Analysis of Covariance: Completely Randomized Design with One Covariate

Data: anocova_fertilizer.sav

Example: Study the three treatment levels: Type I fertilizing procedure and Type II fertilizing procedure and a control, on seed yield of plants, with the height of plant as the covariate for adjusting the preexisting difference. Ten replications of each treatment method were observed and the yields and heights are recorded in the following table.

Goal: To investigate the difference between release methods.

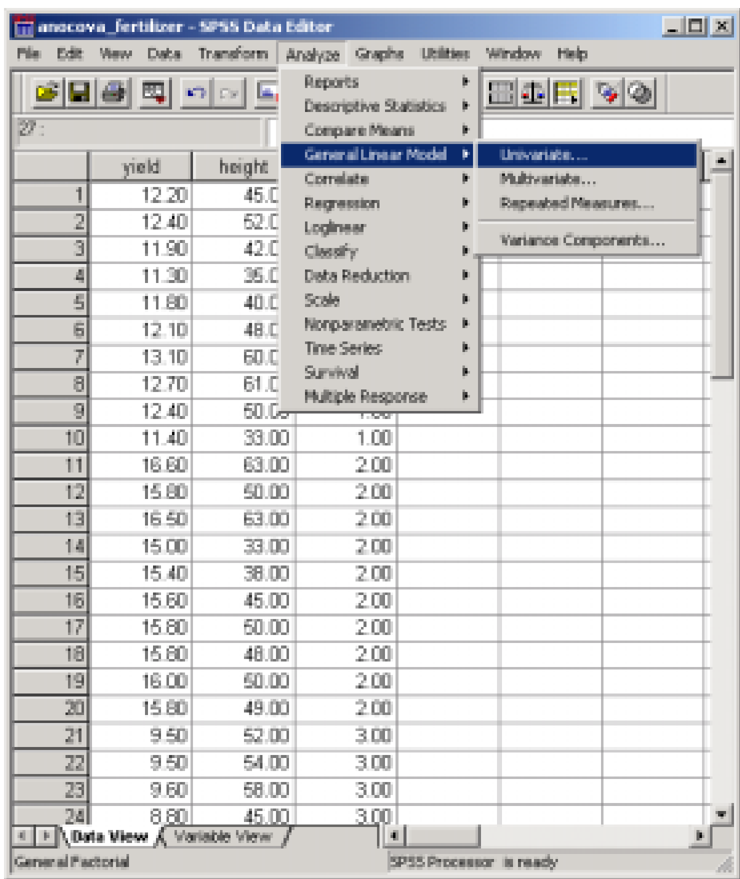
Control		Type I		Type II	
Yield	Height	Yield	Height	Yield	Height
12.20	45.00	16.60	63.00	9.50	52.00
12.40	52.00	15.80	50.00	9.50	54.00
11.90	42.00	16.50	63.00	9.60	58.00
11.30	35.00	15.00	33.00	8.80	45.00
11.80	40.00	15.40	38.00	9.50	57.00
12.10	48.00	15.60	45.00	9.80	62.00
13.10	60.00	15.80	50.00	9.10	52.00
12.70	61.00	15.80	48.00	10.30	67.00
12.40	50.00	16.00	50.00	9.50	55.00
11.40	33.00	15.80	49.00	8.50	40.00

Besides the normality, independent and homogeneity of errors, the additional conditions that need to be checked for using a parametric ANOCOVA test are:

1. The relation between the response and the covariate is linear.
2. The regression coefficient for the covariate is the same for all treatments.
3. The treatments do not affect the covariate. (The covariate is measured prior to the assignment of treatment.)

Data Entry

The data should be entered as in the Data Editor shown on the right with a categorical treatment variable (1=control, 2=Type I, 3=Type II). There are totally 30 cases.



Analysis

I. Click through the following menu selections:
Analyze/General Linear Model/Univariate…

II. Select the dependent variable, factor, and the covariate into the proper box as in the Univariate dialog box shown in figure 2 and click **Model…** to specify the model.

III. In the Model dialog box check **Custom** as in figure 3 and include the two variables as the Main effects terms, and click **Continue**.

IV. In the Model dialog box click **Options…**, one can select options to perform model assumption checking and interval estimates for adjusted treatment yields. (See figure 4) Click Continue to go back to the main Univariate dialog box.

V. Click **Save** button in the Univariate dialog box for saving residuals or other statistics for model diagnostics. Click Continue to go back to the main Univariate dialog box. (One can run a normality test of the residuals.)

VI. Click **OK**, if the desired options are all checked.

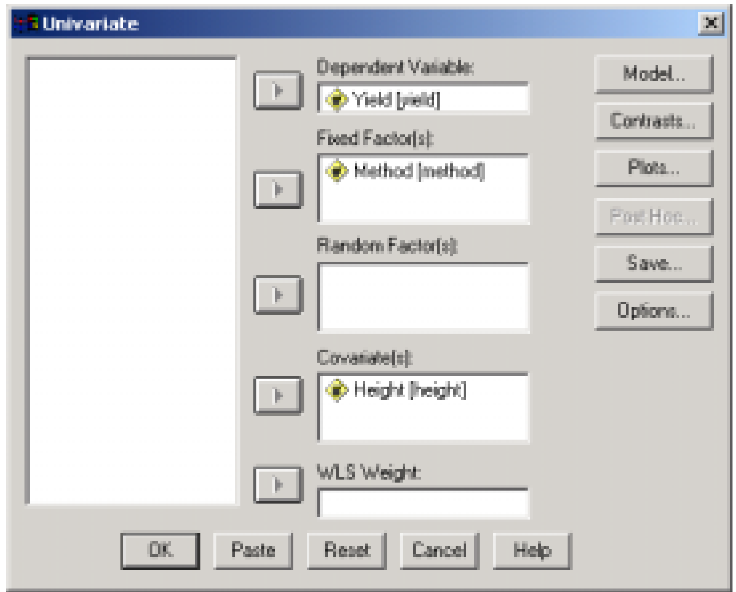


Figure 2. Univariate Dialog box

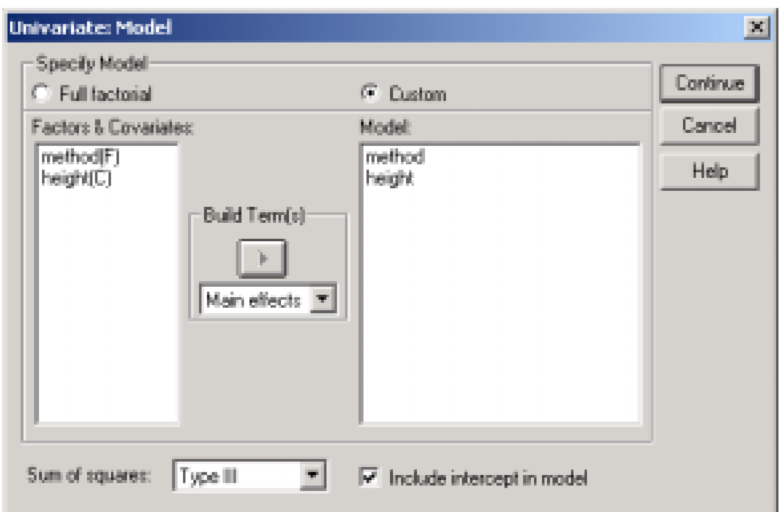


Figure 3. Model

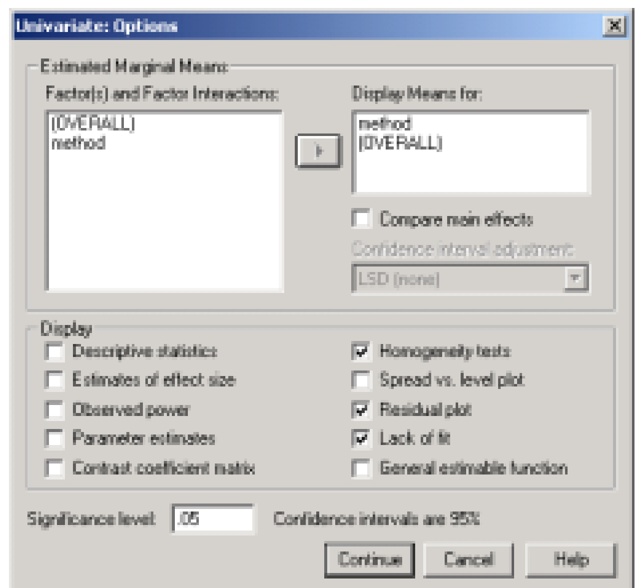


Figure 4. Options

SPSS Outputs:

Tests of Between-Subjects Effects

Dependent Variable: Yield

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	214.376[a]	3	71.459	4447.853	.000
Intercept	78.471	1	78.471	4884.317	.000
METHOD	213.904	2	106.952	6657.085	.000
HEIGHT	6.693	1	6.693	416.615	.000
Error	.418	26	1.607E-02		
Total	4869.850	30			
Corrected Total	214.794	29			

a. R Squared = .998 (Adjusted R Squared = .998)

The p-value for METHOD variable is .000. It implies that the differences between treatment methods are statistically significant if the model assumptions are all valid.

The confidence interval estimates for the average yields from the three treatment methods adjusted by covariate are shown in the table on the right.

2. Method

Dependent Variable: Yield

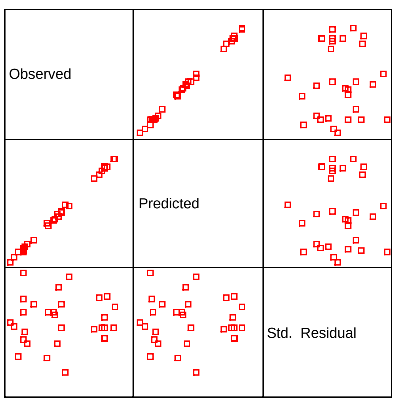
Method	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Fast Release	9.170[a]	.042	9.084	9.256
Slow Release	15.886[a]	.040	15.803	15.968
Control	12.314[a]	.041	12.230	12.399

a. Evaluated at covariates appeared in the model: Height = 49.9000.

Checking model conditions:(Normality, equal variance and lack of fit)

The Test of Equality of Variances has a p-value of .403. This implies that the difference in variances in statistically insignificant. The residual plot supports this conclusion.

Dependent Variable: Yield



Model: Intercept + METHOD + HEIGHT + HEIGHT

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Yield

F	df1	df2	Sig.
.939	2	27	.403

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept+METHOD+HEIGHT

The p-value from the Lack of Fit test is .871. It suggests a good fit.

Lack of Fit Tests

Dependent Variable: Yield

Source	Sum of Squares	df	Mean Square	F	Sig.
Lack of Fit	.306	22	1.391E-02	.498	.871
Pure Error	.112	4	2.792E-02		

The test of normality on residuals indicates that the distribution of residuals is not significantly difference from normal.

Tests of Normality

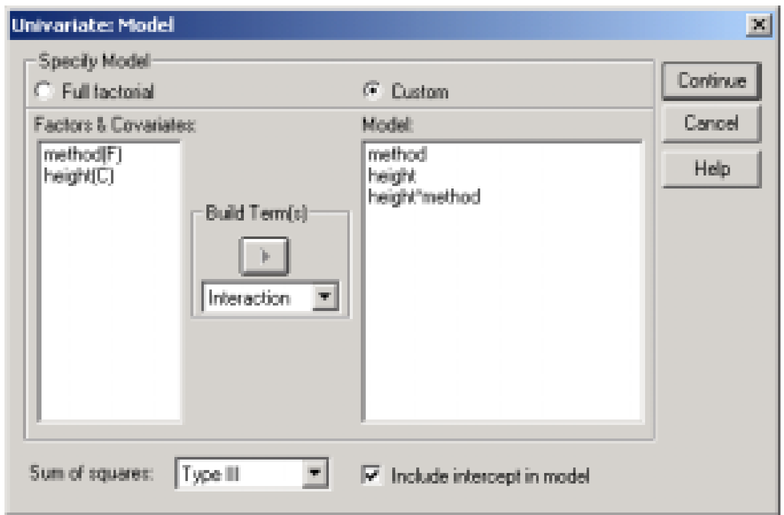
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Residual for YIELD	.077	30	.200*	.974	30	.672

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Checking equal slopes condition:

Equal slopes condition is the same as no interaction between Method and Height variables. To test for interaction between Method and Height variables, one can use the full factorial model as shown in the picture in the right. The p-value for the interaction term is .149. It means that the interaction between Method and Height variables is statistically insignificant. This is shown in the scatter plot on the right in which the slopes of the three sets of data are about the same.



Tests of Between-Subjects Effects

Dependent Variable: Yield

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	214.437[a]	5	42.887	2887.703	.000
Intercept	73.105	1	73.105	4922.286	.000
METHOD	6.696	2	3.348	225.439	.000
HEIGHT	6.653	1	6.653	447.975	.000
METHOD * HEIGHT	6.127E-02	2	3.064E-02	2.063	.149
Error	.356	24	1.485E-02		
Total	4869.850	30			
Corrected Total	214.794	29			

a. R Squared = .998 (Adjusted R Squared = .998)