THE DESIGN AND MIXED-MODEL ANALYSIS OF EXPERIMENTS

PRACTICAL XI
SOLUTIONS

XI.1 An experiment on celery is to be conducted to investigate the effect on the yield of three methods of seedling propagation, two levels of nutrient and four harvest dates. The six combinations of propagation methods and nutrients are to applied to main plots using a completely randomized design with three replicates of each treatment combination. The harvest dates are to be randomized to the four subplots within each main plot.

What are the components of the study?

1. Observational unit – a subplot
2. Response variable – Yield
3. Unrandomized factors – MainPlots, Subplots
4. Randomized factors – Propagation, Nutrient, Harvest
5. Type of study – Split-plot with main-plots in a CRD and subplots completely randomized

What is the experimental structure for this experiment?

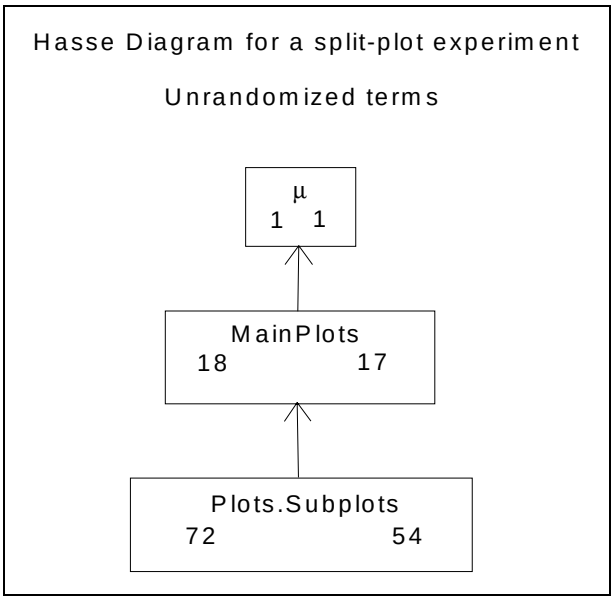
Structure	Formula
unrandomized	*18* MainPlots/*4* Subplots
randomized	*3* Propagation**2* Nutrient**4* Harvests

What are the terms derived from the experimental structure? Write out the Hasse diagram for each structure formula.

Plots/Subplots = MainPlots + MainPlots.Subplots

Propagation*Nutrient*Harvests
= (Propagation + Nutrient + Propagation.Nutrient) *Harvests
= Propagation + Nutrient + Propagation.Nutrient
+ Propagation.Harvests + Nutrient.Harvests
+ Propagation.Nutrient.Harvests

In this case we only do the Hasse diagram for the unrandomized factors because the degrees of freedom for the randomized factors can be obtained using the rule for completely crossed structures.



What are the expectation and variation models based on the same dichotomization of the factors into random/fixed factors as for unrandomized/randomized factors?

E[Y] = Propagation.Nutrient.Harvests and

Var[Y] = MainPlots + MainPlots.Subplots

Write down the analysis of variance table, including the expected mean squares for the lines in it.

Source	df	E[MSq]
MainPlots	17	
Propagation	2	$\sigma^2_{MS} + 4\sigma^2_M + f_P(\psi)$
Nutrient	1	$\sigma^2_{MS} + 4\sigma^2_M + f_N(\psi)$
Propagation.Nutrient	2	$\sigma^2_{MS} + 4\sigma^2_M + f_{PN}(\psi)$
Residual	12	$\sigma^2_{MS} + 4\sigma^2_M$
MainPlots.Subplots	54	
Harvests	3	$\sigma^2_{MS} + f_H(\psi)$
Propagation.Harvests	6	$\sigma^2_{MS} + f_{PH}(\psi)$
Nutrient.Harvests	3	$\sigma^2_{MS} + f_{NH}(\psi)$
Propagation.Nutrient.Harvests	6	$\sigma^2_{MS} + f_{PNH}(\psi)$
Residual	36	σ^2_{MS}
Total	71	

Obtain a randomized layout for the experiment in Genstat using the seed 445566. Do not ask for it to be printed when you generate the design or to have the analysis checked by ANOVA. If you do the Dummy factor will be included. Instead after you have generated the design, used PDESIGN and ANOVA commands that you write to obtain the design and to check the analysis that you derived above.

Use Genstat to generate an orthogonal, hierarchical design with 2 block factors, MainPlots and Subplots. Ask for the factors Propagation, Nutrient and Dummy with 3, 2 and 3 levels respectively too be randomized to the block factor MainPlots. Ask for the factor Harvests with 4 levels to be randomized to the Subplots factor.

The use the PDESIGN, BLOCK, TREAT and ANOVA commands as shown in the following output to print the layout and check the design.

```
Genstat 5  Release 4.1  (PC/Windows NT)              18 April 2000 16:59:51
Copyright 1998, Lawes Agricultural Trust (Rothamsted Experimental Station)

 ___________________________________________________

 Genstat 5 Fourth Edition - (for Windows)
 Genstat 5 Procedure Library Release PL11
 ___________________________________________________
```

```
  4  %WSPREAD MainPlot,Subplot,Propagat,Nutrient,Harvests
  5  PDESIGN [BLOCK=MainPlot/Subplot; TREAT=Propagat*Nutrient*Harvests]

*** Treatment combinations on each unit of the design ***


 Subplot   1       2       3       4
MainPlot
       1   3 2 4   3 2 1   3 2 2   3 2 3
       2   1 1 1   1 1 4   1 1 2   1 1 3
       3   2 2 4   2 2 2   2 2 1   2 2 3
       4   2 1 1   2 1 3   2 1 2   2 1 4
       5   1 2 1   1 2 2   1 2 3   1 2 4
       6   1 2 2   1 2 4   1 2 3   1 2 1
       7   3 2 1   3 2 3   3 2 4   3 2 2
       8   1 1 3   1 1 1   1 1 2   1 1 4
       9   1 1 1   1 1 3   1 1 4   1 1 2
      10   2 2 4   2 2 3   2 2 1   2 2 2
      11   3 1 2   3 1 3   3 1 4   3 1 1
      12   2 2 4   2 2 2   2 2 3   2 2 1
      13   3 1 4   3 1 2   3 1 1   3 1 3
      14   2 1 2   2 1 1   2 1 4   2 1 3
      15   2 1 1   2 1 3   2 1 4   2 1 2
      16   3 1 2   3 1 3   3 1 1   3 1 4
      17   1 2 1   1 2 4   1 2 3   1 2 2
      18   3 2 1   3 2 4   3 2 3   3 2 2

 Treatment factors are listed in the order: Propagat Nutrient Harvests

  6  BLOCK MainPlot/Subplot
  7  TREAT Propagat*Nutrient*Harvests
  8  ANOVA


8.....................................................................

***** Analysis of variance *****
Source of variation     d.f.

MainPlot stratum
Propagat                   2
Nutrient                   1
Propagat.Nutrient          2
Residual                  12

MainPlot.Subplot stratum
Harvests                   3
Propagat.Harvests          6
Nutrient.Harvests          3
Propagat.Nutrient.Harvests
                           6
Residual                  36

Total                     71
```

XI.2 An animal scientist conducts an experiment using five donkeys to investigate the motility of semen samples collected from them. The first ejaculation from each donkey was divided into three aliquots. Each aliquot was diluted with one of three diluents, the particular diluent used with an aliquot being chosen at random. The resulting solution was again divided into three producing three subaliquots for each diluent from each donkey. Three times of preservation of the subaliquots (8, 24 and 36 hours) were randomized to each set of three subaliquots. The data from the experiment are given in the following table.

Donkey	Aliquot	SubAliquot	Diluent	Time of Preservation	Motility
1	1	1	1	8	75
		2	1	24	73
		3	1	36	66
	2	1	2	8	81
		2	2	24	75
		3	2	36	62
	3	1	3	8	68
		2	3	24	61
		3	3	36	50
2	1	1	1	8	65
		2	1	24	60
		3	1	36	61
	2	1	2	8	69
		2	2	24	62
		3	2	36	51
	3	1	3	8	60
		2	3	24	55
		3	3	36	50
3	1	1	1	8	78
		2	1	24	83
		3	1	36	70
	2	1	2	8	79
		2	2	24	76
		3	2	36	60
	3	1	3	8	72
		2	3	24	68
		3	3	36	61
4	1	1	1	8	68
		2	1	24	61
		3	1	36	51
	2	1	2	8	76
		2	2	24	66
		3	2	36	51
	3	1	3	8	61
		2	3	24	57
		3	3	36	53
5	1	1	1	8	44
		2	1	24	43
		3	1	36	37
	2	1	2	8	55
		2	2	24	51
		3	2	36	41
	3	1	3	8	34
		2	3	24	24
		3	3	36	21

What are the components of the study?

1. Observational unit – a subaliquot
2. Response variable – Motility
3. Unrandomized factors – Donkeys, Aliquots, Subaliquots
4. Randomized factors – Diluent, Preservation Time
5. Type of study – Split-plot with main-plots in a RCBD and subplots completely randomized

What is the experimental structure for this experiment?

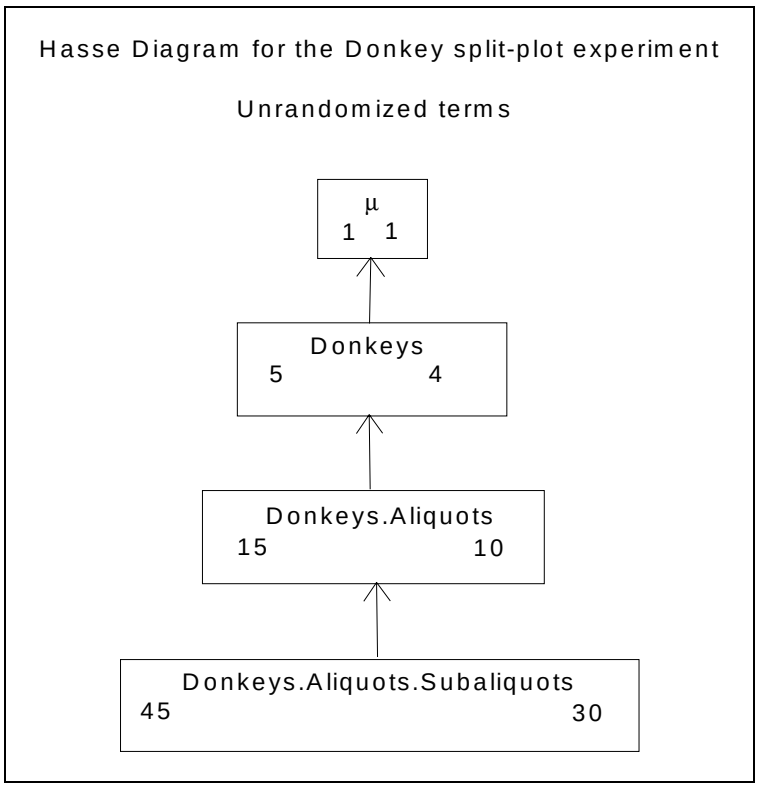
Structure	Formula
unrandomized	*5* Donkeys/*3* Aliquots/*3* Subaliquots
randomized	*3* Diluent**3* Times

What are the terms derived from the experimental structure? Write out the Hasse diagram for each structure formula.

Donkeys/Aliquots/Subaliquots
= Donkeys + Donkeys.Aliquots + Donkeys.Aliquots.Subaliquots

Diluent*Times = Diluent + Times + Diluent.Times

In this case we only do the Hasse diagram for the unrandomized factors because the degrees of freedom for the randomized factors can be obtained using the rule for completely crossed structures.



What are the expectation and variation models based on the same dichotomization of the factors into random/fixed factors as for unrandomized/randomized factors?

E[Y] = Diluent.Times and

Var[Y] = Donkeys + Donkeys.Aliquots + Donkeys.Aliquots.Subaliquots

Write down the analysis of variance table, including the expected mean squares for the lines in it.

Source	df	E[MSq]
Donkeys	4	$\sigma^2_{dAS} + 3\sigma^2_{dA} + 9\sigma^2_{d}$
Donkeys.Aliquots	10	
Diluent	2	$\sigma^2_{dAS} + 3\sigma^2_{dA} + f_D(\psi)$
Residual	8	$\sigma^2_{dAS} + 3\sigma^2_{dA}$
Donkeys.Aliquots.Subaliquots	30	
Times	2	$\sigma^2_{dAS} + f_T(\psi)$
Diluent.Times	4	$\sigma^2_{dAS} + f_{DT}(\psi)$
Residual	24	σ^2_{dAS}
Total	44	

The motility values have been saved in *SplDonky.gsh* in the directory *G:\Disciplina\Genstat*. Add the necessary factors to this spreadsheet and then use Genstat to analyse the data, including diagnostic checking and to obtain a description of how the factors Diluent and Time of Preservation affect the motility of donkey semen.

The following Genstat output contains an analysis of the donkey data. It includes fitting polynomials of order 2 to the Times means.

```
Genstat 5  Release 4.1  (PC/Windows NT)              19 April 2000 11:59:51
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                ____________________________________________________

                Genstat 5 Fourth Edition - (for Windows)
                Genstat 5 Procedure Library Release PL11
                ____________________________________________________

   3  "Data taken from File: D:/ANALYSES/LM/MULTIFAC/SPLDONKYALL.GSH"
   4  DELETE [redefine=yes] Donkey,Aliquot,SubAliq,Diluent,TimePres,Motility
   5  FACTOR [modify=yes;nvalues=45;levels=5] Donkey
   6  READ Donkey; frepresentation=ordinal
```
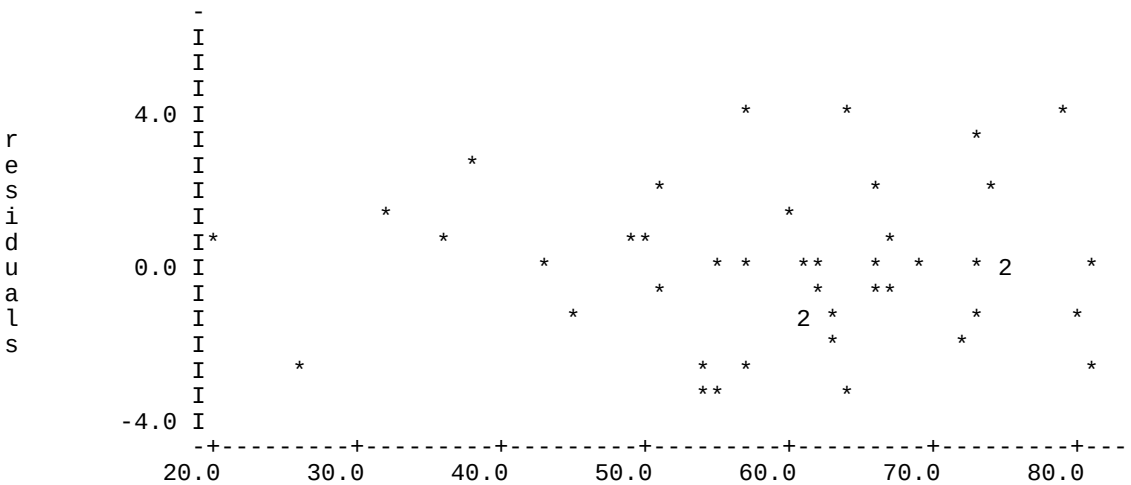
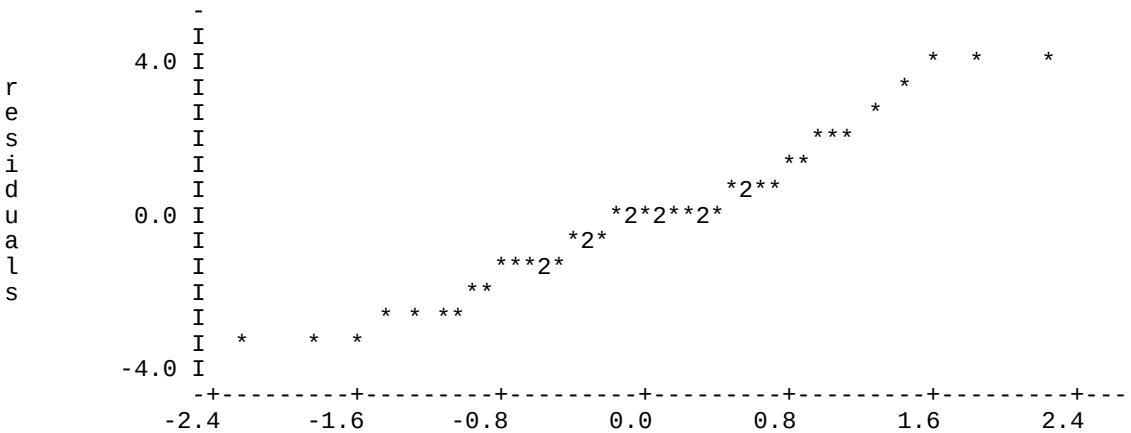

```
  Identifier    Values   Missing    Levels
      Donkey        45         0         5

 9  FACTOR [modify=yes;nvalues=45;levels=3] Aliquot
10  READ Aliquot; frepresentation=ordinal

  Identifier    Values   Missing    Levels
     Aliquot        45         0         3

13  FACTOR [modify=yes;nvalues=45;levels=3] SubAliq
14  READ SubAliq; frepresentation=ordinal

  Identifier    Values   Missing    Levels
     SubAliq        45         0         3

17  FACTOR [modify=yes;nvalues=45;levels=3] Diluent
18  READ Diluent; frepresentation=ordinal

  Identifier    Values   Missing    Levels
     Diluent        45         0         3

21  FACTOR [modify=yes;nvalues=45;levels=!(8,24,36)] TimePres
22  READ TimePres; frepresentation=ordinal

  Identifier    Values   Missing    Levels
    TimePres        45         0         3

25  VARIATE [nvalues=45] Motility
26  READ Motility

  Identifier   Minimum      Mean   Maximum    Values   Missing
    Motility     21.00     59.67     83.00        45         0

29
30  PRINT Donkey,Aliquot,SubAliq,Diluent,TimePres,Motility

    Donkey     Aliquot     SubAliq     Diluent    TimePres    Motility
         1           1           1           1        8.00       75.00
         1           1           2           1       24.00       73.00
         1           1           3           1       36.00       66.00
         1           2           1           2        8.00       81.00
         1           2           2           2       24.00       75.00
         1           2           3           2       36.00       62.00
         1           3           1           3        8.00       68.00
         1           3           2           3       24.00       61.00
         1           3           3           3       36.00       50.00
         2           1           1           1        8.00       65.00
         2           1           2           1       24.00       60.00
         2           1           3           1       36.00       61.00
         2           2           1           2        8.00       69.00
         2           2           2           2       24.00       62.00
         2           2           3           2       36.00       51.00
         2           3           1           3        8.00       60.00
         2           3           2           3       24.00       55.00
         2           3           3           3       36.00       50.00
         3           1           1           1        8.00       78.00
         3           1           2           1       24.00       83.00
         3           1           3           1       36.00       70.00
         3           2           1           2        8.00       79.00
         3           2           2           2       24.00       76.00
         3           2           3           2       36.00       60.00
         3           3           1           3        8.00       72.00
         3           3           2           3       24.00       68.00
         3           3           3           3       36.00       61.00
         4           1           1           1        8.00       68.00
         4           1           2           1       24.00       61.00
         4           1           3           1       36.00       51.00
         4           2           1           2        8.00       76.00
         4           2           2           2       24.00       66.00
         4           2           3           2       36.00       51.00
         4           3           1           3        8.00       61.00
         4           3           2           3       24.00       57.00
```

```
          4           3           3           3       36.00       53.00
          5           1           1           1        8.00       44.00
          5           1           2           1       24.00       43.00
          5           1           3           1       36.00       37.00
          5           2           1           2        8.00       55.00
          5           2           2           2       24.00       51.00
          5           2           3           2       36.00       41.00
          5           3           1           3        8.00       34.00
          5           3           2           3       24.00       24.00
          5           3           3           3       36.00       21.00

  31  BLOCK Donkey/Aliquot/SubAliq
  32  TREAT Diluent*POL(TimePres; 2)
  33  ANOVA [FPROB=Y; PSE=LSD] Motility


33.....................................................................

***** Analysis of variance *****

Variate: Motility

Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.

Donkey stratum             4   5845.556   1461.389   28.81

Donkey.Aliquot stratum
Diluent                    2   1013.333    506.667    9.99  0.007
Residual                   8    405.778     50.722    6.89

Donkey.Aliquot.SubAliq stratum
TimePres                   2   1373.333    686.667   93.28  <.001
  Lin                      1   1286.757   1286.757  174.80  <.001
  Quad                     1     86.577     86.577   11.76  0.002
Diluent.TimePres           4    153.333     38.333    5.21  0.004
  Diluent.Lin              2    126.667     63.333    8.60  0.002
  Diluent.Quad             2     26.667     13.333    1.81  0.185
Residual                  24    176.667      7.361

Total                     44   8968.000


* MESSAGE: the following units have large residuals.

Donkey 5    Aliquot 2            6.11   s.e. 3.00

Donkey 2    Aliquot 1    SubAliq 3           4.33   s.e. 1.98
Donkey 3    Aliquot 1    SubAliq 2           4.33   s.e. 1.98
Donkey 4    Aliquot 1    SubAliq 1           4.33   s.e. 1.98


***** Tables of means *****

Variate: Motility

Grand mean  59.67

  Diluent        1        2        3
             62.33    63.67    53.00

 TimePres     8.00    24.00    36.00
             65.67    61.00    52.33

  Diluent TimePres     8.00    24.00    36.00
        1             66.00    64.00    57.00
        2             72.00    66.00    53.00
        3             59.00    53.00    47.00
```

```
*** Least significant differences of means (5% level) ***

Table              Diluent    TimePres     Diluent
                                          TimePres
rep.                    15          15           5
l.s.d.               5.997       2.045       6.384
d.f.                     8          24       12.95
Except when comparing means with the same level(s) of
 Diluent                                     3.542
 d.f.                                           24


  34  CALC pA=1-FPROB(1461.389 / 50.722; 4; 8)
  35  &    pSA=1-FPROB(50.722 / 7.361; 8; 24)
  36  PRINT pA,pSA

          pA         pSA
  0.00008415   0.0001033

  37  APLOT METHOD=fit,normal
```



Normal plot



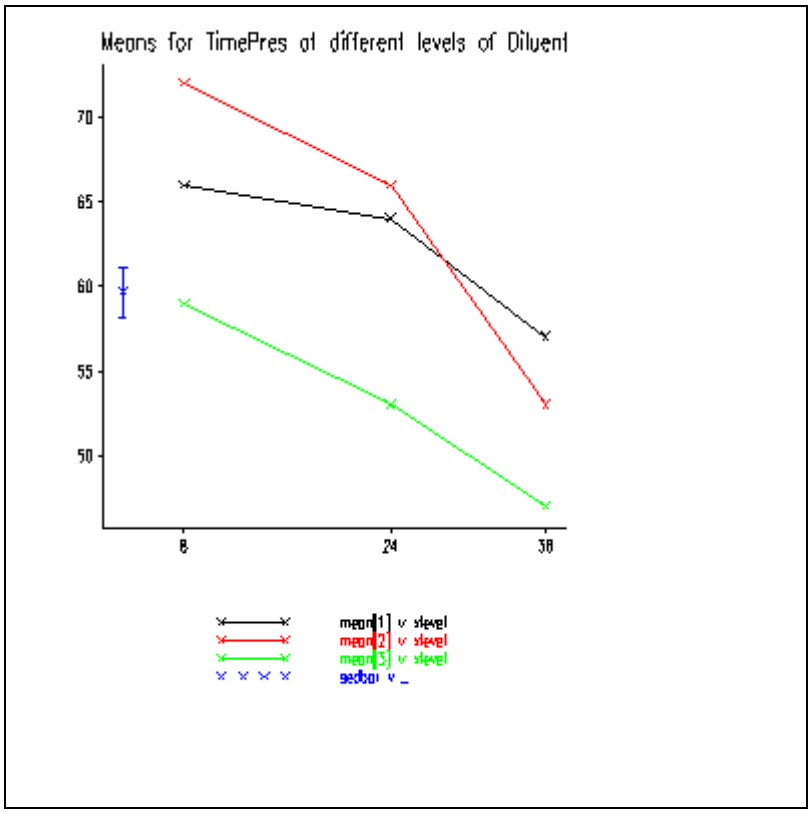
```
 38  "
-39  **** Tukey''s one-degree-of-freedom-for-non-additivity.
-40  **** It is the term designated covariate in the following analysis
-41  "
 42  AKEEP [FIT=Fit]
 43  CALC ResSq=Fit*Fit
 44  ANOVA [PRINT=*]  ResSq; RES=ResSq
 45  COVAR ResSq                          "A computational trick"
 46  ANOVA [PRINT=A; FPROB=Y] Motility


46.....................................................................

***** Analysis of variance (adjusted for covariate) *****

Variate: Motility
Covariate: ResSq

Source of variation     d.f.       s.s.       m.s.    v.r. cov.ef.  F pr.

Donkey stratum             4   5845.556   1461.389   28.81

Donkey.Aliquot stratum
Diluent                    2   1013.333    506.667    9.99    1.00  0.007
Residual                   8    405.778     50.722    6.80    1.00

Donkey.Aliquot.SubAliq stratum
TimePres                   2   1373.333    686.667   92.02    1.00  <.001
  Lin                      1   1286.757   1286.757  172.44    1.00  <.001
  Quad                     1     86.577     86.577   11.60    1.00  0.002
Diluent.TimePres           4    153.333     38.333    5.14    1.00  0.004
  Diluent.Lin              2    126.667     63.333    8.49    1.00  0.002
  Diluent.Quad             2     26.667     13.333    1.79    1.00  0.190
Covariate                  1      5.042      5.042    0.68          0.420
Residual                  23    171.624      7.462            0.99

Total                     44   8968.000
```

Source	df	MSq	E[MSq]	F	Prob
Donkeys	4	1461.39	$\sigma^2_{dAS} + 3\sigma^2_{dA} + 9\sigma^2_{d}$	28.81	<.001
Donkeys.Aliquots	10				
Diluent	2	506.67	$\sigma^2_{dAS} + 3\sigma^2_{dA} + f_D(\psi)$	9.99	0.007
Residual	8	50.72	$\sigma^2_{dAS} + 3\sigma^2_{dA}$	6.89	<.001
Donkeys.Aliquots.SubAliquots	30				
Times	2	686.67	$\sigma^2_{dAS} + f_T(\psi)$	93.28	<.001
Lin	1	1286.76		174.80	<.001
Quad	1	86.58		11.76	0.002
Diluent.Times	4	38.33	$\sigma^2_{dAS} + f_{DT}(\psi)$	5.21	0.004
Diluent.Lin	2	63.33		8.60	0.002
Diluent.Quad	2	13.33		1.81	0.185
Residual	24	7.36	σ^2_{dAS}		
Nonadditivity	1	5.04		0.68	0.420
Deviations	23	7.46			

As for the assumptions, the residual-versus-fitted-values plot look fine and Tukey's test for nonadditivity is not significant so that there is no evidence of nonadditivity. However, the normal probability plot is displaying curvature indicating that the data is not normal. Because the other assumptions are met and this assumption is not crucial, we will not take any action to change this.

The Diluent.Quad term is not significant indicating that any curvature in the trend for Times of Preservation does not differ between the diluents. However, the Diluent.Lin line is significant so that there are significant differences between the diluents in the slope over times of preservation. The Quad line is also significant indicating that there is curvature in the trend but that this curvature is the same for all diluents.

So for each diluent a quadratic equation is required to describe the trend. However, while the slope differs between the diluents the quadratic coefficient does not. The following plot of the Times means for each diluent, obtained using A2GRAPH, shows the trend.




```
47  AGRAPH [METHOD=lines] XFACTOR=TimePres; GROUP=Diluent
```

Unfortunately, APOLYNOMIAL will not provide the fitted equation when more than one factor is involved. However, it can be obtained using regression. It is not expected that you know how to do this, but out of interest the commands and output from them are as follows:

```
  48  "
 -49  **** Use regression to obtain the fitted equation
 -50  "
  51  VARI [45] Times
  52  CALC Times=TimePres & TimesSq=Times*Times
  53  MODEL Motility
  54  TERMS Diluent/Times+TimesSq
  55  FIT Diluent/Times+TimesSq


55.............................................................


***** Regression Analysis *****

 Response variate: Motility
     Fitted terms: Constant + Diluent + Times.Diluent + TimesSq


*** Summary of analysis ***

              d.f.         s.s.         m.s.      v.r.
Regression       6        2513.        418.9      2.47
Residual        38        6455.        169.9
Total           44        8968.        203.8

Percentage variance accounted for 16.7
Standard error of observations is estimated to be 13.0
* MESSAGE: The following units have large standardized residuals:
         Unit     Response    Residual
           44         24.0       -2.47


*** Estimates of parameters ***

                              estimate         s.e.     t(38)
Constant                          64.2         10.4      6.17
Diluent 2                          9.3         10.5      0.88
Diluent 3                         -6.7         10.5     -0.64
Times.Diluent 1                  0.356        0.979      0.36
Times.Diluent 2                  0.004        0.979      0.00
Times.Diluent 3                  0.241        0.979      0.25
TimesSq                        -0.0154       0.0215     -0.71
```

The fitted equations are:

For diluent 1, $Motility = 64.2 + 0.356\,Time - 0.0154\,Time^2$

For diluent 2, $Motility = 73.5 + 0.004\,Time - 0.0154\,Time^2$

For diluent 3, $Motility = 57.5 + 0.241\,Time - 0.0154\,Time^2$

XI.3 An experiment was conducted to look at the effect of irrigation and canopy type on the number of shoot per node of grape vines. The area consisted of 3 rows each containing 56 vines. Each row formed a rep and was divided into 2 halves which are called Columns. Each column was divided into 2 plots to which the irrigation treatments (no irrigation, irrigation) were randomized. Each plot was subdivided into 2 subplots to which 2 canopy treatments were randomized. Each subplot consisted of 7 vines. The layout for the experiment is given in the table below.

Layout for a vineyard experiment

Reps		Columns 1				Columns 2			
		Plots 1		Plots 2		Plots 1		Plots 2	
		Subplots 1	2	1	2	1	2	1	2
1	Irrigation	Yes		No		No		Yes	
	Canopy	L	S	S	L	S	L	L	S
2	Irrigation	No		Yes		Yes		No	
	Canopy	L	S	L	S	S	L	S	L
3	Irrigation	No		Yes		No		Yes	
	Canopy	L	S	L	S	L	S	S	L

S = Severe Pruning, Low Trellis
L = Light Pruning, High Trellis

The number of shoots and the number of nodes was measured on each vine and the resulting data, in randomized order, are given in the table below.

Results for a vineyard experiment

				Vine 1		2		3		4		5		6		7	
Reps	Cols	Plot	SubP	Sh	N	Sh	N	Sh	N	Sh	N	Sh	N	Sh	N	Sh	N
1	1	1	1	46	36	42	36	40	36	46	36	37	36	39	36	39	36
			2	55	52	64	72	69	72	60	72	71	72	60	72	67	72
		2	1	41	36	47	36	48	36	45	36	40	36	41	36	48	36
			2	66	72	71	72	50	72	56	72	52	72	56	62	65	62
	2	1	1	51	36	37	36	33	36	39	36	28	26	39	36	38	36
			2	60	72	43	52	56	72	62	72	55	62	50	50	53	52
		2	1	50	36	39	36	47	36	39	36	47	36	32	36	34	36
			2	55	72	50	72	66	72	59	62	59	72	56	62	57	72
2	1	1	1	53	36	40	36	50	36	36	36	38	36	49	36	40	36
			2	68	62	54	62	57	72	68	72	67	72	65	72	62	72
		2	1	50	36	41	36	47	36	58	36	51	36	56	36	47	36
			2	55	72	50	72	66	72	71	72	54	62	55	72	45	62
	2	1	1	45	36	45	36	52	36	52	36	52	36	44	36	47	36
			2	67	62	52	62	66	72	57	62	59	62	48	62	49	62
		2	1	59	72	71	67	53	62	68	62	49	52	58	62	59	62
			2	48	36	37	36	38	26	48	36	33	36	43	36	40	36
3	1	1	1	40	36	46	36	42	36	47	36	50	36	49	36	49	36
			2	82	72	57	72	68	72	68	72	76	60	60	36	73	68
		2	1	36	38	50	36	45	36	44	36	35	36	61	36	51	36
			2	63	72	76	59	62	63	90	74	65	72	52	45	78	72
	2	1	1	40	36	49	36	48	36	53	36	49	36	32	36	36	28
			2	63	69	61	52	52	61	65	72	80	62	70	65	67	69
		2	1	47	36	53	36	54	36	47	36	41	36	53	36	48	36
			2	64	72	70	82	73	72	64	72	72	72	75	72	76	72

What are the components of the study?

1. Observational unit – a vine
2. Response variable – Number of shoots and number of nodes
3. Unrandomized factors – Reps, Columns, Plots, Subplots, Vines
4. Randomized factors – Irrigation, Canopy
5. Type of study – Split-plot with main-plots in a generalized RCBD and subplots completely randomized

What is the experimental structure for this experiment?

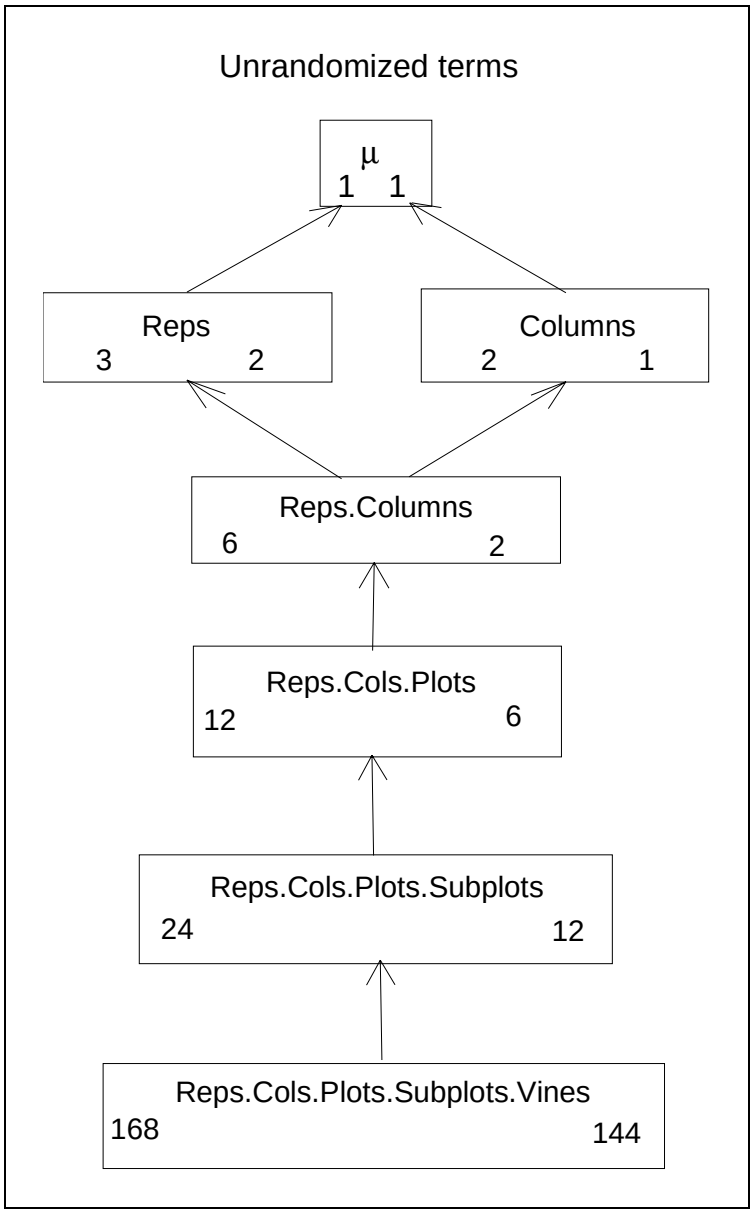
Structure	Formula
unrandomized	(*3* Reps**2* Columns)/*2* Plots/*2* Subplots/*7* Vines
randomized	*2* Irrig**2* Canopy

What are the terms derived from the experimental structure? Write out the Hasse diagram for each structure formula.

(Reps*Columns)/Plots/Subplots/Vines
= (Reps + Columns + Reps.Columns)/Plots/Subplots/Vines
= Reps + Columns + Reps.Columns
+ Reps.Columns.Plots/Subplots/Vines
= Reps + Columns + Reps.Columns
+ Reps.Columns.Plots
+ Reps.Columns.Plots.Subplots/Vines
= Reps + Columns + Reps.Columns
+ Reps.Columns.Plots
+ Reps.Columns.Plots.Subplots
+ Reps.Columns.Plots.Subplots.Vines

Irrig*Canopy = Irrig + Canopy + Irrig.Canopy

In this case we only do the Hasse diagram for the unrandomized factors because the degrees of freedom for the randomized factors can be obtained using the rule for completely crossed structures.



What are the expectation and variation models based on the same dichotomization of the factors into random/fixed factors as for unrandomized/randomized factors?

E[Y] = Irrig.Canopy and

Var[Y] = Reps + Columns + Reps.Columns
+ Reps.Columns.Plots + Reps.Columns.Plots.Subplots
+ Reps.Columns.Plots.Subplots.Vines

Write down the analysis of variance table, including the expected mean squares for the lines in it.

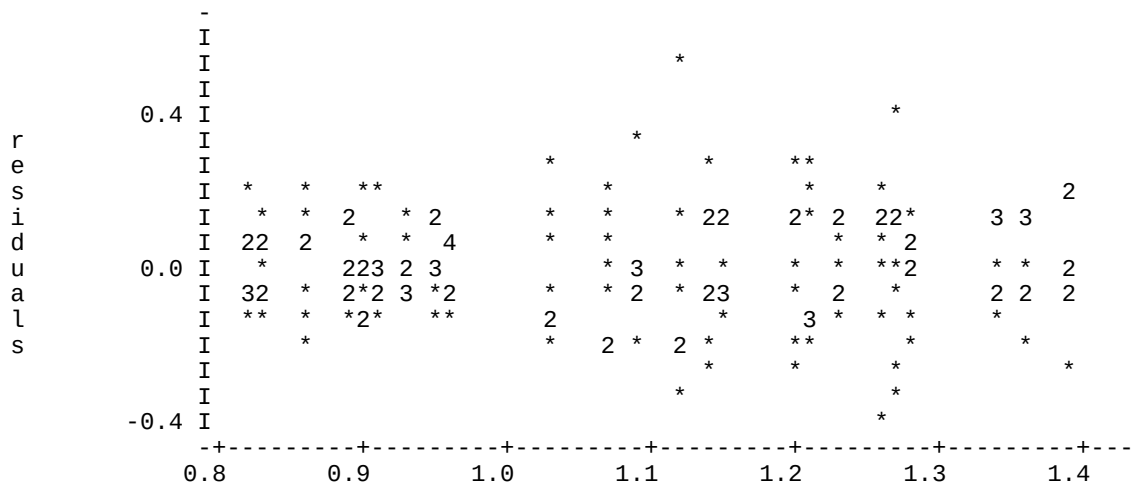
Source	df	E[MSq]
Reps	2	$\sigma^2_{RCPSV}+7\sigma^2_{RCPS}+14\sigma^2_{RCP}+28\sigma^2_{RC}+56\sigma^2_{R}$
Cols	2	$\sigma^2_{RCPSV}+7\sigma^2_{RCPS}+14\sigma^2_{RCP}+28\sigma^2_{RC}+84\sigma^2_{C}$
Reps.Cols	2	$\sigma^2_{RCPSV}+7\sigma^2_{RCPS}+14\sigma^2_{RCP}+28\sigma^2_{RC}$
Reps.Cols.Plots	6	
Irrig	1	$\sigma^2_{RCPSV}+7\sigma^2_{RCPS}+14\sigma^2_{RCP}+f_{I}(\psi)$
Residual	5	$\sigma^2_{RCPSV}+7\sigma^2_{RCPS}+14\sigma^2_{RCP}$
Reps.Cols.Plots.Subplots	12	
Canopy	1	$\sigma^2_{RCPSV}+7\sigma^2_{RCPS}+f_{C}(\psi)$
Irrig.Canopy	1	$\sigma^2_{RCPSV}+7\sigma^2_{RCPS}+f_{CI}(\psi)$
Residual	10	$\sigma^2_{RCPSV}+7\sigma^2_{RCPS}$
Reps.Cols.Plots.Subplots.Vine	144	σ^2_{RCPSV}
Total	168	

The data and factors have been saved in *SplRejuv.gsh* in the directory *G:\Disciplina\Genstat*. Use Genstat to analyse the shoots per node (ShotPNod) data, including diagnostic checking. What are the fitted models?

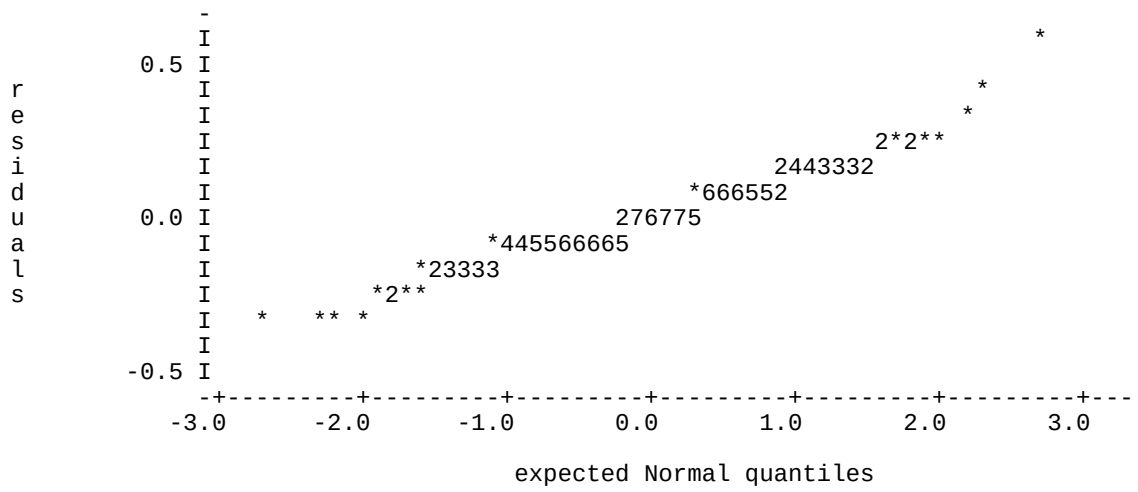
```
Genstat 5  Release 4.1  (PC/Windows NT)              23 April 2000 21:15:42
Copyright 1998, Lawes Agricultural Trust (Rothamsted Experimental Station)

                ________________________________________________

                Genstat 5 Fourth Edition - (for Windows)
                Genstat 5 Procedure Library Release PL11
                ________________________________________________

  3  "Data taken from File: D:/ANALYSES/LM/MULTIFAC/SPLREJUV.GSH"
  4  DELETE [redefine=yes] Reps,Rows,Columns,Plots,SubPlots,Vines,Irrig,Canopy\
  5  ,Shoots,Nodes,ShotPNod
  6  FACTOR [modify=yes;nvalues=168;levels=3] Reps
  7  READ Reps; frepresentation=ordinal

   Identifier    Values   Missing    Levels
         Reps       168         0         3

 13  FACTOR [modify=yes;nvalues=168;levels=2] Rows
 14  READ Rows; frepresentation=ordinal

   Identifier    Values   Missing    Levels
         Rows       168         0         2

 20  FACTOR [modify=yes;nvalues=168;levels=2] Columns
 21  READ Columns; frepresentation=ordinal
```

```
  Identifier    Values   Missing    Levels
     Columns       168         0         2

 27  FACTOR [modify=yes;nvalues=168;levels=2] Plots
 28  READ Plots; frepresentation=ordinal

  Identifier    Values   Missing    Levels
       Plots       168         0         2

 34  FACTOR [modify=yes;nvalues=168;levels=2] SubPlots
 35  READ SubPlots; frepresentation=ordinal

  Identifier    Values   Missing    Levels
    SubPlots       168         0         2

 41  FACTOR [modify=yes;nvalues=168;levels=7] Vines
 42  READ Vines; frepresentation=ordinal

  Identifier    Values   Missing    Levels
       Vines       168         0         7

 48  FACTOR [modify=yes;nvalues=168;levels=2;labels=!t('NonIrrig','Irrigated')\
 49  ] Irrig
 50  READ Irrig; frepresentation=ordinal

  Identifier    Values   Missing    Levels
       Irrig       168         0         2

 56  FACTOR [modify=yes;nvalues=168;levels=2;labels=!t('Sev_Low','Lt_High')\
 57  ] Canopy
 58  READ Canopy; frepresentation=ordinal

  Identifier    Values   Missing    Levels
      Canopy       168         0         2

 64  VARIATE [nvalues=168] Shoots
 65  READ Shoots

  Identifier   Minimum      Mean   Maximum    Values   Missing
      Shoots     28.00     53.24     90.00       168         0

 73  VARIATE [nvalues=168] Nodes
 74  READ Nodes

  Identifier   Minimum      Mean   Maximum    Values   Missing
       Nodes     26.00     51.23     82.00       168         0

 82  VARIATE [nvalues=168] ShotPNod
 83  READ ShotPNod

  Identifier   Minimum      Mean   Maximum    Values   Missing
    ShotPNod     0.694     1.091     1.694       168         0

117
118  BLOCK (Reps*Columns)/Plots/SubPlots/Vines
119  TREAT Irrig*Canopy
120  ANOVA [FPROB=Y;  PSE=LSD] ShotPNod
```

```
120.....................................................................

***** Analysis of variance *****

Variate: ShotPNod

Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.

Reps stratum               2    0.65701    0.32851   21.60

Columns stratum            1    0.02557    0.02557    1.68

Reps.Columns stratum       2    0.03042    0.01521    2.34

Reps.Columns.Plots stratum
Irrig                      1    0.00002    0.00002    0.00  0.961
Residual                   5    0.03250    0.00650    0.04

Reps.Columns.Plots.SubPlots stratum
Canopy                     1    2.91801    2.91801   19.06  0.001
Irrig.Canopy               1    0.00026    0.00026    0.00  0.968
Residual                  10    1.53133    0.15313    6.71

Reps.Columns.Plots.SubPlots.Vines stratum
                         144    3.28607    0.02282

Total                    167    8.48119


* MESSAGE: the following units have large residuals.

Reps 2    Columns 2    Plots 2    SubPlots 1          -0.256   s.e. 0.095
Reps 2    Columns 2    Plots 2    SubPlots 2           0.256   s.e. 0.095

Reps 3    Columns 1    Plots 1    SubPlots 2    Vines 6
                                                     0.549   s.e. 0.140
Reps 3    Columns 1    Plots 2    SubPlots 1    Vines 6
                                                     0.424   s.e. 0.140


***** Tables of means *****

Variate: ShotPNod

Grand mean  1.091

    Irrig  NonIrrig Irrigated
              1.092     1.091

   Canopy  Sev_Low  Lt_High
             1.223    0.960

     Irrig   Canopy  Sev_Low  Lt_High
  NonIrrig             1.222    0.961
 Irrigated             1.224    0.958


*** Least significant differences of means (5% level) ***

Table                Irrig      Canopy       Irrig
                                             Canopy
rep.                    84          84          42
l.s.d.              0.0320      0.1345      0.1360
d.f.                     5          10       10.83
Except when comparing means with the same level(s) of
 Irrig                                      0.1903
 d.f.                                           10


 121  APLOT METHOD=fit,normal
```


residuals
0.4
0.0
-0.4
0.8
0.9
1.0
1.1
1.2
1.3
1.4
fitted values

Normal plot


residuals
0.5
0.0
-0.5
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
expected Normal quantiles

```
 122  "
-123  **** Tukey''s one-degree-of-freedom-for-non-additivity.
-124  **** It is the term designated covariate in the following analysis
-125  "
 126  AKEEP [FIT=Fit]
 127  CALC ResSq=Fit*Fit
 128  ANOVA [PRINT=*]  ResSq; RES=ResSq
 129  COVAR ResSq                          "A computational trick"
 130  ANOVA [PRINT=A; FPROB=Y] ShotPNod


130.....................................................................

***** Analysis of variance (adjusted for covariate) *****

Variate: ShotPNod
Covariate: ResSq

Source of variation     d.f.       s.s.       m.s.    v.r. cov.ef.  F pr.

Reps stratum               2    0.65701    0.32851   21.60

Columns stratum            1    0.02557    0.02557    1.68

Reps.Columns stratum       2    0.03042    0.01521    2.34

Reps.Columns.Plots stratum
Irrig                      1    0.00002    0.00002    0.00    1.00  0.961
Residual                   5    0.03250    0.00650    0.04    1.00

Reps.Columns.Plots.SubPlots stratum
Canopy                     1    2.91801    2.91801   19.06    1.00  0.001
Irrig.Canopy               1    0.00026    0.00026    0.00    1.00  0.968
Residual                  10    1.53133    0.15313    6.71    1.00

Reps.Columns.Plots.SubPlots.Vines stratum
                         144    3.28607    0.02282

Total                    167    8.48119

 131  COVAR
```

Generally the assumptions appear to be met. Except for two outliers the residual-versus-fitted-values and normal probability plots are satisfactory. Also, Tukey's test for nonadditivity is not significant indicating that there is no evidence of nonadditivity.

The analysis of variance itself indicates that there is no Irrigation.Canopy interaction but that there are overall canopy differences. The table of Canopy means is

```
   Canopy  Sev_Low  Lt_High
             1.223    0.960
```

Clearly, the severe pruning with low trellis produces more shoots per node than the other canopy.