3.5: SAS Output for ANOVA

The first output of the ANOVA procedure as shown below, gives useful details about the model.

ANOVA of Greenhouse Data: The Mixed Procedure

Model Information	
Data Set	WORK.GREENHOUSE
Dependent Variable	Height
Covariance Structure	Diagonal
Estimation Method	Type 3
Residual Variance Method	Factor
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Residual

Class Level Information		
Class	Levels	Values
fert	4	Control F1 F2 F3

Dimensions	
Covariance Parameters	1
Columns in X	5
Columns in Z	0
Subjects	0
Max Obs Per Subject	24

The output below titled '**Type 3 Analysis of Variance**' is similar to the ANOVA table we are already familiar with. Note that it does not include the Total SS, however it can be computed as the sum of all SS values in the table.

Type 3 Analysis of Variance

Sources	DF	Sum of Squares	Mean Square	Expected Mean Square	Error Term	Error DF	F Value	Pr > F
fert	3	251.440000	83.813333	Var(Residual)+Q(fert)	MS(Residual)	20	27.46	<.0001
Residual	20	61.033333	3.051667	Var(Residual)				

Covariance Parameter Estimates	
Cov Parm	Estimate
Residual	3.0517

Fit Statistics	
-2 Res Log Likelihood	86.2
AIC (smaller is better)	88.2
AICC (smaller is better)	88.5
BIC (smaller is better)	89.2

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
fert	3	20	27.46	<.0001

The output above titled "**Type 3 Tests of Fixed Effects**" will display the $F_{calculated}$ and p-value for the test of any variables that are specified in the model statement. Additional information can also be requested. For example, the `method = type 3` option will include the Expected Mean Squares for each source, which will prove to be useful and will be seen in Chapter 6.

The Mixed Procedure also produces the following diagnostic plots:

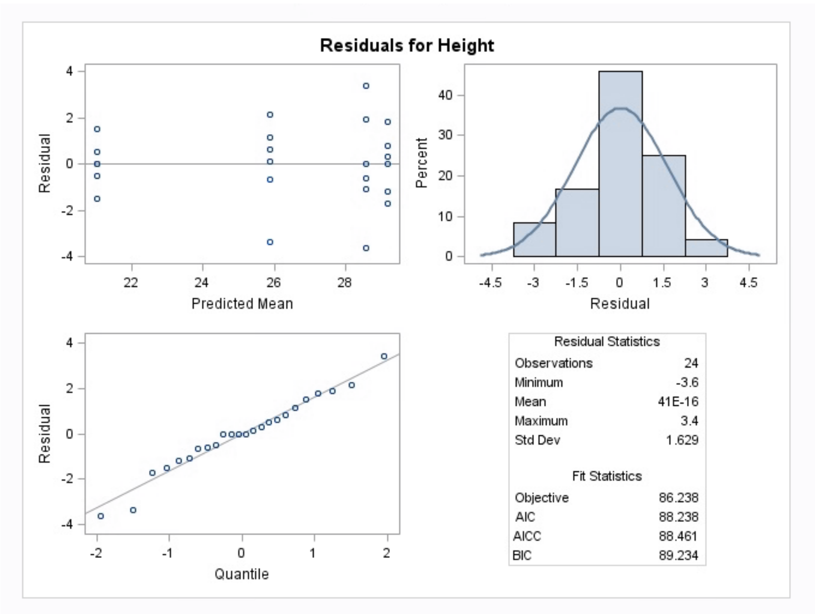

Figure 3.5.1: Diagnostic plots for residuals for height.

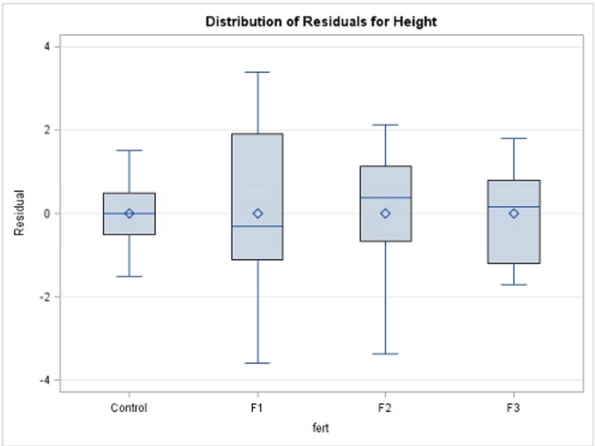

Figure 3.5.2: Box plots for distribution of residuals for height.

The following display is a result of the LSmeans statement in the PLM procedure which was included in the programming code.

Differences of fert Least Squares Means								
fert	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
Control	21.0000	0.7132	20	29.45	<.0001	0.05	19.5124	22.4876
F1	28.6000	0.7132	20	40.10	<.0001	0.05	27.1124	30.0876
F2	25.8667	0.7132	20	36.27	<.0001	0.05	24.3790	27.3543
F3	29.2000	0.7132	20	40.94	<.001	0.05	27.7124	30.6876

In the "Least Squares Means" table above, note that the t-value and $Pr > |t|$ are testing null hypotheses that each group mean= 0. (These tests usually do not provide any useful information). The Lower and Upper values are the 95% confidence limits for the group means. Note also that the least square means are the same as the original arithmetic means that were generated in the Summary procedure in Section 3.3 because all 4 groups have the same sample sizes. With unequal sample sizes or if there is a covariate present, the least square means can differ from the original sample means.

Next, the Plot= mean plot option in the LSmeans statement yields a mean plot and also a diffogram, shown below. The confidence intervals in the mean plot are commonly used to identify the significantly different treatment levels or groups. If two confidence intervals do not overlap, then the difference between the two associated means is statistically significant, which is a valid conclusion. However, if they overlap, it may be the case that the difference might still be significant. Consequently, conclusions made based on the visual inspection of the mean plot may not match with those arrived at using the table of "Difference of Least Square Means", another output of the Tukey procedure, and is displayed below.

Notice that this is different from the previous table because it displays the results of each pairwise comparison. For example, the first row shows the comparison between the control and F1. The interpretation of these results is similar to any other confidence interval for the difference in two means—if the confidence interval does not contain zero, then the difference between the two associated means is statistically significant.

Differences of fert Least Squares Means Adjustment for Multiple Comparisons: Tukey												
fert	_fert	Estimate	Standard Error	DF	t Value	Pr > |t|	Adj P	Alpha	Lower	Upper	Adj Lower	Adj Upper
Control	F1	-7.6000	1.0086	20	-7.54	<.0001	<.0001	0.05	-9.7038	-5.4962	-10.4229	-4.7771
Control	F2	-4.8667	1.0086	20	-4.83	0.0001	0.0006	0.05	-6.9705	-2.7628	-7.6896	-2.0438
Control	F3	-8.2000	1.0086	20	-8.13	<.0001	<.0001	0.05	-10.3038	-6.0962	-11.0229	-5.3771
F1	F2	2.7333	1.0086	20	2.71	0.0135	0.0599	0.05	0.6295	4.8372	-0.08957	5.5562
F1	F3	-0.6000	1.0086	20	-0.59	0.5586	0.9324	0.05	-2.7038	1.5038	-3.4229	2.2229
F2	F3	-3.3333	1.0086	20	-3.30	0.0035	.0171	0.05	-5.4372	-1.2295	-6.1562	-0.5104

This discrepancy between the mean plot and the "Difference of Least Square Means" results occurs because the testing is done in terms of the difference of two means, using the standard error of the difference of the two-sample means, but the confidence intervals of the mean plot are computed for the individual means which are in terms of the standard error of individual sample means. Consistent results can be achieved by using the diffogram as discussed below or the confidence intervals displayed in the "difference in mean plot" available in SAS 14, but not included here.

The diffogram has two useful features. It allows one to identify the significant mean pairs and also gives estimates of the individual means. The diagonal line shown in the diffogram is used as a reference line. Each group (or factor level) is marked on the horizontal and vertical axes and has vertical and horizontal reference lines with their intersection point falling on the diagonal reference line. The x or the y coordinates of this intersection point which are equal is the sample mean of that group. For example, the sample mean for the Control group is about 21, which matches with the estimate provided in the "Least Squares Means" table displayed above. Furthermore, each slanted line represents a mean pair. Start with any group label from the horizontal axis and run your cursor up, along the associated vertical line until it meets a slanted line, and then go across the intersecting horizontal line to identify the other group (or factor level). For example, the lowermost solid line (colored blue) represents the Control and F2. As stated at the bottom of the chart, the solid (or blue) lines indicate significant pairs, and the broken (or red) lines correspond to the non-significant pairs. Furthermore, a line corresponding to a nonsignificant pair will cross the diagonal reference line.

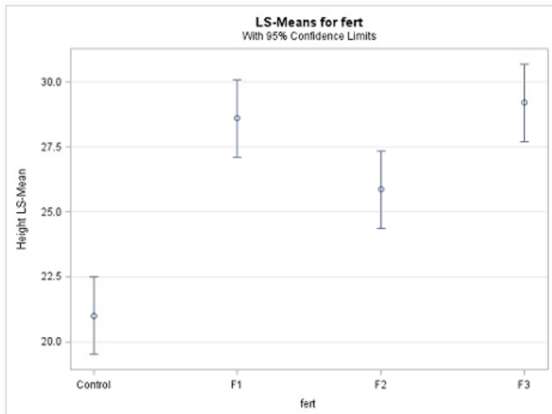

Figure 3.5.3: LS-Means plot.

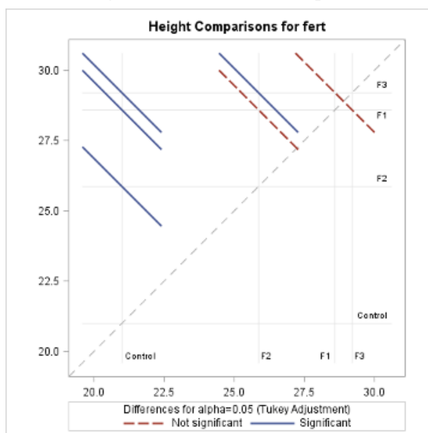

Figure 3.5.4: Diffogram.

The non-overlapping confidence intervals in the mean plot above indicate that the average plant height due to control is significantly different from those of the other 3 fertilizer levels and that the F2 fertilizer type yields a statistically different average plant height from F3. The diffogram also delivers the same conclusions and so, in this example, conclusions are not contradictory. In general, the diffogram always provides the same conclusions as derived from the confidence intervals of difference of least-square means shown in the "Difference of Least Square Means" table, but the conclusions based on the mean plot may differ.

There are two contrasts of interest: contrast to compare the control and F3 with F1 (i.e. $\mu_{control} - \mu_{F1} - \mu_{F2} + \mu_{F3}$) and the contrast to compare control and F2 with F1 (i.e., $\mu_{control} - 2\mu_{F1} + \mu_{F2}$). Since we are testing for two contrasts, we should adjust for multiple comparisons. We use Bonferroni adjustment. In SAS, we can use the `estimate` command under `proc plm` to make these computations.

In general, the `estimate` command estimates linear combinations of model parameters and performs t-tests on them. Contrasts are linear combinations that satisfy a special condition. We will discuss the model parameters in Chapter 4.

Estimates Adjustment for Multiplicity: Bonferroni						
Label	Estimate	Standard Error	DF	t Value	Pr > |t|	Adj P
Compare control + F3 with F1 and F2	-4.2667	1.4263	20	-2.99	0.0072	0.0144
Compare control + F2 with F1	-10.3333	1.7469	20	-5.92	<.0001	<.0001

SAS returns both unadjusted and adjusted p-values. Suppose we wanted to make the comparisons at 1% level. If we ignored the multiple comparisons (i.e. using unadjusted p-values), the both comparisons are statistically significant. However, if we consider the adjusted p-values, we will fail to reject the hypothesis corresponding to the first contrast at the 1% level.