CHAPTER VI

APPLICATION OF LINEAR REGRESSION MODEL TO PREDICT PROCESS YIELD AND PROCESS CAPACITY OF FERTILIZER GRANULE BY GENERAL MULTI LINEAR REGRESSION

6.1 Introduction

Unless engineers try to operate a fertilizer plant with good understanding of the granulation process, it could produce large amount of off-grade fertilizer during process disturbance, the adding of sulfuric concentration for ammonium sulfate synthesis in pipe reactor. The general linear regression models – constructed and divided by fertilizer formulation – are useful tool and could enhance the understanding and reduce losses due to off-grade fertilizer

Up to now, from chapter 4 and 5, the only high liquid phase and low liquid phase fertilizer formulation, the useful decisive fertilizer formulations have the same relation both sulfuric concentration versus process yield and sulfuric concentration versus process capacity that are selected to make general linear regression model.

To achieve the objective for this work, the author use both results of chapter 4 & 5 and plant manual phenomena that mentions about 3 substantial parameters affecting to efficiency and capacity of granulation.

1. Mole ratio of ammonia gas to phosphoric liquid raw material feed to reactor.
2. Specific gravity of phosphoric liquid raw material feed to reactor.
3. Recycle ratio of solid recycle feed stream to all raw material feed.

In this chapter, this extended work concludes 2 independent variables, the mole ratio and the specific gravity, operated by multiple linear regression. The recycle ratio of solid recycle feed stream to raw material feed is significant but it can not draw to analyze because of the substantial errors from measurements in this plant.

6.2 Estimation of Process Yield and Process Capacity by Multiple Linear Regression

These result parameters of multiple linear regression, shown in Table (6.2) to (6.6), express more decisive significant parameters than simple linear regression parameters. In Table 6.1, the summary table of considerable parameter, shows that multiple linear regression method is more useful to gain exact parameters, taken to construct the general model to predict process yield and process capacity, than simple linear regression model.

Table 6.1 Summary of Estimated Parameters of SPSS Multiple Linear Regression Model

Formulation (month)	β_0	β_1	β_2	β_3	R	R^2	Significance F_0	Significance t_0			
								Constant	SO_4	S.G.	M_R
16-20-0 June	81.489	-0.267	-19.941	3.862	0.117	0.014	0.591	0.199	0.440	0.609	0.708
	72.582	0.317	1.183	-4.998	0.2	0.04	0.129	0.063	0.137	0.961	0.429
16-20-0 July	28.740	-0.129	1.875	12.994	0.134	0.018	0.477	0.780	0.678	0.978	0.213
	-102.275	0.066	113.798	-3.222	0.215	0.046	0.089	0.135	0.947	0.012	0.640
16-8-8 April	-121.891	0.001	112.084	6.842	0.269	0.072	0.375	0.299	0.997	0.180	0.383
	79.891	0.078	0.135	-4.830	0.737	0.543	0.0	0.000	0.042	0.989	0.000
16-8-8 July	-36.62	1.614	25.879	12.263	0.75	0.563	0.001	0.675	0.000	0.664	0.374
	187.176	0.806	-34.875	-33.344	0.832	0.692	0.0	0.001	0.000	0.278	0.000
15-7-18 April	147.817	0.759	-73.154	-2.223	0.419	0.176	0.364	0.263	0.233	0.391	0.922
	-86.206	0.681	97.951	-2.463	0.623	0.388	0.044	0.359	0.139	0.118	0.880

From above table, R^2 value - the coefficient of determination - enhance more than those in simple linear regression. Especially for the low liquid phase fertilizer formulation, almost R^2 value nearly approaches 0.6-0.7 and F_0 value - the significant F_0 – is less than α = 0.05. Then it is reject null hypothesis $H_0 = \beta_1 = \beta_2 = \ldots = \beta_K = 0$ referring to confirm that there are at least 1 independent variable - sulfuric acid concentration, mole ratio, or SG – relate to process yield and process capacity

Nevertheless, it can accept the multiple linear regression if the test of individual coefficient is proved. Significance t_0 – from table 6.1-of low liquid phase fertilizer formulation show that sulfuric acid concentration and mole ratio of fluid raw material feed relate to process yield and process capacity because of t_0 value is less than α = 0.05.

From Table (6.1), this parameter shows that only the 16-8-8 fertilizer formulation – having the best decisive parameters – is proper to make concise model to predict process yield and process capacity. Furthermore, during actual plant operation, a large number of disturbance variables, disturbing the process all time, should study further and introduce to analyze by multiple linear regression to obtain all models of fertilizer formulations.

Table 6.2 The Parameter of Multiple Linear Regression for Process Yield and Process Capacity Dependent Parameters of 16-20-0 June, the High Liquid Phase Fertilizer Formulation

Variables Entered/Removed [b]

Model	Variables Entered	Variables Removed	Method
1	MR, SG, SO4 [a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: YIELD

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.117[a]	.014	-.008	8.34906	.014	.640	3	139	.591	1.041

a. Predictors: (Constant), MR, SG, SO4

b. Dependent Variable: YIELD

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	133.744	3	44.581	.640	.591[a]
	Residual	9689.249	139	69.707		
	Total	9822.993	142			

a. Predictors: (Constant), MR, SG, SO4

b. Dependent Variable: YIELD

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	81.489	63.169		1.290	.199					
	SO4	-.267	.345	-.077	-.774	.440	-.103	-.065	-.065	.717	1.394
	SG	-19.941	38.851	-.044	-.513	.609	-.060	-.043	-.043	.976	1.025
	MR	3.862	10.276	.037	.376	.708	.083	.032	.032	.723	1.383

a. Dependent Variable: YIELD

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions			
				(Constant)	SO4	SG	MR
1	1	3.832	1.000	.00	.01	.00	.00
	2	.167	4.793	.00	.68	.00	.00
	3	.001	59.098	.02	.31	.03	.96
	4	6.563E-05	241.628	.98	.00	.97	.04

a. Dependent Variable: YIELD

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	53.1489	59.4383	55.9930	.97049	143
Residual	-21.5238	15.9871	.0000	8.26040	143
Std. Predicted Value	-2.931	3.550	.000	1.000	143
Std. Residual	-2.578	1.915	.000	.989	143

a. Dependent Variable: YIELD

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MR, SG, SO4[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: CAP

Model Summary[b]

Model	R	R Square	djusted R Squar	td. Error of the Estimate	Change Statistics					urbin-Watson
					Square Change	F Change	df1	df2	Sig. F Change	
1	.200[a]	.040	.019	5.12316	.040	1.921	3	139	.129	.877

a. Predictors: (Constant), MR, SG, SO4

b. Dependent Variable: CAP

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	151.275	3	50.425	1.921	.129[a]
	Residual	3648.303	139	26.247		
	Total	3799.578	142			

a. Predictors: (Constant), MR, SG, SO4

b. Dependent Variable: CAP

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	72.582	38.762		1.873	.063					
	SO4	.317	.212	.147	1.497	.137	.188	.126	.124	.717	1.394
	SG	1.183	23.840	.004	.050	.961	.035	.004	.004	.976	1.025
	MR	-4.998	6.306	-.077	-.793	.429	-.155	-.067	-.066	.723	1.383

a. Dependent Variable: CAP

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions			
				(Constant)	SO4	SG	MR
1	1	3.832	1.000	.00	.01	.00	.00
	2	.167	4.793	.00	.68	.00	.00
	3	.001	59.098	.02	.31	.03	.96
	4	6.563E-05	241.628	.98	.00	.97	.04

a. Dependent Variable: CAP

Casewise Diagnostics[a]

Case Number	Std. Residual	CAP
25	-3.537	50.00
26	-3.328	50.00
38	-3.348	50.00
140	-3.503	50.00

a. Dependent Variable: CAP

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	66.1999	70.8173	67.5091	1.03214	143
Residual	-18.1221	8.2964	.0000	5.06875	143
Std. Predicted Value	-1.268	3.205	.000	1.000	143
Std. Residual	-3.537	1.619	.000	.989	143

a. Dependent Variable: CAP

Table 6.3 The Parameter of Multiple Linear Regression for Process Yield and Process Capacity Dependent Parameters of 16-20-0 July , the High Liquid Phase Fertilizer Formulation

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MR, SG, SO4[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: YIELD

Model Summary[b]

					Change Statistics					
Model	R	R Square	djusted R Squar	td. Error of th Estimate	Square Chang	F Change	df1	df2	Sig. F Change	urbin-Watson
1	.134[a]	.018	-.004	8.97373	.018	.834	3	137	.477	.944

a.Predictors: (Constant), MR, SG, SO4

b.Dependent Variable: YIELD

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	201.441	3	67.147	.834	.477[a]
	Residual	11032.318	137	80.528		
	Total	11233.759	140			

a. Predictors: (Constant), MR, SG, SO4

b. Dependent Variable: YIELD

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions			
				(Constant)	SO4	SG	MR
1	1	3.826	1.000	.00	.01	.00	.00
	2	.173	4.706	.00	.85	.00	.00
	3	.001	56.842	.01	.14	.01	.98
	4	2.671E-05	378.499	.99	.00	.99	.02

a. Dependent Variable: YIELD

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	50.9838	56.9590	53.3972	1.19953	141
Residual	-22.7989	20.2728	.0000	8.87706	141
Std. Predicted Value	-2.012	2.969	.000	1.000	141
Std. Residual	-2.541	2.259	.000	.989	141

a. Dependent Variable: YIELD

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MR, SG, SO4[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: CAP

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.215[a]	.046	.025	5.94811	.046	2.220	3	137	.089	.910

a. Predictors: (Constant), MR, SG, SO4

b. Dependent Variable: CAP

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	235.635	3	78.545	2.220	.089[a]
	Residual	4847.065	137	35.380		
	Total	5082.700	140			

a. Predictors: (Constant), MR, SG, SO4

b. Dependent Variable: CAP

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	-102.275	68.026		-1.503	.135					
	SO4	.066	.206	.029	.323	.747	.038	.028	.027	.878	1.139
	SG	113.798	44.819	.217	2.539	.012	.207	.212	.212	.953	1.049
	MR	-3.222	6.877	-.043	-.468	.640	-.007	-.040	-.039	.840	1.191

a. Dependent Variable: CAP

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions			
				(Constant)	SO4	SG	MR
1	1	3.826	1.000	.00	.01	.00	.00
	2	.173	4.706	.00	.85	.00	.00
	3	.001	56.842	.01	.14	.01	.98
	4	2.671E-05	378.499	.99	.00	.99	.02

a. Dependent Variable: CAP

Casewise Diagnostics[a]

Case Number	Std. Residual	CAP
113	-3.473	50.00

a. Dependent Variable: CAP

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	65.8543	72.7103	69.1294	1.29735	141
Residual	-20.6579	10.0142	.0000	5.88404	141
Std. Predicted Value	-2.524	2.760	.000	1.000	141
Std. Residual	-3.473	1.684	.000	.989	141

a. Dependent Variable: CAP

Table 6.4 The Parameter of Multiple Linear Regression for Process Yield and Process Capacity Dependent Parameters of 16-8-8 April, the Low Liquid Phase Fertilizer Formulation

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MR, SG, SO4[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: YIELD

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.269[a]	.072	.004	9.84517	.072	1.065	3	41	.375	1.814

a. Predictors: (Constant), MR, SG, SO4

b. Dependent Variable: YIELD

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	309.622	3	103.207	1.065	.375[a]
	Residual	3974.023	41	96.927		
	Total	4283.644	44			

a. Predictors: (Constant), MR, SG, SO4

b. Dependent Variable: YIELD

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	-121.891	115.848		-1.052	.299					
	SO4	.001	.321	.001	.004	.997	.051	.001	.001	.718	1.393
	SG	112.084	82.082	.229	1.366	.180	.228	.209	.205	.804	1.244
	MR	6.842	7.752	.142	.883	.383	.140	.137	.133	.872	1.146

a. Dependent Variable: YIELD

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions			
				(Constant)	SO4	SG	MR
1	1	3.959	1.000	.00	.00	.00	.00
	2	.037	10.374	.00	.61	.00	.04
	3	.004	31.695	.01	.24	.01	.96
	4	7.788E-05	225.464	.99	.15	.99	.00

a. Dependent Variable: YIELD

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	52.2546	63.8469	57.9111	2.65271	45
Residual	-23.4958	14.1204	.0000	9.50361	45
Std. Predicted Value	-2.132	2.238	.000	1.000	45
Std. Residual	-2.387	1.434	.000	.965	45

a. Dependent Variable: YIELD

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MR, SG, SO4[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: CAP

Model Summary[b]

Model	R	R Square	djusted R Squar	td. Error of the Estimate	Change Statistics					Durbin-Watson
					Square Change	F Change	df1	df2	Sig. F Change	
1	.737[a]	.543	.509	1.140687	.543	16.232	3	41	.000	1.471

a. Predictors: (Constant), MR, SG, SO4

b. Dependent Variable: CAP

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	63.361	3	21.120	16.232	.000[a]
	Residual	53.348	41	1.301		
	Total	116.709	44			

a. Predictors: (Constant), MR, SG, SO4

b. Dependent Variable: CAP

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	79.891	13.422		5.952	.000					
	SO4	.078	.037	.262	2.104	.042	.462	.312	.222	.718	1.393
	SG	.135	9.510	.002	.014	.989	.117	.002	.001	.804	1.244
	MR	-4.830	.898	-.608	-5.378	.000	-.694	-.643	-.568	.872	1.146

a. Dependent Variable: CAP

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions			
				(Constant)	SO4	SG	MR
1	1	3.959	1.000	.00	.00	.00	.00
	2	.037	10.374	.00	.61	.00	.04
	3	.004	31.695	.01	.24	.01	.96
	4	7.788E-05	225.464	.99	.15	.99	.00

a. Dependent Variable: CAP

Casewise Diagnostics[a]

Case Number	Std. Residual	CAP
1	-4.052	66.000

a. Dependent Variable: CAP

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	69.24611	73.43138	71.06556	1.200012	45
Residual	-4.62222	2.90840	.00000	1.101114	45
Std. Predicted Value	-1.516	1.972	.000	1.000	45
Std. Residual	-4.052	2.550	.000	.965	45

a. Dependent Variable: CAP

Table 6.5 The Parameter of Multiple Linear Regression for Process Yield and Process Capacity Dependent Parameters of 16-8-8 July, the Low Liquid Phase Fertilizer Formulation

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MR, SG, SO4[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: YIELD

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.750[a]	.563	.494	8.53756	.563	8.148	3	19	.001	1.900

a. Predictors: (Constant), MR, SG, SO4

b. Dependent Variable: YIELD

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1781.700	3	593.900	8.148	.001[a]
	Residual	1384.908	19	72.890		
	Total	3166.609	22			

a. Predictors: (Constant), MR, SG, SO4

b. Dependent Variable: YIELD

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	-36.620	86.001		-.426	.675					
	SO4	1.614	.361	.731	4.476	.000	.731	.716	.679	.864	1.158
	SG	25.879	58.685	.072	.441	.664	-.138	.101	.067	.874	1.144
	MR	12.263	13.474	.142	.910	.374	.269	.204	.138	.942	1.061

a. Dependent Variable: YIELD

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions			
				(Constant)	SO4	SG	MR
1	1	3.947	1.000	.00	.00	.00	.00
	2	.050	8.870	.00	.86	.00	.00
	3	.003	39.215	.03	.02	.03	.99
	4	.000	132.359	.97	.12	.97	.00

a. Dependent Variable: YIELD

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	38.7000	74.6458	59.1304	8.99924	23
Residual	-14.5678	16.5807	.0000	7.93413	23
Std. Predicted Value	-2.270	1.724	.000	1.000	23
Std. Residual	-1.706	1.942	.000	.929	23

a. Dependent Variable: YIELD

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MR, SG, SO4[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: CAP

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.832[a]	.692	.643	4.53871	.692	14.213	3	19	.000	1.272

a. Predictors: (Constant), MR, SG, SO4

b. Dependent Variable: CAP

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	878.341	3	292.780	14.213	.000[a]
	Residual	391.398	19	20.600		
	Total	1269.739	22			

a. Predictors: (Constant), MR, SG, SO4

b. Dependent Variable: CAP

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	187.176	45.720		4.094	.001					
	SO4	.806	.192	.576	4.204	.000	.525	.694	.535	.864	1.158
	SG	-34.875	31.198	-.152	-1.118	.278	-.404	-.248	-.142	.874	1.144
	MR	-33.344	7.163	-.611	-4.655	.000	-.536	-.730	-.593	.942	1.061

a. Dependent Variable: CAP

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions			
				(Constant)	SO4	SG	MR
1	1	3.947	1.000	.00	.00	.00	.00
	2	.050	8.870	.00	.86	.00	.00
	3	.003	39.215	.03	.02	.03	.99
	4	.000	132.359	.97	.12	.97	.00

a. Dependent Variable: CAP

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	69.0923	90.9333	81.4783	6.31859	23
Residual	-8.8976	9.5852	.0000	4.21792	23
Std. Predicted Value	-1.960	1.496	.000	1.000	23
Std. Residual	-1.960	2.112	.000	.929	23

a. Dependent Variable: CAP

Table 6.6 The Parameter of Multiple Linear Regression for Process Yield and Process Capacity Dependent Parameters of 15-7-18 April, the Low Liquid phase Fertilizer Formulation

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MR, SG, PERC.SO4[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: YIELD

Model Summary[b]

Model	R	R Square	djusted R Squar	td. Error of the Estimate	Change Statistics					Durbin-Watson
					Square Chang	F Change	df1	df2	Sig. F Change	
1	.419[a]	.176	.021	8.52982	.176	1.138	3	16	.364	2.113

a. Predictors: (Constant), MR, SG, PERC.SO4

b. Dependent Variable: YIELD

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	248.424	3	82.808	1.138	.364[a]
	Residual	1164.126	16	72.758		
	Total	1412.550	19			

a. Predictors: (Constant), MR, SG, PERC.SO4

b. Dependent Variable: YIELD

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	147.817	127.497		1.159	.263					
	PERC.SO	.759	.612	.446	1.241	.233	.368	.296	.282	.399	2.509
	SG	-73.154	82.917	-.208	-.882	.391	-.102	-.215	-.200	.930	1.075
	MR	-2.223	22.445	-.035	-.099	.922	.278	-.025	-.022	.418	2.394

a. Dependent Variable: YIELD

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions			
				(Constant)	PERC.SO4	SG	MR
1	1	3.976	1.000	.00	.00	.00	.00
	2	.023	13.256	.00	.43	.00	.00
	3	.001	60.058	.01	.45	.04	.92
	4	.000	181.153	.98	.12	.96	.08

a. Dependent Variable: YIELD

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	46.9854	61.6427	57.1500	3.61593	20
Residual	-17.7746	12.9587	.0000	7.82750	20
Std. Predicted Value	-2.811	1.242	.000	1.000	20
Std. Residual	-2.084	1.519	.000	.918	20

a. Dependent Variable: YIELD

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MR, SG, PERC.SO4[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: CAP

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.623[a]	.388	.273	6.10807	.388	3.378	3	16	.044	1.875

a. Predictors: (Constant), MR, SG, PERC.SO4

b. Dependent Variable: CAP

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	378.063	3	126.021	3.378	.044[a]
	Residual	596.937	16	37.309		
	Total	975.000	19			

a. Predictors: (Constant), MR, SG, PERC.SO4

b. Dependent Variable: CAP

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Correlations Zero-order	Correlations Partial	Correlations Part	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	-86.206	91.298		-.944	.359					
	PERC.S	.681	.438	.482	1.555	.139	.529	.362	.304	.399	2.509
	SG	97.951	59.375	.335	1.650	.118	.447	.381	.323	.930	1.075
	MR	-2.463	16.072	-.046	-.153	.880	.362	-.038	-.030	.418	2.394

a. Dependent Variable: CAP

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions (Constant)	Variance Proportions PERC.SO4	Variance Proportions SG	Variance Proportions MR
1	1	3.976	1.000	.00	.00	.00	.00
	2	.023	13.256	.00	.43	.00	.00
	3	.001	60.058	.01	.45	.04	.92
	4	.000	181.153	.98	.12	.96	.08

a. Dependent Variable: CAP

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	55.3210	73.3345	67.5000	4.46072	20
Residual	-15.3210	9.7767	.0000	5.60515	20
Std. Predicted Value	-2.730	1.308	.000	1.000	20
Std. Residual	-2.508	1.601	.000	.918	20

a. Dependent Variable: CAP

6.3 Comparison of Estimated Process Yield and Process Capacity by Multiple Linear Regression Model with Actual Process Yield and Process Capacity

The scatter plot graphs between actual yield in the y-axis and estimated yield in the x-axis, estimated by multiple linear regression, are shown in Figure (6.1) to (6.5) for high liquid phase and low liquid phase fertilizer formulations.

Moreover, consideration of figure 6.4, the 16-8-8 fertilizer formulation, is the vivid confirmation of the good multiple regression that can predict process yield and process capacity

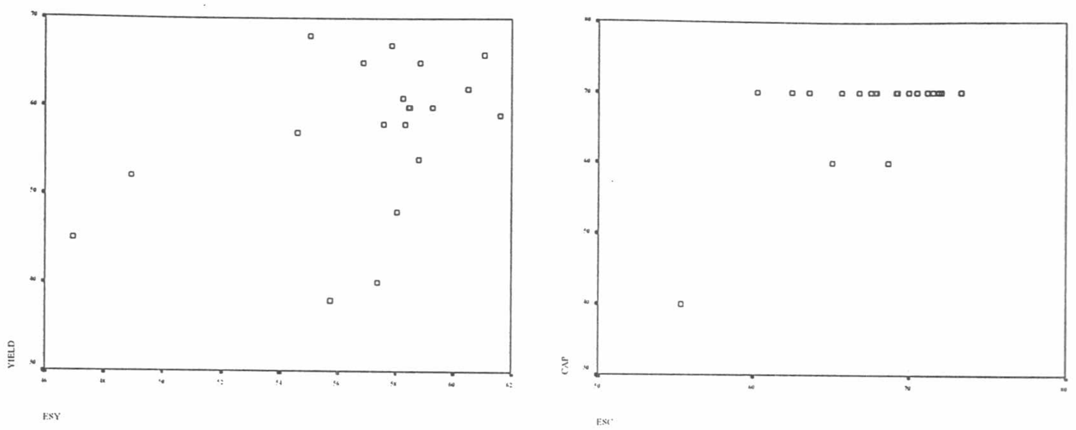

Figure 6.1 The Comparison Graph Plot of 16-20-0 June, the High Liquid Phase Fertilizer Formulation

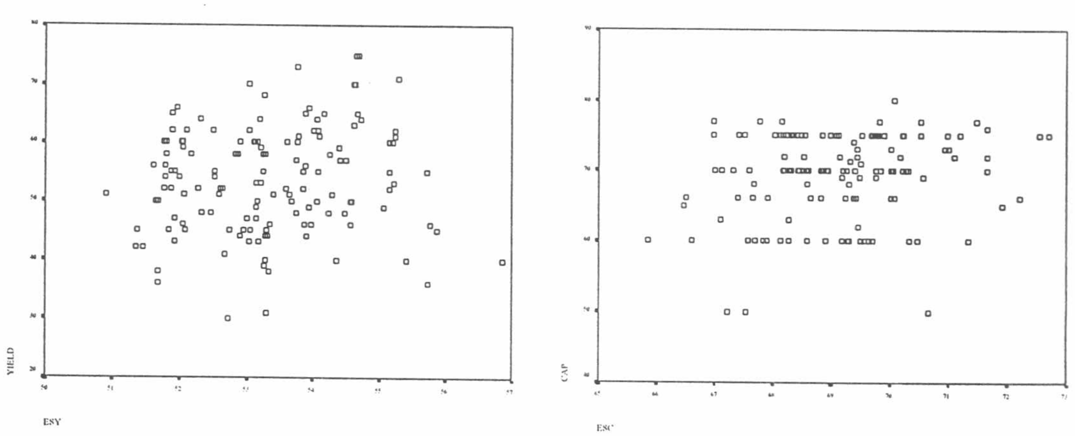

Figure 6.2 The Comparison Graph Plot of 16-20-0 July, the High Liquid Phase Fertilizer Formulation

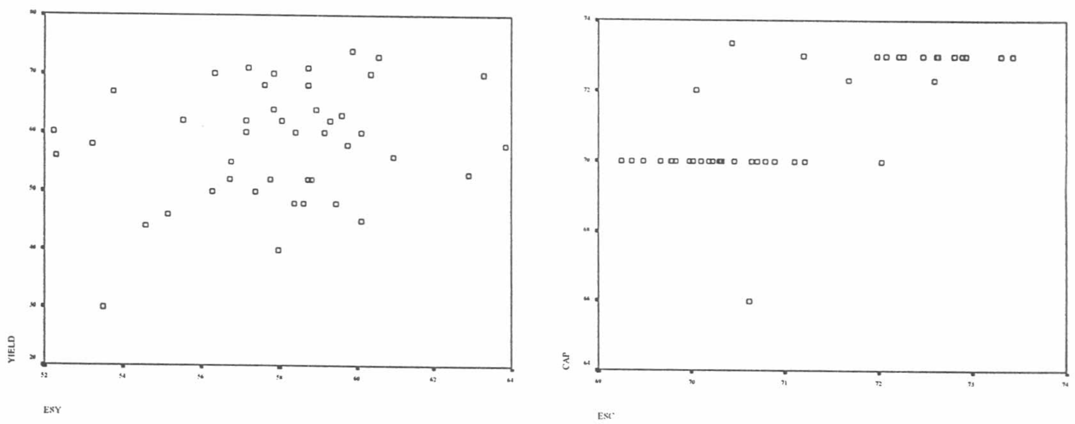

Figure 6.3 The Comparison Graph Plot of 16-8-8 April, the Low Liquid Phase Fertilizer Formulation

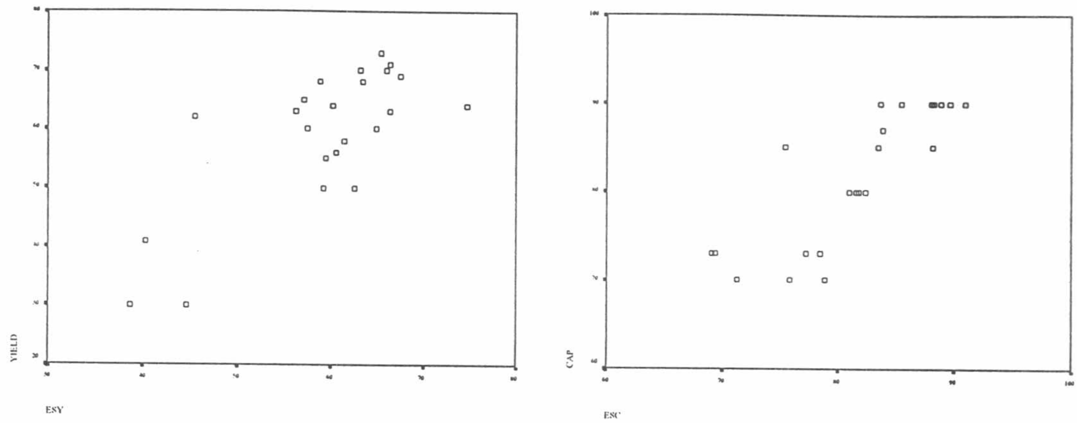

Figure 6.4 The Comparison Graph Plot of 16-8-8 July, the Low Liquid Phase Fertilizer Formulation

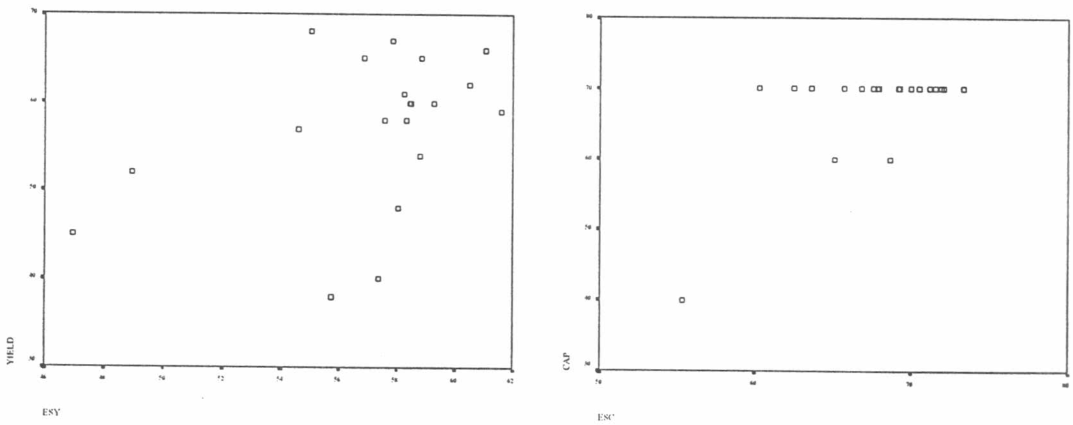

Figure 6.5 The Comparison Graph Plot of 15-7-18 April, the Low Liquid Phase Fertilizer Formulation