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Improving the Quality of Palm Oil NPK Fertilizer Products at PT.XYZ Using Statistical Process Control Methods and Taguchi Experiment

Hariono Hariono[1] and Mokh. Suef[2]
[1]Department of Technology Management, Institut Teknologi Sepuluh Nopember, Surabaya
[2]Department of Industrial and System Engineering, Institut Teknologi Sepuluh Nopember, Surabaya
e-mail: harryibanezsaputra@gmail.com

Abstract—**Quality palm oil NPK fertilizer products are fertilizer products that meet the quality requirements specified in SNI Standard 2801: 2010 and SIRIM Standards. This research was conducted with the aim to improve the quality of oil palm NPK fertilizer products at PT. XYZ. To maintain the stability of nutrients, the production process must be strictly considered with the aim of minimizing product variations. To achieve these objectives the production process control system is designed using Statistical Process Control. Then a process is designed to produce a robust product using the Taguchi experiment. Taguchi experiment obtained the results of the optimization of the process parameter level settings in combination as follows: raw material intake 27 mt / hour; water usage 1100 m3 / hour; gas usage 100 MMBtu; material temperature granulator 52°C; dryer material temperature 52°C; cooler material temperature of 44°C; finish product temperature 39°C; process environment temperature of 31°C. From the results of ANOVA for each nutrient showed that the highest levels of nutrient N were obtained from the finish product temperature 38°C; the highest P2O5 nutrient content is obtained from the variable water usage of 1000 m3 / hour; the highest K2O nutrient content is obtained from the variable water usage of 1100 m3 / hour; the highest MgO nutrient content is obtained from the variable gas usage of 90 MMBtu; The highest levels of B2O3 nutrients are obtained from the variable water usage of 1100 m3/hour and the best physical size of the granules is obtained from the variable cooler material temperature of 42oC. The results of this study can reduce as much as possible complaints from customers because the product meets the quality standard specifications required.**

Keywords—**solid NPK fertilizer, nutrients, standard quality specifications, Statistical Process Control, Taguchi experiment.**

I. INTRODUCTION

IN THE PRODUCTION process of palm oil NPK fertilizer it is not easy to maintain consistency in product quality. This is related to the factors that follow. Including the price of raw materials, utility costs (electricity, water and gas) used during the production process, the number of defective products that must be reprocessed which will have an impact on increasing production costs, diversification and substitution of raw materials which results in varying machine settings in the process.

If the factors causing variations in the product do not immediately get the right treatment will have an impact on the quality of the fertilizer product itself. Especially for fertilizer nutrient content which tends to be unstable (out-spec) or not in accordance with the quality standards stated in the Indonesian National Standard (SNI 2803: 2010) and the Standard and Industrial Research Institute of Malaysia (SIRIM) regarding the quality specifications of NPK solid fertilizer products.

II. METHOD

A. Statistical Process Control

Statistical process control is a statistical procedure using control diagrams to see if there are parts of the production process that are not functioning properly and can cause poor quality. Statistical process control is used to examine and measure the production process if there is something different from what it is supposed to do. If unusual or unwanted variability is found, the process will be corrected to minimize product defects.

The purpose of Statistical Process Control (SPC) is to achieve and maintain the process so that it remains in a statistically controlled state. This means that diversity in the process must be maintained within the established limits so that its reliability can improved continuously

B. Taguchi Methods

The Taguchi method was first developed by Dr. Genichi Taguchi in 1949. The purpose of the Taguchi method is to make a product that is robust to noise by improving product and process quality at the same time so that costs and resources can be minimized. Taguchi method is often referred to as Robust Design. By using this method we can determine the dominant parameters in influencing the process (control factor) and which factors are included as a noise factor. By knowing the dominant factors, optimization can be done so that the optimal process is obtained.

There are three fundamental concepts in the Taguchi method to produce quality products that are also resilient (Robust Performance) namely: 1. Quality robustness (products must be designed to be able to withstand environmental factors that cannot be controlled); 2. Target oriented quality (good product quality can be achieved by minimizing deviations from established specifications); 3.Quality loss function (is a function of loss that must be borne by consumers due to the quality of the product

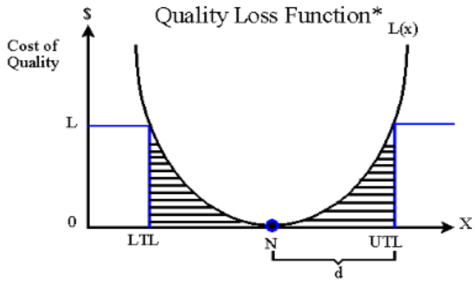


Figure 1. Taguchi quality loss function.
L= Loss associated with producing outside of the tolerance limits in the traditional quality loss function
L(x)= Loss associated with producing anything other than the nominal specification in the Taguchi Loss Function
LTL= Lower Tolerance Limit
UTL= Upper Tolerance Limit N = Nominal specification
d= difference between the nominal specification and the tolerance limit

Table 1.
Factors that influence the process

No	Variabel Name
1	Raw material intake
2	Water usage
3	Gas usage
4	Granulator material temperature
5	Dryer material temperature
6	Cooler material temperature
7	Finish product temperature
8	Process environment temperature

Table 2.
The parameter level setting values for the factors that affect the process

Factor	Descriptions	Unit	Level 1	Level 2	Level 3
A	Raw material intake	mt/hr	25	26	27
B	Water usage	m^3/hr	900	1000	1100
C	Gas usage	MBTU	90	100	110
D	nulator material temperature	^oC	34	35	36
E	Dryer material temperature	^oC	50	51	52
F	ooler material temperature	^oC	42	43	44
G	Finish product temperature	^oC	38	39	40
H	ess environment temperature	^oC	27	29	31

Table 3.
Factors and Responses Orthogonal Array

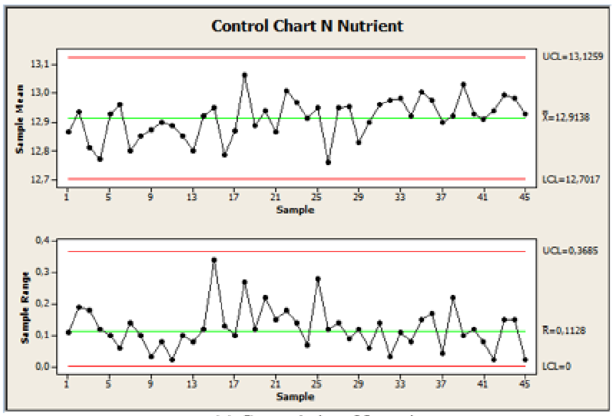
No. Experiments	FACTORS								RESPONSES					
	A	B	C	D	E	F	G	H	N	P_2O_5	K_2O	MgO	B_2O_3	Physical
1	25	900	90	34	50	42	38	27	12,50	5,85	25,78	3,63	0,55	3,56
2	25	900	90	34	51	43	39	29	12,20	6,03	25,85	3,68	0,55	3,45
3	25	900	90	34	52	44	40	31	12,20	5,81	25,85	3,76	0,53	3,35
4	25	1000	100	35	50	42	38	29	12,40	6,04	25,65	3,81	0,55	3,36
5	25	1000	100	35	51	43	39	31	12,34	6,12	26,05	3,73	0,53	3,47
6	25	1000	100	35	52	44	40	27	12,41	5,95	25,71	3,76	0,60	3,44
7	25	1100	110	36	50	42	38	31	12,40	5,76	25,94	3,71	0,57	3,61
8	25	1100	110	36	51	43	39	27	12,38	5,96	26,05	3,76	0,67	3,46
9	25	1100	110	36	52	44	40	29	12,30	6,01	26,37	3,72	0,60	3,32
10	26	900	100	36	50	43	40	27	12,34	5,83	26,05	3,76	0,52	3,40
11	26	900	100	36	51	44	38	29	12,41	6,06	26,08	3,79	0,55	3,52
12	26	900	100	36	52	42	39	31	12,52	5,91	26,26	3,77	0,54	3,50
13	26	1000	110	34	50	43	40	29	12,28	5,93	25,87	3,74	0,56	3,44
14	26	1000	110	34	51	44	38	31	12,55	5,83	25,90	3,73	0,53	3,51
15	26	1000	110	34	52	42	39	27	12,36	5,94	26,26	3,82	0,53	3,38
16	26	1100	90	35	50	43	40	31	12,02	5,98	26,20	3,88	0,58	3,49
17	26	1100	90	35	51	44	38	27	12,33	6,23	26,23	3,77	0,60	3,58
18	26	1100	90	35	52	42	39	29	12,42	5,92	26,37	3,79	0,58	3,43
19	27	900	110	35	50	44	39	27	12,27	5,96	26,20	3,83	0,57	3,36
20	27	900	110	35	51	42	40	29	12,37	5,83	26,15	3,71	0,57	3,40
21	27	900	110	35	52	43	38	31	12,49	6,22	26,28	3,84	0,56	3,49
22	27	1000	90	36	50	44	39	29	12,61	6,10	25,88	3,79	0,53	3,42
23	27	1000	90	36	51	42	40	31	12,49	6,14	25,80	3,75	0,54	3,38
24	27	1000	90	36	52	43	38	27	12,24	6,36	25,91	3,70	0,53	3,42
25	27	1100	100	34	50	44	39	31	12,29	6,19	26,35	3,81	0,59	3,45
26	27	1100	100	34	51	42	40	27	12,25	6,20	26,68	3,84	0,57	3,45
27	27	1100	100	34	52	43	38	29	12,47	6,44	26,04	3,73	0,53	3,47

purchased does not meet specifications). Resulting in disappointment or feeling dissatisfied with the product.

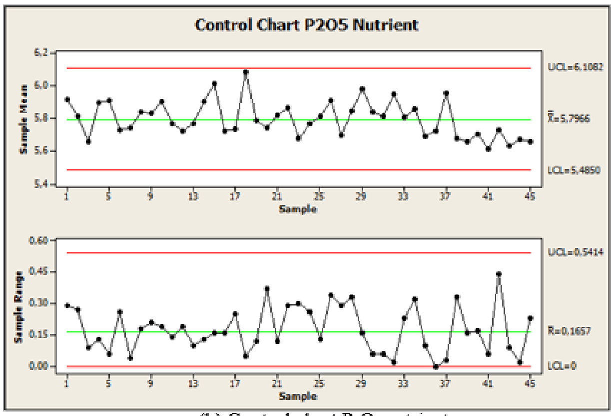
III. RESULT AND DISCUSSION

A. Analysis of Product Variations Using Statistical Process Control Methods

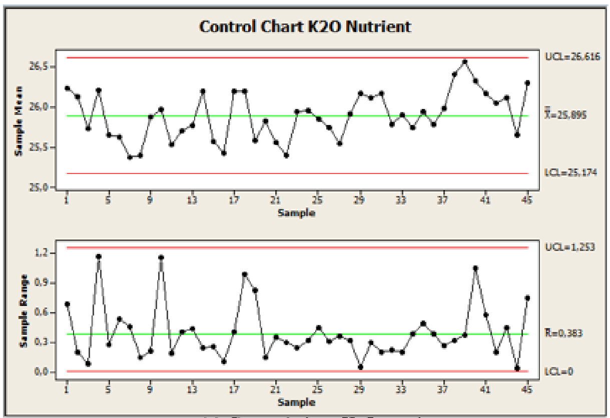
For the initial stage, process conditions will be identified using a control chart. The function of the control chart is to identify whether a process is in a controlled state or not. The figure below will show the results of testing the condition of the process using X bar - R Chart variable data.



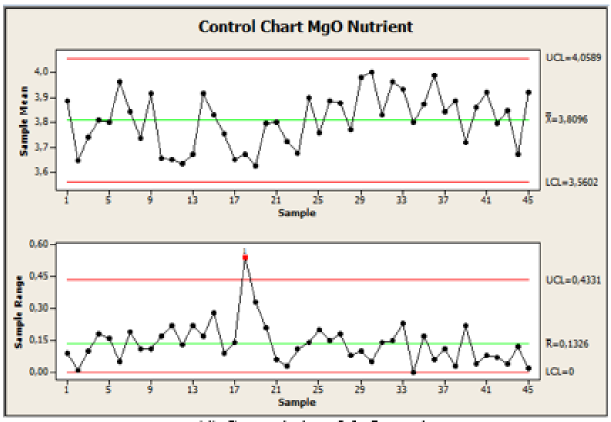
(a) Control chart N nutrient



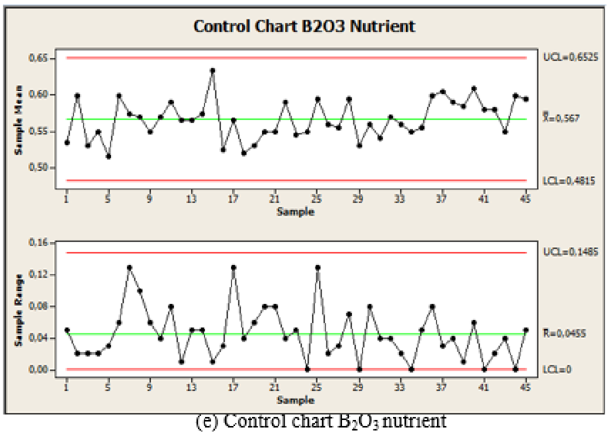
(b) Control chart P_2O_5 nutrient



(c) Control chart K_2O nutrient



(d) Control chart MgO nutrient



(e) Control chart B_2O_3 nutrient

Figure 2. Test Results for Process Conditions Using Control Chart Data Variable X bar - R chart.

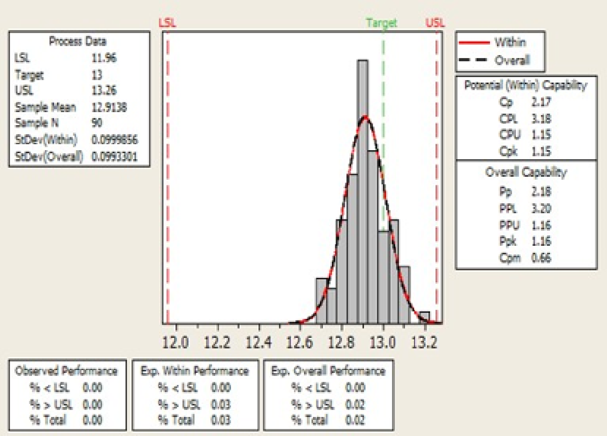
From the test results above, the process conditions can be said to be not completely controlled statistically. Still found several points touching the Upper Control Limit (LCL) line. This indicates that the process is in an unstable condition and corrective action must be taken immediately. So that product variance can be minimized.

The next step is to test the process capability. Process capability is the ability of a process to produce products or services that are in accordance with customer needs or expected specifications. If a process has a Cp value ≥ 1, then the process can be accepted or the process has good capabilities. However, if the value of Cp <1, then the process is not considered capable to meet consumer needs.

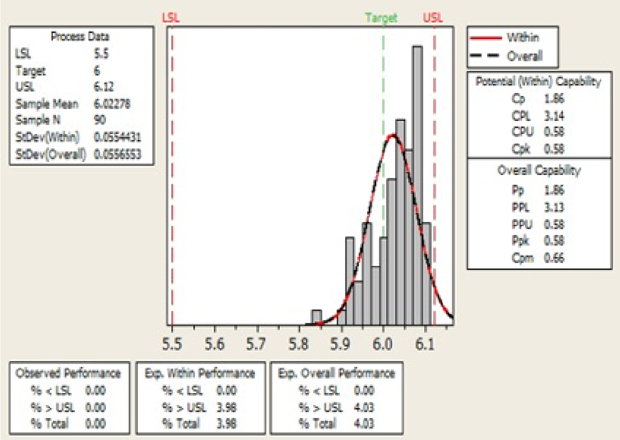
B. *Taguchi Experiments*

After the analysis of the process capability is finished, the next step is to carry out the process of identifying the factors that influence the process, especially related to the adequacy of nutrient content (nutrient) and the physical condition of the product. Factors that influence the process mainly related to the adequacy of nutrient content (nutrient) and the physical condition of the product are shown in Table 1 – 3.

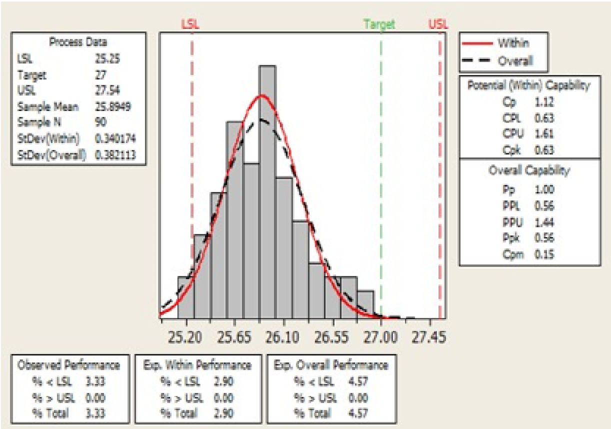
After the orthogonal array of factors and responses are completed, the next step is to graph the main effect plot to determine the level of factors that can optimize responses simultaneously and calculate the mean value at each level. So



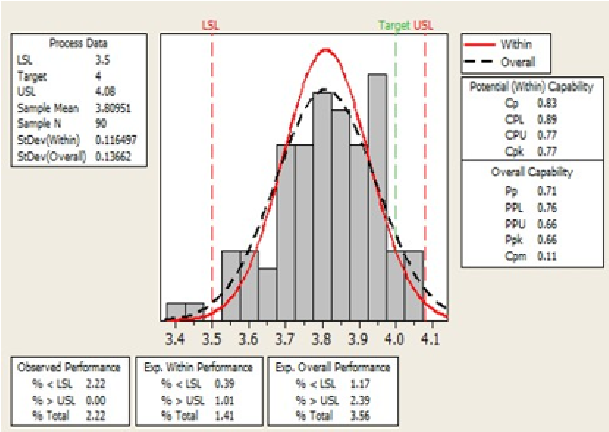
(a) Capability analysis N nutrient



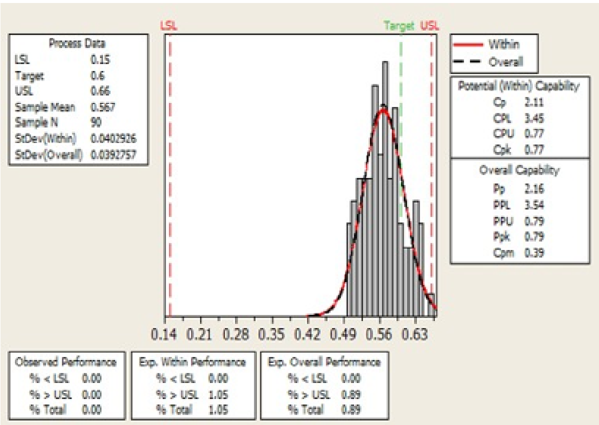
(b) Capability analysis P_2O_5 nutrient



(c) Capability analysis K_2O nutrient



(d) Capability analysis MgO nutrient



(f) Capability analysis B_2O_3 nutrient

Figure 3. Nutrient Process Capability Analysis

in this step we can know the level of factors that can optimize the response to each process variable.

It can be seen in the image of main effect plot signal to noise ratio that produces the optimum value shown in combination of factors and level: A3 - B2 - C1 - D2 -E2 - F2 - G1 - H2. After the data collection is complete, the next step is to carry out the calculation and data proces using analysis of variance (ANOVA). ANOVA is used to find out what factors influence the experimental results.

From the ANOVA calculation results for each nutrient in the Taguchi experiment showed that nutrient N were obtained from the 38°C finish product temperature factor; P2O5 nutrient content is obtained from the water usage factor of 1000 m3 / hour; K2O nutrient content was obtained from the water usage factor of 1100 m3/hour; MgO nutrient levels were obtained from the gas usage 90 MMBtu factor; B2O3 nutrients are obtained from the water usage factor of 1100 m3/hour; physical granule size was obtained from the cooler material temperature 42°C.

Percent contribution is the portion of each factor or factor interaction that is significant to the amount of variance observed. Besides that, the percent contribution also represents an indication of the strength of a factor or interaction between several factors.

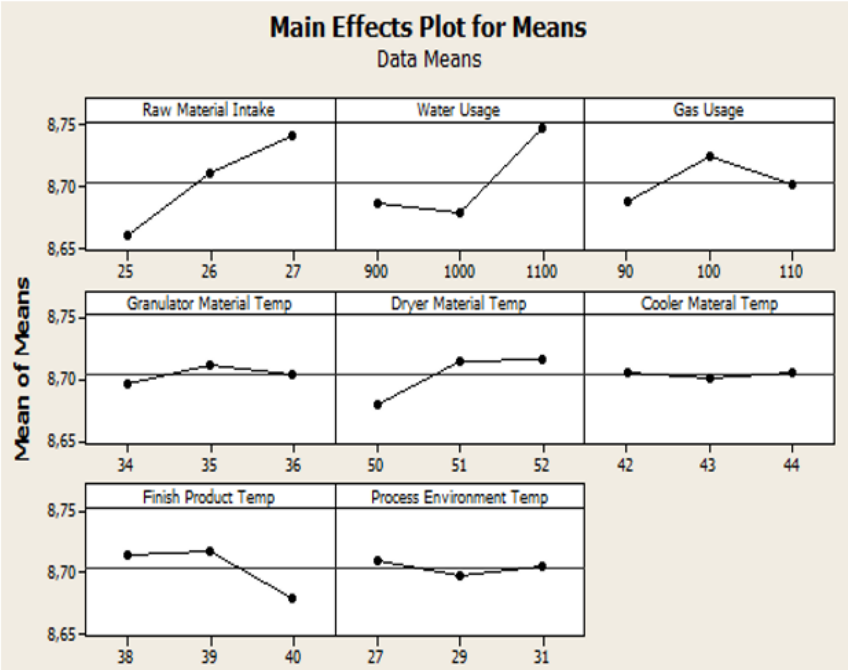


Figure 4. Main effect plot for means.

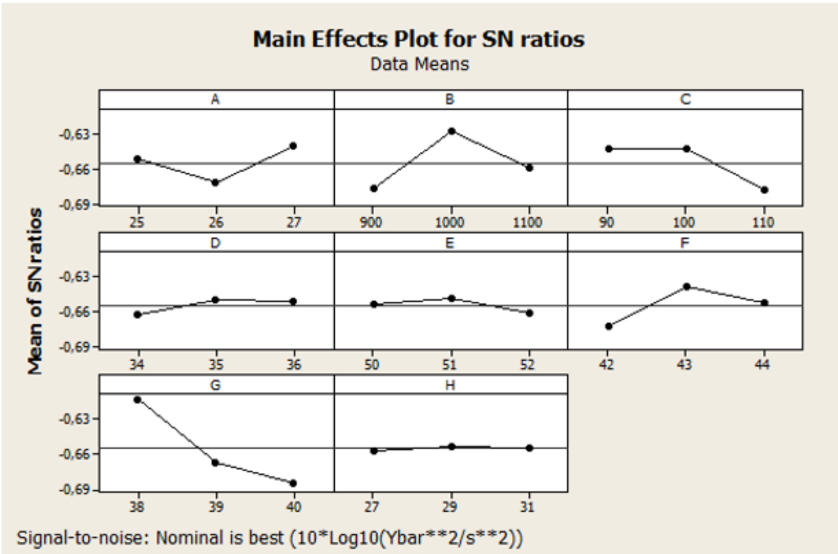


Figure 5. Main Effect Plot Signal to Noise Ratio

In the table above, it is known that the average contribution value is less than 15%. So we can assumed that there are no important factors that must be eliminated from experiments.

IV. CONCLUSION

Referring to the data above, it is found that the nutrient conditions P205, K2O, MgO and B2O3 have not been able to meet product quality specifications marked with a Cpk value <1. Then we need a treatment of the current process conditions so that product variance can be reduced to the maximum extent possible and able to create process conditions the robust one is using Taguchi experiment. Taguchi experiment obtained the results of the optimization of the process parameter level settings in combination as follows: raw material intake 27 mt/hour; water usage 1100 m3/hour; gas usage 100 MMBtu; granulator material temperature 35oC; dryer material temperature 52oC; cooler material temperature of 44oC; finish product temperature 39oC; process environment temperature of 31oC. From the results of ANOVA calculations for each nutrient showed that the highest levels of nutrient N were obtained from the finish product temperature 38oC; P2O5 nutrient content is obtained from the variable water usage of 1000 m3/hour; K2O nutrient content is obtained from the variable water usage of 1100 m3/hour; MgO nutrient content is obtained from the variable gas usage of 90 MMBtu; B2O3 nutrients are obtained from the variable water usage of 1100 m3/hour and the best physical size of the granules is obtained from the variable cooler material temperature of 42oC. The results of this study

Table 4.
ANOVA N Nutrient

Source	DF	Adj SS	Adj MS	F-Value	F-Table	P-Value
Factor	7	19.229	27.470	13.28	2.024	0.000
Level	2	0.661	0.3305	1.60	3.010	0.203
Factor*Level	14	11.089	0.7921	3.83	1.708	0.000
Error	624	129.065	0.2068			
Total	647	160.044				

Table 5.
ANOVA P2O5 Nutrient

Source	DF	Adj SS	Adj MS	F-Value	F-Table	P-Value
Factor	7	10.832	15.474	8.26	2.024	0.000
Level	2	2.349	11.747	6.27	3.010	0.002
Factor*Level	14	14.706	10.504	5.61	1.708	0.000
Error	624	116.867	0.1873			
Total	647	144.754				

Table 6.
ANOVA K2O Nutrient

Source	DF	Adj SS	Adj MS	F-Value	F-Table	P-Value
Factor	7	9.340	13.343	2.47	2.024	0.017
Level	2	3.999	19.995	3.70	3.010	0.025
Factor*Level	14	24.197	17.284	3.20	1.708	0.000
Error	624	337.251	0.5405			
Total	647	374.788				

can reduce as much as possible complaints from customers because the product meets the quality standard specifications required.

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Table 7.
ANOVA MgO Nutrient

Source	DF	Adj SS	Adj MS	F-Value	F-Table	P-Value
Factor	7	49.697	0.70996	15.03	2.024	0.000
Level	2	0.0735	0.03674	0.78	3.010	0.460
Factor*Level	14	13.010	0.09293	1.97	1.708	0.018
Error	624	294.684	0.04723			
Total	647	358.126				

Table 8.
ANOVA B_2O_3 Nutrient

Source	DF	Adj SS	Adj MS	F-Value	F-Table	P-Value
Factor	7	33.681	0.481159	65.71	2.024	0.000
Level	2	0.3519	0.175945	24.03	3.010	0.000
Factor*Level	14	13.883	0.099161	13.54	1.708	0.000
Error	624	45.690	0.007322			
Total	647	96.772				

Table 9.
Contribution Percentage Data

Faktor	Contribution Percentage					
	N	P_2O_5	K_2O	MgO	B_2O_3	Physical
A	12,35	12,15	12,29	11,78	13,70	12,17
B	12,07	13,43	12,60	12,74	18,35	11,87
C	12,06	13,26	12,50	13,45	12,71	10,80
D	12,64	12,21	12,54	13,18	14,60	12,07
E	12,31	12,30	12,61	12,71	14,14	11,78
F	12,72	11,78	12,62	12,09	9,00	14,13
G	13,08	12,70	12,35	12,32	9,69	13,55
H	12,89	12,15	12,50	11,72	7,71	13,63

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