Visualizing multivariate data using lattice and direct labels
http://directlabels.r-forge.r-project.org

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Outline

Brief history of lattice

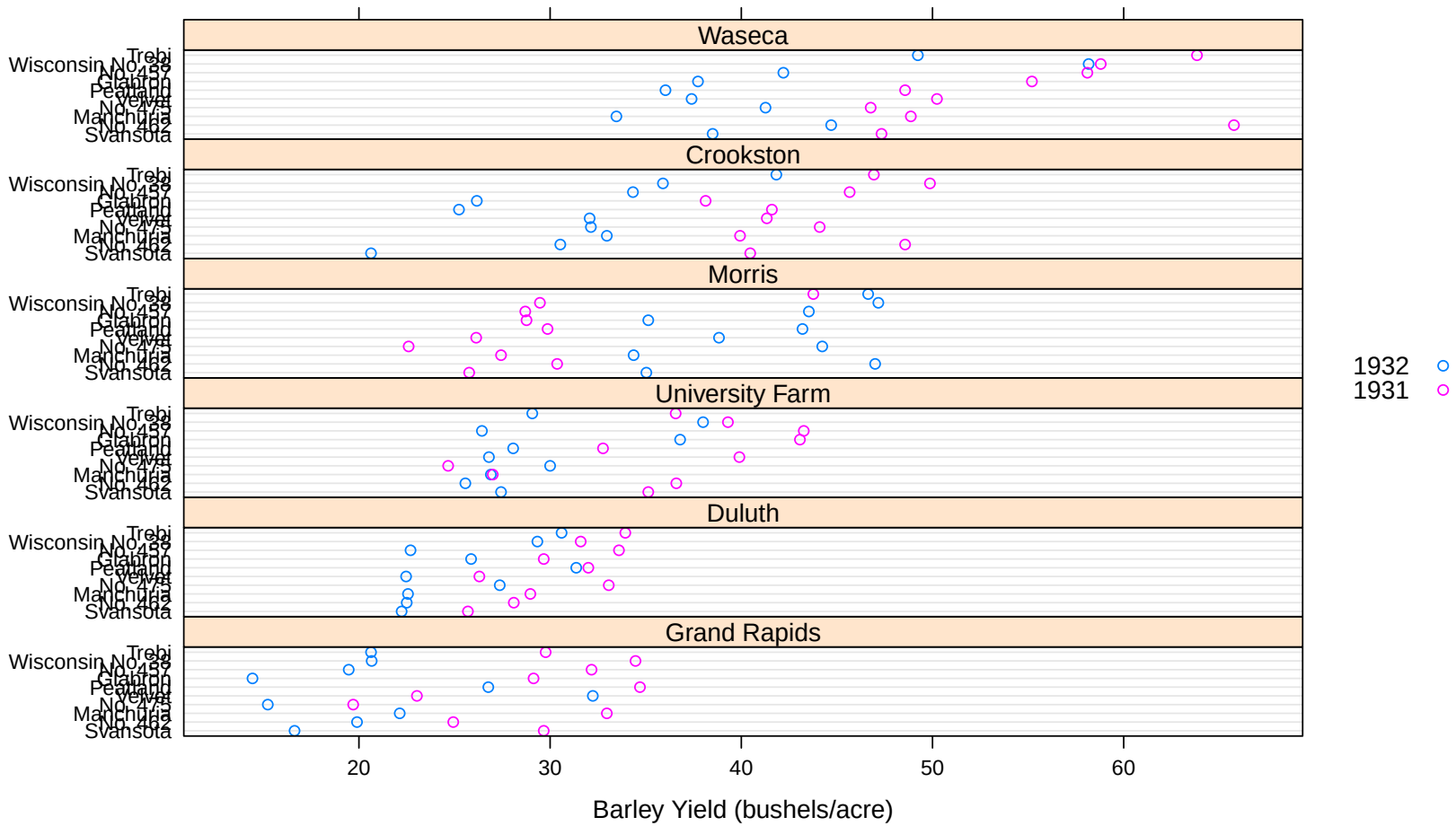
- Bill Cleveland, *Visualizing Data* (1993).
- Bill Cleveland, Rick Becker, Bell Labs, 1990s: trellis graphics system for S: `http://cm.bell-labs.com/cm/ms/departments/sia/project/trellis/`
- Deepayan Sarkar, 2000s: the lattice package for R.
- Deepayan Sarkar (2008) Lattice: Multivariate Data Visualization with R, Springer.

Installing the required packages

- I used R 2.9.2 for the following examples.
- lattice is preinstalled with R.
- `library(lattice)`
- `install.packages(c("latticeExtra","latticedl"))`
- `library(latticeExtra)`
- `library(latticedl)`

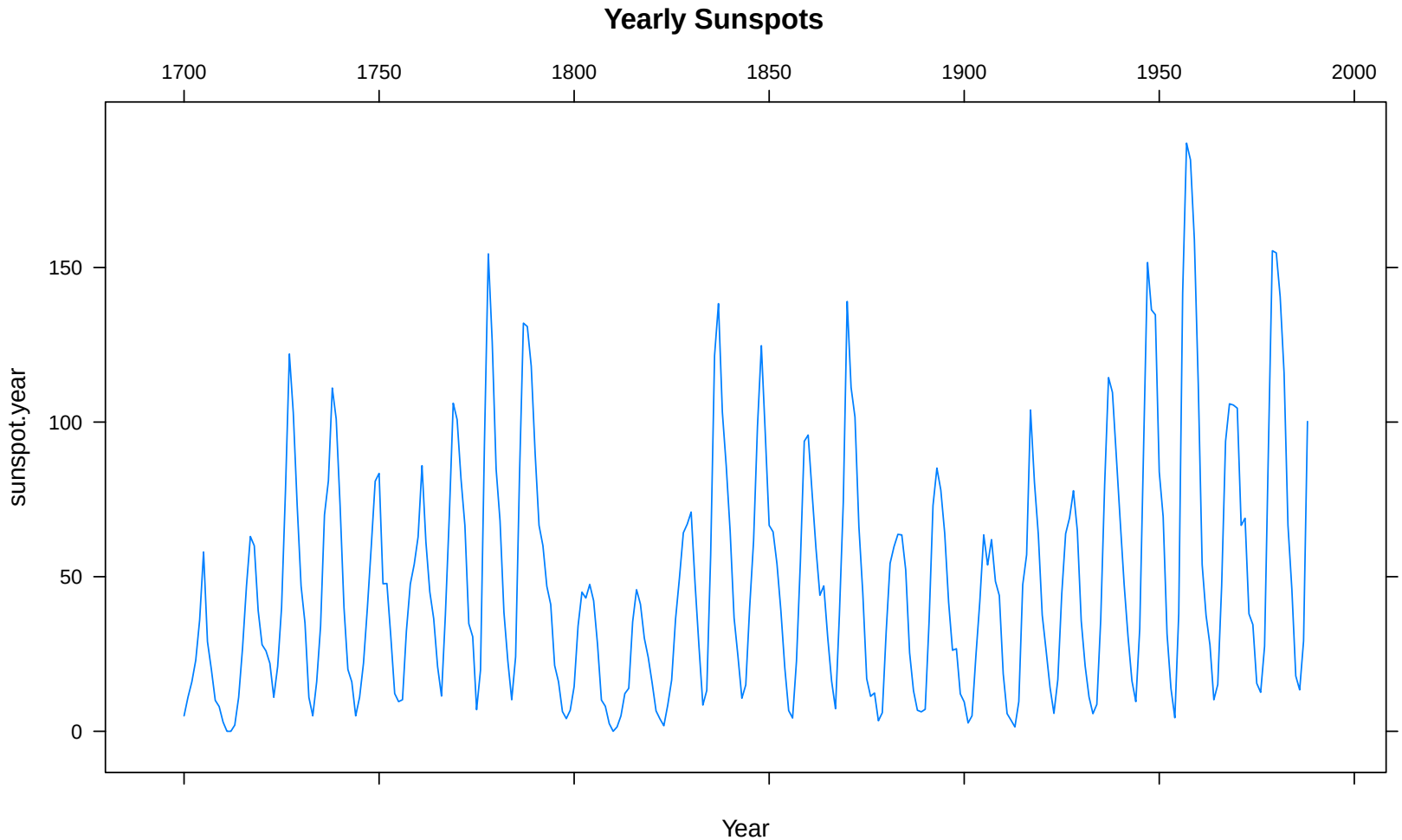
Lattice allows easy visualization of many variables

```
> options(width = 55)
> library(lattice)
> dotplot(variety ~ yield | site, data = barley,
+     groups = year, auto.key = list(space = "right"),
+     layout = c(1, 6), xlab = "Barley Yield (bushels/acre)")
```



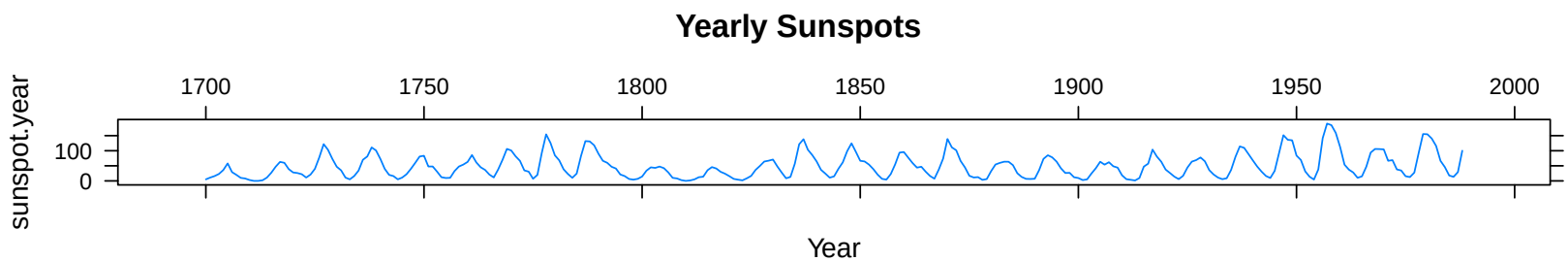
Aspect ratio in scatterplots is important

```
> xyplot(sunspot.year ~ 1700:1988, xlab = "Year",
+     type = "l", scales = list(x = list(alternating = 2)),
+     main = "Yearly Sunspots")
```



Lattice also automatically calculates aspect ratio for optimal decoding

```
> xyplot(sunspot.year ~ 1700:1988, xlab = "Year",
+     type = "l", scales = list(x = list(alternating = 2)),
+     main = "Yearly Sunspots", aspect = "xy")
```

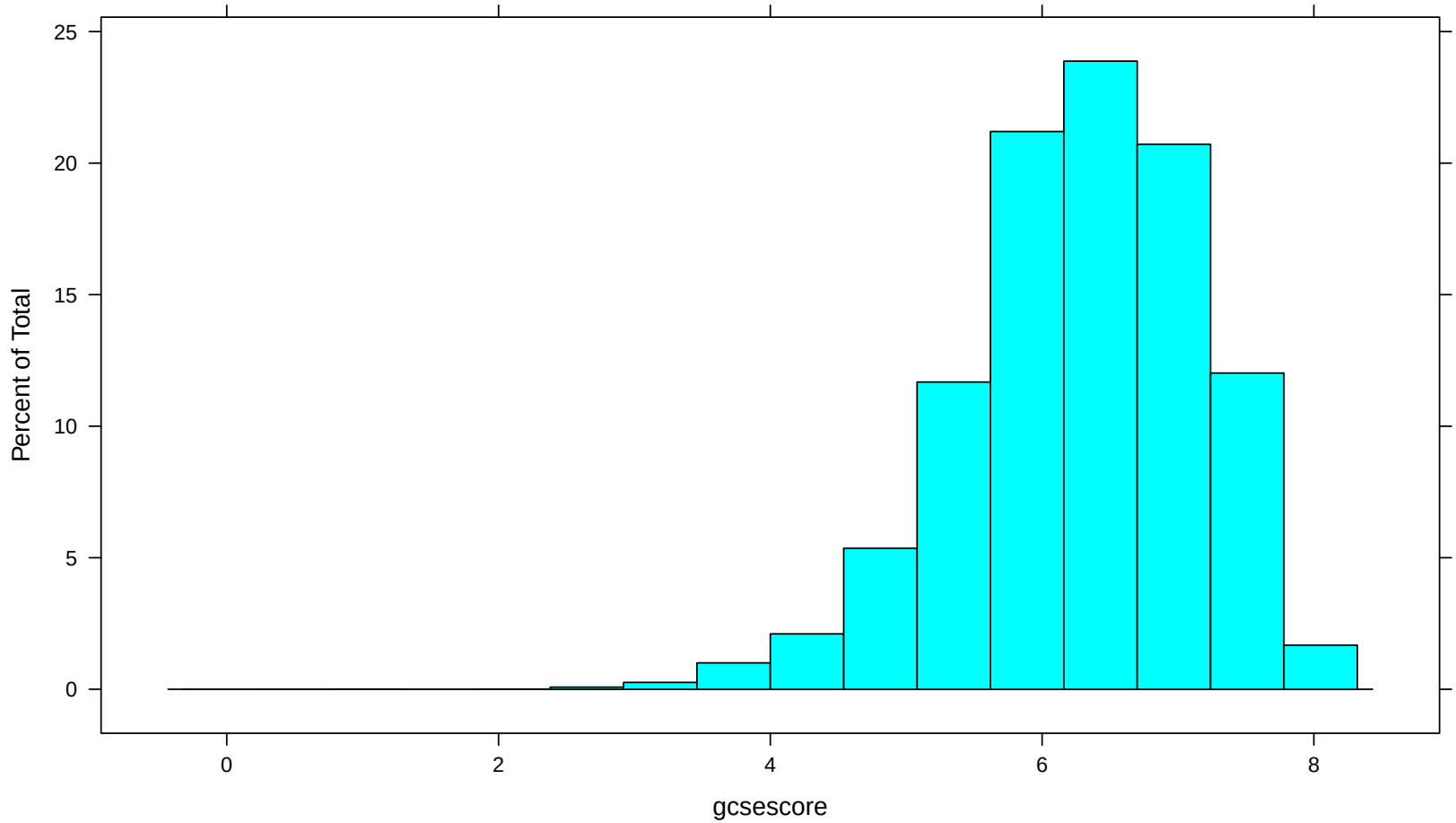


Load a data set

```
> data(Chem97, package = "mlmRev")
> head(Chem97)
  lea school student score gender age gcsescore
1   1      1       1     4      F   3     6.625
2   1      1       2    10      F  -3     7.625
3   1      1       3    10      F  -4     7.250
4   1      1       4    10      F  -2     7.500
5   1      1       5     8      F  -1     6.444
6   1      1       6    10      F   4     7.750
    gcsecnt
1 0.3393157
2 1.3393157
3 0.9643157
4 1.2143157
5 0.1583157
6 1.4643157
```

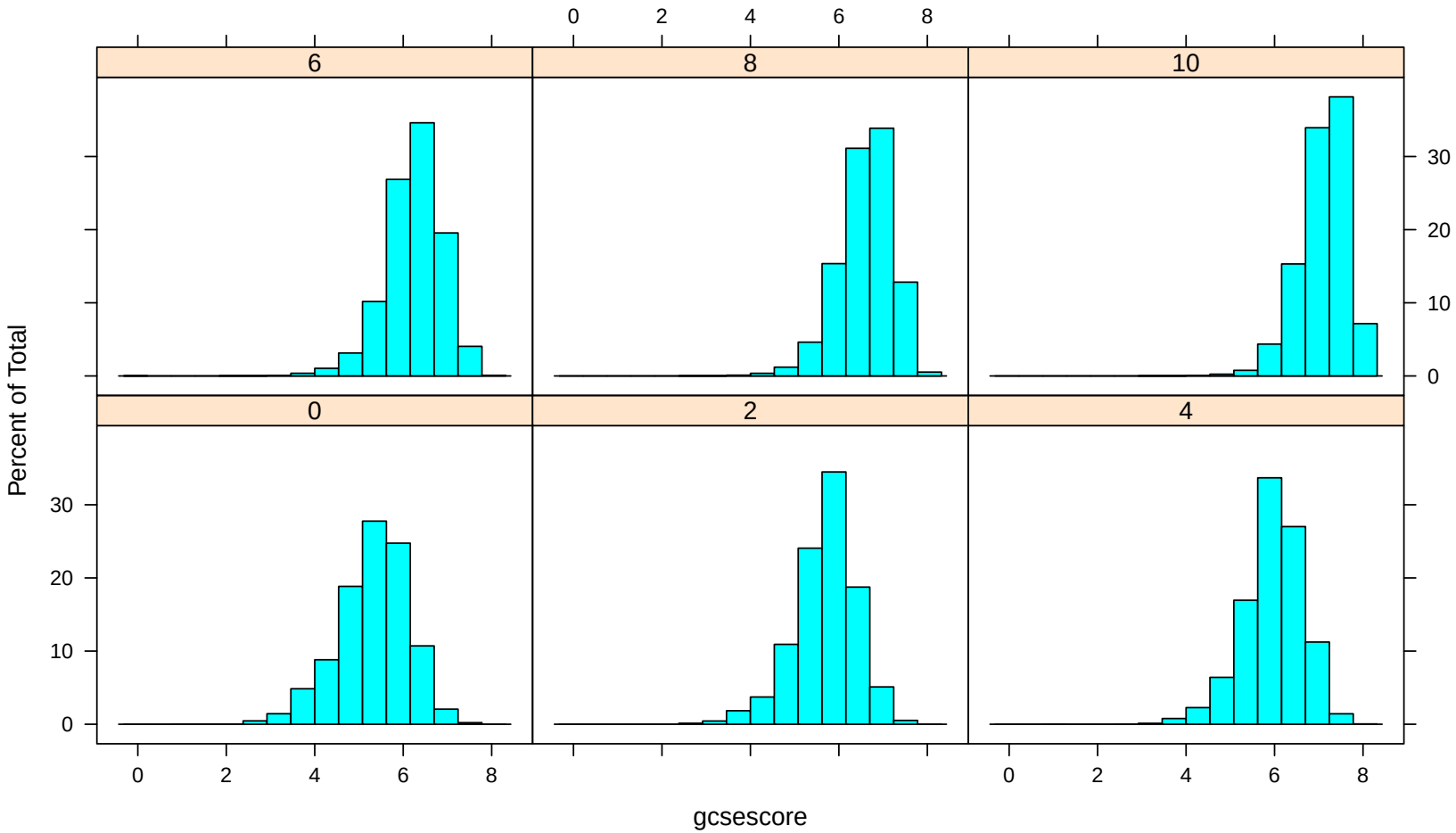
Simple histogram

```
> histogram(~gcsescore, Chem97)
```



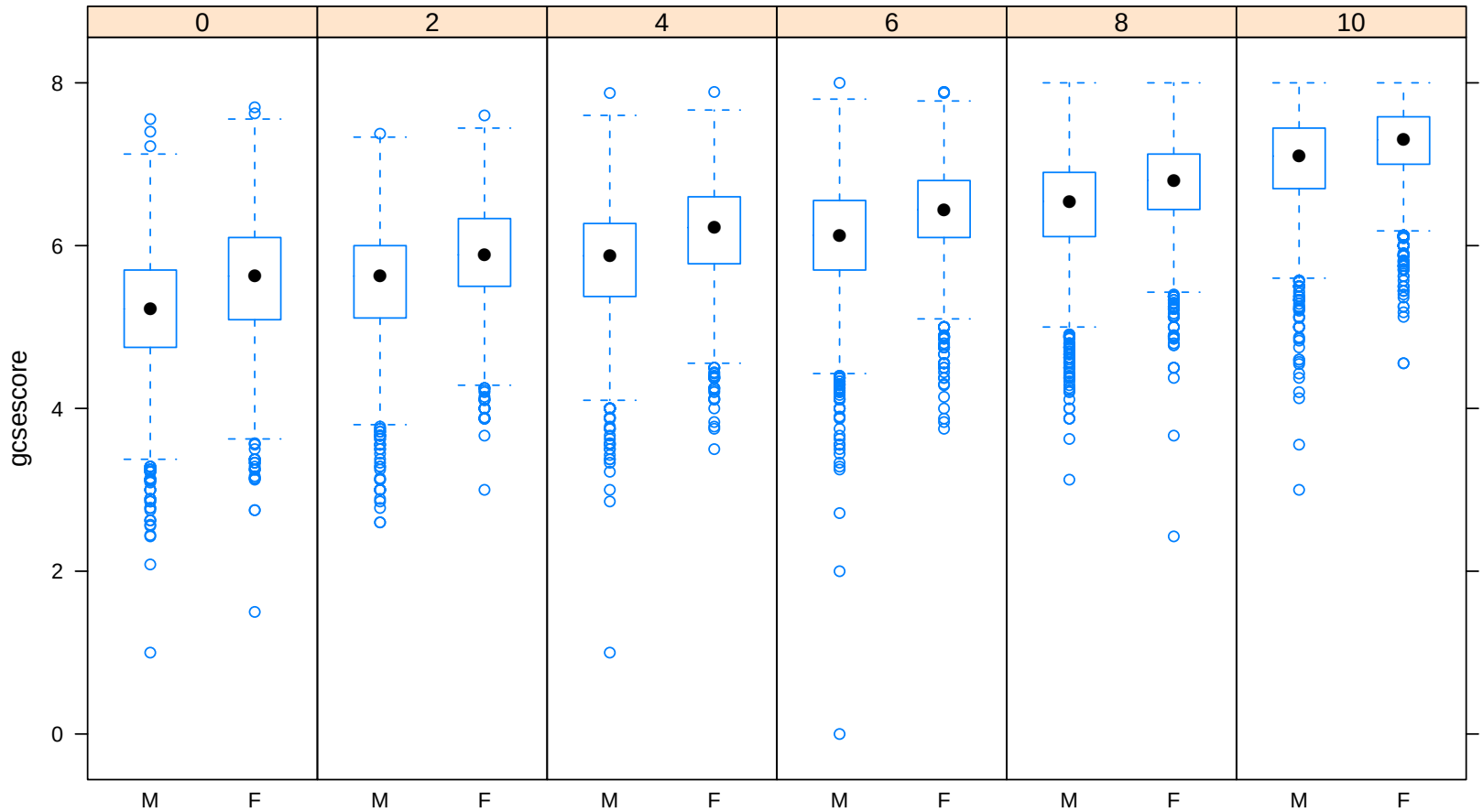
Histograms conditional on a categorical variable

```
> histogram(~gcsescore | factor(score),
+     Chem97)
```



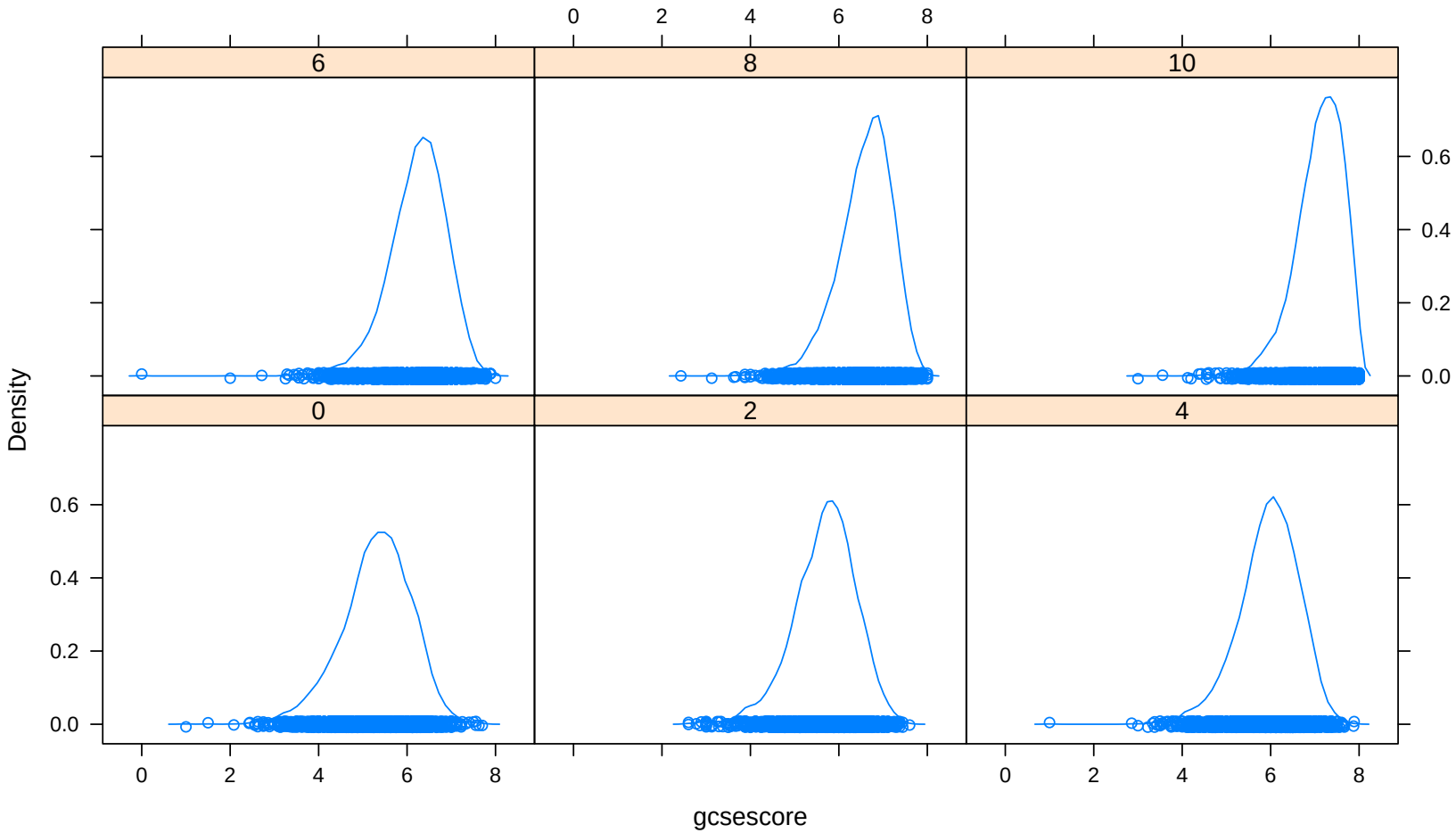
Box and whisker plots

```
> bwplot(gcsescore ~ gender | factor(score),
+     Chem97, layout = c(6, 1))
```



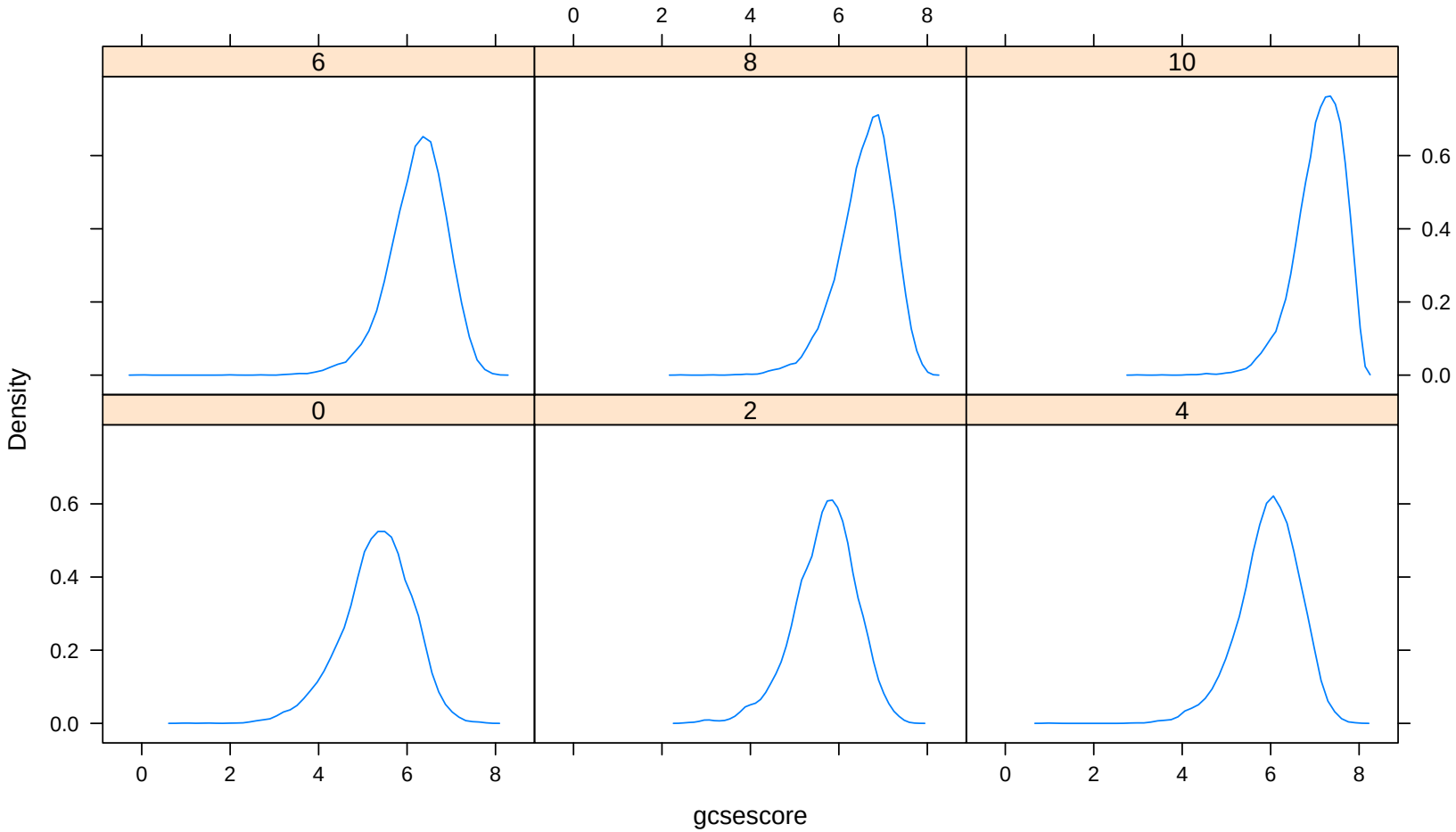
Conditioned plots of kernel density estimates

```
> densityplot(~gcsescore | factor(score),
+     Chem97)
```



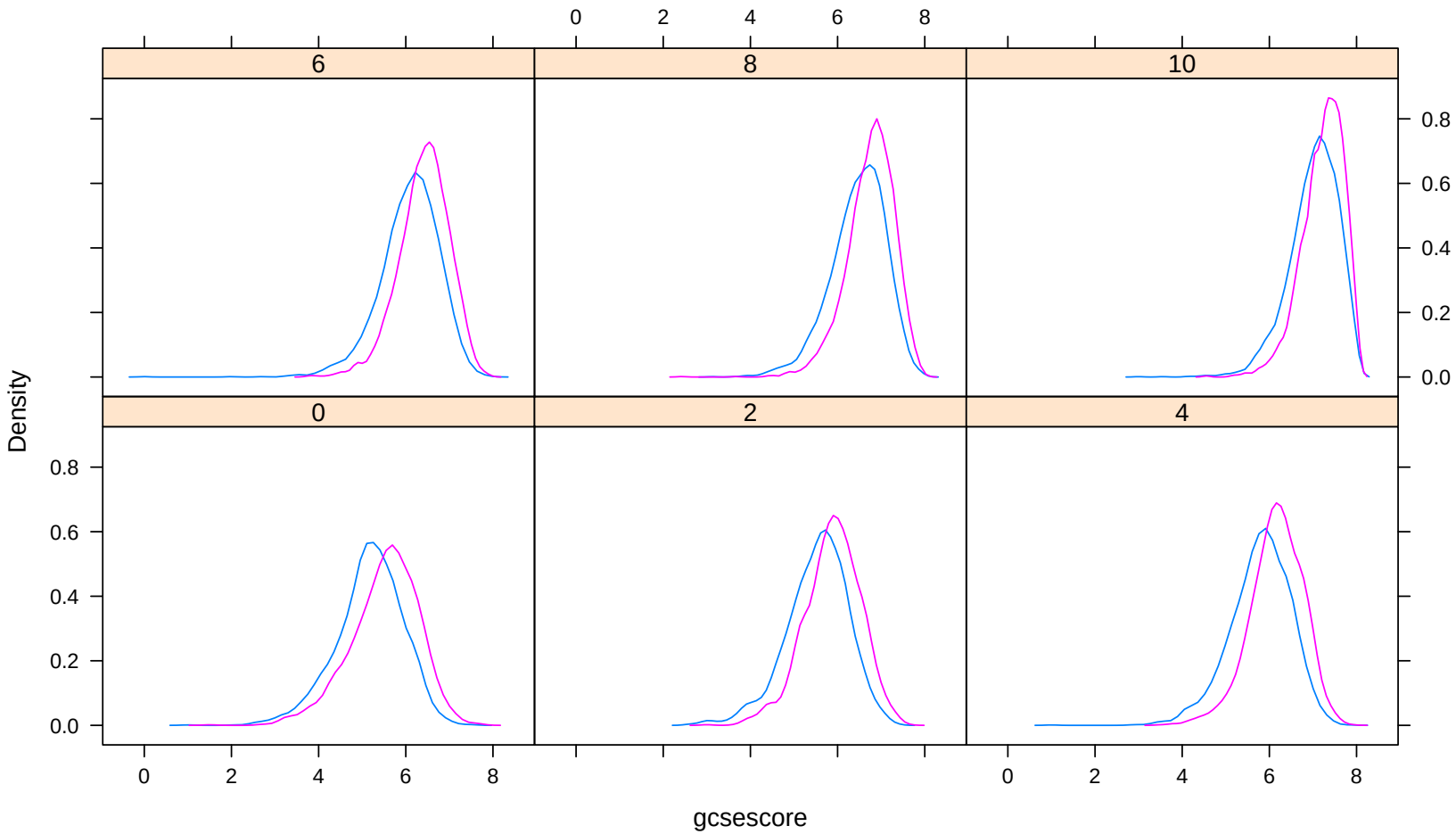
Hide the actual points with the plot.points argument

```
> densityplot(~gcsescore | factor(score),
+     Chem97, plot.points = FALSE)
```



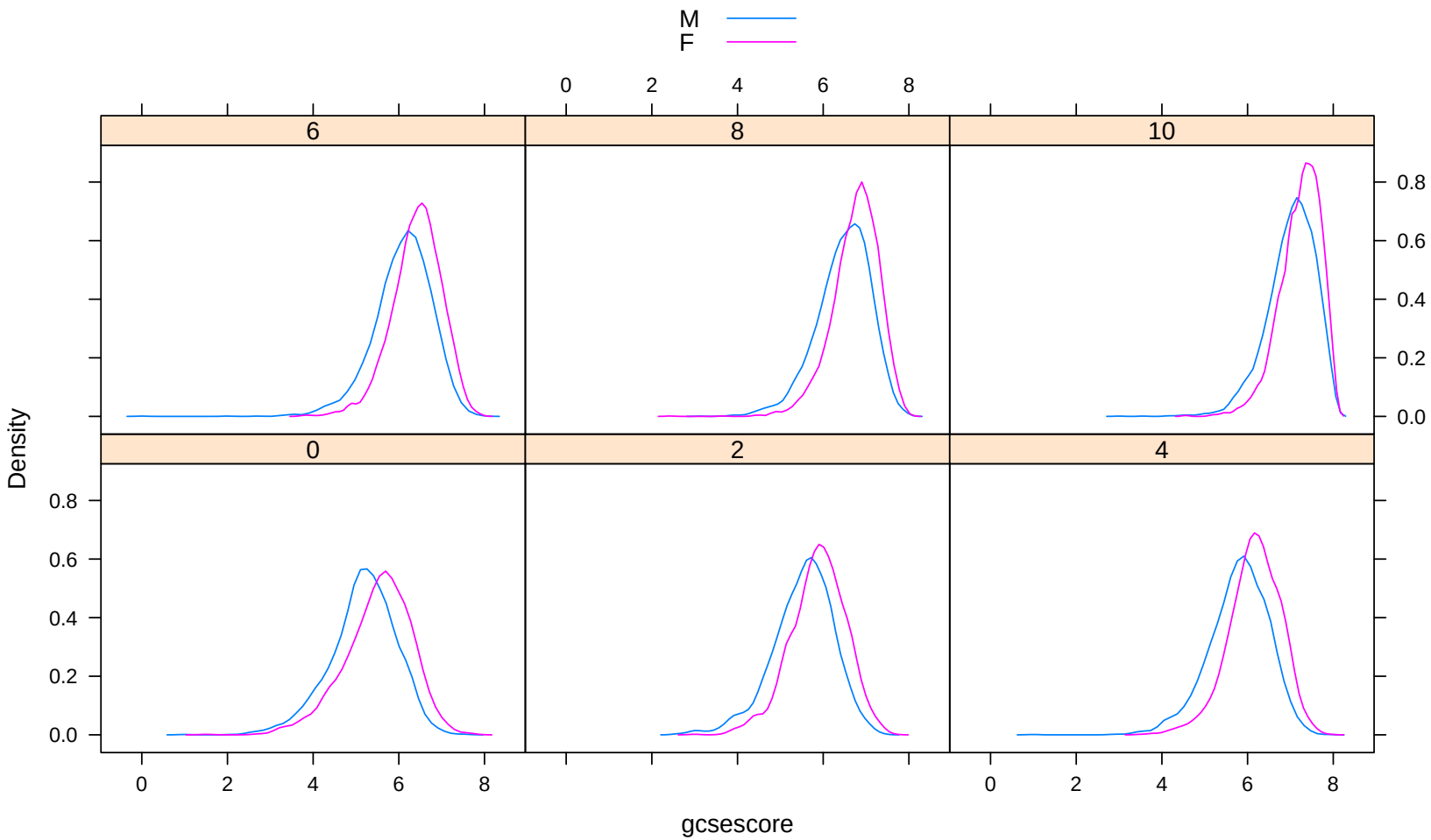
Conditioned and grouped density plots

```
> densityplot(~gcsescore | factor(score),
+     Chem97, plot.points = FALSE, groups = gender)
```



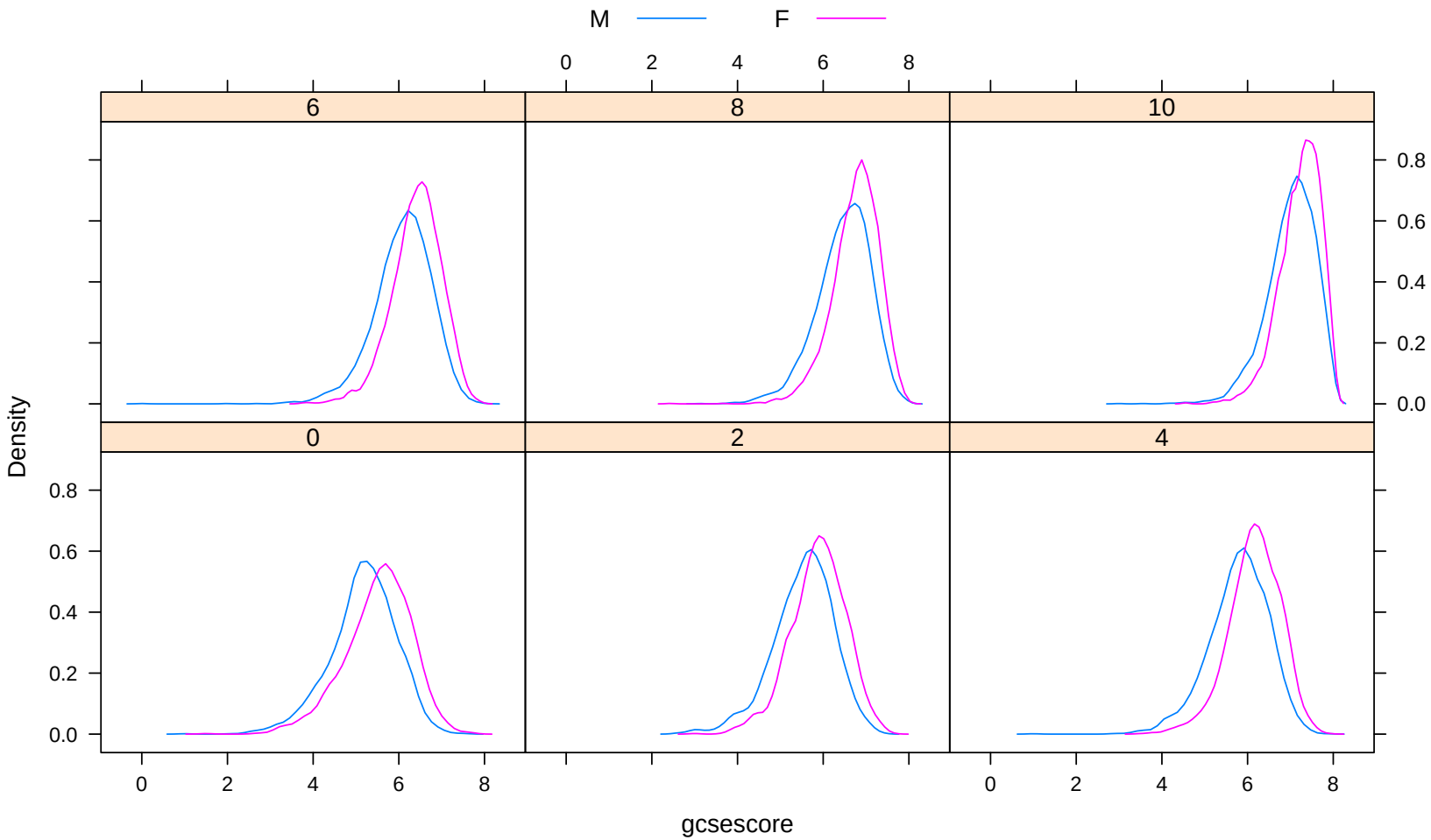
Add a legend with the auto.key argument

```
> densityplot(~gcsescore | factor(score),
+     Chem97, plot.points = FALSE, groups = gender,
+     auto.key = list())
```



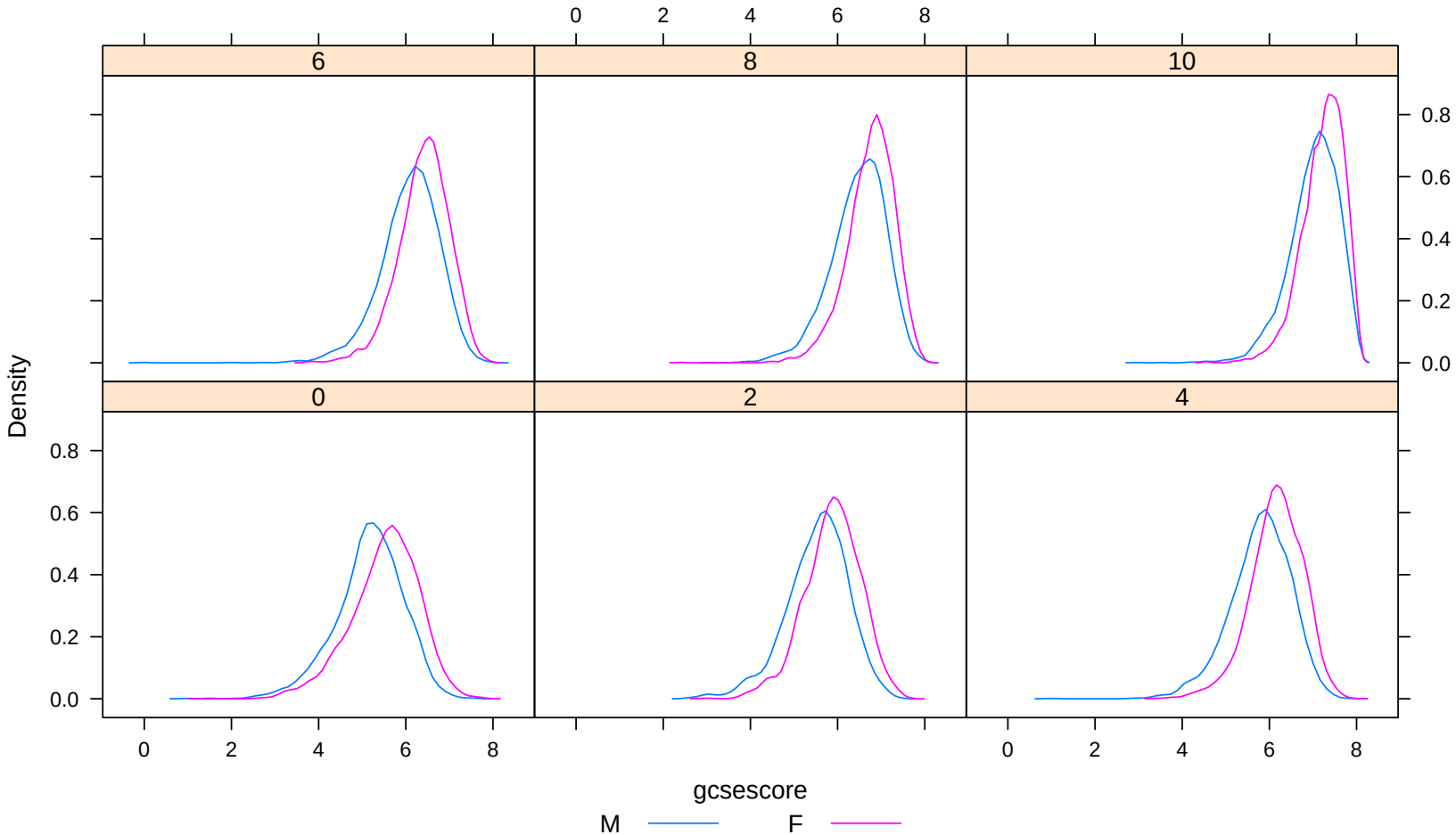
Legend layout with the columns argument

```
> densityplot(~gcsescore | factor(score),
+     Chem97, plot.points = FALSE, groups = gender,
+     auto.key = list(columns = 2))
```



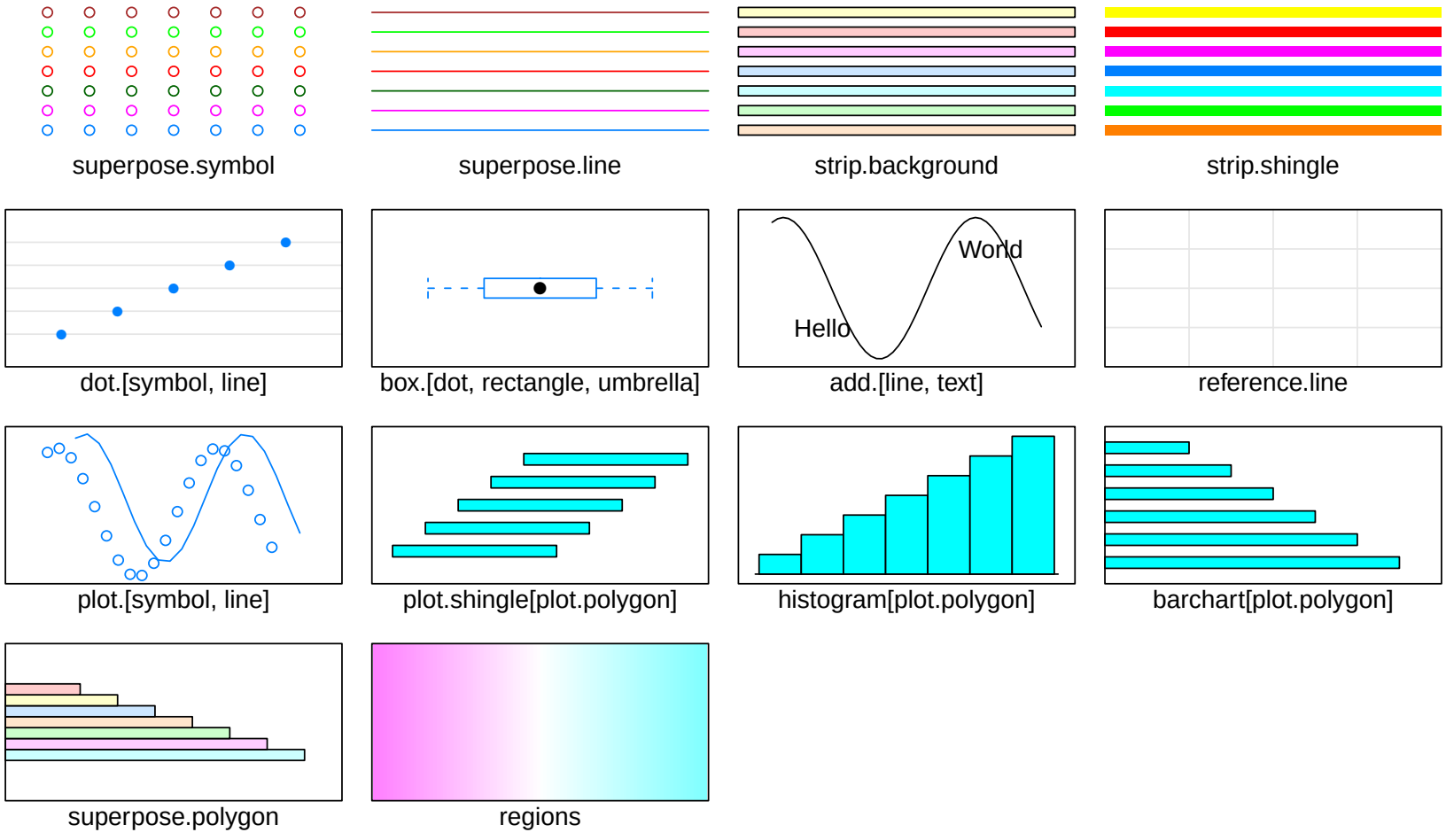
Legend positioning with the space argument

```
> densityplot(~gcsescore | factor(score),
+     Chem97, plot.points = FALSE, groups = gender,
+     auto.key = list(columns = 2, space = "bottom"))
```



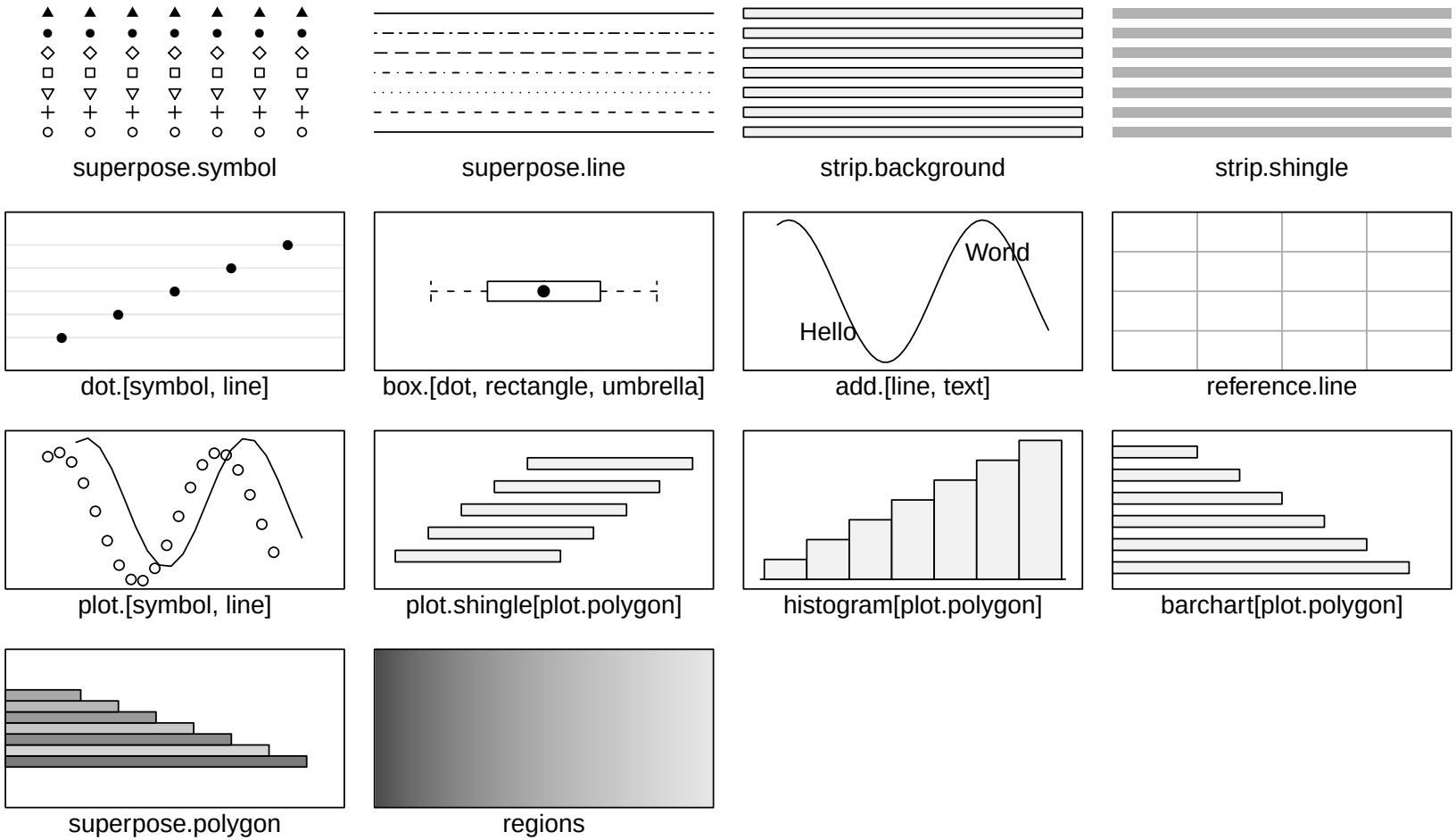
Show all default settings

```
> show.settings()
```



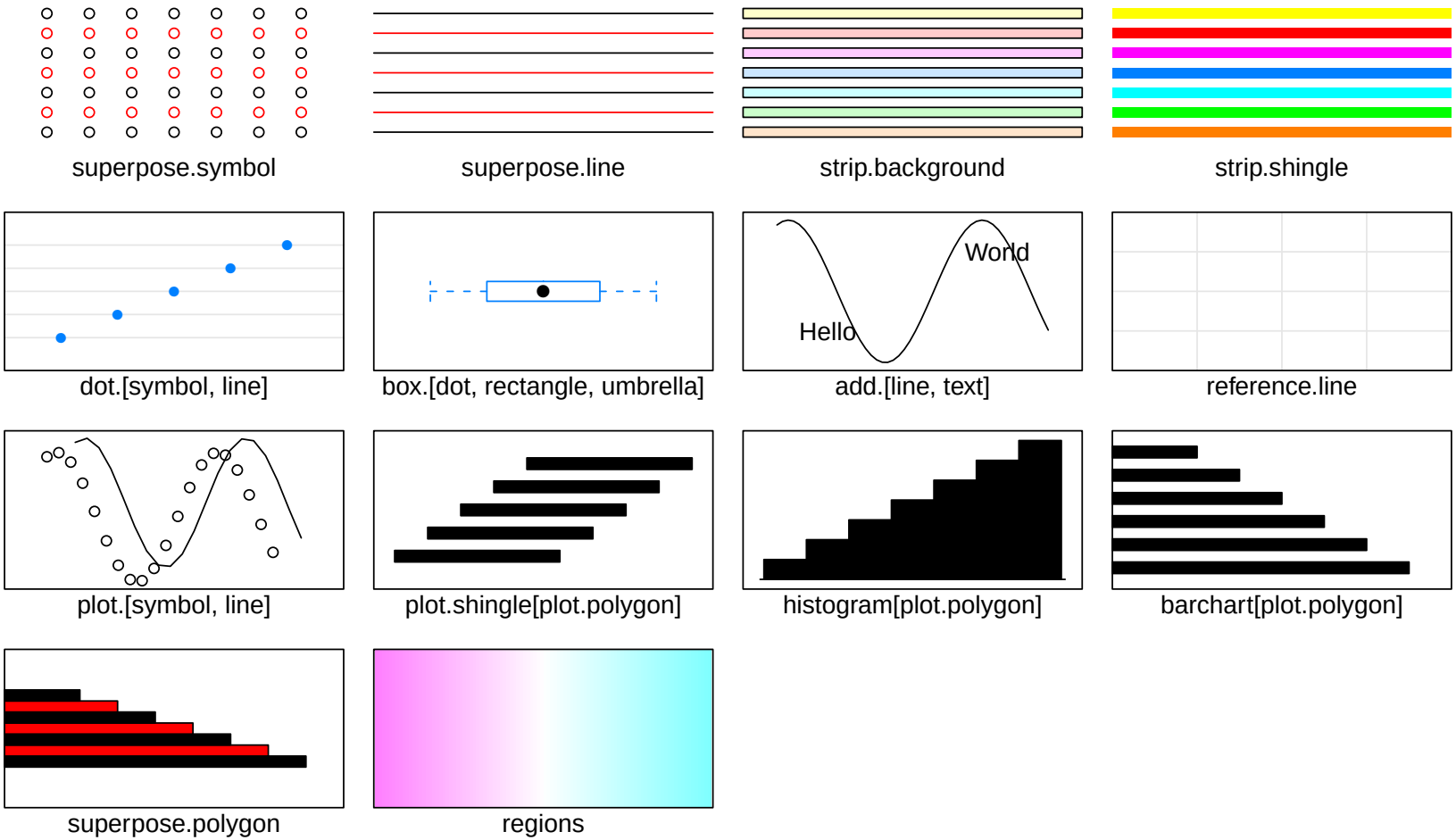
Show settings good for printout

```
> show.settings(standard.theme(color = FALSE))
```



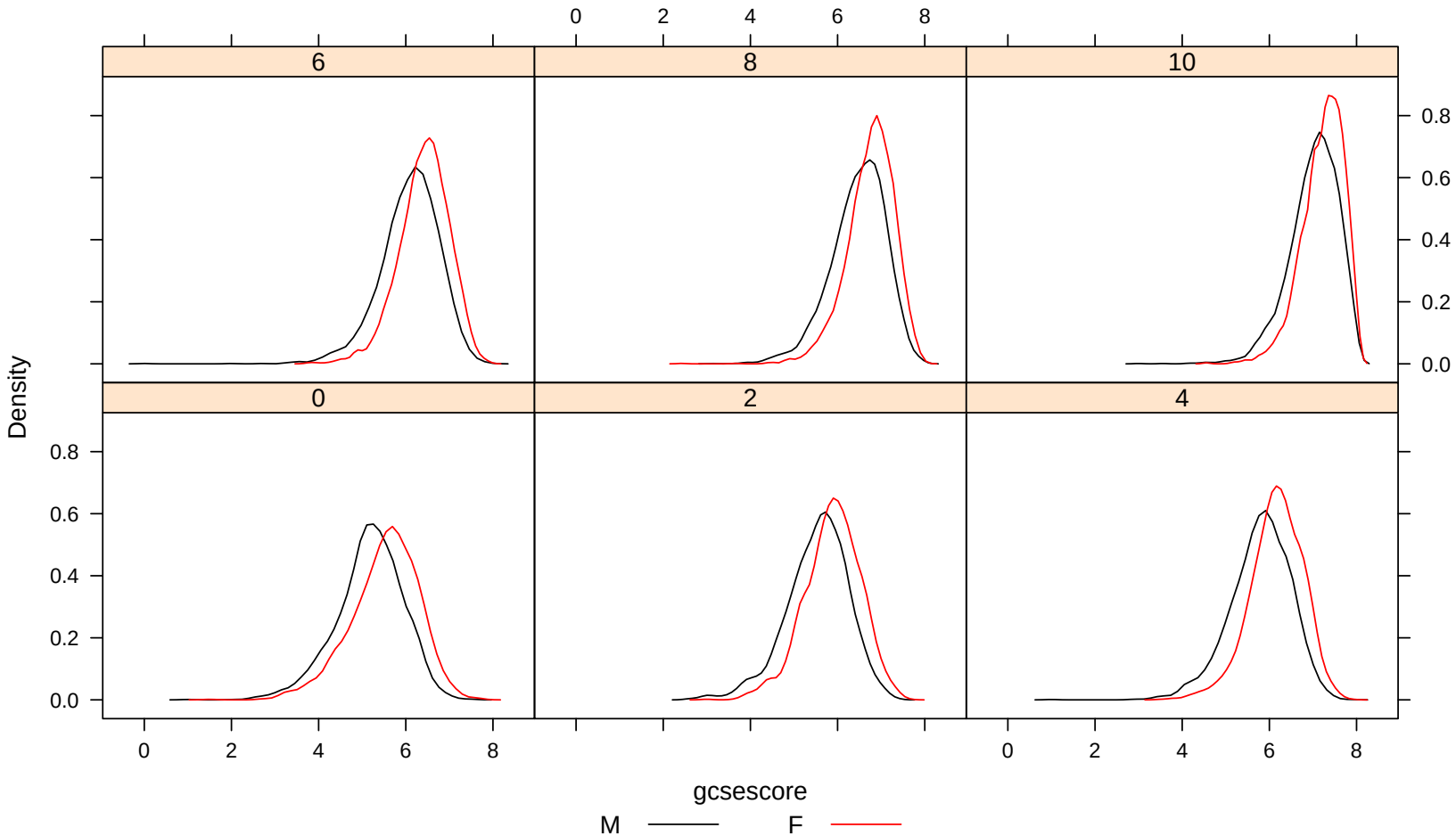
Change the settings

```
> br <- simpleTheme(col = c("black", "red"))
> show.settings(br)
```



Change group colors with par.settings

```
> densityplot(~gcsescore | factor(score),
+     Chem97, plot.points = FALSE, groups = gender,
+     auto.key = list(columns = 2, space = "bottom"),
+     par.settings = br)
```



Load a tabular data set

```
> print(VADeaths)
      Rural Male Rural Female Urban Male Urban Female
50-54       11.7          8.7       15.4          8.4
55-59       18.1         11.7       24.3         13.6
60-64       26.9         20.3       37.0         19.3
65-69       41.0         30.9       54.6         35.1
70-74       66.0         54.3       71.1         50.0
```

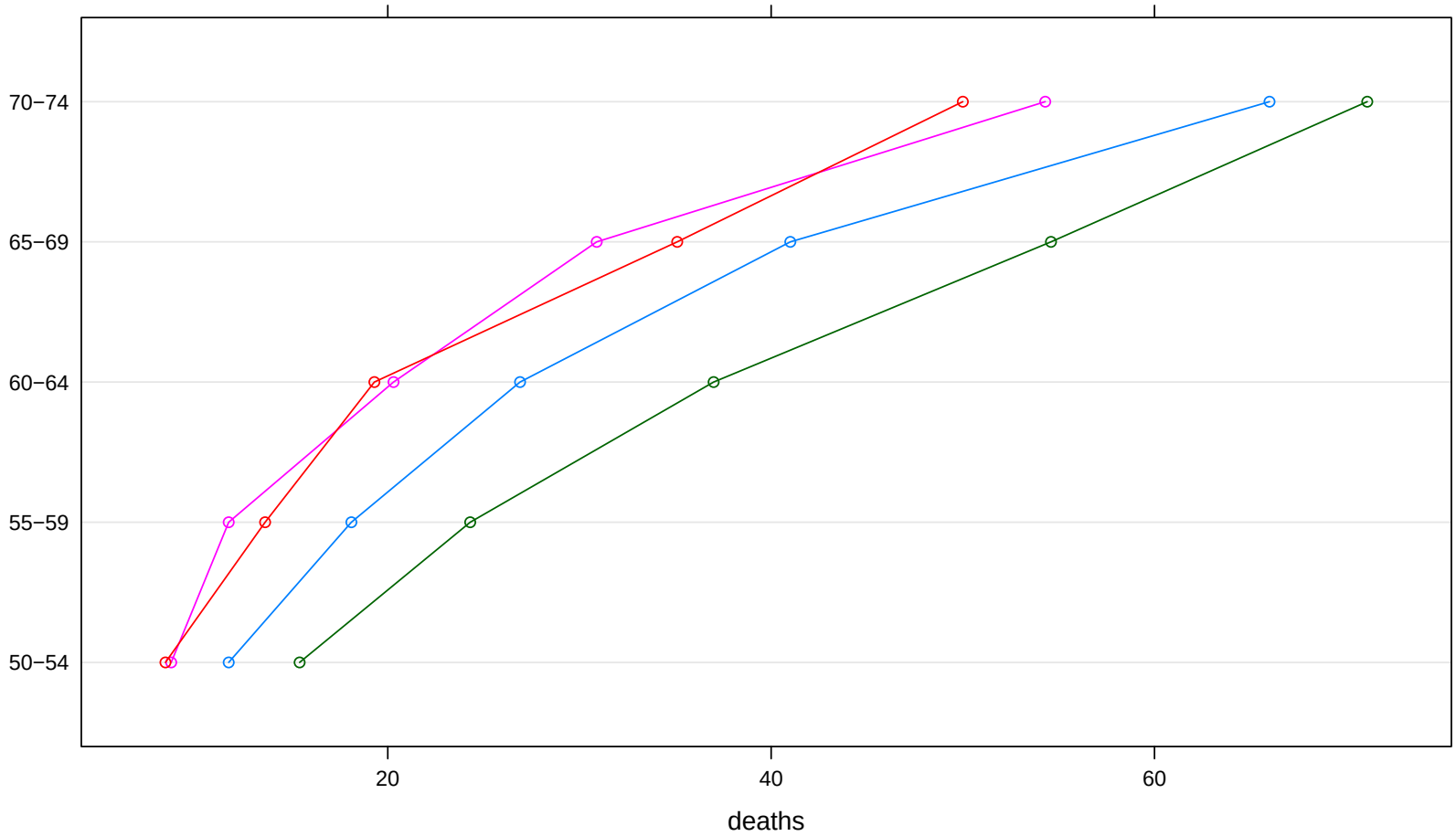
Convert to data frame to work with lattice

```
> vad <- as.data.frame.table(VADeaths)
> names(vad) <- c("age", "demographic", "deaths")
> head(vad)
```

```
    age  demographic deaths
1 50-54   Rural Male   11.7
2 55-59   Rural Male   18.1
3 60-64   Rural Male   26.9
4 65-69   Rural Male   41.0
5 70-74   Rural Male   66.0
6 50-54 Rural Female    8.7
```

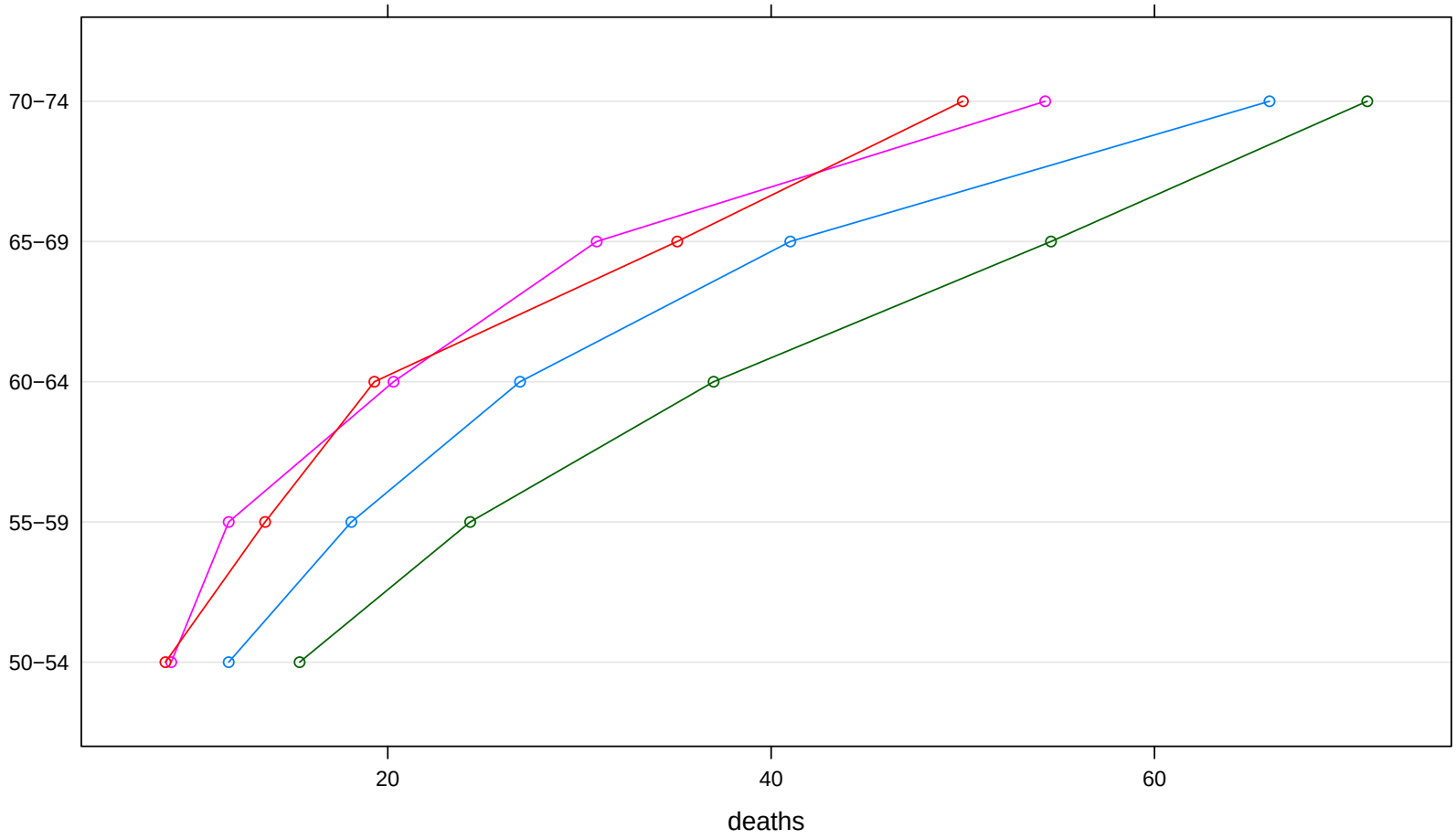
Grouped dotplots work well for these data

```
> dotplot(age ~ deaths, vad, groups = demographic,
+     type = "o")
```



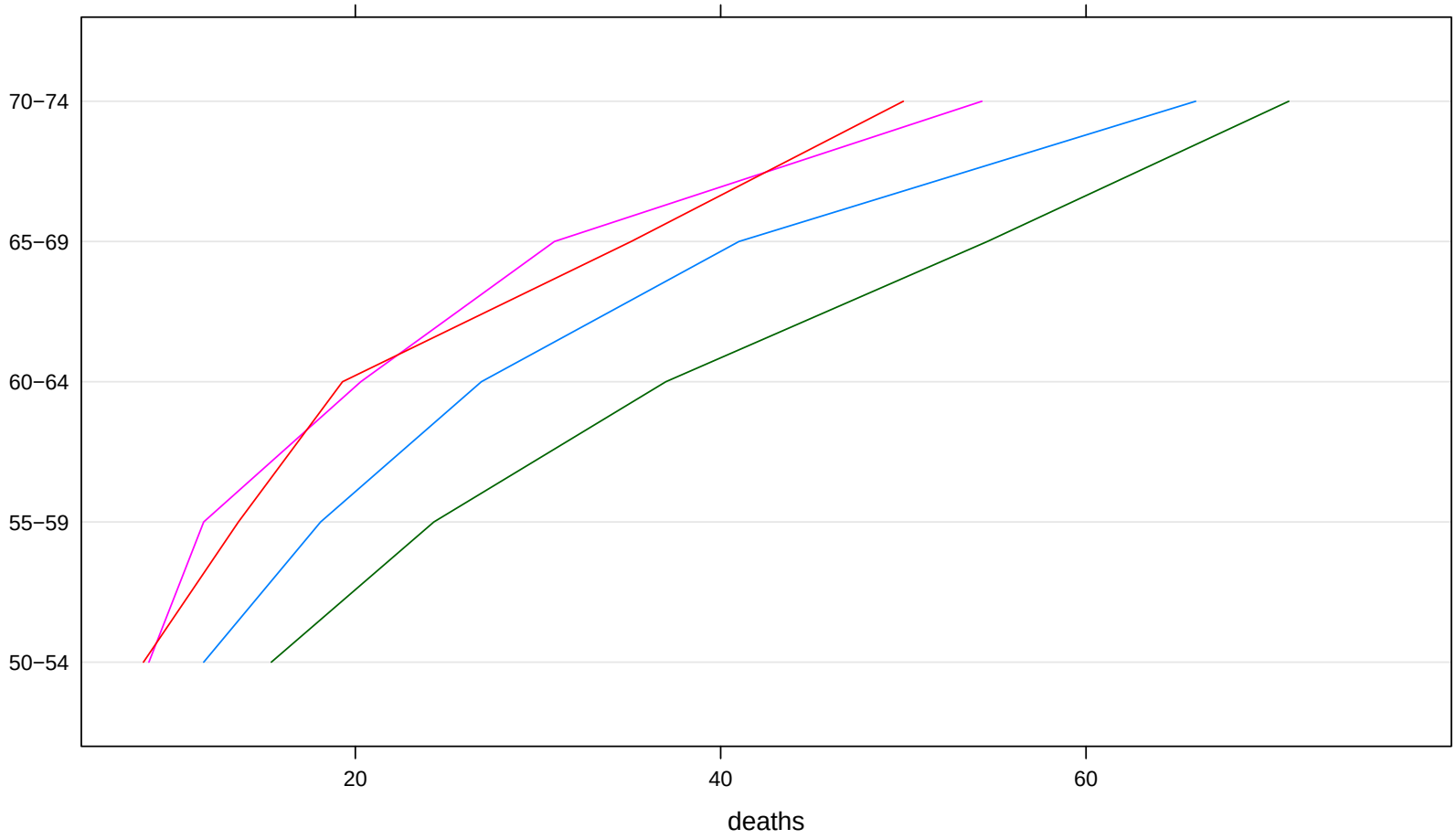
Plots can be saved as R objects

```
> dots <- dotplot(age ~ deaths, vad, groups = demographic,
+     type = "o")
> dots
```



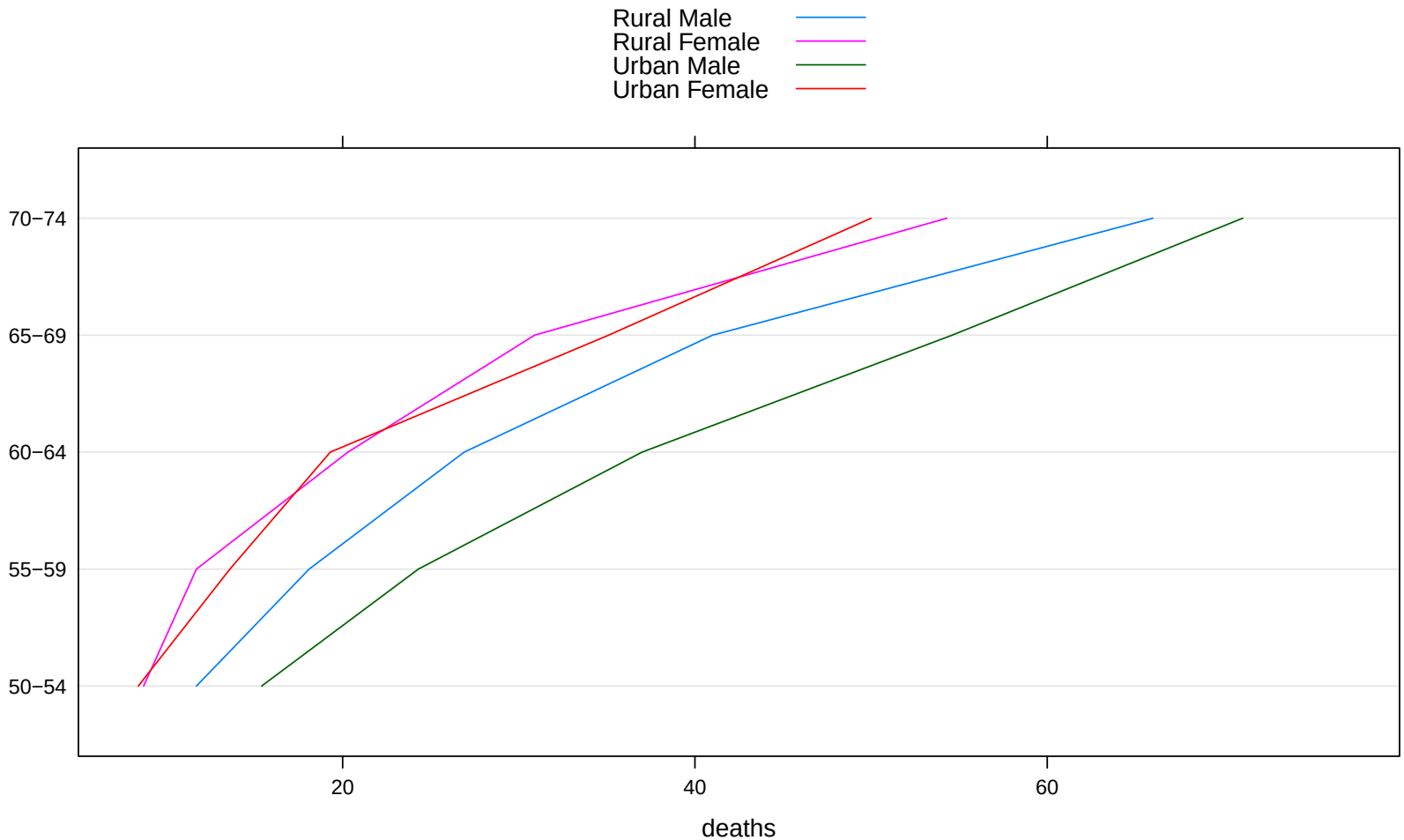
Saved plots can be updated later

```
> dots2 <- update(dots, type = "l", xlim = c(5,
+     80))
> dots2
```



Add a confusing legend ... how can we label more intuitively?

```
> update(dots2, auto.key = list(points = FALSE,
+     lines = TRUE))
```



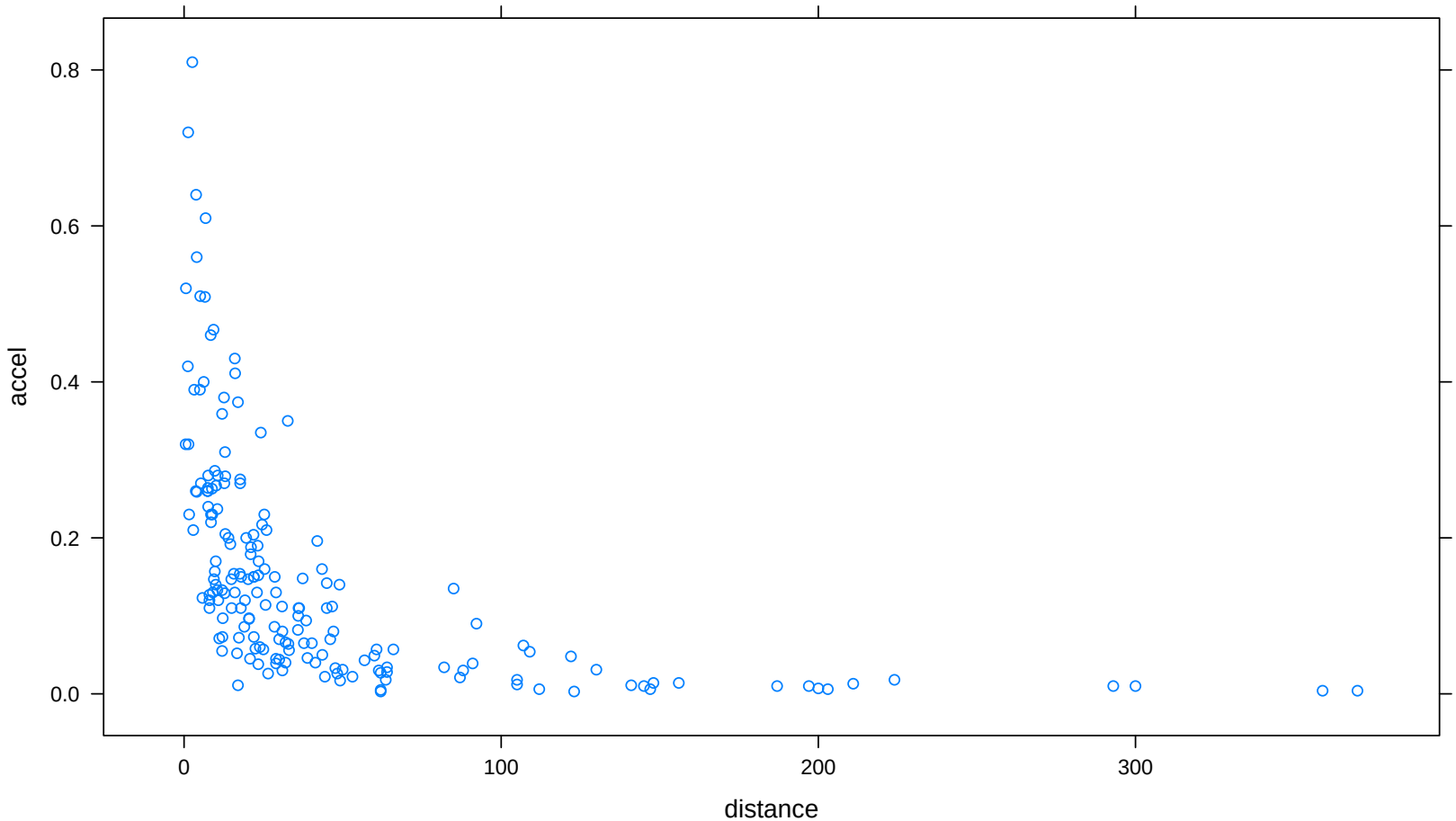
Load some earthquake measurements

```
> data(Earthquake, package = "nlme")
> head(Earthquake)
```

	Quake	Richter	distance	soil	accel
132	20	5	7.5	1	0.264
133	20	5	8.8	1	0.263
134	20	5	8.9	1	0.230
135	20	5	9.4	1	0.147
136	20	5	9.7	1	0.286
137	20	5	9.7	1	0.157

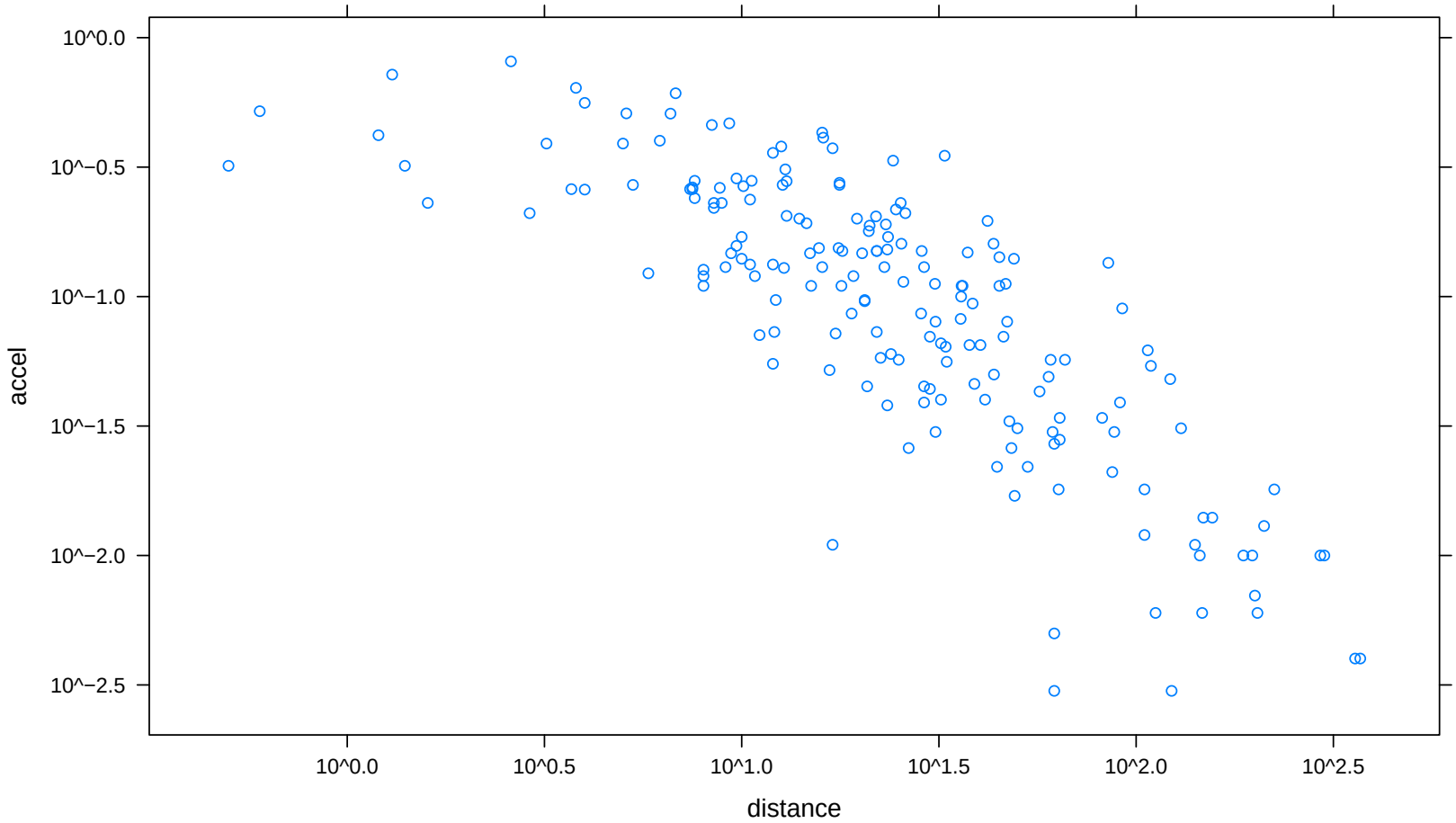
Scatterplot with xyplot

```
> xyplot(accel ~ distance, Earthquake)
```



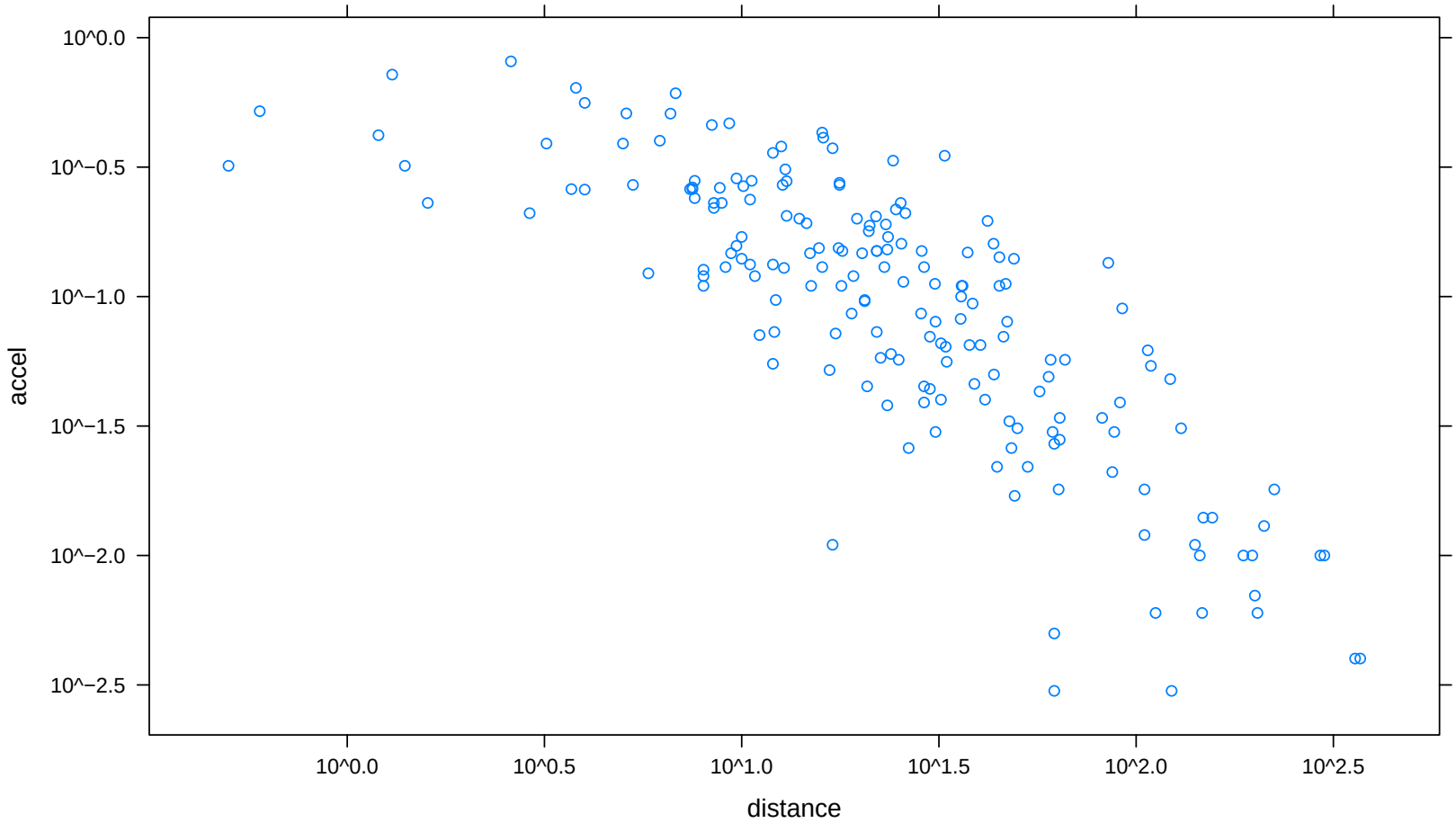
Log scales with scales argument

```
> xyplot(accel ~ distance, Earthquake,
+     scales = list(log = TRUE))
```



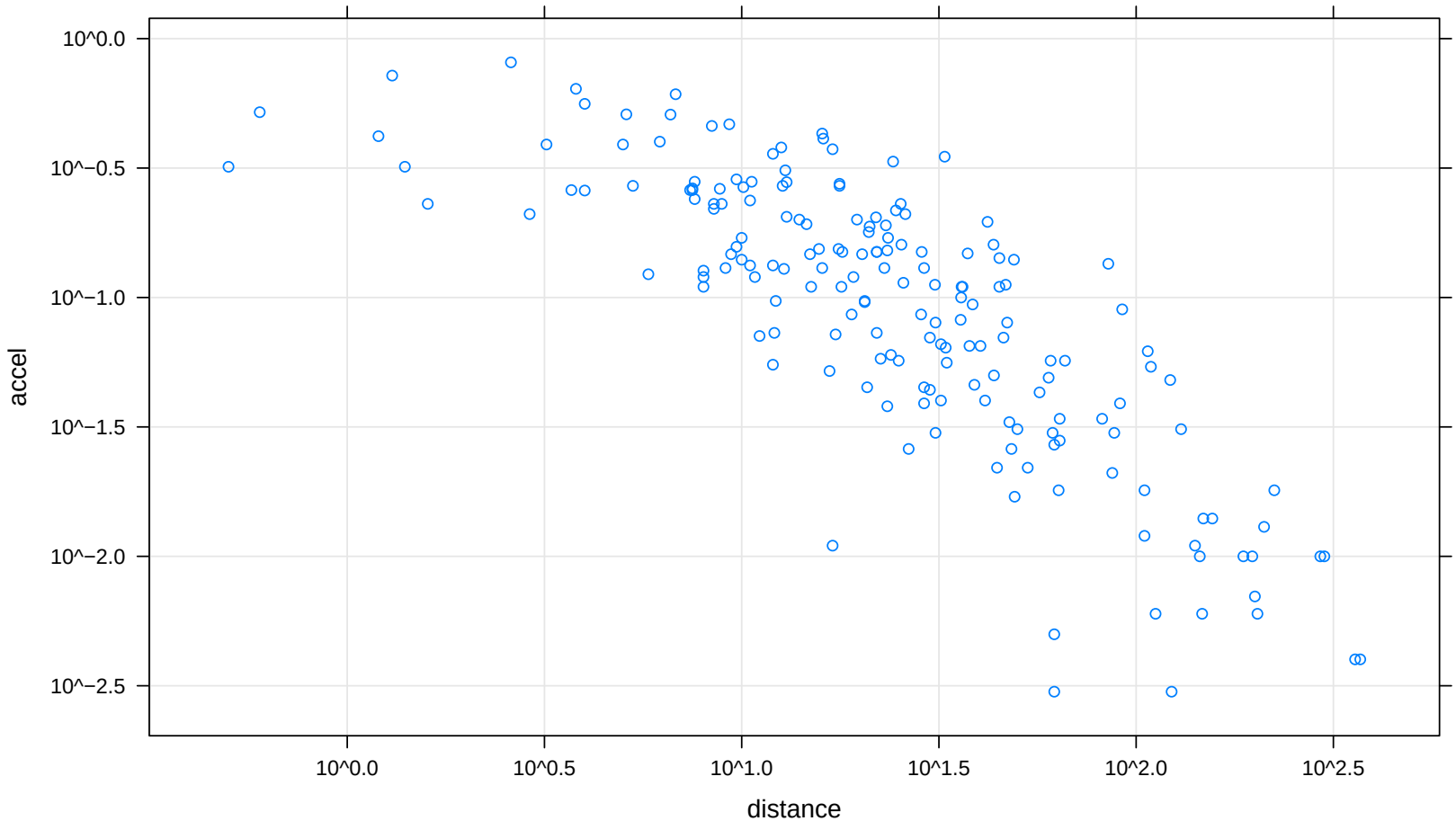
Type "p" is the default

```
> xyplot(accel ~ distance, Earthquake,
+     scales = list(log = TRUE), type = c("p"))
```



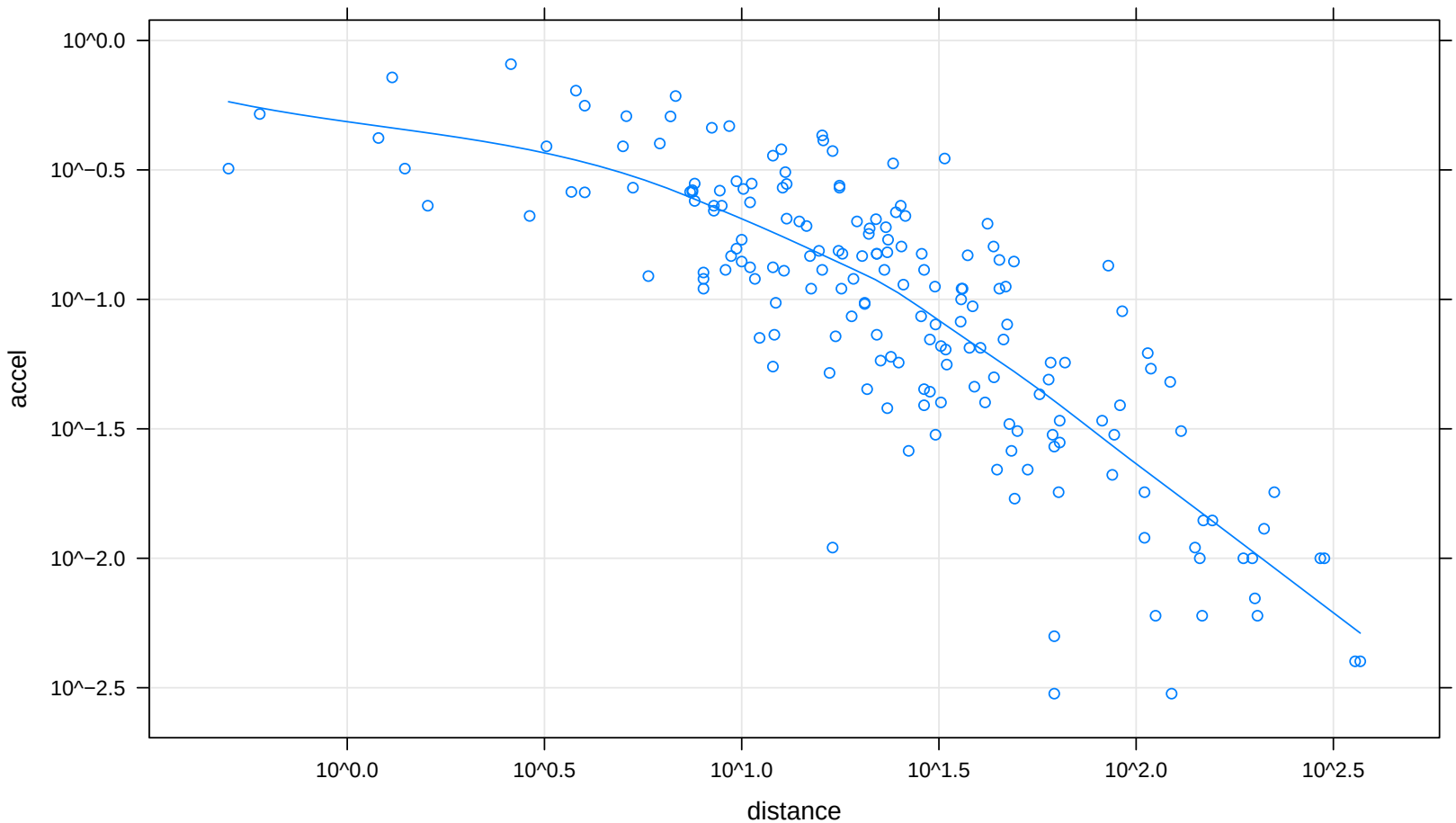
Type "g" adds a grid

```
> xyplot(accel ~ distance, Earthquake,
+     scales = list(log = TRUE), type = c("p",
+         "g"))
```



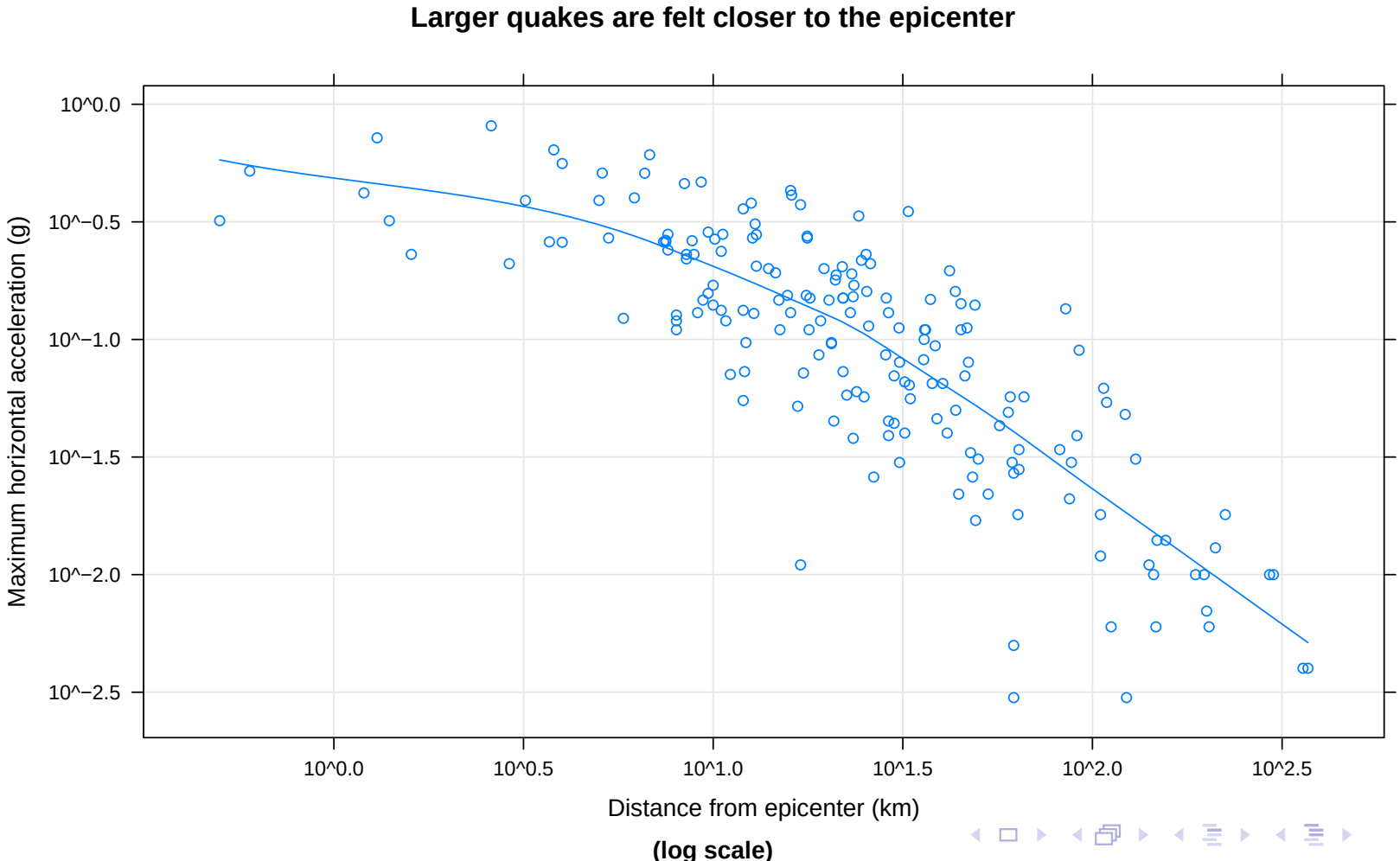
Type "smooth" adds a smooth line

```
> xyplot(accel ~ distance, Earthquake,
+     scales = list(log = TRUE), type = c("p",
+         "g", "smooth"))
```



Add some labels

```
> xyplot(accel ~ distance, Earthquake,
+     scales = list(log = TRUE), type = c("p",
+         "g", "smooth"), sub = "(log scale)",
+     xlab = "Distance from epicenter (km)",
+     ylab = "Maximum horizontal acceleration (g)",
+     main = "Larger quakes are felt closer to the epicenter")
```

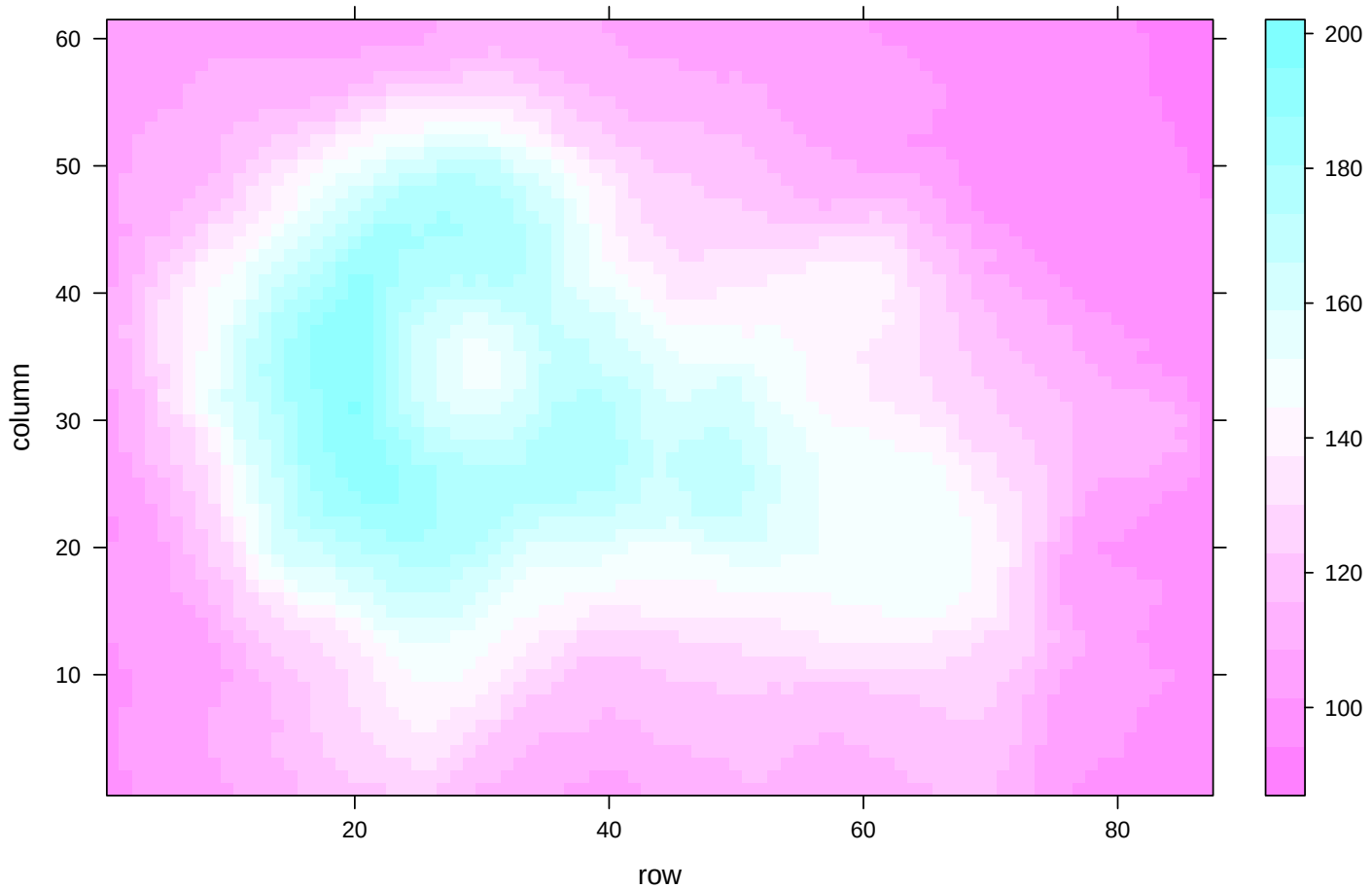


Volcano elevation data in matrix form

```
> dim(volcano)

[1] 87 61

> print(volcano[1:5, 1:5])

     [,1] [,2] [,3] [,4] [,5]
[1,]  100  100  101  101  101
[2,]  101  101  102  102  102
[3,]  102  102  103  103  103
[4,]  103  103  104  104  104
[5,]  104  104  105  105  105
```

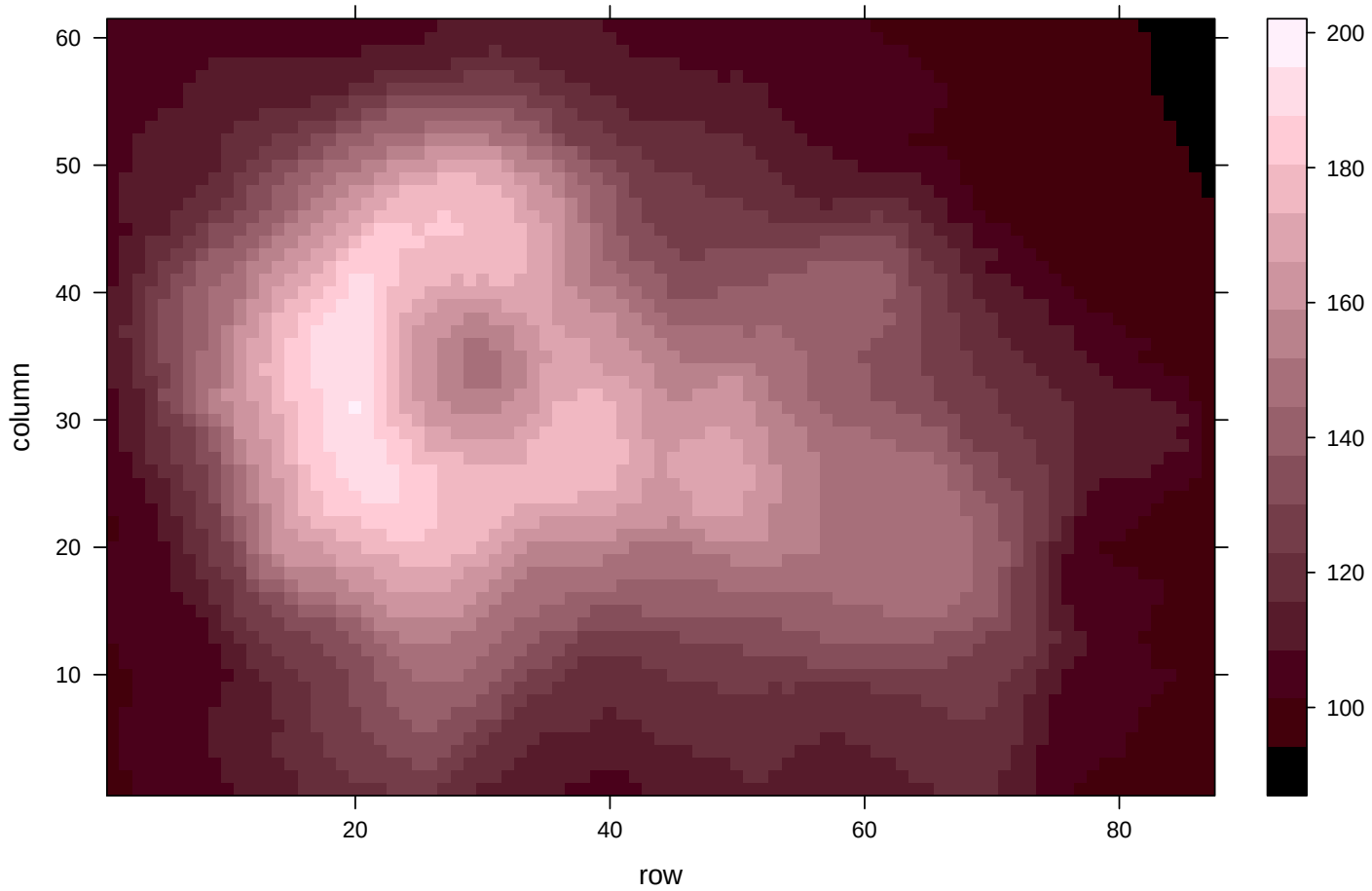
Plot volcano elevations in a matrix using color

```
> levelplot(volcano)
```



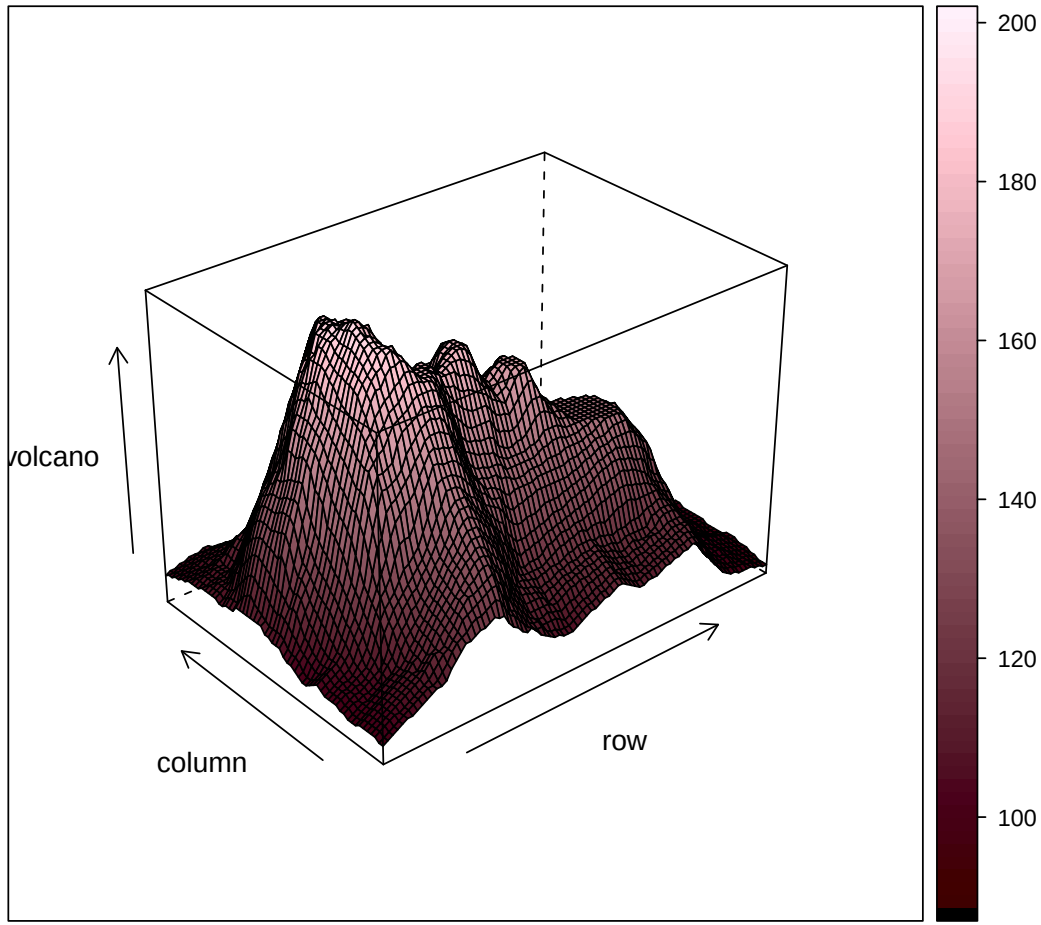
Use a different color scale

```
> my.colors <- sapply(0:100, function(l) hcl(l = l))
> levelplot(volcano, col.regions = my.colors)
```



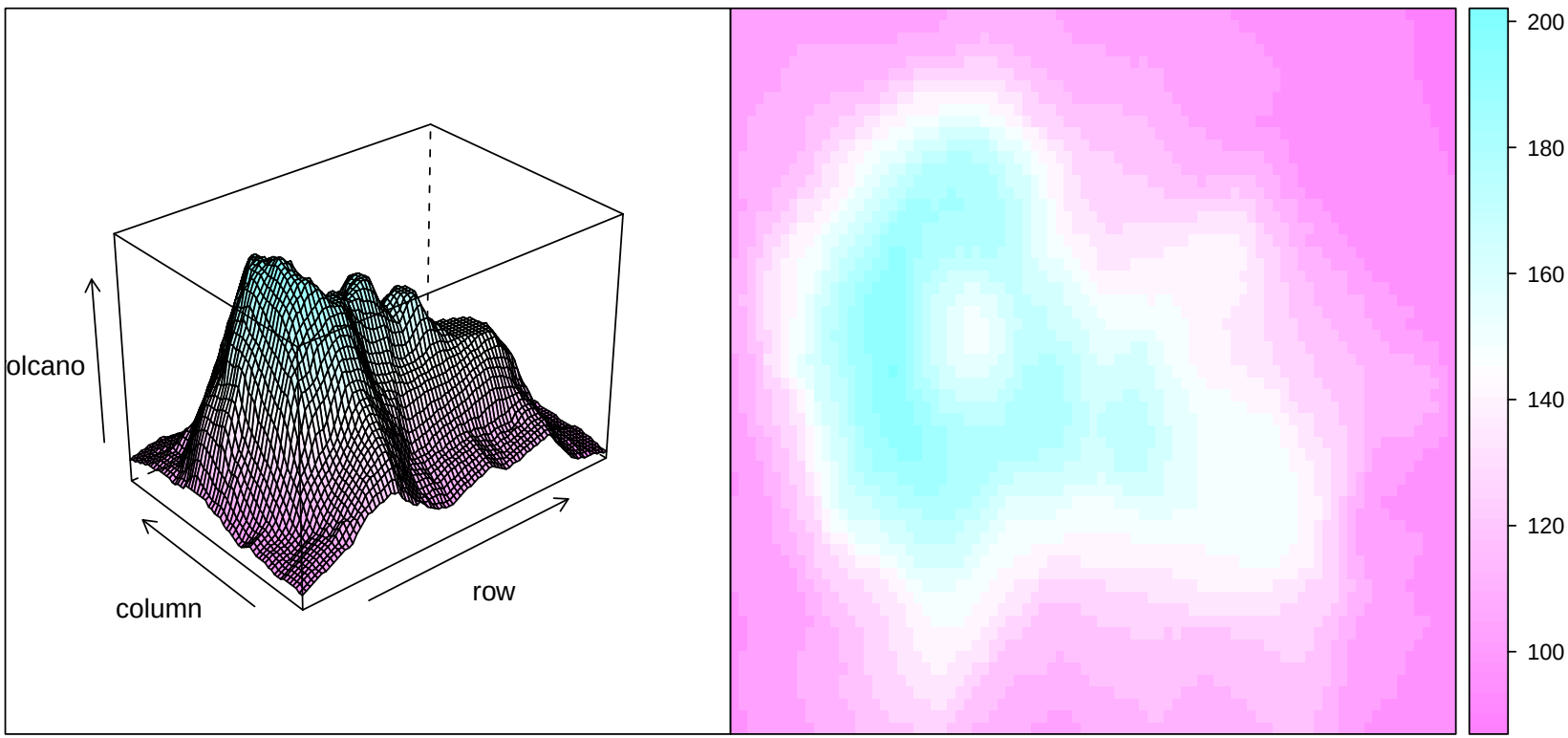
Use 3d wireframe plots

```
> wireframe(volcano, drape = TRUE, col.regions = my.colors)
```



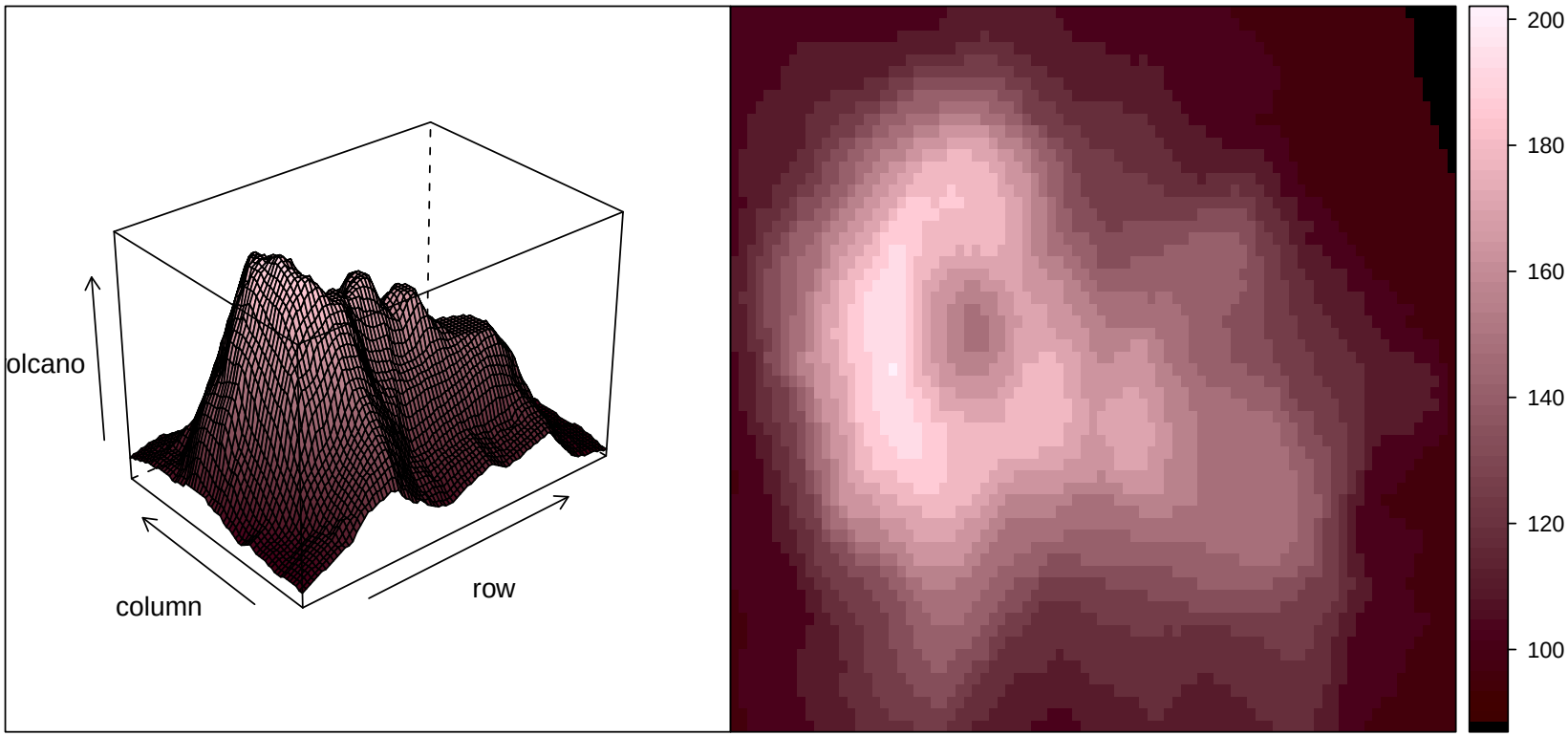
Combine plots using latticeExtra

```
> library(latticeExtra)
> both <- c(wireframe(volcano, drape = TRUE),
+     levelplot(volcano))
> both
```



Globally change the plot parameters

```
> trellis.par.set(regions = list(col = my.colors))
> both
```

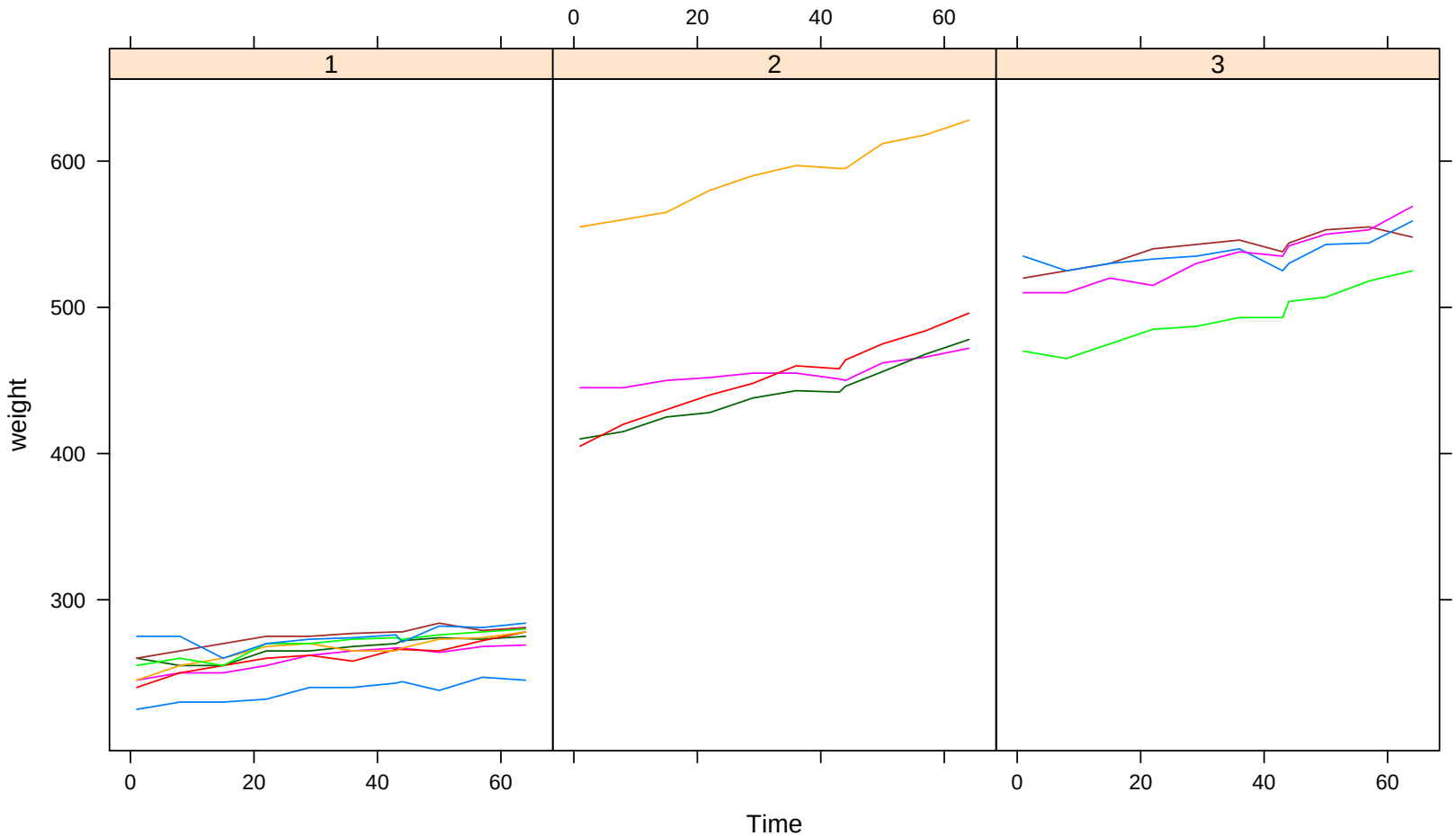


Longitudinal data

```
> data(BodyWeight, package = "nlme")
> head(BodyWeight)
  weight Time Rat Diet
1    240    1   1    1
2    250    8   1    1
3    255   15   1    1
4    260   22   1    1
5    262   29   1    1
6    258   36   1    1
```

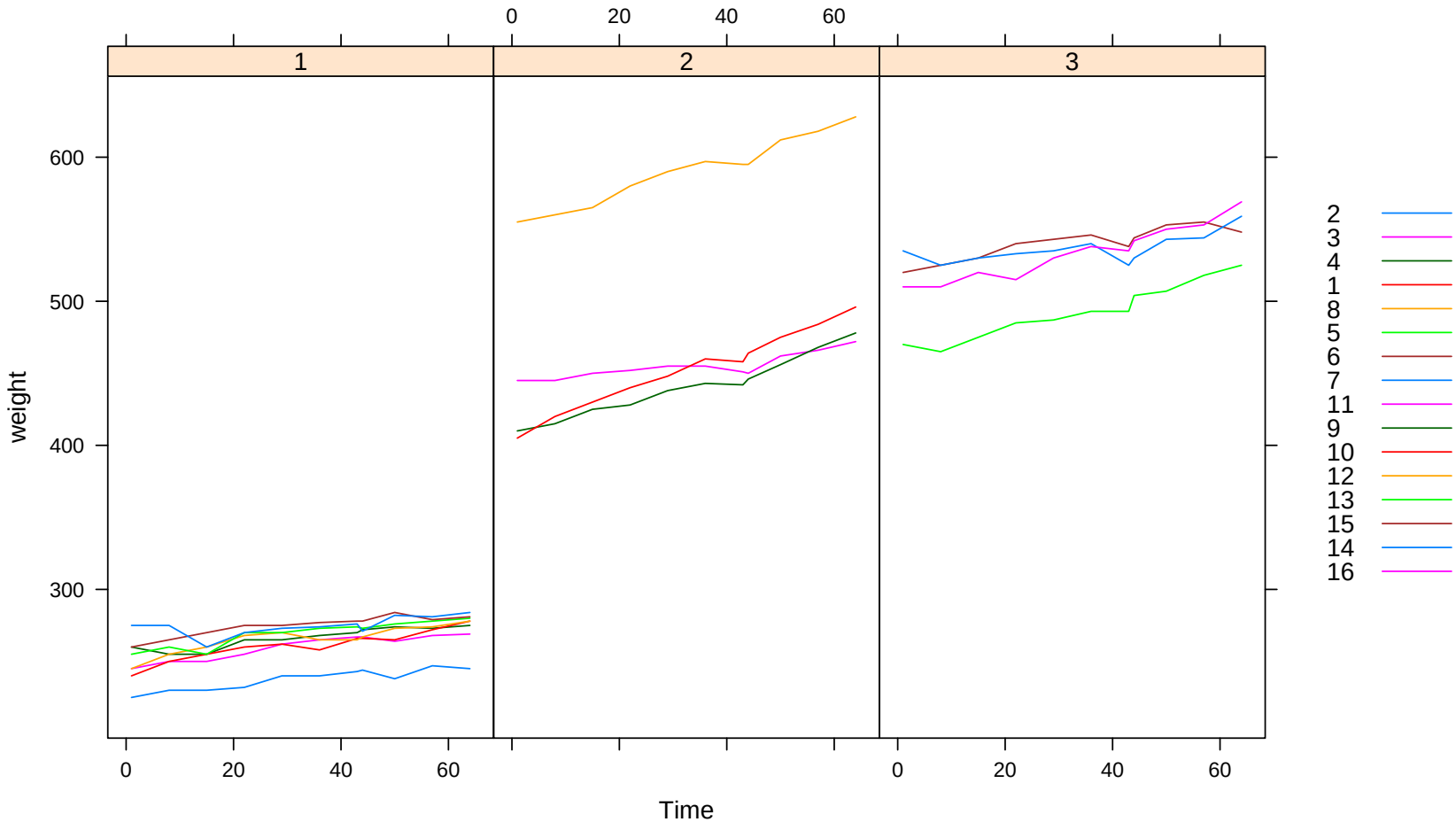
Conditional scatterplots reveal difference between treatments

```
> xyplot(weight ~ Time | Diet, BodyWeight,
+     groups = Rat, type = "l", layout = c(3,
+         1))
```



Legends with more than a few items are very confusing

```
> xyplot(weight ~ Time | Diet, BodyWeight,
+     groups = Rat, type = "l", layout = c(3,
+         1), auto.key = list(space = "right",
+         points = FALSE, lines = TRUE))
```



Outline

Why use direct labels instead of legends?

- Edward Tufte, professor emeritus of statistics at Yale.
- The Visual Display of Quantitative Information (1983).

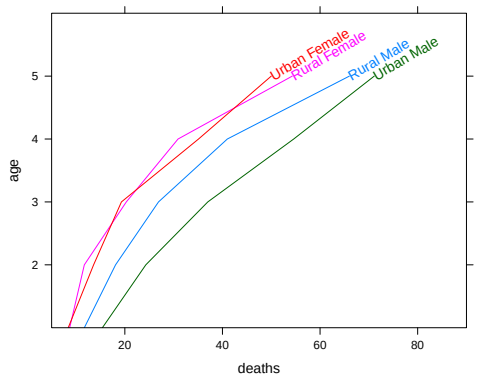
- One of his points: legends make it harder to decode a statistical graphic.
- Use direct labels whenever possible.

How to plot direct labels in R?

- Lattice + latticedl: direct.label(xyplot(y∼x,data,groups=z),method=f)
- Positions of direct labels can be specified as a function of the data:

```
f <- function(d,...){
  # d is a data frame with columns x,y,groups of the data points
  #... analyze the points and return the label positions:
  return(data.frame(x=a,y=b,groups=c))
}
```

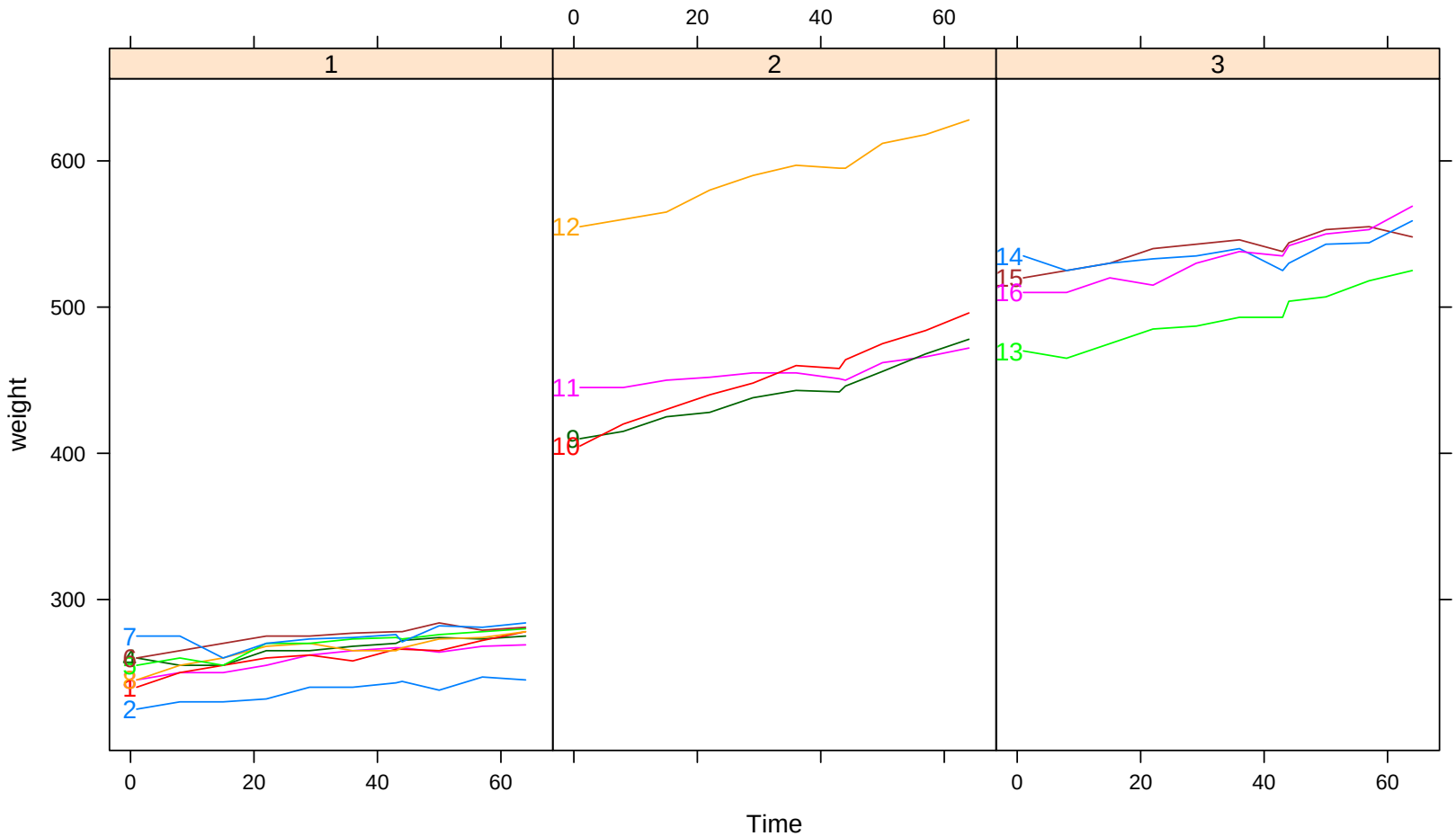
```
        groups    x y hjust vjust rot
1   Rural Male 66.0 5     0   0.5  30
2 Rural Female 54.3 5     0   0.5  30
3   Urban Male 71.1 5     0   0.5  30
4 Urban Female 50.0 5     0   0.5  30
```



- latticedl does the labeling for you, keeping track of the correct colors.
- Common plot types have default direct labeling methods.

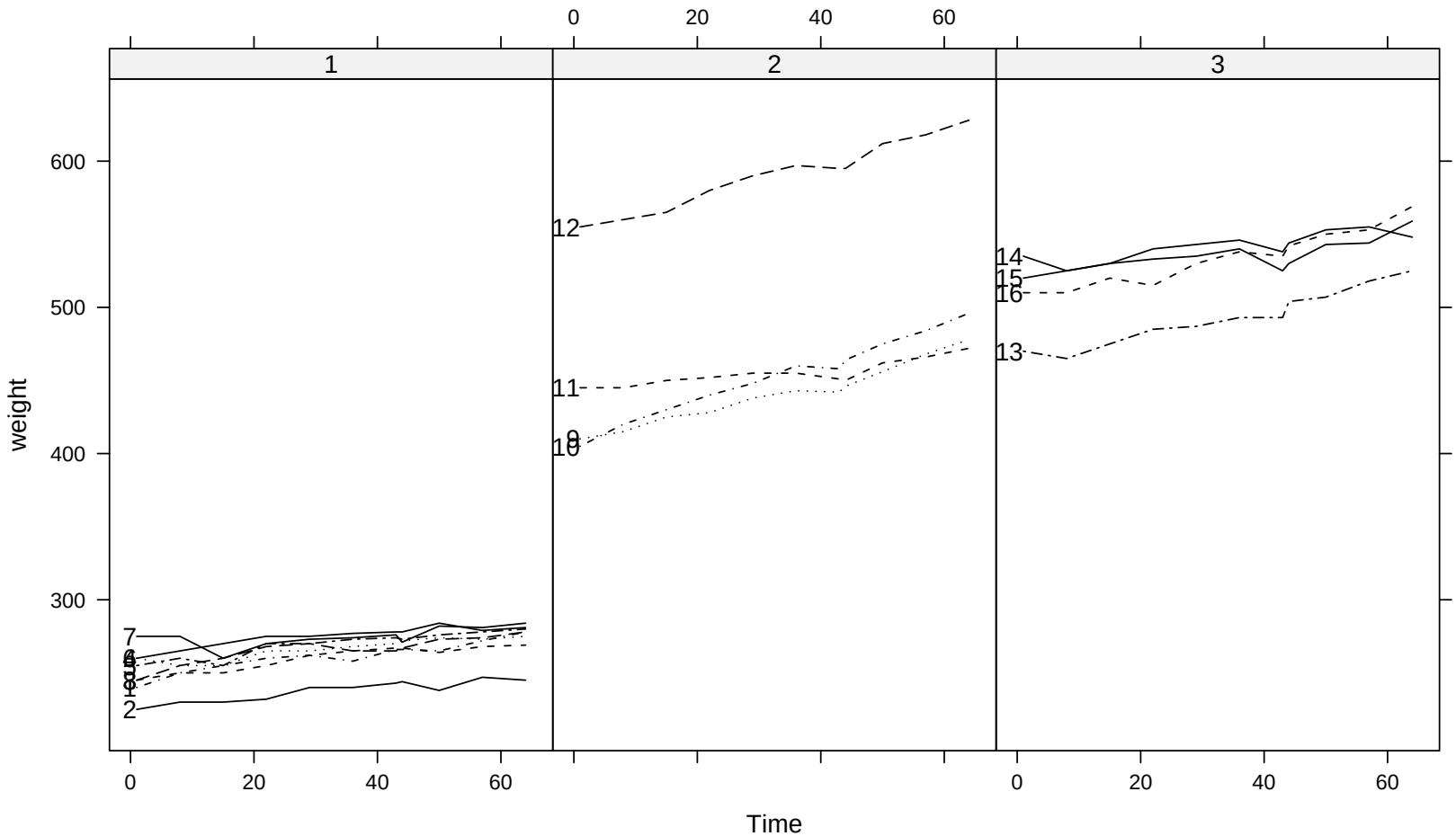
Easy fix for confusing legend: direct labels

```
> library(latticedl)
> long <- xyplot(weight ~ Time | Diet, BodyWeight,
+     groups = Rat, type = "l", layout = c(3,
+         1))
> direct.label(long)
```



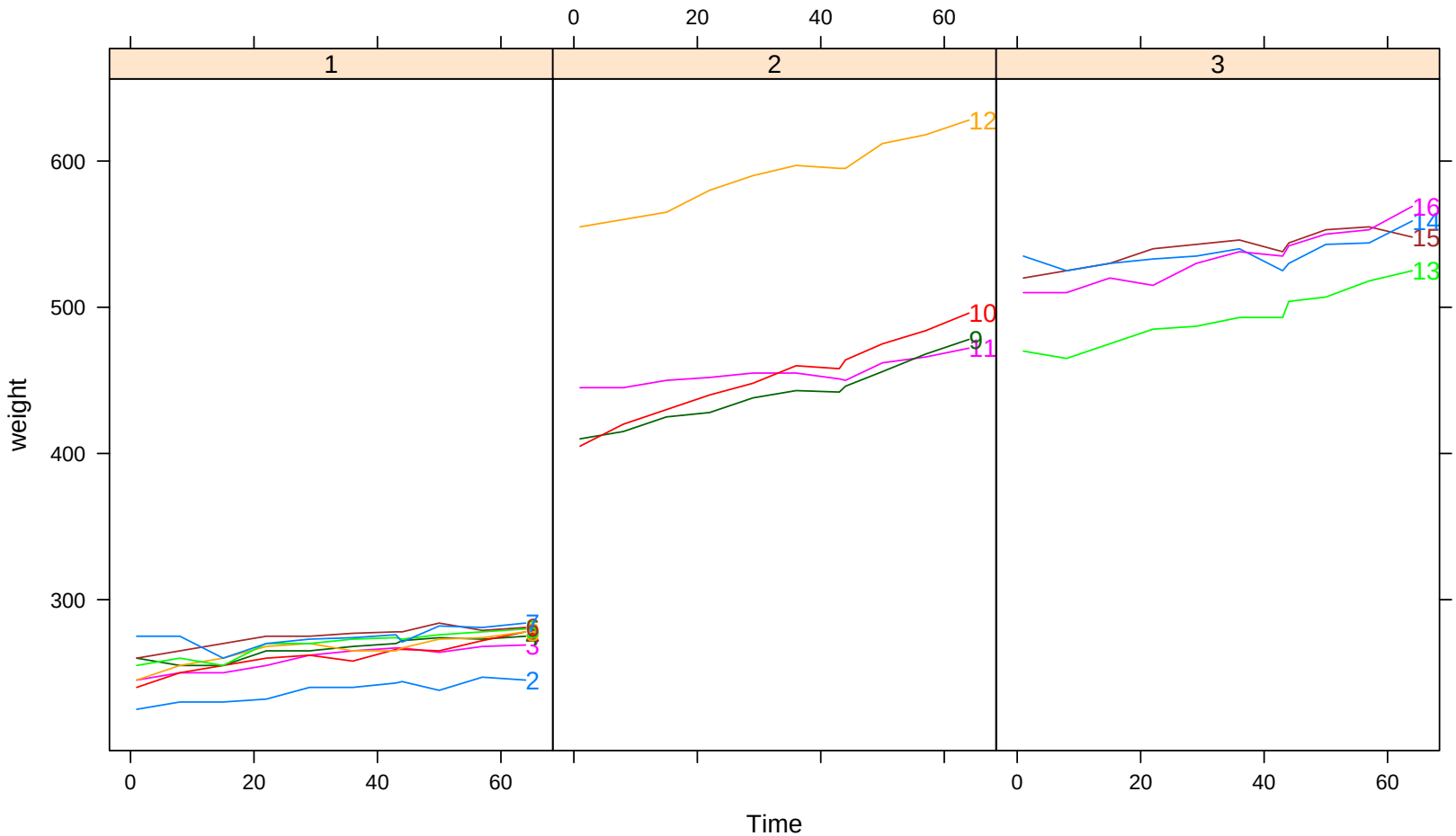
Even works in black and white

```
> longbw <- update(long, par.settings = standard.theme(color = FALSE))
> direct.label(longbw)
```



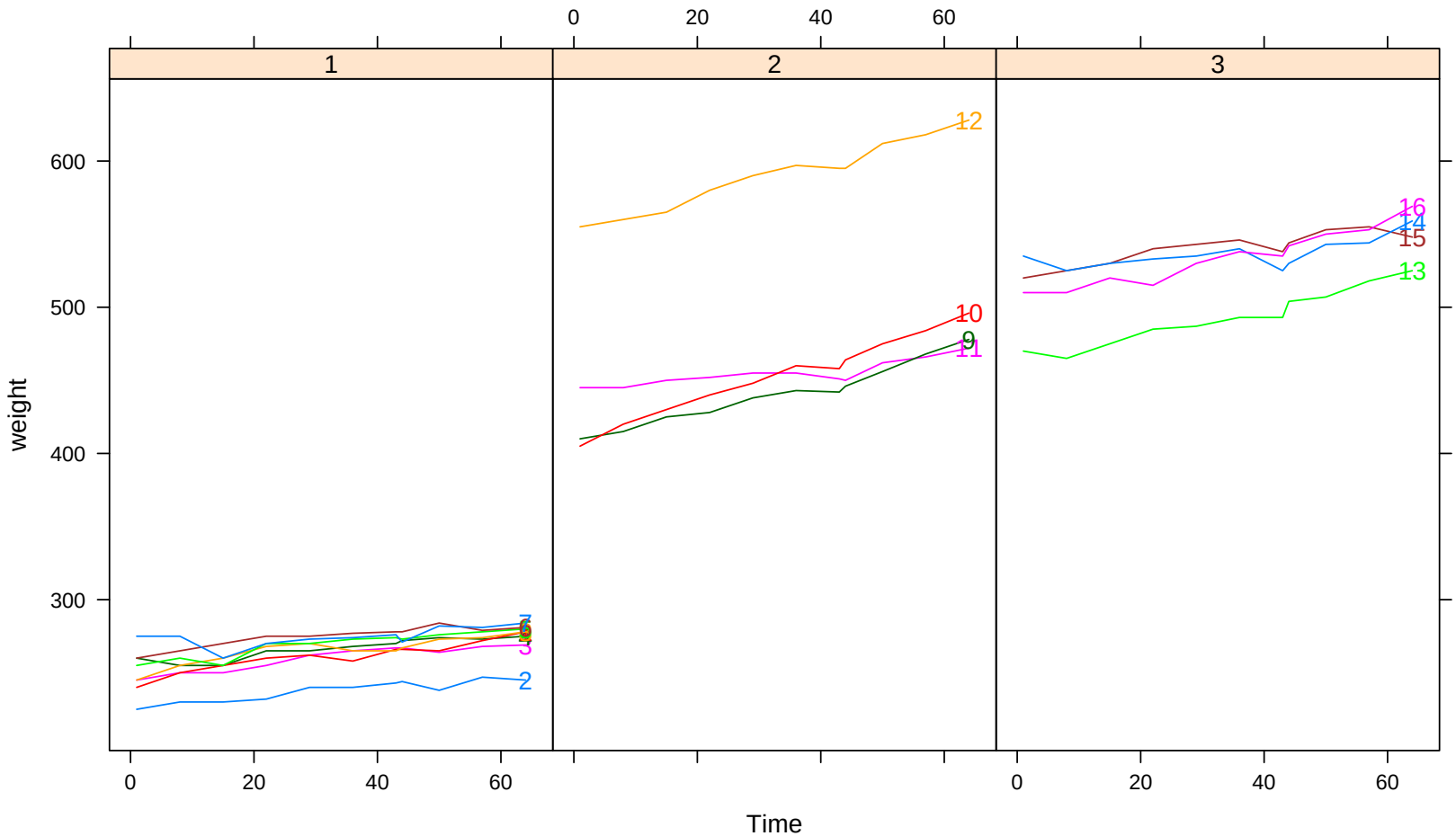
Change label positions with the method argument

```
> direct.label(long, method = last.points)
```



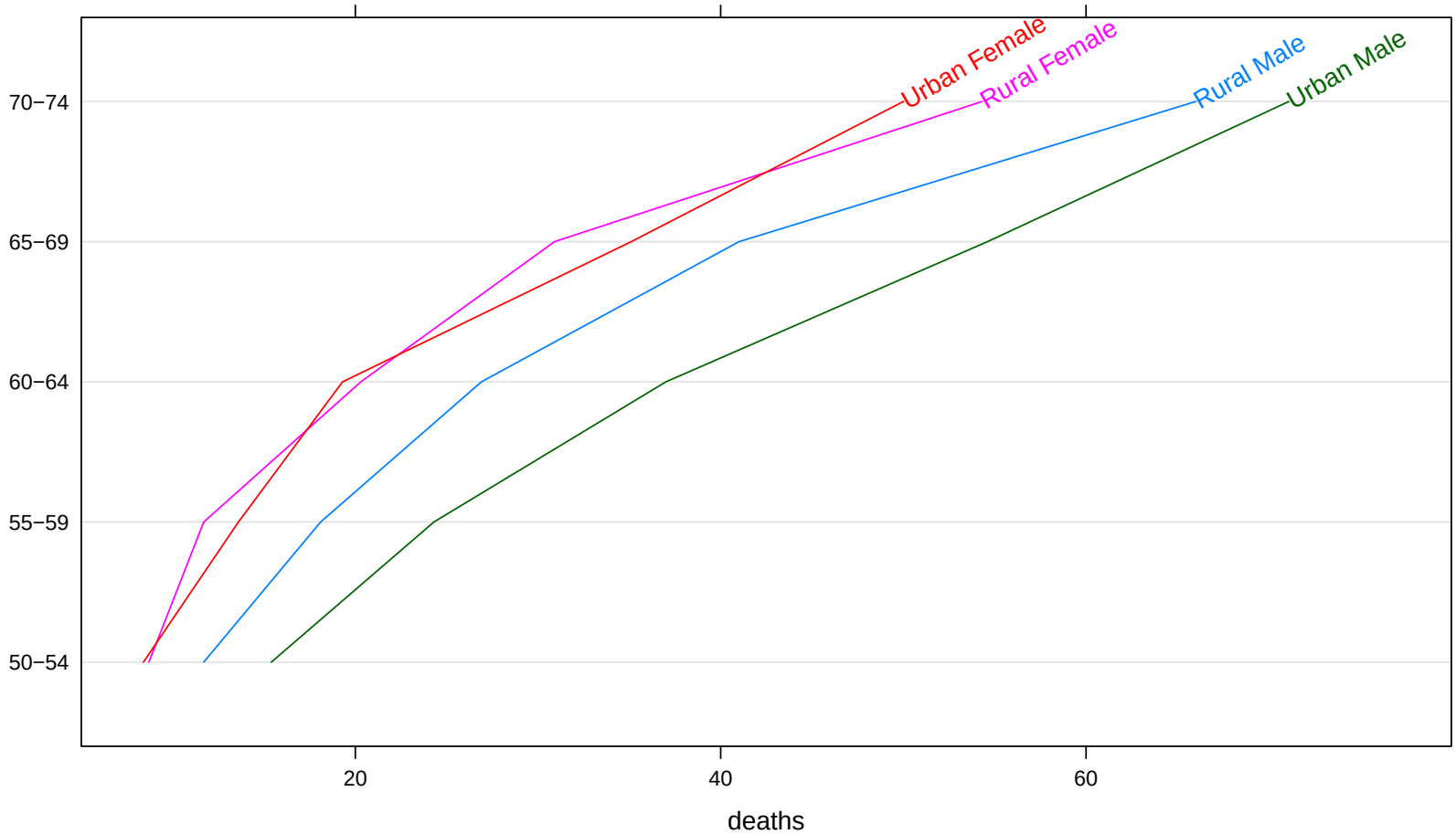
Make your own positioning function using dl.indep

```
> direct.label(long, method = dl.indep(d[which.max(d$x),
+     ]))
```



You can change text parameters (same as grid::grid.text)

```
> direct.label(dots2, method = list("last.points",
+      rot = 30))
```

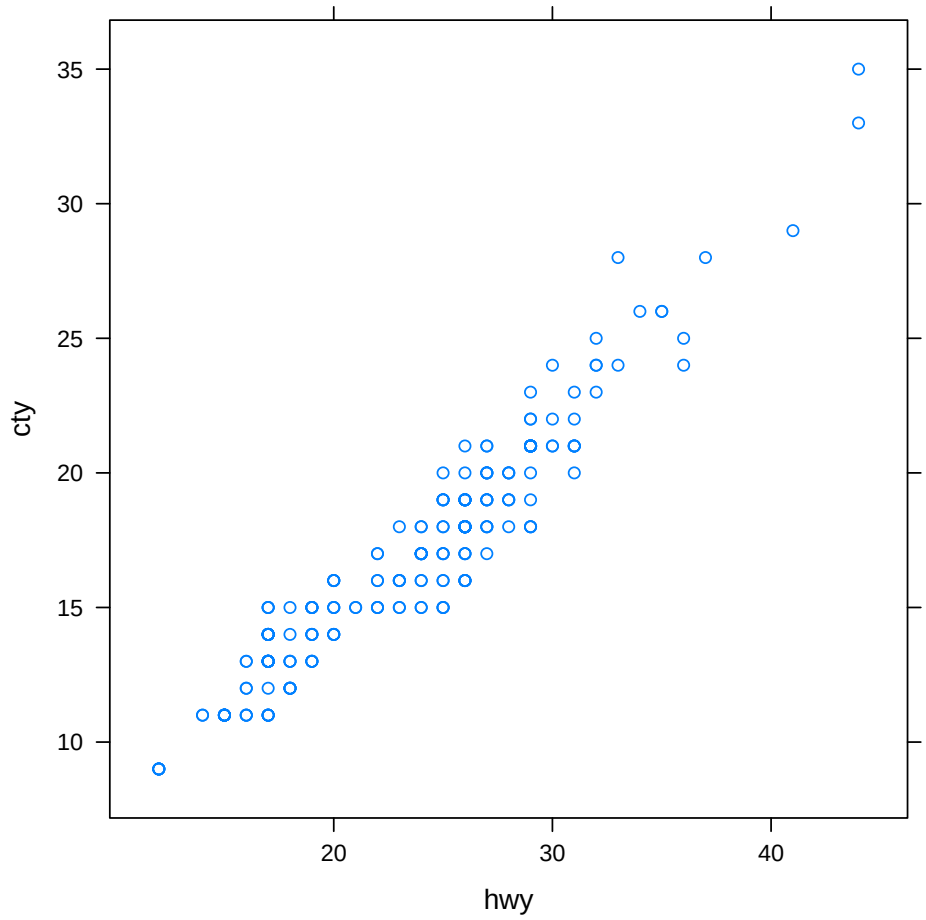


Load some data on car fuel efficiency

```
> data(mpg, package = "ggplot2")
> head(mpg)
  manufacturer model displ year cyl      trans drv cty
1         audi    a4   1.8 1999   4   auto(l5)   f  18
2         audi    a4   1.8 1999   4 manual(m5)   f  21
3         audi    a4   2.0 2008   4 manual(m6)   f  20
4         audi    a4   2.0 2008   4   auto(av)   f  21
5         audi    a4   2.8 1999   6   auto(l5)   f  16
6         audi    a4   2.8 1999   6 manual(m5)   f  18
  hwy fl   class
1  29  p compact
2  29  p compact
3  31  p compact
4  30  p compact
5  26  p compact
6  26  p compact
```

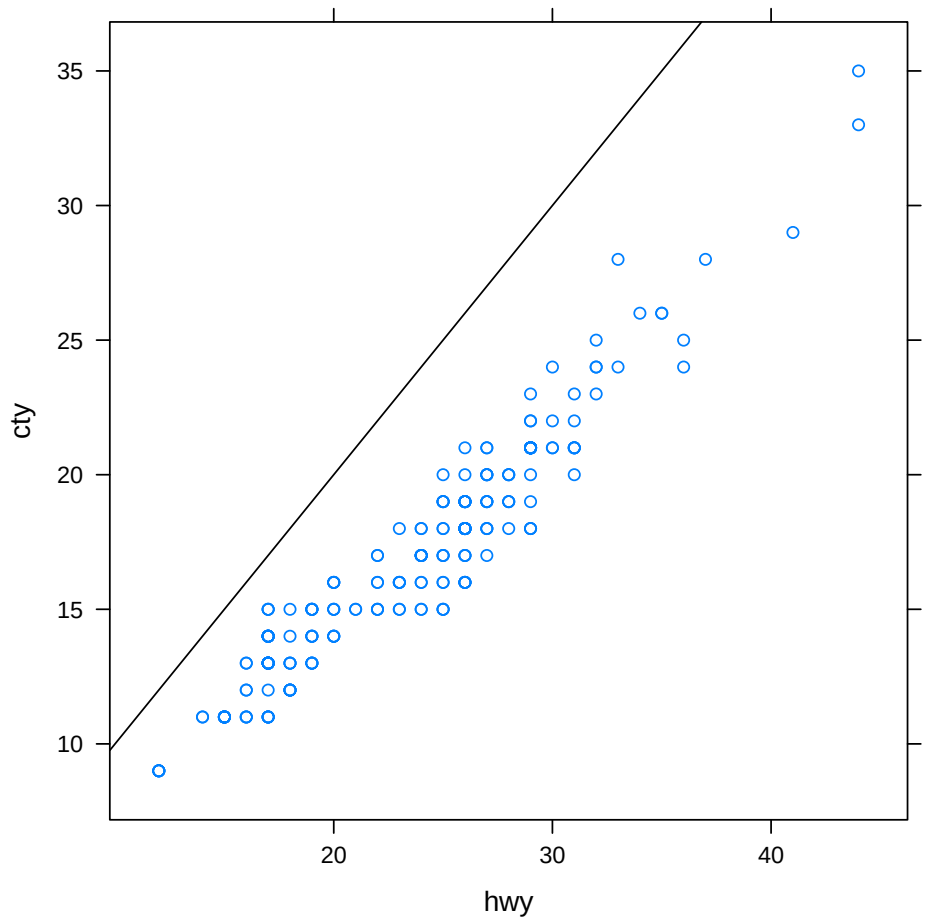
Plot city versus highway fuel efficiency

```
> xyplot(cty ~ hwy, mpg, aspect = 1)
```



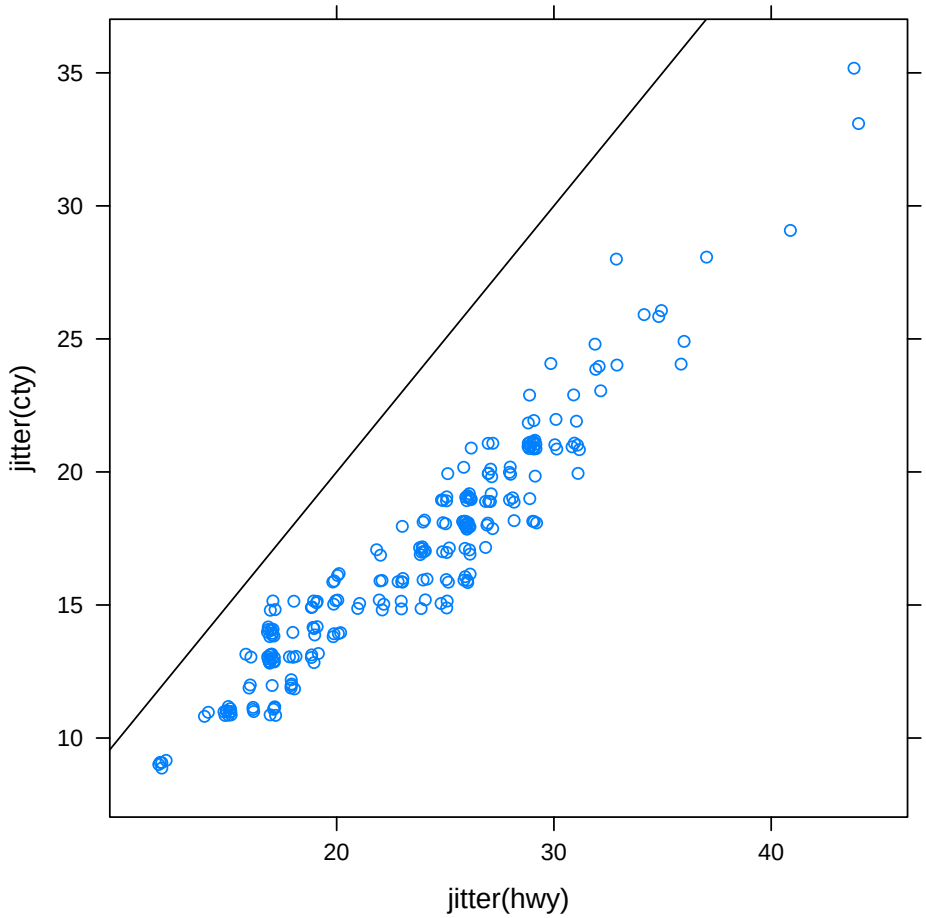
Add a reference line x=y

```
> panel.xyref <- function(...) {
+     panel.xyplot(...)
+     panel.abline(0, 1)
+ }
> xyplot(cty ~ hwy, mpg, aspect = 1, panel = panel.xyref)
```



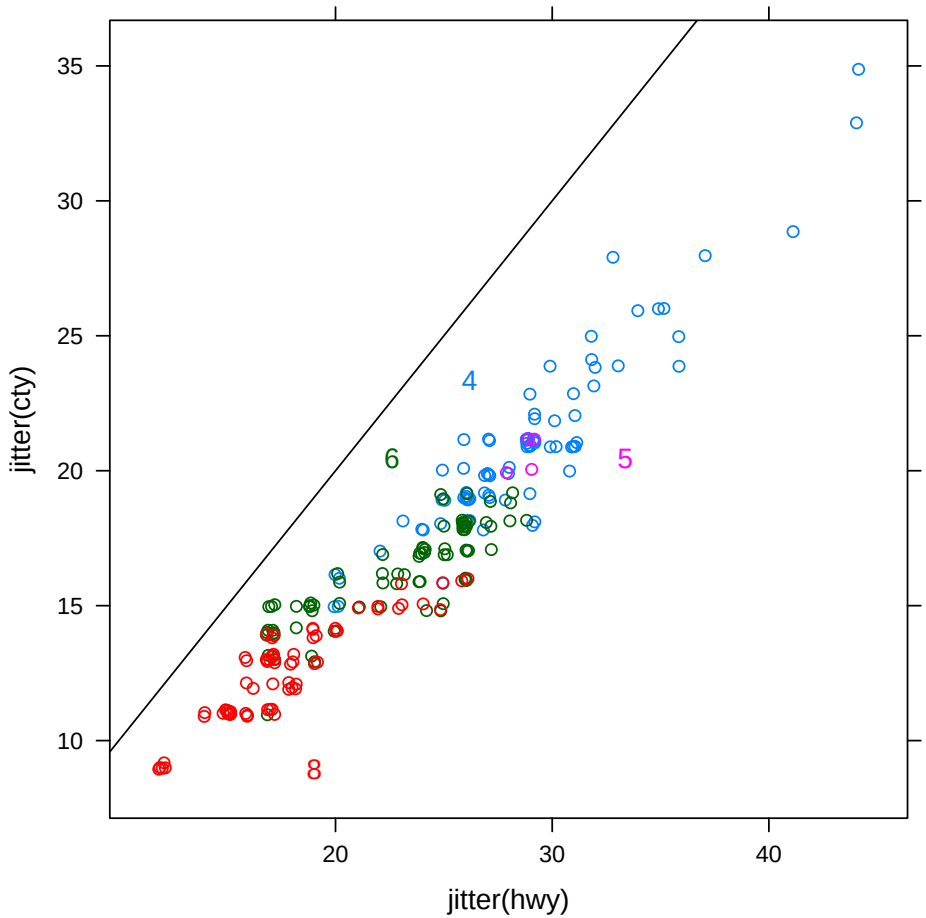
Jitter the data to see all the points

```
> xyplot(jitter(cty) ~ jitter(hwy), mpg,
+     aspect = 1, panel = panel.xyref)
```



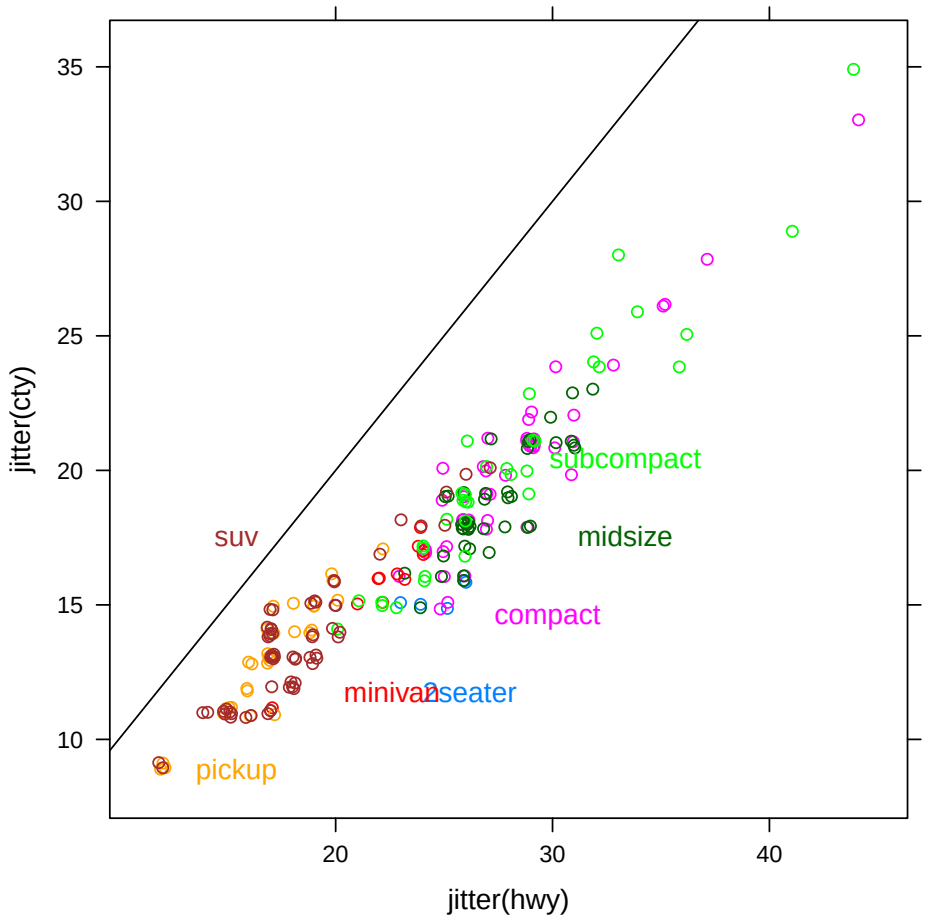
Group data by number of cylinders in the engine

```
> direct.label(xyplot(jitter(cty) ~ jitter(hwy),
+     mpg, aspect = 1, panel = panel.xyref,
+     groups = factor(cyl)))
```



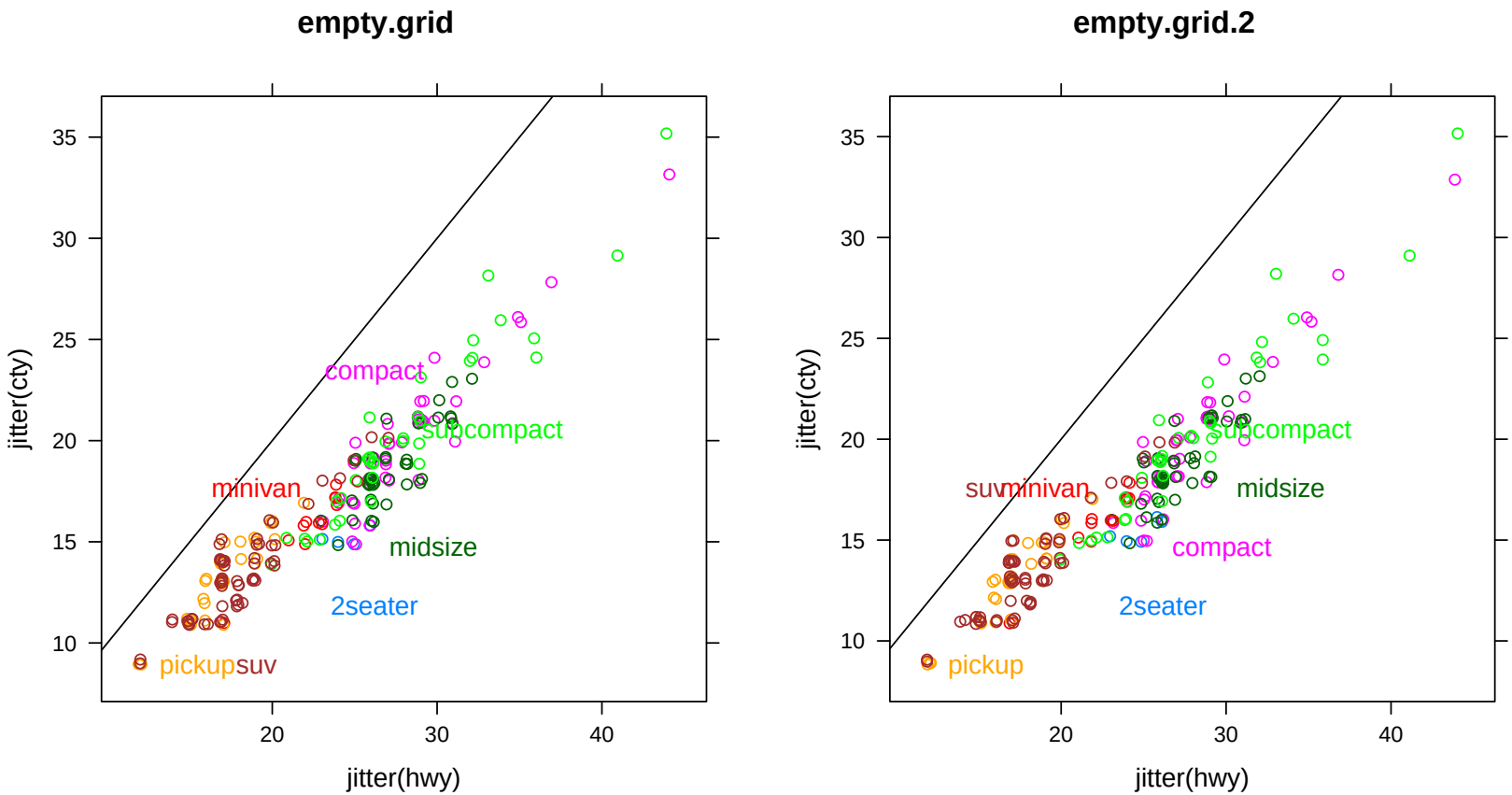
Group data by car class

```
> direct.label(xyplot(jitter(cty) ~ jitter(hwy),
+     mpg, aspect = 1, panel = panel.xyref,
+     groups = class))
```



Compare direct labeling methods

```
> compare.methods(c("empty.grid", "empty.grid.2"),
+     xyplot, mpg, jitter(cty) ~ jitter(hwy),
+     class, aspect = 1, panel = panel.xyref,
+     horiz = TRUE)
```



References for learning more about lattice and latticedl

- First load the libraries in R
  - library(lattice)
  - library(latticeExtra)
  - library(latticedl)
- Then you can look at the interactive help pages

Overview	?Lattice
Customizing plots	?xyplot
Included panel functions	?panel.functions, ?llines
Multiple plots per page	?plot.trellis, ?c.trellis
Direct labeling	?direct.label

- Deepayan Sarkar (2008) Lattice: Multivariate Data Visualization with R, Springer.
- R code from the slides available on the web: `http://directlabels.r-forge.r-project.org`
- Email me directly: toby.hocking AT inria.fr