A Survey of Factors on Design for Manufacture of Chemical Fertilizer Granulating Machine

J. A. Ikimi, W. E. Odinikuku, and T. B. Adeleke

Abstract — The design for manufacturing of granulating machines to produce fertilizer granules in small scale using locally available materials is often challenging and this results in low fertilizer usage among Nigerian farmers when compared with the world's average usage. A lot of factors are associated with chemical fertilizer granulating machine, and it is necessary to examine and understand the interplay among these factors. This study weighs up a number of variables that relates with the design and usage of chemical fertilizer granulating machine and offers increased insight and awareness about their insidiousness. The study employed a survey approach, using the Rensis Likert's attitudinal scale, to generate respondents' data matrix that was analyzed with Principal Component Analysis (PCA), and which was facilitated by statistiXL software. Kendall's Coefficient of Concordance (KCC) was used to rank the thirty two (32) identified variables and PCA was thereafter deployed to ascertain the degree of interplay among the variables. Results obtained by KCC suggested that judges ranking were consistent as there was sufficient evidence to reject the null hypothesis. Also, PCA was indicating parsimony in data reduction from 32 variables to mere five. The result established five principal factors creatively labeled Miscellany Components, Technical Considerations, Granulation Efficiency, Agricultural National policy and Biophysical Elements. The most influential variable by its factor loading of 0.894 is Agricultural National policy. A gamut of variables which seem to affect chemical fertilizer granulating machine has been examined. This has helped in discerning similarities in dissimilarities.

Index Terms — Chemical Fertilizer, Scree Plot, Hypotheses, Granulating.

I. INTRODUCTION

The state of food insecurity in Nigeria has become so deplorable that we are called a "food deficit" country in the world. Our agriculture is said to be characterized by low productivity, low technology, and high labor intensity [1]. A body of literature on fertilizers has addressed the need for individuals and organizations to get involved in its production. For instance, [2] called for the involvement and encouragement of private individuals who know how to tap our abundant natural resources in the production of fertilizers. According to [4], one should know that having fertilizers in granules control dust from forming, decrease transportation costs and losses, reduce the risk of freezing and caking. Advance technology of forming inorganic fertilizer granules employed in large-scale production are reported by [5] and [6]. In Nigeria, little appears to be known on the appropriate technology for small-scale production of inorganic fertilizers

in granules. This has resulted to a huge lack of fertilizer or fertilizer machines for use by the local farmer in the absence of government subsidized commercial chemical fertilizer. There is a concomitant overutilization of the arable land which leads to poor crop yields for a given space. The need therefore to boost land fertility through the use of both organic and chemical fertilizers has been canvassed [6] and [7]. The arable farmland of the country has remained highly uncultivated because the government is not involved in large scale farming as was the case in the colonial era. The need therefore to boost land fertility through the use of both organic and inorganic fertilizers is desirable. More so is this necessary because the application of fertilizer in Nigeria is very low when compared with the average application in the world as stated by [8]. Granulation as a process of improving flowability and appearance of fertilizers is one of the major processes involved in fertilizer production which transforms fine powders into granules in order to improve the characteristics of materials used as fertilizers and as a means of protecting the end users from hazards such as dust, [9]. Efforts made by past and present government through the combine provisions of importing and producing fertilizer and supply/distribution of fertilizer to farmers at subsidized prices to boost farmers' productivity has not been very successful. The result is that fertilizer usage among Nigerian farmers has remained very low (13 kg/hectare) as compared with the world's average usage (100 kg/hectare). It becomes urgent therefore to meet this huge demand through the design and construction of fertilizer granulating machine to produce fertilizer granules in small-scale using available local materials. There is drought of information vis-à-vis the technology to develop and produce fertilizer in small scale using locally sourced materials. Hence, appropriate technology of producing fertilizer in the most acceptable way have to be explored there after designed and constructed with the acquired and previous engineering know-how. A novel application of two statistical techniques namely Kendall Coefficient of Concordance and Principal Component are novel statistical tools used in this study. PCA is a dimensional-reduction tool that can be used to reduce a large set of variables to a small set that still contains most of the information in the large set. The goal is dimension reduction, and it selects a subset of variables from a larger set, based on which original variables have the highest correlations with the principal component. In the context of management and factorial analysis [10] asserts that a trivial fraction of the entirety is accountable for a great quantity of the total result.

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There is gamut of variables that individually and collectively affect the design, manufacture and usage of chemical fertilizer granulating machine. These variables need to be analyzed collectively in order to have a systemic understanding of them.

II. METHODOLOGY

A. Kendall's Coefficient of Concordance

An exploratory survey of the factors was conducted using well-crafted questionnaires. 32 variables were used to craft questionnaires scaled with 5-point likert's attitudinal scale and administered to over 100 respondents. Also, 13 judges knowledgeable in the area were required to rank variables in order of importance from the most to the least important and respondents' scores were transposed into matrix variables.

Kendall's Coefficient of Concordance (W), can be calculated using (1):

$$W = \frac{S}{\frac{1}{12} K^2 (N^3 - N)} \quad (1)$$

where,

$$S = \sum \left(R_j - \frac{\sum R_j}{N} \right)^2$$

R_j = Column sum of ranks;
 N = Total number of Variables;
 S = Variance;
 K = Number of experts.

B. Principal Component Analysis

The Principal Component Analysis is one of the methods of factor Analysis. Respondents' scores were collated as data matrix. The data matrix was fed into StatistiXL software that gave the outputs which include scree plot, factor plot, varimax rotated factor loadings amongst others.

$$r_{ij} = \frac{\sum xy}{\sqrt{(\sum x^2)(\sum y^2)}}$$

where

$$x = x_{ij} - \bar{x}_{ij}$$

$$y = y_{ij} - \bar{y}_{ij}$$

$$\bar{x}_{ij} = \frac{\sum_{i=1}^N x_{ij}}{N}$$

$$\bar{y}_{ij} = \frac{\sum_{i=1}^N y_{ij}}{N}$$

$$N = n_j = i_{\max}$$

$$J = j_{\max}$$

III. RESULT AND DISCUSSION

A. Results of Kendall's Coefficient of Concordance

The test hypotheses are:

H_0 : The ranking of the 13 judges is not coherent.

H_1 : The ranking of the 13 judges is coherent.

Therefore, to calculate for:

$$\begin{aligned} \chi^2 &= K(N-1)W \\ &= 13(32-1)0.466 \\ &= 13(31)0.466 \\ &= 187.79 \end{aligned}$$

$$\chi^2_{cal.} = 187.79$$

Therefore, to calculate for the χ^2_{tab} because we need to plot the tabulated values and also the calculated value and then apply our decision rule in order to get a reliable conclusion.

$$\chi^2_{tab_{0.01,32}}$$

From our chi-square table, χ^2_{tab} whereby -1 is introduced which signify the degree of freedom.

$$\chi^2_{0.01,32}$$

Note: our alpha level (α) = 0.01

$$\chi^2_{0.01,31} = 79.65$$

The coefficient of concordance was computed as $W = 0.54$, which is a middling.

From our decision rule which say:

Reject H_0 if $F_{cal} > F_{tab}$

Accept H_0 if $F_{cal} < F_{tab}$

And $79.65 < 187.79$

Since our $F_{cal} > F_{tab}$, this concludes that experimental data do not furnish enough evidence for us to accept the null hypothesis claim which says experts ranking were at discordance. This then implies that experts ranking is at concordance. The chi square test at 0.01 significant levels shows the critical values is 79.65. This made us to not accept the null hypothesis that the judges ranking is discordant. Our conclusion therefore is that the judges use the same criteria for the ranking of all the scale items. Consequently, the statistical tool was able to rank the scale items in merit order of sequentially and they are depicted hereunder in Table I.

The import of this ordering of the variables by the judges enabled us to know that Agricultural national policy is considered most important in the use of fertilizer granulating machine.

Fig. 1. Scree plot.

TABLE I: MERIT ORDER SEQUENTIALITY OF THE 32 VARIABLES

S/No	R_j	Variables	S/No	R_j	
1	76	Agricultural national policy	17.	207	Natural deposits
2	80	Design Considerations	18.	213	Granules spill rate
3	83	Machine Production Cost	19.	238	High power requirements
4	84	Availability of Raw materials	20.	254	Soil fertility
5	92	High cost of maintenance	21.	264	Granulation process efficiency
6	102	Fertilization Demand	22.	270	Fertilizer production know-how
7	145	Associated Legislation and Regulation	23.	274	Granulometric content
8	149	Production of Biofertilizers	24.	275	Physical-chemical properties
9	153	Optimum Granules Formation	25.	280	Fertilizer granulation disc
10	164	Preference for Pelletizer	26.	281	Atmospheric conditions
11	167	Scarcity of Inorganic fertilizer	27.	285	Granulation method
12	172	Lack of indigenous Technology	28.	306	Safety considerations
13	173	Enhanced efficiency fertilizer	29.	312	Ease of use
14	195	Environmental issues	30.	335	Complexity of design
15	196	Level of farmers productivity	31.	337	Characteristics of granules
16	207	Lack of innovation	32	340	Equipment type

TABLE II: VARIMAX ROTATED FACTOR LOADINGS

S/N	Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
1	Agricultural national policy	0.516	0.385	0.316	0.894	0.097
2	Design Considerations	0.815	0.463	0.228	0.057	0.103
3	Machine Production Cost	0.452	0.776	0.255	0.236	0.134
4	Availability of Raw materials	0.594	0.437	0.380	0.266	0.333
5	High cost of maintenance	0.530	0.742	0.207	0.137	0.126
6	Fertilization Demand	0.540	0.724	0.300	0.142	0.067
7	Associated Legislation and Regulation	0.811	0.465	0.208	0.150	0.144
8	Production of Biofertilizers	0.543	0.737	0.222	0.185	0.081
9	Optimum Granules Formation	0.739	0.376	0.245	0.359	0.033
10	Preference for Pelletizer	0.577	0.455	0.458	0.193	0.181
11	Scarcity of Inorganic fertilizer	0.830	0.425	0.211	0.165	0.144
12	Lack of indigenous Technology	0.723	0.344	0.355	0.268	0.113
13	Enhanced efficiency fertilizer	0.405	0.597	0.619	0.223	0.114
14	Environmental issues	0.382	0.793	0.312	0.246	0.146
15	Level of farmers productivity	0.411	0.826	0.260	0.107	0.121
16	Lack of innovation	0.819	0.433	0.214	0.192	0.109
17	Natural deposits	0.424	0.500	0.361	0.093	0.626
18	Granules spill rate	0.426	0.667	0.238	0.115	0.149
19	High power requirements	0.787	0.480	0.270	0.100	0.134
20	Soil fertility	0.790	0.498	0.233	0.101	0.078
21	Granulation process efficiency	0.771	0.384	0.264	0.263	0.244
22	Fertilizer production know-how	0.506	0.776	0.212	0.157	0.089
23	Granulometric content	0.461	0.384	0.561	0.233	0.123
24	Amount of rainfall	0.392	0.469	0.383	0.176	0.598
25	Fertilizer granulation disc	0.470	0.786	0.234	0.124	0.106
26	Atmospheric conditions	0.783	0.380	0.267	0.254	0.031
27	Granulation method	0.312	0.599	0.694	0.176	0.105
28	Safety considerations	0.395	0.721	0.334	0.165	0.174
29	Ease of use	0.667	0.344	0.374	0.320	0.126
30	Complexity of design	0.398	0.710	0.419	0.204	0.124
31	Characteristics of granules	0.418	0.789	0.297	0.232	0.133
32	Equipment type	0.725	0.567	0.182	0.168	0.022

B. Factor Interpretation

The PCA adopted with the aid of Statistix software, generated five (5) clusters or platoons. A principal factor embodying fourteen (14) variables which were creatively labelled; Notable factors in this cluster are design considerations, associated legislation and regulation, scarcity of inorganic fertilizer and lack of innovation with factor loadings of 0.815, 0.811, 0.830 and 0.879. These are important scale items that affect the design of a fertilizer granulating machine. The rest variables under this factor in themselves are also important and should be looked at accordingly.

TABLE III: TECHNICAL CONSIDERATIONS

Clusters 2(Factor 2): Technical Considerations		
S/N	Variable description	Factor loading
3	Machine Production Cost	0.776
5	High cost of maintenance	0.742
6	Fertilization Demand	0.724
13	Enhanced efficiency fertilizer	0.597
14	Environmental issues	0.793
15	Level of farmers productivity	0.826
18	Granules spill rate	0.607
22	Fertilizer production know-how	0.776
25	Fertilizer granulation disc	0.786
28	Safety considerations	0.721
30	Complexity of design	0.710
31	Characteristics of granules	0.789

Cluster 2 is creatively labelled Technicalities. The factor loadings are all positive. The cluster also encapsulates a wide variety of factors. Of note amongst them are machine production costs, environmental issues, level of farmer's productivity with factor loadings of 0.776, 0.793 and 0.826. The cost of a granulating machine will determine if it can be easily bought by farmers. Relatedly, how productive a farmer is will also determine if he should purchase the granulating machine or look for other cheap means or source of fertilizer application.

TABLE IV: GRANULATION EFFICIENCY

Clusters 3(Factor 3): Granulation Efficiency		
S/N	Variable description	Factor loading
13	Enhanced efficiency fertilizer	0.619
23	Granulometric content	0.561
27	Granulation method	0.694

The third factor is a trio comprising Enhanced efficiency fertilizer, Granulometric content and Granulation method. They have middling factor loadings suggesting that their role is moderately influenced.

TABLE V: AGRICULTURAL NATIONAL POLICY

Clusters 4(Factor 4): Agricultural National Policy		
S/N	Variable description	Factor loading
1	Agricultural national policy	0.894

There is also a lone factor creatively labeled Agricultural national policy. It is a lone factor that is a major factor of its own. Its factor loading is very substantial. Every country's agricultural national policy differs, and this is also what needs to be considered in the manufacture of chemical fertilizer granulating machine.

TABLE VI: BIOPHYSICAL ELEMENTS

Clusters 5(Factor 5): Biophysical Elements		
S/N	Variable description	Factor loading
17	Natural deposits	0.626
24	Amount of rainfall	0.598

Finally, we encounter a dual factor creatively labelled Biophysical element. They were labeled so because an important obstacle to promoting fertilizers demand is the diversity of biophysical conditions across the country. The amount of annual rainfall differs from north to south. Also, natural deposits vary from place to place.

IV. CONCLUSION

The results established five principal factors which were creatively labeled. Results obtained by KCC suggested that judges ranking were consistent. Also, PCA was indicating parsimony in data reduction from 32 variables to mere five. The most influential variable by its factor loading of 0.894 is Agricultural national policy. This has helped in discerning similarities in dissimilarities. The Rj totals were arranged in increasing order of sequence. R1, R2, R3....Rn, and this helped to determine the order of importance of the variable as ranked by the thirteen Judges. Five clusters of variables were generated from the study with the aid of statistical XL software. The general and latent implications and results of each cluster which are creatively labeled with regards to the design, manufacture and usage of chemical fertilizer granulating machine have been highlighted and the study has established inter correlations among the variables. Kendall Coefficient of Concordance provided a merit order sequentiality of these variables. A null hypothesis claiming that the ranking of the range of factors by thirteen (13) Judges is discordant was rejected. The results obtained from the study are not only figure-hugging but also tight-fitting.

REFERENCES

- [1] Ammani, A.A., Alamu, J.F. and Kudi, T.M. (2010) Effects of Fertilizer Liberalization on Maize Production in Nigeria. Journal of Development and Agricultural Economics, 2(11): pp. 401-405.
- [2] I.A. Daniyan1, A.M. Omokhuale1, A.A. Aderoba1, O.M. Ikumapayil and B.A. Adaramola (2017), Development and performance evaluation of organic fertilizer machinery September Cogent Engineering 4(1).
- [3] Fayed, M. E. and Otten, L. (Eds) (1984) Handbook of Powder Science Technology, Size Enlargement Methods and Equipment, pp. 230-344.
- [4] Food and Agriculture Organization of the United Nations, FAO (1975) The state of food and agriculture 1974 world review by regions population, food supply and agricultural development Rome, Italy.
- [5] Capes C. E. (1982) Particle Size Enlargement, Elsevier Scientific Publishing Company, New York.
- [6] Ezeokonkwo, J. C. (2011) Engineering Properties of NPK Fertilizer Modified Soil. Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) 2 (6): 962-966.
- [7] Phillip, D., Nkoya, E., Pender, J. And Oni O.A. (2009) Constraints to Increasing Agricultural Productivity in Nigeria: A Review. Nigeria Strategy Support Program (NSSP) Background Paper No. NSSP 006, Abuja, Nigeria.
- [8] Deb Ratul, Ahmed Abdul Baquee. 2013. Pellet and pelletization techniques: A critical review. International Research Journal of Pharmacy; 4(4): 90-95.

- [9] Sochon R. P. J., S. Zomer, J. J. Cartwright, M. J. Hounslow, and A. D. Salman. 2010. The variability of pharmaceutical granulation. *Chemical Engineering Journal* 164: 285 – 291.
- [10] Ekejiuba, A.I.B., 2017. Real-Time Monetization of the Flared Associated Stranded Natural Gas in Nigeria: Quantitative Analysis and Qualitative Values. *The International Journal of Science & Technology*, Vol. 5 Issue 8, pp. 96-98.