MATH 204 - SOLUTIONS 4

For these questions we will use the method of ANOVA-F testing for nested models, and the test statistic

$$F = \frac{(\text{SSE}_R - \text{SSE}_C)/(k-g)}{\text{SSE}_C/(n-k-1)}$$

where SSE_R is the error sum of squares for the **Reduced Model**, specified using $g+1$ parameters including the intercept, and SSE_C is the error sum of squares for the **Complete Model**, specified using $k+1$ parameters including the intercept.

If the reduced model is an adequate simplification of the complete model, then

$$F \sim \text{Fisher-F}(k-g, n-k-1)$$

Note here that

$$k - g = (n - g - 1) - (n - k - 1) = \text{EDF}_R - \text{EDF}_C$$

so the $k-g$ quantities can be deduced directly from the EDFs.

1. For this problem, we use ANOVA and linear regression techniques, specifically multiple regression. Note that **Model** and **Vendor** are factor predictors, so we use the `General Linear Model` pulldown menu in SPSS.

   The SPSS output for a series of models is attached; we fit in turn each of the single predictor models, then the multiple regression model with all variables included, then different models with variables and interactions included. We use inspection of p-values in ANOVA tables and R^2 statistics to assess the most suitable model fit. For the analysis, price is in thousands of pounds.

   Note that this is only an informal model comparison procedure; we do not use the formal ANOVA-F test comparison models developed later.

   Our conclusions are summarized as follows:

   - In the main effects only models (Models 1 - 4), **Model**, **Age**, and **Mileage** are important predictors, as all have significant p-values in the one-way ANOVA. Of these variables, **Model** seems to be the most important predictor, with an R^2 value of 0.77. The variable **Vendor** is not significant at the $\alpha = 0.05$ significance level ($p = 0.089$).
   - In the multiple regression model with interaction between the two factor predictors (Model 5), **Age** and **Model** appear to be significant predictors (precise interpretation may be difficult in this unbalanced design). The R^2 value is now 0.947, indicating good explanatory power.
   - After checking a selection of models (Model 6 - 10) it seems that the best model in terms of simplicity and good explanatory power is the model

     Age + **Model**

     No other terms appear to be significant, and also $R^2 = 0.906$ with Adjusted $R^2 = 0.896$, so the explanatory power is good.
   - Inspection of the residuals indicates that overall the model assumptions are met, as we see no pattern in the residuals. There may be evidence of a single outlier (the car with the highest observed price)
   - Inspection of the parameter estimates indicates that price **decreases** with increasing **Age** (estimated coefficient is -1.079, standard error 0.138), and that the 500 series (**Model**=0) has the highest price, with coefficient 13.486+11.966 = 25.452.

	Model	k	EDF	SSE
M0	Null	0	19	358.670
M1	`trt`	4	15	160.263
M2	`initialwt`	1	18	16.312
M3	`trt` + `initialwt`	5	14	4.222
M4	`trt` + `initialwt` + `trt . initialwt`	9	10	2.834

2. **Oysters Data Set** Here we can fit the five models listed below. For these data $n = 20$.
Inspection of the ANOVA tables implies that, rather than go through forward or backward selection, we might start with the model M3, `trt` + `initialwt`, and try to include or omit terms.

   - M3 vs M4
   $$F = \frac{(4.222 - 2.834)/(9-5)}{2.834/10} = 1.224$$
   From tables Fisher-$F_{0.05}(4, 10) = 3.48 > 1.224$, so we **do not reject** M3 as an adequate simplification of M4.
   - M1 vs M3
   $$F = \frac{(160.263 - 4.222)/(5-4)}{4.222/14} = 517.462$$
   From tables Fisher-$F_{0.05}(1, 14) = 4.60 < 517.462$, so we **reject** M1 as an adequate simplification of M3.
   - M2 vs M3
   $$F = \frac{(16.312 - 4.222)/(5-1)}{4.222/14} = 10.022$$
   From tables Fisher-$F_{0.05}(4, 14) = 3.11 < 10.022$, so we **reject** M2 as an adequate simplification of M3.

   Hence the most suitable model is M3. The R^2 and Adjusted R^2 values are 0.988 and 0.984, indicating that the fit is very good.

3. **Oranges Data Set** Here we have two regression models for `Q1` and `Q2` in terms of the predictors. For these data $n = 36$.

   First for `Q1` ; note that we cannot fit the interaction `day . store` as we do not have sufficient data, as we only have one replicate per `day` $\times$ `store` combination.

   The models are listed in the order they are presented in the output:

	Model	k	EDF	SSE
M0	Null	0	35	1622.676
M1	`day` + `store` + `P1` + `day . P1` + `store . P1`	21	14	286.786
M2	`day` + `store` + `P1` + `day . P1`	16	19	368.863
M3	`day` + `store` + `P1`	11	24	447.850
M4	`day` + `P1`	6	29	686.545
M5	`day` + `P1` + `day . P1`	11	24	522.153
M6	`P1`	1	34	1117.084

   We proceed with the relevant comparisons:

   - M2 vs M1
   $$F = \frac{(368.863 - 286.786)/(21-16)}{286.786/14} = 0.801$$
   From tables Fisher-$F_{0.05}(5, 14) = 2.96 > 0.801$, so we **do not reject** M2 as an adequate simplification of M1.

- M3 vs M2
$$F = \frac{(447.850 - 368.863)/(16 - 11)}{368.863/19} = 0.814$$
From tables Fisher-$F_{0.05}(5, 19) = 2.740 > 0.814$, so we **do not reject** M3 as an adequate simplification of M2.

- M4 vs M3
$$F = \frac{(686.545 - 447.850)/(11 - 6)}{447.850/24} = 2.558$$
From tables Fisher-$F_{0.05}(5, 24) = 2.62 > 2.558$, so we **do not reject** M4 as an adequate simplification of M3, although the result is almost significant.
- M4 vs M5
$$F = \frac{(686.545 - 522.153)/(11 - 6)}{522.153/24} = 1.511$$
From tables Fisher-$F_{0.05}(5, 24) = 2.62 > 1.511$, so we **do not reject** M4 as an adequate simplification of M5.
- M6 vs M4
$$F = \frac{(1117.084 - 686.545)/(6 - 1)}{686.54/29} = 3.63$$
From tables Fisher-$F_{0.05}(5, 29) = 2.55 < 3.63$, so we **reject** M6 as an adequate simplification of M4.

Hence it seems that the model `day + P1` is the most appropriate model. For this model, the R^2 and Adjusted R^2 values are 0.580 and 0.493 respectively, so the explanatory power of the model is only moderate.

Secondly for `Q2` . The models are listed in the order they are presented in the output:

	Model	k	EDF	SSE
M0	Null	0	35	2750.208
M1	`day + store + P2 + day . P2 + store . P2`	21	14	275.701
M2	`day + store + P2 + day . P2`	16	19	464.396
M3	`day + store + P2`	11	24	790.864
M4	`day + P2`	6	29	1100.743
M5	`day + P2 + day . P2`	11	24	845.661
M6	`P2`	1	34	1864.648

We proceed with the relevant comparisons

- M2 vs M1
$$F = \frac{(464.396 - 275.701)/(21 - 16)}{275.701/14} = 1.916$$
From tables Fisher-$F_{0.05}(5, 14) = 2.96 > 1.916$, so we **do not reject** M2 as an adequate simplification of M1.

- M3 vs M2
$$F = \frac{(790.864 - 464.396)/(16 - 11)}{464.396/19} = 2.671$$
From tables Fisher-$F_{0.05}(5, 19) = 2.740 > 2.671$, so we **do not reject** M3 as an adequate simplification of M2, although the result is almost significant.

- M4 vs M3
$$F = \frac{(1100.743 - 790.864)/(11 - 6)}{790.864/24} = 1.881$$

From tables Fisher-$F_{0.05}(5, 24) = 2.62 > 1.881$, so we **do not reject** M4 as an adequate simplification of M3.

- M4 vs M5

$$F = \frac{(1100.743 - 845.661)/(11 - 6)}{845.661/24} = 1.448$$

From tables Fisher-$F_{0.05}(5, 24) = 2.62 > 1.448$, so we **do not reject** M4 as an adequate simplification of M5.

- M6 vs M4

$$F = \frac{(1864.648 - 1100.743)/(6 - 1)}{1100.743/29} = 4.025$$

From tables Fisher-$F_{0.05}(5, 29) = 2.55 < 4.025$, so we **reject** M6 as an adequate simplification of M4.

Hence it seems that the model `day` + `P2` is the most appropriate model. For this model, the R^2 and Adjusted R^2 values are 0.600 and 0.517 respectively, so the explanatory power of the model is only moderate.

Note that for the two models, the estimates of the random error variance σ^2 are given by the quantity SSE/EDF, so

$$\texttt{Q1} : \widehat{\sigma}^2 = \frac{686.545}{29} = 23.674 \qquad \texttt{Q2} : \widehat{\sigma}^2 = \frac{1100.743}{29} = 37.957$$

that is, the random error variances seem very different in the two data sets. Hence a combined analysis is **not carried out**, as this would require a common σ^2.

4. **Cotton Data Set** For these data $n = 49$. Inspection of the SPSS output suggests that we may simplify the full model

`variety` ⋆ `spacing` ⋆ `bollwt`

by dropping some of the higher order interactions. The models compared are listed below:

	Model	k	EDF	SSE
M0	Null	0	48	33.091
M1	`variety` ⋆ `spacing` ⋆ `bollwt`	7	41	1.730
M2	`variety` + `spacing` + `bollwt` + `variety . bollwt`	4	44	1.809
M3	`variety` + `spacing` + `bollwt`	3	45	2.291
M4	`variety` + `bollwt` + `variety . bollwt`	3	45	2.184

- M2 vs M1

$$F = \frac{(1.809 - 1.730)/(7 - 4)}{1.730/41} = 0.624$$

From tables Fisher-$F_{0.05}(3, 41) \doteq 2.84 > 0.624$, so we **do not reject** M2 as an adequate simplification of M1.

- M3 vs M2

$$F = \frac{(2.291 - 1.809)/(4 - 3)}{1.809/44} = 11.724$$

From tables Fisher-$F_{0.05}(1, 44) <$ Fisher-$F_{0.05}(1, 40) = 4.08 < 11.724$, so we **reject** M3 as an adequate simplification of M2.

- M4 vs M2

$$F = \frac{(2.184 - 1.809)/(4 - 2)}{1.809/44} = 4.561$$

From tables Fisher-$F_{0.05}(2, 44) <$ Fisher-$F_{0.05}(2, 40) = 3.23$, so we **reject** M4 as an adequate simplification of M2.

Hence the selected model is M2

$$\texttt{variety} + \texttt{spacing} + \texttt{bollwt} + \texttt{variety.bollwt}$$

Parameter estimates confirm that the response is an **increasing** function of `bollwt` (coefficient 0.240, standard error 0.025). The R^2 and adjusted R^2 of the model are large (0.945 and 0.940), so the predictive power is high. The residual plot indicates that the final model is adequate.

5. **Doses Data Set** For these data $n = 24$, and we have a balanced complete factorial design. We cannot fit a three-way interaction model as we do not have sufficient replicates (one observation in each combination of the $4 \times 2 \times 3 = 24$ factor levels). Inspection of the SPSS output suggests that we may simplify the most complex model

$$\texttt{bloc} + \texttt{type} + \texttt{dose} + \texttt{bloc.type} + \texttt{bloc.dose} + \texttt{type.dose}$$

by dropping some of the interaction terms. The models compared are listed below:

	Model	k	EDF	SSE
M0	Null	0	24	1068.958
M1	`bloc+ type+ dose+ bloc. type+ bloc. dose+ type. dose`	17	6	74.917
M2	`bloc+ type+ dose+ bloc. dose+ type. dose`	14	9	122.375
M3	`bloc+ type+ dose+ type. dose`	8	15	252.458
M4	`bloc+ type+ dose`	6	17	396.542

- M2 vs M1

$$F = \frac{(122.375 - 74.917)/(9-6)}{74.917/6} = 1.267$$

From tables Fisher-$F_{0.05}(3, 6) = 4.76 > 1.267$, so we **do not reject** M2 as an adequate simplification of M1.

- M3 vs M2

$$F = \frac{(252.458 - 122.375)/(15-9)}{122.375/9} = 1.594$$

From tables Fisher-$F_{0.05}(6, 9) = 3.37 > 1.594$, so we **do not reject** M3 as an adequate simplification of M2.

- M4 vs M3

$$F = \frac{(396.542 - 252.458)/(8-6)}{252.458/15} = 4.280$$

From tables Fisher-$F_{0.05}(2, 15) = 3.68 < 4.28$, so we **reject** M4 as an adequate simplification of M3.

No further terms can be dropped from the model, so we select M3

$$\texttt{bloc} + \texttt{type} + \texttt{dose} + \texttt{type.dose}$$

as the most suitable model. The R^2 and adjusted R^2 of the model are large (0.764 and 0.638), so the predictive power is good. The residual plot indicates that the final model is adequate.

SPSS Output for Exercises 4

Model 1: Mod

Dependent Variable: Price (1000 GBP)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1105.468(a)	4	276.367	45.279	.000
Intercept	11607.038	1	11607.038	1901.661	.000
Mod	1105.468	4	276.367	45.279	.000
Error	299.078	49	6.104		
Total	13658.417	54			
Corrected Total	1404.546	53			

a R Squared = .787 (Adjusted R Squared = .770)

Dependent Variable: Price (1000 GBP)

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	9.236	.618	14.953	.000	7.994	10.477
[Mod=0]	12.843	1.070	12.005	.000	10.693	14.993
[Mod=1]	5.610	1.266	4.432	.000	3.067	8.154
[Mod=2]	9.922	.996	9.963	.000	7.921	11.923
[Mod=3]	5.648	.888	6.361	.000	3.863	7.432
[Mod=4]	0(a)	.	.	.	.	.

a This parameter is set to zero because it is redundant.

Model 2: Age

Dependent Variable: Price (1000 GBP)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	258.133(a)	1	258.133	11.709	.001
Intercept	4109.494	1	4109.494	186.402	.000
Age	258.133	1	258.133	11.709	.001
Error	1146.413	52	22.046		
Total	13658.417	54			
Corrected Total	1404.546	53			

a R Squared = .184 (Adjusted R Squared = .168)

Dependent Variable: Price (1000 GBP)

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	19.409	1.422	13.653	.000	16.557	22.262
Age	-1.128	.330	-3.422	.001	-1.790	-.467

Model 3: Mile

Dependent Variable: Price (1000 GBP)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	326.165(a)	1	326.165	15.728	.000
Intercept	5063.081	1	5063.081	244.144	.000
Mile	326.165	1	326.165	15.728	.000
Error	1078.381	52	20.738		
Total	13658.417	54			
Corrected Total	1404.546	53			

a R Squared = .232 (Adjusted R Squared = .217)

Dependent Variable: Price (1000 GBP)

					95% Confidence Interval	
Parameter	B	Std. Error	t	Sig.	Lower Bound	Upper Bound
Intercept	19.302	1.235	15.625	.000	16.823	21.781
Mile	-.209	.053	-3.966	.000	-.315	-.103

Model 4: Vend

Dependent Variable: Price (1000 GBP)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	209.561(a)	4	52.390	2.148	.089
Intercept	12329.637	1	12329.637	505.573	.000
Vend	209.561	4	52.390	2.148	.089
Error	1194.985	49	24.387		
Total	13658.417	54			
Corrected Total	1404.546	53			

a R Squared = .149 (Adjusted R Squared = .080)

Dependent Variable: Price (1000 GBP)

					95% Confidence Interval	
Parameter	B	Std. Error	t	Sig.	Lower Bound	Upper Bound
Intercept	13.503	1.370	9.859	.000	10.751	16.256
[Vend=0]	3.015	2.023	1.490	.143	-1.050	7.081
[Vend=1]	5.054	2.219	2.278	.027	.595	9.514
[Vend=2]	1.925	2.141	.899	.373	-2.378	6.229
[Vend=3]	-.511	1.937	-.264	.793	-4.403	3.382
[Vend=4]	0(a)	.	.	.	.	.

a This parameter is set to zero because it is redundant.

Model 5: Age + Mile + Mod + Vend + Mod.Vend

Dependent Variable: Price (1000 GBP)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1329.511(a)	24	55.396	21.410	.000
Intercept	1907.237	1	1907.237	737.122	.000
Age	47.504	1	47.504	18.360	.000
Mile	1.769	1	1.769	.684	.415
Mod	604.015	4	151.004	58.361	.000
Vend	14.839	4	3.710	1.434	.248
Mod * Vend	36.082	14	2.577	.996	.482
Error	75.035	29	2.587		
Total	13658.417	54			
Corrected Total	1404.546	53			

a R Squared = .947 (Adjusted R Squared = .902)

Model 6: Age + Mile + Mod + Vend

Dependent Variable: Price (1000 GBP)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1293.428(a)	10	129.343	50.053	.000
Intercept	2413.866	1	2413.866	934.113	.000
Mod	888.417	4	222.104	85.949	.000
Vend	16.608	4	4.152	1.607	.190
Age	60.368	1	60.368	23.361	.000
Mile	2.461	1	2.461	.952	.335
Error	111.117	43	2.584		
Total	13658.417	54			
Corrected Total	1404.546	53			

a R Squared = .921 (Adjusted R Squared = .902)

Model 7: Age + Mod + Vend

Dependent Variable: Price (1000 GBP)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1290.967(a)	9	143.441	55.569	.000
Intercept	2474.277	1	2474.277	958.528	.000
Mod	927.675	4	231.919	89.845	.000
Vend	18.131	4	4.533	1.756	.155
Age	123.195	1	123.195	47.726	.000
Error	113.579	44	2.581		
Total	13658.417	54			
Corrected Total	1404.546	53			

a R Squared = .919 (Adjusted R Squared = .903)

Model 8: Age + Mod

Dependent Variable: Price (1000 GBP)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1272.836(a)	5	254.567	92.774	.000
Intercept	2949.842	1	2949.842	1075.032	.000
Mod	1014.703	4	253.676	92.449	.000
Age	167.368	1	167.368	60.995	.000
Error	131.710	48	2.744		
Total	13658.417	54			
Corrected Total	1404.546	53			

a R Squared = .906 (Adjusted R Squared = .896)

Model 9: Age + Mile + Mod

Dependent Variable: Price (1000 GBP)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1276.820(a)	6	212.803	78.307	.000
Intercept	2953.826	1	2953.826	1086.941	.000
Mod	920.691	4	230.173	84.698	.000
Age	61.768	1	61.768	22.729	.000
Mile	3.985	1	3.985	1.466	.232
Error	127.725	47	2.718		
Total	13658.417	54			
Corrected Total	1404.546	53			

a R Squared = .909 (Adjusted R Squared = .897)

Model 10: Age + Mod + Mod . Age

Dependent Variable: Price (1000 GBP)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1292.291(a)	9	143.588	56.282	.000
Intercept	2147.345	1	2147.345	841.688	.000
Mod	270.552	4	67.638	26.512	.000
Age	160.470	1	160.470	62.899	.000
Mod * Age	19.455	4	4.864	1.906	.126
Error	112.254	44	2.551		
Total	13658.417	54			
Corrected Total	1404.546	53			

a R Squared = .920 (Adjusted R Squared = .904)

Final Model: Age + Mod

Dependent Variable: Price (1000 GBP)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1272.836(a)	5	254.567	92.774	.000
Intercept	2949.842	1	2949.842	1075.032	.000
Mod	1014.703	4	253.676	92.449	.000
Age	167.368	1	167.368	60.995	.000
Error	131.710	48	2.744		
Total	13658.417	54			
Corrected Total	1404.546	53			

a R Squared = .906 (Adjusted R Squared = .896)

Parameter Estimates

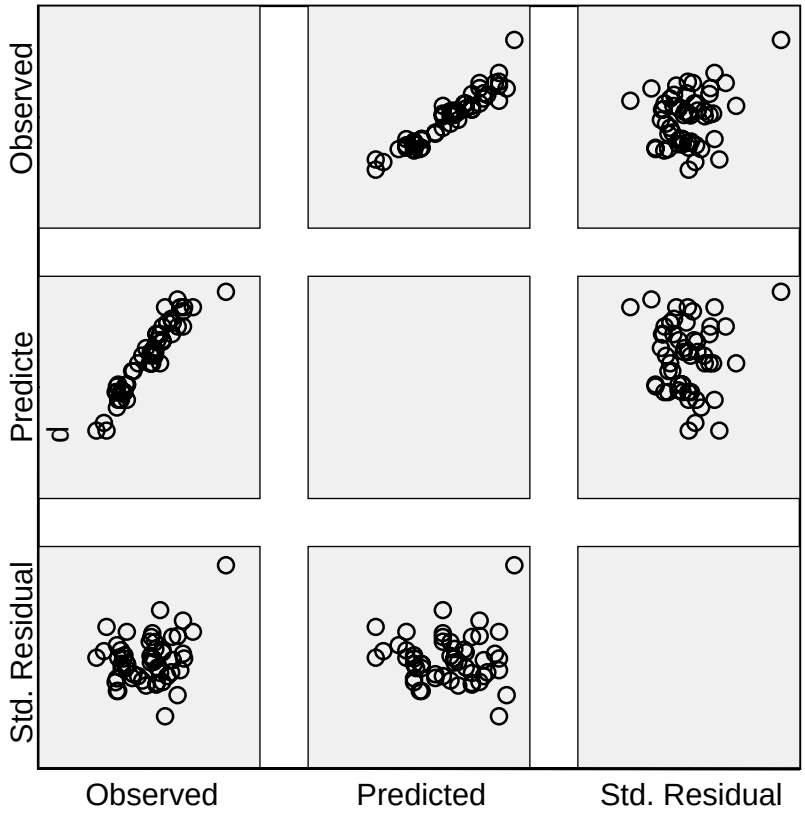
Dependent Variable: Price (1000 GBP)

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	13.486	.684	19.720	.000	12.111	14.861
[Mod=0]	11.966	.726	16.482	.000	10.506	13.426
[Mod=1]	8.916	.948	9.401	.000	7.009	10.823
[Mod=2]	9.234	.674	13.709	.000	7.880	10.588
[Mod=3]	5.139	.599	8.582	.000	3.935	6.344
[Mod=4]	0(a)	.	.	.	.	.
Age	-1.079	.138	-7.810	.000	-1.357	-.802

a This parameter is set to zero because it is redundant.

Residuals

Dependent Variable: Price (1000 GBP)



Model: Intercept + Mod + Age

Q2. Oysters Data

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	198.407(a)	4	49.602	4.643	.012
Intercept	19028.281	1	19028.281	1780.979	.000
trt	198.407	4	49.602	4.643	.012
Error	160.263	15	10.684		
Total	19386.950	20			
Corrected Total	358.670	19			

a R Squared = .553 (Adjusted R Squared = .434)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	342.358(a)	1	342.358	377.793	.000
Intercept	6.466	1	6.466	7.135	.016
initialwt	342.358	1	342.358	377.793	.000
Error	16.312	18	.906		
Total	19386.950	20			
Corrected Total	358.670	19			

a R Squared = .955 (Adjusted R Squared = .952)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	354.447(a)	5	70.889	235.049	.000
Intercept	1.718	1	1.718	5.696	.032
trt	12.089	4	3.022	10.021	.000
initialwt	156.040	1	156.040	517.384	.000
Error	4.222	14	.302		
Total	19386.950	20			
Corrected Total	358.670	19			

a R Squared = .988 (Adjusted R Squared = .984)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	355.835(a)	9	39.537	139.510	.000
Intercept	.064	1	.064	.228	.644
trt	1.696	4	.424	1.496	.275
initialwt	68.529	1	68.529	241.809	.000
trt * initialwt	1.388	4	.347	1.225	.360
Error	2.834	10	.283		
Total	19386.950	20			
Corrected Total	358.670	19			

a R Squared = .992 (Adjusted R Squared = .985)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	354.447(a)	5	70.889	235.049	.000
Intercept	1.718	1	1.718	5.696	.032
trt	12.089	4	3.022	10.021	.000
initialwt	156.040	1	156.040	517.384	.000
Error	4.222	14	.302		
Total	19386.950	20			
Corrected Total	358.670	19			

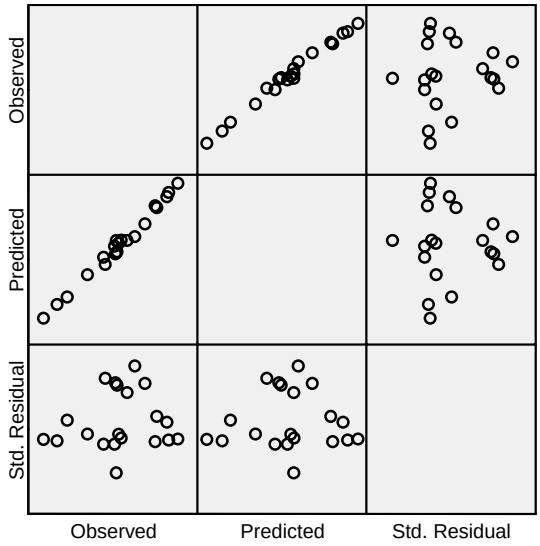
a R Squared = .988 (Adjusted R Squared = .984)

Parameter Estimates

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	2.495	1.028	2.427	.029	.290	4.699
[trt=1]	-.244	.577	-.424	.678	-1.481	.992
[trt=2]	-.280	.493	-.569	.579	-1.337	.777
[trt=3]	1.655	.429	3.853	.002	.734	2.576
[trt=4]	1.107	.472	2.347	.034	.095	2.119
[trt=5]	0(a)	.	.	.	.	.
initialwt	1.083	.048	22.746	.000	.981	1.185

a This parameter is set to zero because it is redundant.

Dependent Variable: Final Weight (g)



Model: Intercept + trt + initialwt

Q3. Oranges Data : Variety 1 data

Dependent Variable: Quantity Variety 1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1346.889(a)	21	64.138	3.131	.016
Intercept	474.876	1	474.876	23.182	.000
day	113.659	5	22.732	1.110	.399
store	83.136	5	16.627	.812	.561
P1	336.892	1	336.892	16.446	.001
day * P1	106.533	5	21.307	1.040	.432
store * P1	82.077	5	16.415	.801	.567
Error	286.786	14	20.485		
Total	5391.693	36			
Corrected Total	1633.676	35			

a R Squared = .824 (Adjusted R Squared = .561)

Dependent Variable: Quantity Variety 1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1264.813(a)	16	79.051	4.072	.002
Intercept	727.513	1	727.513	37.474	.000
day	98.792	5	19.758	1.018	.435
store	153.290	5	30.658	1.579	.214
P1	488.523	1	488.523	25.164	.000
day * P1	78.987	5	15.797	.814	.555
Error	368.863	19	19.414		
Total	5391.693	36			
Corrected Total	1633.676	35			

a R Squared = .774 (Adjusted R Squared = .584)

Dependent Variable: Quantity Variety 1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1185.825(a)	11	107.802	5.777	.000
Intercept	929.926	1	929.926	49.834	.000
day	456.054	5	91.211	4.888	.003
store	238.695	5	47.739	2.558	.054
P1	622.008	1	622.008	33.333	.000
Error	447.850	24	18.660		
Total	5391.693	36			
Corrected Total	1633.676	35			

a R Squared = .726 (Adjusted R Squared = .600)

SPSS OUTPUT FOR EXERCISES 4 Q3

Dependent Variable: Quantity Variety 1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	947.131(a)	6	157.855	6.668	.000
Intercept	1094.386	1	1094.386	46.227	.000
day	430.538	5	86.108	3.637	.011
P1	696.733	1	696.733	29.430	.000
Error	686.545	29	23.674		
Total	5391.693	36			
Corrected Total	1633.676	35			

a R Squared = .580 (Adjusted R Squared = .493)

Dependent Variable: Quantity Variety 1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1111.523(a)	11	101.048	4.644	.001
Intercept	854.684	1	854.684	39.284	.000
P1	554.786	1	554.786	25.500	.000
day	201.172	5	40.234	1.849	.141
day * P1	164.392	5	32.878	1.511	.224
Error	522.153	24	21.756		
Total	5391.693	36			
Corrected Total	1633.676	35			

a R Squared = .680 (Adjusted R Squared = .534)

Dependent Variable: Quantity Variety 1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	516.592(a)	1	516.592	15.723	.000
Intercept	882.193	1	882.193	26.851	.000
P1	516.592	1	516.592	15.723	.000
Error	1117.084	34	32.855		
Total	5391.693	36			
Corrected Total	1633.676	35			

a R Squared = .316 (Adjusted R Squared = .296)

Q2. Oranges Data : Variety 2 data

Dependent Variable: Quantity Variety 2

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2474.507(a)	21	117.834	5.984	.001
Intercept	856.079	1	856.079	43.471	.000
store	189.615	5	37.923	1.926	.154
day	321.845	5	64.369	3.269	.037
P2	475.965	1	475.965	24.169	.000
day * P2	277.857	5	55.571	2.822	.058
store * P2	188.695	5	37.739	1.916	.155
Error	275.701	14	19.693		
Total	7155.720	36			
Corrected Total	2750.208	35			

a R Squared = .900 (Adjusted R Squared = .749)

Dependent Variable: Quantity Variety 2

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2285.812(a)	16	142.863	5.845	.000
Intercept	986.830	1	986.830	40.375	.000
store	381.265	5	76.253	3.120	.032
day	438.673	5	87.735	3.590	.019
P2	587.279	1	587.279	24.028	.000
day * P2	326.468	5	65.294	2.671	.054
Error	464.396	19	24.442		
Total	7155.720	36			
Corrected Total	2750.208	35			

a R Squared = .831 (Adjusted R Squared = .689)

Dependent Variable: Quantity Variety 2

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1959.344(a)	11	178.122	5.405	.000
Intercept	1682.016	1	1682.016	51.043	.000
store	309.879	5	61.976	1.881	.135
day	773.130	5	154.626	4.692	.004
P2	1001.024	1	1001.024	30.378	.000
Error	790.864	24	32.953		
Total	7155.720	36			
Corrected Total	2750.208	35			

a R Squared = .712 (Adjusted R Squared = .581)

SPSS OUTPUT FOR EXERCISES 4 Q3

Dependent Variable: Quantity Variety 2

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1649.465(a)	6	274.911	7.243	.000
Intercept	1529.311	1	1529.311	40.291	.000
day	763.905	5	152.781	4.025	.007
P2	862.204	1	862.204	22.715	.000
Error	1100.743	29	37.957		
Total	7155.720	36			
Corrected Total	2750.208	35			

a R Squared = .600 (Adjusted R Squared = .517)

Dependent Variable: Quantity Variety 2

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1904.547(a)	11	173.141	4.914	.001
Intercept	894.399	1	894.399	25.383	.000
day	371.719	5	74.344	2.110	.099
P2	510.672	1	510.672	14.493	.001
day * P2	255.082	5	51.016	1.448	.244
Error	845.661	24	35.236		
Total	7155.720	36			
Corrected Total	2750.208	35			

a R Squared = .693 (Adjusted R Squared = .552)

Dependent Variable: Quantity Variety 2

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	885.560(a)	1	885.560	16.147	.000
Intercept	1600.103	1	1600.103	29.176	.000
P2	885.560	1	885.560	16.147	.000
Error	1864.648	34	54.843		
Total	7155.720	36			
Corrected Total	2750.208	35			

a R Squared = .322 (Adjusted R Squared = .302)

Q4. Cotton Data

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	31.361(a)	7	4.480	106.169	.000
Intercept	.008	1	.008	.188	.667
variety	.057	1	.057	1.349	.252
spacing	.026	1	.026	.611	.439
bollwt	8.210	1	8.210	194.569	.000
variety * spacing	.003	1	.003	.075	.785
variety * bollwt	.328	1	.328	7.768	.008
spacing * bollwt	.001	1	.001	.014	.907
variety * spacing * bollwt	4.13E-008	1	4.13E-008	.000	.999
Error	1.730	41	.042		
Total	187.560	49			
Corrected Total	33.091	48			

a R Squared = .948 (Adjusted R Squared = .939)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	31.361(a)	6	5.227	126.884	.000
Intercept	.009	1	.009	.221	.641
variety	.078	1	.078	1.889	.177
spacing	.031	1	.031	.749	.392
bollwt	8.718	1	8.718	211.637	.000
variety * spacing	.032	1	.032	.769	.386
variety * bollwt	.448	1	.448	10.881	.002
spacing * bollwt	.001	1	.001	.015	.904
Error	1.730	42	.041		
Total	187.560	49			
Corrected Total	33.091	48			

a R Squared = .948 (Adjusted R Squared = .940)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	31.360(a)	5	6.272	155.829	.000
Intercept	.015	1	.015	.377	.542
variety	.091	1	.091	2.250	.141
spacing	.390	1	.390	9.691	.003
bollwt	11.649	1	11.649	289.413	.000
variety * spacing	.079	1	.079	1.953	.169
variety * bollwt	.467	1	.467	11.606	.001
Error	1.731	43	.040		
Total	187.560	49			
Corrected Total	33.091	48			

a R Squared = .948 (Adjusted R Squared = .942)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	31.281(a)	4	7.820	190.179	.000
Intercept	.011	1	.011	.258	.614
variety	.079	1	.079	1.929	.172
spacing	.375	1	.375	9.123	.004
bollwt	11.573	1	11.573	281.444	.000
variety * bollwt	.482	1	.482	11.717	.001
Error	1.809	44	.041		
Total	187.560	49			
Corrected Total	33.091	48			

a R Squared = .945 (Adjusted R Squared = .940)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	30.906(a)	3	10.302	212.222	.000
Intercept	.022	1	.022	.459	.502
bollwt	11.452	1	11.452	235.905	.000
variety	.109	1	.109	2.241	.141
variety * bollwt	.573	1	.573	11.810	.001
Error	2.184	45	.049		
Total	187.560	49			
Corrected Total	33.091	48			

a R Squared = .934 (Adjusted R Squared = .930)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	30.799(a)	3	10.266	201.645	.000
Intercept	.003	1	.003	.065	.800
variety	1.197	1	1.197	23.517	.000
spacing	.467	1	.467	9.165	.004
bollwt	11.572	1	11.572	227.282	.000
Error	2.291	45	.051		
Total	187.560	49			
Corrected Total	33.091	48			

a R Squared = .931 (Adjusted R Squared = .926)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	30.333(a)	2	15.166	252.979	.000
Intercept	.000	1	.000	.007	.934
variety	1.264	1	1.264	21.076	.000
bollwt	11.434	1	11.434	190.724	.000
Error	2.758	46	.060		
Total	187.560	49			
Corrected Total	33.091	48			

a R Squared = .917 (Adjusted R Squared = .913)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	29.069(a)	1	29.069	339.755	.000
Intercept	.743	1	.743	8.689	.005
bollwt	29.069	1	29.069	339.755	.000
Error	4.021	47	.086		
Total	187.560	49			
Corrected Total	33.091	48			

a R Squared = .878 (Adjusted R Squared = .876)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	31.281(a)	4	7.820	190.179	.000
Intercept	.011	1	.011	.258	.614
variety	.079	1	.079	1.929	.172
spacing	.375	1	.375	9.123	.004
bollwt	11.573	1	11.573	281.444	.000
variety * bollwt	.482	1	.482	11.717	.001
Error	1.809	44	.041		
Total	187.560	49			
Corrected Total	33.091	48			

a R Squared = .945 (Adjusted R Squared = .940)

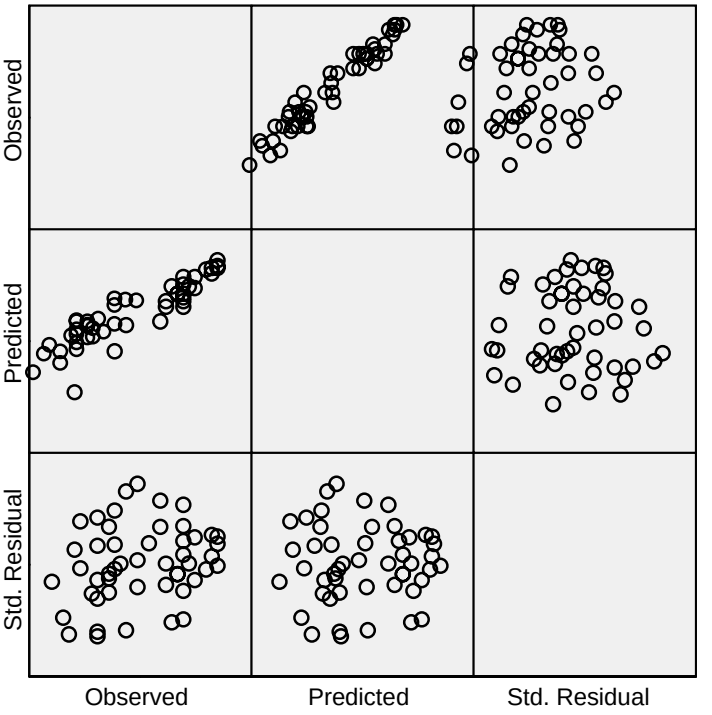
Parameter Estimates

Dependent Variable: Total Lint Weight (g)

					95% Confidence Interval	
Parameter	B	Std. Error	t	Sig.	Lower Bound	Upper Bound
Intercept	.006	.125	.051	.959	-.245	.258
[variety=37]	-.312	.224	-1.389	.172	-.764	.141
[variety=213]	0(a)	.	.	.	.	.
[spacing=30]	.185	.061	3.020	.004	.062	.308
[spacing=40]	0(a)	.	.	.	.	.
bollwt	.240	.025	9.414	.000	.188	.291
[variety=37] * bollwt	.124	.036	3.423	.001	.051	.196
[variety=213] * bollwt	0(a)	.	.	.	.	.

a This parameter is set to zero because it is redundant.

Dependent Variable: Total Lint Weight (g)



Model: Intercept + variety + spacing + bollwt + bollwt .variety

Q5. Doses Data

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	994.042(a)	17	58.473	4.683	.033
Intercept	72490.042	1	72490.042	5805.654	.000
bloc	538.792	3	179.597	14.384	.004
type	12.042	1	12.042	.964	.364
dose	121.583	2	60.792	4.869	.055
bloc * type	47.458	3	15.819	1.267	.367
bloc * dose	130.083	6	21.681	1.736	.260
type * dose	144.083	2	72.042	5.770	.040
Error	74.917	6	12.486		
Total	73559.000	24			
Corrected Total	1068.958	23			

a R Squared = .930 (Adjusted R Squared = .731)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	946.583(a)	14	67.613	4.973	.010
Intercept	72490.042	1	72490.042	5331.239	.000
bloc	538.792	3	179.597	13.208	.001
type	12.042	1	12.042	.886	.371
dose	121.583	2	60.792	4.471	.045
bloc * dose	130.083	6	21.681	1.594	.254
type * dose	144.083	2	72.042	5.298	.030
Error	122.375	9	13.597		
Total	73559.000	24			
Corrected Total	1068.958	23			

a R Squared = .886 (Adjusted R Squared = .707)

Dependent Variable: Response

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	816.500(a)	8	102.063	6.064	.001
Intercept	72490.042	1	72490.042	4307.050	.000
bloc	538.792	3	179.597	10.671	.001
type	12.042	1	12.042	.715	.411
dose	121.583	2	60.792	3.612	.052
type * dose	144.083	2	72.042	4.280	.034
Error	252.458	15	16.831		
Total	73559.000	24			
Corrected Total	1068.958	23			

a R Squared = .764 (Adjusted R Squared = .638)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	672.417(a)	6	112.069	4.804	.005
Intercept	72490.042	1	72490.042	3107.695	.000
bloc	538.792	3	179.597	7.699	.002
type	12.042	1	12.042	.516	.482
dose	121.583	2	60.792	2.606	.103
Error	396.542	17	23.326		
Total	73559.000	24			
Corrected Total	1068.958	23			

a R Squared = .629 (Adjusted R Squared = .498)

Final Model

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	816.500(a)	8	102.063	6.064	.001
Intercept	72490.042	1	72490.042	4307.050	.000
bloc	538.792	3	179.597	10.671	.001
dose	121.583	2	60.792	3.612	.052
type	12.042	1	12.042	.715	.411
dose * type	144.083	2	72.042	4.280	.034
Error	252.458	15	16.831		
Total	73559.000	24			
Corrected Total	1068.958	23			

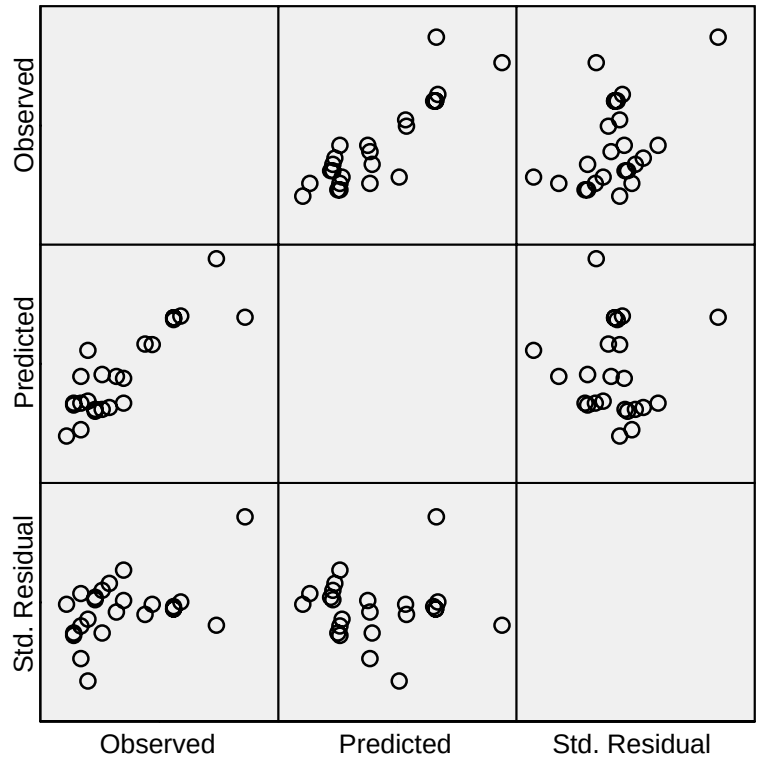
a R Squared = .764 (Adjusted R Squared = .638)

Parameter Estimates

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	62.042	2.512	24.696	.000	56.687	67.396
[bloc=1]	7.667	2.369	3.237	.006	2.618	12.715
[bloc=2]	-3.500	2.369	-1.478	.160	-8.549	1.549
[bloc=3]	-4.333	2.369	-1.830	.087	-9.382	.715
[bloc=4]	0(a)	.	.	.	.	.
[dose=1]	-11.250	2.901	-3.878	.001	-17.433	-5.067
[dose=10]	-7.750	2.901	-2.672	.017	-13.933	-1.567
[dose=100]	0(a)	.	.	.	.	.
[type=1]	-8.000	2.901	-2.758	.015	-14.183	-1.817
[type=2]	0(a)	.	.	.	.	.
[dose=1] * [type=1]	11.750	4.103	2.864	.012	3.006	20.494
[dose=1] * [type=2]	0(a)	.	.	.	.	.
[dose=10] * [type=1]	8.000	4.103	1.950	.070	-.744	16.744
[dose=10] * [type=2]	0(a)	.	.	.	.	.
[dose=100] * [type=1]	0(a)	.	.	.	.	.
[dose=100] * [type=2]	0(a)	.	.	.	.	.

a This parameter is set to zero because it is redundant.

Dependent Variable: Response



Model: Intercept + bloc + dose + type + dose * type