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## 7.7. Parametric two-way ANOVA with equal numbers of replicates

**EXAMPLE 7.5.** The weaning of *Cosmos atrosaguineus* var. 'Pip' and var. 'Christopher' onto one of four composts following propagation by tissue culture

**BOX 7.8.** How to carry out a two-way parametric ANOVA with equal replicates

**Step 1.** Starting with a new spreadsheet, the data can be entered in a two-way table with the columns representing the composts and the rows representing the final heights. Data labels must be entered for both rows and columns. Failure to do this will result in the first datum of each row and column being used as the label and not as part of the data. Data for 'Pip' are entered first with one datum per row and the data for 'Christopher' follow without leaving a gap between the two sets.

The screenshot shows a Microsoft Excel spreadsheet with a two-way ANOVA data table. The data is organized as follows:

	A	B	C	D	E
1		Weaning compost			
2		A	B	C	D
3	Final	20.4	19.4	18.7	20.1
4	height	20.4	22.9	18.7	20.1
5	(cm) of	24.9	28.7	18.5	25.9
6	Cosmos	19.6	25.2	22.2	18.1
7	patrosagu	19.2	21.1	23.2	17.1
8	ineus	22	27.7	22.9	24.1
9	var 'Pip'	21.6	24.5	20.6	22.7
10		22.7	26.3	22.3	17.5
11		23.5	22.8	24.1	25.2
12		25.4	18	22.7	25.2
13	Final	19.5	8.9	22.9	21.6
14	height	21.9	18.1	10.8	17.8
15	(cm) of	21.9	8.4	6.4	15.2
16	Cosmos	21.9	15.8	17	15.1
17	patrosagu	19.9	15.3	14.1	11
18	ineus	7.9	16.2	21.4	14.1
19		20.7	13.1	18	22.9
20		25.5	14.8	15.6	7
21		22.6	13.8	19.3	21
22		15.7	22.6	17.6	12.2

The 'Anova: Two-Factor With Replication' dialog box is open, showing the following settings:

- Input Range: \$A\$2:\$E\$22
- Rows per sample: 10
- Alpha: 0.05
- Output options:
  - Output Range: \$A\$27:\$H\$32
  - New Worksheet Ply:
  - New Workbook:

**Step 2.** After entering the data, click on 'Tools', then 'Data Analysis' and select 'Anova: Two-Factor With Replication' from the menu. A dialogue box will open. It is essential to enter all cells including the column and row labels as one block into the input range. The number of rows per sample (i.e. the number of replicates per sample) is entered into the next box. Alpha ( $p$ ) defaults to 0.05, but can be changed if desired.

**Step 3.** Next, select the output options. To return the output data below the input data, select 'Output Range:' and then click in the box (the cursor will now flash in the box). Drag over an area where you want the results to be displayed. Note that you could just select a couple of cells—Excel will determine the actual size that it requires for the results table. Note too, that it is essential to click in the box as well as selecting the 'Output Range' button. If this is not done the location is entered into the 'Input Range' box and the analysis cannot be completed.

You can choose to have the results entered on to a 'New Worksheet Ply', in which case the results will be given on a fresh sheet, accessed by the tabs at the bottom of the current sheet. Alternatively a 'New Workbook' can be selected. Click 'OK' to obtain the output data.

	A	B	C	D	Total		
27	Anova: Two-Factor With Replication						
28							
29	SUMMARY	A	B	C	D	Total	
30	<i>Final height (cm) of Cosmos atrosaguineus var 'Pip'</i>						
31	Count	10	10	10	10	40	
32	Sum	219.7	236.6	213.9	215.8	886	
33	Average	21.97	23.66	21.39	21.58	22.15	
34	Variance	4.620111	12.20267	4.394333	11.87733	8.461538	
35							
36	<i>Final height (cm) of Cosmos atrosaguineus var 'Christopher'</i>						
37	Count	10	10	10	10	40	
38	Sum	197.5	147	163.1	157.9	665.5	
39	Average	19.75	14.7	16.31	15.79	16.6375	
40	Variance	23.65167	17.16667	24.13656	25.80767	24.60343	
41							
42	<i>Total</i>						
43	Count	20	20	20	20		
44	Sum	417.2	383.6	377	373.7		
45	Average	20.86	19.18	18.85	18.685		
46	Variance	14.68884	35.03853	20.30579	26.67292		
47							
48							
49	ANOVA						
50	<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
51	Sample	607.7531	1	607.7531	39.25515	2.42E-08	3.973895
52	Columns	59.87137	3	19.95712	1.289043	0.284731	2.731809
53	Interaction	114.9494	3	38.31646	2.474884	0.068332	2.731809
54	Within	1114.713	72	15.48213			
55							
56	Total	1897.287	79				

**Step 4.** Summary data are given first for both varieties and all four composts independently and then for the totals across varieties and across all composts. The ANOVA table is then given below. Note that three  $F$  values are given for the different sources of variation: one for varieties (sample), one for composts (columns), and the last for interaction between the two factors (interaction).

For each source of variation, compare the  $F$  (calculated) value with that of  $F_{\text{critical}}$ . Where  $F$  (calculated) is greater than the critical value the null hypothesis can be rejected. On inspecting the data, it can be noted that this

only occurs for 'sample', so there is a difference between varieties. The  $p$  value quoted for this is 2.42E-08 or  $2.42 \times 10^{-8}$ . The value is therefore highly statistically significant. The other two results are not significant, i.e. there is no difference in mean heights due to the type of compost and there is no interaction between the two factors.