Development and Testing of Chemical Fertilizer

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Abstract
Food and agriculture offers key solutions for sustainable development and is central for hunger eradication and job creation. The decline and lack of inorganic fertilizer for the local farmers to ensure availability of food in Nigeria has been a cause for concern. In the same vein, appropriate technology for small scale manufacture of inorganic fertilizers to improve crop yields are in short supply. This paper reports studies carried out first to formulate NPK (Nitrogen, Phosphorous and Potassium) (15:15:15) chemical fertilizer through basic and accurate experimental processes. It goes further to show how a model pan granulating machine was designed and manufactured such that it works effortlessly and efficiently to give typical fertilizer granules. And lastly it evaluates the results from agricultural experiments carried out on maize plant to prove that the fertilizer granules produced is potent and compares favorably with the performance of commercial fertilizer.

Keywords: fertilizer, development, granulation, sustainable, randomized,

INTRODUCTION
Pan granulating machine is specialized equipment that is used to produce granules from chemical fertilizer powders. Each granule formed must have all the constituent nutrients in the correct proportion and of sizes from 2.5mm to 4.0mm. As a whole the granules are such that promotes easy handling and distribution without caking.

It is worthy of note that arable land in Nigeria is gradually narrowing on account of several factors such as desertification, increasing population, erosive activities, developmental activities, etc. Also there is a concomitant over utilization of these 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 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 reported by FAO (1975). Added to the foregoing is the strong campaign to end hunger and promote sustainable agriculture by the united nation organization (UNO), Umberto Pisano et al (2015).

A body of literature on fertilizers has addressed the need for individuals and organizations to get involved in its production. For instance, Aromaye (1997) called for the involvement and encouragement of private individuals who know how to tap our abundant natural resources in the production of fertilizers. Also, the subsidy on fertilizer, as it is in the budget of 1997, will promote a healthy competition in the production and sales of fertilizers in the country so states Aromaye (1997). To this end A. J. Sacket industry has gone about building medium scale fertilizer plants in several northern and middle-belt states in the federation, explained Bello (2002). But a major setback in the production of fertilizer is the process of producing the fertilizers into granules. Sastry (1977) helps us to realize 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 Capes (1981), Fayed and Otten (1984), Carolyn (1996), Richard and Burks (1997). But 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.

The main aim of this research is to formulate NPK (15:15:15) chemical fertilizer, using appropriate available raw materials and ascertain the relative quantity that would chemically combine to yield potent fertilizer. Also in this research a model granulating machine that formed the fertilizer in granules was designed and produced by the authors Ikimi and Edegbe (1997), Ikimi (2002) and Ohworeko et al (2012). Next, the experimental fertilizer was tested and compared with commercial fertilizer using maize plant on the soil. A major constraint in this research is the obvious short period of time (ten weeks) out of the academic year used to carry out testing on maize plant. This research is relevant in that it helps our local farmers to become equipped to provide for their fertilizer needs and to be an asset to the government in improving food production thus ensuring sustainable agricultural development.

METHODOLOGY
Experimental Methods
A number of experiments are involved in the determination of the relative amounts of Nitrogen, Phosphorus and Potassium from the sample raw
material for the manufacture of NPK fertilizer. The basic raw materials include ammonium sulphate or ammonium chloride, phosphoric acid, potassium sulphate or potassium chloride. I what follows, we describe the determination of the relative quantity of Nitrogen, Phosphorus and Potassium in the sample.

**Percentage Determination of Nitrogen in Sample of Ammonium Sulphate or Ammonium Chloride**

Weigh and put into a 25ml Kjedah 1 flask about 2g of sample. Add 5g of anhydrous sodium sulphate, 1g of copper sulphate and a speck of selenium dioxide (Selenium dioxide is a catalyst), followed by 25ml of concentrated sulphuric acid. Heat and shake the flask for about 10 minutes. Allow content to cool and then transfer to 250ml graduated flask where distilled water is added to make to mark.

Transfer mixture to Markham distillation apparatus and introduce a strong caustic soda that would facilitate the release of ammonia, but steam out the apparatus for 10 minutes before use. Add boric acid while observing all necessary precautions to prevent violent suck back. Titrate the content of the receiving flask with 0.01ml hydrochloric acid.

Calculation: Go to Appendix I

**Percentage Determination of Phosphorus in Sample of Phosphoric Acid**

Measure into a silica dish 2ml of sample and moisten with 5ml of 20% calcium solution. Heat to dryness for about 30 minutes and allow for cooling. Add 15ml of 10% nitric acid using a pipette and cover the basin with a watch glass. On completion, rinse the watch glass with nitric acid and digest the content of the basin over small flame. Filter and wash filter paper with hot nitric acid and water. Make to mark after cooling and transfer into a beaker.

Add 2ml concentrated nitric acid and 10g of solid ammonium nitrate and stir to dissolve. Add 25ml special ammonium molybdate reagent and heat to 550°C on a water bath and after stirring allow to stand over-night where precipitation takes place. Filter off the precipitate and wash with sodium nitrate. Add 100ml distilled water and a measured amount of 0.2ml sodium hydroxide to dissolve the precipitate. Add 10 drops of phenolphthalein and back-titrator with 0.2ml perchloric acid until the last trace of pink has disappeared.

Calculation: Go to Appendix II

**Percentage Determination of Potassium in Sample of Potassium Sulphate or Potassium Chloride**

Dry the sample at 105°C and grind to fine powder. Weigh accurately 2g of sample into a beaker, then add and mix 25ml nitric acid, 5ml sulphuric acid and 5ml perchloric acid then mix by swiveling the beaker. Warm the solutions until frosting commences and stop for reaction to subside. Then warm further with low heat to allow sulphuric acid to evolve because high rate heating boils off the nitric acid. After cooling, add 10ml de-ionized water and filter the solution into a 100ml volumetric flask. Make to mark the filtrate with water. This final solution is used in the determination of percentage concentration employing standard curves provided for different minerals.

The results of the various experiments are shown in tables 1 and 2.

<table>
<thead>
<tr>
<th>Trial</th>
<th>% Nitrogen</th>
<th>% Phosphorus</th>
<th>% Potassium</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20.5</td>
<td>45.9</td>
<td>49.7</td>
</tr>
<tr>
<td>2</td>
<td>21.2</td>
<td>46.1</td>
<td>49.8</td>
</tr>
<tr>
<td>3</td>
<td>20.8</td>
<td>43.8</td>
<td>50.3</td>
</tr>
<tr>
<td>Total</td>
<td>62.5</td>
<td>139.8</td>
<td>149.7</td>
</tr>
<tr>
<td>Mean</td>
<td>20.83</td>
<td>45.93</td>
<td>49.9</td>
</tr>
</tbody>
</table>

**Product Formulation**

In the formulation of NPK (15:15:15) chemical fertilizer, ammonium sulphate or ammonium chloride and potassium sulphate or potassium chloride were respectively reduced to 15% composition by weight through the addition of kaolin which is used as filler in this instance according to the formulation shown in Table 2. By adding appropriate amounts of kaolin 1000g resulted. A similar approach using distilled water was applied in diluting to 15% of 100ml Phosphoric acid. At this stage, each of these samples is said technically to be a straight fertilizer, but when combined, it becomes a compound fertilizer, that is NPK (15:15:15) compound chemical fertilizer. Next is to formulate the fertilizer to granules by means of granulating machine.

**Model Pan Granulating Machine design**

**Design Objectives**

The following were the objectives of the design and manufacture of the pan granulating machine.

- Granules should be well formed
- Granules should not be lost to the surrounding because of the spinning of the pan
- Dust or fumes should not build up.
- The cost should be minimal as materials will be sourced locally.

**Theoretical Analysis**

The analysis is aimed at satisfying the above stated objectives and the machine is structured into three units: Feeding unit, granulating unit and outlet unit.
The feeding unit is the hopper while the granulating unit is a complete circular base bounded by the edge to form a pan-like piece with a scraper attached and the last is the outlet unit that consist of a cap-like cover/guide. All of these are made of mild steel sheet but of various thicknesses. Below are the related mathematical formulas employed in the design process.

**Load on machine**
Two loads are prominent here and they are the pan load and the pulley load and they acts vertically downward with the force, \( F_p = \frac{m \times g}{\cos \theta} \) \(-i\)
where \( m \) = mass of pan or of pulley, \( g \) = acceleration due to gravity and \( \cos \theta \) = cosine of the angle of inclination to the horizontal

**Torque required to rotate loads**
\( T = F_p \times r \) in N-m \(-ii\)
where \( F_p \) = Force of pan acting on shaft \( r \) = Radius of pan to the center

**Power of electric motor**
Power sufficient to produce the torque, \( P = \frac{2 \times \pi \times N \times T}{60} \) watts \(-iii\)
also note that \( \frac{watts}{746} = Hp \)

**Diameter of shaft**
The shaft is subjected to both torsional and bending moments. Based on strength, the diameter of shaft was therefore obtained theoretically using the relation, \( T = T_c \). The formula for equivalent twisting moment, \( T_c = \sqrt{(K_s M)^2 + (K_t T)^2} \) \(-iv\)
where \( M \) = Bending moment, Nm; \( T \) = Torsional moment or Torque, Nm; \( K_s \) = Combined shock and fatigue factor applied to bending moment; \( K_t \) = Combine shock and fatigue factor applied to torsional moment.

Whereas torque, \( T = \frac{\pi \times \tau \times d^3}{16} \) \(-v\)
where \( \tau \) = maximum permissible shear stress of shaft

**Belt Drive**
Belts are employed to transmit power from one shaft to another. The flat belt was chosen because of its numerous advantages.
The following relations were used to determine the required parameters

\[ \frac{T_1}{T_2} = e^{\mu \theta} \] \(-vii\)

where \( T_1 \) = tension on tight side of belt and \( T_2 \) = tension on slack side of belt

**Belt tension power relation**
\( T_1 - T_2 = \frac{P_d}{V_p} \) \(-viii\)

**Peripheral velocity**
\( V_p = \pi \frac{D_p \times N_1}{60} \) \(-ix\)

**Centrifugal tension**
\( T_c = \frac{m \times v^2}{2} \) \(-x\)
where \( m \) = mass of belt, \( m \) = Area x length x Density

**Maximum tension**
\( T_{max} = T_1 + T_c \) \(-xi\)

**Gears**
The granulator pan is driven by a pinion meshed with a spur gear. The arrangement was considered using the Speed Ratio relationship:
\( \frac{N_1}{N_2} = \frac{T_2}{T_1} \) \(-xii\)
where \( N_1 \) = the speed of pinion, \( N_2 \) = speed of gear, \( T_1 \) = the teeth on pinion and \( T_2 \) = the teeth of gear. Other parameters of the gears were determined using the following relations:

**Dynamic load**
\( W_D = W_t + \frac{21v \times (b \times C + W_T)}{21v + \sqrt{b \times C + W_T}} \) \(-xiii\)
where \( v \) = pitch line velocity, \( b \) = face width of gears, and \( C \) = a deformation or dynamic factor

**Designed tangential load**
\( W_T = \frac{P}{V} \) \(-xiv\)
where \( P \) = Power transmitted, \( V \) = pitch line velocity and \( C_s \) = Service factor

**Velocity of pinion**
\( V = \frac{\pi D_p N_p}{60} \) \(-xv\)

**Wear load**
\( W_W = D_p b Q K \) \(-xvi\)
where \( D_p \) = pitch circle diameter of pinion, \( b \) = face width of pinion, \( Q \) = ratio factor

Where Ratio factor, \( Q = \frac{2 \times V \times R}{\pi \times d_4 + 1} \) \(-xvii\)
for external gears.

**Shear stress on the pan shaft**
Where second moment of area of the section about the polar axis, \( J = \frac{\pi \times d^4}{32} \) \(-xviii\)

The maximum shear stress from the combine load of pan and raw material that is induced on the shaft, \( \tau = \frac{T \cdot v}{J} \) \(-xix\)

**RESULTS**
The fertilizer produced by the granulating machine under reference was applied on maize plant and the growth process observed for 10 weeks as shown in Table I and Graph 1 below.
Table 1: Maize Growth Rate

<table>
<thead>
<tr>
<th># of Weeks</th>
<th>Height</th>
<th>Size</th>
<th># of leaves</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>6.5</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>10.8</td>
<td>8.2</td>
<td>7.8</td>
</tr>
<tr>
<td>4</td>
<td>13.6</td>
<td>10.2</td>
<td>9.7</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td>14</td>
<td>13.5</td>
</tr>
<tr>
<td>6</td>
<td>38.6</td>
<td>18.8</td>
<td>18</td>
</tr>
<tr>
<td>7</td>
<td>74</td>
<td>32.4</td>
<td>27.5</td>
</tr>
<tr>
<td>8</td>
<td>116.8</td>
<td>60</td>
<td>48</td>
</tr>
<tr>
<td>9</td>
<td>140</td>
<td>100</td>
<td>77</td>
</tr>
<tr>
<td>10</td>
<td>162</td>
<td>154</td>
<td>128</td>
</tr>
</tbody>
</table>

Graph 1: Growth Rate

Analysis of Data

In analyzing the above findings a parametric statistical method called randomized block design was applied as a basis for the analysis of variance (ANOVA) method. The commercial fertilizer was used as control to establish if there were block effects. Maize features under the two blocks were treatments. The observations obtained are randomized as shown in Appendix IV. The population of interest is generally called treatments and they are observed growth in form of height, size and number of leaves. The responses of greater interest are the blocks, which comprises the commercial and experimental fertilized soil.

When the order of responses is randomized, the resulting design now becomes a randomized block design. In this way any true treatment or block differences are more likely to show up in the analysis. The analysis of variance in this experiment will provide answer to the test of the null hypothesis:

\[ H_0: \sum_0 = 0, \quad \text{against the alternative} \quad H_1: \sum_0 = 0 \]

\[ H_0': \sum_0 = 0, \quad \text{against the alternative} \quad H_1': \sum_0 = 0 \]

Appendix V shows the result of the calculations.

The ANOVA result for maize growth rate table at Appendix V shows that \( F_{cal} = 4.031 > F_{1.54.0.05} = 2.203 \). It is a clear indication that \( F_{cal} \) is located far into the rejection region suggesting that we lack sufficient evidence to accept the null hypothesis which avers that there is no differential treatment. However, our main focus is on the block effect. Row 3 shows that \( F_{cal} = 2.203 < F_{2.54.0.05} = 3.17 \) (from chart) thus prompting us to state that we do not have enough evidence to reject the null hypothesis that there is no differential block effects, i.e \( \Sigma_0 = 0 \). In other words, there appears to be practically no difference in potency between the commercial fertilizer and experimental one.
DISCUSSION
In this study, a potent inorganic fertilizer has been compounded with the aid of a model pan granulating machine designed and constructed by the authors. As explained the machine works efficiently and satisfies all design parameters to be able to produce granules. It is also reliable, simple to operate and does not spill out granules or produce dusts. The cost of producing the pan granulating machine is ₦85,000.00 (Eighty Five Thousand Naira) or $274.00 (Two Hundred and Seventy four US Dollars). Hence we can say it is inexpensive when compared with what it takes the government to build large-scale fertilizer plant. In addition, the above simple and concise experimental studies simply validate the research claim that the experimental fertilizer is suitable and meets international standards. The experimental fertilizer do not cake when stored in bags, though not hygroscopic but dissolve readily and poses no threat to plant (maize) used in the experiment. It was observed in the study that the plant nurtured with the experimental fertilizer later outgrew and out distanced the control plant grown with the commercial fertilizer. This particular observation was noticed beyond the 10 weeks schedule of the experiment. Perhaps a spectacular result of this study is that the inorganic fertilizer developed has proved to be easy to handle and appears to fulfill the yearnings of Nigerian farmers.

CONCLUSIONS
A potent NPK (15:15:15) inorganic fertilizer has been developed with a model pan granulating machine. The machine meets all known design criteria and works efficiently. Statistical tests carried out confirm that the performance of the fertilizer compares favorably with commercial type. Bulk of the materials used for blending the fertilizer was locally sourced thereby giving the hope that sustainable agricultural development is within reach. Further research may be necessary for the improvement on the result obtained on this study and create awareness on this research theme.

It is my recommendation that state and local governmental authorities as well as private entrepreneurs should invest in this inexpensive technology so as to stimulate fertilizer and food production, agricultural development, employment growth, and rural prosperity. This will go a long way in contributing to sustainable development locally and by a large extent globally.

REFERENCES
Aromaye, L. (1997): Former President of the council of Nigeria Farmers. The Guardians, February 21

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
Umberto Pisano, Lisa Lange, Gerald Berger and Markus Hametner (2015): The Sustainable Development Goals (SDGs) and their impact on the European SD governance framework - Preparing for the post-2015 agenda. ESDN Quarter Report, Vienna Austria
APPENDIX I
Where sample is ammonium sulphate or ammonium chloride we have the following:
\[(NH_4)_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2NH_3 + 2H_2O\] or
\[NH_4CL + NaOH \rightarrow NaCL + NH_3 + H_2O\]
5ml containing 0.001M = 5.85 x 0.0014% of N
25ml of 1M will contain = \[\frac{250 \times 5.85 \times 0.0014}{5 \times 100}\] of N
2g of sample contains = \[\frac{250 \times 5.85 \times 0.0014}{2 \times 5 \times 100}\] of N
Therefore 100g of sample will contain = \[\frac{2500 \times 5.85 \times 0.0014 \times 100}{2 \times 5 \times 100}\] of N = 0.205 of Nitrogen = 20.5% of Nitrogen.

Appendix II
\[H_3PO_4 + NaOH \rightarrow NaPO_4 + H_2O + H_2\]
25ml containing 0.001M = 5.92 x 0.0031% of P
Therefore, 100ml of sample will contain \(100 \times 5.92 \times 0.0031\) / \(100 \times 25\) of P = 0.459 of Phosphorus = 45.9% of Phosphorus.

Appendix III
We now obtain the force of the pan from equation (i) \(F_{Pan} = \frac{15 \times 9.81}{\cos 50}\) = 228.9 N
Then we obtain the torque required to rotate the pan, which is drawn from equation (ii) as Torque, \(T = 228.9 \times 0.4 = 91.56\) N-m
With this values and assuming a turning speed for the granulator pan to be 155rev/min, the power of the electric motor from equation (iii) can be determine as
\[Power, P = \frac{91.56 \times 2 \times 3.142 \times 155}{60} = 1490\] watts.
Since 1Hp = 746 watts, therefore \(\frac{1490}{746} = 1997\) Hp or 2Hp
Considering factor of safety, a 2Hp electric motor with a speed of 1500 rev/min is required to drive the shaft.
Note that the pulley also acts vertically downward with a force from equation (i), \(F_{Pulley} = \frac{2 \times 9.81}{\cos 50}\) = 31N
We were able to find that Maximum tension from equation (xi), \(T_{max} = 103.23 + 2.7 = 106N\)
Total load on pulley = 106 + 31 = 137 N

First of all let us find out the reactions \(R_C\) and \(R_D\)
Taking moment about D, we have
\[R_C \times 250 = (R_A \times 200) + (R_B \times 120) = (137 \times 200) + (228.9 \times 120)\]
\[250 \times R_C = 27400 + 27468 = 54868\]
\[R_C = \frac{54868}{250} = 219.5N\]
\[R_D = R_A + R_B - R_C = 137 + 228.9 - 219.5 = 146.4N\]
Shear force diagram
\(F_A = R_A = 137N\)
\[ F_C = 137 - 146.4 = -9.4N \]
\[ F_D = -9.4 - 146.4 = -155.8N \]

**Bending moment diagram**

\[ M_C = 0 \]
\[ M_A = 219.5 \times 200 = 43900N\text{-}\text{mm} \]
\[ M_B = 146.4 \times 250 = 36600N\text{-}\text{mm} \]
\[ M_D = 0 \]

From here the **maximum bending moment** is at \( M_A = 43900N\text{-}\text{mm} \)

The American society of mechanical engineers (ASME) code for the design of transmission shafts gives maximum permissible shear stress as 42N/mm\(^2\).

Equivalent twisting moment from equation (iv) is obtained from

\[ T_e = \sqrt{(1.5 \times 43900)^2 + (1.0 \times 15453)^2} = 67.7 \times 10^3 \text{ N}\text{-}\text{mm} \]

From here the shaft diameter is obtained using equation (v),

\[ 67.7 \times 10^3 = \frac{\pi \times 42 \times d^3}{16} \]

\[ d = \sqrt[3]{\frac{67.7 \times 10^3 \times 16}{42 \times 3.142}} = 20.17\text{mm} \]

**Hence shaft diameter is 20mm**
Consider the primary pulleys first in the compound pulleys arrangement

The angle of lap for small pulley, from equation (vi)

\[ \theta_1 = 3.142 - \left[ \frac{150 - 60}{400} \right] = 2.917 \text{ rad} \]

The angle of lap for large pulley,

\[ \theta_2 = 3.142 + \left[ \frac{150 - 60}{400} \right] = 3.367 \text{ rad} \]

We obtain belt tension through the ratio from equation (vii) as

\[ \frac{T_1}{T_2} = e^{0.25 \times 2.917} = 2.07 \]

Hence \( T_1 = 2.07T_2 \) in relation to belt tension

Since \( V_P = \frac{(3.142 \times 0.06 \times 3450)}{60} = 10.84 \text{ m/s} \)

Then equation (viii) applies as \( T_1 - T_2 = 1119 / 10.84 = 103.23 \) relating to what is above we now have \( 2.07T_2 - T_2 = 103.23 \) thus \( 1.07T_2 = 103.23 \)

Therefore, \( T_1 = 103.23 / 1.07 = 96.48 \text{ N} \)

Mass of belt, \( m = 0.013 \times 0.225 \times 1000 = 0.023 \text{ kg} \)

\( T_C = 0.023 (10.84)^2 = 2.7 \text{ N} \)

Maximum tension from equation (xi) is \( T_{\text{max}} = 103.23 + 2.7 = 106 \text{ N} \)

We know angular velocity, \( \omega = \frac{60}{361.33} = 1.67 \text{ rad/s} \)

Torque, \( T = \frac{P}{\omega} = \frac{1119}{361.33} = 3.10 \text{ Nm} \)

We know that \( \frac{N_2}{N_1} = \frac{D_1}{D_2} \), \( N_2 = \frac{3450 \times 60}{150} = 1380 \text{ rev/min} \)

Power required by machine from the primary pulleys, from equation (iii)

\[ P_2 = \frac{3.142 \times 2 \times 3.142 \times 1380}{60} = 448.1 \text{ Watts} \]

We now consider the secondary pulleys in the compound pulleys arrangement

The angle of lap for small pulley from equation (vi), \( \theta_3 = 3.142 - \left[ \frac{200 - 80}{360} \right] = 2.809 \text{ rad} \)

The angle of lap for large pulley as above, \( \theta_4 = 3.142 + \left[ \frac{200 - 80}{360} \right] = 3.475 \text{ rad} \)

We obtain belt tension through the ratio equation (vii),

\[ \frac{T_3}{T_4} = e^{0.25 \times 2.809} = 2.02 \]

Hence \( T_3 = 2.02T_4 \) and in relation to belt tension we now have

Since peripheral velocity from equation (ix), \( V_P = \frac{3.142 \times 0.08 \times 1380}{60} = 5.78 \text{ m/s} \)

Then \( T_3 - T_4 = \frac{448.1}{5.78} = 77.53 \)

Recall that \( 2.02T_4 - T_4 = 77.53 \) in this case \( 1.02T_4 = 77.53 \)

As such \( T_4 = \frac{77.53}{1.02} = 76.0 \text{ N} \). Hence \( T_3 = 2.02 \times 76 = 153.53 \text{ N} \)

\( m = 0.013 \times 0.180 \times 1000 = 0.0187 \text{ kg} \)

Centrifugal tension from equation (x), \( T_C = 0.0187 (5.78)^2 = 0.63 \text{ N} \)

Maximum tension from equation (xi), \( T_{\text{max}} = 153.53 + 0.63 = 154.16 \text{ N} \)

We know angular velocity, \( \omega = \frac{2 \times 3.142 \times 1380}{60} = 144.5 \text{ rad/s} \)

Torque, \( T = \frac{P}{\omega} = \frac{448.1}{144.5} = 3.10 \text{ Nm} \)

We know that \( N_4 = \frac{\frac{1380 \times 80}{200}}{200} = 552 \text{ rev/min} \)

To obtain the speed of the granulating pan consider the gear arrangements.

Speed of gear pinion \( N_1 = ? \)

Speed of gear \( N_2 = 552 \text{ rev/min} \)

Number of teeth on gear pinion \( T_1 = 165 \)

Number of teeth on gear \( T_2 = 15 \)
From speed Ratio, \( N_1 / 552 = 15 / 165 \) Therefore \( N_1 = 552 \times 0.09090 = 50.2 \text{ rev/min} \). The granulator pan speed at 50.2 rev/min is appropriate for the desired size range due to collision between balls formed and impact amongst them, confirmed Kapur, P.C. (1978). This proves the design to be appropriate.

We know that Velocity of pinion fro equation (xv), \( V = \frac{3.142 \times 440 \times 48}{60} = 1106 \text{ m/s} \)

So designed tangential load from equation (xiv), \( W_T = \frac{179.22}{1106} \times 1 = 0.162 \text{ N} \)

Dynamic load from equation (xiii),
\[
W_D = 0.162 + \frac{21 \times 1106 (22 \times 80 + 0.162)}{21 \times 1105 + \sqrt{22 \times 80 + 0.162}} = 1.842.94 \text{ N}
\]

The ratio factor obtained from equation (xvii), \( Q = \frac{2 \times 11}{11 + 1} = 22/12 = 11/6 \)

Load – stress factor, \( K = 1.4 \text{ N/mm}^2 \)

Wear load from equation (xvi), \( W_W = \frac{440 \times 22 \times 11 \times 1.4}{6} = 24,845.33 \text{ N} \)

Since \( W_W \) is greater than \( W_D \), therefore the design is safe.

Where assumed mass of pan with raw material = 38 kg

The pan load, \( W = \frac{38 \times 9.81}{\cos 50^0} = 386.3 \text{ N} \)

While the Torque, \( T = 386.3 \times 40 = 15453 \text{ N-mm} \)

Then second moment of area of the section about the polar axis from equation (xviii),
\[
J = \frac{\pi \times 40^4}{32} = 25.1360 \text{ mm}^4
\]

The maximum shear stress from the combine load of pan and product that is induced on the shaft from equation (xix), \( \tau = (15453 \times 2) / 25.136 = 1229.6 \text{ N/mm}^2 \).
## Appendix IV

### Randomized block Table

<table>
<thead>
<tr>
<th>TREATMENT</th>
<th>WEEKS</th>
<th>HEIGHT (CM)</th>
<th>SIZE (CM)</th>
<th># OF LEAVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMMERCIAL FERTILIZER SOIL</td>
<td>1</td>
<td>4.0</td>
<td>12.0</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>74.0</td>
<td>7.2</td>
<td>14</td>
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<tr>
<td></td>
<td>3</td>
<td>10.8</td>
<td>14.3</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>13.6</td>
<td>2.7</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>162.0</td>
<td>3.2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>38.6</td>
<td>4.8</td>
<td>7</td>
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<tr>
<td></td>
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<td>7.0</td>
<td>1.2</td>
<td>12</td>
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<tr>
<td></td>
<td>8</td>
<td>116.8</td>
<td>1.8</td>
<td>6</td>
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<tr>
<td></td>
<td>9</td>
<td>140.0</td>
<td>0.6</td>
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<tr>
<td></td>
<td>10</td>
<td>20.0</td>
<td>10.8</td>
<td>4</td>
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<tr>
<td>EXPERIMENTAL FERTILIZER SOIL</td>
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</tbody>
</table>

To get the evidence of significant difference, \( \alpha = 0.05 \)

## Appendix V ANOVA RESULT

### Decision Rule

1. Treatment combinations
   \[ F_{cal} > F_{c-1, cr(n-1) \alpha} \] , reject \( H_0 \) and infer \( H_1 \)

2. Block effects
   \[ F_{cal} > F_{r-1, cr(n-1) \alpha} \] , infer \( H_1 \)

The results of ANOVA are presented in Table below

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>dof</th>
<th>SS</th>
<th>MS</th>
<th>F-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatments</td>
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<td>673.35</td>
<td>673.35</td>
<td>2.203</td>
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<td>Blocks</td>
<td>2</td>
<td>2464.62</td>
<td>12347.30</td>
<td>4.031</td>
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<tr>
<td>Errors</td>
<td>54</td>
<td>16508.23</td>
<td>305.71</td>
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<tr>
<td>Total</td>
<td>59</td>
<td>41876.18</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SST = Treatment sum of squares, dof = Degree of freedom, MS = Mean square, \( F_{cal} = \) F-ratio calculated.