 3.5.

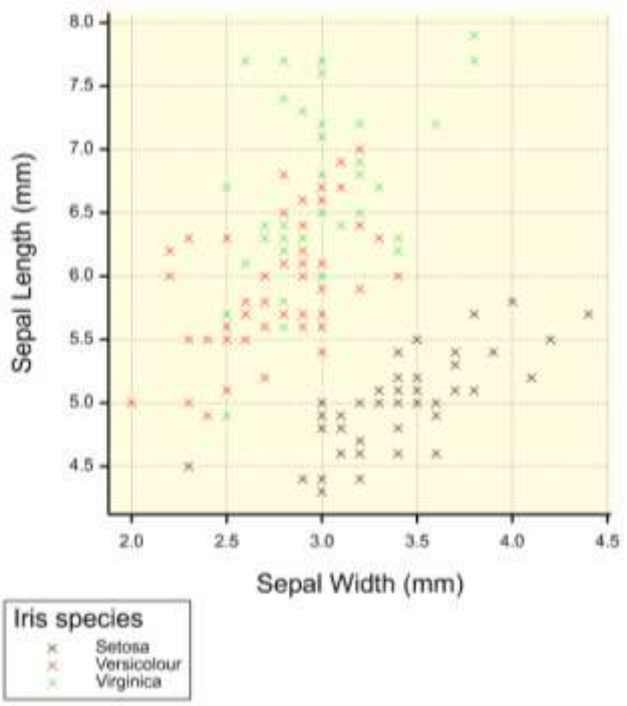


Figure 3.5: Graph plotted in redefined window 1, using the `FRAME` directive.

The default settings of window 1 can be restored using the command:

```
FRAME [RESET=yes] WINDOW=1
```

Further examples, in which the `FRAME` directive is used to modify the appearance of the graph, are provided in the next section.

3.3.1 Illustrative examples

In this section we provide a series of examples to demonstrate the effect that different option and parameter settings of FRAME have on the graphical output.

Recall that the WINDOW parameter specifies the *window* whose definition is to be altered. After changes have been made, the option RESET=yes may be used to revert all options and parameters back to their default values. If not, their current values are retained.

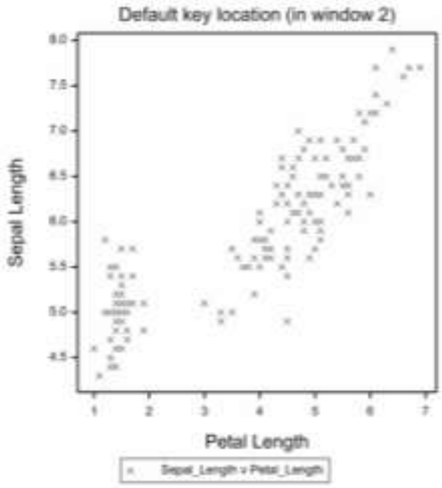
Note, in the commands that follow, the XAXIS and YAXIS directives have been used to add titles to the axes. Refer to Section 3.5 for more information.

3.3.1.1 Position and size of the window

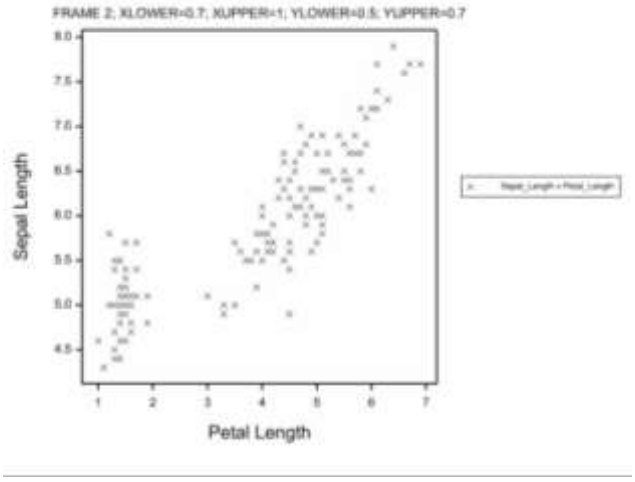
A graph (or key) is plotted into a rectangular *window* on the screen/device. The position and size of the window is defined using the parameters YLOWER, YUPPER, XLOWER and XUPPER (using normalized device coordinates). Below we demonstrate how to move the window used for the key (window 2) from its default position (Example 1) to a new location on the right of the graph (Example 2).

```
JOB
SPLOAD '%GENDIR%/Data/Iris.gsh'
XAXIS WINDOW=1; TITLE='Petal Length'
YAXIS WINDOW=1; TITLE='Sepal Length'

"Example 1"
DGRAPH [KEYWINDOW=2; \
       TITLE='Default key location (in window 2)'] \
       Y=Sepal_Length; X=Petal_Length

"Example 2"
FRAME WINDOW=2; XLOWER=0.7; XUPPER=1; YLOWER=0.5; YUPPER=0.7
DGRAPH [WINDOW=1; KEYWINDOW=2; \
       TITLE='FRAME 2; XLOWER=0.7; XUPPER=1; YLOWER=0.5; \
YUPPER=0.7'] \
       Y=Sepal_Length; X=Petal_Length

ENDJOB
```

Example 1



Example 2



3.3.1.2 Size of the margins

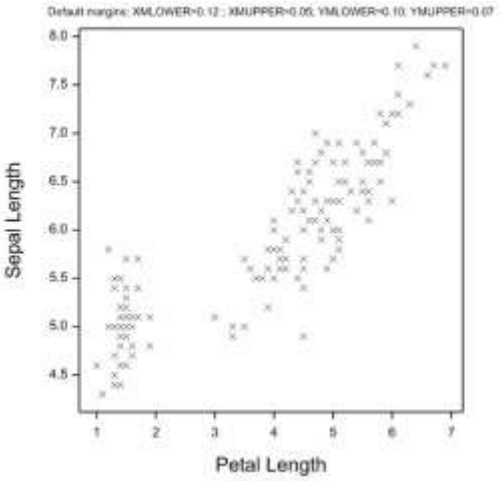
In the following set of examples, Examples 3-5, we are adjusting the parameters that control the size of the margins for the x-axis labels (YMLOWER), the title (YMUPPER), the y-axis labels (XMLOWER) and the right-hand side (XUPPER).

Notice how in Example 3 the size of the font used for the title is automatically decreased to accommodate the much longer title.

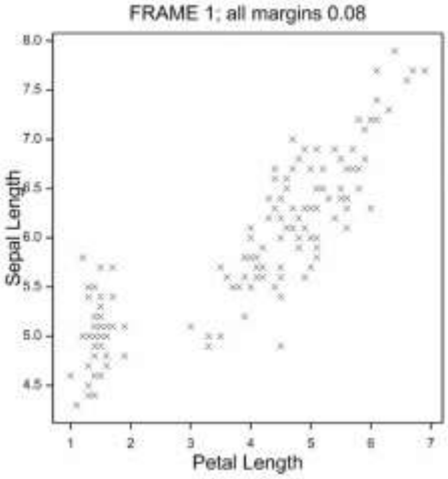
```
JOB
SPLOAD '%GENDIR%/Data/Iris.gsh'
XAXIS WINDOW=1; TITLE= 'Petal Length'
YAXIS WINDOW=1; TITLE= 'Sepal Length'

"Example 3: default margins"
FRAME WINDOW=1; \
      XMLOWER=0.12; XMUPPER=0.05; YMLOWER=0.10; YMUPPER=0.07
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='Default margins: XMLOWER=0.12; XMUPPER=0.05; \
YMLOWER=0.10; YMUPPER=0.07']\
       Y=Sepal_Length; X=Petal_Length

"Example 4"
FRAME WINDOW=1; \
      XMLOWER=0.08; XMUPPER=0.08; YMLOWER=0.08; YMUPPER=0.08
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='FRAME 1; all margins 0.08'] \
       Y=Sepal_Length; X=Petal_Length
```

```
"Example 5"
FRAME WINDOW=1; \
      XMLOWER=0; XMUPPER=0; YMLOWER=0; YMUPPER=0
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='FRAME 1; all margins 0'] \
       Y=Sepal_Length; X=Petal_Length

ENDJOB
```

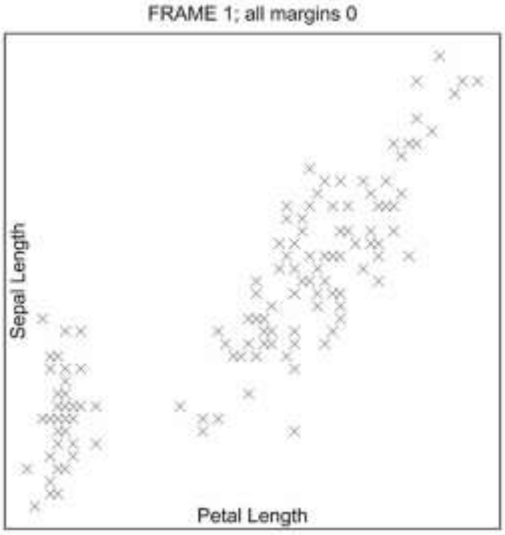
Example 3



Example 4



Example 5

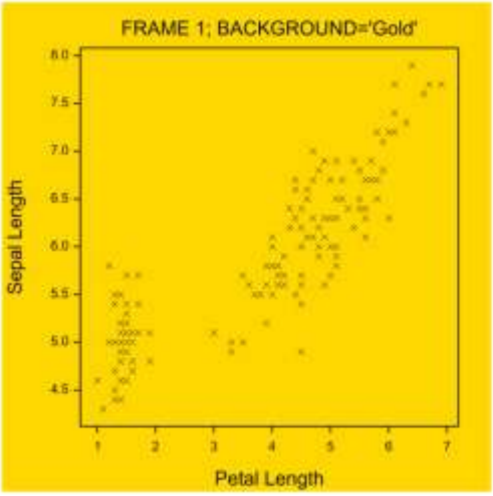


3.3.1.3 Colour of the window

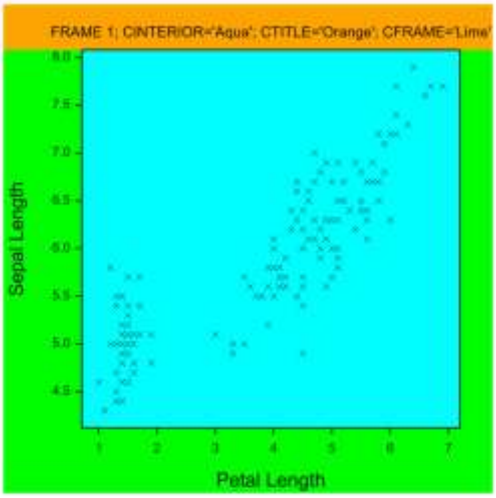
Examples 6 and 7 illustrate how to alter the colour of the plotting window using the parameter BACKGROUND, or the parameters CINTERIOR, CTITLE and CFRAME. The BACKGROUND parameter defines the colour of the entire plotting window, whereas CINTERIOR, CTITLE and CFRAME define specific aspects of it (overriding the setting of BACKGROUND). CINTERIOR defines the interior colour of the plot (i.e. where the data is plotted), CTITLE the colour of the title bar, and CFRAME the colour of the outer frame.

```
JOB
SPLOAD '%GENDIR%/Data/Iris.gsh'
XAXIS WINDOW=1; TITLE='Petal Length'
YAXIS WINDOW=1; TITLE='Sepal Length'

"Example 6"
FRAME WINDOW=1; BACKGROUND='Gold'
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='FRAME 1; BACKGROUND=''Gold'''] \
       Y=Sepal_Length; X=Petal_Length

"Example 7"
FRAME WINDOW=1; CINTERIOR='Aqua'; CTITLE='Orange'; CFRAME='Lime'
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='FRAME 1; CINTERIOR=''Aqua''; CTITLE=''Orange''; \
CFRAME=''Lime'''] \
       Y=Sepal_Length; X=Petal_Length

ENDJOB
```

Example 6



Example 7

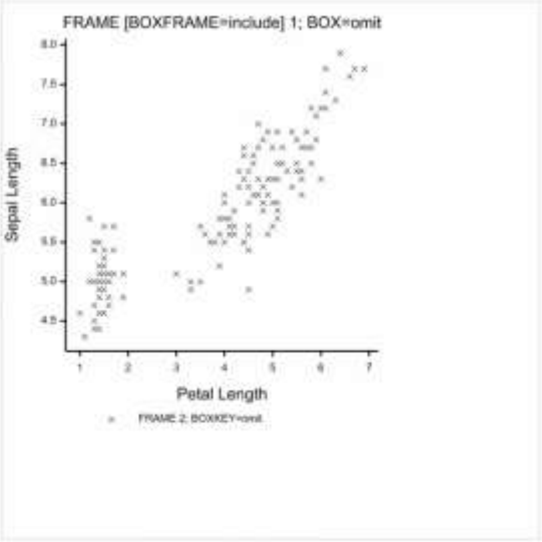


3.3.1.4 Visibility of boxes surrounding frame, graph and key

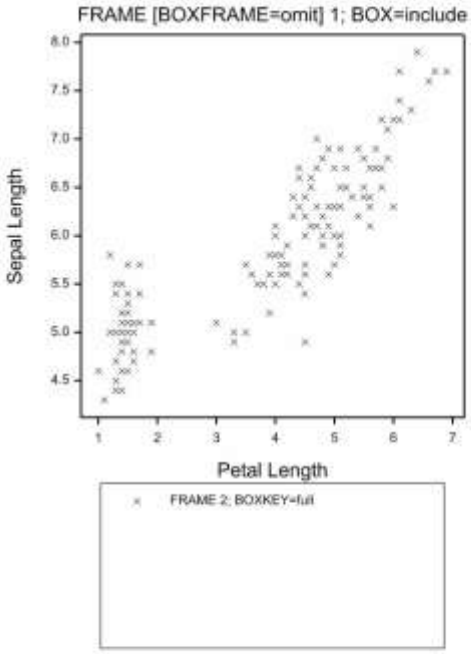
Examples 8-10 demonstrate the different settings of the BOXFRAME option, and the BOX and BOXKEY parameters of FRAME. These control the visibility of the boxes surrounding the frame, graph and key, respectively.

```
JOB
SPLOAD '%GENDIR%/Data/Iris.gsh'
XAXIS WINDOW=1; TITLE='Petal Length'
YAXIS WINDOW=1; TITLE='Sepal Length'

"Example 8"
FRAME [BOXFRAME=include] WINDOW=1; BOX=omit
FRAME [RESET=yes] WINDOW=2; BOXKEY=omit
DGRAPH [WINDOW=1; KEYWINDOW=2; \
       TITLE='FRAME [BOXFRAME=include] 1; BOX=omit'] \
       Y=Sepal_Length; X=Petal_Length; \
       DESCRIPTION='FRAME 2; BOXKEY=omit'

"Example 9"
FRAME [BOXFRAME=omit] WINDOW=1; BOX=include
FRAME [RESET=yes] WINDOW=2; BOXKEY=full
DGRAPH [WINDOW=1; KEYWINDOW=2; \
       TITLE='FRAME [BOXFRAME=omit] 1; BOX=include'] \
       Y=Sepal_Length; X=Petal_Length; \
       DESCRIPTION='FRAME 2; BOXKEY=full'

"Example 10"
FRAME [BOXFRAME=include] WINDOW=1; BOX=include
FRAME [RESET=yes] WINDOW=2; BOXKEY=bounded
DGRAPH [WINDOW=1; KEYWINDOW=2; \
       TITLE='FRAME [BOXFRAME=include] 1; BOX=include'] \
       Y=Sepal_Length; X=Petal_Length; \
       DESCRIPTION='FRAME 2; BOXKEY=bounded'

ENDJOB
```

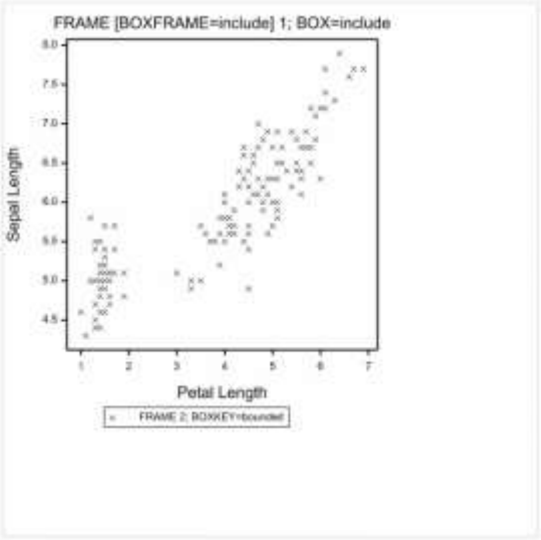
Example 8



Example 9



Example 10



Note: the PENKEY parameter allows you to select the pen used to write the key. In the above examples the default pen, -6, has been used. Refer to Section 3.4 to learn about defining the attributes of a pen using the PEN directive.

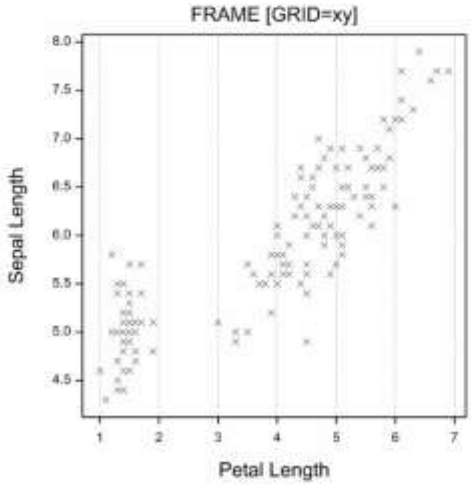
3.3.1.5 Drawing grid lines

Next we illustrate the settings of the GRID option that specifies which grid lines to draw (Examples 11-14). In the first example, Example 11, grid lines are drawn parallel to the y-axis (i.e. in the xy plane running from the x-axis) using the setting GRID=xy. In the second example (Example 12) grid lines are drawn parallel to the x-axis (i.e. in the xy plane running from the y-axis) using the setting GRID=yx.

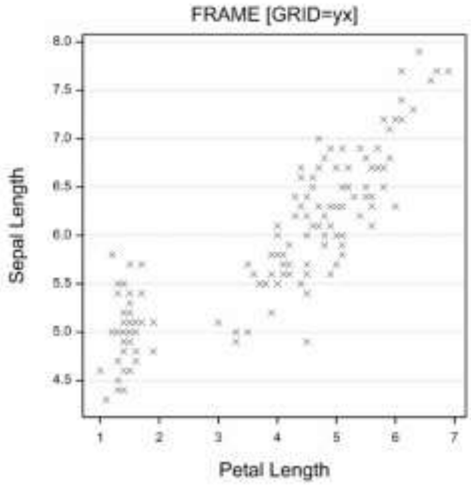
Note: The colour and style of the grid lines can be specified using the PENGRID parameter. In these examples the default pen, -4, is used. Refer to Section 3.4 to learn how to define the colour and style of a pen using the PEN directive.

```
JOB
SPLOAD '%GENDIR%/Data/Iris.gsh'
XAXIS WINDOW=1; TITLE='Petal Length'
YAXIS WINDOW=1; TITLE='Sepal Length'

"Example 11"
FRAME [GRID=xy] WINDOW=1
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='FRAME [GRID=xy]'] \
       Y=Sepal_Length; X=Petal_Length

"Example 12"
FRAME [GRID=yx] WINDOW=1
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='FRAME [GRID=yx]'] \
       Y=Sepal_Length; X=Petal_Length

"Example 13"
FRAME [GRID=xy,yx] WINDOW=1
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='FRAME [GRID=xy,yx]'] \
       Y=Sepal_Length; X=Petal_Length

"Example 14"
FRAME [GRID=*] WINDOW=1
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='FRAME [GRID=*]'] \
       Y=Sepal_Length; X=Petal_Length

ENDJOB
```

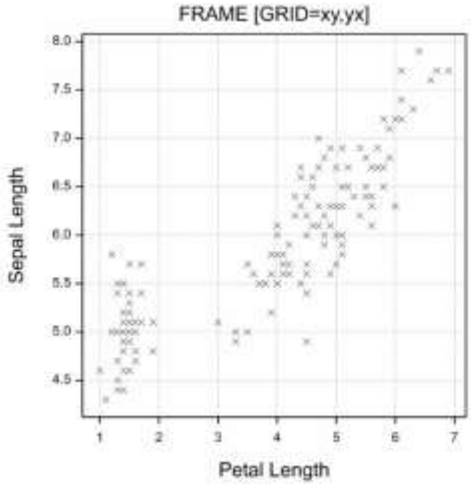
Example 11



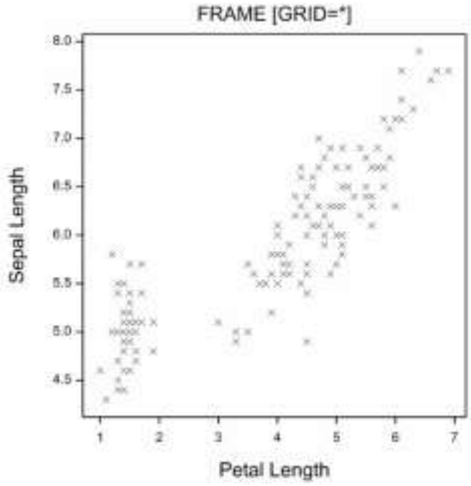
Example 12



Example 13



Example 14



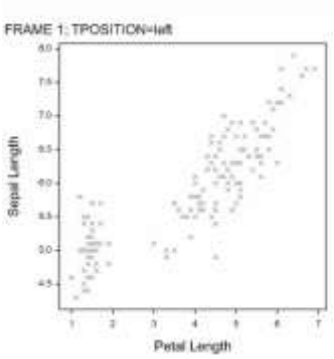
3.3.1.6 Position of the title

The `TPOSITION` parameter is used to control the position of the title. This is illustrated in Examples 15-17.

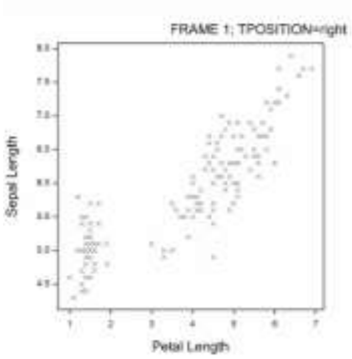
The style, colour and size of the font used to display the title can be specified with the `PENTITLE` parameter. In the following examples the default pen, `-5`, is used. Refer to Section 3.4 to learn how to define the font of a pen using the `PEN` directive.

```
JOB
SPLOAD '%GENDIR%/Data/Iris.gsh'
XAXIS WINDOW=1; TITLE='Petal Length'
YAXIS WINDOW=1; TITLE='Sepal Length'

"Example 15"
FRAME WINDOW=1; TPOSITION=left
DGRAPH [WINDOW=1; KEYWINDOW=0; \
        TITLE='FRAME 1; TPOSITION=left'] \
        Y=Sepal_Length; X=Petal_Length

"Example 16"
FRAME WINDOW=1; TPOSITION=right
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='FRAME 1; TPOSITION=right'] \
       Y=Sepal_Length; X=Petal_Length

"Example 17"
FRAME  WINDOW=1; TPOSITION=center
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='FRAME 1; TPOSITION=center'] \
       Y=Sepal_Length; X=Petal_Length

ENDJOB
```

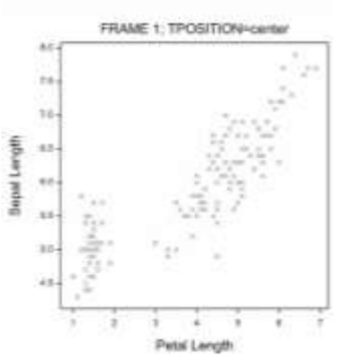
Example 15



Example 16



Example 17

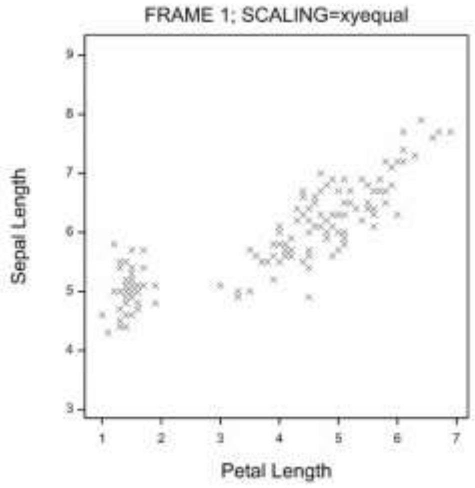


3.3.1.7 Scaling of the axes

Finally, Example 18 illustrates the use of the SCALING parameter that specifies which axes are to be equally scaled. Compare Example 18 with the earlier examples in which the y- and x-axes are scaled differently.

```
JOB
SPLOAD '%GENDIR%/Data/Iris.gsh'
XAXIS WINDOW=1; TITLE='Petal Length'
YAXIS WINDOW=1; TITLE='Sepal Length'

"Example 18"
FRAME WINDOW=1; SCALING=xyequal
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='FRAME 1; SCALING=xyequal'] \
       Y=Sepal_Length; X=Petal_Length

ENDJOB
```

Example 18



3.4 PEN directive

All the elements of graphical output, such as symbols, lines, axes, titles, labels, annotation and filled polygons are drawn by *pens*, which have associated definitions covering various attributes, like colour and symbol type. The pen also indicates the plotting method (e.g. scatter, line, spline, etc.).

Pens for plotting are available with numbers 1 up to 256, each with its own attribute settings. The default settings for each pen are designed so that they will differ in appearance, for example by using different colours or line styles, depending on the output device. Thus, if you specify several data structures to appear in the same plot, the different sets of points or lines will be clearly distinguished by their different pens.

Negatively-numbered pens (-1 to -12) have specific roles in certain directives, and they cannot be used for any other purpose. The roles of the negatively-numbered pens are described in Table 3-3 below.

Table 3-3: Roles of the negatively-numbered pens.

Pen	Role
-1	default for PENTITLE parameter of XAXIS, YAXIS and ZAXIS
-2	default for PENAXIS parameter of XAXIS, YAXIS and ZAXIS
-3	default for PENLABEL parameter of XAXIS, YAXIS and ZAXIS
-4	default for PENGRID parameter of FRAME
-5	default for PENTITLE parameter of FRAME
-6	default for PENKEY parameter of FRAME
-7	default for PENGRID option of DSHADE
	default for PENGRID option of DBITMAP
-8	default for PENOUTLINE option of DHISTOGRAM
-9	default for PENOUTLINE option of BARCHART
-10	default for PENOUTLINE option of DPIE
-11	default for XBARPEN and YBARPEN parameter of DGRAPH
	default for PENERRORBARS parameter of BARCHART
-12	pen for title in DSTART

The PEN directive is used to change the attributes of the pens, modifying the appearance of the resulting graph. The options and parameters controlling PEN are briefly described in Table 3-4. A more comprehensive description is provided within the Genstat Help System (). In addition, a suite of example graphs demonstrating the various option and parameter settings of PEN is provided in Section 3.4.1.

Table 3-4: Options and parameters of PEN.

Options	
RESET = *string token*	Specifies whether to reset the pen definition to the default values (yes, no). Default no.
BOXUNITS = *string tokens*	Units to use when defining the sizes and positions of the text boxes (characters, distance). The default is to retain the existing setting.
Parameters	
NUMBER = *scalars*	Numbers associated with the pens to be redefined (in the range 1 to 256 or -1 to -12). Pens 1 to 256 are used for the information that is plotted in a graph (points, lines, and so on). Pens -1 to -12 have specific roles in some directives: e.g. pen -11 is the default pen used to draw the vertical and horizontal error bars in DGRAPH (see Table 3-1). The roles of negatively-numbered pens are listed in Table 3-3.
COLOUR = *scalars* or *texts*	Colour to use with each pen unless otherwise specified by the CSYMBOL, CLINE, CFILL or CAREA parameters. See Appendix 5.2 for the list of pre-defined colours.
LINESTYLE = *scalars* or *texts*	Style for line used by each pen when joining points. The exact appearance of the different line styles is device-specific, but line style 1 should always produce a solid line. See Appendix 5.3 for the list of pre-defined line styles.
METHOD = *string tokens*	Method used for plotting (point, line, monotonic, closed, open, fill, spline, polygon). Default point.
SYMBOLS = *scalars*, *texts*, *pointers* or *matrices*	Defines the plotting symbol for each pen, by a text or scalar for a pre-defined symbol, a pointer for a user-defined symbol, or a matrix to supply a bitmap. If you don't want to plot symbols, set SYMBOL='none' or SYMBOL=0. See Appendix 5.3 for the list of pre-defined symbols.
LABELS = *texts* or *factors*	Provides labels that will be printed alongside the plotting symbols.
ROTATION = *scalars* or *variates*	Controls the angle (in degrees) at which to plot symbols and labels.
JOIN = *string tokens*	Controls the order in which points are to be joined by each pen (ascending, given).

`BRUSH`= *scalars*	Not yet available in Genstat *for Windows*. Controls how areas are shaded when `METHOD=fill`, or when plotting histograms and pie charts. There are 16 available patterns indicated by the integers 1 to 16. In general, the higher the number, the denser the hatching.
`FONT` = *scalars* or *texts*	Font to use for any text written by each pen. This can be set to a text containing the name of a font family, or to a scalar containing an integer between 1 and 25.
`THICKNESS` = *scalars*	Controls the thickness of any lines drawn.
`SIZEMULTIPLIER` = *scalars* or *variates*	Multiplier used in the calculation of the size in which to draw symbols and labels by each pen unless otherwise specified by `SMSYMBOL` or `SMLABEL`.
`CSYMBOL` = *scalars* or *texts*	Defines the colour to use for drawing symbols.
`CLINE` = *scalars* or *texts*	Defines the colour to use for drawing lines.
`CFILL` = *scalars* or *texts*	Defines the colour to use when filling areas inside hollow symbols.
`CAREA` = *scalars* or *texts*	Defines the colour to use when filling areas inside polygons and bars of histograms.
`SMSYMBOL` = *scalars* or *variates*	Multiplier used in the calculation of the size in which to draw symbols by each pen.
`SMLABEL` = *scalars* or *variates*	Multiplier used in the calculation of the size in which to draw labels by each pen.
`DFSPLINE` = *scalars*	Number of degrees of freedom to use when `METHOD=spline`.
`YMISSING` = *string token*	How to treat missing y-values when `METHOD=spline` (`break`, `interpolate`).
`XMISSING` = *string token*	How to treat missing x-values when `METHOD=spline` (`break`, `interpolate`).
`YLPOSITION` = *string token*	Controls the y-direction position of the labels with respect to the points (`above`, `centre`, `below`, `automatic`).
`XLPOSITION` = *string token*	Controls the x-direction position of the labels with respect to the points (`left`, `centre`, `below`, `automatic`).
`YLSIZE` = *scalars* or *variates*	Defines the width in the y-direction of the text boxes into which the labels are plotted in.
`XLSIZE` = *scalars* or *variates*	Defines the width in the x-direction of the text boxes into which the labels are plotted in.
`YLOFFSET` = *scalars* or *variates*	Defines the amount the text boxes (into which the labels are plotted in) are offset in the y-direction.

XLOFFSET = *scalars* or *variates*	Defines the amount the text boxes (into which the labels are plotted in) are offset in the x-direction.
BARTHICKNESS = *scalars*	Controls the thickness with which error bars are drawn.
BARCAPWIDTH = *scalars*	Controls the width of the cap drawn at the top and bottom of any error bars.
DESCRIPTION = *texts*	Description for points plotted by the pen, to be used by the *Data Information* tool in the Graphics Viewer (see Section 1.2).
TSYMBOL = *scalars*	Defines the transparency of symbols on a scale of 0 (opaque) to 255 (completely transparent).
TLINE = *scalars*	Defines the transparency of lines.
TFILL = *scalars*	Defines the transparency to use when filling areas inside hollow symbols.
TAREA = *scalars*	Defines the transparency to use when filling areas inside polygons and bars of histograms.
SAVE = *pointers*	Saves the current pen settings.

The type of graph that is produced is determined by the METHOD parameter. This can be point, to produce a point plot or scatterplot; line to join the points with straight lines; monotonic, open or closed to plot various types of curve through the points; spline to plot a smoothing spline fitted to the points; or fill to produce shaded polygons (see the example in Section 3.4.1.6).

To illustrate the PEN directive, we'll modify Figure 3.4 so that:

- different plotting symbols denote the three iris species, using the SYMBOLS parameter
- smoothing splines (with 2 degrees of freedom) for each iris species are added, using the parameters METHOD and DFSPLINE

using the commands:

```
PEN NUMBER=1,2,3; SYMBOLS=1,2,3; METHOD=spline; DFSPLINE=2
DGRAPH [KEYWINDOW=12; KEYDESCRIPTION='Sepal Length v Width'] \
  Y=Sepal_Length; X=Sepal_Width; PEN=Species; \
  DESCRIPTION=!T(Setosa,Versicolour,Virginica)
```

The resulting graph is shown in Figure 3.6. Note that default settings of pens 1, 2 and 3 can be redefined using the command:

```
PEN [RESET=yes] NUMBER=1,2,3
```

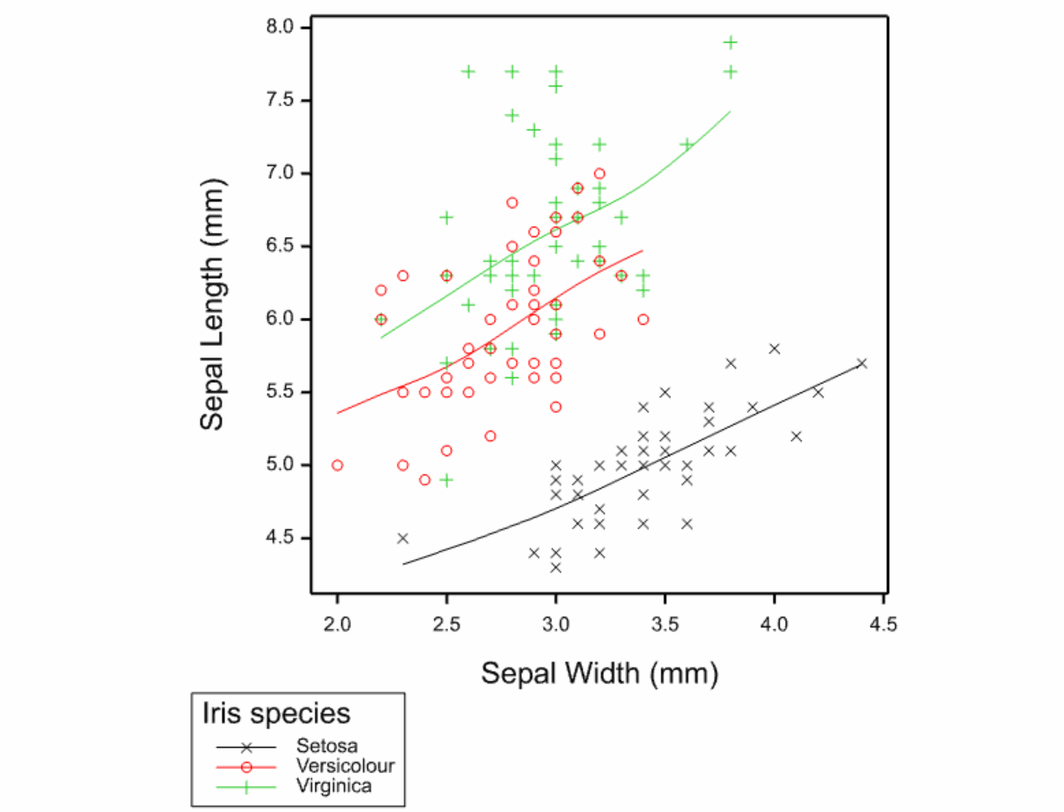


Figure 3.6: Graph plotted with redefined pens, 1,2,3, using the PEN directive.

More example graphs, in which the PEN directive is used to modify the appearance of the graph, are given in the following section.

3.4.1 Illustrative examples

In this section, a suite of examples is given to demonstrate the effect different option and parameter settings of PEN have on the graphical output.

Recall that the NUMBER parameter specifies the *pen* whose attributes are to be altered. After changes have been made, the option RESET=yes may be used to revert all attributes back to their default values. Otherwise, any previous modifications to the parameter and option settings of PEN are retained throughout the Genstat job.

Note, in the commands that follow, the XAXIS and YAXIS directives have been used to add axes titles. Refer to Section 3.5 for more information.

3.4.1.1 Changing the appearance of plotted data

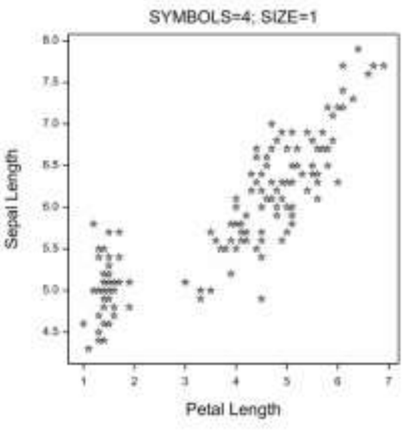
The first set of examples (Examples 1-7) showcases the changing appearance of the plotted data according to various settings of the SYMBOLS, SIZEMULTIPLIER and LABELS parameters. Note, these examples make use of the TXCONSTRUCT directive (to form a text structure), the CONCATENATE directive (to join text structures together) and the GETRGB procedure (to get the RGB values and names of the initial default colours of the pens). For more information on these commands, refer to the Genstat Help ().

Additional parameters of PEN enable finer control over the appearance of specific elements in a plot. For example, SMSYMBOL, CAREA, CFILL, CSYMBOL, TSYMBOL and TFILL can be used to set the size, colour and transparency of plotted symbols. This is illustrated in subsequent sections.

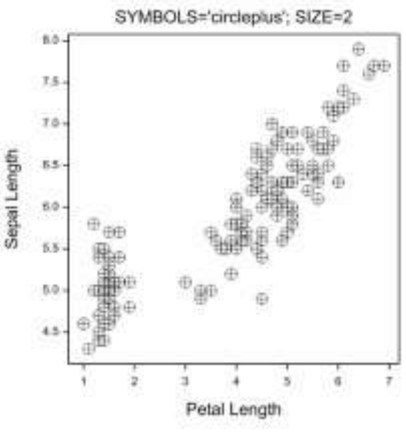
```
JOB
SPLOAD '%GENDIR%/Data/Iris.gsh'
XAXIS WINDOW=1; TITLE='Petal Length'
YAXIS WINDOW=1; TITLE='Sepal Length'

"Example 1"
PEN NUMBER=1; SYMBOLS=4; SIZE=1
DGRAPH [WINDOW=1; KEYWINDOW=0; TITLE='SYMBOLS=4; SIZE=1'] \
       Y=Sepal_Length; X=Petal_Length

"Example 2"
PEN [RESET=yes] NUMBER=1; SYMBOLS='circleplus'; SIZE=2
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='SYMBOLS=''circleplus''; SIZE=2'] \
       Y=Sepal_Length; X=Petal_Length

"Example 3"
PEN [RESET=yes] NUMBER=1; SYMBOLS=0; LABELS=Species
DGRAPH [WINDOW=1; KEYWINDOW=0; \
 TITLE='SYMBOLS=0; LABELS=Factor with labels'] \
       Y=Sepal_Length; X=Petal_Length

"Example 4"
FACTOR [LEVELS=3] SpeciesLev
CALCULATE SpeciesLev = Species
PEN [RESET=yes] NUMBER=1; SYMBOLS=0; LABELS=SpeciesLev
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='SYMBOLS=0; LABELS=Factor with levels'] \
       Y=Sepal_Length; X=Petal_Length

"Example 5"
TXCONSTRUCT [TEXT=tSpecies] Species
```

```
CONCATENATE tSpecies; WIDTH=4
PEN [RESET=yes] NUMBER=1; SYMBOLS=0; LABELS=tSpecies
DGRAPH [WINDOW=1; KEYWINDOW=0; TITLE='SYMBOLS=0; LABELS=text'] \
       Y=Sepal_Length; X=Petal_Length

"Example 6"
GETRGB !(2...5); RGB=rgb
MATRIX [ROWS=2; COLUMNS=2] mat; VALUES=rgb
PEN [RESET=yes] NUMBER=1; SYMBOLS=mat; SIZE=2
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='SYMBOLS=matrix to supply a bitmap'] \
       Y=Sepal_Length; X=Petal_Length

"Example 7"
VARIATE [VALUES= -1, 1,  1, -1, -1] square[1]
VARIATE [VALUES= -1, -1, 1, 1, -1] square[2]
VARIATE [VALUES= 3(-1, -.5 ... 1), (-1, 1, *)2] vert[1]
VARIATE [VALUES= (-1, 1, *)5, (-1, -1, *), (1, 1, *)] vert[2]
CALCULATE vert[1]$[3, 6...15] = 0/0
VARIATE [VALUES= (-1, 1, *)5, (-1, -1, *), (1, 1, *)] hori[1]
VARIATE [VALUES= 3(-1, -.5 ... 1), (-1, 1, *)2] hori[2]
CALCULATE hori[1]$[3, 6...15] = 0/0
VARIATE [VALUES= #vert[1], #hori[1]] verthori[1]
VARIATE [VALUES= #vert[2], #hori[2]] verthori[2]
PEN [RESET=y] NUMBER=1...3; SYMBOLS=square,vert,verthori; SIZE=2
DGRAPH [WINDOW=1; TITLE='SYMBOLS=self made'] \
       Y=Sepal_Length; X=Petal_Length; PEN=Species; \
       DESCRIPTION=!t('Setosa','Versicolor','Virginica')

ENDJOB
```

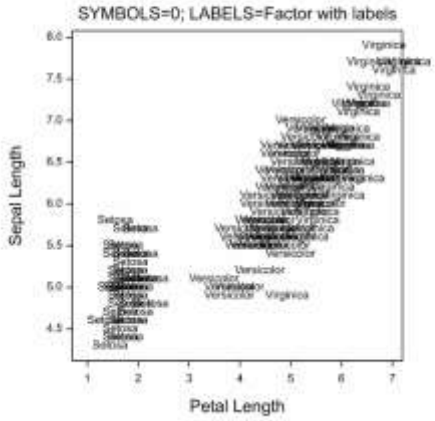
Example 1



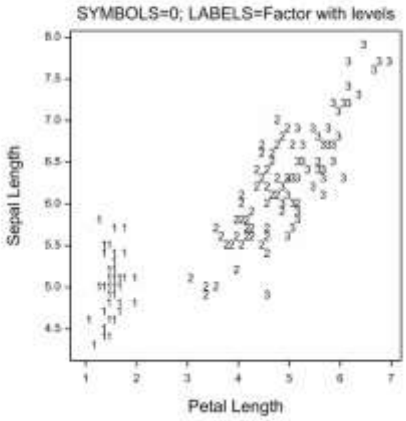
Example 2



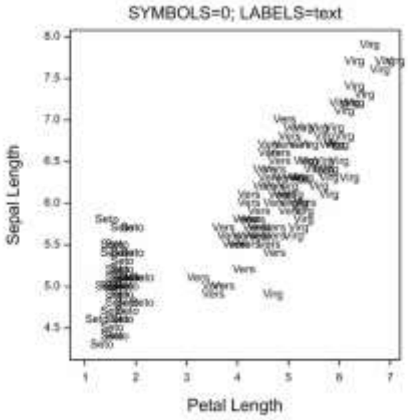
Example 3


SYMBOLS=0; LABELS=Factor with labels

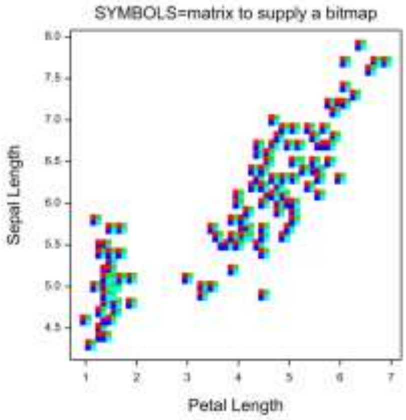
Example 4


SYMBOLS=0; LABELS=Factor with levels

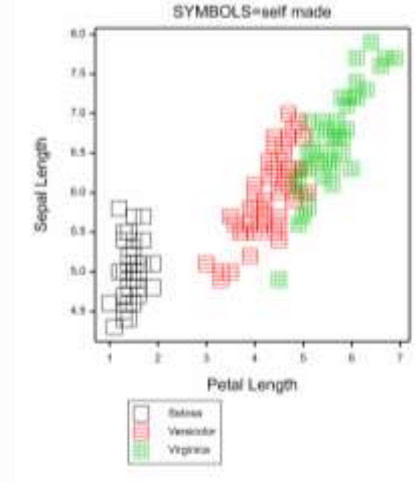
Example 5


SYMBOLS=0; LABELS=text

Example 6


SYMBOLS=matrix to supply a bitmap

Example 7


SYMBOLS=self made

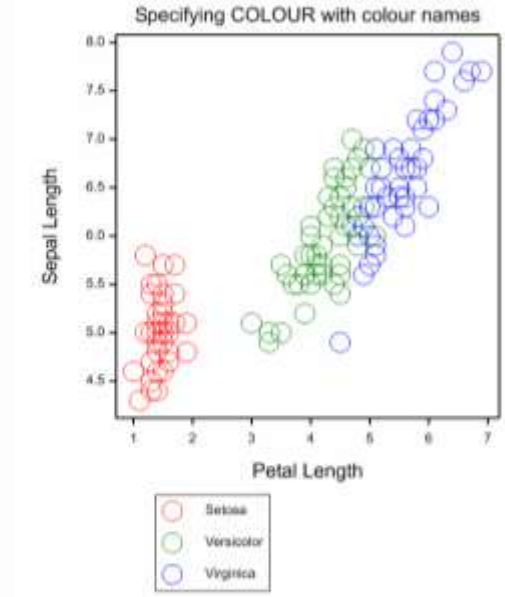
3.4.1.2 Colour of the pen

The COLOUR, CSYMBOL, CLINE, CFILL and CAREA parameters is used to specify the colours used by the pen. Unless otherwise specified by CSYMBOL, CLINE, CFILL or CAREA, the COLOUR parameter defines the colour used for everything plotted by the pen. CSYMBOL explicitly defines the colour used for drawing symbols, CLINE the colour for lines, CFILL the colour for filling areas inside hollow symbols (setting CFILL='match' provides a simple way to create filled symbols), and CAREA the colour for filling areas inside polygons and bars of histograms.

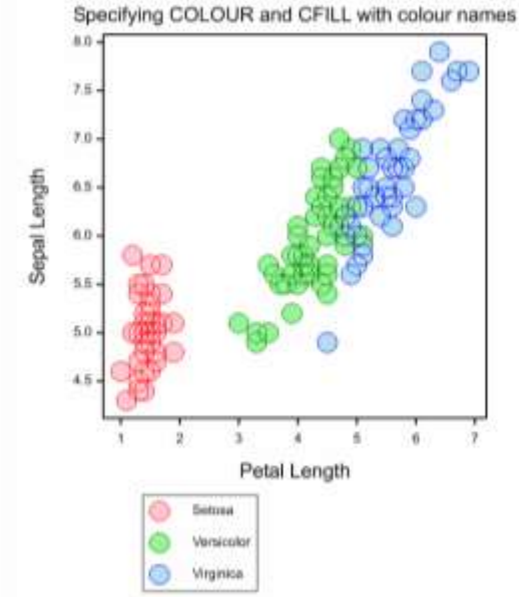
The first set of examples of this section, Examples 8-10, illustrates how to modify the colour of the plotted data using the COLOUR and CFILL parameters.

```
JOB
SPLOAD '%GENDIR%/Data/Iris.gsh'
XAXIS WINDOW=1; TITLE='Petal Length'
YAXIS WINDOW=1; TITLE='Sepal Length'

"Example 8"
PEN NUMBER=1...3; SYMBOLS=2; COLOUR='red','green','blue'; SIZE=3
DGRAPH [WINDOW=1; TITLE='Specifying COLOUR with colour names'] \
       Y=Sepal_Length; X=Petal_Length; PEN=Species; \
       DESCRIPTION=!t('Setosa','Versicolor','Virginica')

"Example 9"
PEN NUMBER=1...3; SYMBOLS=2; COLOUR='red','green','blue'; \
   CFILL='pink','lightgreen','lightblue'; SIZE=3
DGRAPH [WINDOW=1; \
       TITLE='Specifying COLOUR and CFILL with colour names'] \
       Y=Sepal_Length; X=Petal_Length; PEN=Species; \
       DESCRIPTION=!t('Setosa','Versicolor','Virginica')

"Example 10"
PEN NUMBER=1...3; SYMBOLS=2; \
    COLOUR=RGB(255,0,0; 0,128,0; 0,0,255); SIZE=3
DGRAPH [WINDOW=1; TITLE='Specifying COLOUR with RGB values'] \
       Y=Sepal_Length; X=Petal_Length; PEN=Species; \
       DESCRIPTION=!t('Setosa','Versicolor','Virginica')

ENDJOB
```

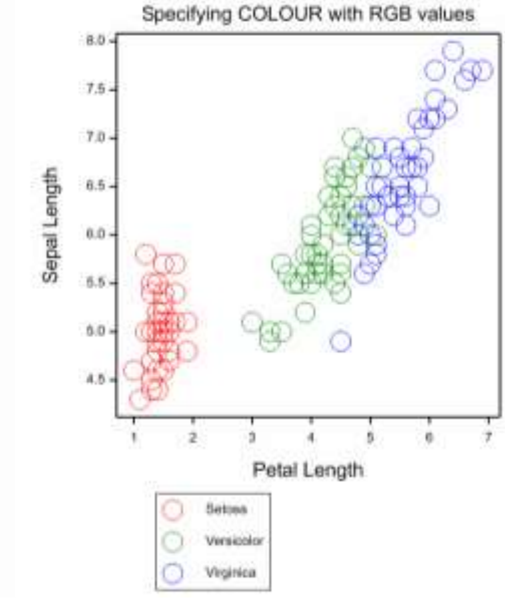
Example 8



Example 9



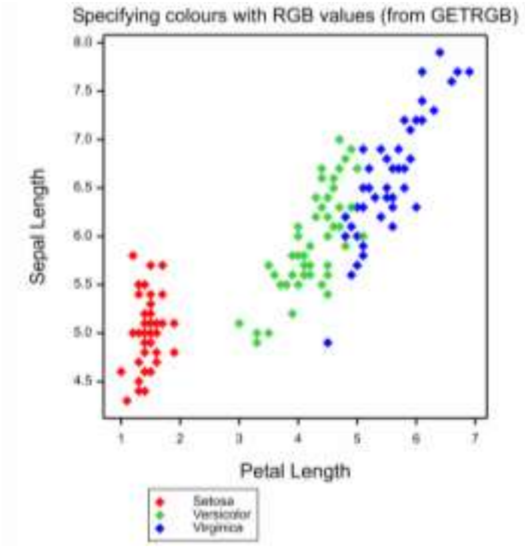
Example 10



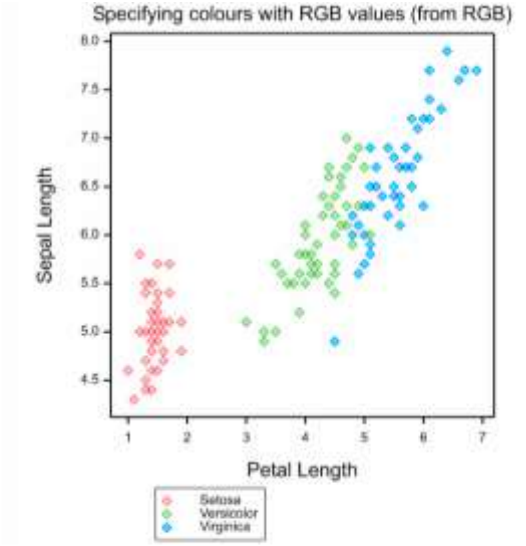
As illustrated above, colours in Genstat can be specified using either names of pre-defined colours or in terms of RGB values (see Appendix 5.2). In this second set of examples (Examples 11-14), we demonstrate how to modify the colours of a pen using RGB values. Here, we make use of the `GETRGB` procedure (to obtain RGB values of the default pen colours) and the `RGB` function (to obtain RGB values for pre-defined colours).

```
JOB
SPLOAD '%GENDIR%/Data/Iris.gsh'
XAXIS WINDOW=1; TITLE='Petal Length'
YAXIS WINDOW=1; TITLE='Sepal Length'

"Example 11: Specifying colours by RGB values from GETRGB"
"GETRGB gets the RGB values of the initial colours of the pens"
GETRGB 2...4; RGB=pen2default,pen3default,pen4default
PEN [RESET=yes] NUMBER=1...3; SYMBOLS=6; \
    COLOUR=pen2default,pen3default,pen4default; \
    CFILL=pen2default,pen3default,pen4default
DGRAPH [WINDOW=1; TITLE='Specifying colours with RGB values \
(from GETRGB)'] \
       Y=Sepal_Length; X=Petal_Length; PEN=Species; \
       DESCRIPTION=!t('Setosa','Versicolor','Virginica')

"Example 12: Specifying colours by RGB values calculated by RGB"
"The RGB function gets the RGB values of named colours "
CALCULATE cred,cgreen,cblue,cpink,cpalegreen,caqua = \
          RGB('red','green','blue','pink','palegreen','aqua')
PEN [RESET=yes] NUMBER=1...3; SYMBOLS=6; \
    COLOUR=cred,cgreen,cblue; CFILL=cpink,cpalegreen,caqua
DGRAPH [WINDOW=1; \
       TITLE='Specifying colours with RGB values (from RGB)'] \
       Y=Sepal_Length; X=Petal_Length; PEN=Species; \
       DESCRIPTION=!t('Setosa','Versicolor','Virginica')

"Example 13: Specifying colours using the RGB values directly"
PEN [RESET=yes] NUMBER=1...3; SYMBOLS=6; \
    COLOUR=16711680,3329330,255 "red,limegreen,blue"
DGRAPH [WINDOW=1; \
       TITLE='Specifying colours with RGB values (directly)']\
       Y=Sepal_Length; X=Petal_Length; PEN=Species; \
       DESCRIPTION=!t('Setosa','Versicolor','Virginica')

"Example 14: Specifying colours using red, green & blue values"
PEN [RESET=yes] NUMBER=1...3; SYMBOLS=6; \
    COLOUR=RGB(255;2152;0); \ "gold"
    CFILL=RGB(139,46,65; \ "darkred"
               0,139,105; \ "seagreen"
               0,87,225)    "royalblue"
DGRAPH [WINDOW=1; TITLE='Specifying colours with red, blue & \
green values (using RGB)'] \
       Y=Sepal_Length; X=Petal_Length; PEN=Species; \
       DESCRIPTION=!t('Setosa','Versicolor','Virginica')

ENDJOB
```

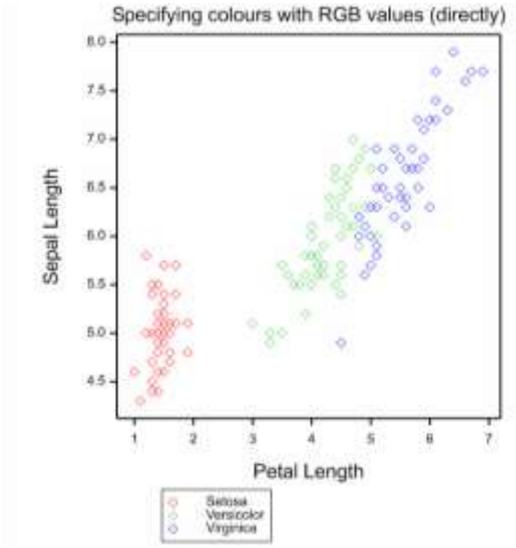
Example 11



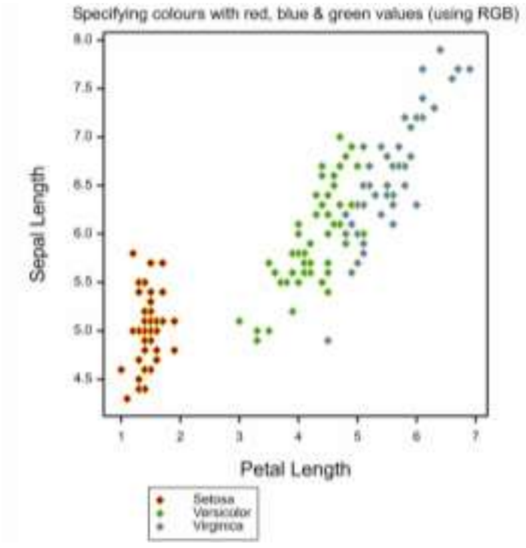
Example 12



Example 13



Example 14



3.4.1.3 Font of the pen

To select different fonts for text appearing as titles, axis annotation, plotting symbols and key information the `FONT` parameter can be set to an integer between 1 and 25, or to a text containing the name of a font family. The initial default for each pen is font 1, the *default graphics font*. When Genstat is first installed, the *default graphics font* is set automatically to Arial, however it can be changed in the Graphics tab of the Tools |

Options… menu, in the Fonts tab of the Options menu in the *Graphics Viewer* (Section 1.2.5), or using the DFONT directive (see Section 4.2.2).

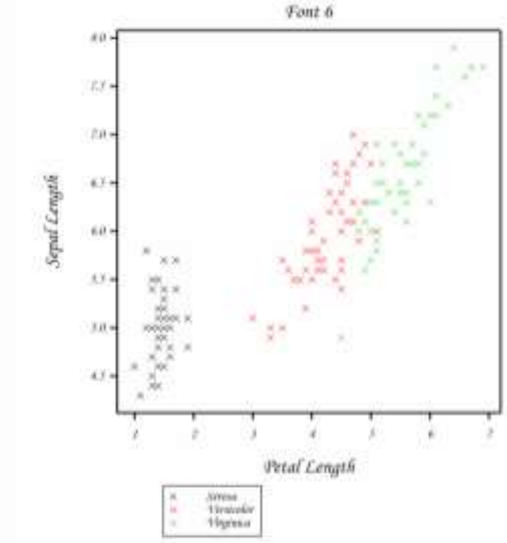
A list of the 1…25 font assignments used by the PEN directive can be obtained by running the command:

```
DHELP TOPIC=possible
```

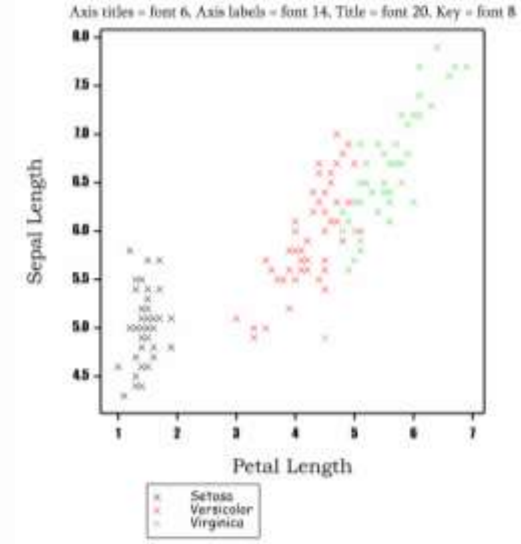
Examples 15 and 18 below illustrate how to change the fonts appearing in axis titles (pen -1, see Table 3-3), axis labels (pen -2), plot titles (pen -5) and in keys (pen -6).

```
JOB
SPLOAD '%GENDIR%/Data/Iris.gsh'
XAXIS WINDOW=1; TITLE='Petal Length'
YAXIS WINDOW=1; TITLE='Sepal Length'

"Example 15"
PEN NUMBER=-1,-3,-5,-6; FONT=18
DGRAPH [WINDOW=1; TITLE='Font 6'] \
       Y=Sepal_Length; X=Petal_Length; PEN=Species;\
       DESCRIPTION=!t('Setosa','Versicolor','Virginica')

"Example 16"
PEN [RESET=y] NUMBER=-1,-3,-5,-6; FONT=6,14,20,8
DGRAPH [WINDOW=1; TITLE='Axis titles = font 6, \
Axis labels = font 14, Title = font 20, Key = font 8'] \
       Y=Sepal_Length; X=Petal_Length; PEN=Species;\
       DESCRIPTION=!t('Setosa','Versicolor','Virginica')

"Example 17"
PEN [RESET=y] NUMBER=-1,-3,-5,-6; FONT='Times New Roman'
DGRAPH [WINDOW=1; TITLE='Font = Times New Roman'] \
       Y=Sepal_Length; X=Petal_Length; PEN=Species;\
       DESCRIPTION=!t('Setosa','Versicolor','Virginica')

"Example 18"
PEN [RESET=y] NUMBER=-1,-3,-5,-6; \
    FONT='Garamond','Courier New','Arial','Trebuchet MS';
DGRAPH [WINDOW=1; TITLE='Axis titles = Garamond, \
Axis labels = Courier New, Title = Arial, Key = Trebuchet MS'] \
       Y=Sepal_Length; X=Petal_Length; PEN=Species;\
       DESCRIPTION=!t('Setosa','Versicolor','Virginica')

ENDJOB
```

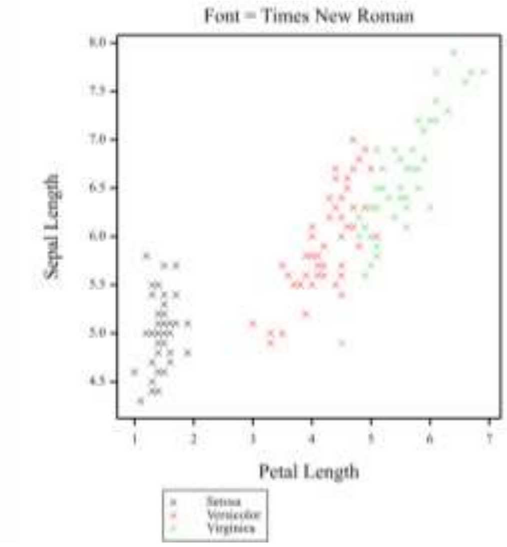
Example 15



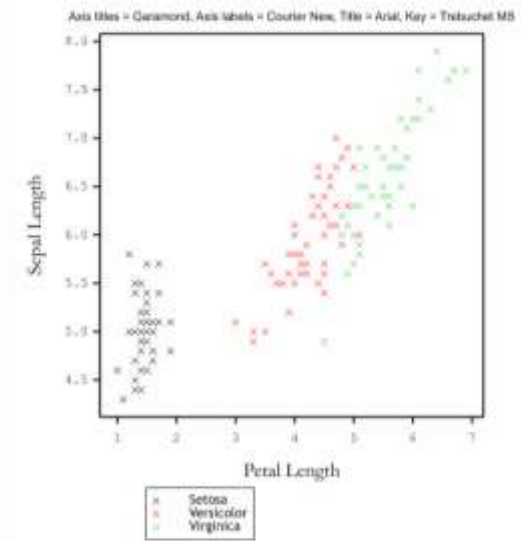
Example 16



Example 17



Example 18



Note: you can view a list of the available Windows fonts in the Graphics tab of Genstat's Tools | Options… menu, or in the Fonts tab of the *Graphics Viewer*'s Tools | Options… menu (see Section 1.2.5).

3.4.1.4 Symbol type, colour, size and transparency

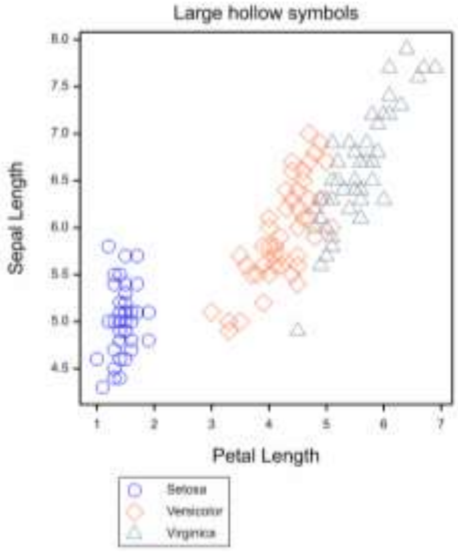
In Sections 3.4.1.1 and 3.4.1.2, we demonstrated how to modify the colour and size of the pen used for plotting using the `COLOUR` and `SIZEMULTIPLIER` parameters, respectively. However, the colour used for drawing symbols and the colour used for filling hollow symbols can be explicitly set using the parameters `CSYMBOL` and `CFILL`, respectively (overriding any setting of COLOUR). Similarly, the size of the plotted symbol can be explicitly set using the SMSYMBOL parameter (overriding any setting of SIZEMULTIPLIER). We can also set the transparency of the symbols and their fill colour using the parameters TSYMBOL and TFILL, respectively. Transparency values can range from 0 (opaque) to 255 (completely transparent).

The following examples (Examples 19-22) showcase symbols of different type, colour, size and transparency. Recall that the type of symbol plotted is set using the SYMBOL parameter, and setting CFILL='match' provides a simple way to plot filled symbols. See Appendix 5.3 for the list of pre-defined symbols.

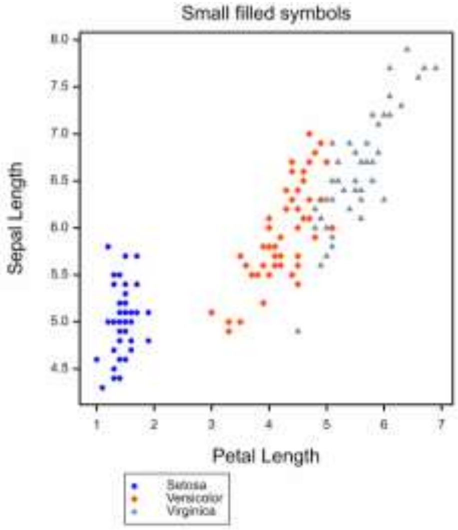
```
JOB
SPLOAD '%GENDIR%/Data/Iris.gsh'
XAXIS WINDOW=1; TITLE='Petal Length'
YAXIS WINDOW=1; TITLE='Sepal Length'

"Example 19"
PEN NUMBER=1,2,3; SYMBOL=2,6,7; SMSYMBOL=2; \
    CSYMBOL='blue','orangered','slategray'
DGRAPH [WINDOW=1; TITLE='Large hollow symbols'] \
       Y=Sepal_Length; X=Petal_Length; PEN=Species;\
       DESCRIPTION=!t('Setosa','Versicolor','Virginica')

"Example 20"
PEN NUMBER=1,2,3; SYMBOL=2,6,7; SMSYMBOL=0.75; \
    CSYMBOL='blue','orangered','slategray'; CFILL='match'
DGRAPH [WINDOW=1; TITLE='Small filled symbols'] \
       Y=Sepal_Length; X=Petal_Length; PEN=Species; \
       DESCRIPTION=!t('Setosa','Versicolor','Virginica')

"Example 21"
PEN NUMBER=1,2,3; SYMBOL=2,6,7; SMSYMBOL=3; \
    CSYMBOL='blue','orangered','slategray'; CFILL='match'; \
    TFILL=150
DGRAPH [WINDOW=1; TITLE='Very large symbols with transparent \
 fill'] Y=Sepal_Length; X=Petal_Length; PEN=Species; \
       DESCRIPTION=!t('Setosa','Versicolor','Virginica')

"Example 22"
PEN NUMBER=1,2,3; SYMBOL=2,6,7; SMSYMBOL=3; \
    CSYMBOL='blue','orangered','slategray'; TSYMBOL=150; \
    CFILL='match'; TFILL=150
DGRAPH [WINDOW=1; TITLE='Very large transparent symbols'] \
       Y=Sepal_Length; X=Petal_Length; PEN=Species; \
       DESCRIPTION=!t('Setosa','Versicolor','Virginica')
```

```
ENDJOB
```

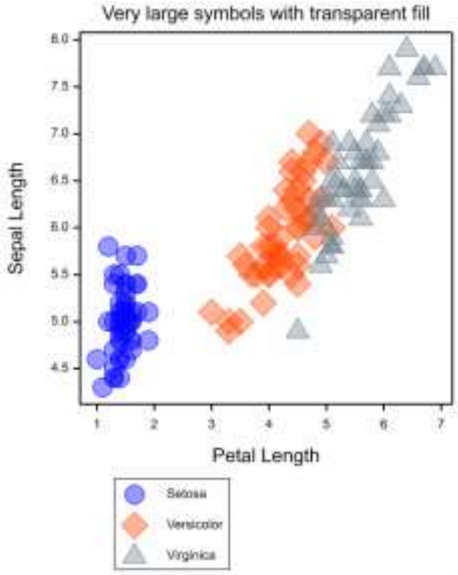
Example 19



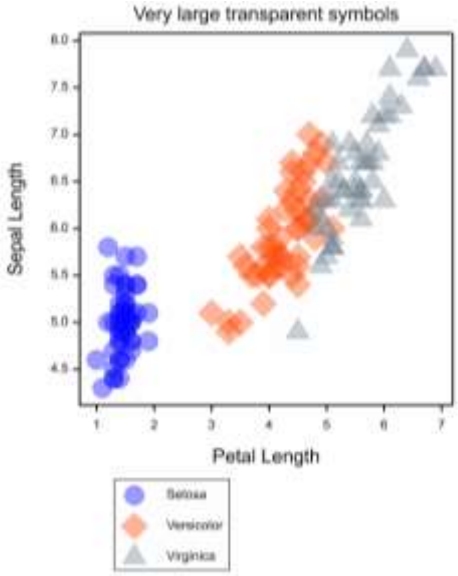
Example 20



Example 21



Example 22



In the examples above, three series have been plotted by `DGRAPH`, defined by `PEN=Species` (i.e. one for each level of `Species`). The attributes of series 1 (corresponding to the first ordinal value of `Species`, Setosa) are defined by pen 1, series

2 (corresponding to the second ordinal value of Species, Versicolor) by pen 2, and series 3 (corresponding to the third ordinal value of Species, Virginica) by pen 3.

The ROTATION parameter can be used to rotate the symbols (and the labels). See Section 3.4.1.7.

3.4.1.5 Line style, colour, transparency and thickness

The initial default for every pen, METHOD=point, results in points being plotted. However, a line plot can be requested by setting METHOD=line. (SYMBOLS=0 prevents symbols from being plotted.)

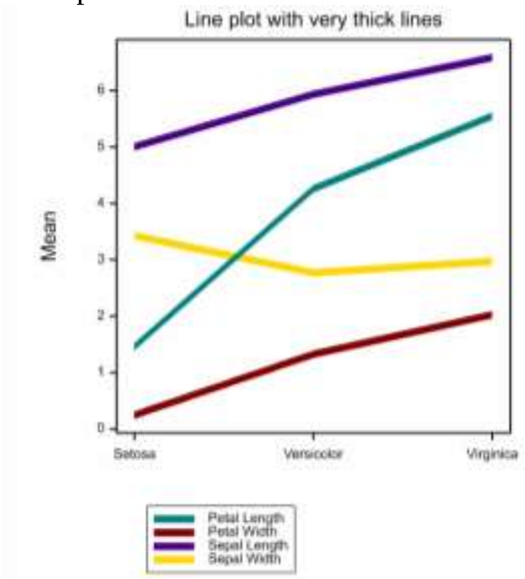
As for symbols, the attributes of plotted lines can be explicitly set. The colour used for drawing lines is specified using the parameter CLINE, overriding any setting of COLOUR. In addition, the transparency of lines can be modified using the TLINE parameter (with values ranging from 0 (opaque) to 255 (completely transparent)), the thickness of lines using the THICKNESS parameter, and the style of the lines (e.g. solid, dotted or dashed line) using the LINESTYLE parameter. Note, the line style can be specified by either a name (see Appendix 5.3 for the list of pre-defined line styles) or a number in the range of 1 to 10. The exact appearance of the different line styles is device-specific, but line style 1 (solid) should always produce a solid line.

Examples 23 and 24 demonstrate how to create a line graph and how to modify the appearance of its plotted lines.

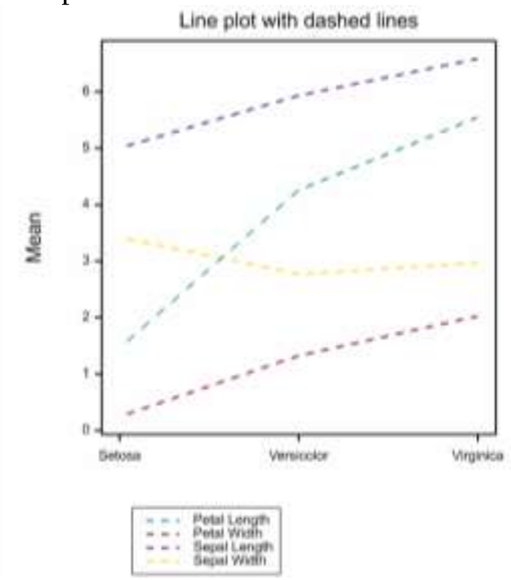
Note, in the examples that follow, first we calculate the means of the four measurements for each species. Then we construct two variates (Means and xSpecies) and a factor (Measurement) to enable these means to be plotted against species in DGRAPH. Furthermore, we use the MARKS and LABELS parameters of the XAXIS directive to label the x-axis by iris species (see Section 3.5 for more information).

```
JOB
SPLOAD '%GENDIR%/Data/Iris.gsh'
YAXIS WINDOW=1; TITLE='Mean'

"Calculate mean values for each species"
DESCRIBE [PRINT=*; SELECTION=mean; GROUPS=Species] \
         Petal_Length,Petal_Width,Sepal_Length,Sepal_Width; \
         SUMMARIES=M_Petal_Length,M_Petal_Width, \
         M_Sepal_Length,M_Sepal_Width
"Store all means in a single variate"
VARIATE [VALUES=#M_Petal_Length,#M_Petal_Width,\
                 #M_Sepal_Length,#M_Sepal_Width] Means
"Set up a factor to identify the mean by measurement type"
FACTOR [LABELS=!t('Petal length','Petal width',\
                  'Sepal length','Sepal width')] Measurement; \
        VALUES=!t(3('Petal length'),3('Petal width'),\
                  3('Sepal length'),3('Sepal width'))\
"Set up variate to identify the mean by species
(i.e. 1 = Setosa, 2 = Versicolor, 3 = Virginica)"
VARIATE [VALUES=(1...3)4] xSpecies
"Set up x-axis labels"
XAXIS WINDOW=1; MARKS=!(1,2,3); \
      LABELS=!t('Setosa','Versicolor','Virginica')

"Example 23"
PEN NUMBER=1,2,3,4; METHOD=line; SYMBOLS=0; THICKNESS=10; \
    CLINE='teal','maroon','indigo','gold'
DGRAPH [WINDOW=1; TITLE='Line plot with very thick lines'] \
       Y=Means; X=xSpecies; PEN=Measurement; \
       DESCRIPTION=!t('Petal Length','Petal Width', \
       'Sepal Length','Sepal Width')

"Example 24"
PEN NUMBER=1,2,3,4; THICKNESS=2; LINESTYLE=3
DGRAPH [WINDOW=1; TITLE='Line plot with dashed lines'] \
       Y=Means; X=xSpecies; PEN=Measurement; \
       DESCRIPTION=!t('Petal Length','Petal Width', \
       'Sepal Length','Sepal Width')

ENDJOB
```

Example 23



Example 24



3.4.1.6 Type of object plotted

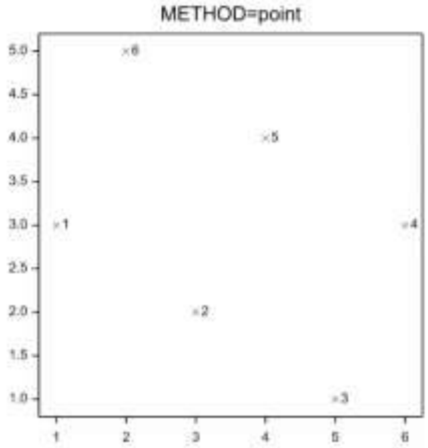
The METHOD parameter determines whether points, lines or filled polygons are plotted. Different types of line can be drawn; either straight lines (line and polygon) or smooth curves (monotonic, open, closed and spline). The line setting connects the points using straight lines (by default in ascending order of the x-values). The polygon setting draws lines to connect points in ascending order of x-values, and then draws a line connecting the first and last data points. The monotonic setting specifies that a smooth single-valued curve is drawn through the data points. The open and closed settings specify that a smooth curve, possibly multi-valued, is drawn through the data points (by default in ascending order of the x-values). With the closed setting, the first and last data points are also connected. The spline setting plots a smoothing spline fitted through the data points using the degrees of freedom set by the DFSPLINE parameter. (Additional parameters YMISSING and XMISSING determine how missing values are dealt with when fitting a spline. Refer to Genstat's help documentation for more details.) The fill setting joins the data points by straight lines to produce one or more polygons. (Additional parameters BRUSH and CAREA control how the polygon(s) is filled. Refer to Genstat's help documentation for more details. In Example 30, the CAREA parameter is used to fill the polygon lime green.)

Examples 25 to 32 demonstrate the different methods of plotting. To help visualise how the different lines are drawn, the points are labelled according to the order in which they are stored.

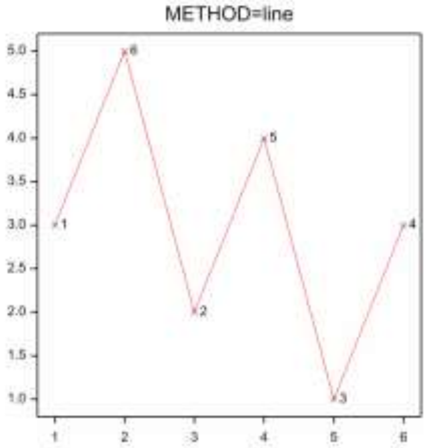
```
JOB
VARIATE [VALUES=3,2,1,3,4,5] y
VARIATE [VALUES=1,3,5,6,4,2] x

"Example 25"
PEN NUMBER=1; METHOD=point; SYMBOLS=1; LABELS=!(1...6);
DGRAPH [WINDOW=1; TITLE='METHOD=point'; KEYWINDOW=0] \
       Y=y; X=x; PEN=1

"Example 26"
PEN NUMBER=1; METHOD=line; CLINE='red'
DGRAPH [WINDOW=1; TITLE='METHOD=line'; KEYWINDOW=0] \
       Y=y; X=x; PEN=1

"Example 27"
PEN NUMBER=1; METHOD=monotonic
DGRAPH [WINDOW=1; TITLE='METHOD=monotonic'; KEYWINDOW=0] \
       Y=y; X=x; PEN=1

"Example 28"
PEN NUMBER=1; METHOD=open
DGRAPH [WINDOW=1; TITLE='METHOD=open'; KEYWINDOW=0] \
       Y=y; X=x; PEN=1

"Example 29"
PEN NUMBER=1; METHOD=closed
DGRAPH [WINDOW=1; TITLE='METHOD=closed'; KEYWINDOW=0] \
       Y=y; X=x; PEN=1

"Example 30"
PEN NUMBER=1; METHOD=fill; CAREA='limegreen'
DGRAPH [WINDOW=1; TITLE='METHOD=fill; CAREA=''limegreen'''; \
       KEYWINDOW=0] Y=y; X=x; PEN=1

"Example 31"
PEN NUMBER=1; METHOD=spline; DFSPLINE=3
DGRAPH [WINDOW=1; TITLE='METHOD=spline; DFSPLINE=3'; \
       KEYWINDOW=0] Y=y; X=x; PEN=1

"Example 32"
PEN NUMBER=1; METHOD=polygon
DGRAPH [WINDOW=1; TITLE='METHOD=polygon'; KEYWINDOW=0] \
       Y=y; X=x; PEN=1
```

```
ENDJOB
```

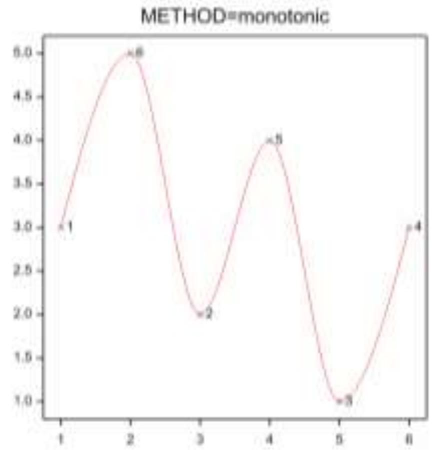
Example 25



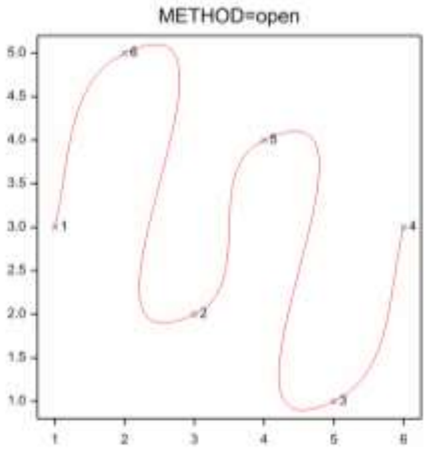
Example 26



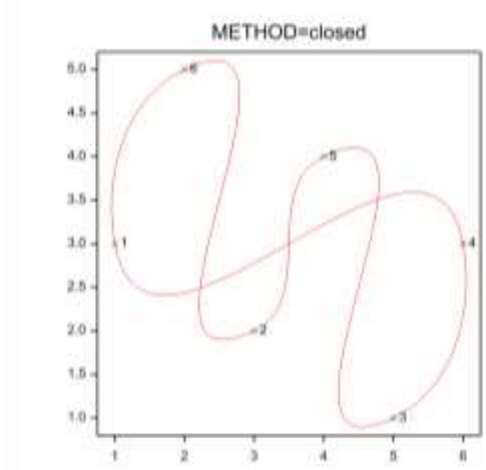
Example 27



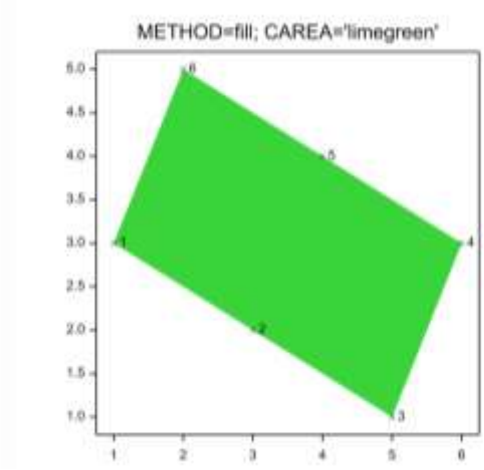
Example 28



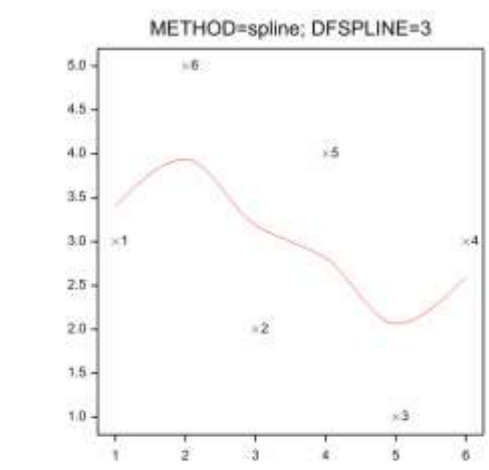
Example 29



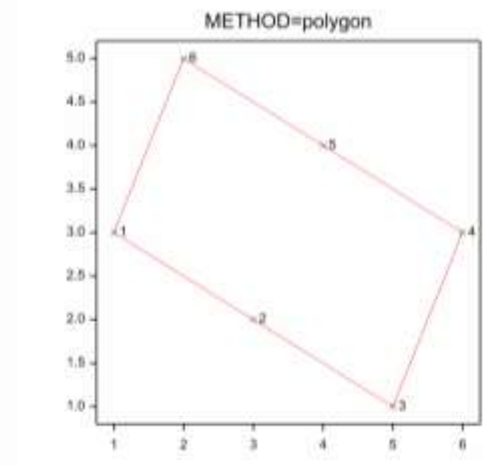
Example 30



Example 31



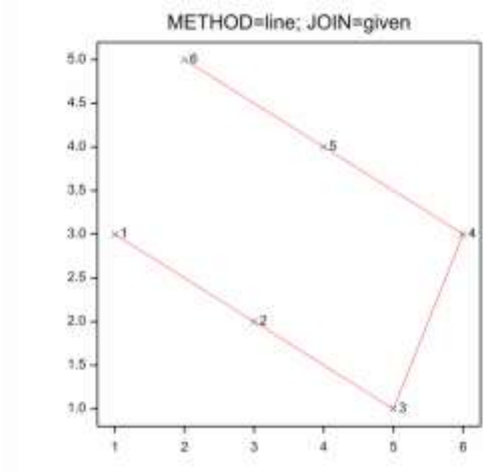
Example 32



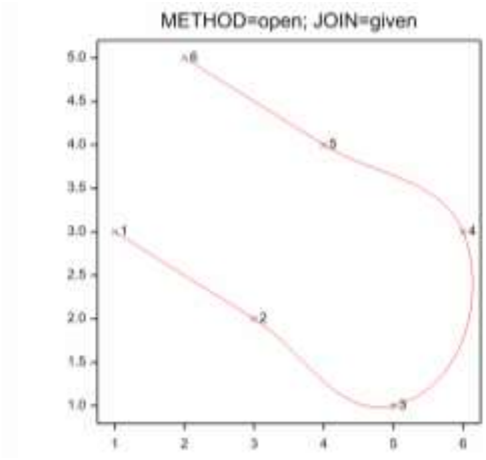
In Examples 26 (`METHOD=line`), 28 (`METHOD=open`) and 29 (`METHOD=closed`) the points have been connected in ascending order of the x-values. However, we can specify that the points are connected in the order they are stored by setting the `JOIN` parameter to `given`. See Examples 33-35. (Note, for all other methods the `JOIN` parameter is ignored.)

```
JOB
VARIATE [VALUES=3,2,1,3,4,5] y
VARIATE [VALUES=1,3,5,6,4,2] x

"Example 33"
PEN NUMBER=1; METHOD=line; CLINE='red'; LABELS=!(1...6); \
    JOIN=given
DGRAPH [WINDOW=1; TITLE='METHOD=line; JOIN=given'; \
        KEYWINDOW=0] Y=y; X=x; PEN=1

"Example 34"
PEN NUMBER=1; METHOD=open; JOIN=given
DGRAPH [WINDOW=1; TITLE='METHOD=open; JOIN=given'; \
        KEYWINDOW=0] Y=y; X=x; PEN=1

"Example 35"
PEN NUMBER=1; METHOD=closed; JOIN=given
DGRAPH [WINDOW=1; TITLE='METHOD=closed; JOIN=given'; \
        KEYWINDOW=0] Y=y; X=x; PEN=1

ENDJOB
```

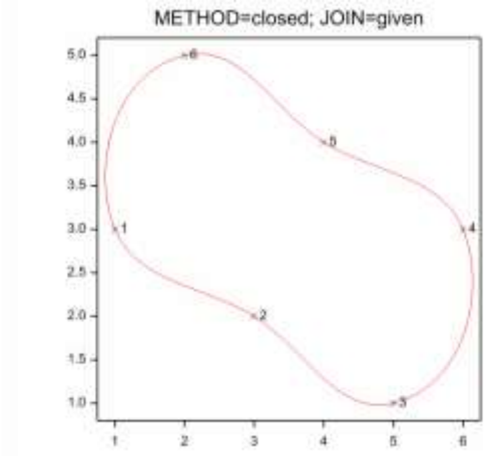
Example 33



Example 34



Example 35

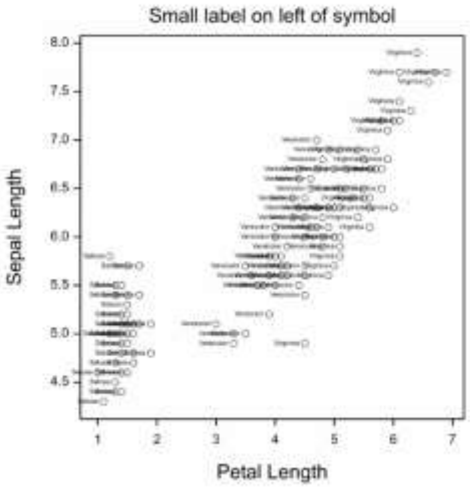


3.4.1.7 Label size, colour and position

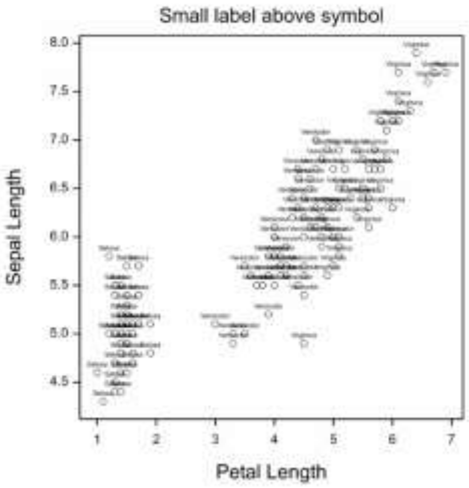
In Examples 3-5 we plotted labels in place of symbols. In Examples 36-39 of this section, we demonstrate the parameters of PEN for changing the size (SMLABEL), position (YLPOSITION, XLPOSITION) and orientation (ROTATION) of the labels.

```
JOB
SPLOAD '%GENDIR%/Data/Iris.gsh'
XAXIS WINDOW=1; TITLE='Petal Length'
YAXIS WINDOW=1; TITLE='Sepal Length'

"Example 36"
PEN [RESET=yes] NUMBER=1; SYMBOLS=2; LABELS=Species; \
    SMLABEL=0.5; YLPOSITION=centre; XLPOSITION=left
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='Small label on left of symbol'] \
       Y=Sepal_Length; X=Petal_Length

"Example 37"
PEN NUMBER=1; YLPOSITION=above; XLPOSITION=centre
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='Small label above symbol'] \
       Y=Sepal_Length; X=Petal_Length

"Example 38"
PEN NUMBER=1; ROTATION=90; YLPOSITION=automatic; \
    XLPOSITION=automatic; SYMBOLS=1
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='Small label above symbol, rotated 90 degrees'] \
       Y=Sepal_Length; X=Petal_Length

"Example 39"
PEN NUMBER=1; ROTATION=45; SMLABEL=0.8; SYMBOLS=1
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='Larger label above symbol, rotated 45 degrees'] \
       Y=Sepal_Length; X=Petal_Length

ENDJOB
```

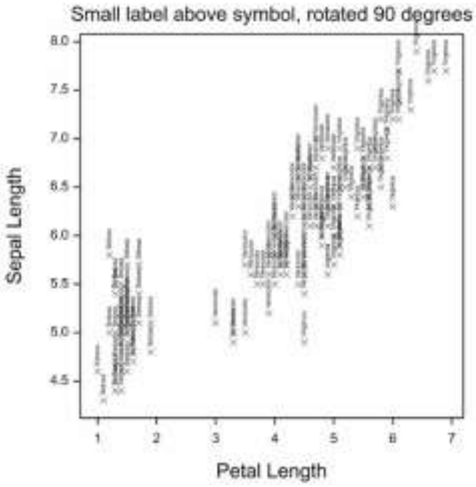
Example 36



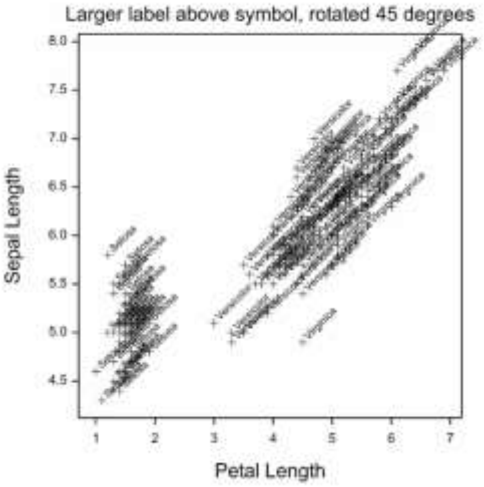
Example 37



Example 38



Example 39

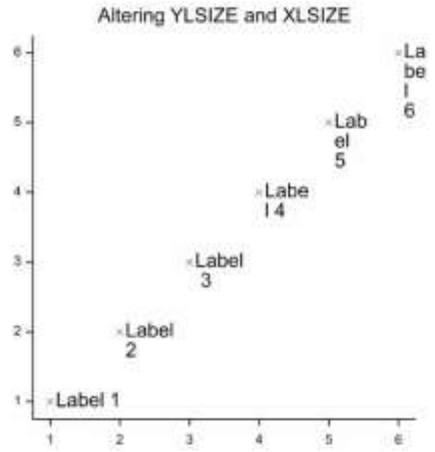


Note, the ROTATION parameter causes both the labels and symbols to rotate. Compare Example 38 with Example 39.

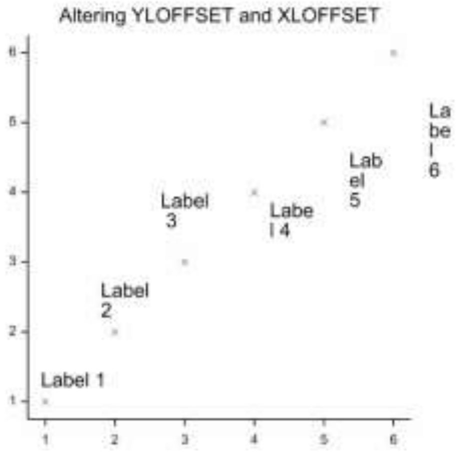
The labels are plotted into text boxes. The widths of the text boxes in the x- and y-directions are set using the YLSIZE and XLSIZE parameters, respectively (see Example 40). If these are not set, the labels are plotted as a single line of characters. The amounts by which the boxes are offset from the data point in the x- and y-directions can be set using by the YLOFFSET and XLOFFSET parameters, respectively (see Example 41). If an offset is not specified the positions of the text boxes are defined automatically according to the position specified by the YLPOSITION and XLPOSITION parameters.

```
JOB
VARIATE [VALUES=1...6] y
VARIATE [VALUES=1...6] x
FRAME WINDOW=1; BOX='omit'

"Example 40"
PEN NUMBER=1; LABELS=!t('Label 1','Label 2','Label 3', \
                       'Label 4','Label 5','Label 6'); \
    YLSIZE=!(1...6); XLSIZE=!(7...2); SMLABEL=1.5
DGRAPH [WINDOW=1; TITLE='Altering YLSIZE and XLSIZE'; \
       KEYWINDOW=0] Y=y; X=x; PEN=1

"Example 41"
PEN NUMBER=1; YLOFFSET=!(1,2,3,-1,-2,-3); \
              XLOFFSET=!(-1,-2,-3,1,2,3)
DGRAPH [WINDOW=1; TITLE='Altering YLOFFSET and XLOFFSET'; \
       KEYWINDOW=0] Y=y; X=x; PEN=1

ENDJOB
```

Example 40



Example 41



3.4.1.8 Appearance of error bars

The thickness of the line used to draw error bars is set using the BARTHICKNESS parameter. Here we supply a multiplier which is used to adjust the standard thickness (as with THICKNESS). The width of the lines at the top and bottom of the error bars is set using the BARCAPWIDTH parameter, again by suppling a multiplier.

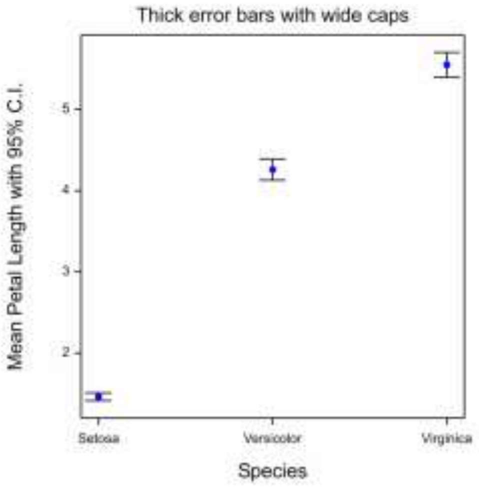
With DGRAPH (see Section 3.2), to plot vertical error bars we set the YLOWER and YUPPER parameters to variates defining the lower and upper values of the error bar for each point. Similarly, parameters XLOWER and XUPPER allow horizontal bars to be plotted. The YBARPEN and XBARPEN parameters set the pens used for drawing the vertical and horizontal bars, respectively.

In Examples 42 and 43 we plot the mean petal length for each species together with their 95% confidence intervals. In the first example, we modify the settings of BARTHICKNESS and BARCAPWIDTH of the default pen for error bars, pen -11. In the second example, we use pen 1 to draw the error bars.

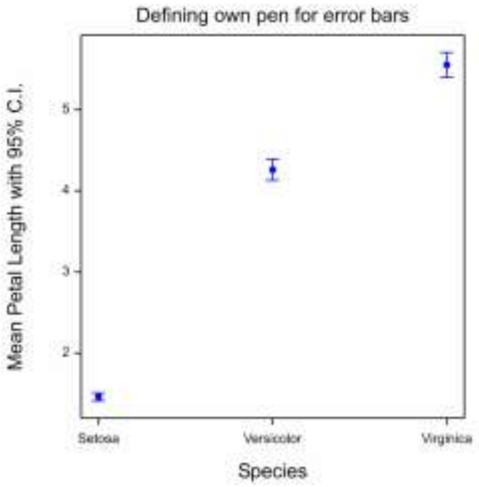
```
JOB
SPLOAD '%GENDIR%/Data/Iris.gsh'
YAXIS WINDOW=1; TITLE='Mean Petal Length with 95% C.I.'
GETATTRIBUTE [ATTRIBUTE=labels] Species; SAVE=SpeciesLabels
XAXIS WINDOW=1; TITLE='Species'; LABELS=#SpeciesLabels; \
      MARKS=!(1...3)

"Calculate the mean petal length for each species"
DESCRIBE [PRINT=*; SELECTION=mean; GROUPS=Species] \
         Petal_Length; SUMMARIES=M_Petal_Length
"Store means in a variate"
VARIATE [VALUES=#M_Petal_Length] Mean_Petal_Length

"Calculate the standard error of the mean for each species"
DESCRIBE [PRINT=*; SELECTION=sem; GROUPS=Species] \
         Petal_Length; SUMMARIES=S_Petal_Length
"Store standard errors in a variate"
VARIATE [VALUES=#S_Petal_Length] SEM_Petal_Length

"Example 42"
PEN NUMBER=-11; BARTHICKNESS=3; BARCAPWIDTH=4
PEN NUMBER=1; SYMBOLS=2; COLOUR='blue'; CFILL='blue'
DGRAPH [WINDOW=1; TITLE='Thick error bars with wide caps'; \
       KEYWINDOW=0] Y=Mean_Petal_Length; X=!(1...3); PEN=1; \
       YUPPER=Mean_Petal_Length+1.96*SEM_Petal_Length; \
       YLOWER=Mean_Petal_Length-1.96*SEM_Petal_Length

"Example 43"
PEN NUMBER=1; BARTHICKNESS=2; BARCAPWIDTH=2; \
    SYMBOLS=2; CFILL='blue'; COLOUR='blue'
DGRAPH [WINDOW=1; TITLE='Defining own pen for error bars'; \
       KEYWINDOW=0] Y=Mean_Petal_Length; X=!(1...3); PEN=1; \
       YUPPER=Mean_Petal_Length+1.96*SEM_Petal_Length; \
       YLOWER=Mean_Petal_Length-1.96*SEM_Petal_Length; \
       YBARPEN=1
```

```
ENDJOB
```

Example 42



Example 43



In the code above, the `GETATTRIBUTE` directive was used as a convenient method for extracting the species names (i.e. labels of the `SPECIES` factor) with which the x-axis was labelled.

3.5 XAXIS, YAXIS and ZAXIS directives

The `XAXIS`, `YAXIS` and `ZAXIS` directives allow you to control various aspects of the axes within each window, for example the titles, spacing of tick marks and the position of labels. The options and parameters controlling these directives are briefly described in Table 3-5. For a more comprehensive description, refer to the Genstat Help (📄). In addition, a suite of examples is provided in Section 3.5.1

Table 3-5: Options and parameters of `XAXIS`, `YAXIS` and `ZAXIS`.

Options	***Directive***	
`RESET` = *string token*		Specifies whether to reset the axis definition to the default values (`yes`, `no`). Default `no`.
Parameters		
`WINDOW` = *scalars*		Specifies the window whose axis definition is to be altered.

TITLE = *texts*		Title for the axis.
TPOSITION = *string tokens*		Controls whether the title is placed in the middle or at the end of the axis.
TDIRECTION = *string tokens*		Controls whether the title is written parallel or perpendicular to the axis.
LOWER = *scalars*		Lower bound for axis.
UPPER = *scalars*		Upper bound for axis.
MARKS = *scalars* or *variates*		Distance between each tick mark (scalar) or positions of the marks along the axis (variate).
MPOSITION = *string tokens*		Controls the positioning of the tick marks, which can be drawn on the inside or the outside of the axis, or can be drawn across the axis. Setting MPOSITION=* will switch off any tick marks.
LABELS= *texts* or *variates*		Supplies labels to print at each major tick mark. Setting LABELS=* will switch off any labels previously specified.
LPOSITION = *string tokens*		Position of the axis labels (inside, outside). Setting LPOSITION=* will switch off any labels.
LDIRECTION = *string tokens*		Direction of the axis labels (parallel, perpendicular). Setting LDIRECTION=* will switch off any labels.
LROTATION = *scalars* or *variates*		Specifies the direction of the labels, as a rotation in degrees from the horizontal (i.e. parallel) direction. If LROTATION is specified, any setting of LDIRECTION is ignored.
NSUBTICKS = *scalars*		Number of subticks per interval (ignored if MARKS is a variate).
XORIGIN = *scalars*	YAXIS, ZAXIS only	Position on x-axis at which the axis is drawn.
YORIGIN = *scalars*	XAXIS, ZAXIS only	Position on y-axis at which the axis is drawn.
ZORIGIN = *scalars*	XAXIS, YAXIS only	Position on z-axis at which the axis is drawn.
PENTITLE = *scalars*		Pen to use to write the axis title.
PENLABELS = *scalars*		Pen to use to draw the axis.

ARROWHEAD = *string tokens*		Specifies whether the axis should have an arrowhead (include, omit).
ACTION = *string tokens*		Specifies whether to display or hide the axis (display, hide).
TRANSFORM = *string token*		Transformed scale for the axis (identity, log, log10, logit, probit, cloglog, square, exp, exp10, ilogit, iprobit, icloglog, root). The tick marks are still defined and labelled according to the original scale, but their physical positions on the graph are transformed. Default identity.
LINKED = *scalars*		Linked axis whose definitions should be used for this axis in 2-dimensional graphs.
MLOWER% = *scalars*		Controls the size of the lower margin, expressed as a percentage of the range of data values. For example, for XAXIS, MLOWER% controls the size of margin (expressed as a percentage of the range of the x-values) that is provided between the lower value of the axis and the smallest x-value, if the lower axis value is not set explicitly by LOWER.
MUPPER% = *scalars*		Controls the size of the upper margin, expressed as a percentage of the range of data values.
DECIMALS = *scalars* or *variates*		Controls the number of decimal places to use for numbers printed at the marks.
DREPRESENTATION = *scalars* or *variates*		Controls the format to use for dates and times printed at the marks. (See the PRINT directive for details).
VREPRESENTATION = *scalars* or *variates*		Format to use for numbers printed at the marks (decimal, engineering, scientific). Default decimal.
XOMETHOD = *string tokens*	YAXIS, ZAXIS only	Method to set the position of the origin on the x-axis if not set explicitly by XORIGIN (upper, lower, center, centre).
YOMETHOD = *string tokens*	XAXIS, ZAXIS only	Method to set the position of the origin on the y-axis if not set explicitly by YORIGIN (upper, lower, center, centre).

ZOMETHOD = *string tokens*	XAXIS, YAXIS only	Method to set the position of the origin on the z-axis if not set explicitly by ZORIGIN (upper, lower, center, centre).
REVERSE = *string tokens*		Specifies whether to reverse the axis direction to run from upper to lower (yes, no). Default no.
SAVE = *pointers*		Saves details of the current settings for the axis concerned

Using the XAXIS and YAXIS directives, we'll modify Figure 3.4 to

- include axes titles (TITLE parameter)
- adjust the lower and upper axes limits (LOWER and UPPER parameters)
- place tick marks at 1mm intervals (MARKS parameter)
- place subticks at 0.25mm intervals (NSUBTICKS parameter)

using the commands:

```
XAXIS WINDOW=1; Title='Sepal Width (mm)'; LOWER=1; UPPER=5; \
  MARKS=1; NSUBTICKS=3
YAXIS WINDOW=1; Title='Sepal Length (mm)'; LOWER=4; UPPER=8; \
  MARKS=1; NSUBTICKS=3
DGRAPH [KEYWINDOW=12; KEYDESCRIPTION='Iris species'] \
  Y=Sepal_Length; X=Sepal_Width; PEN=Species; \
  DESCRIPTION=!T(Setosa,Versicolour,Virginica)
```

Note, as the graph produced by DGRAPH is to be plotted in window 1 (the default), the WINDOW parameter of both XAXIS and YAXIS is set to 1. The resulting graph is shown in Figure 3.6.

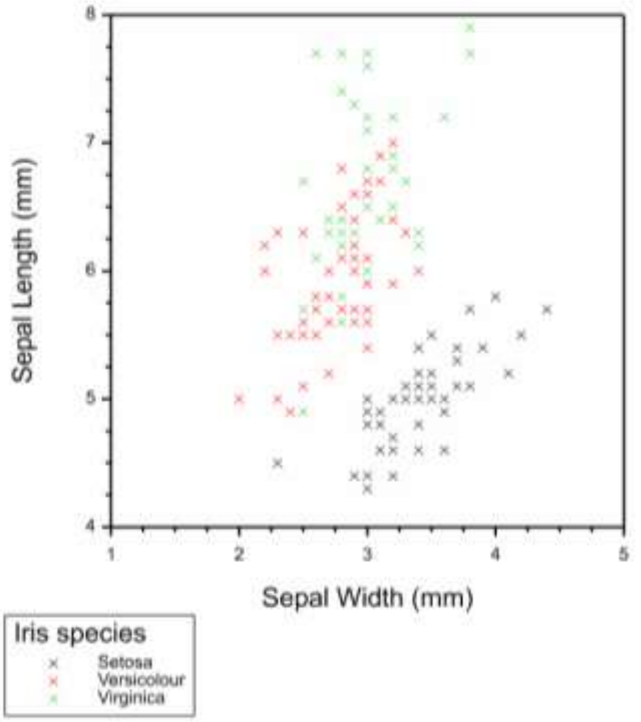


Figure 3.7: Graph plotted with redefined x- and y-axes attributes, using the XAXIS and YAXIS directives, respectively.

The default x- and y-axes settings can be restored using the commands:

```
XAXIS [RESET=yes] WINDOW=1
YAXIS [RESET=yes] WINDOW=1
```

The AXIS directive may also be used to specify how the x-, y- and z-axes are to be drawn, using similar options and parameters to those described above. In addition, the AXIS directive can be used to include additional axes which run in oblique directions. An example is provided in Section 4.2.7.

More example graphs, in which the XAXIS and YAXIS directives are used to modify the appearance of the axes, are given in the following section.

3.5.1 Illustrative examples

In this section we provide some examples to demonstrate the effect that different option and parameter settings of XAXIS and YAXIS have on the graphical output.

Recall that the WINDOW parameter specifies the *window* whose axis definition is to be altered. After changes have been made, the option RESET=yes may be used to revert all options and parameters back to their default values.

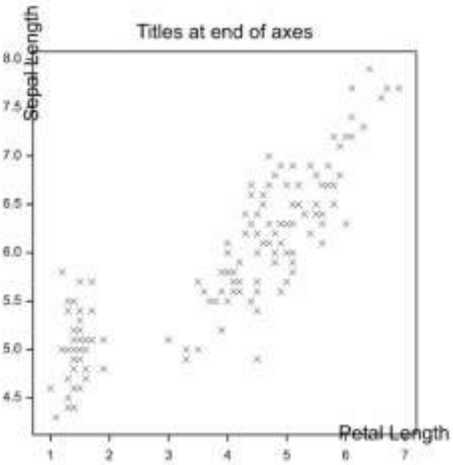
3.5.1.1 Position of the axis title

In the first three examples (Examples 1-3) we demonstrate how the position and orientation of the axis title can be changed using the TPOSITION and TDIRECTION parameters. To accommodate the axis titles, it may be necessary to alter the margins of the plotting window using the FRAME directive (as in Examples 2 and 3).

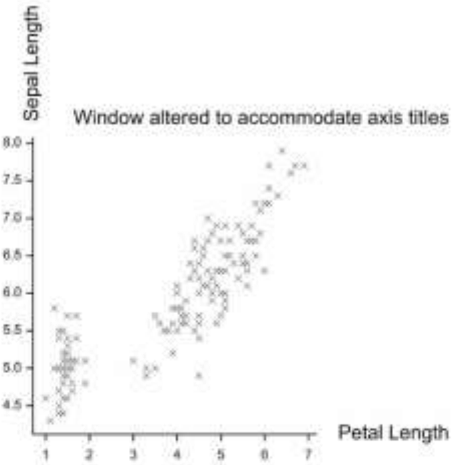
Notice that by not specifying the option RESET=yes in the calls to XAXIS, YAXIS and FRAME, any modifications to their parameter and option settings are retained throughout the Genstat job.

```
JOB
SPLOAD '%GENDIR%/Data/Iris.gsh'

"Example 1"
XAXIS WINDOW=1; TITLE='Petal Length'; TPOSITION=end
YAXIS WINDOW=1; TITLE='Sepal Length'; TPOSITION=end
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='Titles at end of axes’] \
       Y=Sepal_Length; X=Petal_Length

"Example 2"
"Margins altered to accommodate the axis titles"
FRAME WINDOW=1; XMUPPER=0.20; YMUPPER=0.20; BOX=omit; \
      TPOSITION=right
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='Window altered to accommodate axis titles'] \
       Y=Sepal_Length; X=Petal_Length

"Example 3"
"Margins altered to accommodate the axis titles"
FRAME WINDOW=1; YMUPPER=0.06; TPOSITION=right
YAXIS WINDOW=1; TDIRECTION=perpendicular
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='y-axis title printed perpendicular to axis'] \
       Y=Sepal_Length; X=Petal_Length

ENDJOB
```

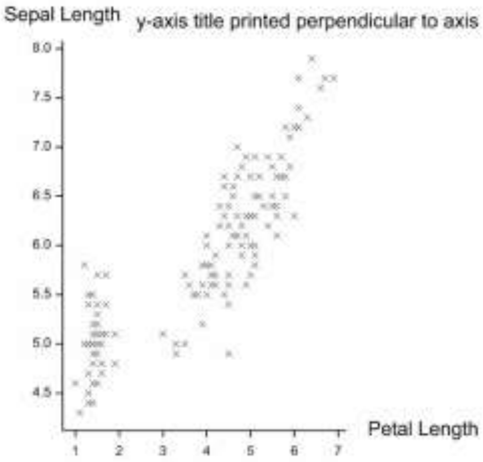
Example 1



Example 2



Example 3



The style, colour and size of the font used to display the title can be modified using the PENTITLE parameter (examples are given in Section 3.5.1.7). In the above examples the default pen has been used.

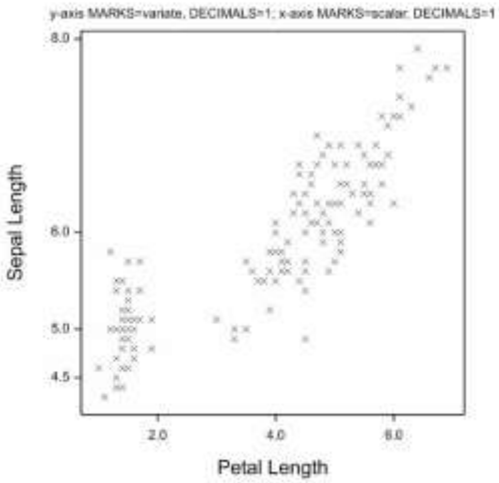
3.5.1.2 Positioning and labelling of tick marks

In the next set of examples, Examples 4-10, we alter the appearance (including number, position and orientation) of the axis tick marks and labels using MARKS, NSUBTICKS, DECIMALS, LABELS, LPOSITION, MPOSITION, LDIRECTION and LROTATION.

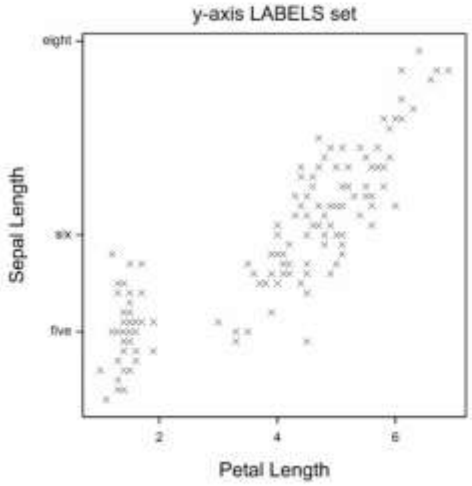
```
JOB
SPLOAD '%GENDIR%/Data/Iris.gsh'

"Example 4"
XAXIS 1; TITLE='Petal Length'; MARKS=2; DECIMALS=1
YAXIS 1; TITLE='Sepal Length'; MARKS=!(4.5,5,6,8); DECIMALS=1
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='y-axis MARKS=variate, DECIMALS=1; \
x-axis MARKS=scalar, DECIMALS=1'] \
       Y=Sepal_Length; X=Petal_Length

"Example 5"
XAXIS 1; DECIMALS=0
YAXIS WINDOW=1; MARKS=!(5,6,8); LABELS=!t(five,six,eight)
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='y-axis LABELS set'] \
       Y=Sepal_Length; X=Petal_Length

"Example 6"
YAXIS WINDOW=1; MARKS=!(4,5,6,8); LDIRECTION=parallel; \
      LABELS=!t(four,five,six,eight)
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='y-axis LDIRECTION=parallel'] \
       Y=Sepal_Length; X=Petal_Length

"Example 7"
YAXIS WINDOW=1; LROTATION=45
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='y-axis LROTATION=45'] \
       Y=Sepal_Length; X=Petal_Length

"Example 8"
XAXIS WINDOW=1; MARKS=2; MPOSITION=across
YAXIS [RESET=yes] WINDOW=1; TITLE='Sepal Length'; \
      MARKS=!(4,5,6,8); MPOSITION=inside; \
      LABELS=!t(four,five,six,eight)
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='y-axis MPOSITION=inside; \
x-axis MPOSITION=across'] \
       Y=Sepal_Length; X=Petal_Length

"Example 9"
XAXIS WINDOW=1; LPOSITION=inside
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='x-axis MPOSITION=inside'] \
       Y=Sepal_Length; X=Petal_Length
```

```
"Example 10"
XAXIS [RESET=yes] WINDOW=1; TITLE='Petal Length'; \
      MARKS=2; NSUBTICKS=1
YAXIS [RESET=yes] WINDOW=1; TITLE='Sepal Length';\
      NSUBTICKS=4
DGRAPH [WINDOW=1; KEYWINDOW=0; \
        TITLE='y-axis NSUBTICKS=4; x-axis NSUBTICKS=1'] \
        Y=Sepal_Length; X=Petal_Length

ENDJOB
```

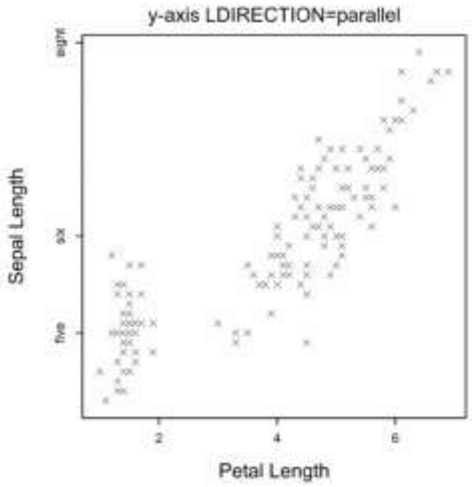
Example 4



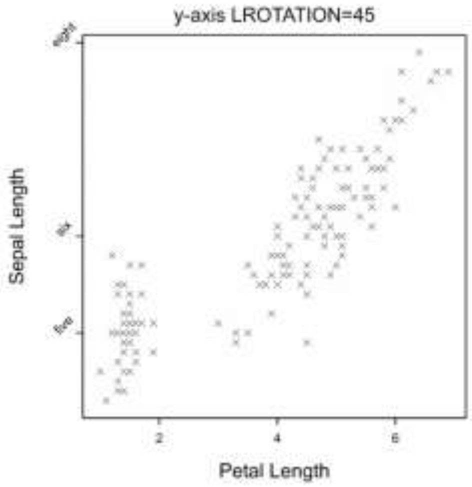
Example 5



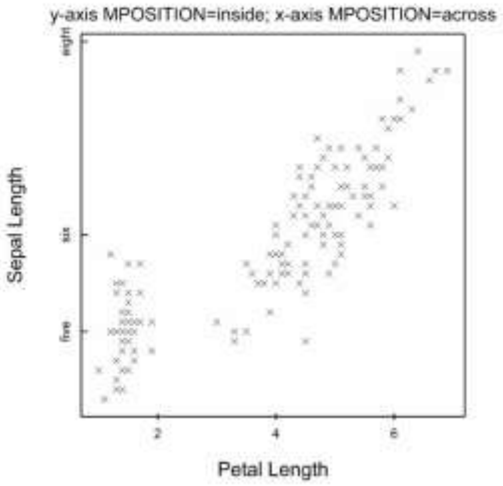
Example 6



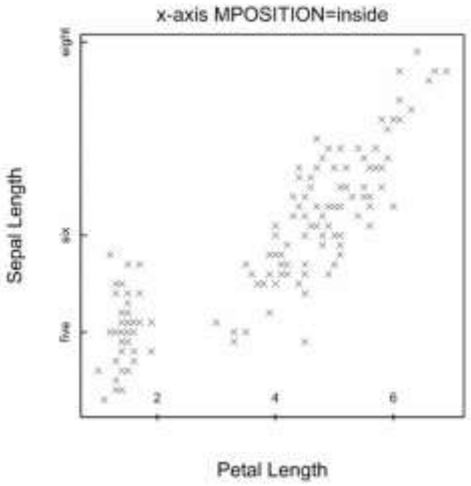
Example 7



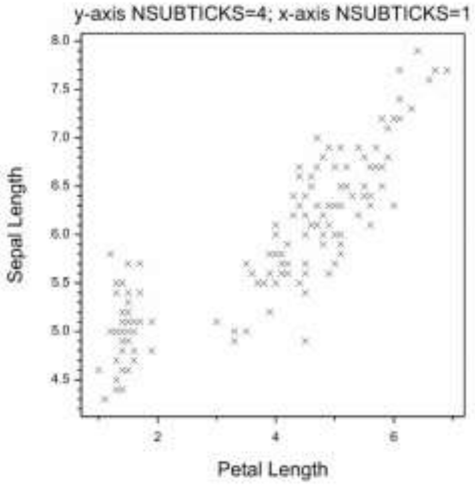
Example 8



Example 9



Example 10



The style, colour and size of the font used for the labels can be modified by the PENLABELS parameter (examples are given in Section 3.5.1.7). In the above examples, the default pen has been used.

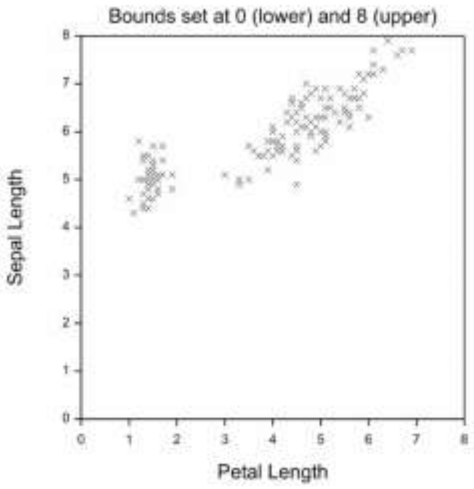
By default, numbers at the tick marks are printed in decimal form (as in the above examples). However, you can specify that these are printed in scientific or engineering format using the VREPRESENTATION parameter. Furthermore, if the numbers represent dates or times, you can specify their formats using the DREPRESENTATION parameter.

3.5.1.3 Axis bounds

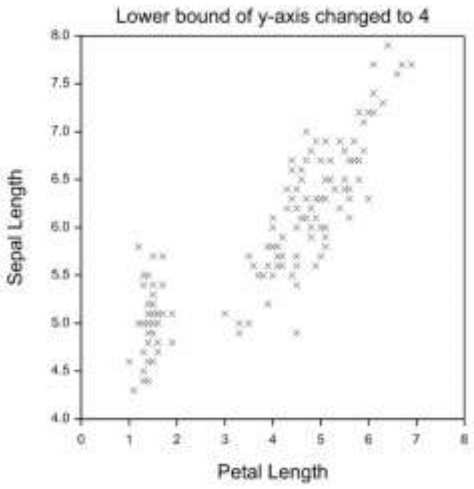
The lower and upper bounds for the axis can be set using the `LOWER` and `UPPER` parameters, respectively. Compare Examples 11 and 12 to Example 1, in which the default axis bounds have been used.

```
JOB
SPLOAD '%GENDIR%/Data/Iris.gsh'

"Example 11"
XAXIS WINDOW=1; TITLE='Petal Length'; LOWER=0; UPPER=8
YAXIS WINDOW=1; TITLE='Sepal Length'; LOWER=0; UPPER=8
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='Bounds set at 0 (lower) and 8 (upper)'] \
       Y=Sepal_Length; X=Petal_Length

"Example 12"
YAXIS WINDOW=1; LOWER=4
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='Lower bound of y-axis changed to 4'] \
       Y=Sepal_Length; X=Petal_Length

ENDJOB
```

Example 11



Example 12

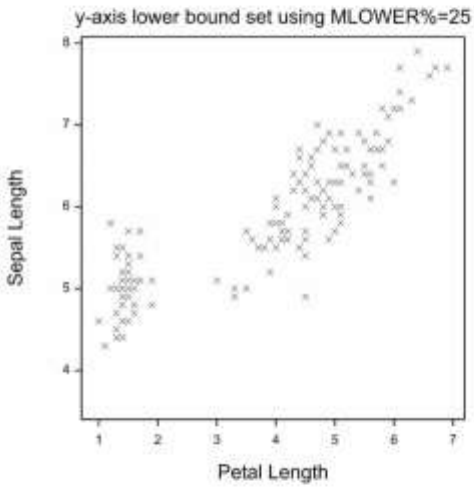


If the lower and upper bounds haven’t already been explicitly set by the LOWER and UPPER parameters, they may instead be defined using the MLOWER% and MUPPER% parameters. The MLOWER% parameter, expressed as a percentage of the data range, controls the size of margin between the lower bound and the smallest data value. Similarly the MUPPER% parameter controls the size of the upper margin.

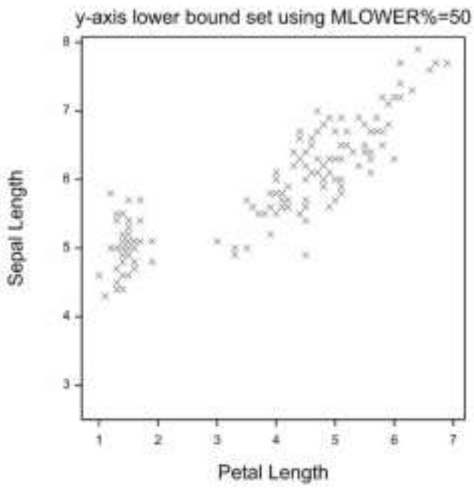
In Example 13 below, the lower bound of the y-axis is defined using MLOWER%=25. As the data on the y-axis ranges from 4.3-7.9 (range = 3.6), this sets the lower bound to 3.4 (i.e. 4.3 - 0.25 × 3.6). A smaller value for the lower bound (of 2.5) has been set for Example 14 by setting MLOWER%=50 (i.e. 4.3 - 0.5 × 3.6).

```
JOB
SPLOAD '%GENDIR%/Data/Iris.gsh'

"Example 13"
XAXIS WINDOW=1; TITLE='Petal Length';
YAXIS WINDOW=1; TITLE='Sepal Length'; MLOWER%=25
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='y-axis lower bound set using MLOWER%=25'] \
       Y=Sepal_Length; X=Petal_Length

"Example 14"
YAXIS WINDOW=1; MLOWER%=50;
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='y-axis lower bound set using MLOWER%=50'] \
       Y=Sepal_Length; X=Petal_Length

ENDJOB
```

Example 13



Example 14



3.5.1.4 Position of the origin

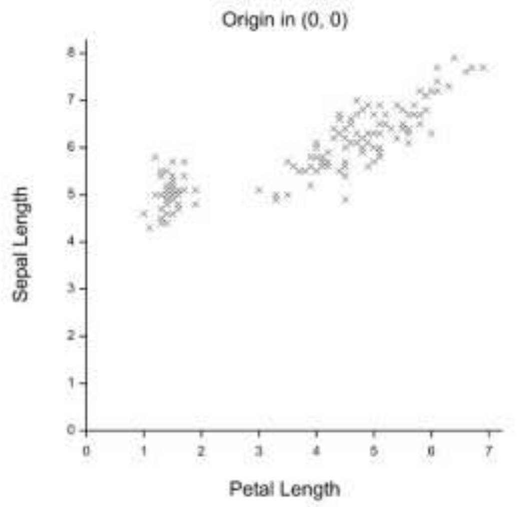
In Examples 15-17 we move the origin (i.e. position on the plot where the axes intersect) using the XORIGIN parameter of YAXIS and the YORIGIN parameter of XAXIS. (Note, in Example 17, the UPPER parameter is used to set the upper bound of the axis to accommodate the position of the origin.)

Alternatively, if YORIGIN has not been set, the YOMETHOD parameter of the XAXIS directive can be used to set the position of the origin at either the upper, the lower, or the centre value on the y-axis. Likewise, the XOMETHOD parameter of the YAXIS directive can be used to set the position of the origin on the x-axis. See Example 18.

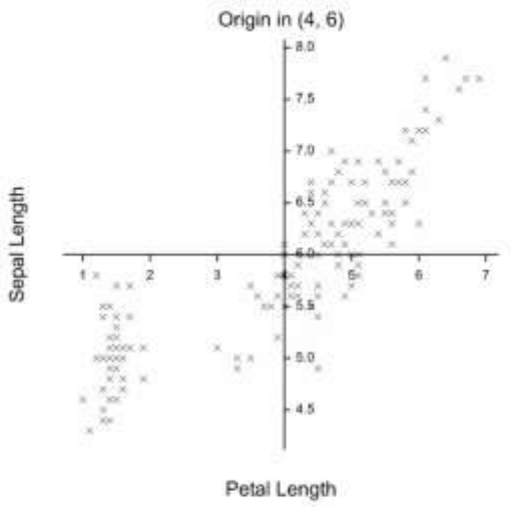
```
JOB
SPLOAD '%GENDIR%/Data/Iris.gsh'

"Example 15"
FRAME [RESET=yes] WINDOW=1; YMLOWER=0.08; YMUPPER=0.05; \
      XMLOWER=0.09; XMUPPER=0; BOX=omit
YAXIS WINDOW=1; XORIGIN=0; TITLE='Sepal Length'
XAXIS WINDOW=1; YORIGIN=0; TITLE='Petal Length'
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='Origin in (0, 0)'] \
       Y=Sepal_Length; X=Petal_Length

"Example 16"
YAXIS WINDOW=1; XORIGIN=4
XAXIS WINDOW=1; YORIGIN=6
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='Origin in (4, 6)'] \
       Y=Sepal_Length; X=Petal_Length

"Example 17"
FRAME [RESET=yes] WINDOW=1; XMLOWER=0.05; XMUPPER=0.10; BOX=omit
YAXIS [RESET=yes] WINDOW=1; XORIGIN=0; TITLE='Sepal Length'; \
      UPPER=9
XAXIS [RESET=yes] WINDOW=1; YORIGIN=9; TITLE='Petal Length'; \
       MPOSITION=inside; LPOSITION=inside; UPPER=8
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='Origin in (0, 9)'] \
       Y=Sepal_Length; X=Petal_Length

"Example 18"
FRAME [RESET=yes] WINDOW=1; XMLOWER=0.05; XMUPPER=0.10; \
      YMLOWER=0.05; YMUPPER=0.20; BOX=omit
YAXIS [RESET=yes] WINDOW=1; XOMETHOD=upper; TITLE='Sepal Length'
```

```
XAXIS [RESET=yes] WINDOW=1; YOMETHOD=centre; TITLE='Petal
Length'
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='y-axis XOMETHOD=upper; x-axis YOMETHOD=centre'] \
       Y=Sepal_Length; X=Petal_Length

ENDJOB
```

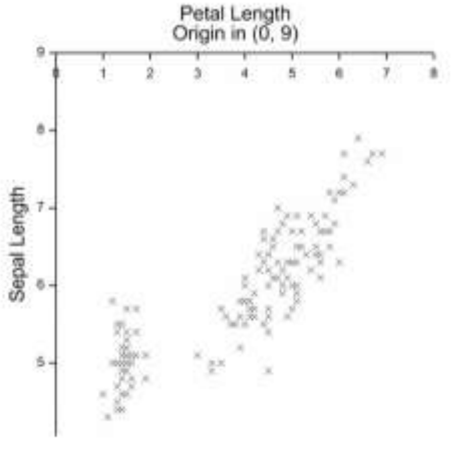
Example 15



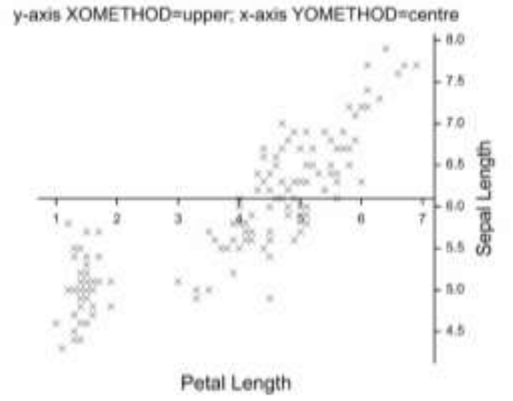
Example 16



Example 17



Example 18



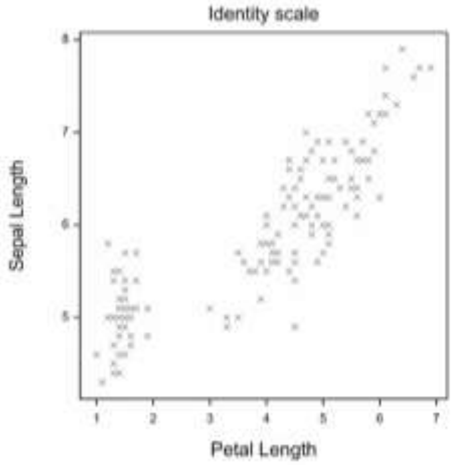
3.5.1.5 Transformed scale

Examples 19-22 showcase the changing appearance of the axis achieved from transforming the scale, using the TRANSFORM parameter. On the transformed scale, the tick marks are still defined and labelled according to the original scale, but their physical positions on the graph are transformed. To better observe the rescaling, we'll use the MARKS parameter to space the tick marks 1 unit apart.

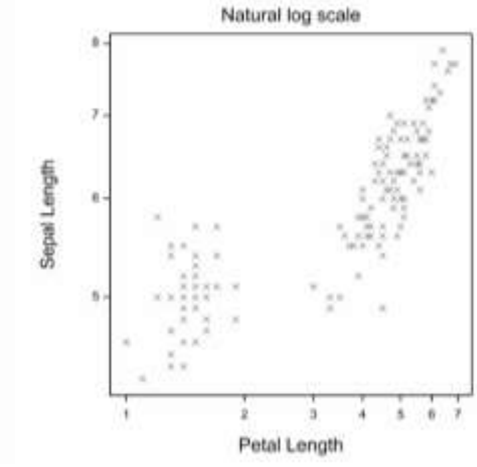
An inverted scale, in which the axis is reversed to run from the upper bound to the lower bound, may be obtained by setting the REVERSE parameter to yes. This is demonstrated by Example 23.

```
JOB
SPLOAD '%GENDIR%/Data/Iris.gsh'

"Example 19"
XAXIS WINDOW=1; TITLE='Petal Length'; MARKS=1
YAXIS WINDOW=1; TITLE='Sepal Length'; MARKS=1
DGRAPH [WINDOW=1; KEYWINDOW=0; TITLE='Identity scale'] \
       Y=Sepal_Length; X=Petal_Length

"Example 20"
XAXIS WINDOW=1; TRANSFORM=log
YAXIS WINDOW=1; TRANSFORM=log
DGRAPH [WINDOW=1; KEYWINDOW=0; TITLE='Natural log scale'] \
       Y=Sepal_Length; X=Petal_Length

"Example 21"
XAXIS WINDOW=1; TRANSFORM=square
YAXIS WINDOW=1; TRANSFORM=square
DGRAPH [WINDOW=1; KEYWINDOW=0; TITLE='Square scale'] \
       Y=Sepal_Length; X=Petal_Length

"Example 22"
XAXIS WINDOW=1; TRANSFORM=root
YAXIS WINDOW=1; TRANSFORM=root
DGRAPH [WINDOW=1; KEYWINDOW=0; TITLE='Square root scale'] \
       Y=Sepal_Length; X=Petal_Length

"Example 23"
XAXIS WINDOW=1; TRANSFORM=*; REVERSE=yes
YAXIS WINDOW=1; TRANSFORM=*; REVERSE=yes
DGRAPH [WINDOW=1; KEYWINDOW=0; TITLE='Inverted scale'] \
       Y=Sepal_Length; X=Petal_Length

ENDJOB
```

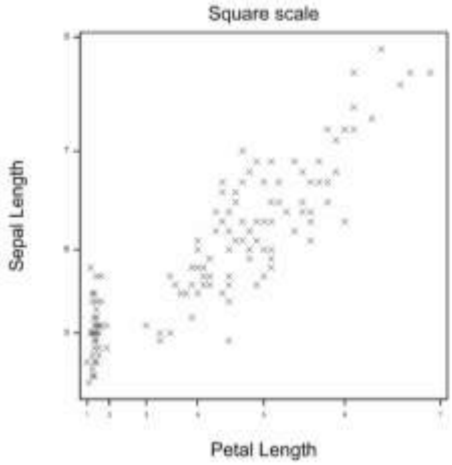
Example 19



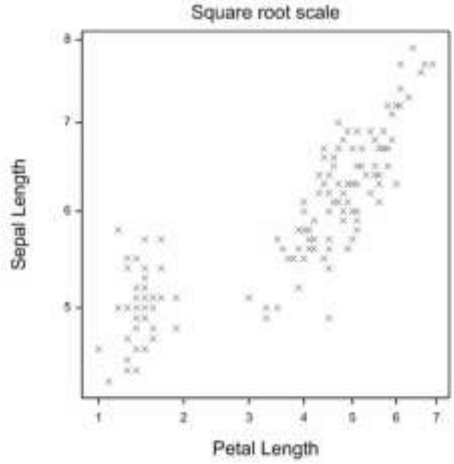
Example 20



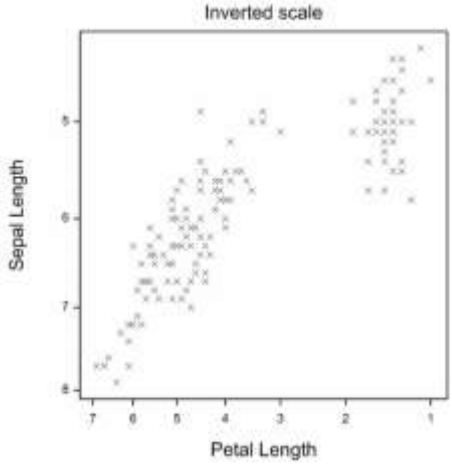
Example 21



Example 22



Example 23

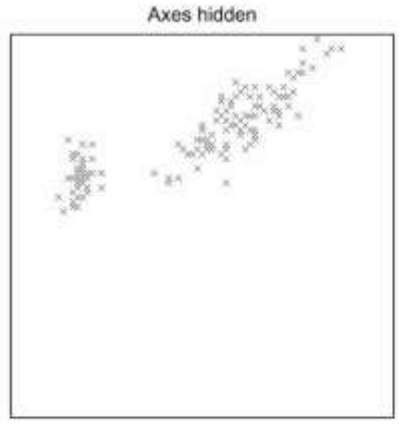


3.5.1.6 Hidden axis

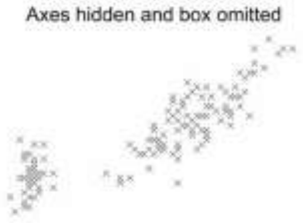
By default, the axis is displayed. However, you may wish to hide the axis, for example, when using the axis definition merely to control the positioning of the plot. The ACTION parameter controls whether the axis is displayed or hidden, as demonstrated by Example 24. In Example 25 the box enclosing the plot is also omitted.

```
JOB
SPLOAD '%GENDIR%/Data/Iris.gsh'

"Example 24"
XAXIS WINDOW=1; TITLE='Petal Length'; LOWER=0; UPPER=8; \
      ACTION=hide
YAXIS WINDOW=1; TITLE='Sepal Length'; LOWER=0; UPPER=8; \
      ACTION=hide
DGRAPH [WINDOW=1; KEYWINDOW=0; TITLE='Axes hidden'] \
       Y=Sepal_Length; X=Petal_Length

"Example 25"
FRAME WINDOW=1; BOX=omit
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='Axes hidden and box omitted'] \
       Y=Sepal_Length; X=Petal_Length

ENDJOB
```

Example 24



Example 25

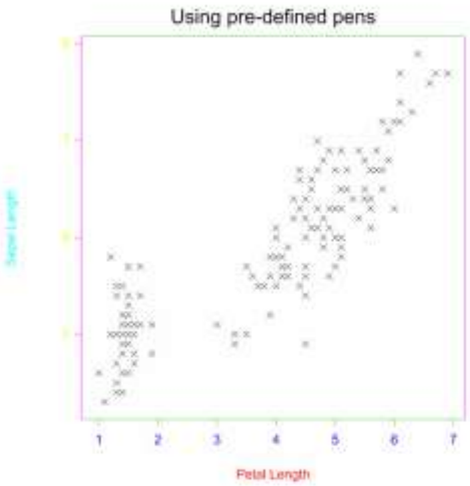


3.5.1.7 Colour of the axis

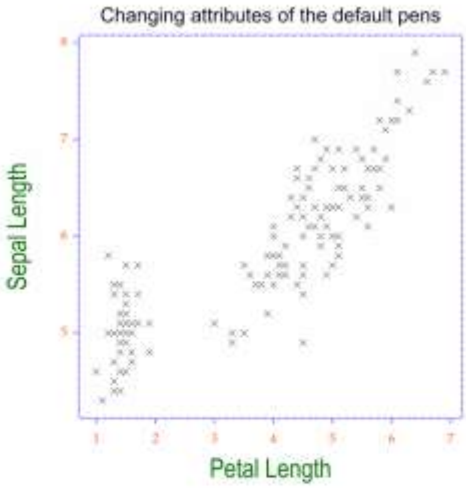
Three parameters control the pens used to draw the axis: PENTITLE specifies the pen for the title (default -1), PENAXIS specifies the pen for drawing the axis (default -2) and PENLABEL specifies the pen for labelling (default -3). In Examples 26-28 we show how to use the PEN directive to modify the colours used when drawing the axes.

```
JOB
SPLOAD '%GENDIR%/Data/Iris.gsh'

"Example 26"
XAXIS WINDOW=1; TITLE='Petal Length'; MARKS=1; \
      PENTITLE=2; PENAXIS=3; PENLABELS=4
YAXIS WINDOW=1; TITLE='Sepal Length'; MARKS=1;\
      PENTITLE=5; PENAXIS=6; PENLABELS=7
DGRAPH [WINDOW=1; KEYWINDOW=0; TITLE='Using pre-defined pens'] \
       Y=Sepal_Length; X=Petal_Length

"Example 27"
"Titles"
PEN NUMBER=-1; COLOUR='darkgreen'; FONT=4; SIZE=2
"Axis"
PEN NUMBER=-2; COLOUR='blue'; LINESTYLE=2
"Labels"
PEN NUMBER=-3; COLOUR='orangered'; FONT=5
XAXIS [RESET=yes] WINDOW=1; TITLE='Petal Length'; MARKS=1
YAXIS [RESET=yes] WINDOW=1; TITLE='Sepal Length'; MARKS=1
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='Changing attributes of the default pens'] \
       Y=Sepal_Length; X=Petal_Length

"Example 28"
"Pen for x-axis titles"
PEN NUMBER=10; COLOUR='darkgreen'; FONT=8; SIZE=2
"Pen for x-axis axis"
PEN NUMBER=20; COLOUR='lawngreen'; THICKNESS=2
"Pen for x-axis labels"
PEN NUMBER=30; COLOUR='seagreen'; FONT=9; SIZE=1.5
"Pen for y-axis titles"
PEN NUMBER=40; COLOUR='darkviolet'; FONT=8; SIZE=2
"Pen for y-axis axis"
PEN NUMBER=50; COLOUR='indigo'; THICKNESS=2
"Pen for y-axis labels"
PEN NUMBER=60; COLOUR='magenta'; FONT=9; SIZE=1.5
XAXIS WINDOW=1; TITLE='Petal Length'; MARKS=1; \
      PENTITLE=10; PENAXIS=20; PENLABELS=30
YAXIS WINDOW=1; TITLE='Sepal Length'; MARKS=1; \
      PENTITLE=40; PENAXIS=50; PENLABELS=60
DGRAPH [WINDOW=1; KEYWINDOW=0; \
       TITLE='Defining own pens'] \
       Y=Sepal_Length; X=Petal_Length

ENDJOB
```

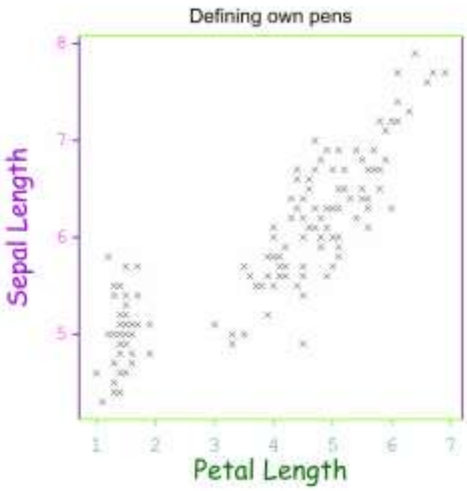
Example 26



Example 27



Example 28



3.6 DEVICE directive

Genstat can generate high-resolution graphics in two forms: either on-screen, for interactive use, or outputted to a file in one of a number of standard formats suitable for plotters, printers or word processors, for later use outside Genstat. Each type of output, whether screen or file, is referred to as a *device*. Genstat has built-in interfaces to several different graphics devices. These vary according to the Genstat implementation, however details of the available devices can be obtained from the DHELP procedure by running the command

```
DHELP TOPIC=possible
```

The devices available in Genstat19 are:

```
DEVICE:
Device 1 ... 13
* 1     Graphics Window
 2      Windows Bitmap File (*.bmp)
 3      Windows Default Printer
 4      Portable Document Format (*.pdf)
 5      Encapsulated PostScript File (*.eps)
 6      Windows Enhanced Metafile (*.emf)
 7      JPEG Files (*.jpg, *.jpeg)
 8      TIFF Files (*.tif, *.tiff)
 9      Portable Network Graphics Files (*.png)
 10     Genstat Metafile (*.gmf)
 11     Windows Bitmap File (*.bmp)
 12     Windows Default Printer
 13     Portable Document Format (*.pdf)
* marks the current device
```

The default device, selected automatically when you start Genstat, is device 1. However, you may switch between devices using the DEVICE directive. The parameters controlling DEVICE are briefly described in Table 3-6. (Note, there are no options.) A more comprehensive description is provided within the Genstat Help System (📄).

Table 3-6: Parameters of DEVICE.

Parameters	
NUMBER = *scalar*	Device number.
ENDACTION = *string token*	Controls the action taken by default at the end of each plot (pause, continue).
ORIENTATION = *string token*	Specifies landscape or portrait orientation of graphical output on PostScript and Interacter raster devices. Default portrait.
PALETTE = *string token*	Specifies how to represent colour (monotone, greyscale, grayscale, colour).
SIZEPAGE = *string token*	Size of page for each screen (A4, A3) for HPGL devices.
RESOLUTION = *scalar*	Specifies the height of the image for hard-copy output, in pixels.
ACTION = *string token*	Specifies how to create graphs for file types such as .emf, .jpg, .tif or .png. The setting synchronous creates the graph before executing another command, whereas the setting asynchronous allows subsequent commands to be executed whilst the graph is created. Default asynchronous.

When selecting a file-based device you must open a file to receive the output, using the OPEN directive before any graphical output is generated. After the graphics are complete, you can close the file using the CLOSE directive. Note, when opening or closing files for graphical output the CHANNEL parameter of the OPEN and CLOSE statements must be set to the device NUMBER specified by the DEVICE statement. The parameters controlling the OPEN and CLOSE directives are briefly described in Table 3-7 and Table 3-8, respectively. Refer to the Genstat Help (📄) for more information.

To illustrate the use of the DEVICE, OPEN and CLOSE directives, we'll output the graphic of Figure 3.4 to a pdf file (device 4) using the commands:

```
OPEN NAME='PLOT.pdf'; CHANNEL=4; FILETYPE=graphics
DEVICE NUMBER=4
DGRAPH [KEYWINDOW=12; KEYDESCRIPTION='Iris species'] \
  Y=Sepal_Length; X=Sepal_Width; PEN=Species; \
  DESCRIPTION=!T(Setosa,Versicolour,Virginica)
CLOSE CHANNEL=4; FILETYPE=graphics
```

The file will be saved in your current working directory.

Table 3-7: Parameters of OPEN.

Parameters	
NAME = *texts*	Name of the file.
CHANNEL = *scalars*	Channel number used to refer to the file in other statements (e.g. DEVICE)
FILETYPE = *string tokens*	File type (input, output, unformatted, backingstore, procedurelibrary, graphics). Default input.
WIDTH = *scalars*	Maximum number of characters per line for input and output files. Default 80.
INDENTATION = *scalar*	Number of spaces to leave at the start of each line. Default 0.
PAGE = *scalars*	Number of lines per page in an output file. Set automatically, by default.
ACCESS= *string token*	Controls the way in which unformatted and backingstore files can be accessed (readonly, writeonly, both). Default both.
STYLE = *string token*	Style used to represent the information in an output file (plaintext, html, latex, rtf). Default plain.
HTMLHEAD = *texts*	Text structures containing custom content for the header of an HTML document.

Table 3-8: Parameters of CLOSE.

Parameters	
CHANNEL = *scalars*	Channel number used to refer to the file in other statements (e.g. OPEN, DEVICE)
FILETYPE = *string tokens*	File type (input, output, unformatted, backingstore, procedurelibrary, graphics). Default input.
DELETE = *texts*	Whether to delete the file on closure (yes, no). Default no.

3.7 Saving and loading a Graphics Environment

The appearance of high-resolution graphics in Genstat is controlled by the *Graphics Environment* (see Section 1.3). The FRAME, PEN, XAXIS, YAXIS and ZAXIS directives described in this chapter allow you to modify the graphics environment to obtain control over the appearance of your graphical output. Once you have defined the *Graphics*

Environment, say for a particular type of plot, you may wish to save it for future use. The DSAVE directive allows you to save the current settings of the *Graphics Environment* to an external file. You can then use the DLOAD directive to read it back into Genstat at a later date, so that you can produce plots in the same style. (Note: *Graphics Environments* are saved in a special file format with extension .ggd, see Section 1.3.3).

DSAVE has only two parameters (and no options): The FILENAME parameter gives the name of the file in which to save the current settings of the *Graphics Environment*. The optional DESCRIPTION parameter allows you to supply a text structure containing a one-line description of the *Graphics Environment*. This is useful, for example, to note the particular type of publication the *Graphics Environment* was created for.

DLOAD has only one unnamed parameter (and no options). This is used to supply the file from which to load the settings for the *Graphics Environment*. If this parameter is unset, Genstat restores the default *Graphics Environment*.

In the example code below, we create a grayscale *Graphics Environment*. We save its settings to a .ggd file named “grayscale” (in our working directory). This environment can be loaded at a later date using the statement DLOAD 'grayscale.ggd'.

```
JOB

DLOAD "Set default environment"

"Define the new environment"
FRAME [RESET=yes; GRID=*] 1...32; BOX=include; BOXKEY=bounded; \
      BOXSURFACE=*
PEN [RESET=yes] -1; \ "Axis Title Pen"
    FONT=1; SIZE=1.6; COLOUR='black'
PEN [RESET=yes] -2; \ "Axis Pen"
    THICKNESS=1.6; LINESTYLE=1; COLOUR='black'
PEN [RESET=yes] -3; \  "Axis Labels Pen"
    FONT=1; SIZE=1.4; COLOUR='black'
PEN [RESET=yes] -4; \ "Grid Pen"
    THICKNESS=1; LINESTYLE=2; COLOUR='black'
PEN [RESET=yes] -5; \ "Title Pen"
    FONT=1; SIZE=2; COLOUR='black'
PEN [RESET=yes] -6; \ "Key Pen"
    FONT=1; SIZE=1; COLOUR='black'
PEN [RESET=yes] -7; \ "DSHADE grid"
    THICKNESS=1; LINESTYLE=1; COLOUR='black'
PEN [RESET=yes] -8; \ "Histogram Outlines"
    THICKNESS=1; LINESTYLE=1; COLOUR='black'
PEN [RESET=yes] -9; \  "Barchart Outlines"
    THICKNESS=1; LINESTYLE=1; COLOUR='black'
```

```
PEN [RESET=yes] -10; \ "Pie Outlines"
    THICKNESS=1; LINESTYLE=1; COLOUR='black'
PEN [RESET=yes] -11; \ "Error Bars"
    COLOUR='black'; LINESTYLE=1; METHOD=line; SIZE=1
VARIATE [NVAL=256] symbols; !((2,5,6,7,8,4,12,13,18,11,1,3,9,\
                               19,20,21,22)15,2)
VARIATE [NVAL=256] linestyle; !((1...10)25,1...6)
PEN [RESET=yes] 1...256; SYMBOL=#symbols; COLOUR='black'; \
    CSYMBOL='black'; \
    CFILL='black'; LINESTYLE=#linestyle; SIZE=1; THICKNESS=2

"Save the environment"
DSAVE 'grayscale.ggd'; DESCRIPTION='Grayscale graphics'

ENDJOB
```

3.8 Example

Creating a pink heart (Figure 3.8a) using the fundamental Genstat directives, FRAME, XAXIS, YAXIS, PEN and DGRAPH.

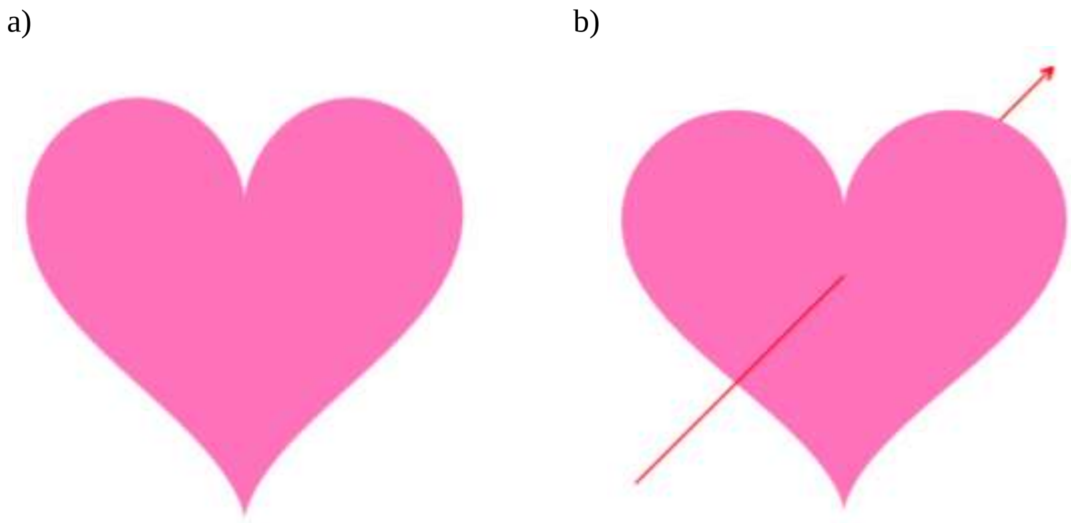


Figure 3.8: Plot of a pink heart (a) pierced with a red arrow (b).

```
"Generate y and x coordinates to create a heart-shaped polygon"
CALC twopi = 2*C('pi')
CALC t = !(0,0.01...#twopi)
CALC xheart = 16*sin(t)**3
CALC yheart = 13*cos(t) - 5*cos(2*t) - 2*cos(3*t) - cos(4*t)
```

```
"Turn off usual axes and frame (window 3 = full screen)"
XAXIS [RESET=yes] WINDOW=3; ACTION=hide
YAXIS [RESET=yes] WINDOW=3; ACTION=hide
FRAME [RESET=yes] WINDOW=3; BOX=omit

"Turn off symbols and fill polygon with hot pink"
PEN [RESET=yes] NUMBER=1; METHOD=fill; SYMBOL=0; JOIN=given; \
    CAREA='hotpink'
DGRAPH [WINDOW=3; KEYWINDOW=0] X=xheart; Y=yheart
```

Pierce the heart with a red arrow, diagonally through the centre, making use of the SCREEN option and LAYER parameter of DGRAPH. (Figure 3.8b).

```
"Generate the coordinates of the arrow"
CALC xarrow = !(0,15,15,14.1,*,14.7,15)
CALC yarrow = !(0,15,15,14.7,*,14.1,15)
"(arrow-head created by breaking the line with missing values)"

CALC yline,xline = !(-15,0)
"(line to heart centre)"

"Add red arrow to existing plot"
PEN [RESET=yes] NUMBER=2; METHOD=line; SYMBOL=0; JOIN=given; \
    COLOUR='red'; THICK=5
DGRAPH [WINDOW=3; SCREEN=resize] PEN=2; LAYER=-1,2; \
  X=xarrow,xline; Y=yarrow,yline
"(appropriate section of the arrow plotted behind the heart
using the LAYER option)"
```

4 Example graphics

This chapter showcases the wide variety of graphics that can be produced by Genstat. The examples contain both the Genstat program as well as the produced figure.

The chapter begins by presenting the graphs generated by directives under their default parameter and option settings (Section 4.1). (A library of example graphs from Genstat's collection of procedures is provided in Appendix 5.1.) The next section (Section 4.2) demonstrates some special features that can be used to create a customized graph. For example, how to add text, a reference line or an oblique axis to a plot. In the final section, an array of example graphs are produced that showcase the breadth of figures possible in Genstat (Section 4.2.17).

Complementary to this chapter are Genstat's built-in example programs. These programs provide examples of how to use the Genstat command language for different directives and procedures. The example programs are accessible via the Help | Example | Commands | Example Programs menu (Figure 4.1). For example, to access the example programs for the DGRAPH directive, search for 'DGRAPH' in the Look for: field and click the Open button. Where multiple examples are available, this launches the Select Example menu window (Figure 4.1) where you can select an example program to display.

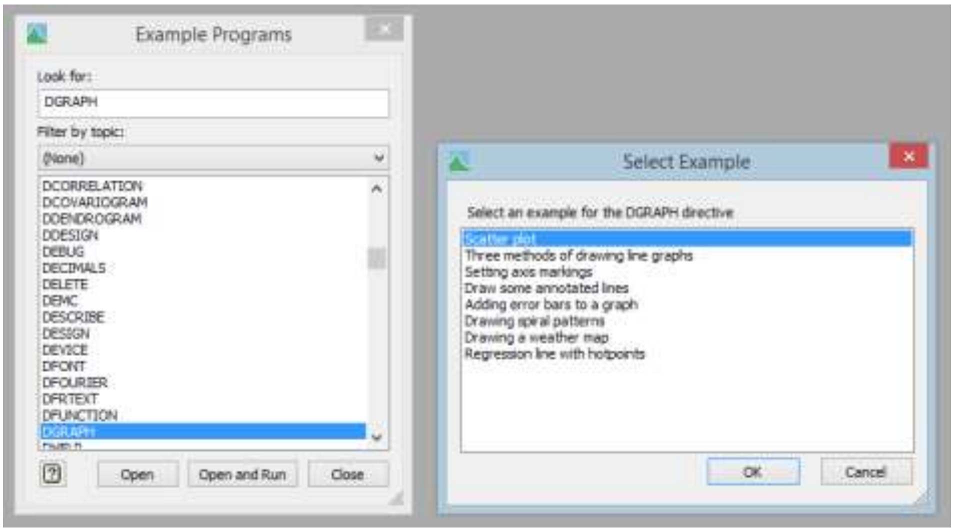


Figure 4.1: Accessing the built-in example programs for the DGRAPH directive.

In this chapter you will:

- generate a plot from each of Genstat's graphical directives (Section 4.1)

- be introduced to many of Genstat’s graphical directives and procedures (Sections 4.1 and 4.2)
- create a wide variety of graphs using the command language (Sections 4.2 and 4.3)

4.1 Default output from Genstat's graphical directives

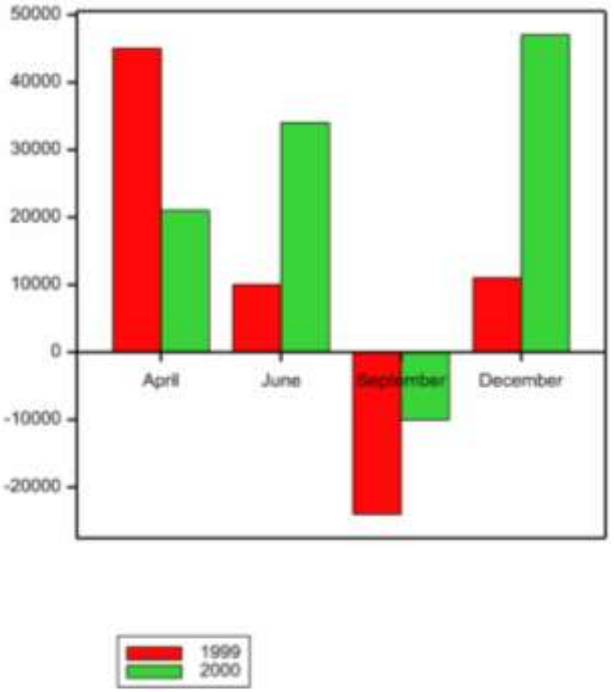
Genstat can produce graphical output in two distinctively different styles: *high-resolution graphics* and *line-printer graphics*. In this section we illustrate the graphs produced by the 10 directives for high-resolution plots (Appendix 5.1.2) and the 3 directives for line-printer plots (Appendix 5.1.1) under their default parameter and options settings. Help documentation for these directives is available within the Genstat Help System (📘) – also see in *Genstat Reference Manual (Part 2 for Directives)* accessible via Help | Reference Manual | Directives….

Note, many additional graphical facilities are provided by Genstat procedures (see Appendix 5.1.3).

Directives for high-resolution plots

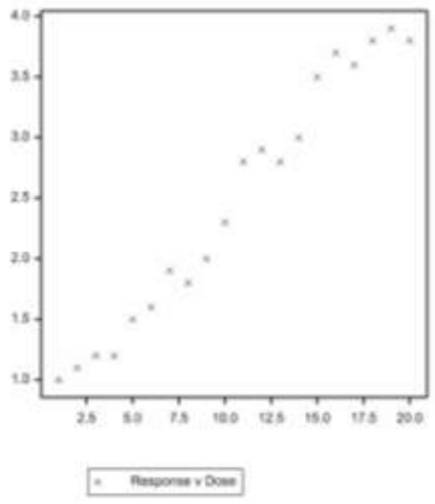
Default output for BARCHART (plots bar charts)

```
JOB 'Default output from BARCHART'

FACTOR [LEVELS=!(1999,2000)] Year
FACTOR [LABELS=!t(April,June,September,December)] Month
TABLE [CLASSIFICATION=Year,Month; \
      VALUES=45000,10000,-24000,11000,\
             21000,34000,-10000,47000] Results

BARCHART Results

ENDJOB
```



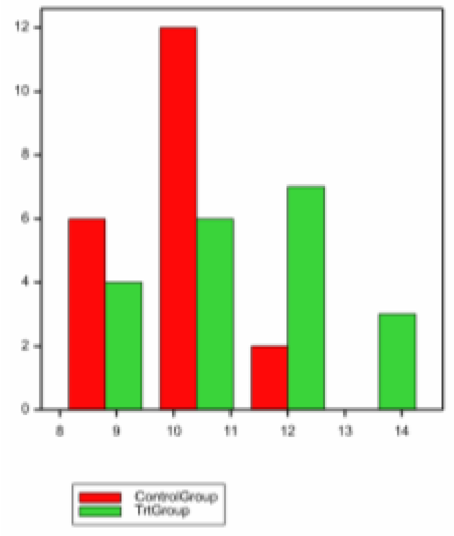
Default output for DGRAPH (plots scatter plots and line graphs)

```
JOB 'Default output from DGRAPH'

VARIATE [VALUES=1...20] Dose
VARIATE [VALUES=1,1.1,1.2,1.2,1.5,1.6,1.9,1.8,2,2.3,2.8,\
                2.9,2.8,3,3.5,3.7,3.6,3.8,3.9,3.8] \
        Response

DGRAPH Response; Dose

ENDJOB
```



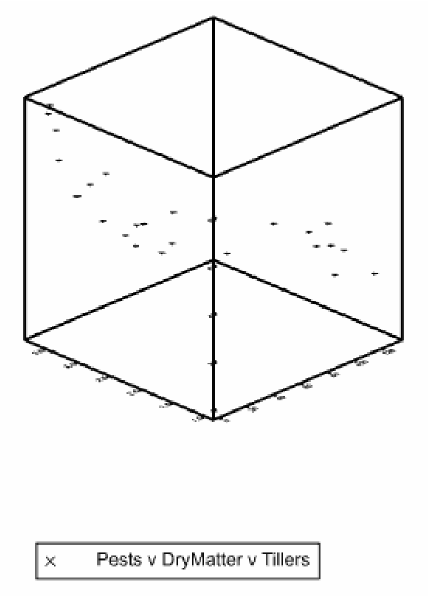
Default output for DHISTOGRAM (plots histograms)

```
JOB 'Default output from DHISTOGRAM'

VARIATE [VALUES=11.6,9.9,10.7,10.7,10.3,10.0,9.7,9.3,\
                10.1,9.0,8.8,11.9,9.5,10.4,8.2,10.4,\
                10.9,9.4,11.1,10.2] ControlGroup
VARIATE [VALUES=13.6,13.3,11.8,13.6,10.2,12.6,10.3,\
                12.7,10.2,8.3,8.8,12.0,9.2,12.6,9.0,\
                11.4,10.2,12.2,10.9,10.7] TrtGroup

DHISTOGRAM ControlGroup,TrtGroup

ENDJOB
```



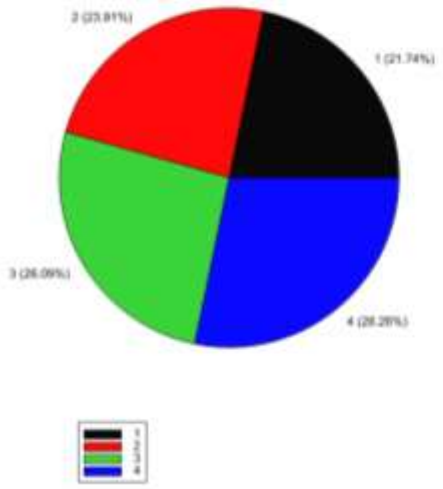
Default output for D3GRAPH (plots a 3-dimensional graph)

```
JOB 'Default output from D3GRAPH'

VARIATE [VALUES=25,27,29,31,31,34,36,37,39,42,42,45,46,\
                48,49,49,50,56,58,63,67,72,85,91,92]\
        Tillers
VARIATE [VALUES=1,1.2,1.5,1.7,1.6,1.9,1.8,2,2.1,2.4,2.3,\
                2.5,2.8,2.7,2.6,2.7,3,3.4,3.3,3.2,3.1,\
                3.5,3.5,3.6,3.7] DryMatter
VARIATE [VALUES=121,101,122,111,117,129,110,59,98,37,25,\
                15,35,52,12,25,14,13,10,14,21,5,3,2,8] \
                Pests

D3GRAPH  Pests; DryMatter; Tillers

ENDJOB
```



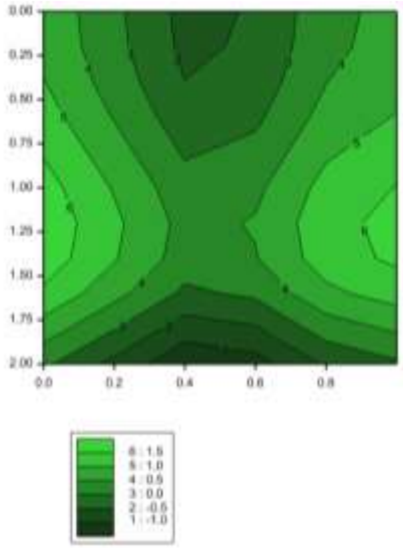
Default output for DPIE (plots pie charts)

```
JOB  'Default output from DPIE'

VARIATE [VALUES=1,1.1,1.2,1.3] Amount

DPIE #Amount

ENDJOB
```



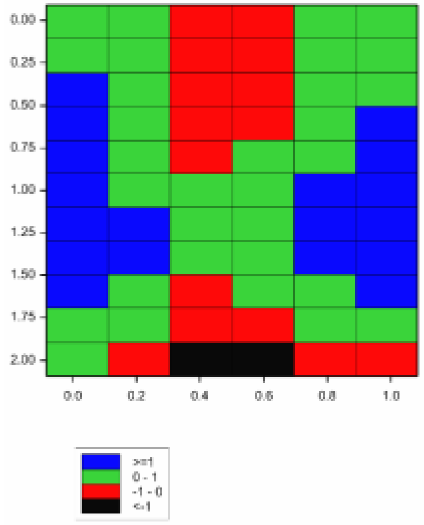
Default output for DCONTOUR (plots contour maps)

```
JOB 'Default output from DCONTOUR'

VARIATE [VALUES=0,0.2...2] Rows
VARIATE [VALUES=0,0.2...1] Columns
MATRIX [ROWS=Rows; COLUMNS=Columns] X, Y, Function
MATRIX [MODIFY=yes; VALUES=(#Columns)11] X
CALCULATE Y$[*;1...6] = Rows
CALCULATE Function=COS(1/(X+0.1)** 2)+SIN(Y**2)

DCONTOUR Function

ENDJOB
```



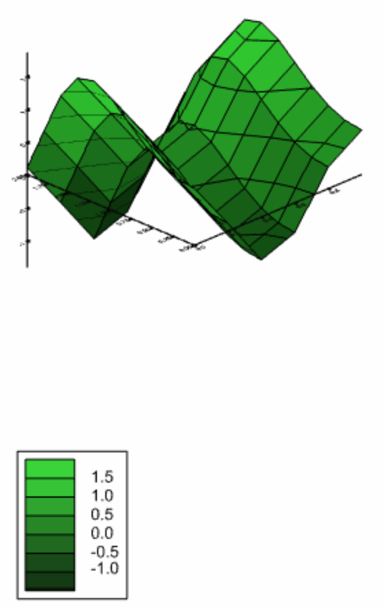
Default output for DSHADE with INTERVAL=1 (plots a shade diagram)

```
JOB 'Default output from DSHADE'

VARIATE [VALUES=0,0.2...2] Rows
VARIATE [VALUES=0,0.2...1] Columns
MATRIX [ROWS=Rows; COLUMNS=Columns] X, Y, Function
MATRIX [MODIFY=yes; VALUES=(#Columns)11] X
CALCULATE Y$[*;1...6] = Rows
CALCULATE Function=COS(1/(X+0.1)** 2)+SIN(Y**2)

DSHADE Function; INTERVAL=1

ENDJOB
```



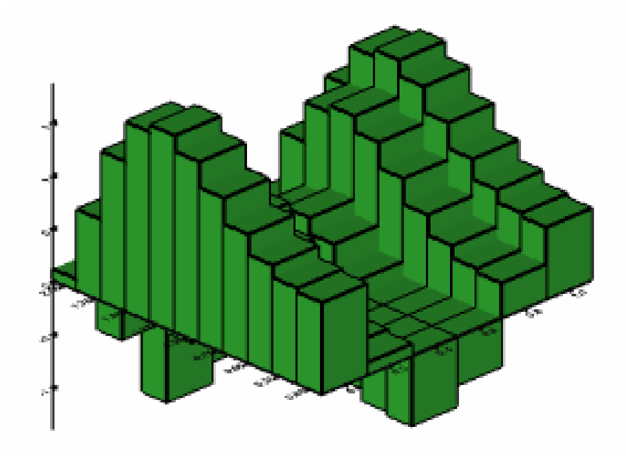
Default output for DSURFACE (draws a perspective plot)

```
JOB 'Default output from DSURFACE'

VARIATE [VALUES=0,0.2...2] Rows
VARIATE [VALUES=0,0.2...1] Columns
MATRIX [ROWS=Rows; COLUMNS=Columns] X, Y, Function
MATRIX [MODIFY=yes; VALUES=(#Columns)11] X
CALCULATE Y$[*;1...6] = Rows
CALCULATE Function=COS(1/(X+0.1)** 2)+SIN(Y**2)

DSURFACE Function

ENDJOB
```



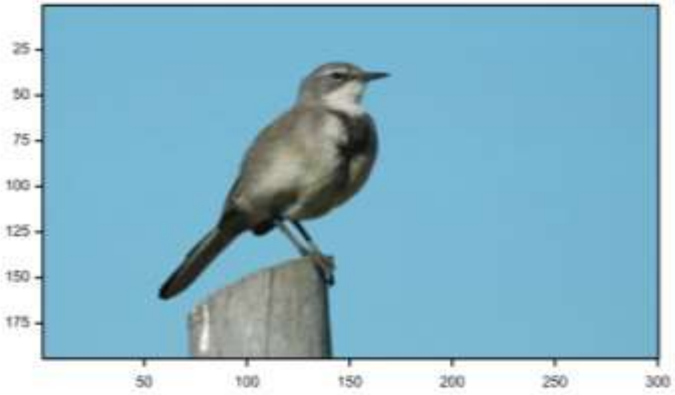
Default output for D3HISTOGRAM (plots a 3-dimensional histogram)

```
JOB 'Default output from D3HISTOGRAM'

VARIATE [VALUES=0,0.2...2] Rows
VARIATE [VALUES=0,0.2...1] Columns
MATRIX [ROWS=Rows; COLUMNS=Columns] X, Y, Function
MATRIX [MODIFY=yes; VALUES=(#Columns)11] X
CALCULATE Y$[*;1...6] = Rows
CALCULATE Function=COS(1/(X+0.1)** 2)+SIN(Y**2)

D3HISTOGRAM Function

ENDJOB
```



Default output for DBITMAP (plots bitmaps of RGB colours)

```
JOB  'Default output from DBITMAP'

IMPORT [RGBMETHOD=matrix] \
       '%GENDIR%/Examples/GuidePart1/CapeWagtail.jpg'; \
       COLUMNS='RGB'
" Resize window 3 to match the dimensions of the bitmap "
CALCULATE Nr = NROWS(RGB)
CALCULATE Nc = NCOLUMNS(RGB)
FRAME 3; YUPPER= Nr / Nc

DBITMAP [WINDOW=3] RGB

ENDJOB
```



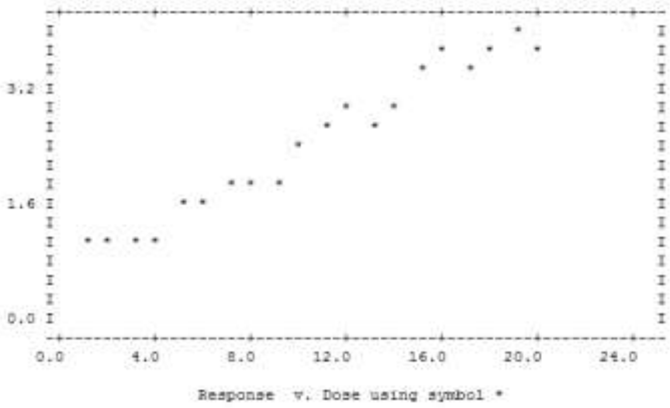
Directives for line-printer plots

As the name suggests, line-printer graphics are designed for printing on ordinary printers. They are also suitable for displaying on computer screens. Line-printer plots form an integral part of the Genstat output, and can thus be interspersed with other results during the analysis of the data.

With line-printer graphics, the standard character set, made up of letters, digits and punctuation characters, is used to produce a graphical representation of the data. This will be of low resolution, but it is often adequate for a quick assessment of the data, or for checking the assumptions of an analysis. Graphs, histograms and contour plots can be produced in this basic style.

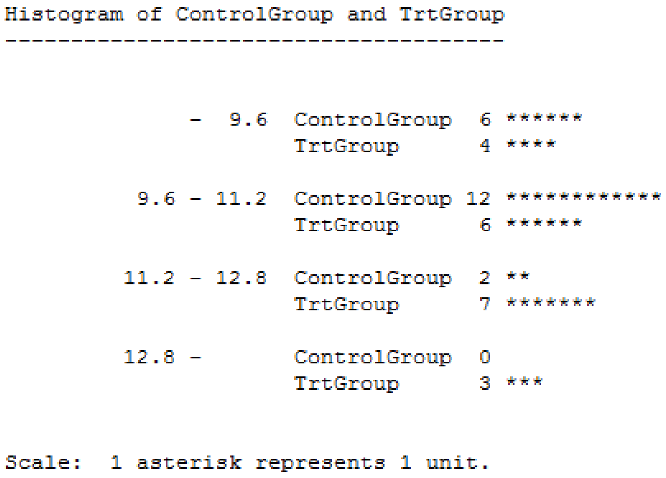
Default output for LPGRAPH (plots scatter plots and line graphs)

```
JOB 'Default output from LPGRAPH'

VARIATE [VALUES=1...20] Dose
VARIATE [VALUES=1,1.1,1.2,1.2,1.5,1.6,1.9,1.8,2,2.3,2.8,\
                2.9,2.8,3,3.5,3.7,3.6,3.8,3.9,3.8] \
        Response

LPGRAPH Response; Dose

ENDJOB
```



Default output for LPHISTOGRAM (plots histograms)

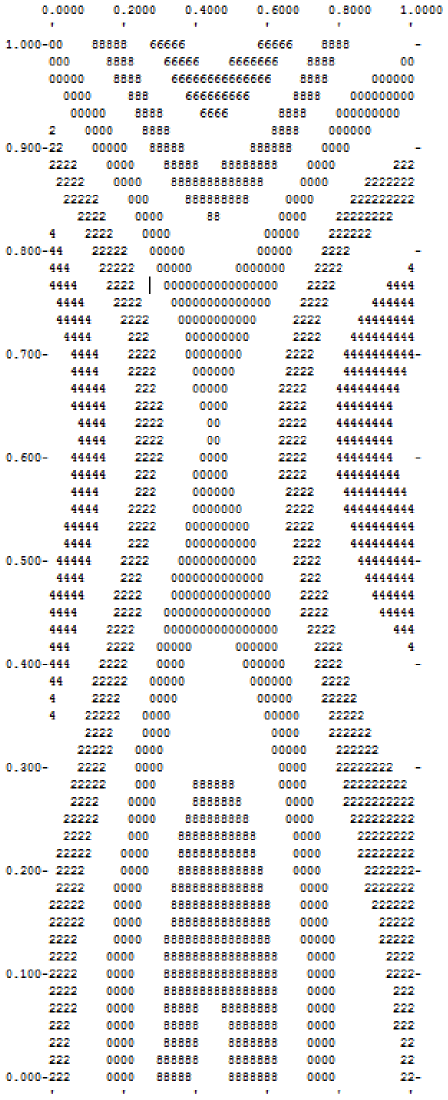
```
JOB 'Default output from LPHISTOGRAM'

VARIATE [VALUES=11.6,9.9,10.7,10.7,10.3,10.0,9.7,9.3,\
                10.1,9.0,8.8,11.9,9.5,10.4,8.2,10.4,\
                10.9,9.4,11.1,10.2] ControlGroup
VARIATE [VALUES=13.6,13.3,11.8,13.6,10.2,12.6,10.3,\
                12.7,10.2,8.3,8.8,12.0,9.2,12.6,9.0,\
                11.4,10.2,12.2,10.9,10.7] TrtGroup

LPHISTOGRAM ControlGroup,TrtGroup

ENDJOB
```



```
Histogram of ControlGroup and TrtGroup
--------------------------------------


           -  9.6   ControlGroup  6 ******
                    TrtGroup      4 ****

       9.6 - 11.2   ControlGroup 12 ************
                    TrtGroup      6 ******

      11.2 - 12.8   ControlGroup  2 **
                    TrtGroup      7 *******

      12.8 -        ControlGroup  0
                    TrtGroup      3 ***


Scale:  1 asterisk represents 1 unit.
```

Default output for LPCONTOUR (plots contour maps)

```
JOB 'Default output from LPCONTOUR'

VARIATE [VALUES=0,0.2...2] Rows
VARIATE [VALUES=0,0.2...1] Columns
MATRIX [ROWS=Rows; COLUMNS=Columns] X, Y, Function
MATRIX [MODIFY=yes; VALUES=(#Columns)11] X
CALCULATE Y$[*;1...6] = Rows
CALCULATE Function=COS(1/(X+0.1)** 2)+SIN(Y**2)

LPCONTOUR Function

ENDJOB
```



```
     0.0000    0.2000    0.4000    0.6000    0.8000    1.0000
      '         '         '         '         '         '
1.000-00    88888   66666          66666    8888         -
      000     8888    66666    6666666    8888         00
      00000    8888    66666666666666    8888      000000
        0000     888     666666666      8888    000000000
         00000    8888     6666       8888    000000000
      2    0000    8888              8888    000000
0.900-22    00000   88888         888888    0000         -
      2222    0000    88888   88888888    0000        222
       2222    0000    8888888888888     0000     2222222
        22222    000     888888888     0000     222222222
          2222    0000      88        0000    22222222
      4    2222    0000             00000    222222
0.800-44    22222   00000          00000    2222         -
      444    22222   00000      0000000    2222         4
      4444    2222  | 0000000000000000    2222       4444
       4444    2222    00000000000000    2222      444444
       44444    2222    00000000000     2222     44444444
        4444     222     000000000      2222    444444444
0.700-   4444    2222    00000000      2222    4444444444-
         4444    2222     000000       2222    444444444
         44444    222     00000       2222    444444444
         44444    2222     0000       2222    44444444
          4444    2222      00        2222    44444444
          4444    2222      00        2222    44444444
0.600-   44444    2222     0000       2222    44444444   -
         44444    222     00000       2222    444444444
         4444     222     000000       2222    444444444
         4444    2222     0000000      2222    4444444444
        44444    2222    000000000     2222     444444444
        4444     222     0000000000     2222    444444444
0.500- 44444    2222    00000000000     2222     44444444-
       4444     222    0000000000000     222      4444444
      44444    2222    00000000000000    2222      444444
      4444     2222   000000000000000    2222       44444
      4444    2222    0000000000000000    2222        444
      444     2222   00000      000000     2222         4
0.400-444    2222    0000        000000    2222          -
      44    22222   00000         000000    2222
      4     2222    0000           00000    22222
      4    22222   0000             00000    22222
           2222    0000              0000    222222
          22222   0000               00000    222222
0.300-    2222    0000                0000    22222222   -
         22222    000     888888      0000     222222222
         2222    0000     8888888      0000    2222222222
        22222    0000    888888888     0000     222222222
        2222     000    88888888888     0000     22222222
       22222    0000    88888888888     0000     22222222
0.200- 2222     0000    888888888888    0000      2222222-
       2222    0000    8888888888888     0000     2222222
      22222    0000    88888888888888    0000      222222
      22222    0000    88888888888888    0000       22222
      2222     0000   888888888888888    00000      22222
      2222    0000    8888888888888888    0000       2222
0.100-2222    0000    8888888888888888    0000       2222-
      2222    0000    8888888888888888    0000        222
      2222    0000    88888   88888888    0000        222
      222     0000    88888    8888888    0000        222
      222     0000    88888    8888888    0000         22
      222     0000   888888    8888888    0000         22
0.000-222     0000   88888     8888888    0000         22-
      '         '         '         '         '         '
```

4.2 Special graphical facilities

Genstat's many graphical directives and procedures (see Appendix 5.1) enable a wide variety of different graphs to be created and customized. This section demonstrates some of the special features that can be used to form a bespoke graph.

4.2.1 Adding text to a graph containing typesetting

Text strings, used for example to add a title or label to a graph, can contain typesetting commands that represent Greek, mathematical and special symbols, or control text formatting. Typesetting commands are introduced by the character tilde (~). They are automatically converted by Genstat to match the style of output (HTML, LaTeX, plain-text or RTF). If Genstat encounters a mistake in the syntax of a typesetting command, it will not issue a failure diagnostic but will output the remainder of the string (including any commands) as plain text.

The following commands define Greek characters and various special and mathematical symbols. The character definitions (within the curly brackets,`{}`) can be abbreviated. Genstat checks through the possibilities, in the order defined below, until it finds the first match. Lower-case Greek characters are obtained by beginning the character definition with a lower-case letter, for example `~{sigma}`, and upper-case by beginning with an upper-case letter, for example `~{Sigma}`.

Symbol	Command	Description	Symbol	Command
~	`~{~}`	tilde symbol; also see `~{tilde}`		
α	`~{alpha}`	Greek character alpha	A	`~{Alpha}`
β	`~{beta}`	Greek character beta	B	`~{Beta}`
γ	`~{gamma}`	Greek character gamma	Γ	`~{Gamma}`
δ	`~{delta}`	Greek character delta	Δ	`~{Delta}`
ϵ	`~{epsilon}`	Greek character epsilon	E	`~{Epsilon}`
ε	`~{varepsilon}`	Greek character epsilon (variant)	E	`~{Varepsilon}`
ζ	`~{zeta}`	Greek character zeta	Z	`~{Zeta}`
η	`~{eta}`	Greek character eta	H	`~{Eta}`

Symbol	Command	Description	Symbol	Command
θ	`~{theta}`	Greek character theta	Θ	`~{Theta}`
ϑ	`~{vartheta}`	Greek character theta (variant)	Θ	`~{Vartheta}`
ι	`~{iota}`	Greek character iota	Ι	`~{Iota}`
κ	`~{kappa}`	Greek character kappa	Κ	`~{Kappa}`
λ	`~{lambda}`	Greek character lambda	Λ	`~{Lambda}`
μ	`~{mu}`	Greek character mu	Μ	`~{Mu}`
ν	`~{nu}`	Greek character nu	Ν	`~{Nu}`
ξ	`~{xi}`	Greek character xi	Ξ	`~{Xi}`
ο	`~{omicron}`	Greek character omicron	Ο	`~{Omicron}`
π	`~{pi}`	Greek character pi	Π	`~{Pi}`
ϖ	`~{varpi}`	Greek character pi (variant)	Π	`~{Varpi}`
ρ	`~{rho}`	Greek character rho	Ρ	`~{Rho}`
ϱ	`~{varrho}`	Greek character rho (variant)	Ρ	`~{Varrho}`
σ	`~{sigma}`	Greek character sigma	Σ	`~{Sigma}`
ς	`~{varsigma}`	Greek character sigma (terminal version)	Σ	`~{Varsigma}`
τ	`~{tau}`	Greek character tau	Τ	`~{Tau}`
υ	`~{upsilon}`	Greek character upsilon	Υ	`~{Upsilon}`
ϕ	`~{phi}`	Greek character phi	Φ	`~{Phi}`
φ	`~{varphi}`	Greek character phi (variant)	Φ	`~{Varphi}`
χ	`~{chi}`	Greek character chi	Χ	`~{Chi}`
ψ	`~{psi}`	Greek character psi	Ψ	`~{Psi}`
ω	`~{omega}`	Greek character omega	Ω	`~{Omega}`

Symbol	Command	Description
•	`~{bullet}`	bullet
·	`~{cdot}`	centred dot; also see `~{middot}`
÷	`~{divide}`	divide symbol
>>	`~{gg}`	">>" symbol; also see `~{raquo}`
<<	`~{laquo}`	"<<" symbol; also see `~{ll}`
<<	`~{ll}`	"<<" symbol; also see `~{laquo}`
·	`~{middot}`	centred dot; also see `~{cdot}`
-	`~{minus}`	minus symbol
±	`~{plusminus}`	plus-minus symbol; also see `~{pm}`
±	`~{pm}`	plus-minus symbol; also see `~{plusminus}`
>>	`~{raquo}`	">>" symbol; also see `~{gg}`
√	`~{sqrt}`	square-root symbol
⊕	`~{oplus}`	plus within circle
(-)	`~{ominus}`	minus symbol within round brackets
⊗	`~{otimes}`	multiply symbol within circle
ø	`~{oslash}`	slash symbol within circle
(.)	`~{odot}`	dot within round brackets
~	`~{tilde}`	tilde symbol; also see ~{~}
×	`~{times}`	multiply symbol

The following commands control formatting:

Command	Description
`~{break}`	starts a new line
`~bold` or `~b`	introduces a sequence of bold characters; these must be placed within curly brackets e.g. `~bold{this text is formatted bold}`
`~italic` or `~i`	introduces a sequence of italic characters; these must be placed within curly brackets e.g. `~italic{this text is italicized}`
`~_`	introduces a subscript; if the subscript is a single character it can be placed immediately after _, otherwise it must be placed within curly brackets
`~^`	introduces a superscript; if the superscript is a single character it can be placed immediately after `^`, otherwise it must be placed within curly brackets

You can use special characters in subscripts or superscripts, but fonts must be specified outside the subscript or superscript. For example:

`~italic{x~_{i,j}}` defines $x_{i,j}$

`x~^{2~{alpha}}` defines $\mathrm{x}^{2\alpha}$

`~bold{X}~italic{~_{i,j}}~^2` defines $\mathbf{X}_{i,j}{}^{2}$

Figure 4.2 provides the output from the various typesetting commands below.

```
JOB
XAXIS 1; ACTION=hide; LOWER=0; UPPER=11
YAXIS 1; ACTION=hide; LOWER=0; UPPER=11
FRAME WINDOW=1; BOX=omit

PEN 1; SYMBOLS=0; \
    LABELS='~{alpha} ~{beta} ~{gamma} ~{delta} ~{epsilon}   ...\
   ~{phi} ~{varphi} ~{chi} ~{psi} ~{omega}'; SIZE=2
DGRAPH [WINDOW=1; KEYWINDOW=0] 10; 1

PEN 1; \
    LABELS='~{Alpha} ~{Beta} ~{Gamma} ~{Delta} ~{Epsilon}   ...\
    ~{Phi} ~{Varphi} ~{Chi} ~{Psi} ~{Omega}'; SIZE=2
DGRAPH [WINDOW=1; KEYWINDOW=0; SCREEN=keep] 9; 1

PEN 1; LABELS='~{bullet} ~{cdot} ~{divide} ~{gg} ~{ll}   ...\
   ~{otimes} ~{oslash} ~{odot} ~{tilde}  ~{times}'
DGRAPH [WINDOW=1; KEYWINDOW=0; SCREEN=keep] 8; 1

PEN 1; LABELS='x~^{2n}'
DGRAPH [WINDOW=1; KEYWINDOW=0; SCREEN=keep] 7; 1

PEN 1; LABELS='~i{x~_{i,j}}'
DGRAPH [WINDOW=1; KEYWINDOW=0; SCREEN=keep] 6; 1

PEN 1; LABELS='~i{x~_{i,j}}~^2'
DGRAPH [WINDOW=1; KEYWINDOW=0; SCREEN=keep] 5; 1

PEN 1; LABELS='x~_{i} - y~_{j}'
DGRAPH [WINDOW=1; KEYWINDOW=0; SCREEN=keep] 4; 1

PEN 1; LABELS='~b{X}~i{~_{i,j}}~^2'
DGRAPH [WINDOW=1; KEYWINDOW=0; SCREEN=keep] 3; 1

PEN 1; LABELS='a~^p + b~^q'
DGRAPH [WINDOW=1; KEYWINDOW=0; SCREEN=keep] 2; 1
```

```
PEN 1; LABELS='y = ~{alpha} + ~{beta} e~^{~{kappa}x}'
DGRAPH [WINDOW=1; KEYWINDOW=0; SCREEN=keep] 1; 1

ENDJOB
```

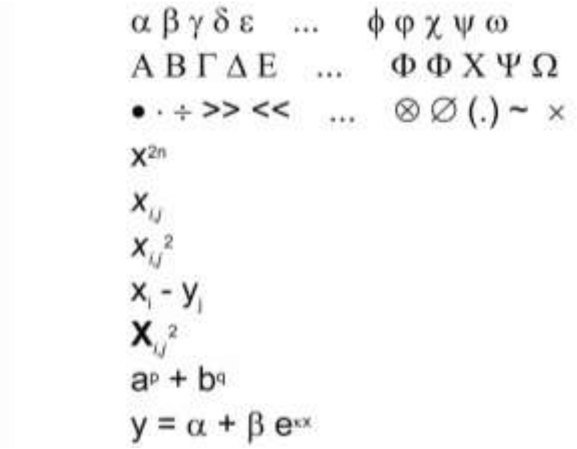


Figure 4.2: Examples of typesetting within text strings.

4.2.2 Specifying the default font using DFONT

Textual information in high-resolution graphs can be displayed in a variety of fonts. The font of a *graphical pen* may be set using the FONT parameter of the PEN directive (see Section 3.4). If this is not done, the pen is assumed to use the *default graphics font*. When Genstat is first installed, the *default graphics font* is set automatically to Arial. However, a new *default graphics font* can be set either:

- in the Fonts tab of the Tools | Options… menu in the *Graphics Viewer* (see Section 1.2.5);
- in the Graphics tab of the Tools | Options… menu in Genstat; or,
- using the DFONT directive (as described here).

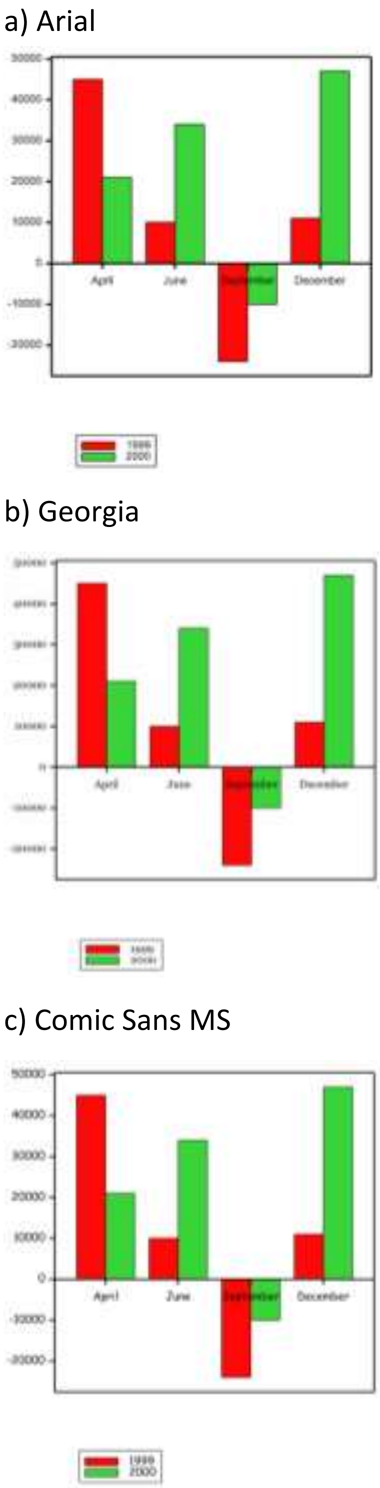
The DFONT directive has a single, unnamed, parameter. This can be used to supply the name of the font family to be used as the default. For example, the command

```
DFONT 'Calibri'
```

sets the *default graphics font* to Calibri. By doing so, all textual information displayed using the *default graphics font* will now appear in the Calibri font. This applies to all graphs that are displayed or redisplayed in the *Graphics Viewer*, including those stored in *Genstat Meta Files*. (Note, the standard Genstat font (i.e. Arial) can be restored as the *default graphics font* by calling DFONT without setting the parameter.)

The example code below draws a bar chart using the *default graphics font* for all textual information. Observe the changing appearance of the bar chart in the *Graphics Viewer* as the DFONT directive is used to modify the *default graphics font* (Figure 4.3).

```
JOB

FACTOR [LEVELS=!(1999,2000)] Year
FACTOR [LABELS=!t(April,June,\
                  September,December)]\
       Month
TABLE [CLASSIFICATION=Year,Month; \
      VALUES=45000,10000,-24000,11000,\
             21000,34000,-10000,47000]\
      Results
"Sets the default graphics font to
 the standard Genstat font, i.e. Arial"
DFONT
"Draw bar chart"
BARCHART Results
"Change default font to Georgia"
DFONT 'Georgia'
"Change default font to Comic Sans MS"
DFONT 'Comic Sans MS'
"Restore the standard Genstat font"
DFONT

ENDJOB
```



a) Arial

b) Georgia

c) Comic Sans MS

Figure 4.3: Changing appearance of a bar chart displayed in the *Graphics Viewer* as the `DFONT` directive is used to alter the *default graphics font* from a) the Genstat standard font, Arial, to b) Georgia, and to c) Comic Sans MS.

The DFONT directive can also be used to save the name of the *default graphics font*. This is achieved by setting the DFONT parameter to supply either a text structure or an undeclared data structure. For example:

```
JOB

"Text string with no values"
DFONT 'Courier New'
TEXT Currentdefault_1
DFONT Currentdefault_1
PRINT Currentdefault_1

"Undeclared structure"
DFONT 'Impact'
DFONT Currentdefault_2
PRINT Currentdefault_2

ENDJOB
```

Note, a list of available fonts can be viewed in the Graphics tab of Genstat's Tools | Options… menu, or in the Fonts tab of the *Graphics Viewer*'s Tools | Options… menu (see Section 1.2.5).

4.2.3 Adding text to a plot using DTEXT

The DTEXT procedure provides a simple method for adding text to an existing plot. The text to be plotted is supplied using the TEXT parameter. This can be either a single string, or a Genstat text structure containing several lines of text. The Y and X parameters define the location that the text is to be plotted. (These are scalars for a single string or line of text, or variates for multiple lines of text.) The PEN parameter specifies the pen (or pens) used to plot the text, and the WINDOW option specifies the window number of the existing plot to which the text is to be added (default 1). In the example below, DTEXT is used to label a Venn diagram (see Figure 4.4).

```
JOB

"Plot Venn diagram in Window 3"
VARIATE [VALUES=0...100] theta
CALCULATE theta = 2 * C('pi') * theta / 100
&          X  = COS(theta)
&          Y1 = SIN(theta)
&          Y2 = Y1 + 1
PEN 1,2; METHOD=fill; SYMBOL=0; JOIN=given; \
    CAREA='blue','red'; TAREA=0,100
```

```
DGRAPH [TITLE='Venn diagram'; WINDOW=3; KEY=0] Y=Y1,Y2; X=X; \
       PEN=1,2

"Add labels using DTEXT"
PEN 3...5; SMLABEL=4; COLOUR='white'; XLPOSITION=centre
DTEXT [WINDOW=3] Y=1.5,0.5,-0.5; X=0; \
      TEXT='A','A and B','B'; PEN=3,4,5

ENDJOB
```

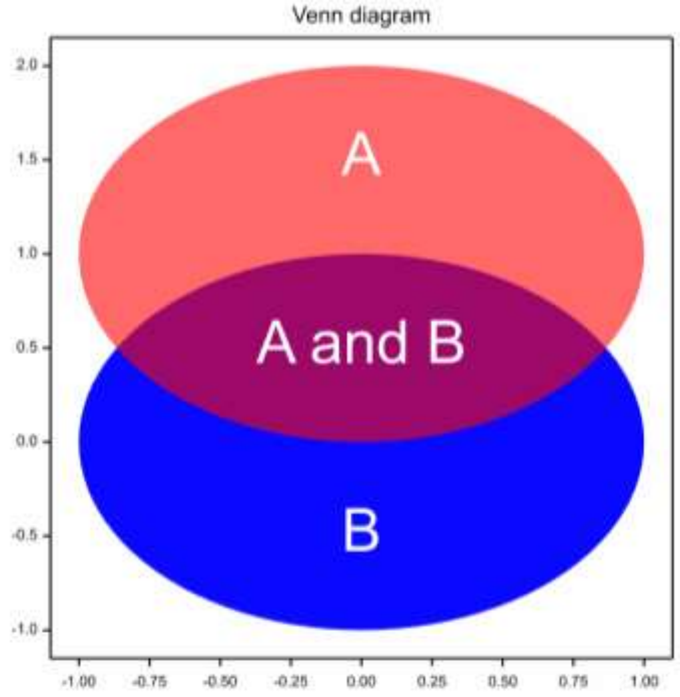


Figure 4.4: Labels added to a Venn diagram using the DTEXT procedure.

4.2.4 Adding text to a graphic frame using DFRTEXT

Similarly to the way in which the DTEXT procedure can add text to a plot inside the graphics frame (Section 4.2.1), the DFRTEXT procedure enables text to be added to the frame. The text to plot is specified by the TEXT parameter. This can be either a single string, or a Genstat text structure containing several lines of text. The Y and X parameters specify the coordinates where the text is to be plotted. These coordinates relate to the *standard device coordinates* used to define windows within the frame (see Section 3.3). They must lie between 0 and the values supplied by the YUPPER and XUPPER parameters (default 1), which set the maximum values in the y- and x-dimensions, respectively. The PEN parameter specifies the pen (or pens) used to plot the text (default 1).

The use of `DFRTEXT` is demonstrated by the commands below to produce Figure 4.5.

```
JOB

"Plot a simple line graph"
PEN 1; METHOD=line; SYMBOL=0
VARIATE [VALUES=1...10] x
XAXIS 3; TITLE='x~^{2}'
YAXIS 3; TITLE='x~^{3}'
DGRAPH [WINDOW=3; KEY=0] x**3; x**2

"Add text to the frame using DFRTEXT"
PEN [RESET=yes] 1,2; ROTATION=315; SIZE=12,3; FONT=1,18; \
    COLOUR='red'
DFRTEXT Y=1.1,0.9; X=0,0; YUPPER=1.1; PEN=1,2; \
        TEXT='DRAFT ONLY', \
             'Text has been added to the frame using DFRTEXT'

ENDJOB
```

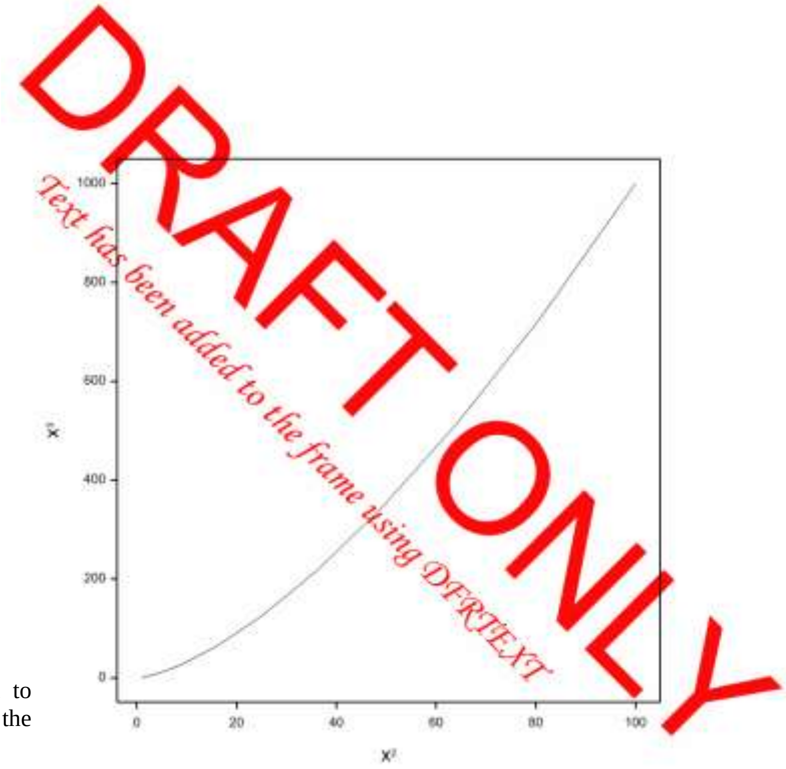


Figure 4.5: Text added to the graphics frame using the `DFRTEXT` procedure.

Note, to include superscripts in the x- and y-axes labels, typesetting commands have been used. See Section 4.2.1 for more information on typesetting.

4.2.5 Adding a reference line to a plot using DREFERENCELINE

The DREFERENCELINE procedure can be used to add horizontal or vertical reference lines to an existing plot.

The window containing the plot to which the reference lines are to be added is specified by the WINDOW option (default 1). The ORIENTATION option controls whether horizontal or vertical reference lines are drawn (default horizontal). The POSITION parameter defines the position of each line, on the y-axis for horizontal lines, or the x-axis for vertical lines. The PEN parameter specifies the pen (or pens) used to draw the reference lines (default 255).

Further parameters (LABEL, YLPOSITION, XLPOSITION and PENLABEL) enable labels to be plotted alongside the reference lines. LABEL supplies the text, YLPOSITION defines the position of the label in the y-direction (above, below, centre; default below), XLPOSITION defines the position in the x-direction (left, right, centre; default left), and PENLABEL specifies the pen to use to write each label (default 256).

In the example that follows, we add vertical and horizontal reference lines to a scatter plot of petal length against petal width to indicate the mean values (see Figure 4.6).

```
JOB

"Plot graph of petal length vrs petal width"
SPLOAD '%GENDIR%/Data/Iris.gsh'
PEN 1...3; SYMBOL='circle'; CFILL='black'; SIZE=1,2,2; \
    COLOUR='black','red','blue
XAXIS WINDOW=3; TITLE='Petal Width'; PENTITLE=2
YAXIS WINDOW=3; TITLE='Petal Length'; PENTITLE=3
DGRAPH [WINDOW=3; KEY=0] Y=Petal_Length; X=Petal_Width

"Calculate petal length and width"
CALCULATE mpl,mpw = MEAN(Petal_Length,Petal_Width)
PEN 2,3; THICKNESS=2; SIZE=1
DREFERENCELINE [WINDOW=3; ORIENTATION=horizontal] mpl; \
               LABEL='Mean length';PEN=3; \
               PENLABEL=3; YLPOSITION=above
DREFERENCELINE [WINDOW=3; ORIENTATION=vertical] mpw; \
               LABEL='  Mean width';\
               PEN=2; PENLABEL=2; XLPOSITION=right

ENDJOB
```

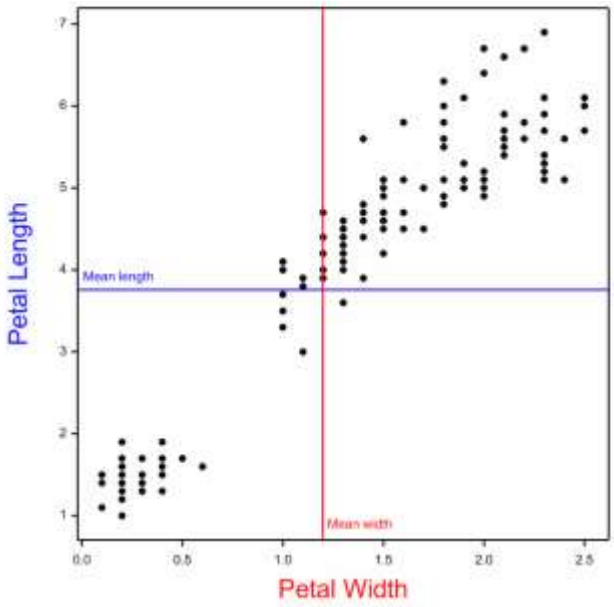


Figure 4.6 Reference lines, with labels, added to a scatter plot using the DREFERENCELINE procedure.

4.2.6 Adding an arrow to a plot using DARROW

Arrows (or lines) can be added to an existing plot using the DARROW procedure.

The options of this procedure are:

- WINDOW: number of the window containing the plot to which arrows are to be added (default 3).
- COORDINATETYPE: whether the points defining the arrows are specified in terms of the x- and y-axes (setting graph, the default) or relative to the frame (setting frame).
- YUPPER and XUPPER: the maximum size of the frame used when COORDINATETYPE=frame (default 1).
- ISTYLE and ESTYLE: symbol at the start and end of the arrows, respectively (none, open, closed, circle; default none).
- ISIZE and ESIZE: size of symbol at the start and end of the arrows, respectively (default 1).
- IANGLE and EANGLE: angle between the two sides at the start and end of the arrowheads, respectively (default 45).
- LAYER: plot layer for the arrows. By default they overlay all previous items.

The IY, IX, EY and EX parameters of the DARROW procedure define the starting and ending y- and x-positions of the arrows. The COLOUR, LINESTYLE, THICKNESS and

TRANSPARENCY parameters specify the colour, line style, thickness and transparency of each arrow.

To illustrate the DARROW procedure, using the code below we create a circle of blue and red arrows of varying thickness. The resulting plot is shown in Figure 4.7.

```
JOB

"Initiate the plotting window"
CALCULATE x1,x2 = 1,8 * COS(C('radians') * !(0,5...355))
CALCULATE y1,y2 = 1,8 * SIN(C('radians') * !(0,5...355))
PEN 1; SYMBOLS=0
XAXIS WINDOW=3; ACTION=hide
YAXIS WINDOW=3; ACTION=hide
DGRAPH [WINDOW=3; KEY=0; TITLE='Circle of arrows'] \
       Y=!(-9,9); X=!(-9,9)

"Add arrows to window 3"
DARROW [WINDOW=3; ESIZE=2; EANGLE=30; ESTYLE='closed'] \
       IY=y1; IX=x1; EY=y2; EX=x2; \
       COLOUR=!t(('red','blue')36); THICKNESS=!((1...3)24)

ENDJOB
```

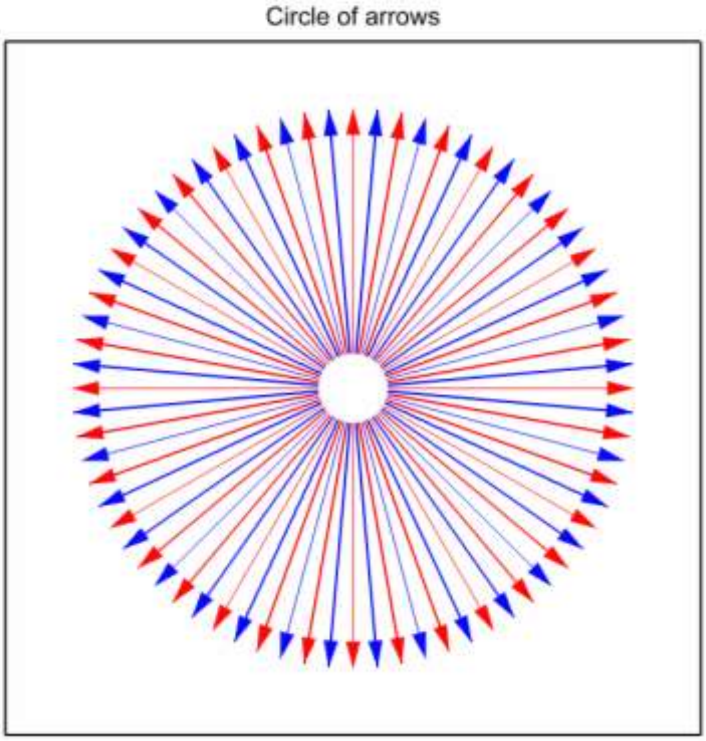


Figure 4.7: Circle of thick and thin blue and red arrows created using DARROW.

4.2.7 Adding error bars to a plot using DERRORBAR

Many graphical directives and procedures allow error bars to be plotted. However, you may want to add error bars to an existing graph or require greater control over the placement and appearance of the error bars. The DERRORBAR procedure enables error bars to be plotted on a graph.

The window containing the graph to which the error bars are to be added is specified by the WINDOW option (default 1). The ORIENTATION option controls whether the bars are plotted horizontally or vertically (default vertical). The BARLENGTH parameter defines the length of each bar, and the Y and X parameters their positions. The BARCAPWIDTH option sets the size of the caps drawn at the ends of the bars, and the PEN parameter specifies the pen (or pens) used to draw the error bars (default 255). The DESCRIPTION parameter enables annotation to be added on the graph's key, and the key's window is specified by the KEYWINDOW option (default 2). Further parameters (LABEL, YLPOSITION, XLPOSITION and PENLABEL) enable labels to be plotted alongside the error bars.

To illustrate the DERRORBAR procedure, we'll add error bars representing the standard error of the mean (SEM), the standard error of the difference (SED) and the least significant difference at the 5% level (LSD(5%)) to a plot of means. The commands below produce Figure 4.8.

```
JOB

"Obtain means, SEMs, SEDs and LSD(5%)s from one-way ANOVA"
SPLOAD '%GENDIR%/Data/Rat.gsh'
A2WAY [PRINT=*; TREATMENTS=diet; PLOT=*] weight
AKEEP diet; MEANS=meanT; SEMEANS=semT; SEDMEAN=sedT; \
     DFMEANS=dfT
CALCULATE lsd = MEAN(sedT*EDT(0*dfT + 0.975; dfT))

"Plot means"
VTABLE TABLE=meanT; VARIATE=means; CLASSIFICATION=!P(dietC); \
       LABELS=label_diet
GETATTRIBUTE [ATTRIBUTE=levels] dietC; levels_diet
XAXIS WINDOW=3; MARKS=#levels_diet; LABELS=label_diet; UPPER=7
PEN 1; SYMBOL=2; SIZE=2; COLOUR='blue'; CFILL='blue'
DGRAPH [WINDOW=3; TITLE='Mean gain weight for each diet'; \
       KEYWINDOW=0] Y=means; X=dietC

"Add error bars representing the SEM, SED and LSD(5%)"
CALCULATE sem = MEAN(semT)
CALCULATE sed = MEAN(sedT)
```

```
PEN [RESET=yes] 1...3; COLOUR='black','darkgreen','red'
DERRORBAR [WINDOW=3] BARLENGTH=sem,sed,lsd; X=4.15,5.15,6.15; \
  LABEL='SEM','SED','LSD(5%)'; PEN=1...3; PENLABEL=1...3; \
  YLPOSITION=below

ENDJOB
```

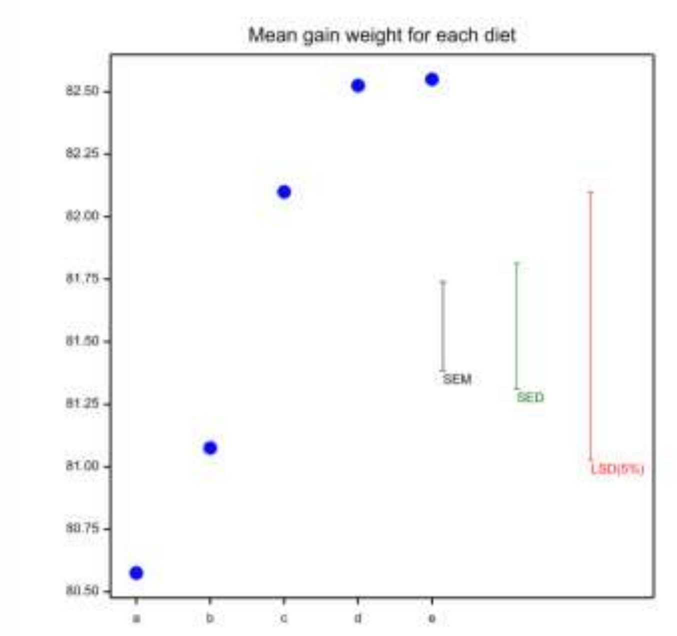


Figure 4.8: Error bars, with labels, added to a plot using the DERRORBAR procedure.

4.2.8 Adding a bespoke key to a graph using DKEY

Keys are automatically added to graphs generated using the ordinary plotting commands. (These can be suppressed by setting the option KEYWINDOW in these commands to zero). However, greater flexibility over the layout and appearance of the key, including allowing the key to span multiple columns, is obtained by defining the key using the DKEY procedure.

The labels to appear in the key are supplied by the DESCRIPTIONS parameter of DKEY. Their size, font and colour can be controlled using either the PENLABELS option or the LSIZE, LFONT and LCOLOUR options.

The types of items to be plotted in the key (points, lines, lines and points, or filled rectangles) are specified using the METHOD parameter. The appearance of these items (symbol type, colour, size, line style, line thickness and transparency) can be controlled using either the PEN parameter or the SYMBOL, COLOUR, CSYMBOL, CFILL, SIZEMULTIPLIER, LINESTYLE, THICKNESS and TRANSPARENCY parameters.

The WINDOW, NCOLUMNS, NROWS, ORDER, XLOFFSET, COLSPACING, ROWGAP, COLGAP, BORDER and CBORDER options control the layout of the key, and the TITLE, PENTITLE and TPOSITION options are used to define the title.

The examples below demonstrate how DKEY can be used to enhance a graph's key. The default key of DGRAPH is shown in Figure 4.9a. Using DKEY, a key is drawn over 3 columns in Figure 4.9b, in a user defined window in Figure 4.9c, and with bespoke labels in Figure 4.9d.

```
JOB

SPLOAD [PRINT=*] '%GENDIR%/Data/Iris.gsh'
XAXIS [RESET=yes] WINDOW=1; Title='Sepal Width (mm)'
YAXIS [RESET=yes] WINDOW=1; Title='Sepal Length (mm)'
PEN [RESET=yes] 1...6; COLOUR=('red','blue','darkgreen')2; \
    SYMBOL=(1,2,3)2; SIZE=3(1,1.2)

"Default key"
DGRAPH Y=Sepal_Length; X=Sepal_Width; PEN=Species

"Define a three-columned key using factor labels with DKEY"
DGRAPH [KEYWINDOW=0] Y=Sepal_Length; X=Sepal_Width; PEN=Species
GETATTRIBUTE [ATTRIBUTE=labels] Species; SAVE=SpeciesLabels
DKEY [NCOLUMNS=3; TITLE='Iris species'; TPOSITION=left,inside] \
     PEN=!(4...6); DESCRIPTIONS=#SpeciesLabels

"Plot key in a bespoke window"
FRAME WINDOW=6; XLOWER=0.72
DGRAPH [KEYWINDOW=0] Y=Sepal_Length; X=Sepal_Width; PEN=Species
DKEY [WINDOW=6; NCOLUMNS=1; BORDER=none; LSIZE=1.2] \
     PEN=!(4...6); DESCRIPTIONS=#SpeciesLabels

"Use coloured labels to define the key"
PEN 1...6; SYMBOL='circle'; CFILL=('red','blue','darkgreen')2
DGRAPH [KEYWINDOW=0] Y=Sepal_Length; X=Sepal_Width; PEN=Species
DKEY [WINDOW=6; NCOLUMNS=1; PENLABELS=!(4...6); BORDER=none; \
      XLOFFSET=-6] !T('~i{Iris setosa}','~i{Iris versicolour}',\
                     '~i{Iris virginica}'); METHOD='none'
PEN [RESET=yes] 1...6
FRAME [RESET=yes] WINDOW=6

ENDJOB
```

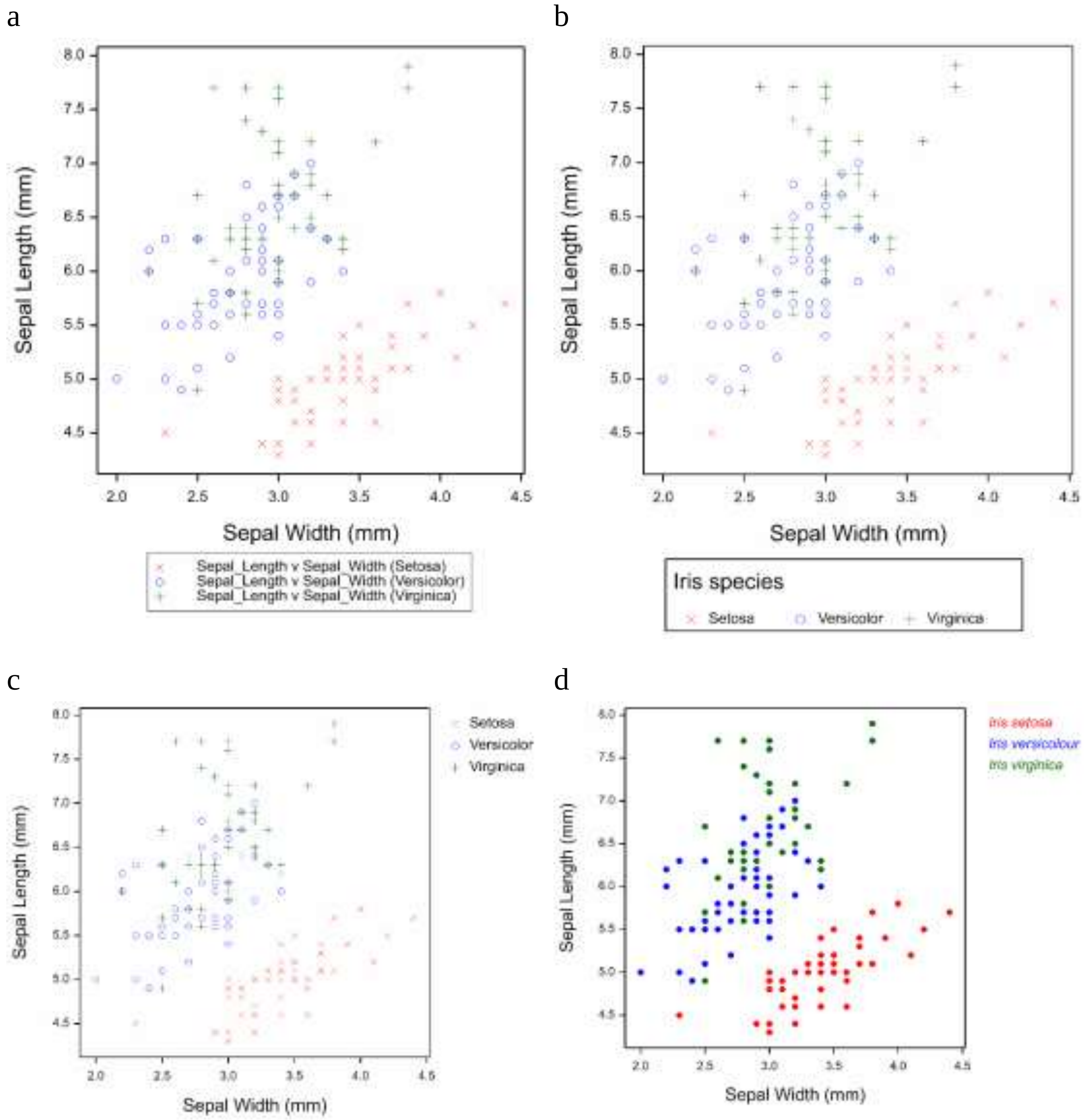


Figure 4.9: Examples of different keys. a) default key, b-d) keys added using DKEY.

4.2.9 Adding an oblique axis using AXIS

Using the AXIS directive an oblique axis can be added to a high-resolution graph. Six parameters are used to define the location and direction of the axis:

- The position of the axis origin in the x-, y- and z-dimensions is specified by the XZERO, YZERO and ZZERO parameters, respectively.
- The size of the steps in the x-, y- and z-directions, corresponding to a step of length

one along the axis, are specified by XSTEP, YSTEP and ZSTEP parameters, respectively.

The IDENTIFIER parameter is used to supply an identifier to store the axis definition. You can then use this as a setting of the AXES parameter of the FRAME directive to display the axis in a particular graphics window.

The other parameters (TITLE, TPOSITION, TDIRECTION, LOWER, UPPER, MARKS, MPOSITION, LABELS, LPOSITION, LDIRECTION, LROTATION, NSUBTICKS, PENTITLE, PENAXIS, PENLABELS, ARROWHEAD, ACTION, TRANSFORM, DECIMALS, DREPRESENTATION, VREPRESENTATION, SAVE) define particular attributes of the axis (as for XAXIS, YAXIS and ZAXIS, see Section 3.5). For example, the LOWER and UPPER parameters specify the lower and upper bounds for the axis, respectively. The option, RESET, determines whether the axis definition is reset to the default values.

In the following example, we examine two methods of measuring peak expiratory flow rate (data from Bland & Altman (1986), Lancet, 307-310). The data comprises Wright peak flow meter and mini Wright meter measurements made on 17 samples. We plot the data, and use the AXIS directive to add an oblique axes through the 1-1 line. The resulting graph is shown in Figure 4.10.

```
JOB

"Create two variates containing the data."
VARIATE [NVALUES=17] peak,mini; VALUES=\
        !(494,395,516,434,476,557,413,442,650,\
          433,417,656,267,478,178,423,427),\
        !(512,430,520,428,500,600,364,380,658,\
          445,432,626,260,477,259,350,451)

"Define the x and y-axes."
XAXIS 1; LOWER=200; UPPER=700; \
      TITLE='Wright peak flow meter'
YAXIS 1; LOWER=200; UPPER=700; \
      TITLE='Mini Wright meter'

"Define an oblique axis through the 1-1 line. That is, set the
origin to (x,y)=(0,0), and move SQRT(0.5) steps along both the x
and y-axes for every 1 step along the 1-1 line. (The values of
XSTEP and YSTEP are readily obtained using the Pythagorean
theorem.) The LOWER and UPPER parameters are set to correspond
to those defined by the XAXIS and YAXIS directives. The pen to
be used to draw the axis is set to 2 using the PENAXIS
```

```
parameter. The resulting axis definition is saved to 'OnetoOne'
using the IDENTIFIER parameter."
AXIS IDENTIFIER=OnetoOne; LOWER=200; UPPER=SQRT(2*700**2); \
     LPOSITION=*; PENAXIS=2; \
     XZERO=0; YZERO=0; XSTEP=SQRT(0.5); YSTEP=SQRT(0.5)

"Set the colour and thickness of the line used to draw the
 oblique axis."
PEN 2; COLOUR='blue'; THICKNESS=4

"Set AXES parameter of FRAME to display the oblique axis
 saved as OnetoOne."
FRAME 1; AXES=OnetoOne

"Plot the data."
DGRAPH [WINDOW=1; KEYWINDOW=0] Y=mini; X=peak

ENDJOB
```

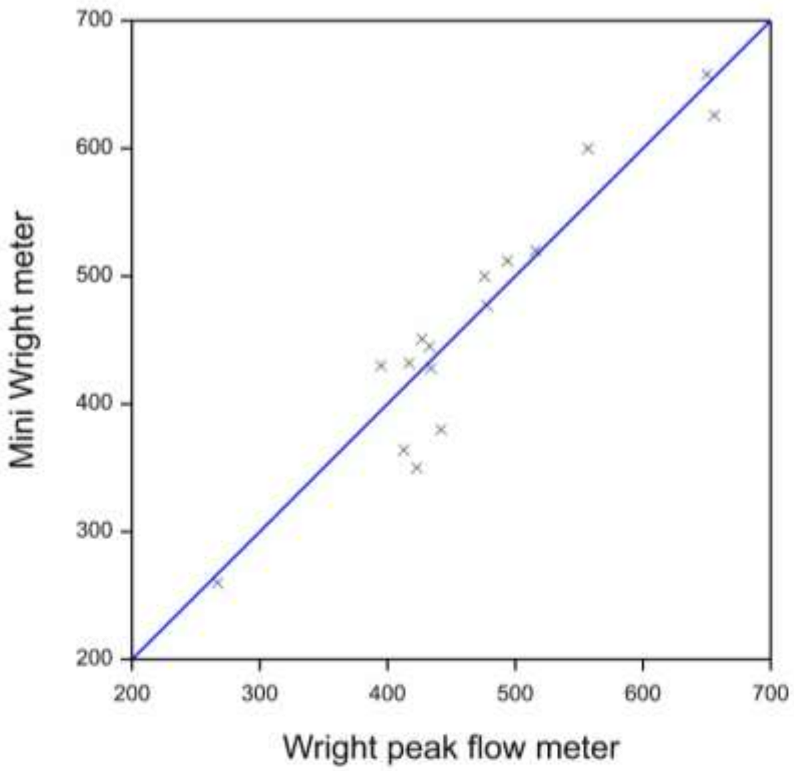


Figure 4.10: Blue line is an oblique axis (at 45 degrees) defined using AXES directive.

4.2.10 Creating a composite graphic

Many Genstat graphics commands have a SCREEN option, which can be set to keep to enable you to add new information to the current display. The output from each graphics command is drawn in one or more *graphics windows* (see FRAME, Section 3.3). These windows are independent of one another, and in most graphics devices they can be displayed simultaneously on the same graphics screen. Furthermore, on most devices, the windows can overlap or contain other windows. This enables you to plot a sequence of windows (keeping the current display) to build up a multiple display with different graphs in adjacent windows. Several Genstat procedures make use of this facility, for example trellis plots (TRELLIS) and scatter-plot matrices (DMSCATTER).

Alternatively, you may be able to plot new information in an existing window to build up a complex picture in several stages. However, there are limitations on what a single window can contain. For example, you can use DGRAPH any number of times *but with no more than one other* DHISTOGRAM, CONTOUR *or* DSHADE *command*. This approach is used in graphics procedures like BOXPLOT and DDENDROGRAM.

The following code generates the multi-layered plot in Figure 4.11, in which a monotonic line plot is superimposed onto a histogram.

```
JOB

"Generate data from the normal distribution"
GRANDOM [DISTRIBUTION=Normal; NVALUES=1000; SEED=12345; \
        MEAN=10; VARIANCE=5] RandomNormal

"Plot histogram"
XAXIS WINDOW=3; LOWER=1; UPPER=18
YAXIS WINDOW=3; LOWER=0; UPPER=200
VARIATE [VALUES=2...17] Limits
DHISTOGRAM [WINDOW=3; KEYWINDOW=0; LIMITS=Limits] RandomNormal

"Superimpose normal curve"
VARIATE [VALUES=1.0,1.1...18.0] X
CALCULATE Mu = MEAN(RandomNormal)
&         Sigma = SQRT(VARIANCE(RandomNormal))
&         Y = 1 / (SQRT(2*C('PI')) * Sigma) * \
              EXP(-0.5*((X-Mu)/Sigma)**2)
&         Y = Y * NVALUES(RandomNormal)
PEN 1; METHOD=monotonic; SYMBOL=0; THICKNESS=5
DGRAPH [WINDOW=3; KEYWINDOW=0; SCREEN=keep] Y; X

ENDJOB
```

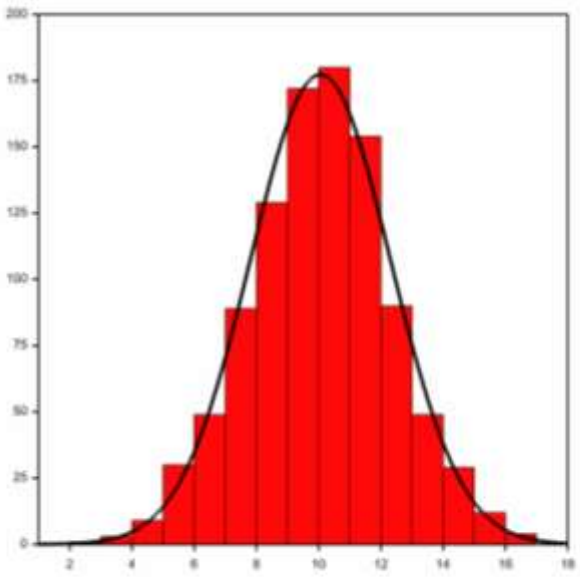


Figure 4.11: Using `SCREEN=keep` to layer graphs.

When generating composite displays using a sequence of graphics commands, it is often convenient to clear the screen at the outset. Doing so means that all subsequent commands can have the option `SCREEN=keep` (or, for `DGRAPH`, `SCREEN=resize`), simplifying the programming particularly if they are in a `FOR` loop. This can be achieved using the `DCLEAR` directive. `DCLEAR` clears the screen of a graphics device so that the next plot produced by this device will be drawn onto an empty screen.

An example illustrating the use of `DCLEAR` before a `FOR` loop follows. This produces the graph given in Figure 4.12.

```
JOB

DCLEAR

"Variate of means"
VARIATE [VALUES=1,4,6,10] means
"Variate of variances"
VARIATE [VALUES=2,4,8,3] variances
"Colour for the pens"
TEXT [VALUES=darkred,forestgreen,navy,orange] colour
"Plot normal curves using a FOR loop"
VARIATE [VALUES=-4,-3.9...20] X
FOR n=1...4
   CALCULATE Mu = means$[n]
   &         Sigma = SQRT(variances$[n])
   &         Y = 1 / (SQRT(2*C('PI')) * Sigma) * \
                 EXP(-0.5*((X-Mu)/Sigma)**2)
   PEN 1; METHOD=monotonic; SYMBOL=0; THICKNESS=2; \
       COLOUR=colour$[n]
   DGRAPH [WINDOW=3; KEYWINDOW=0; SCREEN=resize] Y; X
   TXCONSTRUCT [label] 'mean=',Mu,', variance=',variances$[n]
   FRAME WINDOW=4; BOX=omit; \
         YLOWER=0.7; YUPPER=0.85; XLOWER=0.7; XUPPER=1; \
         YMLOWER=0; YMUPPER=0; XMLOWER=0; XMUPPER=0
   DTEXT [WINDOW=4] Y=n/3; X=0; TEXT=label; PEN=1
ENDFOR

ENDJOB
```

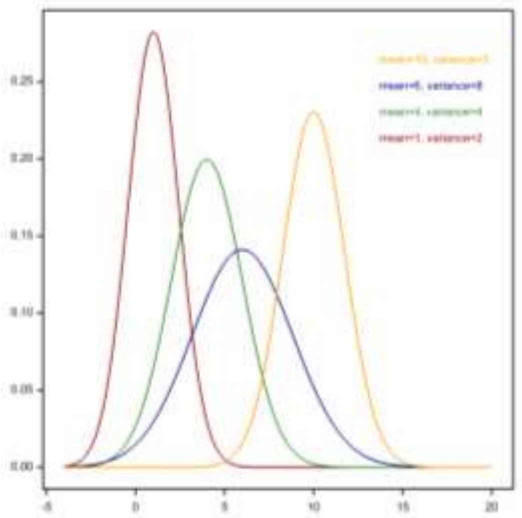


Figure 4.12: Graph produced using DCLEAR before a FOR loop.

An efficient way of generating a composite display is to define an explicit sequence of plots using the DSTART and DFINISH directives. The information from each command is accumulated by Genstat, with no high-resolution plots being drawn until the DFINISH command is received. To demonstrate, replace the DCLEAR statement in the previous code with DSTART, and add a DFINISH statement before ENDJOB. This will result in a plot identical to that in Figure 4.12.

When you use several statements with SCREEN=keep to build up a complex graph, the axes are drawn only the first time, and the same axes bounds are used for all subsequent graphs. If the axis bounds are too narrow, some points may be excluded, a phenomenon known as *clipping*. To avoid this you should define axis limits that enclose all the subsequent data, using YAXIS, XAXIS and ZAXIS. This was the approach we took to generate Figure 4.11. Alternatively, DGRAPH offers the option SCREEN=resize. This causes the axes and their bounds to be adjusted, if necessary, to enclose the additional information. This was the approach we took when generating Figure 4.12.

4.2.11 Forming a plot-matrix using FFRAME

The FFRAME procedure provides a convenient means of forming a plot-matrix, i.e. a multi-windowed figure. The options of FFRAME are used to define the windows comprising the plot-matrix, including their size and arrangement. The parameters are used to save these settings. The options and parameters controlling FFRAME are briefly described in Table 4-1.

Table 4-1: Options and parameters of FFRAME.

Options	
PRINT = *string tokens*	Specifies whether to display the layout and numbering of the plot-matrix in a table or in a high-resolution test-graph (table, testgraph). By default, nothing is displayed.
ARRANGEMENT = *string token*	Defines the arrangement of the plot-matrix. This can be either rectangle (the default), square, lowersymmetric, uppersymmetric or diagonal.
ROWS = *scalar*	Number of rows in the plot-matrix. Default 3.
COLUMNS = *scalar*	Number of columns in the plot-matrix. Default 3.
DIAGONALWINDOWS = *string token*	Specifies whether to include or exclude the diagonal in symmetric plot-matrices (default include).
SQUARESHAPES = *string token*	Specifies whether to force the individual windows (excluding margins for annotation) to be square. Default no.
STARTWINDOW = *scalar*	The number of the first window. Default 1.
TESTGRAPH = *variate*	Windows to be displayed in a test-graph. (Note, if this option is set, only a test-graph is produced and all other settings are ignored).
NUMBERING = *string token*	Specifies whether the individual windows are numbered rowwise (the default) or columnwise.
DEFINE = *string token*	Specifies whether to define the windows within the procedure (windows, nothing). Default windows.
CLEARWINDOW = *scalar* or *variate*	Defines the windows for which the screen should be cleared. Default 1.
RLOWER = *scalar*	Lowest y device coordinate. Default 0.
RUPPER = *scalar*	Highest y device coordinate. Default 1.
CLOWER = *scalar*	Lowest x device coordinate. Default 0.
CUPPER = *scalar*	Highest x device coordinate. Default 1.
RSKIP = *scalar*	Space between windows along the y-axis. Default 0.
CSKIP = *scalar*	Space between windows along the x-axis. Default 0.

`MARGIN`= *string token*	Specifies where title margins are needed (`xtitle`, `ytitle`, `none`, `small`). The size of the margins is set to default values, however these can be explicitly set using `YMLOWER`, `YMUPPER`, `XMLOWER` and `XMUPPER`.
`YMLOWER` = *scalar*	Size of bottom margin (x-axis labelling) in each window.
`YMUPPER` = *scalar*	Size of upper margin (overall title) in each window.
`XMLOWER` = *scalar*	Size of left-hand margin (y-axis labelling) in each window.
`XMUPPER` = *scalar*	Size of right-hand margin in each window.
`RMLOWER` = *scalar*	Additional size of bottom margin (x-axis labelling) in windows at the bottom of the plot-matrix. Default `0`.
`RMUPPER` = *scalar*	Additional size of upper margin (overall title) in windows at the top of the plot-matrix. Default `0`.
`CMLOWER` = *scalar*	Additional size of left-hand margin (y-axis labelling) windows at the left of the plot-matrix. Default `0`.
`CMUPPER` = *scalar*	Additional size of right-hand margin in windows at the right of the plot-matrix. Default `0`.
`BACKGROUND` = *text* or *scalar*	Specifies the background colour to be used in each window.
Parameters	
`NGRAPHS` = *scalar*	Scalar to save the number of windows in the plot-matrix.
`SWINDOW` = *pointer*	Pointer to save scalars with the window numbers.
`SYLOWER` = *pointer*	Pointer to save scalars with the lower and upper y device coordinates for each window, respectively.
`SYUPPER` = *pointer*	
`SXLOWER` = *pointer*	Pointer to save scalars with the lower and upper x device coordinates for each window, respectively.
`SXUPPER` = *pointer*	
`SSCREEN` = *pointer*	Pointer to save single-valued texts with value 'clear' or 'keep' for each window.
`SMYLOWER` = *pointer*	Pointer to save scalars with the size of the bottom and upper margins for each window, respectively.
`SMYUPPER` = *pointer*	
`SMXLOWER` = *pointer*	Pointer to save scalars with the size of the left-hand and right-hand margins for each window, respectively.
`SMXUPPER` = *pointer*	

To illustrate the `FFRAME` procedure, we create an array of 8 windows into which we display boxplots and scatterplots of Fisher's Iris data. The arrangement of the windows in the frame is depicted in the test-graph of Figure 4.13. The resulting multi-windowed figure is shown in Figure 4.14.

```
JOB
```

```
"Define a multi-window frames"
FFRAME [ROWS=1; COLUMNS=2; STARTWINDOW=1; RUPPER=1.0; \
       RLOWER=0.9; MARGIN=none]
FFRAME [ROWS=2; COLUMNS=2; STARTWINDOW=3; RUPPER=0.9; \
       RLOWER=0.3; CMLOWER=0.02]
FFRAME [ROWS=1; COLUMNS=2; STARTWINDOW=7; RUPPER=0.3; \
       RLOWER=0.0; MARGIN=ytitle,xtitle]

"Generate test graph showing layout"
FFRAME [TESTGRAPH=!(1...8)]

"Clear the graphics screen"
DCLEAR

"Text in windows 1 and 2"
FRAME WINDOW=1,2; BOX=omit
PEN 100; SIZE=2; FONT=5; COLOUR='blue'
DTEXT [WINDOW=1] TEXT='Sepal Measurements'; PEN=100; Y=0; X=0
DTEXT [WINDOW=2] TEXT='Petal Measurements'; PEN=100; Y=0; X=0

"Boxplots of iris measurement in windows 3 to 6"
SPLOAD '%GENDIR%/Data/Iris.gsh'
YAXIS WINDOW=3,4; MARKS=1; LOWER=0; UPPER=8
YAXIS WINDOW=5,6; MARKS=1; LOWER=0; UPPER=5
SCALAR win; 3
TEXT [VALUES='Length',*,'Width',*] title
FOR [INDEX=i] var=Sepal_Length,Petal_Length,\
                  Sepal_Width,Petal_Width
   BOXPLOT [WINDOW=win; SCREEN=keep; \
           AXISTITLE=title$[i]] DATA=var; GROUP=Species
   CALC win = win+1
ENDFOR

"Scatterplot of length vrs widths in windows 7 and 8"
YAXIS WINDOW=7,8; MARKS=1; LOWER=0; UPPER=8; TITLE='Length'
XAXIS WINDOW=7,8; MARKS=1; LOWER=0; UPPER=5; TITLE='Width'
DGRAPH [WINDOW=7; SCREEN=keep; KEYWINDOW=0] \
       Y=Sepal_Length; X=Sepal_Width; PEN=Species
DGRAPH [WINDOW=8; SCREEN=keep; KEYWINDOW=0] \
       Y=Petal_Length; X=Petal_Width; PEN=Species

"Add a key in window 8"
DTEXT [WINDOW=8] TEXT='Setosa'; PEN=1; Y=6; X=3.5
DTEXT [WINDOW=8] TEXT='Versicolor'; PEN=2; Y=5; X=3.5
DTEXT [WINDOW=8] TEXT='Virginica'; PEN=3; Y=4; X=3.5

ENDJOB
```

Note, the code above makes use of the DCLEAR directive, which clears the screen so that the next plot produced is drawn onto an empty screen (see Section 4.2.10).

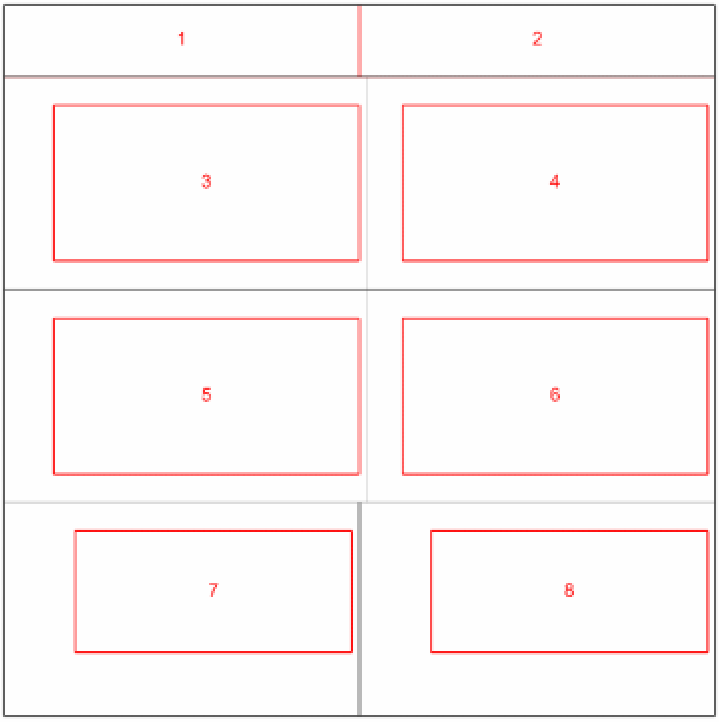


Figure 4.13: Test-graph showing the arrangement of windows 1 to 8 following the three calls to FFRAME.

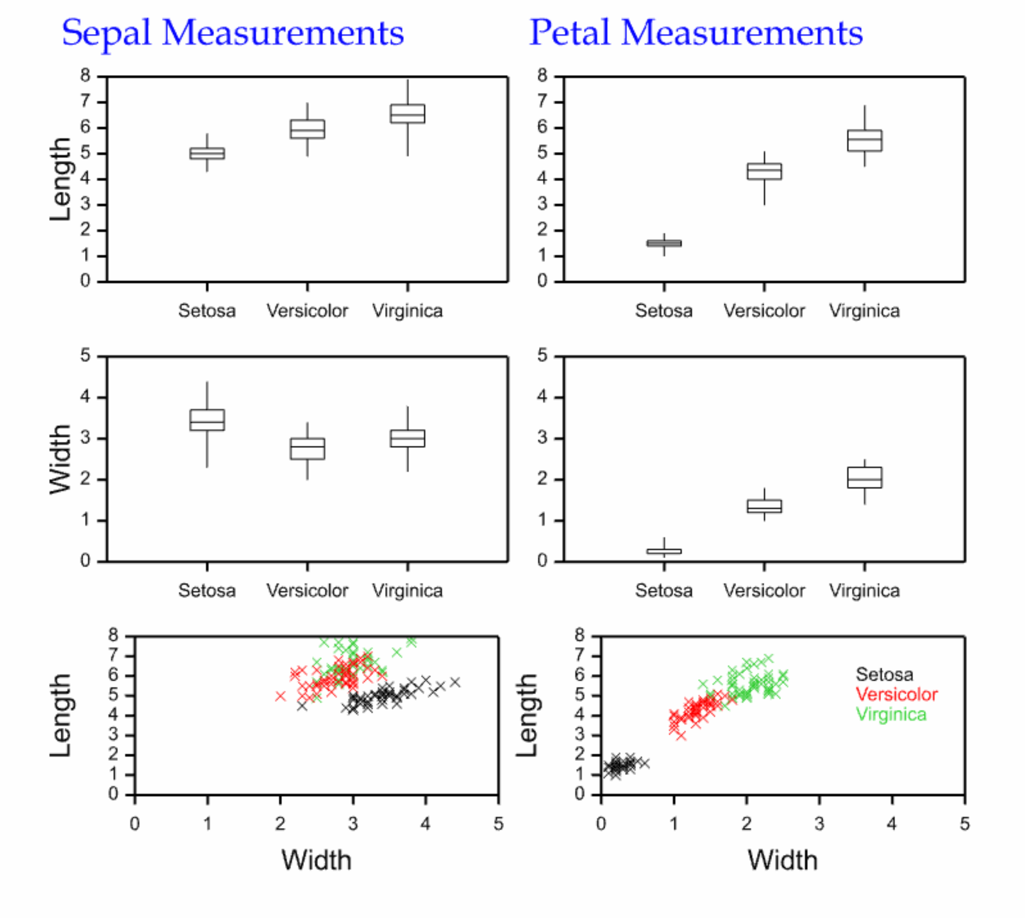


Figure 4.14: Multi-windowed figure created using FFRAME.

4.2.12 Forming a band of graduated colours using DCOLOURS

Procedure DCOLOURS can be used to create a band of graduated colours by interpolating between start and end colour values (set by parameters START and END, respectively). The number of colours in the band is set using the NCOLOURS parameter (default 20).

The type of colour band that is constructed is determined using the METHOD option. The default, METHOD=linear, forms the colour band by interpolating between START and END RGB values. (Text containing the name of a pre-defined colour may also be supplied). Alternatively, METHOD=spectral forms an approximate rainbow spectrum for wavelengths between 380 nm and 780 nm. Here, the START and END parameters specify the start and end wavelengths. The final setting, METHOD=blackbody, forms colours of hot objects with temperatures between 500 K and 11000 K. Here the START and END parameters specify the start and end temperatures.

By default, the red, green and blue values of the colour band are assumed to vary linearly with wavelength, temperature or RGB. However, you can use the `GAMMA` parameter to specify a power transformation (default `1`).

The RGB values of the colours in the band can be saved in a variate using the `RGB` parameter. Alternatively, the red, green and blue components of the colours can be saved using the `RED`, `GREEN` and `BLUE` parameters (again in variates).

To display a test graph of the colour band, we can set option `PLOT=testgraph` (and use the parameters `WINDOW`, `TITLE` and `SCREEN` as normal).

The following code generates a range of colour bands using `DCOLOURS`. These are displayed in a multi-windowed frame (defined using `FFRAME`, see Section 4.2.11) to generate Figure 4.15.

```
JOB
FFRAME [ROWS=9; COLUMNS=2; MARGIN=none; STARTWINDOW=21; \
       YMUPPER=0.02; YMLOWER=0.03; CSKIP=0.02; \
       NUMBERING=columnwise]
PEN -5; SIZE=0.9

DCOLOURS [METHOD=spectral; PLOT=test] GAMMA=0.3; WINDOW=21

DCOLOURS [METHOD=spectral; PLOT=test] GAMMA=1.0; WINDOW=22; \
         SCREEN=keep

DCOLOURS [METHOD=spectral; PLOT=test] GAMMA=3.0; WINDOW=23; \
         SCREEN=keep

DCOLOURS [METHOD=blackbody; PLOT=test] GAMMA=0.3; WINDOW=24; \
         SCREEN=keep

DCOLOURS [METHOD=blackbody; PLOT=test] GAMMA=1.0; WINDOW=25; \
         SCREEN=keep

DCOLOURS [METHOD=blackbody; PLOT=test] GAMMA=3.0; WINDOW=26; \
         SCREEN=keep

DCOLOURS [METHOD=linear; PLOT=test] GAMMA=0.3; WINDOW=27; \
         SCREEN=keep

DCOLOURS [METHOD=linear; PLOT=test] GAMMA=1.0; WINDOW=28; \
         SCREEN=keep

DCOLOURS [METHOD=linear; PLOT=test] GAMMA=3.0; WINDOW=29; \
         SCREEN=keep
```

```
DCOLOURS [METHOD=linear; PLOT=test] START='red'; END='green'; \
         WINDOW=30; SCREEN=keep

DCOLOURS [METHOD=linear; PLOT=test] START='red'; END='blue'; \
         WINDOW=31; SCREEN=keep

DCOLOURS [METHOD=linear; PLOT=test] START='green'; END='blue'; \
         WINDOW=32; SCREEN=keep

DCOLOURS [METHOD=linear; PLOT=test] START='red'; \
         END=!t('yellow','green'); WINDOW=33; SCREEN=keep

DCOLOURS [METHOD=linear; PLOT=test] NCOLOURS=10; START='red'; \
         END=!t('yellow','green'); WINDOW=34; SCREEN=keep

DCOLOURS [METHOD=linear; PLOT=test] START='green'; \
         END=!t('blue','fuchsia','white'); WINDOW=35; \
         SCREEN=keep

DCOLOURS [METHOD=linear; PLOT=test] NCOLOURS=40; START='green';\
         END=!t('blue','fuchsia','white'); WINDOW=36; \
         SCREEN=keep

DCOLOURS [METHOD=linear; PLOT=test] START='green'; \
         END=!t('blue','aqua','red'); WINDOW=37; SCREEN=keep

DCOLOURS [METHOD=linear; PLOT=test] NCOLOURS=5; START='green'; \
         END=!t('blue','aqua','red'); WINDOW=38; SCREEN=keep

ENDJOB
```

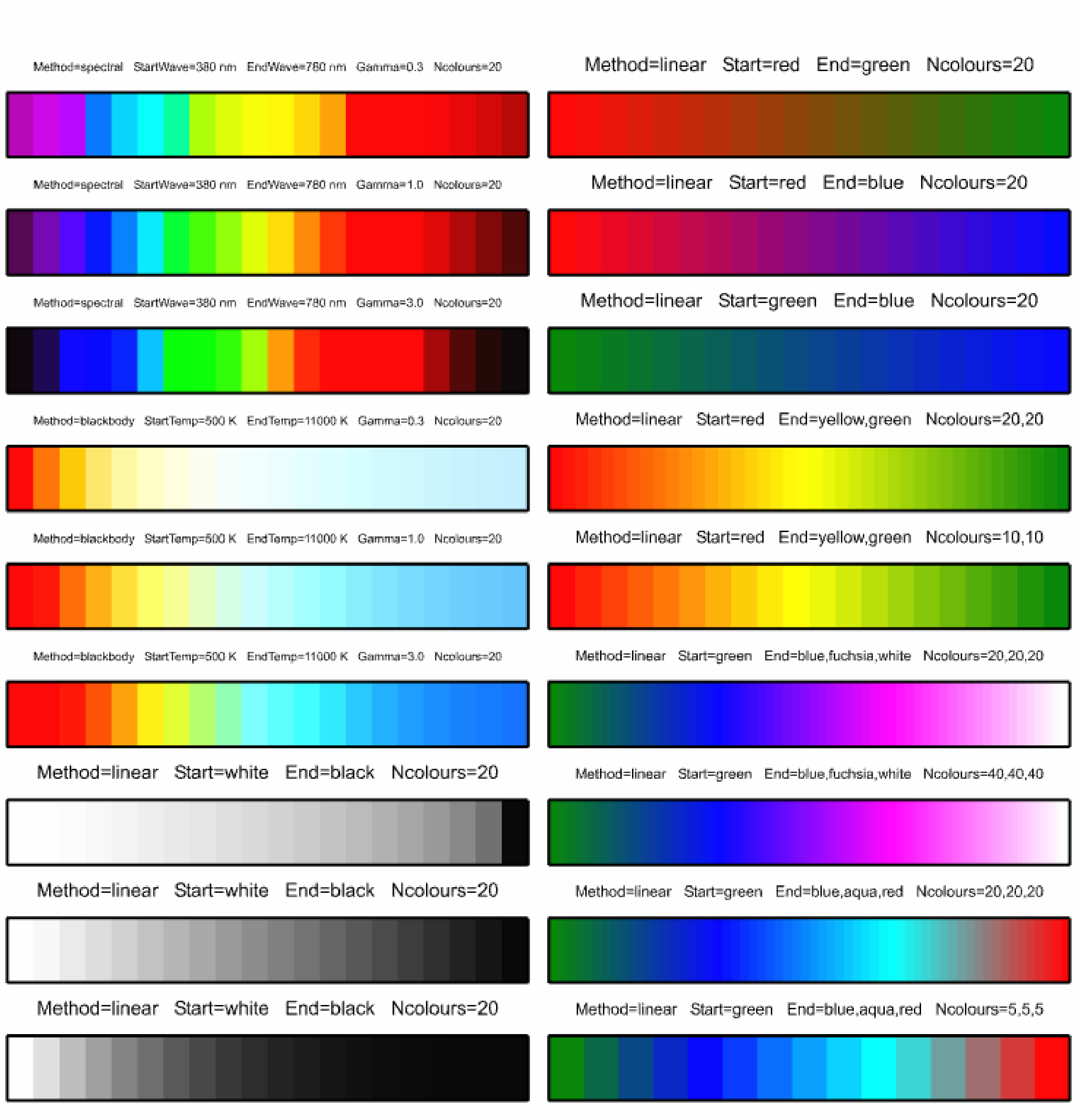


Figure 4.15: Test plots of various colour bands constructed using DCOLOURS.

Colours saved from DCOLOURS can be assigned to pens for use in plotting. In the following example, a yellow to green band of seven colours is created for use in a shade plot (see Figure 4.16).

```
JOB

"Create a color band"
DCOLOURS START='yellow'; END='green'; NCOLOURS=7; RGB=rgbvals
```

```
"Assign colours to pens"
PEN 1...7; CAREA=#rgbvals

"Data to plot"
VARIATE [VALUES=0,0.2...2] Rows
VARIATE [VALUES=0,0.2...1] Columns
MATRIX [ROWS=Rows; COLUMNS=Columns] X, Y, Function
MATRIX [MODIFY=yes; VALUES=(#Columns)11] X
CALCULATE Y$[*;1...6] = Rows
CALCULATE Function=COS(1/(X+0.1)** 2)+SIN(Y**2)

"Shade plot"
DSHADE Function; PEN=!(1...7); INTERVAL=0.5

ENDJOB
```

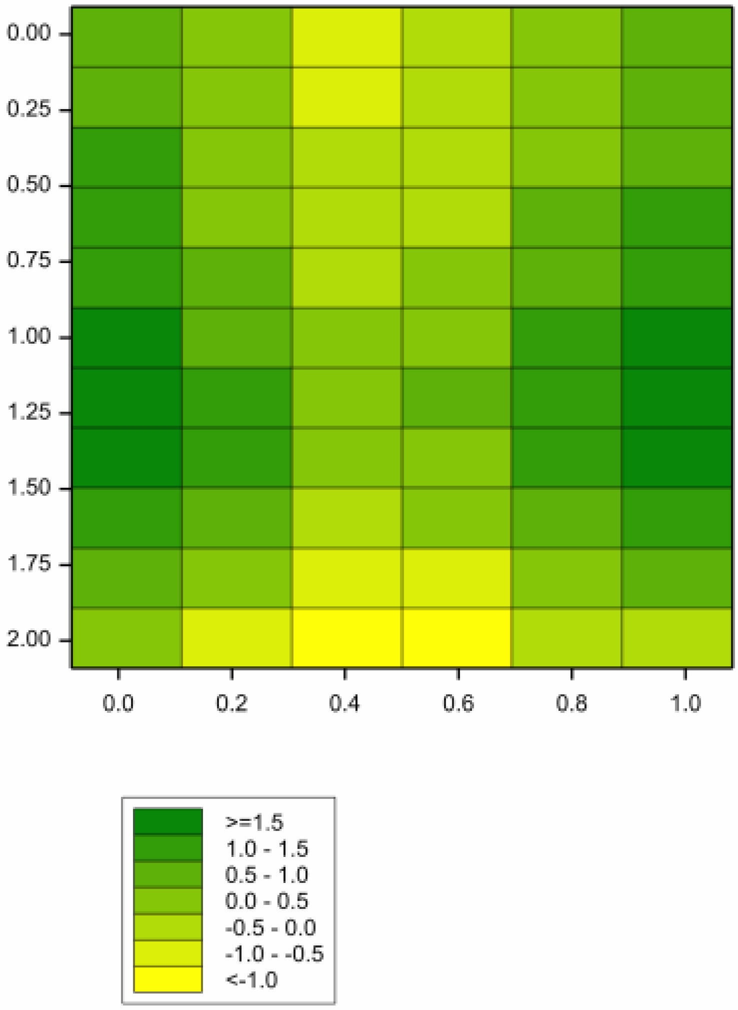


Figure 4.16: Shade plot created using a colour band defined by DCOLOURS.

4.2.13 Hot points with DGRAPH

DGRAPH allows components of the graph (i.e. pairs of Y and X structures) to be defined as "*hot components*" that can be shown or hidden in the *Graphics Viewer* through their association with "*hot points*". The hot components are identified by defining a unique integer number for each one, using the HOTCOMPONENT parameter. The hot points are plotted within the graph using the Y, X and other parameters (e.g. PEN) in the usual way. The extra information that defines them as "*hot*" is supplied by setting the HOTDEFINITION parameter to a matrix with a row for each hot point, and a column for each type of hot component. The elements of the matrix specify the hot components to be associated with each hot point, using the numbers defined by the HOTCOMPONENT parameter.

In this example a regression line with residuals is plotted, and hot points are used to illustrate the size of the residual for each point. The data file, DGRA-8.DAT, contains recordings of blood-pressure (Pressure) from a sample of 38 women whose ages range from 20 to 80 (Age).

```
"Read the data recorded in the file."
FILEREAD [NAME='%gendir%/examples/DGRA-8.DAT'] Age, Pressure

"Fit the linear model."
MODEL Pressure
TERMS Age
FIT [PRINT=*] Age
"Save the fitted values"
RKEEP FITTED=Fitted

"Construct matrix containing data values and the expected values
of X."
CALC nva=NVALUES(Age)
MATRIX [ROWS=nva; COLUMNS=3] mx,my
CALCULATE mx$[*; 1,2,3],my$[*; 1,2,3] = \
          Age,Age,!s(*),Pressure,Fitted,!s(*)

"Set up hot definition matrix by creating a matrix with one
column and values 1...nva. All values of the hot definition
matrix have to be integers."
MATRIX [ROWS=nva; COLUMNS=1; VALUES=1...#nva] h

"Plot Pressure and Fitted values.
```

```
Set HOTDEFINITION so that Pressure is assigned to matrix h. This
means that the first point of (X,Y) has the 'hot value' 1, the
second point of (X,Y) has the 'hot value' 2, etc. The numbers
1,2,3... come from the corresponding elements of matrix h."
PEN [RESET=yes] 2
PEN [RESET=yes] 4; METHOD=line; JOIN=ascending; SYMBOL=0
DGRAPH [WINDOW=1] Y=Pressure, Fitted; X=Age; PEN=2,4; \
        HOTDEFINITION=h,*

"Plot lines linking residuals to fitted line.
Set HOTCOMPONENT so that each row of mx and my is assigned an
integer which appears in the matrix h. For example, when the
point associated with 'hot value' 10 is clicked the line with
HOTCOMPONENT 10 appears."
PEN [RESET=yes] 5; METHOD=line; JOIN=given; SYMBOL=0
DGRAPH [SCREEN=keep] Y=my$[1...#nva;*]; X=mx$[1...#nva;*]; \
       PEN=5; DISPLAY=hide; HOTCOMPONENT=1...nva; DESC=''
```

Running the above program gives the graph in Figure 4.17a. To activate hot definition mode, click on the Hot Choice button (↖) found on the toolbar of the *Graphics Viewer* (see Section 1.2.1). This special button allows you to toggle the visibility of *hot components* in a graph. In this example, clicking on a data point reveals a light blue vertical line, the residual for that data point (see Figure 4.17b). Click again to hide the residual line.

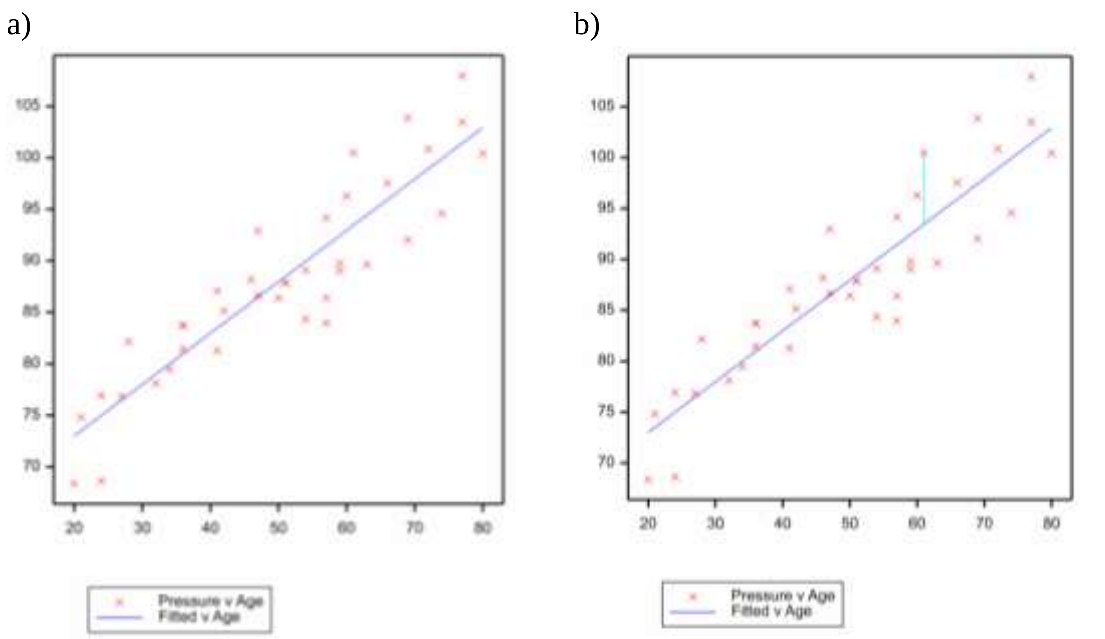


Figure 4.17: a) Initial plot, in which hot components are hidden. b) Plot showing a hot component as a light blue vertical line representing the residual for the data point selected.

4.2.14 Automating the construction of titles and labels using GETATTRIBUTE

The GETATTRIBUTE directive allows us to access and save attributes of a data structure (to pointers), for example the identifier (i.e. variable name). Using GETATTRIBUTE we can automate the construction of text strings for annotation, including titles. This can be particularly useful when generating a series of graphs in a FOR loop.

In the code that follows we demonstrate how an overall title, and x- and y-axis titles, can be automatically generated using GETATTRIBUTE. The directive TXREPLACE is used to “beautify” the overall title by replacing underscores with spaces. In addition, the TXCONSTRUCT directive is used to concatenate text strings.

The code also illustrates how a legend can be constructed by i) saving the factor labels as a pointer to text structures using GETATTRIBUTE and ii) using DTEXT to annotate the plot using the saved labels.

```
JOB
SPLOAD '%GENDIR%/Data/Iris.gsh'
FFRAME [ROWS=2; COLUMNS=2; YMLOWER=0.1; YMUPPER=0.1; \
       XMLOWER=0.1; CSKIP=0.05]
SCALAR win; 1

FOR yvar=Sepal_Length,Petal_Length

   "Get the y variable name"
   GETATTRIBUTE [ATTRIBUTE=identifier] yvar; SAVE=yt
   "Beautify by replacing _ with spaces"
   TXREPLACE OLDTEXT=#yt; NEWTEXT=ytitle; \
             OLDSUBTEXT='_'; NEWSUBTEXT=' '

   FOR  xvar=Sepal_Width,Petal_Width

      "Get the x variable name"
      GETATTRIBUTE [ATTRIBUTE=identifier] xvar; SAVE=xt
      "Beautify by replacing _ with spaces"
      TXREPLACE OLDTEXT=#xt; NEWTEXT=xtitle; \
                OLDSUBTEXT='_'; NEWSUBTEXT=' '

      "Form a title for the plot"
       TXCONSTRUCT [title] ytitle, ' vrs ', xtitle

       "Title the y- and x- axes using the identifier"
       YAXIS WINDOW=win; TITLE=ytitle
       XAXIS WINDOW=win; TITLE=xtitle
```

```
 "Make the graph"
      DGRAPH [WINDOW=win; TITLE=title; KEY=0; SCREEN=keep] \
      Y=yvar; X=xvar; PEN=Species

      CALC win=win+1

      ENDFOR
   ENDFOR

"Add a legend to window 4 using DTEXT"
GETATTRIBUTE [ATTRIBUTE=labels] Species; SAVE=labels
DTEXT [WINDOW=4] Y=3,2.5,2; X=3(1.8); TEXT=#labels[]; \
      PEN=1...3

ENDJOB
```

The resulting graphic is shown in Figure 4.18.

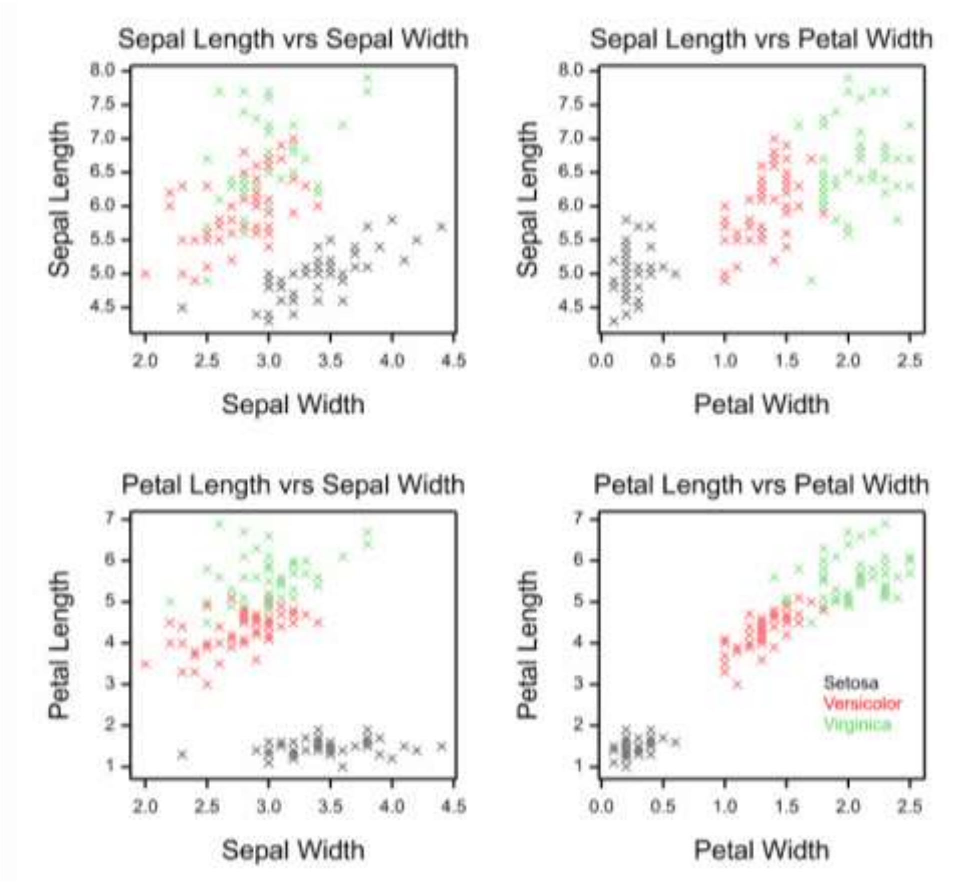


Figure 4.18: Plots with annotation generated using GETATTRIBUTE.

4.2.15 Saving plots with automated filenames

In the examples below, we use the SETDEVICE procedure, the TXCONSTRUCT directive and the GETATTRIBUTE directive to save a series of plots as separate .png files, using automatically generated filenames. In the first example, the filenames simply reflect the order in which the graphs were created. That is, the code below results in four .png files being saved to your working directory with filenames 1.png, 2.png, 3.png and 4.png.

```
JOB
SPLOAD '%GENDIR%/Data/Iris.gsh'

FOR [INDEX=i] var=Sepal_Length,Petal_Length,\
                  Sepal_Width,Petal_Width

   "Get the variable name to use as the title"
   GETATTRIBUTE [ATTRIBUTE=identifier] var; SAVE=title
   "Beautify title by replacing _ with spaces"
   TXREPLACE OLDTEXT=#title; NEWTEXT=bettertitle; \
             OLDSUBTEXT='_'; NEWSUBTEXT=' '

   "Form the file name"
   "Example 1: using index"
   TXCONSTRUCT [tvar] i, '.png'
   "Example 2: using the variable name"
   "TXCONSTRUCT [tvar] #title, '.png'"

   "Open a graphical file"
   SETDEVICE tvar; NUMBER=Device

   "Make the graph"
   BOXPLOT [TITLE=bettertitle] DATA=var; GROUP=Species

   "Close the graphical file"
   CLOSE CHANNEL=Device; FILETYPE=graph

   "Switch the graphics device back to 1 (the default)"
   DEVICE 1

ENDFOR
```

In the second example, we modify the TXCONSTRUCT call so that the variable name (i.e. identifier) is used to construct the filename. That is, we replace

```
TXCONSTRUCT [tvar] i, '.png'
```

with

```
TXCONSTRUCT [tvar] #title, '.png',
```

where `title` is a pointer to a text structure containing the identifier (generated using the `GETATTRIBUTE` directive). Doing so results in four `.png` files being saved to your working directory with filenames `Petal_Length.png`, `Petal_Width.png`, `Sepal_Length.png` and `Sepal_Width`.

4.2.16 Producing a multi-page pdf file of graphs

In Section 3.6 we used the `DEVICE`, `OPEN` and `CLOSE` directives to save a graph to a pdf file. The following example expands on this by demonstrating how to produce a multi-page pdf file using commands. The commands below will save a multi-page pdf file, named IrisGraphs.pdf, to your working directory.

```
JOB
SPLOAD '%GENDIR%/Data/Iris.gsh'

"Open graphics channel 4 or 13 and set DEVICE to that channel"
OPEN 'IrisGraphs.pdf'; CHANNEL=4; FILE=graphics
DEVICE 4

"Generate graphs"
FOR [INDEX=i] var=Sepal_Length,Petal_Length,\
                  Sepal_Width,Petal_Width
   GETATTRIBUTE [ATTRIBUTE=identifier] var; SAVE=title
   TXREPLACE OLDTEXT=#title; NEWTEXT=bettertitle; \
             OLDSUBTEXT='_'; NEWSUBTEXT=' '
   BOXPLOT [TITLE=bettertitle] DATA=var; GROUP=Species
ENDFOR

"Close the graphical file and switch the graphics device back
 to 1 (the default)"
CLOSE CHANNEL=4; FILETYPE=graph
DEVICE 1

ENDJOB
```

(Note: A multi-page pdf file can also be created from the *Graphics Viewer* menu File | Save All to PDF….)

4.2.17 Colourful plot using PEN

In Section 3.4 we showed how the appearance of the graphical elements (e.g. symbols, lines, axes, titles, labels, annotation and filled polygons) could be altered by changing the attributes of the graphical *pens* using the `PEN` directive. In the example below, we use the `PEN` directive to create the multi-coloured plot of Figure 4.19.

```
JOB

"Data for plotting"
VARIATE Y; VALUES=!(2,6,4,8,10)
VARIATE X; VALUES=!(2,4,5,1,6)
VARIATE YL; VALUES=!(1,4,3.9,7.5,5.3)
VARIATE YH; VALUES=!(3,7,6,8.5,11)
VARIATE XL; VALUES=!(1.5,3.4,4.9,0.5,5.3)
VARIATE XH; VALUES=!(2.5,4.4,5.2,1.5,7)

"Setting the pens used when drawing the plotting windows"
FRAME WINDOW=1,2; XLOWER=0,0.5; XUPPER=1
FRAME [GRID=xy] WINDOW=1; PENTITLE=9; PENGRID=10; BOX=omit
FRAME WINDOW=2; PENKEY=11; BOXKEY=omit

"Setting the pens used when drawing the axis"
XAXIS 1; TITLE='X-Title'; PENTITLE=2; PENAXIS=4; PENLABELS=6
YAXIS 1; TITLE='Y-Title'; PENTITLE=3; PENAXIS=5; PENLABELS=8

"Defining the pens"
PEN -5; COLOUR='cyan'
PEN 2...14; COLOUR='red','blue','green','gold','fuchsia',\
    'teal','chocolate','olive','palegoldenrod','lawngreen',\
    'purple','darkred'; SIZE=1.5; THICKNESS=2
PEN 10; LINESTYLE=2
PEN 12; LINESTYLE=4; METHOD=line; JOIN=ascending; SYMBOL=2; \
    CFILL='lavender'; CSYMBOL='navy'
PEN 13,14; BARTHICKNESS=2
" In this example the following pens are used:
  pen 2 and 3 for plotting the titles along x- and y-axis
  pen 4 and 5 for plotting the x-axis and y-axis,
  pen 6 and 8 for plotting the labels along x- and y-axis,
  pen 9, 10 and 11 for plotting the title, grid and key
  pen 12 for plotting the points and line,
  pen 13 for plotting the x-bars,
  pen 14 for plotting the y-bars.
  pen -5 for the key title."
DGRAPH [WINDOW=1; KEYWINDOW=2; TITLE='Colourful plot'; \
       KEYDESCRIPTION='Key'] Y=Y; X=X; \
       YLOWER=YL; YUPPER=YH; XLOWER=XL; XUPPER=XH; \
       PEN=12; XBARPEN=13; YBARPEN=14

ENDJOB
```

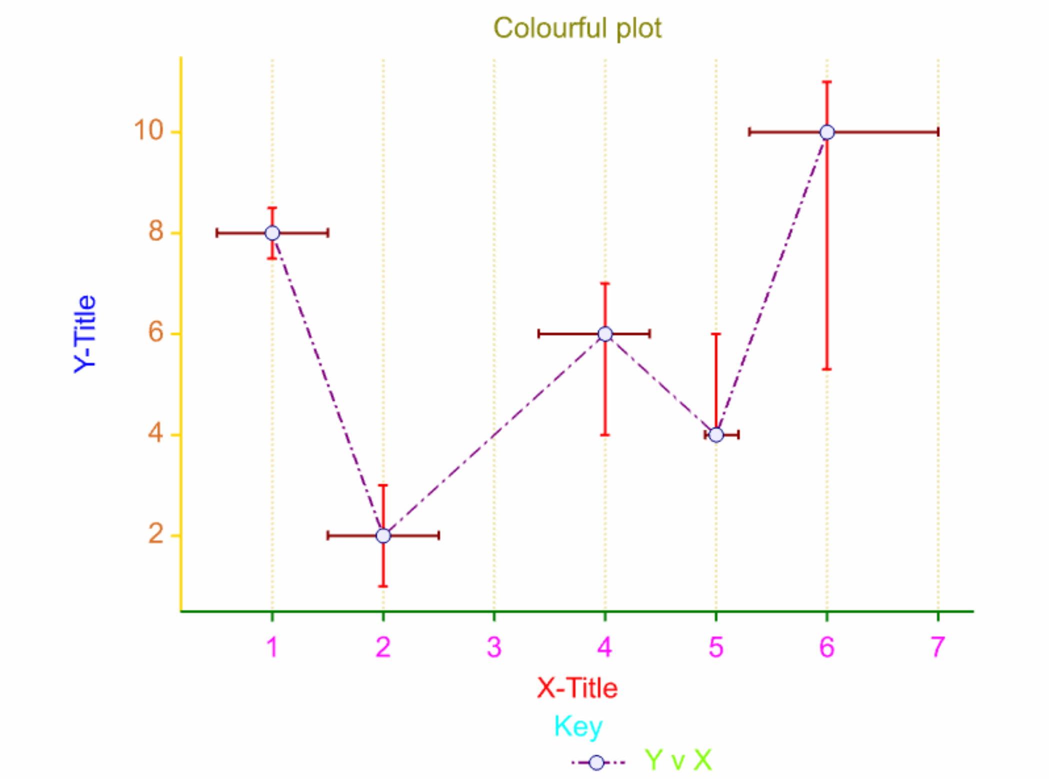


Figure 4.19: Multi-coloured plot created by assigning pens to draw particular elements of the plot.

4.2.18 Plot with bespoke symbols, rotated and labelled using PEN

Genstat provides a selection of pre-defined symbols (see Appendix 5.3). However, the PEN directive also lets us define our own. To do so, we set the SYMBOL parameter to a pointer containing a pair of variates. These variates define a set of points that will be joined using straight lines to form our symbol. (Missing values can be used to break the connection.) The points should be within a notional square with bounds -1.0 to 1.0 in each direction. The square is centred on the data point, and scaled to the same size as the standard symbols.

Alternatively, we can supply an image in the form of a bitmap (i.e. a matrix of RGB colour values).

Using the commands below we generate a panel of four graphs with user-defined symbols: i) a diamond created using a pointer, ii) an arrow created using a pointer, iii) a colourful square created using a matrix of RGB values, and iv) an imported image. Furthermore, we alter the orientation of the symbols using the ROTATION parameter of PEN and add labels using the LABELS parameter. To avoid the labels being rotated, they are added as a separate series using their own pen. See Figure 4.20

```
JOB

"Create a multi-panelled figure"
FFRAME [ROWS=2; COLUMNS=2; STARTWINDOW=1; YMUPPER=0.07; \
       SQUARESHAPES=yes]

"Coordinates of a diamond symbol"
VARIATE [VALUES=-1,0,1,0,-1] Diamond[1]
&       [VALUES= 0,-0.5,0,0.5,0] Diamond[2]

"Coordinates of an arrow symbol"
VARIATE [VALUES=-1,1,0.5,*,1,0.5] Arrow[1]
&       [VALUES=0,0,-0.5,*,0,0.5] Arrow[2]

"Create a matrix of RGB values"
VARIATE [NVALUES=4] rgb
CALCULATE rgb$[1...4]= RGB('limegreen','purple','gold','orange')
MATRIX [ROWS=2; COLUMNS=2] RGBmatrix; VALUES=rgb

"Import an image as a of RGB colours"
IMPORT [RGBMETHOD=matrix] \
       '%GENDIR%/Examples/GuidePart1/CapeWagtail.jpg'; \
       COLUMNS='RGB'

"Define the pens used to plot the data"
PEN 2,3,4,5; SYMBOLS=Diamond,Arrow,RGBmatrix,RGB; \
    SIZE=2,2,2,3; \
    ROTATION=!(0,45,90,135,180,225,270,315)
PEN 6; SYMBOLS=0; \
    LABELS=!T('   0~^o', '   45~^o', '   90~^o', \
              '   135~^o', '   180~^o', '   225~^o', \
              '   270~^o', '   315~^o')

"Plot graphs"
YAXIS 1...4; UPPER=9
XAXIS 1...4; UPPER=10

DGRAPH [WINDOW=1; TITLE='PEN with SYMBOL=Diamond pointer'; \
       KEY=0] 2(!(1...8)); !(1...8); PEN=2,6
DGRAPH  [WINDOW=2; TITLE='PEN with SYMBOL=Arrow pointer'; \
        KEY=0; SCREEN=keep] 2(!(1...8)); !(1...8); PEN=3,6
DGRAPH  [WINDOW=3; TITLE='PEN with SYMBOL=RGB matrix'; \
        KEY=0; SCREEN=keep] 2(!(1...8)); !(1...8); PEN=4,6
DGRAPH  [WINDOW=4; TITLE='PEN with SYMBOL=RGB matrix of an \
imported image'; KEY=0; SCREEN=keep] \
        2(!(1...8)); !(1...8); PEN=5,6

ENDJOB
```

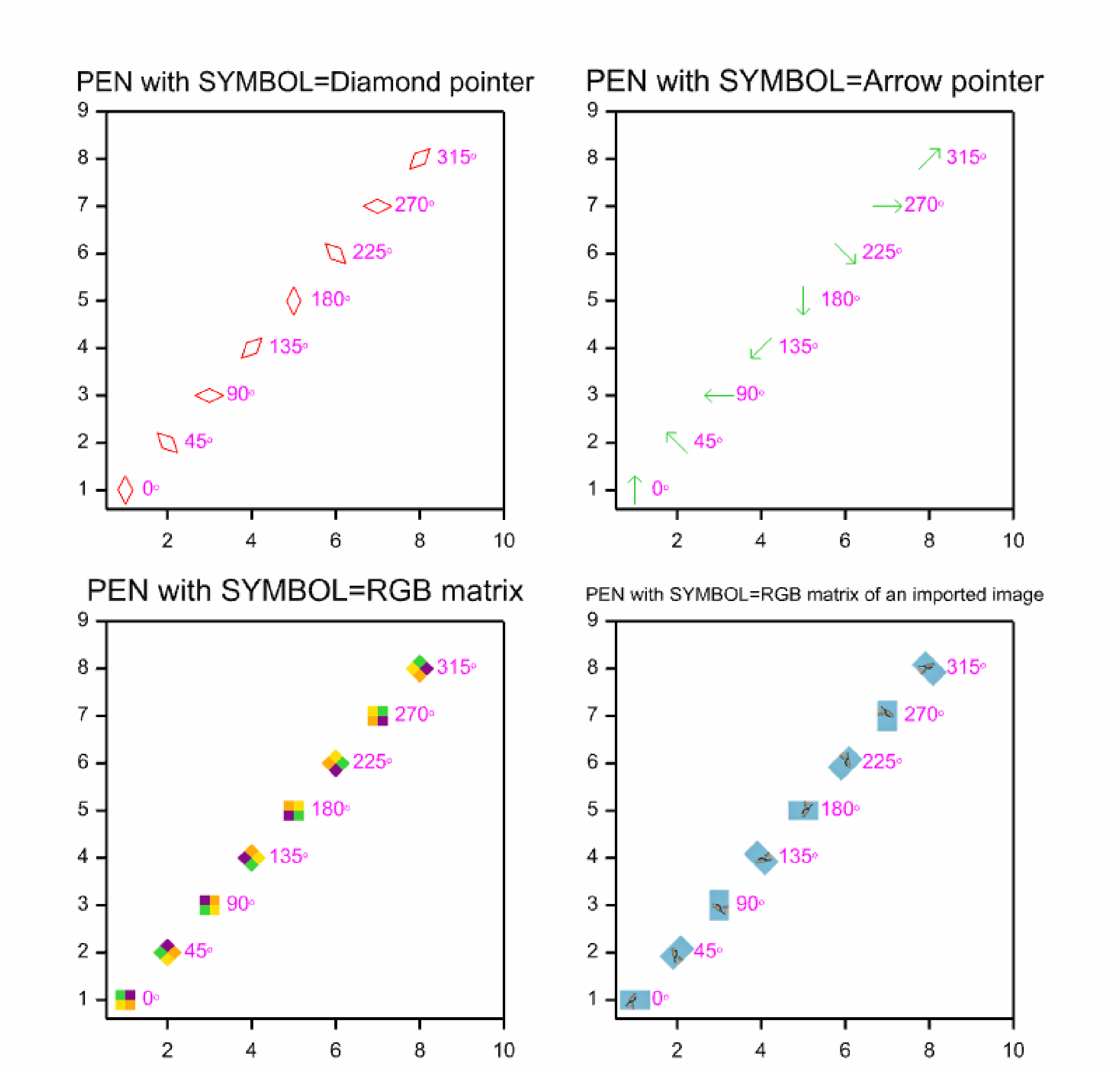
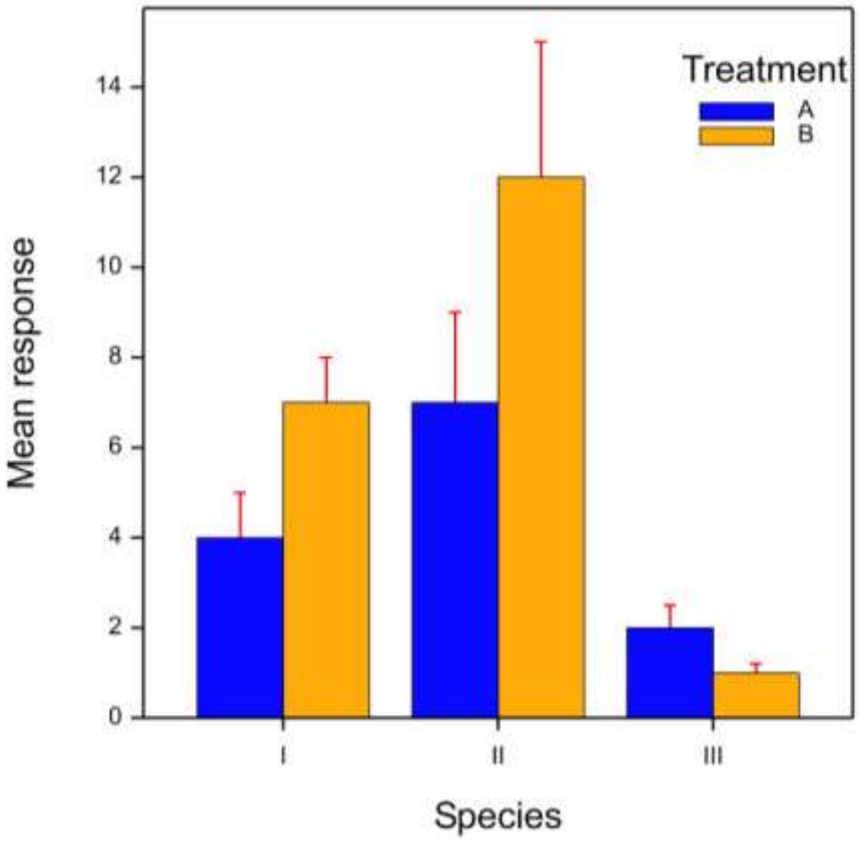


Figure 4.20: Plot with bespoke symbols, rotated and labelled.

4.3 Showcase graphs

Example 1

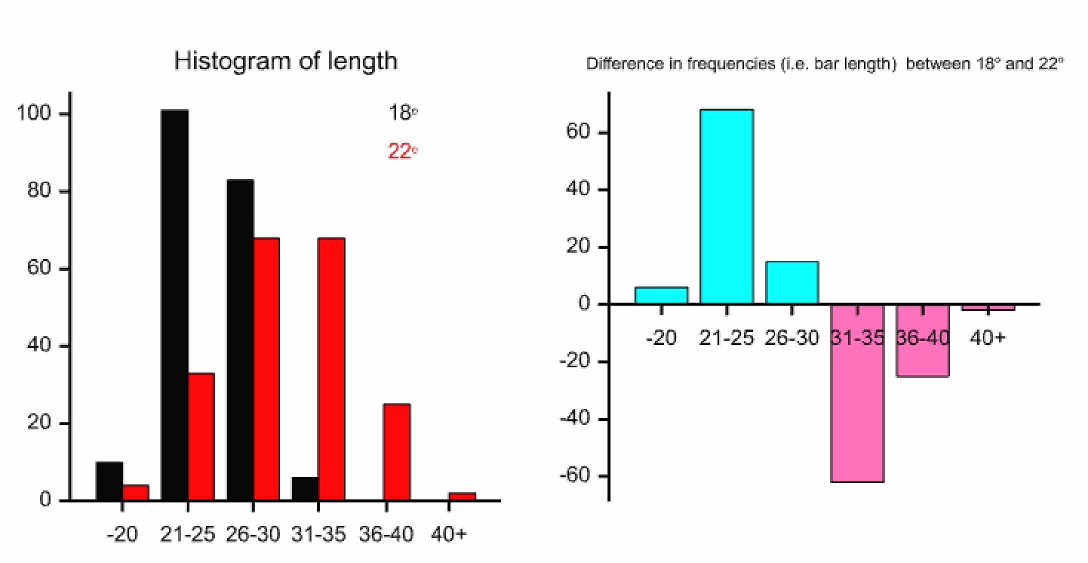
Keywords: Bar chart, error bars, table



```
JOB
FACTOR [LABELS=!T(A,B)] Trt
FACTOR [LABELS=!T(I,II,III)] f2
TABLE [CLASS=Trt,f2; VALUES=4,7,2,7,12,1] mean
TABLE [CLASS=Trt,f2; VALUES=1,2,0.5,1,3,0.2] SEM
TABLE [CLASS=Trt,f2; VALUES=6(0)] lower
PEN 2,3; COLOUR='blue','orange'
PEN -11; COLOUR='red'; BARTHICKNESS=3
YAXIS WINDOW=1; TITLE='Mean response'
XAXIS WINDOW=1; TITLE='Species'
FRAME 2; YLOWER=0.8; YUPPER=0.9; XLOWER=0.55; \
      XUPPER=0.7; BOXKEY=omit
BARCHART [WINDOW=1; KEYDESCRIPTION='Treatment'; KEYWINDOW=2]\
         DATA=mean; ERRORBAR=SEM; LOWERERRORBAR=lower
ENDJOB
```

Example 2

Keywords: Histogram, axis marks, axis labels, adding text, table, multi-windowed

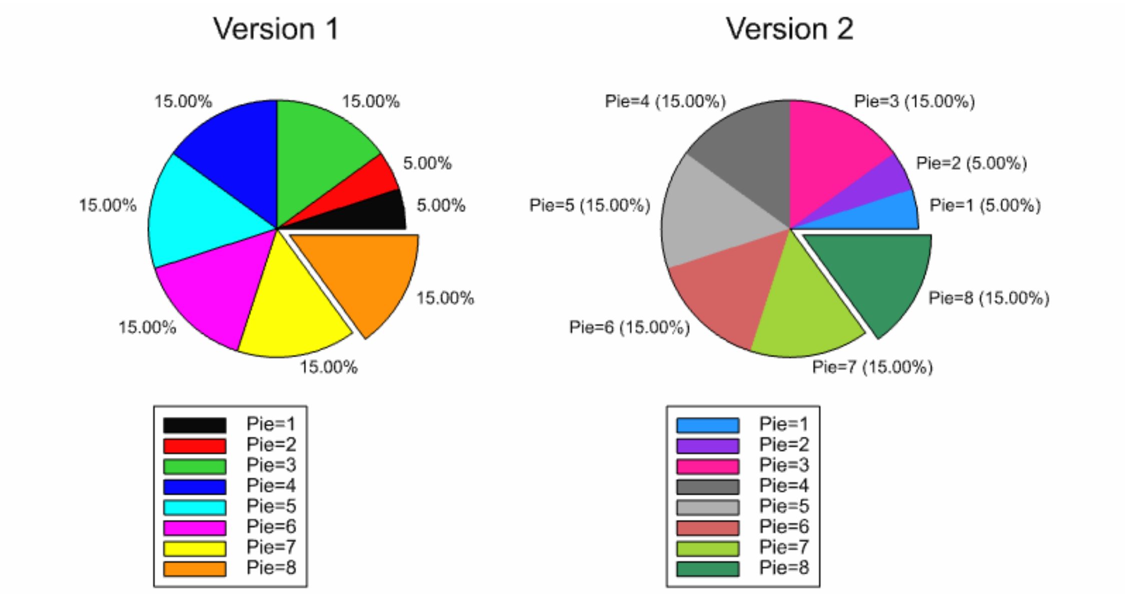


```
JOB
READ Length
24 28 22 22 26 24 29 26 29 25 28 26 24 31 23 30 24 26 30 26
25 31 27 21 30 20 21 29 29 28 21 26 21 22 26 29 20 28 30 30
26 30 23 23 27 25 30 24 32 24 26 23 24 23 30 25 24 26 26 24
22 27 23 26 26 24 21 29 25 25 30 23 25 21 25 26 20 23 27 21
28 27 23 27 30 21 31 27 28 23 23 24 31 29 23 25 26 27 27 28
25 22 30 29 27 29 24 25 19 25 26 20 23 22 26 25 24 23 28 27
24 22 29 25 24 27 26 28 30 25 22 22 27 28 24 23 24 28 25 23
27 27 24 22 26 29 23 22 26 25 26 23 26 26 25 21 24 20 25 23
23 27 26 25 30 27 21 27 19 25 21 25 24 21 23 20 24 21 25 30
25 20 21 27 23 24 25 28 21 28 34 24 23 23 24 30 19 22 27 25
29 34 28 23 35 32 30 28 31 23 36 24 24 31 28 19 35 24 26 39
34 32 41 24 25 34 29 34 23 23 29 25 30 31 31 33 21 24 31 33
33 31 24 31 24 40 33 41 24 29 35 31 28 26 32 31 29 28 27 28
31 30 32 28 25 29 30 28 36 29 34 30 28 32 30 29 30 26 39 37
30 24 36 29 32 28 34 25 31 37 34 33 35 24 28 28 27 23 31 39
36 28 38 31 20 26 23 29 32 37 25 34 29 26 32 28 35 28 26 27
26 36 36 27 39 33 29 34 28 22 26 37 28 36 38 33 24 29 28 34
36 25 34 20 31 28 32 33 26 22 38 27 31 25 31 33 26 26 31 31
24 31 29 37 32 30 23 27 35 30 32 22 25 39 28 34 33 32 31 31
33 16 34 31 32 29 36 35 27 36 30 23 34 29 22 30 27 33 36 28:
FACTOR [LEVELS=!(18,22); VALUES=200(18, 22)] Temp
VARIATE Leng18,Leng22; VALUES=Length
RESTRICT Leng18,Leng22; Temp .EQ. 18, 22
FRAME WINDOW=1,2; YLOWER=0.7; YUPPER=0.92; XLOWER=0.26,0.80; \
      XUPPER=0.5,1; XMLOWER=0; XMUPPER=0
```

```
FRAME 5,6; YMLOWER=0.05; XMLOWER=0.05; BOX=2(omit)
PEN -5; SIZE=1.2
VARIATE [VALUES=20,25...40] Limits
TEXT [VALUES='-20','21-25','26-30','31-35','36-40','40+'] Labels
XAXIS WINDOW=5; MARKS=!(17.5,22.5,27.5,32.5,37.7,42.5);
LABELS=Labels
DHISTOGRAM [WINDOW=5; KEYWINDOW=0; LIMITS=Limits;\
           TITLE='Histogram of length'] \
           Leng18,Leng22; PEN=1,2; \
           NOBSERVATIONS=NObs18,NObs22
DTEXT [WINDOW=5] X=!(35,35); Y=!(100,90); \
      TEXT=!T('18~^o','22~^o'); PEN=!(1,2)
VARIATE VObs18,VObs22; VALUES=NObs18,NObs22
CALCULATE Diff = VObs18 - VObs22
FACTOR [LABELS=Labels] FDiff
TABLE [CLASSIFICATION=FDiff; VALUES=#Diff] TabDiff
CALC Direction = (TabDiff>0)+1
VARIATE [NVALUES=6] DPen
EQUATE Direction; DPen
PEN 1,2; COLOUR='hotpink','aqua'
DHISTOGRAM [WINDOW=6; SCREEN=keep; KEYWINDOW=0; \
           TITLE='Difference in frequencies (i.e. bar length) \
 between 18~^o and 22~^o'] TabDiff; PEN=DPen
ENDJOB
```

Example 3

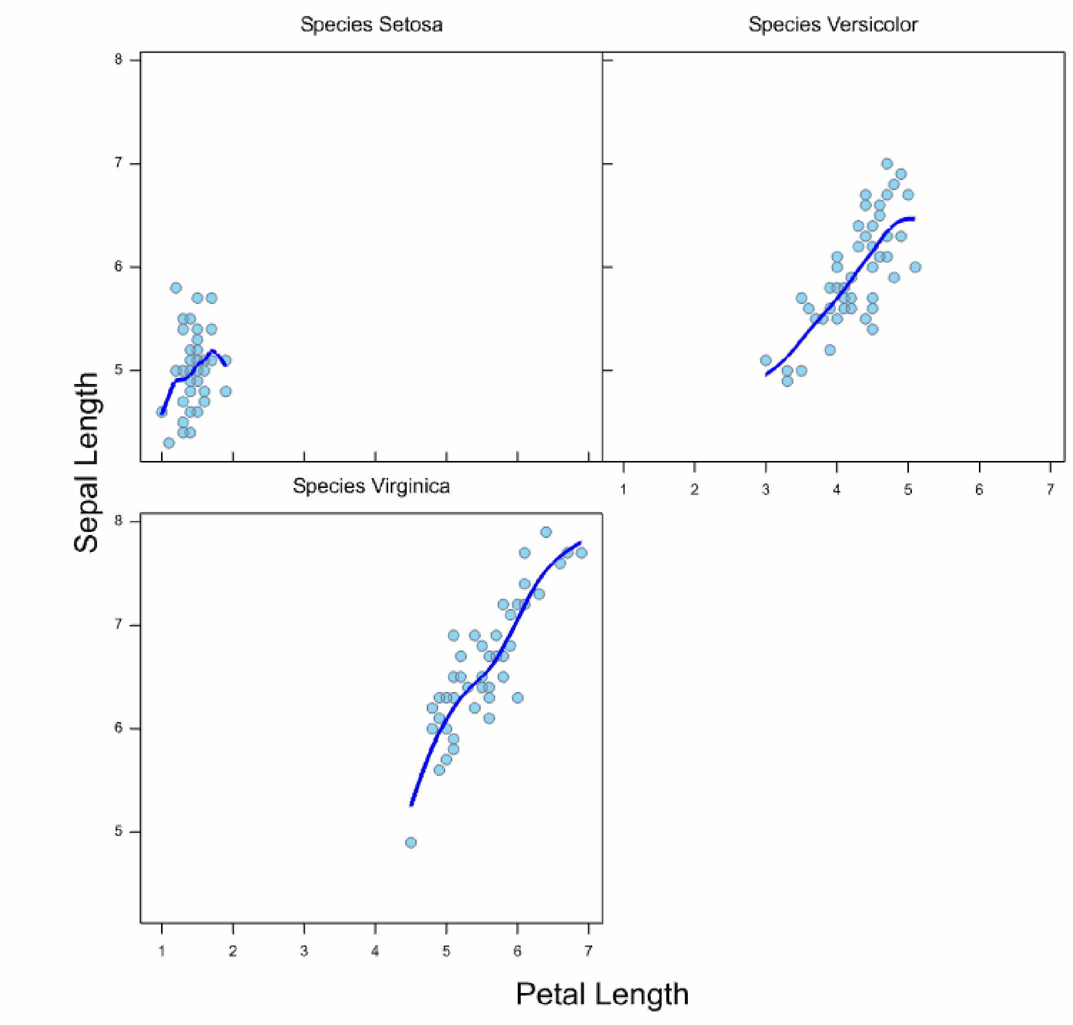
Keywords: Pie chart



```
JOB
FRAME WINDOW=1...4; YLOWER=2(0.25,0); YUPPER=2(0.75,0.35); \
      XLOWER=0,0.50,0.15,0.65; XUPPER=(0.5,1)2
PEN -3,-6,-5; SIZE=0.85,0.95,1.50
DPIE [WINDOW=1; KEYWINDOW=3; ANNOTATION=perc; \
     TITLE='Version 1'] SLICE=2(5),5(15),-15; \
     DESCRIPTION='Pie=1','Pie=2','Pie=3','Pie=4','Pie=5',\
     'Pie=6','Pie=7','Pie=8'
DPIE [WINDOW=2; KEYWINDOW=4; SCREEN=keep; OUTLINE=perimeter; \
     TITLE='Version 2'] SLICE=2(5),5(15),-15; \
     PEN=11...18; DESCRIPTION='Pie=1','Pie=2','Pie=3','Pie=4', \
     'Pie=5','Pie=6','Pie=7','Pie=8'
ENDJOB
```

Example 4

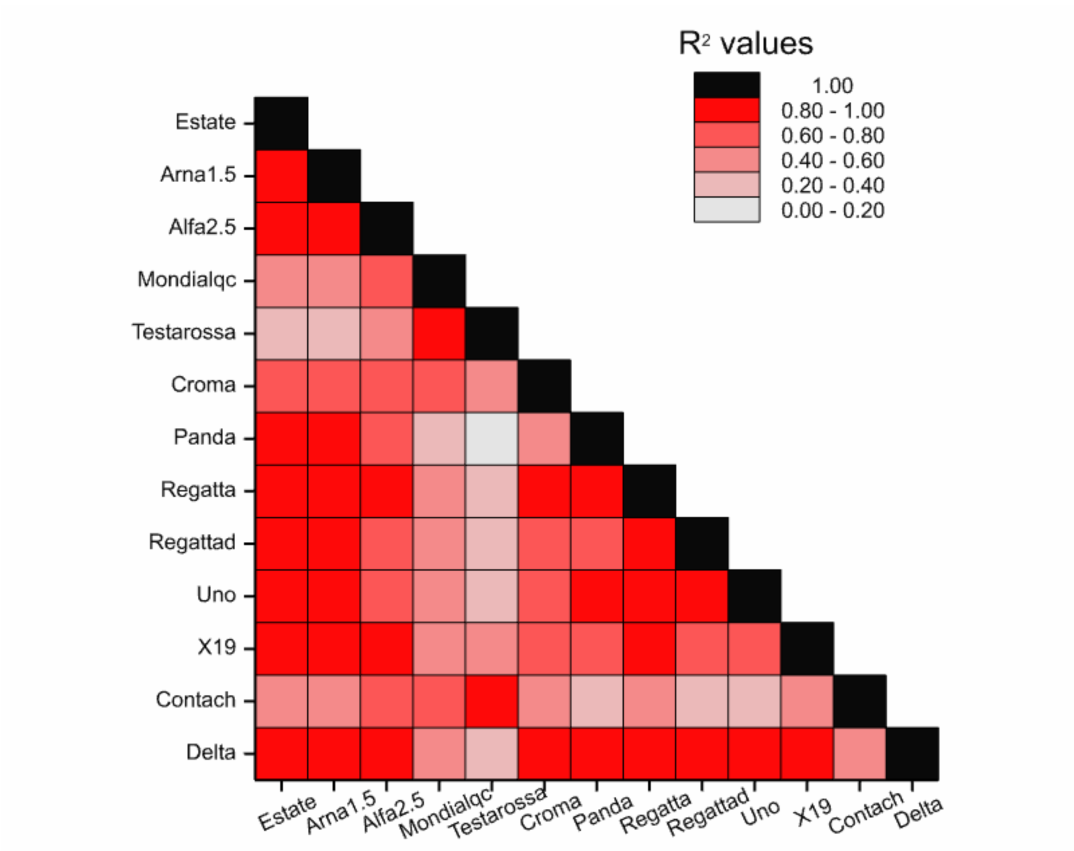
Keywords: Trellis plot



```
JOB
SPLOAD '%GENDIR%/Data/Iris.gsh'
PEN 1; COLOUR='slategray'; SYMBOL='circle'; CFILL='skyblue'
PEN 2; COLOUR='blue'; THICKNESS=4; SYMBOLS=0
TRELLIS [GROUPS=Species; USEPENS=yes; YTITLE='Sepal Length';\
        XTITLE='Petal Length'; KEYHEIGHT=0] \
        Y=2(Sepal_Length); X=2(Petal_Length); \
        METHOD=point,spline
ENDJOB
```

Example 5

Keywords: Shade plot, colour band

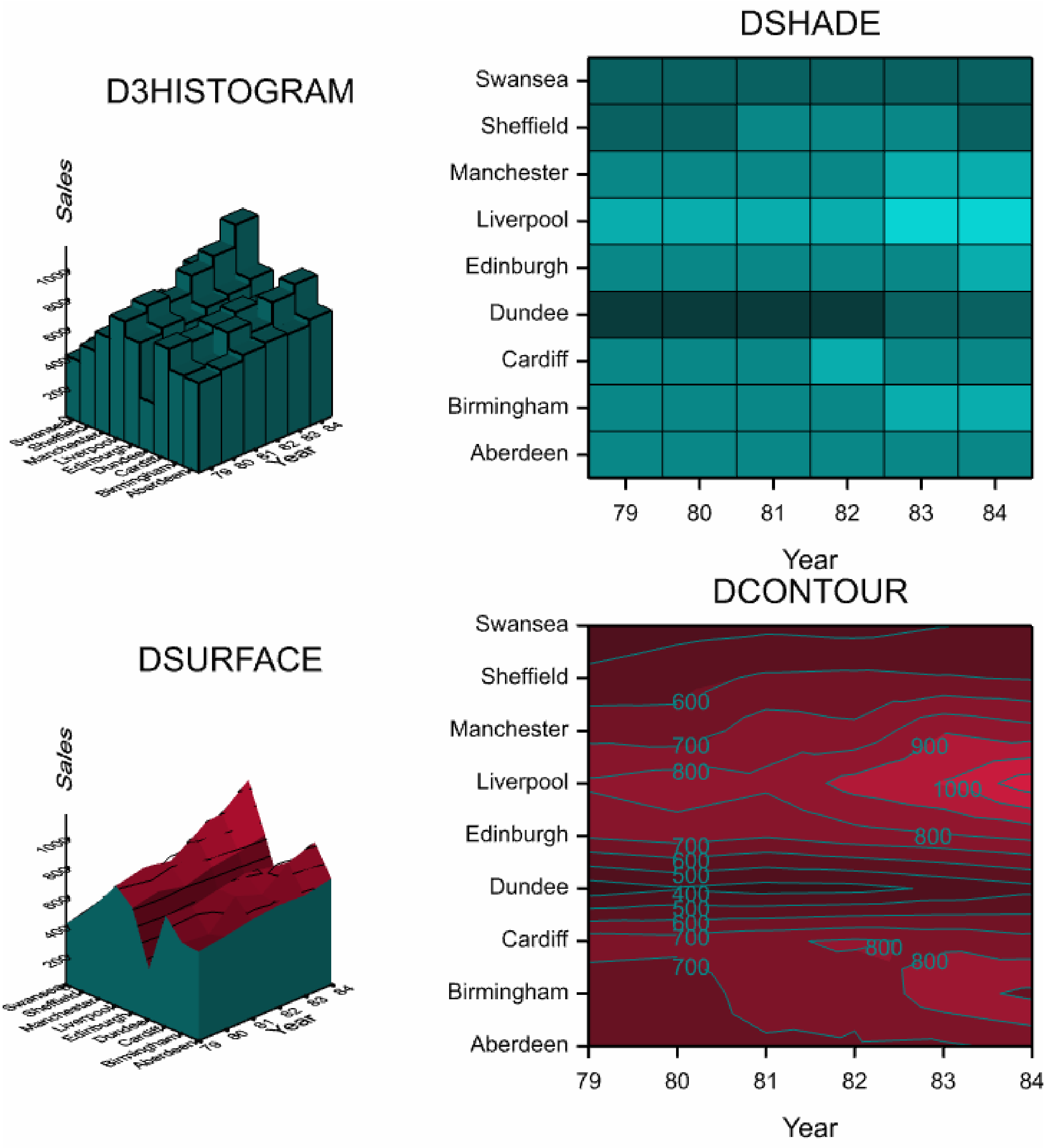


```
JOB
TEXT [VALUES=Estate,'Arna1.5','Alfa2.5',Mondialqc,Testarossa,\
      Croma,Panda,Regatta,Regattad,Uno,X19,Contach,Delta] Car
CALCULATE nCar = NVALUES(Car)
SYMMETRIC [ROWS=Car] Carsim
READ Carsim
 1.000
 0.976 1.000
 0.815 0.800 1.000
 0.576 0.546 0.762 1.000
 0.389 0.355 0.561 0.827 1.000
 0.794 0.776 0.762 0.768 0.567 1.000
 0.820 0.855 0.618 0.296 0.103 0.546 1.000
 0.981 0.969 0.823 0.589 0.394 0.820 0.801 1.000
 0.839 0.822 0.675 0.525 0.329 0.756 0.756 0.844 1.000
 0.884 0.909 0.693 0.409 0.211 0.650 0.960 0.866 0.815 1.000
 0.870 0.858 0.828 0.578 0.425 0.602 0.758 0.836 0.700 0.787 1.000
 0.462 0.432 0.618 0.709 0.885 0.440 0.215 0.458 0.309 0.302 0.531 1.000
 0.959 0.951 0.837 0.585 0.393 0.814 0.813 0.959 0.806 0.871 0.826 0.471 1.000
:
```

```
VARIATE [VALUES=0.2,0.4,0.6,0.8,1] limits
CALCULATE nlim = NVAL(limits)
VARIATE [VALUES=0,#limits] lim0
VARIATE [NVAL=nlim] lim1
EQUATE lim0; NEWSTR=lim1
TXCONSTRUCT [TEXT=hdesc] lim1,' - ',limits; DECIMALS=2
TEXT [VALUES=#hdesc,'     1.00   '] desc
CALCULATE ncolours = NVAL(limits) + 1
CALCULATE ncol_1 = ncolours - 1
VARIATE pen; VALUES = 10 + !(1...ncolours)
CALCULATE revpen  = REVERSE(pen)
TEXT lcol; VALUES=!t(red,black)
VARIATE [VALUES=ncol_1,1] vncolours
DCOLOURS [METHOD=LINEAR] START='lightgrey'; END=lcol; \
         NCOLOURS=vncolours; GAMMA=0.75; WINDOW=0; RGB=rgb
PEN #pen; CAREA=#rgb
FRAME 1; BOX=omit
XAXIS 1; MARKS=!(1...nCar); LABELS=Car; LROTATION=25
YAXIS 1; MARKS=!(1...nCar); LABELS=Car
FRAME 1; YLOWER=0.1; YUPPER=0.9; XLOWER=0.1; XUPPER=0.9; \
      BOXKEY=omit
FRAME 2; YLOWER=0.4; YUPPER=0.9; XLOWER=0.6; XUPPER=1; \
      BOXKEY=omit
DSHADE [KEYDESCRIPTION='R~^{2} values'] Carsim; LIMITS=limits; \
       PEN=pen; DESCRIPTION=desc
ENDJOB
```

Example 6

Keywords: Plotting a table, 3D histogram, shade plot, surface plot, contour plot

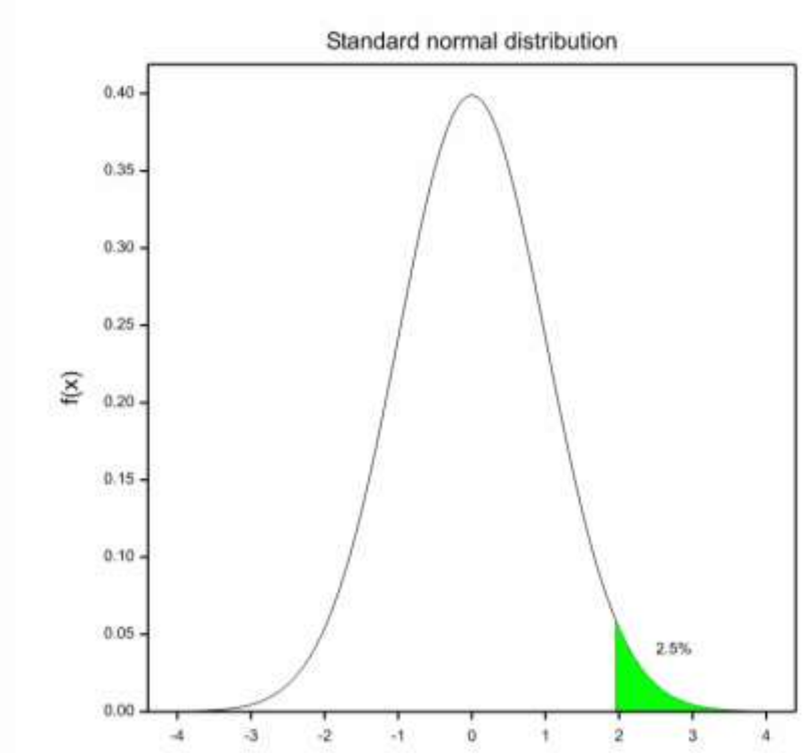


```
JOB
TEXT  [VAL=Aberdeen,Birmingham,Cardiff,Dundee,Edinburgh, \
        Liverpool,Manchester,Sheffield,Swansea] Town
```

```
VARIATE [VAL=79...84] Year; DECIMALS=0
FACTOR [NVALUES=54; LABELS=Town] Factor1
FACTOR [NVALUES=54; LEVELS=Year] Factor2
TABLE [CLASSIFICATION=Factor1,Factor2] TabSales
READ TabSales
    608 635 672 692  685  723
    757 743 785 816  783  737
    714 751 710 763  788  830
    662 632 758 721  893  837
    416 461 478 462  497  520
    618 601 784 720  863  921
    343 391 358 366  418  470
    816 859 820 938 1007 1158
    531 569 615 624  607  593:
VARIATE vTabSales; VALUES=TabSales
GENERATE Factor1, Factor2
FFRAME [ROWS=2; COLUMNS=2; MARGIN=ytitle,xtitle]
XAXIS 1...4; TITLE='Year'; MARKS=Year
YAXIS 1...4; MARKS=!(1...9); LABELS=Town; \
      LDIRECTION=perpendicular
ZAXIS 1...4; TITLE= 'Sales'; TPOSITION=end
PEN -1,-3; SIZE=2.5,1.7
PEN 5,7; COLOUR='crimson','teal'
D3HISTOGRAM [WINDOW=1; TITLE='D3HISTOGRAM'] TabSales; PEN=7
PEN -1,-3; SIZE=1.2,1
DSHADE [WINDOW=2; KEYWINDOW=0; SCREEN=keep; TITLE='DSHADE'; \
       YORIENTATION=normal] TabSales; NGROUPS=9; PEN=7
PEN -1,-3; SIZE=2.5,1.7
DSURFACE [WINDOW=3; KEYWINDOW=0; SCREEN=keep; \
         TITLE='DSURFACE'] TabSales; PENFILL=5; PENMESH=0; \
         PENSIDE=7
PEN -1,-3; SIZE=1.2,1
DCONTOUR [WINDOW=4; KEYWINDOW=0; SCREEN=keep; \
         TITLE='DCONTOUR'; YORIENTATION=normal] TabSales; \
          PENCONTOUR=7; PENFILL=5
ENDJOB
```

Example 7

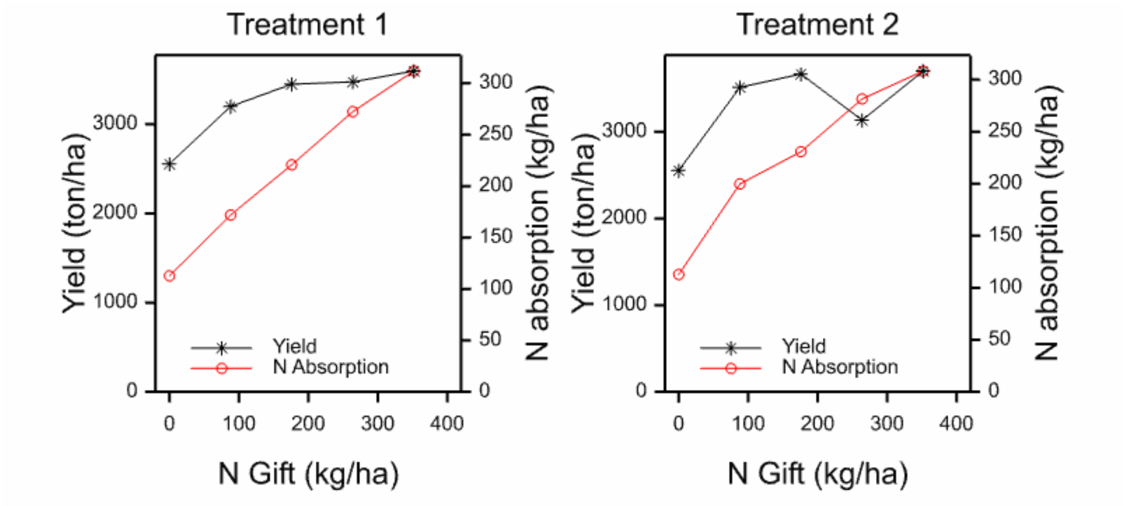
Keywords: Monotonic line plot, shaded polygon, label



```
JOB
SCALAR u; VALUE=1.96 "Modify this to change percentage shaded"
CALCULATE u_1 = u + 0.1
VARIATE [VALUES=-4,-3.9...4] x
&       [VALUES=u,u,u_1...4] xfill
CALCULATE z, fu, zfill = \
          1 / SQRT( 2 * C( 'pi')) * EXP(-0.5 * x, u, xfill ** 2)
&         zfill$[1] = 0
YAXIS 3; LOWER=0; TITLE='f(x)'
PEN [RESET=y] 1...3; METHOD=monotonic,line,fill; \
     COLOUR=*,'black','lime'; SYMBOLS=0; LINESTYLE=1; \
     JOIN=ascending,2(given)
SCALAR %GT2; DECIMALS=1
CALCULATE %GT2 = 100*CUNORMAL(u;0;1)
TXCONSTRUCT [TEXT=label] %GT2,'%'
PEN 4; LABELS=label; SYMBOLS=0; COLOUR= 0
DGRAPH [WINDOW=3; KEYWINDOW=0; SCREEN=clear; \
       TITLE='Standard normal distribution'] \
       Y=z,!(0,fu),zfill; X=x,!(u,u),xfill; PEN=1...3
&      [SCREEN=keep] 0.04; X=2.5; PEN=4
ENDJOB
```

Example 8

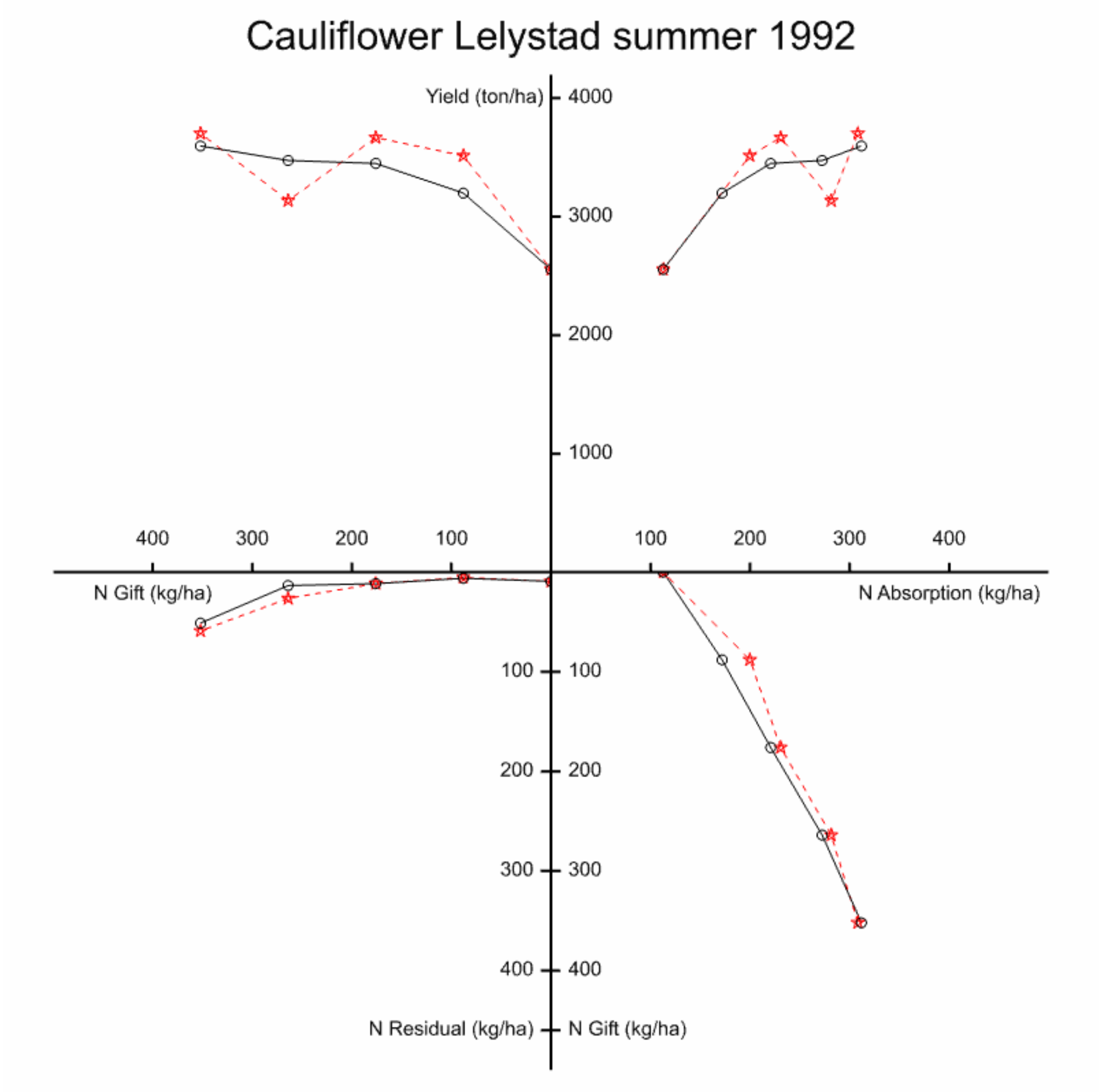
Keywords: Line plot, secondary y-axis, automated title, FOR loop



```
JOB
DCLEAR
FACTOR Treat
READ Treat, Yld, TotN, Ngift, Nres
1     2554    112.8      0    9.2      2    2554    112.8      0    9.2
1     3198    171.9     88    6.1      2    3513    199.8     88    5.3
1     3448    220.7    176   11.5      2    3666    230.8    176   11.4
1     3473    272.4    264   13.4      2    3134    281.5    264   26.3
1     3595    311.9    352   51.1      2    3701    308.3    352   59.0:
FRAME 1...4; YLOWER=0.5; YUPPER=1; XLOWER=2(0,0.5); \
      XUPPER=2(0.5,1); XMUPPER=0.10; XMLOWER=0.10
FRAME 5...8; YLOWER=0.55; YUPPER=0.67,0.65; \
      XLOWER=2(0.11,0.61); \
      XUPPER= 2(0.5,1); BOXKEY=omit
XAXIS 1...4; LOWER=-20; UPPER=420; \
      TITLE= 'N Gift (kg/ha)'; YORIGIN=0; MARKS=100
YAXIS 1...4; MPOSITION=outside; LPOSITION=outside; \
      LOWER=0; XORIGIN=(-20,420)2; MARKS=(1000,50)2; \
      TITLE='Yield (ton/ha)', 'N absorption (kg/ha)'
PEN 1,2; METHOD=line; SYMBOLS= 9, 2
FOR ii=1, 2; jj=1,3; kk=2,4; ll= 5,7; mm=6,8
   TXCONSTRUCT [TEXT=title] 'Treatment ', ii
   RESTRICT Yld, Ngift, TotN; Treat.EQ.ii
   DGRAPH [WINDOW=jj; KEYWINDOW=ll; SCREEN=keep; \
          TITLE=title] Yld; Ngift; PEN=1; DESCRIPTION= 'Yield'
   &       [WINDOW=kk; SCREEN=keep; KEYWINDOW=mm] TotN; Ngift; \
          PEN=2; DESCRIPTION= 'N Absorption'
   RESTRICT Yld, Ngift, TotN
ENDFOR
```

Example 9

Keywords: Line plot, multi-axis

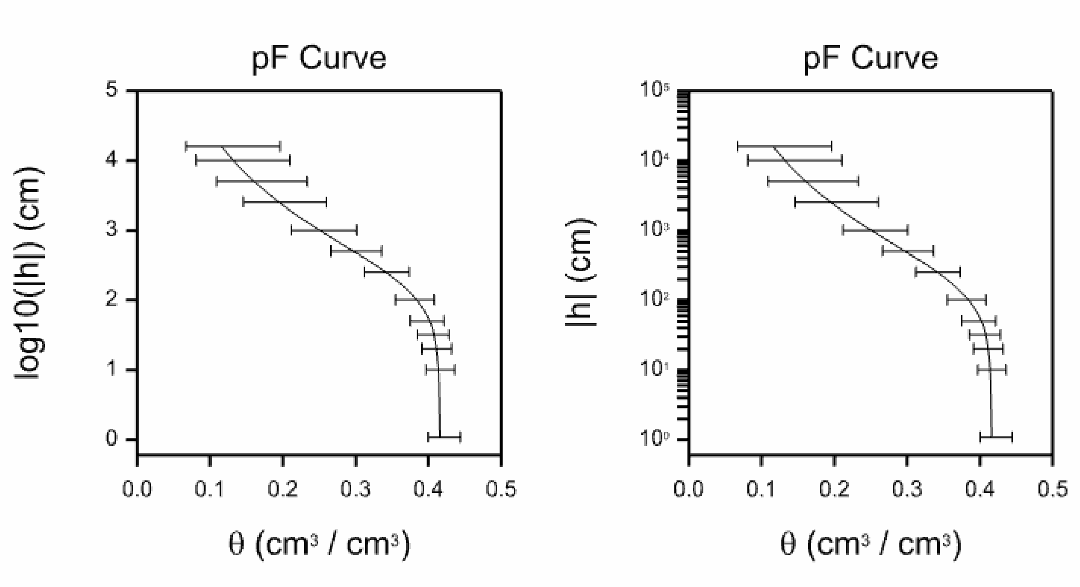


```
JOB
FACTOR Treat
READ Treat, Yld, TotN, Ngift, Nres
1     2554   112.8      0    9.2      2    2554    112.8      0    9.2
1     3198   171.9     88    6.1      2    3513    199.8     88    5.3
1     3448   220.7    176   11.5      2    3666    230.8    176   11.4
1     3473   272.4    264   13.4      2    3134    281.5    264   26.3
1     3595   311.9    352   51.1      2    3701    308.3    352   59.0:
FRAME 5...8; XMLOWER=0; XMUPPER=0; YMLOWER= 2(0,0); \
      YMUPPER= 2(0,0); BOX=omit
```

```
XAXIS 5,7; LOWER=0,0; UPPER=500,500; YORIGIN=0; \
      MARKS=!(100,200,300,400),!(400); \
      LABELS=*,'N Gift (kg/ha)'; \
      MPOSITION=inside,*; LPOSITION=inside,inside; REVERSE=yes
XAXIS 6,8; LOWER=0,0; UPPER=500,500; YORIGIN= 0; \
      MARKS=!(100,200,300,400),!(400); \
      LABELS= *,'N Absorption (kg/ha)'; \
      MPOSITION=inside,*; LPOSITION=inside,inside
YAXIS 5...8; LOWER=0,0,0,0; UPPER=4200,4200,500,500; XORIGIN=0;\
      MARKS=2(!(1000,2000,3000,4000), !(100,200,300,400,460)); \
      LABELS=!T(3(''),'Yield (ton/ha)'),*,\
      !T('100','200','300','400','N Residual (kg/ha)'), \
      !T('100','200','300','400','N Gift (kg/ha)'); \
      MPOSITION=*,inside,inside,inside; \
      LPOSITION=inside,inside,inside,inside; REVERSE=2(no,yes)
PEN 1,2; METHOD=line; LINESTYLE=1,7; SYMBOLS=2,4
DSTART [TITLE='Cauliflower Lelystad summer 1992']
DGRAPH [WINDOW=5; KEYWINDOW=0] Yld; Ngift; PEN= Treat
&      [WINDOW=6; SCREEN=keep] Yld; TotN; PEN= Treat
&      [WINDOW=7] Nres; Ngift; PEN= Treat
&      [WINDOW=8] Ngift; TotN; PEN= Treat
DFINISH
ENDJOB
```

Example 10

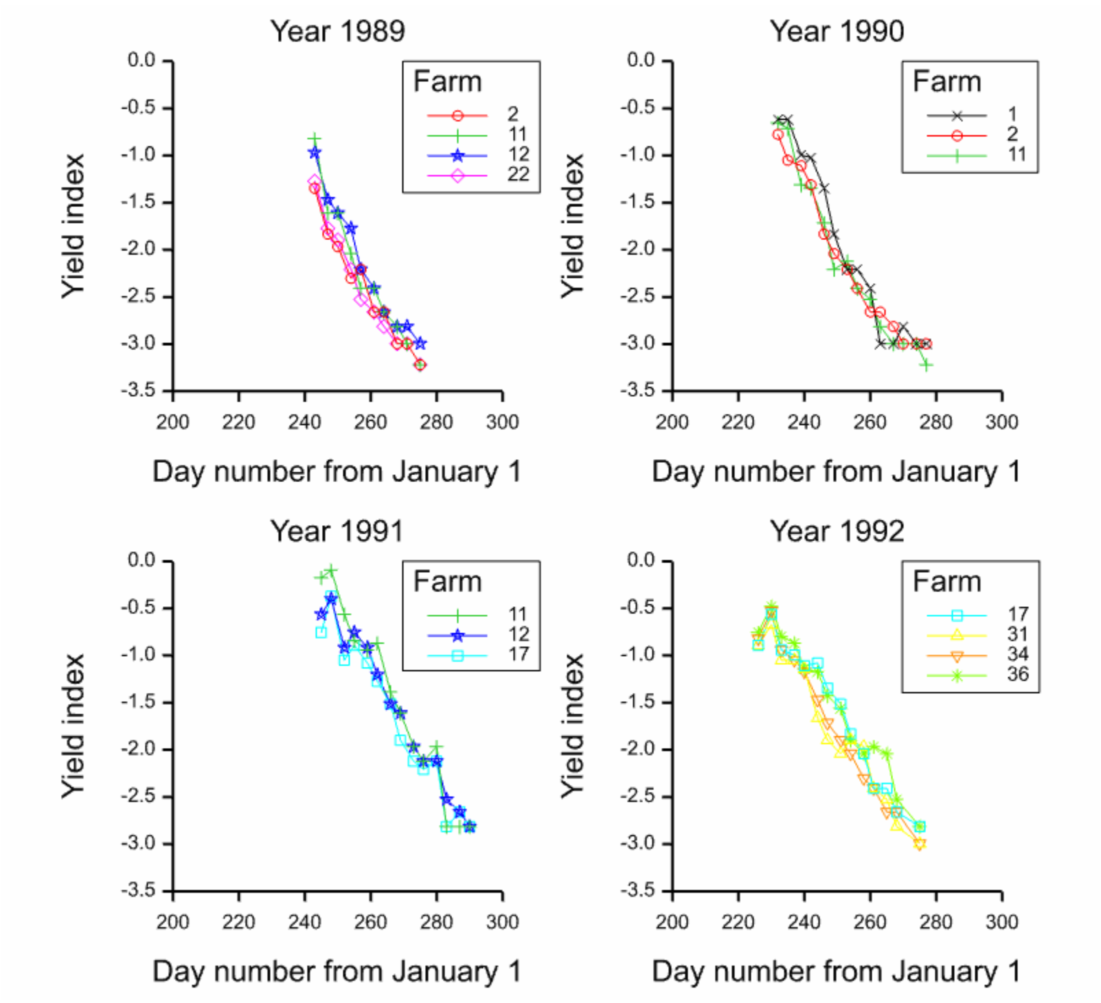
Keywords: Monotonic line plot, error bars, transformed axis, typesetting



```
JOB
READ \
Log_h, Lower, Theta, Upper
0.03 0.400 0.416 0.444 1.00 0.397 0.414 0.436
1.30 0.391 0.411 0.432 1.50 0.385 0.408 0.428
1.70 0.375 0.402 0.422 2.00 0.355 0.384 0.408
2.40 0.312 0.342 0.373 2.70 0.266 0.297 0.336
3.00 0.212 0.251 0.301 3.40 0.146 0.195 0.260
3.70 0.109 0.161 0.233 4.00 0.081 0.132 0.210
4.20 0.067 0.116 0.196 :
CALCULATE h = 10**Log_h
PEN 1; METHOD= monotonic; SYMBOLS= 0
XAXIS 5,6; TITLE='~{theta} (cm~^3 / cm~^3)'; \
      LOWER=0; UPPER=0.5; MARKS=!(0, 0.1 ... 0.5)
YAXIS 5; TITLE='log10(|h|) (cm)'; UPPER=5
DGRAPH [TITLE='pF Curve'; WINDOW=5; KEYWINDOW=0] \
       Log_h; Theta; XLOWER=Lower; XUPPER=Upper
VARIATE [VALUES=1...10,20,30...100,200,300...1000,\
        2000,3000...10000,20000,30000...100000] Marks
YAXIS 6; TITLE='|h| (cm)'; UPPER=10**5; TRANSFORM=log10; \
      MARKS=Marks; LABELS=!t('10~^0',8(''), '10~^1',8(''),\
      '10~^2',8(''),'10~^3',8(''),\
      '10~^4',8(''),'10~^5')
DGRAPH [TITLE='pF Curve'; WINDOW=6; KEYWINDOW=0; SCREEN=keep]\
       h; Theta; XLOWER=Lower; XUPPER=Upper
ENDJOB
```

Example 11

Keywords: Line plot, trellised, automated labelling of key

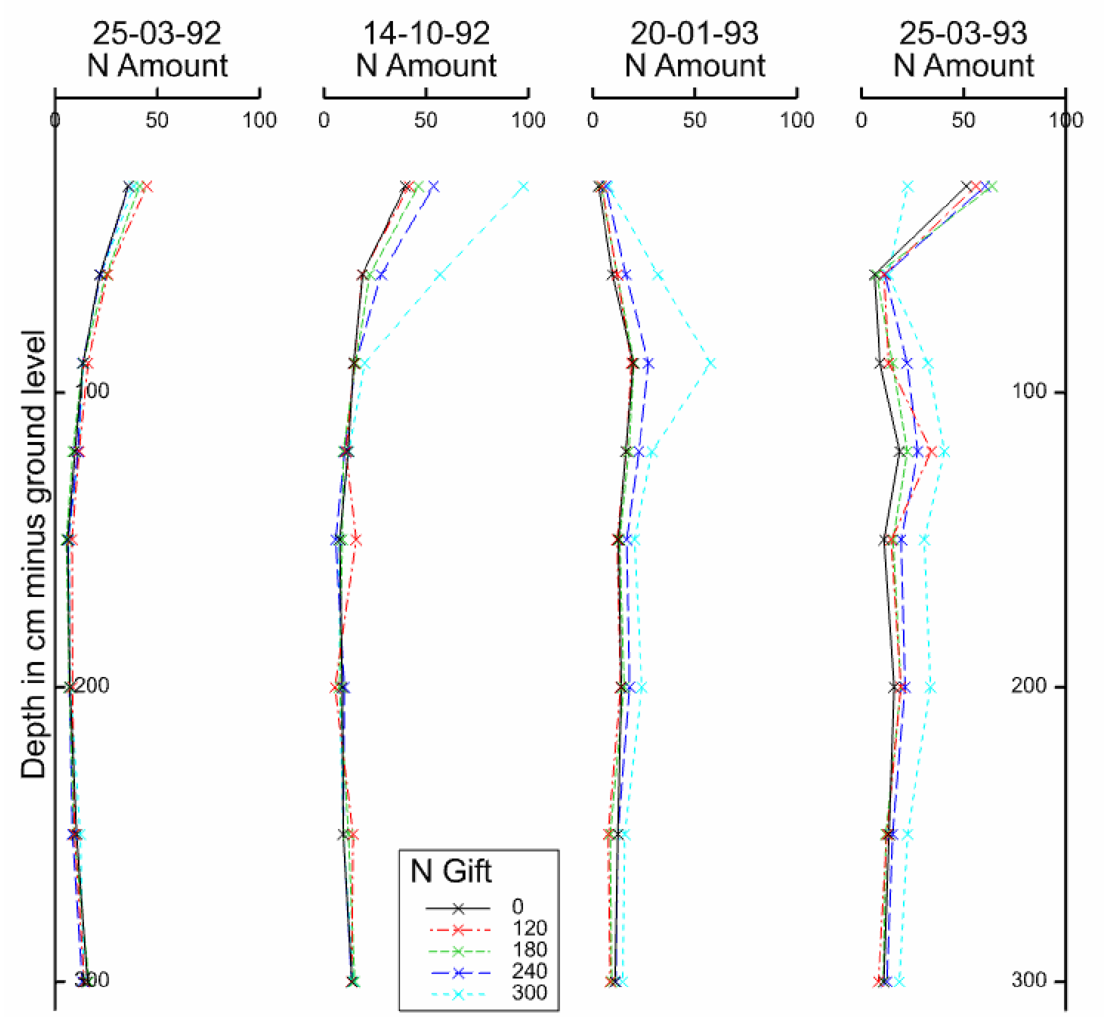


```
JOB
DCLEAR
FACTOR Year, Farm
READ Year, Daynr, Farm, Index
89 243  2 .26  89 243 11 .44  89 243 12 .38  89 243 22 .28  89 247  2 .16
89 247 11 .20  89 247 12 .23  89 247 22 .17  89 250  2 .14  89 250 11 .20
89 250 12 .20  89 250 22 .15  89 254  2 .10  89 254 11 .13  89 254 12 .17
89 254 22 .11  89 257  2 .11  89 257 11 .09  89 257 12 .11  89 257 22 .08
89 261  2 .07  89 261 11 .09  89 261 12 .09  89 261 22 .07  89 264  2 .07
89 264 11 .07  89 264 12 .07  89 264 22 .06  89 268  2 .05  89 268 11 .06
89 268 12 .06  89 268 22 .05  89 271  2 .05  89 271 11 .05  89 271 12 .06
89 271 22 .05  89 275  2 .04  89 275 11 .04  89 275 12 .05  89 275 22 .04
90 232  1 .54  90 232  2 .46  90 232 11 .52  90 235  1 .54  90 235  2 .35
90 235 11 .49  90 239  1 .37  90 239  2 .33  90 239 11 .27  90 242  1 .36
90 242  2 .27  90 242 11 .26  90 246  1 .26  90 246  2 .16  90 246 11 .18
90 249  1 .16  90 249  2 .13  90 249 11 .11  90 253  1 .11  90 253  2 .11
```

```
90 253 11 .12  90 256  1 .11  90 256  2 .09  90 256 11 .09  90 260  1 .09
90 260  2 .07  90 260 11 .08  90 263  1 .05  90 263  2 .07  90 263 11 .06
90 267  1 .05  90 267  2 .06  90 267 11 .05  90 270  1 .06  90 270  2 .05
90 270 11 .05  90 274  1 .05  90 274  2 .05  90 274 11 .05  90 277  1 .05
90 277  2 .05  90 277 11 .04  91 245 11 .84  91 245 12 .57  91 245 17 .47
91 248 11 .91  91 248 12 .67  91 248 17 .69  91 252 11 .57  91 252 12 .40
91 252 17 .35  91 255 11 .43  91 255 12 .47  91 255 17 .41  91 259 11 .39
91 259 12 .40  91 259 17 .34  91 262 11 .42  91 262 12 .30  91 262 17 .28
91 266 11 .25  91 266 12 .22  91 266 17 .22  91 269 11 .20  91 269 12 .20
91 269 17 .15  91 273 11 .14  91 273 12 .14  91 273 17 .12  91 276 11 .12
91 276 12 .12  91 276 17 .11  91 280 11 .14  91 280 12 .12  91 280 17 .12
91 283 11 .06  91 283 12 .08  91 283 17 .06  91 287 11 .06  91 287 12 .07
91 287 17 .07  91 290 11 .06  91 290 12 .06  91 290 17 .06  92 226 17 .41
92 226 31 .41  92 226 34 .44  92 226 36 .47  92 230 17 .57  92 230 31 .51
92 230 34 .59  92 230 36 .62  92 233 17 .39  92 233 31 .35  92 233 34 .39
92 233 36 .45  92 237 17 .37  92 237 31 .35  92 237 34 .35  92 237 36 .42
92 240 17 .33  92 240 31 .32  92 240 34 .31  92 240 36 .32  92 244 17 .34
92 244 31 .19  92 244 34 .23  92 244 36 .31  92 247 17 .26  92 247 31 .15
92 247 34 .18  92 247 36 .24  92 251 17 .22  92 251 31 .13  92 251 34 .15
92 251 36 .21  92 254 17 .16  92 254 31 .15  92 254 34 .13  92 254 36 .15
92 258 17 .13  92 258 31 .14  92 258 34 .10  92 258 36 .13  92 261 17 .09
92 261 31 .09  92 261 34 .09  92 261 36 .14  92 265 17 .09  92 265 31 .08
92 265 34 .07  92 265 36 .13  92 268 17 .07  92 268 31 .06  92 268 34 .07
92 268 36 .08  92 275 17 .06  92 275 31 .05  92 275 34 .05  92 275 36 .06 :
GETATTRIBUTE [levels] Farm; SAVE=SFarm
FTEXT SFarm[]; FarmsLabels
CALCULATE nlevels = NLEV(Farm)
CALCULATE lnIndex= LOG(Index)
FRAME 1...4; YLOWER=2(0.6,0.1); YUPPER=2(0.93,0.43); \
      XLOWER=(0.35,0.85)2; XUPPER=(0.5,1)2
FRAME 5...8; BOX=omit
XAXIS 5...8; TITLE='Day number from January 1'; LOWER=200; \
      UPPER=300
YAXIS 5...8; TITLE='Yield index'; LOWER=-3.5; UPPER=0
PEN 1...nlevels; METHOD=line; SYMBOLS=1...nlevels
FOR jj=89...92; \
    tt='Year 1989','Year 1990','Year 1991','Year 1992'; \
    ww=5...8; kk=1...4
  RESTRICT lnIndex, Daynr; Year .EQ. jj
  DGRAPH [TITLE=tt; WINDOW=ww; KEYWINDOW=kk; SCREEN=keep; \
     KEYDESCRIPTION='Farm'] lnIndex; Daynr; PEN=Farm; \
     DESCRIPTION=FarmsLabels
  RESTRICT lnIndex, Daynr
ENDFOR
ENDJOB
```

Example 12

Keywords: Line plot, trellised, reversed axis, hidden axis, automated annotation

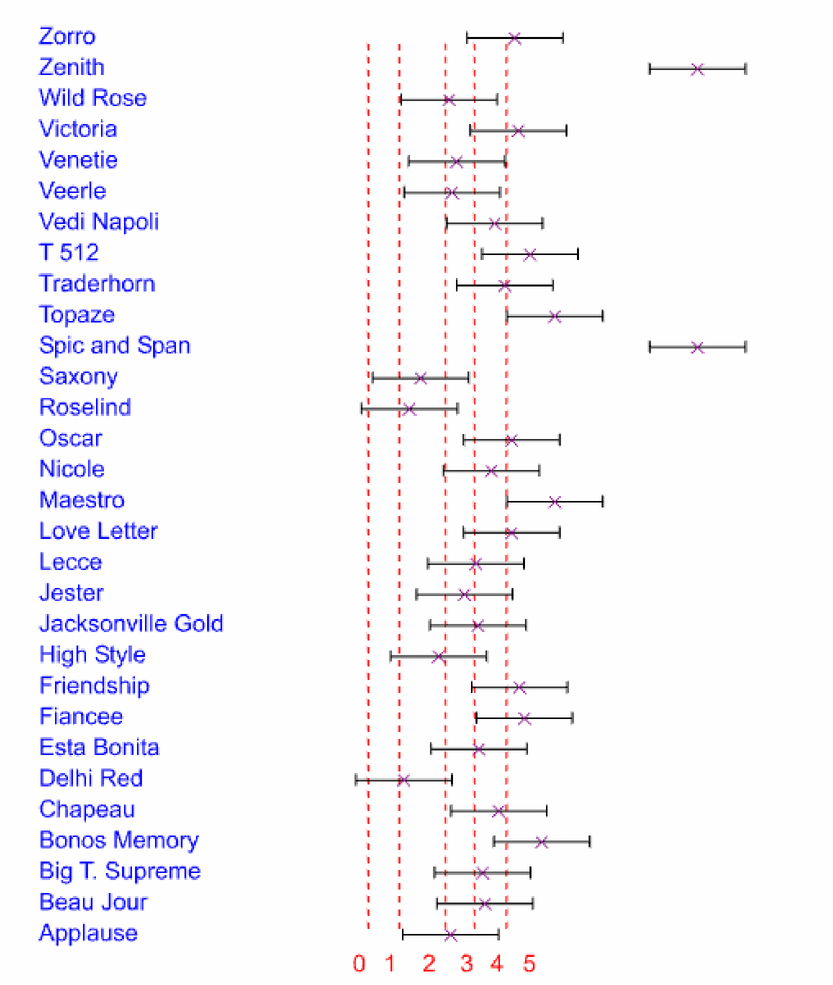


```
JOB
FACTOR Ngift
READ \
Ngift, Depth, m[1...4]; FREP=labels
   0    30  35.85  39.90   2.85  51.30    0    60  21.90  18.90   9.75   6.30
   0    90  13.65  14.55  19.80   9.00    0   120   9.75  11.85  16.20  18.65
   0   150   6.15   7.80  12.60  11.10    0   200   7.25   9.00  14.00  16.00
   0   250  10.50   9.50  12.33  13.50    0   300  15.75  13.75  11.00  11.00
 120    30  44.85  41.70   4.50  55.95  120    60  25.65  18.60  12.00  11.10
 120    90  16.05  14.85  18.90  13.35  120   120  11.70  10.80  16.40  34.20
 120   150   8.25  15.75  12.00  14.55  120   200   8.50   5.50  13.67  19.25
 120   250   9.50  14.25   7.67  12.50  120   300  14.25  13.50   8.67   8.25
 180    30  41.40  46.20   4.05  63.90  180    60  25.05  22.50  12.00   7.35
 180    90  13.50  15.45  20.10  15.15  180   120   8.70   9.60  17.60  22.35
 180  150   5.55   9.00  13.20  15.45  180  200   7.00   7.75  15.33  19.25
 180  250   9.25  12.00   8.67  12.00  180  300  16.50  15.00   9.33  10.75
 240   30  36.00  53.70   6.45  60.45  240   60  22.35  28.05  16.20  11.55
 240   90  13.35  15.45  27.30  22.20  240  120  11.10  10.20  22.60  27.60
 240  150   6.45   5.85  16.60  19.35  240  200   7.00  10.00  18.00  21.25
 240  250   8.50   9.50  12.33  15.25  240  300  13.25  13.50  11.33  12.50
 300   30  38.55  97.75   7.65  22.50  300   60  22.35  56.85  31.95  13.05
 300   90  13.80  19.95  57.75  32.55  300  120  11.40  12.15  29.00  40.50
 300  150   6.75   7.65  20.40  30.75  300  200   7.50   7.75  24.00  33.75
 300  250  12.25   9.50  15.67  22.50  300  300  14.00  14.50  14.67  18.50 :
FRAME 1...4; XLOWER=0,0.25...0.75; XUPPER=0.25,0.5...1; \
      YLOWER=0; YUPPER=1; XMLOWER=0.04; \
      XMUPPER=0.02; YMUPPER=0.07; YMLOWER=0.08; BOX=omit
XAXIS 1...4; TITLE='25-03-92','14-10-92','20-01-93','25-03-93';\
      LOWER=0; UPPER=100; MARKS=!(0,50,100); YORIGIN=0; \
      MPOSITION=outside; LPOSITION=inside
YAXIS 1...4; TITLE='Depth in cm minus ground level',*,*,*; \
      ACTION=display,2(hide),display; \
      LOWER=0; UPPER=310; MARKS=!(100,200,300); \
      XORIGIN=0,0,0,100; MPOSITION=inside,*,*,inside; \
      LPOSITION=inside,*,*,inside; REVERSE=yes
PEN 1...5; METH=line; JOIN=given; LINESTYLE=1,4,5,6,7
GETATT [labels] Ngift; SAVE=SaveN
FRAME 13; XLOWER=0.36; YUPPER=0.23
DGRAPH [KEYWINDOW=13; TITLE='N Amount'; \
       KEYDESCRIPTION='N Gift'] Depth; m[1]; PEN=Ngift; \
       DESCRIPTION=SaveN['labels']
&      [WINDOW=2; KEYWINDOW=0; SCREEN=keep] Depth; m[2]; \
       PEN=Ngift
&      [WINDOW=3] Depth; m[3]; PEN=Ngift
&      [WINDOW=4] Depth; m[4]; PEN=Ngift
ENDJOB
```

Example 13

Keywords: error bars, composite plot, hidden axis, data labels

NB: This example displays the results of a threshold model. The figure can also be produced by Biometris procedure DORDINAL.

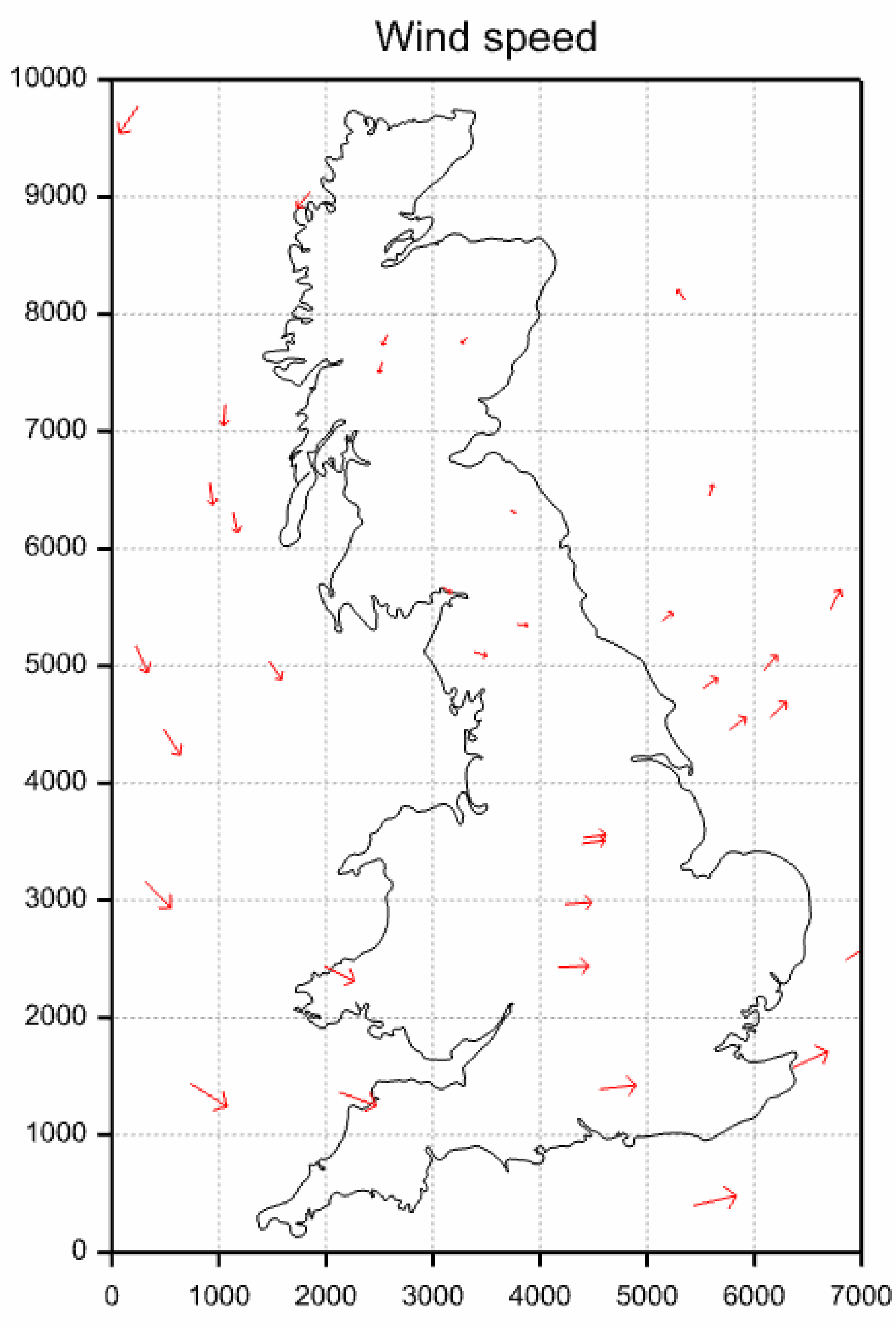


```
JOB
TEXT tname
READ tname, aantal[0...5]; FREPRESENTATION=labels
         'Applause' 0  1  6 11  2  0    'Beau Jour' 0  0  1  7  7  5
   'Big T. Supreme' 0  1  2  5  7  5 'Bonos Memory' 0  0  0  0  2 17
          'Chapeau' 0  0  0  3 10  7    'Delhi Red' 5  4  7  1  1  2
      'Esta Bonita' 0  0  0 10  7  3      'Fiancee' 0  0  0  1  4 15
       'Friendship' 0  0  0  2  4 14   'High Style' 0  0 13  6  0  1
'Jacksonville Gold' 0  1  2  4 12  1       'Jester' 0  2  3  7  7  1
            'Lecce' 0  1  1  6 12  0  'Love Letter' 0  0  0  3  5 12
          'Maestro' 0  0  0  0  1 19       'Nicole' 0  0  0  5 10  5
```

```
           'Oscar' 0  0  0  3  5 12      'Roselind' 0  6 14  0  0  0
          'Saxony' 0  3 15  1  1  0 'Spic and Span' 0  0  0  0  0 20
          'Topaze' 0  0  0  2  9  9    'Traderhorn' 0  0  0  0  4 16
           'T 512' 0  0  0  0  1 19   'Vedi Napoli' 0  0  2  4  6  8
          'Veerle' 0  1 10  1  7  1       'Venetie' 0  0  7  8  4  1
        'Victoria' 0  0  0  0  7 13     'Wild Rose' 0  0  9  8  3  0
          'Zenith' 0  0  0  0  0 20         'Zorro' 0  0  0  3  4 13:
GROUPS tname; name
MODEL [DISTRIBUTION=multinomial; YRELATION=cum] aantal[]
TERMS [FULL=yes] name
FIT [NOMESSAGE=dispersion] name
RKEEP ESTIMATES=esti
VARIATE [NVALUES=5] bound
&       [NVALUES=30] estimate
EQUATE esti; !P(bound,estimate)
CALCULATE diff = DIFF(bound;1)
&         diff$[1] = diff$[2]
&         xpos = bound - diff/2
SCALAR    L
CALCULATE L = bound$[5] + diff$[5] / 2
VARIATE [VALUES=#xpos, L] xpos
TEXT [NVALUES=6; VALUES='0','1','2','3','4','5'] namebound
CALC nlines = NVAL( estimate)
&    nlines1 = nlines + 1
&    minbound = MIN( esti)
&    maxbound = MAX( esti)
&    xlower = minbound - (maxbound - minbound)
&    xupper = maxbound + (maxbound - minbound)
&    lower, upper = estimate - 1, -1 * 2.9444
VARIATE [VAL=(1, #nlines)5] y
VARIATE [VAL=2(#bound)] x
FACTOR [LEV=!(1...5); VAL=2(1...5)] factor
FRAME 3; BOX=omit
XAXIS 3; ACTION=hide; LOWER=xlower; UPPER=xupper
YAXIS 3; ACTION=hide; LOWER=-1; UPPER=nlines1
PEN 1...5; METHOD=line; JOIN=given; SYMBOLS=0; LINESTYLE=7; \
    COLOUR='red'
PEN 6; SYMBOLS=0; LABELS=tname; COLOUR='blue'
PEN 7; LINESTYLE=1; SYMBOLS=1; COLOUR='purple'
PEN 8; SYMBOLS=0; LABELS=namebound; COLOUR='red'
PRINT (factor)2; FREP=ord,lev; DEC=0
DGRAPH [WINDOW=3; KEYWINDOW=0] !(1...nlines); \
       X=!(#nlines(xlower)); PEN=6
&      [SCREEN=keep] y; X=x; PEN=factor
&      !(1...nlines); X=estimate; PEN=7; XLOWER= lower; \
       XUPPER=upper
&      !(6(0)); X=xpos; PEN=8
ENDJOB
```

Example 14

Keywords: Line plots with breaks, smooth curve, grid lines, pointer

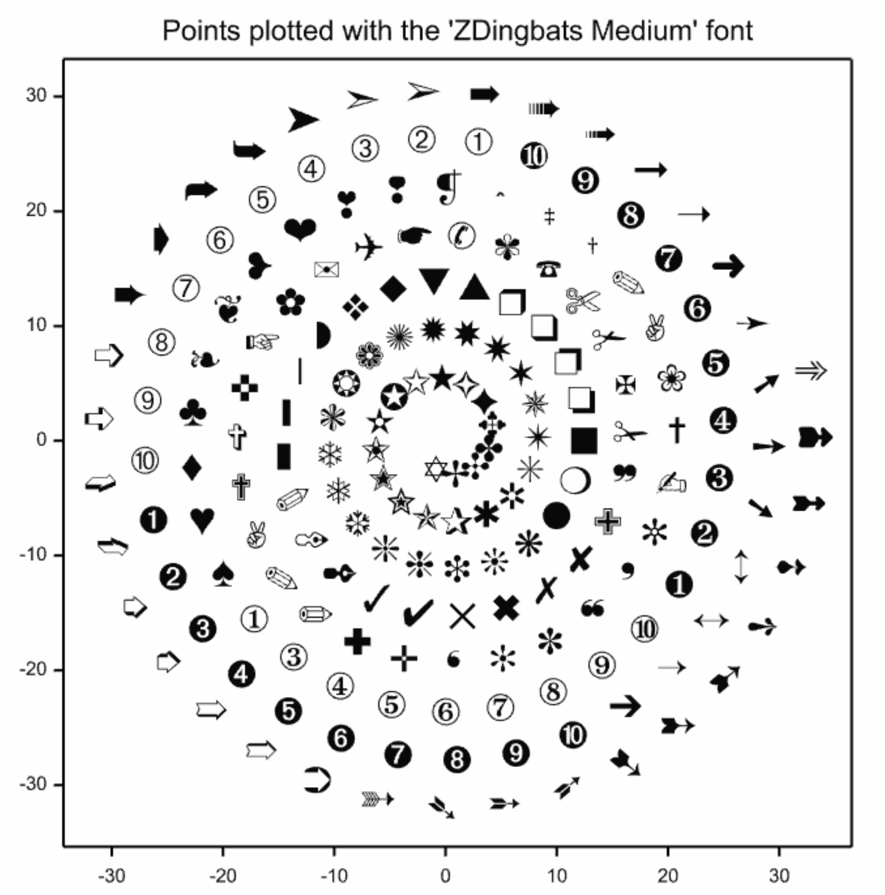


```
JOB
FILEREAD [NAME='%gendir%/examples/DGRA-7.DAT'] X,Y
XAXIS 1; LOWER=0; UPPER=7000; MARK=!(0,1000...7000)
YAXIS 1; LOWER=0; UPPER=10000; MARK=!(0,1000...10000)
FRAME [GRID=xy,yx] 1; YLOWER=0; YUPPER=1; XLOWER=0; XUPPER=0.7
PEN 1; SYMBOL=0; METHOD=closed; JOIN=given; LINESTYLE=1
DGRAPH [KEYWINDOW=0; TITLE='Wind speed'] Y; X
"Add arrows of different sizes and angles at different places"
DELETE [REDEFINE=yes] Y,X
SCALAR N,P; 35,5     "no. units, no. points in shapes "
MATRIX [ROWS=P; COLUMNS=N] XX,YY
DIAGONAL [ROWS=N] Size
POINTER [NVALUES=!T(X,Y)] At,Shape
MATRIX [ROWS=1; COLUMNS=N] Angle,At[]
MATRIX [ROWS=P; COLUMNS=1] Onep,Shape[]; VALUES=!((1)#P),(*)2
READ  Shape[1,2]
   0.0  0.0
   0.0  1.0
  -0.25 0.75
   0.0  1.0
   0.25 0.75 :
OPEN '%gendir%/examples/DGRA-7A.DAT'; CHANNEL=data7
READ [CHANNEL=data7] At[],Size,Angle
CLOSE data7
CALC Rad = ARCCOS(0.5)/60.0
CALC XX,YY = (Shape['X','Y']*+COS(Angle*Rad)+    \
     (-1,+1)*Shape['Y','X']*+SIN(Angle*Rad))*+(Size)*6    \
      + Onep*+At['X','Y']
VARIATE [NVAL=P] Xg[1...N],Yg[1...N]
CALC Xg[1...N] = XX$[*;1...N]
CALC Yg[1...N] = YY$[*;1...N]
"Each Xg[] and Yg[] variate contains 5 points on the
 coordinates scale to draw an arrow"
PEN 1; LINESTYLE=1; SYMBOL=0; METHOD=line; JOIN=given; \
    CLINE='red'
DGRAPH [SCREEN=keep; KEYWINDOW=0] Yg[]; Xg[]; PEN=1
ENDJOB
```

Example 15

Keywords: Symbol font, scatter plot, labels

NB: The ‘ZDingbats Medium’ font was downloaded from https://bigfontsite.com/.



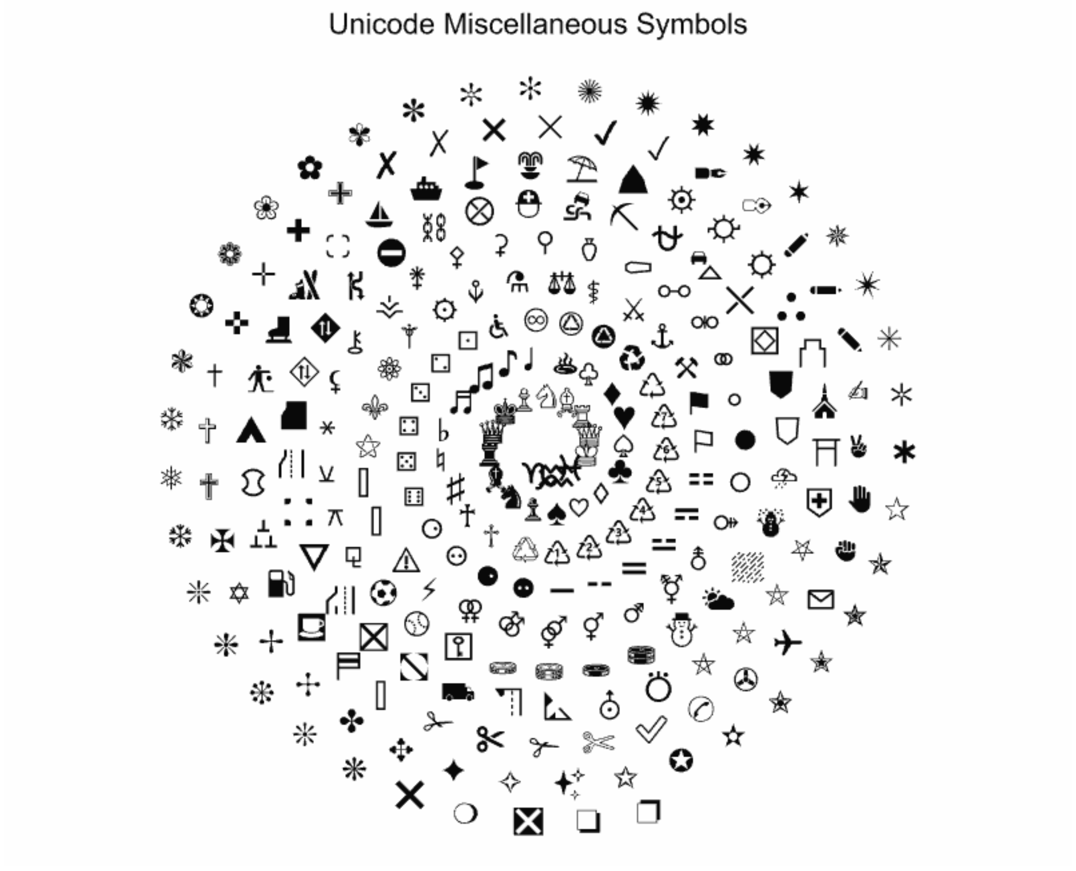
```
JOB
TEXT Labs; VALUES=!t(\
A,B,C,D,E,F,G,H,I,J,K,L,M,N,O,P,Q,R,S,T,U,V,W,X,Y,Z, \
a,b,c,d,e,f,g,h,i,j,k,l,m,n,o,p,q,r,s,t,u,v,w,x,y,z, \
'0','1','2','3','4','5','6','7','8','9','~','!','@', \
'#','$','%','^','&','*','(',')','_','+','<','>','?', \
',','.','/',':',';','{','[',']','}','|','\\','-','=',\
'``',',','.','†','‡','^','¡','¢','£','¤','¥','¦','§',\
'¨','©','ª','«','¬','®','¯','°','±','²','³','´','µ', \
'¶','·','¸','¹','º','»','¼','½','¾','¿','À','Á','Â', \
'Ã','Ä','Å','Æ','Ç','È','É','Ê','Ë','Ì','Í','Î','Ï', \
'Ð','Ñ','Ò','Ó','Ô','Õ','Ö','×','Ø','Ù','Ú','Û','Ü', \
'Ý','Þ','ß','à','á','â','ã','ä','å','æ','ç','è','é', \
'ê','ë','ì','í','î','ï','ñ','ò','ó','ô','õ','ö','÷', \
'ø','ù','ú','û','ü','ý','þ')
```

```
CALC N = NVALUES(Labs)
CALC t = !(1...N) + 4
CALC X = (t)**(2/3)*COS(C('pi')*(t/3)**(2/3))
CALC Y = (t)**(2/3)*SIN(C('pi')*(t/3)**(2/3))

PEN 1; SYMBOL=0; SIZE=2; FONT='ZDingbats Medium'; \
    LABELS=Labs; XLPOSITION=centre; YLPOSITION=centre
DGRAPH [WINDOW=3; KEYWINDOW=0; TITLE='Points plotted with the \
''ZDingbats Medium'' font'] Y; X

ENDJOB
```

Example 16

Keywords: Unicode, non-ASCII characters

NB: If your computer allows it, you can use non-ASCII characters, such as accented letters and Chinese, Korean or Thai characters, in a Genstat graph.



```
JOB

SCALAR N; 256
VARIATE [NVALUES=N] t,X,Y
TEXT[NVALUES=N] Labs
FOR [NTIMES=N; INDEX=i]
    TXINTEGERCODES [CONVERTTO=text] Labs$[i]; CODES=9808+i
ENDFOR
CALC t = !(1...N) + 4
CALC X = (t)**(2/3)*COS(C('pi')*(t/3)**(2/3))
CALC Y = (t)**(2/3)*SIN(C('pi')*(t/3)**(2/3))

PEN 1; SYMBOL=0; SIZE=2; LABELS=Labs; \
    XLPOSITION=centre; YLPOSITION=centre
FRAME WINDOW=3; BOX=omit
YAXIS WINDOW=3; ACTION=hide
XAXIS WINDOW=3; ACTION=hide
DGRAPH [WINDOW=3; KEYWINDOW=0; TITLE='Unicode Miscellaneous \
Symbols'] Y; X

ENDJOB
```

5 Appendices

5.1 Genstat graphical directives and procedures

5.1.1 Directives for line-printer plots

The following directives produce plots in "*line-printer*" style, i.e. using the characters of ordinary textual output:

LPCONTOUR	produces contour maps of two-way arrays of numbers
LPGRAPH	produces scatter plots and line graphs
LPHISTOGRAM	plots histograms

Example plots generated by these directives under their default parameter and option settings are given in Section 4.1.

5.1.2 Directives for high-resolution plots

Directives for high-resolution plots have two main purposes: i) those that define the *Graphics Environment*, and 2) those that do the plotting.

To change the *Graphics Environment*, the following directives can be used:

XAXIS	defines the x-axis in each graphical window
YAXIS	defines the y-axis in each graphical window
ZAXIS	defines the z-axis in each graphical window
AXIS	defines an oblique axis for high-resolution graphics
DEVICE	switches between graphics devices
FRAME	defines the positions of the windows within the frame
PEN	defines the properties of the graphical pens
DFONT	defines the default font for high-resolution graphics
DKEEP	saves information about the *Graphics Environment* in Genstat data structures
DLOAD	loads the *Graphics Environment* settings from an external file
DSAVE	saves the current *Graphics Environment* settings to an external file
GETRGB	provides a standard sequence of colours (defined by the initial defaults of the Genstat pens)

The directives for plotting high-resolution graphs are:

BARCHART	plots bar charts
DGRAPH	produces scatter plots and line graphs
DHISTOGRAM	plots histograms
DPIE	produces pie charts
DCONTOUR	produces contour maps
DBITMAP	plots a bitmap of RGB colours
DSHADE	produces a shade diagram of 3-dimensional data
DSURFACE	draws a perspective plot of a two-way array of numbers
D3GRAPH	plots a 3-dimensional graph
D3HISTOGRAM	produces 3-dimensional histograms
DSTART	starts a sequence of related plots
DFINISH	ends a sequence of related plots
DDISPLAY	redraws the current graphical display
DCLEAR	clears a graphics screen

Example of plots generated by these directives under their default parameter and option settings are given in Section 4.1.

5.1.3 Procedures

Other facilities, provided by procedures include:

A2DISPLAY	provides further output following an analysis of variance by A2WAY
A2PLOT	plots effects from two-level designs with robust s.e. estimates
ABIVARIATE	produces graphs and statistics for bivariate analysis of variance
ADPOLYNOMIAL	plots single-factor polynomial contrasts fitted by ANOVA
AFIELDRESIDUALS	display residuals in field layout
AGRAPH	plots tables of means from an analysis of variance
AKAIKEHISTOGRAM	prints histograms with improved definition of group
AMCOMPARISON	plots pairwise multiple comparison tests between ANOVA means
APLOT	plots residuals from an ANOVA analysis
AUGRAPH	plots tables of means from AUNBALANCED
BANK	calculates the optimum aspect ratio for a graph
BGPLOT	produces plots for output and diagnostics from MCMC simulations
BGRAPH	plots a tree

BIPLOT	produces a biplot from a set of variates
BJFORECAST	plots forecasts of a time series using a previously fitted ARIMA
BLANDALTMAN	produces Bland-Altman plots to assess the agreement between two variates
BOXPLOT	draws box-and-whisker diagrams (schematic plots)
CABIPLOT	plots results from correspondence analysis or multiple correspondence analysis
CRBIPLOT	plots correlation or distance biplots after RDA, or ranking biplots after CCA
CRTRIPLOT	plots ordination biplots or triplots after CCA or RDA
CVAPLOT	plots the mean and unit scores from a canonical variates analysis
DARROW	adds arrows to an existing plot
DBARCHART	plots bar charts for one or two-way tables
DBIPLOT	plots a biplot from an analysis by PCP, CVA or PCO
DCIRCULAR	plots circular data
DCOLOURS	forms a band of graduated colours for graphics
DCOMPOSITIONAL	plots 3-part compositional data within a barycentric triangle
DCORRELATION	plots a correlation matrix
DCOVARIOGRAM	plots 2-dimensional auto-and cross-variograms
DDENDROGRAM	draws dendrograms with control over structure and style
DDESIGN	plots the plan of an experimental design
DELLIPSE	plots 2-dimensional scatter plot with confidence, prediction and/or equal-frequency ellipses superimposed
DERRORBAR	adds error bars to an existing graph
DFRTEXT	adds text to a graphics frame
DFUNCTION	plots a function
DHELP	provides information about Genstat graphics
DHSCATTERGRAM	plots an h-scattergram
DKEY	adds a bespoke key to a plot
DKSTPLOT	produces diagnostic plots for space-time clustering
DMADENSITY	plots the empirical CDF or PDF (kernel smoothed) by groups
DMASS	plots discrete data like mass spectra, discrete probability functions
DMSCATTER	produces a scatter-plot matrix for one or two sets of variables
DMST	produces a plot of an ordination with minimum spanning tree
DOTHISTOGRAM	plots dot histograms
DOTPLOT	produces a dot-plot

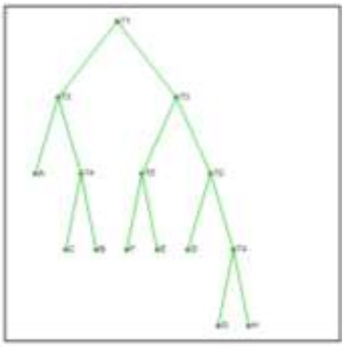
DPOLYGON	draws polygons using high-resolution graphics
DPROBABILITY	creates probability distribution plots
DPSPECTRALPLOT	calculates an estimate of the spectrum of a spatial point pattern
DPTMAP	draws maps for spatial point patterns using high-resolution graphics.
DPTREAD	adds points interactively to a spatial point pattern.
DQMAP	displays a genetic map.
DQMKSCORES	plots a grid of marker scores for genotypes and indicates missing data
DQMQTLSCAN	plots the results of a genome-wide scan for QTL × E effects in multiple environments
DQRECOMBINATIONS	plots a matrix of recombination frequencies between markers
DQSQTLSCAN	plots the results of a genome-wide QTL search in a single environment trial
DREFERENCELINE	adds reference lines to a graph
DRESIDUALS	produces model-checking plots of residuals
DREPMEASURES	plots profiles and differences of profiles for repeated measures data.
DRPOLYGON	reads a polygon interactively from the current graphics device.
DSCATTER	produces a scatter-plot matrix
DSEPARATION	creates a separation plot for visualising the fit of a model with a dichotomous or polytomous outcome
DSPIDERWEB	produces spider-web and star plots
DTABLE	plots tables
DTEXT	adds text to a graph
DTIMEPLOT	produces horizontal bars displaying a continuous time record
DVARIOGRAM	plots fitted models to an experimental variogram
DXDENSITY	produces one-dimensional density (or violin) plots
DXYDENSITY	produces density plots for large data sets
DXYGRAPH	draws two-dimensional graphs with marginal distribution plots alongside the y- and x-axes
DYPOLAR	produces polar plots
FFRAME	forms multiple windows in a plot-matrix for high-resolution graphics
GGEBIPLOT	plots displays to assess genotype+genotype-by-environment variation
HGGRAPH	draws a graph to display the fit of an HGLM or DHGLM analysis
HGPLOT	produces model-checking plots for a HGLM or DHGLM analysis
INSIDE	determines whether points lie within a specified polygon
LORENZ	plots the Lorenz curve and calculates the Gini and asymmetry coefficients

LSIPLOT	plots least significant intervals, saved from SEDLSI
MAHISTOGRAM	plots histograms of microarray data
MAPLOT	produces two-dimensional plots of microarray data
MASHADE	produces shade plots to display spatial variation of microarray data
MAVOLCANO	produces volcano plots of microarray data
MOVINGAVERAGE	calculates and plots the moving average of a time series
PLINK	prints a link to a graphics file into an HTML file
RDESTIMATES	plots one-or two-way tables of regression estimates
RGRAPH	draws a graph to display the fit of a regression model
RQLINEAR	fits and plots quantile regressions for linear models
RQNONLINEAR	fits and plots quantile regressions for nonlinear models
RQSMOOTH	fits and plots quantile regressions for loess or spline models
RUGPLOT	draws rug plots to display the distribution of one or more samples
SETDEVICE	opens a graphical file and specifies the device number on basis of its extension
SPCCHART	plots c or u charts representing numbers of defective items
SPEWMA	plots exponentially weighted moving-average control charts
SPPCHART	plots p or np charts for binomial testing for defective items
SPSHEWHART	plots control charts for mean and standard deviation or range
STEM	produces a simple stem-and-leaf chart
TRELLIS	produces trellis plots for each level of one or more factors
TVGRAPH	plots a vector autoregressive moving average (VARMA) model
VDEFFECTS	plots one-or two-way tables of effects estimated in a REML analysis
VGRAPH	plots tables of means from REML
VMCOMPARISON	plots pairwise multiple comparison tests between REML means
VPLOT	plots residuals from a REML analysis
WINDROSE	plots rose diagrams of circular data like wind speeds

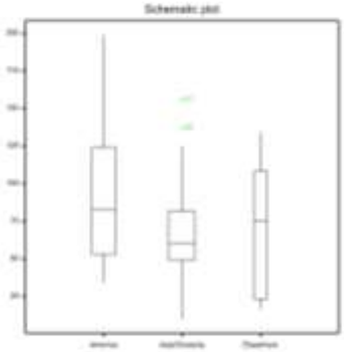
5.1.3.1 Image library of example graphs

Basic plots:

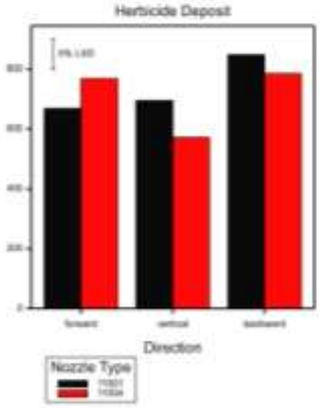
BGRAPH



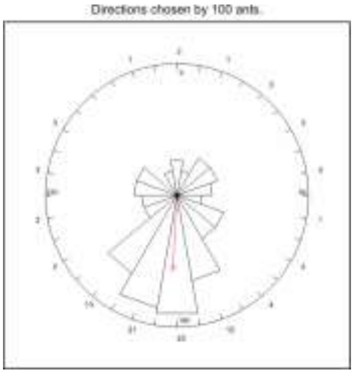
BOXPLOT



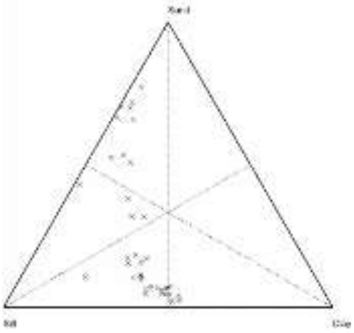
DBARCHART



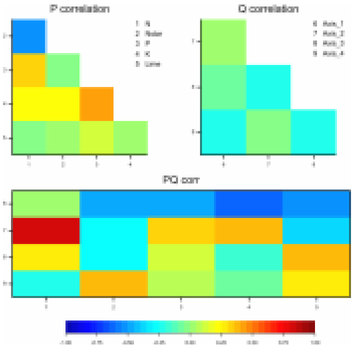
DCIRCULAR



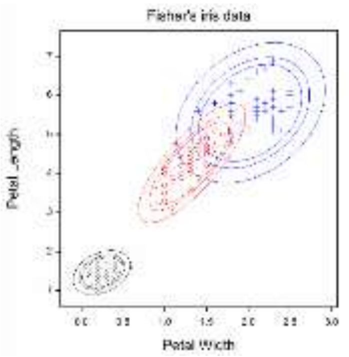
DCOMPOSITIONAL



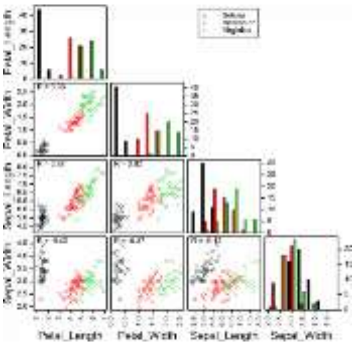
DCORRELATION



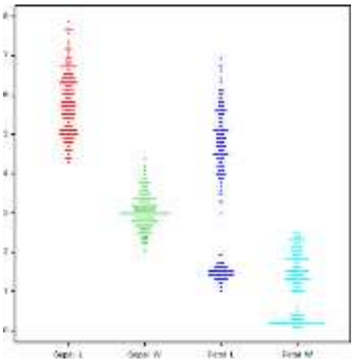
DELLIPSE



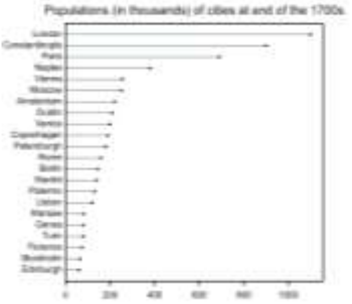
DMSCATTER



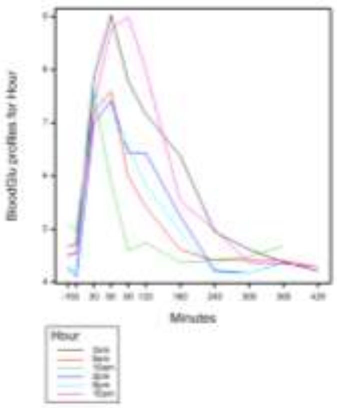
DOTHISTOGRAM



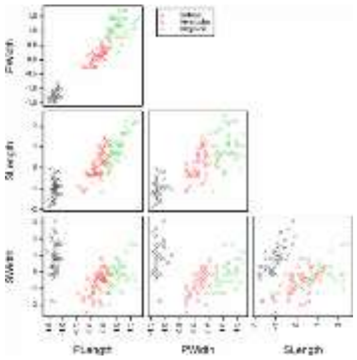
DOTPLOT



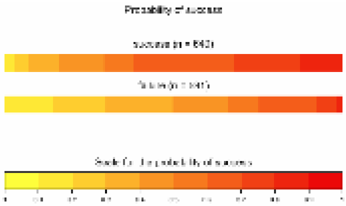
DREPMEASURES



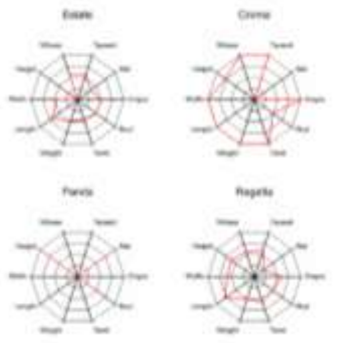
DSCATTER



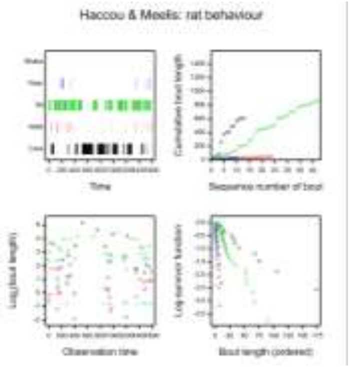
DSEPARATION



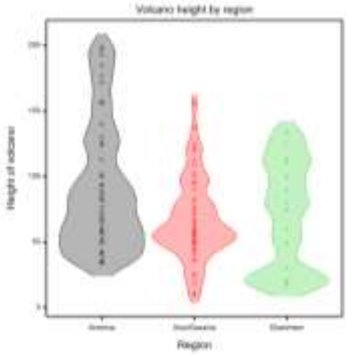
DSPIDERWEB



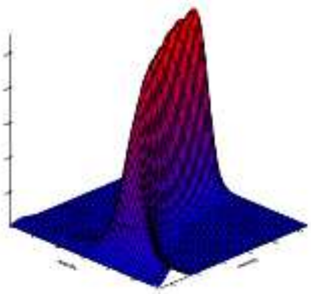
DTIMEPLOT



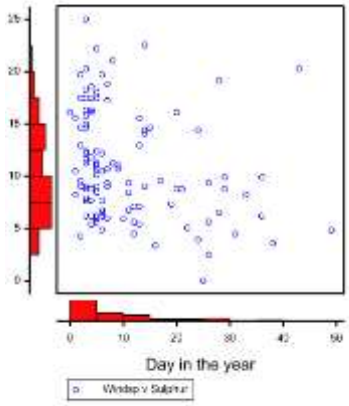
DXDENSITY



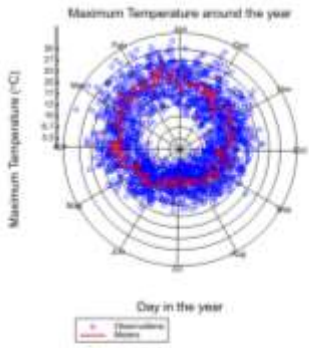
DXYDENSITY



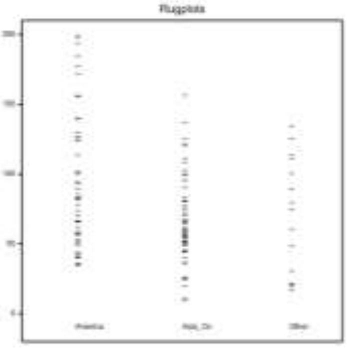
DXYGRAPH



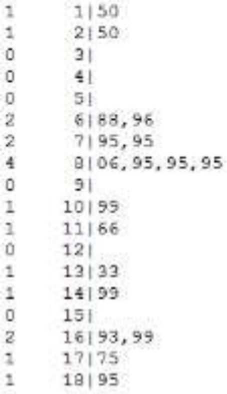
DYPOLAR



RUGPLOT

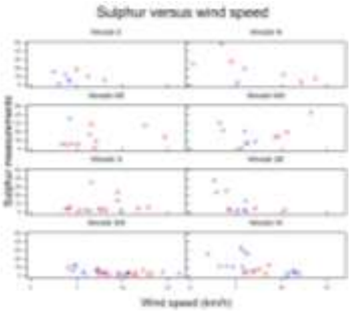


STEM

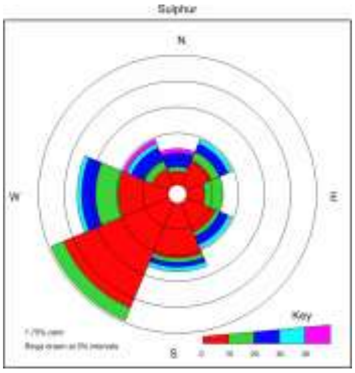


```
1      1|50
1      2|50
0      3|
0      4|
0      5|
2      6|88,96
2      7|95,95
4      8|06,95,95,95
0      9|
1     10|99
1     11|66
0     12|
1     13|33
1     14|99
0     15|
2     16|93,99
1     17|75
1     18|95
```

TRELLIS

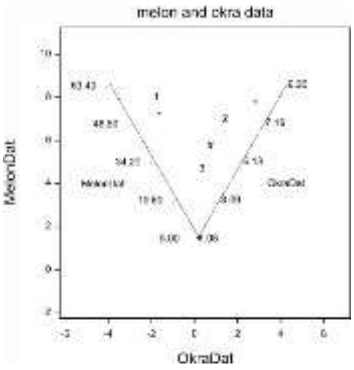


WINDROSE

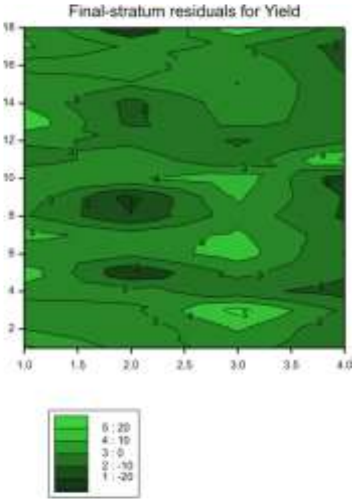


Examples of other plots:

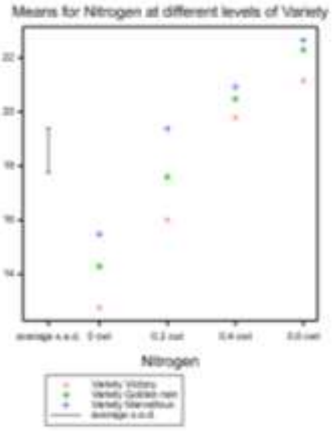
ABIVARIATE



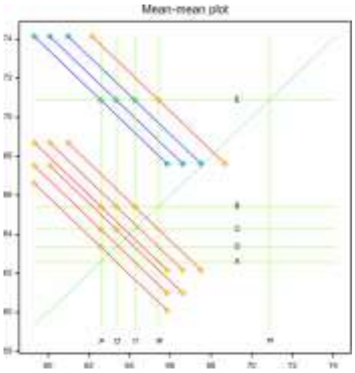
AFIELDRESIDUALS



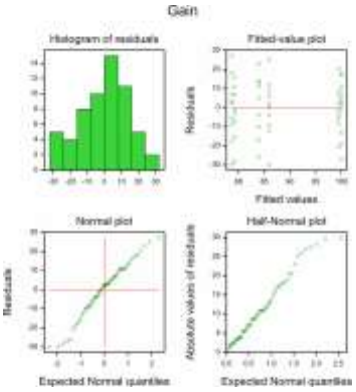
AGRAPH



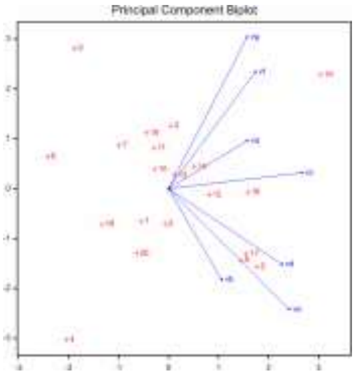
AMCOMPARISON



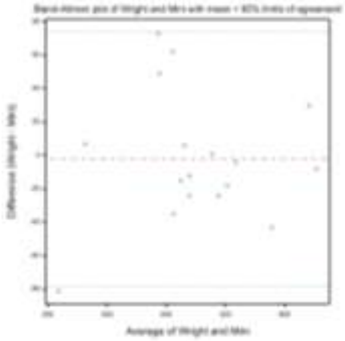
APLOT



BIPLOT



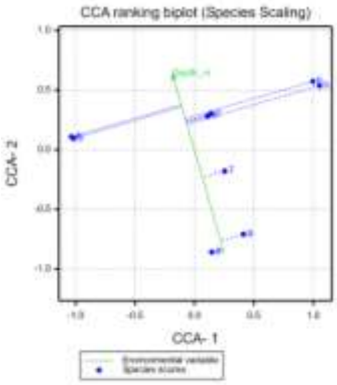
BLANDALTMAN



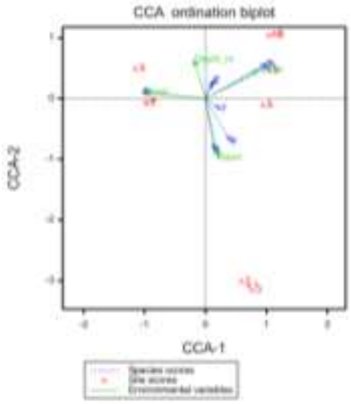
CABIPLOT

Correspondence analysis plot
Dimension 2
Dimension 1

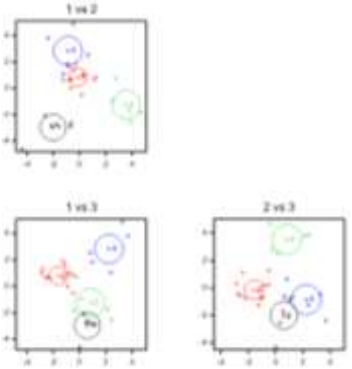
CRBIPLOT



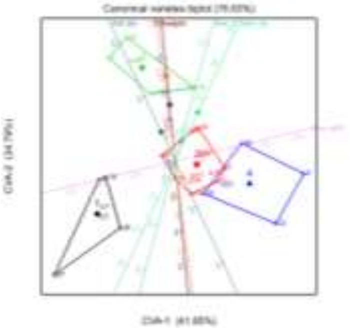
CRTRIPLOT



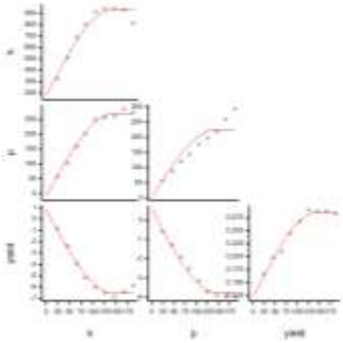
CVAPLOT



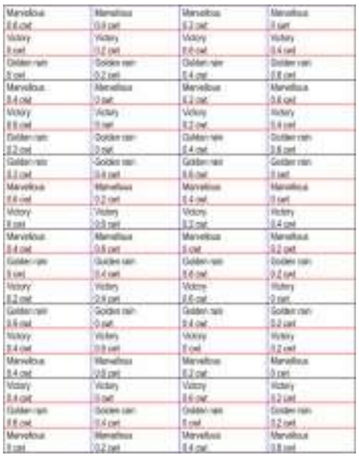
DBIPLOT



DCOVARIOGRAM

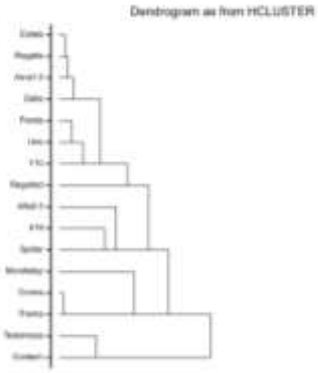


DDESIGN

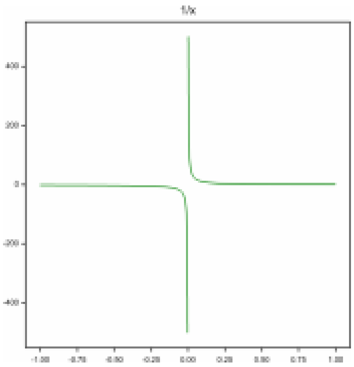


Marvellous 0.6 cwt	Marvellous 0.8 cwt	Marvellous 0.2 cwt	Marvellous 0 cwt
Victory 0 cwt	Victory 0.2 cwt	Victory 0.6 cwt	Victory 0.4 cwt
Golden rain 0 cwt	Golden rain 0.2 cwt	Golden rain 0.4 cwt	Golden rain 0.8 cwt
Marvellous 0.4 cwt	Marvellous 0 cwt	Marvellous 0.2 cwt	Marvellous 0.8 cwt
Victory 0.8 cwt	Victory 0 cwt	Victory 0.2 cwt	Victory 0.4 cwt
Golden rain 0.2 cwt	Golden rain 0 cwt	Golden rain 0.4 cwt	Golden rain 0.6 cwt
Golden rain 0.2 cwt	Golden rain 0.4 cwt	Golden rain 0.6 cwt	Golden rain 0 cwt
Marvellous 0.6 cwt	Marvellous 0.2 cwt	Marvellous 0.4 cwt	Marvellous 0 cwt
Victory 0 cwt	Victory 0.8 cwt	Victory 0.2 cwt	Victory 0.4 cwt
Marvellous 0.4 cwt	Marvellous 0.6 cwt	Marvellous 0 cwt	Marvellous 0.2 cwt
Golden rain 0 cwt	Golden rain 0.4 cwt	Golden rain 0.6 cwt	Golden rain 0.2 cwt
Victory 0.2 cwt	Victory 0.8 cwt	Victory 0.6 cwt	Victory 0 cwt
Golden rain 0.6 cwt	Golden rain 0 cwt	Golden rain 0.4 cwt	Golden rain 0.2 cwt
Victory 0.4 cwt	Victory 0.8 cwt	Victory 0 cwt	Victory 0.2 cwt
Marvellous 0.4 cwt	Marvellous 0.6 cwt	Marvellous 0.2 cwt	Marvellous 0 cwt
Victory 0.4 cwt	Victory 0 cwt	Victory 0.6 cwt	Victory 0.2 cwt
Golden rain 0.8 cwt	Golden rain 0.4 cwt	Golden rain 0 cwt	Golden rain 0.2 cwt
Marvellous 0 cwt	Marvellous 0.2 cwt	Marvellous 0.4 cwt	Marvellous 0.8 cwt

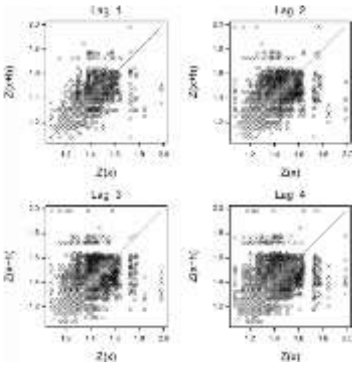
DDENDROGRAM



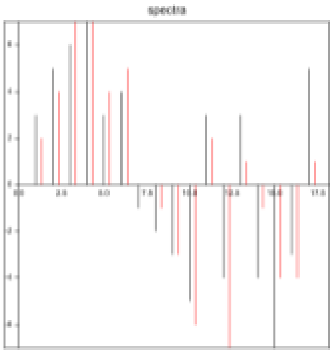
DFUNCTION



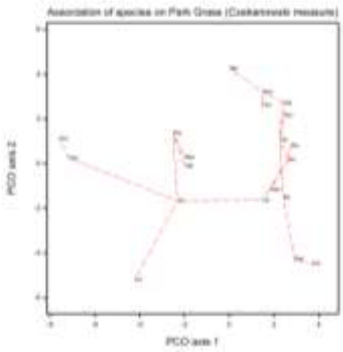
DHSCATTERGRAM



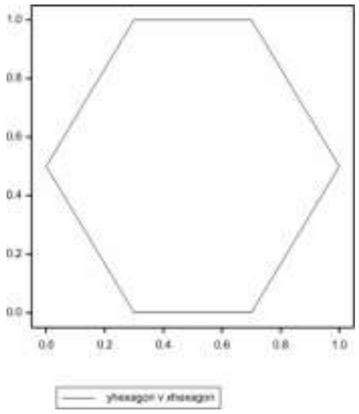
DMASS



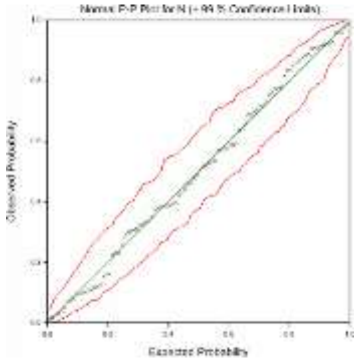
DMST



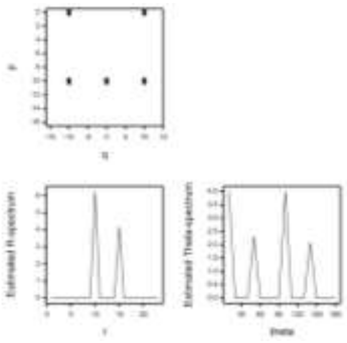
DPOLYGON



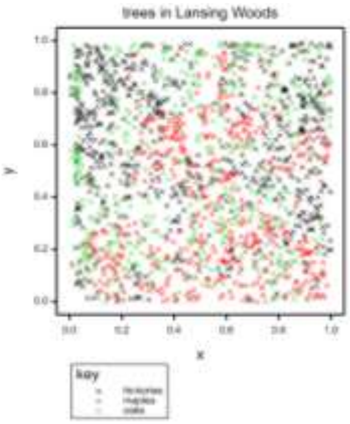
DPROBABILITY



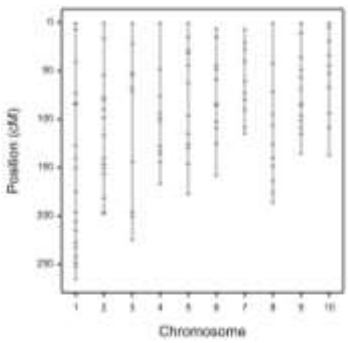
DPSPECTRALPLOT



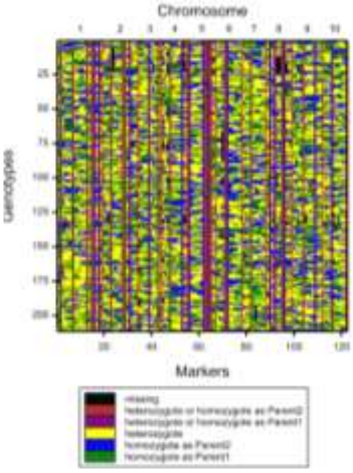
DPTMAP



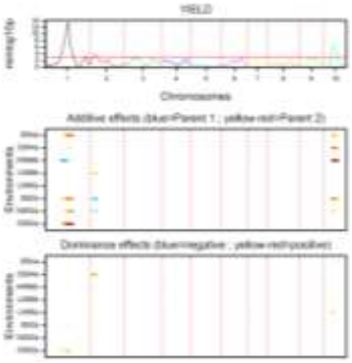
DQMAP



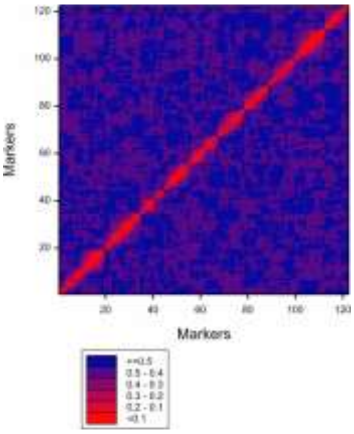
DQMKSCORES



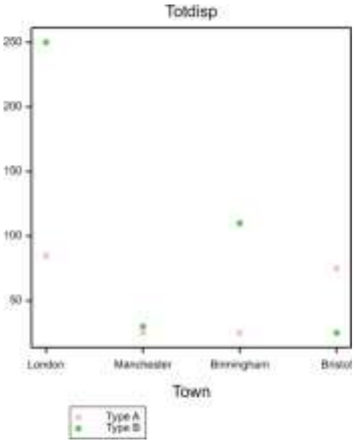
DQMQTLSCAN



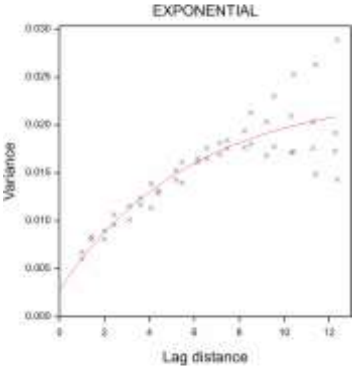
DQRECOMBINATIONS



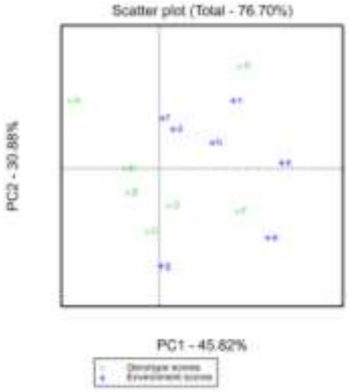
DTABLE



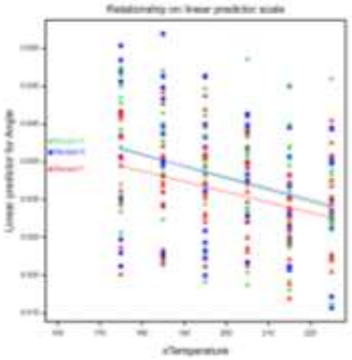
DVARIOGRAM



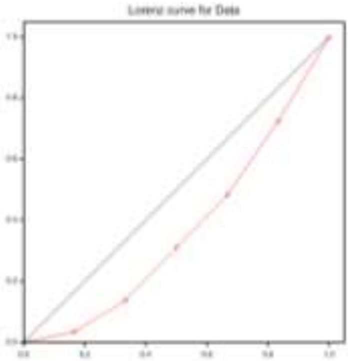
GGEBIPLOT



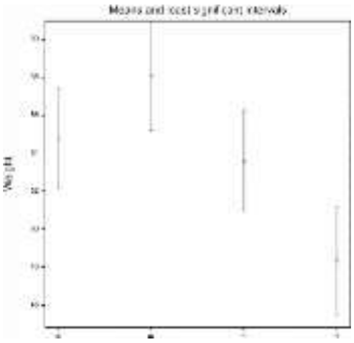
HGGRAPH



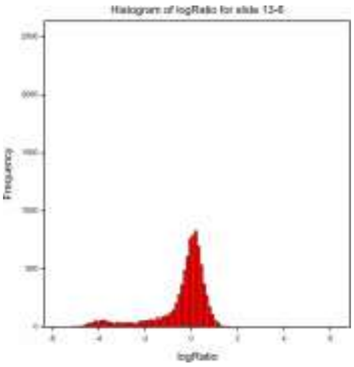
LORENZ



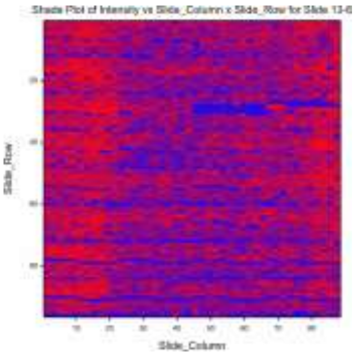
LSIPLOT



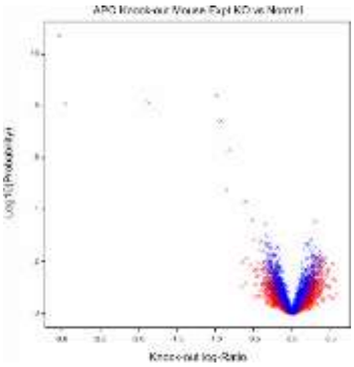
MAHISTOGRAM



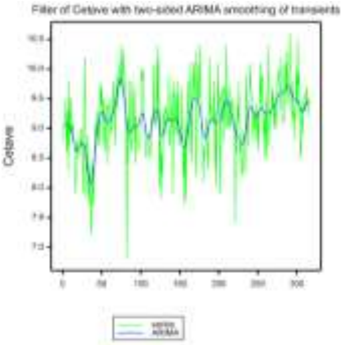
MASHADE



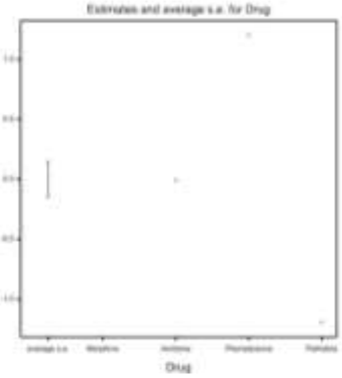
MAVOLCANO



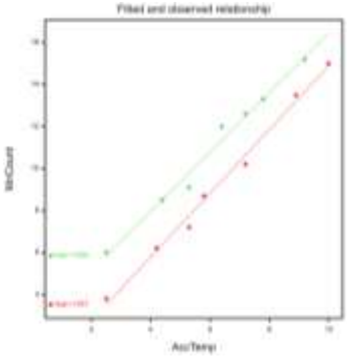
MOVINGAVERAGE



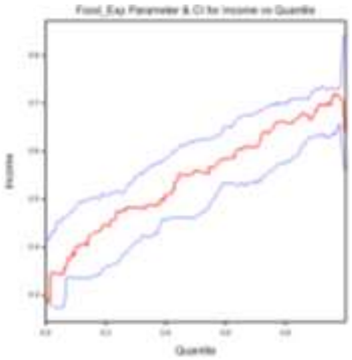
RDESTIMATES



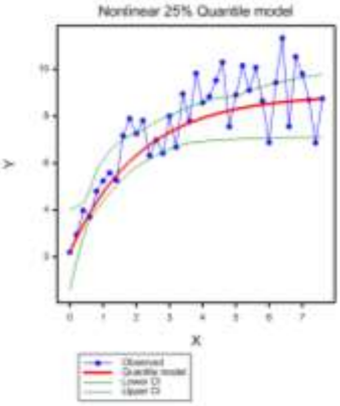
RGRAPH



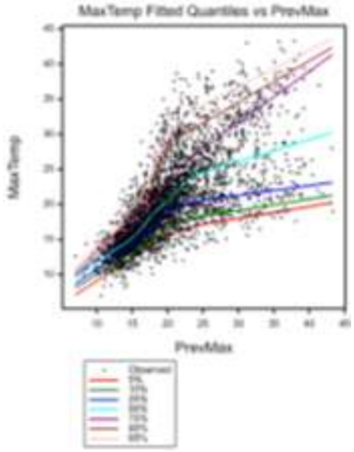
RQLINEAR



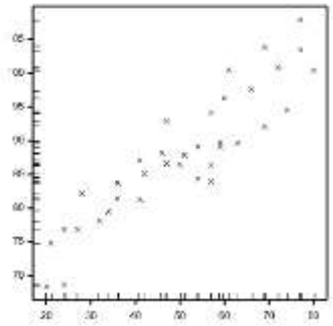
RQNONLINEAR



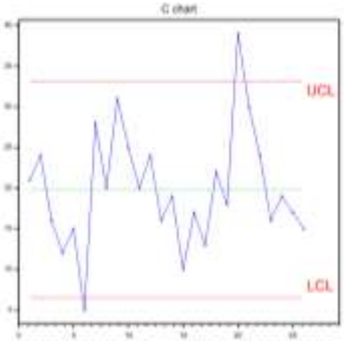
RQSMOOTH



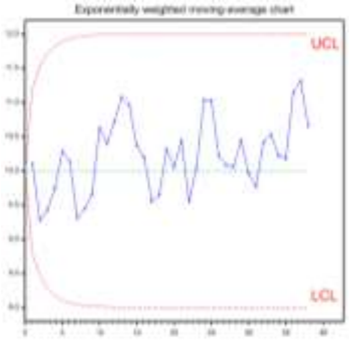
RUGPLOT



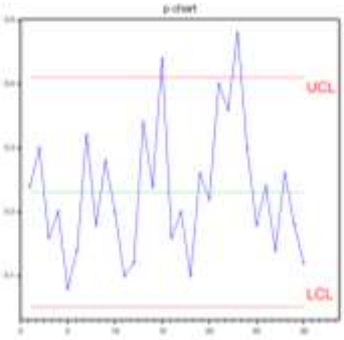
SPCCHART



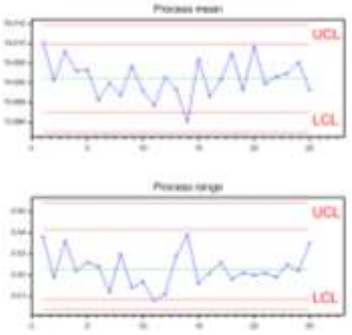
SPEWMA



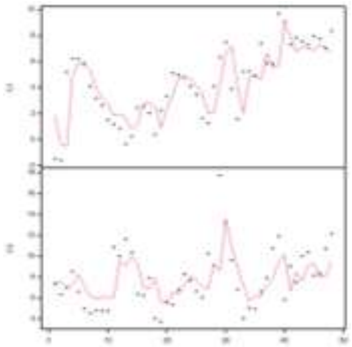
SPPCHART



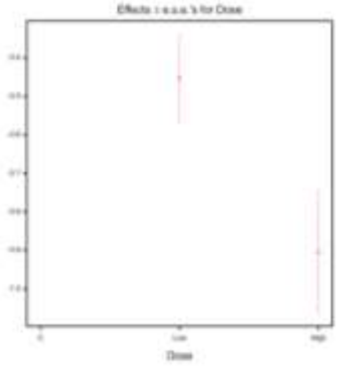
SPSHEWHART



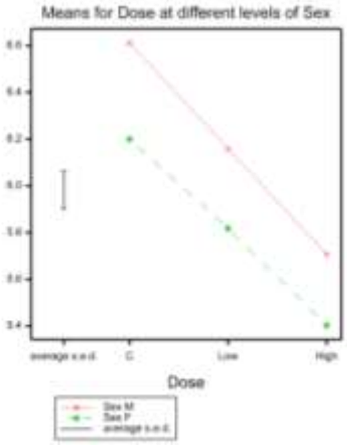
TVGRAPH



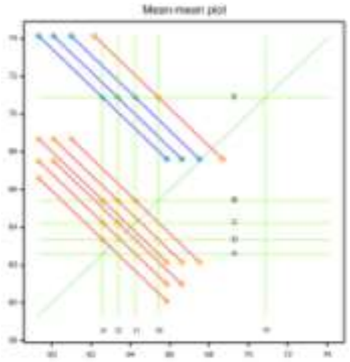
VDEFFECTS



VGRAPH



VMCOMPARISON



5.2 Graphics colours

Colours in Genstat graphs are specified in terms of RGB values, i.e. combinations of red, green and blue components, each of which can take any integer value from 0 to 255. The following table lists some pre-defined colours with their RGB values (and corresponding red, green and blue values). These names are used by the graphics menus and in graphics directives such as `PEN` (see Section 3.4). Note, the physical representation of any particular RGB value will depend on the quality of the display device and some colours may be indistinguishable in practice.

Red Colours

Colour Name	RGB value	R	G	B
IndianRed	13458524	205	92	92
LightCoral	15761536	240	128	128
Salmon	16416882	250	128	114
DarkSalmon	15308410	233	150	122
LightSalmon	16752762	255	160	122
Crimson	14423100	220	20	60
Red	16711680	255	0	0
FireBrick	11674146	178	34	34
DarkRed	9109504	139	0	0

Pink Colours

Colour Name	RGB value	R	G	B
Pink	16761035	255	192	203
LightPink	16758465	255	182	193
HotPink	16738740	255	105	180
DeepPink	16716947	255	20	147
MediumVioletRed	13047173	199	21	133
PaleVioletRed	14381203	219	112	147

Orange Colours

Colour Name	RGB value	R	G	B
LightSalmon	16752762	255	160	122
Coral	16744272	255	127	80
Tomato	16737095	255	99	71
OrangeRed	16729344	255	69	0
DarkOrange	16747520	255	140	0
Orange	16753920	255	165	0

Yellow Colours

Colour Name	RGB value	R	G	B
Gold	16766720	255	215	0
Yellow	16776960	255	255	0
LightYellow	16777184	255	255	224
LemonChiffon	16775885	255	250	205
LightGoldenrodYellow	16448210	250	250	210
PapayaWhip	16773077	255	239	213
Moccasin	16770229	255	228	181
PeachPuff	16767673	255	218	185
PaleGoldenrod	15657130	238	232	170
Khaki	15787660	240	230	140

Purple Colours

Colour Name	RGB value	R	G	B
Lavender	15132410	230	230	250
Thistle	14204888	216	191	216
Plum	14524637	221	160	221
Violet	15631086	238	130	238
Orchid	14315734	218	112	214
Fuchsia	16711935	255	0	255
MediumOrchid	12211667	186	85	211
MediumPurple	9662683	147	112	219
BlueViolet	9055202	138	43	226
DarkViolet	9699539	148	0	211
DarkOrchid	10040012	153	50	204
DarkMagenta	9109643	139	0	139
Purple	8388736	128	0	128
Indigo	4915330	75	0	130
SlateBlue	6970061	106	90	205
DarkSlateBlue	4734347	72	61	139
MediumSlateBlue	8087790	123	104	238

Green Colours

Colour Name	RGB value	R	G	B
GreenYellow	11403055	173	255	47
Chartreuse	8388352	127	255	0
LawnGreen	8190976	124	252	0
Lime	65280	0	255	0
LimeGreen	3329330	50	205	50
PaleGreen	10025880	152	251	152
LightGreen	9498256	144	238	144
MediumSpringGreen	64154	0	250	154
SpringGreen	65407	0	255	127
MediumSeaGreen	3978097	60	179	113
SeaGreen	3050327	46	139	87
ForestGreen	2263842	34	139	34
Green	32768	0	128	0
DarkGreen	25600	0	100	0
YellowGreen	10145074	154	205	50
OliveDrab	7048739	107	142	35
Olive	8421376	128	128	0
DarkOliveGreen	5597999	85	107	47
MediumAquamarine	6737322	102	205	170
DarkSeaGreen	9419919	143	188	143
LightSeaGreen	2142890	32	178	170
DarkCyan	35723	0	139	139
Teal	32896	0	128	128

Blue Colours

Colour Name	RGB	R	G	B
Aqua	65535	0	255	255
Cyan	65535	0	255	255
LightCyan	14745599	224	255	255
PaleTurquoise	11529966	175	238	238
Aquamarine	8388564	127	255	212
Turquoise	4251856	64	224	208
MediumTurquoise	4772300	72	209	204
DarkTurquoise	52945	0	206	209
CadetBlue	6266528	95	158	160
SteelBlue	4620980	70	130	180
LightSteelBlue	11584734	176	196	222
PurwaBlue	10215935	155	225	255
PowderBlue	11591910	176	224	230
LightBlue	11393254	173	216	230
SkyBlue	8900331	135	206	235
LightSkyBlue	8900346	135	206	250
DeepSkyBlue	49151	0	191	255
DodgerBlue	2003199	30	144	255
CornflowerBlue	6591981	100	149	237
RoyalBlue	4286945	65	105	225
Blue	255	0	0	255
MediumBlue	205	0	0	205
DarkBlue	139	0	0	139
Navy	128	0	0	128
MidnightBlue	1644912	25	25	112

Brown Colours

Colour Name	RGB value	R	G	B
Cornsilk	16775388	255	248	220
BlanchedAlmond	16772045	255	235	205
Bisque	16770244	255	228	196
NavajoWhite	16768685	255	222	173
Wheat	16113331	245	222	179
BurlyWood	14596231	222	184	135
Tan	13808780	210	180	140
RosyBrown	12357519	188	143	143
SandyBrown	16032864	244	164	96
Goldenrod	14329120	218	165	32
DarkGoldenrod	12092939	184	134	11
Peru	13468991	205	133	63
Chocolate	13789470	210	105	30
SaddleBrown	9127187	139	69	19
Sienna	10506797	160	82	45
Brown	10824234	165	42	42
Maroon	8388608	128	0	0

White Colours

Colour Name	RGB value	R	G	B
White	16777215	255	255	255
Snow	16775930	255	250	250
Honeydew	15794160	240	255	240
MintCream	16121850	245	255	250
Azure	15794175	240	255	255
AliceBlue	15792383	240	248	255
GhostWhite	16316671	248	248	255
WhiteSmoke	16119285	245	245	245
Seashell	16774638	255	245	238
Beige	16119260	245	245	220
OldLace	16643558	253	245	230
FloralWhite	16775920	255	250	240
Ivory	16777200	255	255	240
AntiqueWhite	16444375	250	235	215
Linen	16445670	250	240	230
LavenderBlush	16773365	255	240	245
MistyRose	16770273	255	228	225

Grey Colours

Colour Name	RGB value	R	G	B
Gainsboro	14474460	220	220	220
LightGray	13882323	211	211	211
Silver	12632256	192	192	192
DarkGray	11119017	169	169	169
Gray	8421504	128	128	128
DimGray	6908265	105	105	105
LightSlateGray	7833753	119	136	153
SlateGray	7372944	112	128	144
DarkSlateGray	3100495	47	79	79
Black	0	0	0	0

The RGB values for pre-defined colours (or specified red, green and blue component values) can be obtained using the `RGB` function. The RGB values and names of the initial default colours of the pens can be obtained using the `GETRGB` procedure.

Two special strings can be used to set colours within the `PEN` directive: `'match'` and `'background'`. `CFILL='match'` takes the colours from `CSYMBOL`, and `CAREA='match'` takes the colours from `CLINE`. Thus, for example, if you want all symbols filled, you could specify `PEN 1...256; CFILL='match'`. The string `'background'` uses the colours specified by the `BACKGROUND` option or parameter of the `FRAME` directive.

5.3 Graphics symbols and line styles

Genstat provides a choice of standard symbols and line styles that can be specified either by giving the name (in a text with a single value), or the number (in a scalar).

Symbols

Number	Name	Symbol	Number	Name	Symbol
1	Cross	×	15	Tinycircle	∘
2	Circle	○	16	Female	♀
3	Plus	+	17	Male	♂
4	Star	✩	18	Rhombus	◊
5	Square	□	19	Circlecross	⊗
6	Diamond	◇	20	Circleplus	⊕
7	Triangle	△	21	Squarecross	⊠
8	Nabla	▽	22	Squareplus	⊞
9	Asterisk	✳	-1	Sphere	●
10	Minus	−	-2	Cone	▲
11	Heavyminus	▭	-3	Cylinder	■
12	Heavyplus	✙	-4	Cube	■
13	Heavycross	☒	0	None	
14	Smallcircle	◦			

Line styles

Number	Name	Line style	Number	Name	Line style
1	solid	————	6	longdash	— — — –
2	dot	....	7	shortdash	- - - - -
3	dash	– – – – – –	8	closedot	....
4	dotdash	– · – · – · ·	9	finedot	┈┈┈┈┈┈
5	tightdash	-----------	10	doubledotdash	– ·· – ·· – ··