# The comparison between powder and granular lime to elevate low soil pH

J.G. Dreyer, Department of Geology and Soil Science, North-West University, Potchefstroom

## 1. Introduction

The North-West University's department of Geology and Soil Science have been approached by Grasland Ondernemings (Pty) Ltd to do a pot trial to compare powder and granular lime with each other, to elevate low soil pH levels.

### 1.1 Soil acidity

Soil acidity is world-wide regarded as one of the major limiting factors in crop production FSSA (2010:42). According to Brady and Weil (2008:358) a wide range of soil chemical and biological properties is being affected by soil pH. The soil chemical properties are the uptake of available elements that include both nutrients and toxins. The biological properties are mainly the activity of soil microorganisms.

Acidification is a natural process involved in soil formation. The cultivation of crops accelerates the acidification process of soils and therefore the need to continuously applying lime in crop production. In crop production it is mainly the application of nitrogen fertilizers and the uptake of cations (plant nutrition elements like $Ca^{2+}$, $Mg^{2+}$ and $K^{+}$) by plants roots that produces $H^{+}$ ions, that causes the soil pH to lower and became acidic (Brady & Weil, 2008:360-362).

Acidic soils can occur naturally under certain climates and geology.

The most common and severe problem associated with acid soils is aluminum ($Al^{3+}$) toxicity. The other problem is the availability of plant nutrients. In strongly acid soils the availability of the macronutrients (Ca, Mg, K, P, N and S) as well as the two micronutrients, Mo and B, is decreased. In low soil pH conditions the availability of the micronutrient cations (Fe, Mn, Zn, Cu, and Co) is increased, even to the extent of toxicity (Brady & Weil, 2008:381 & 384).

### 1.2 Lime

To decrease soil acidity (raise the pH) the soil is usually amended with agricultural limes (Brady & Weil, 2008:381 & 384). According to Mengel and Kirkby (1987:474) the main purpose of liming acid soils is to reduce soluble Al by precipitation.

Liming materials must comply with certain properties to have the necessary reactivity in the soil, to effectively neutralize the acid in the soil. Two of the most important properties of lime must be its:

- Chemical purity. The capability of the product to be able to neutralize acids (Brady & Weil, 2008:390-391, Mengel & Kirkby, 1987:477).

- Fineness. The finer the lime the better it reacts with the soil to rise the pH (Mengel & Kirkby, 1987:478).

Brady and Weil (2008:387) state that unlike fertilizers, which are used to supply plant nutrients in relatively small amounts for plant nutrition, liming materials are used to change the chemical makeup of a substantial part of the root zone. Therefore, lime must be added in large enough quantities to chemically react with a large volume of soil. This requirement dictates that inexpensive, plentiful materials are normally used for liming soils – most commonly finely ground limestone or materials derived from it.

## 2. Material and Methods

A pot trail was conducted to do a comparison between conventional powder lime and granular lime to test how each will elevate low soil pH levels.

2.1 Materials

To get meaningful results from a liming trail a virgin soil with a $pH_{(H2O)}$ of 5.2 and a $pH_{(KCl)}$ of 4.0 was used. According to Van der Watt and Van Rooyen (1990:137) a soil with a $pH_{(H2O)}$ of 5.2 is strongly acidic. The rest of the chemical analysis of the soil can be seen in Appendix 1.

The powder lime used was the “Marico” dolmitic lime obtained from Grasland, with a registred analysis of 48% $CaCO_3$ and 22% $MgCO_3$. The calcium carbonate equivalent (CCE) resin value of the lime is 76%. (The CCE value gives an indication of the relative reactivity of agriculture lime to pure precipitated $CaCO_3$ with soil under incubation conditions of three months (FSSA, 2010:138).) 98% of the lime is finer than 0.25mm and can thus be considered as microfine agriculture lime (FSSA, 2010:138).

The granular lime used was a dolomitic lime by the name of “DOLCA” from Advanced Agri. According to an information brocure of Advanced Agri, “DOLCA” have an analysis of 65% $CaCO_3$ and 30% $MgCO_3$. The calcium carbonate equivalent (CCE) resin value of the lime is 98%.

The pots used in the trail were cone shaped with a top diameter of 296mm and a bottom diameter of 204mm, and 274mm deep. The volume of the pot is about 14.48 litres. The mass of soil used per pot was about 18.5 kg.

The treatments for the trial where the two different forms of lime, namely the powder and granular lime. The powder lime was applied at rates equivalent to 1, 2, 3 and 4 tonnes of lime per hectare. The 1 ton treatment was 0.308g of lime per kg soil, which gives 5.692g lime per 18.5kg of soil. The 2 ton treatment was 0.615g of lime per kg soil, which gives 11.385g lime per 18.5kg of soil. The 3 ton treatment was 0.923g of lime per kg soil, which gives 17.077g lime per 18.5kg of soil. The 4 ton treatment was 1.231g of lime per kg soil, which gives 22.770g lime per 18.5kg of soil.

The granular lime was applied at rates equivalent to 500, 750, 1 000 and 1 500kg of lime per hectare. The 500kg treatment received 3.077g of lime per pot (18.5kg soil). The 750kg treatment received 4.616g of lime per pot (18.5kg soil). The 1 000kg treatment received 6.150g of lime per pot (18.5kg soil). The 1 500kg treatment received 9.231g of lime per pot (18.5kg soil).

Each treatment was replicated 4 times, which gave a total of 32 pots in this trial. The experimental design for this trial was the completely randomized design (Petersen, 1994:36).

The powder lime was mixed with the soil in a concrete mixer and then the pots were filled. At the same time only the soil for the granular lime were put in the pots. The pots were watered and keep wet for two weeks before wheat where planted. The reason for this is to simulate the practice where lime is incorporated into the soil before planting. This practise gives time for the lime to react with the soil before planting.

Planting of 3 wheat seeds per pot took place on the 19$^{th}$ August 2016. With planting the granular lime treatments where applied. The reason for this is to simulate the action of band placement of the granular lime with planting. The granular lime was applied evenly in a band 5cm deep, 5cm from the centre line in the pot. The wheat was planted 1.5cm deep in the centre of the pot.

No fertilizers where applied to the pots in the experiment, to eliminate the effect that fertilizers might have on acidification of the soil or raising the pH of the soil.

The pots in the trial where watered with de-ionized water to cancel the effect that tap water, with high calcium (Ca) and magnesium (Mg) content and a pH of 7 might have on raising the pH of the soil.

### 2.2 Methods

Soil samples were taken of each pot on the 7$^{th}$ of December 2016. Samples were taken at 5cm, 15cm, and 25cm depth from the soil surface. The $pH_{(water)}$ of these samples where measured with the 1:2.5 method (SSSSA, 1990:11).

The data was statistically analyzed by means of the analysis of variance (ANOVA) to test the significance of differences among the treatment means (Petersen, 1994:38).

## 3. Results

The $pH_{(H_2O)}$ results obtained from the different soil depths at the end of the trial is given in Appendix 2.

3.1 One ton powder and granular lime compared with each other

The analysis of variance (ANOVA) for the 1 ton powder and 1 ton granular lime compared with each other is given in Appendix 3. The coefficient of variation (CV) of 3.25% is good and the coefficient of determination ($R^2$) of 97% is very good.

According to the analysis of variance (ANOVA) there was a highly significant difference between the powder and granular lime, as well as between the different depths in the soil. The interaction between the type of lime and the depth in soil also gave a highly significant difference.

The mean pH for the 1 ton application rate for the different lime formulations at different depths is given in Table 1.

**Table 1: Mean pH of the soil with the 1 ton lime application rate at different depths with the different formulations of lime**

| | Soil depth of measured pH | | |
|---|---|---|---|
| **Formulation of lime** | **5 cm** | **15 cm** | **25 cm** |
| **powder** | 6.7 | 6.7 | 6.6 |
| **granular** | 6.1 | 4.8 | 4.6 |

$LSD_{Tukey}$ = 0.535 (0.01) CV = 3.25%

The least significant difference (LSD) between different pH values is 0.535. There is no significant difference between the pH at different depths with the powder lime. A significant difference between the pH of the powder and granular lime at 5cm is observed. With the granular lime there was a significant difference between the top 5cm and the 15cm as well as the 25cm depths. The results are shown graphically in Figure 1.

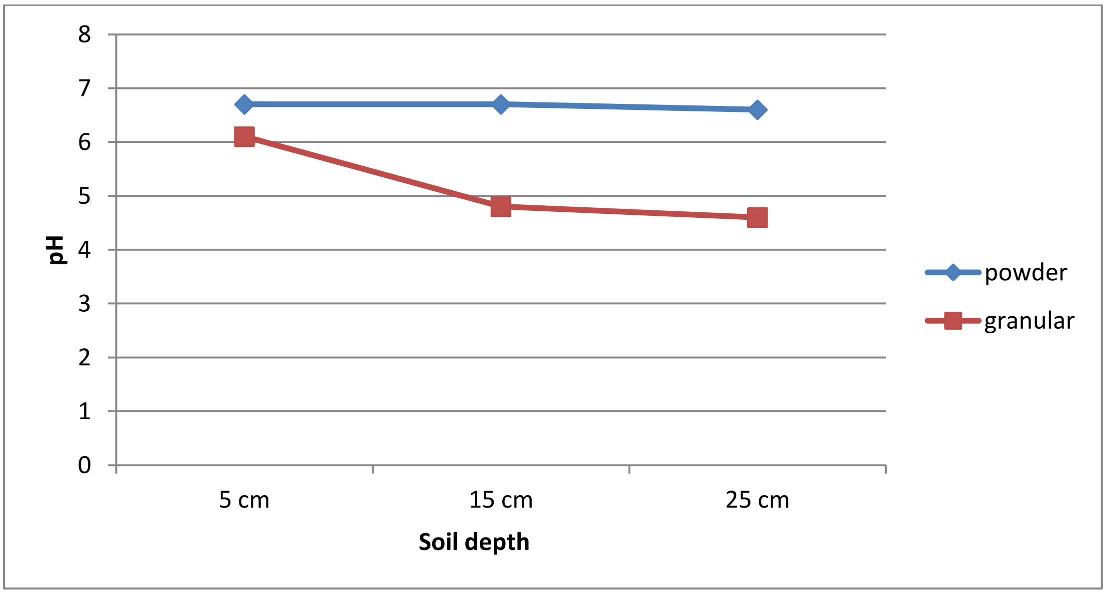


**Figure 1: Mean soil pH for the 1 ton lime application with the different lime at different soil depths.**

3.2 Power lime at different application rates

In Appendix 4 the analysis of variance (ANOVA) for the powder lime at different rates is given. The coefficient of variation (CV) of 1.69% is good and the coefficient of determination ($R^2$) of 49% is a bit low.

The analysis for variance (ANOVA) shows only a highly significant difference for the amount of lime applied with the powdered lime. The mean pH values for the different application rates with the powdered lime are seen in Table 2.

**Table 2: Mean soil pH at different application rates for the powder lime**

| Application rate of powder lime (ton / ha) | Soil pH |
|---|---|
| **1** | 6.63 |
| **2** | 6.75 |
| **3** | 6.77 |
| **4** | 6.90 |

$LSD_{Tukey}$ = 0.156 (0.01) CV = 1.69%

The least significant difference (LSD) between different pH values for the application rates is 0.156. Only the 1 and 4 ton applications of powder lime differ statistically from each other. The difference is highly significance between the 1 and 4 ton powder lime application. There is an increase in soil pH with an increase in the amount of lime applied. With no statistical difference between the pH at different depths, implies that the mixing of the powdered lime into the soil, is effective in raising the pH over the whole mixed zone. Figure 2 shows the results in graph form.

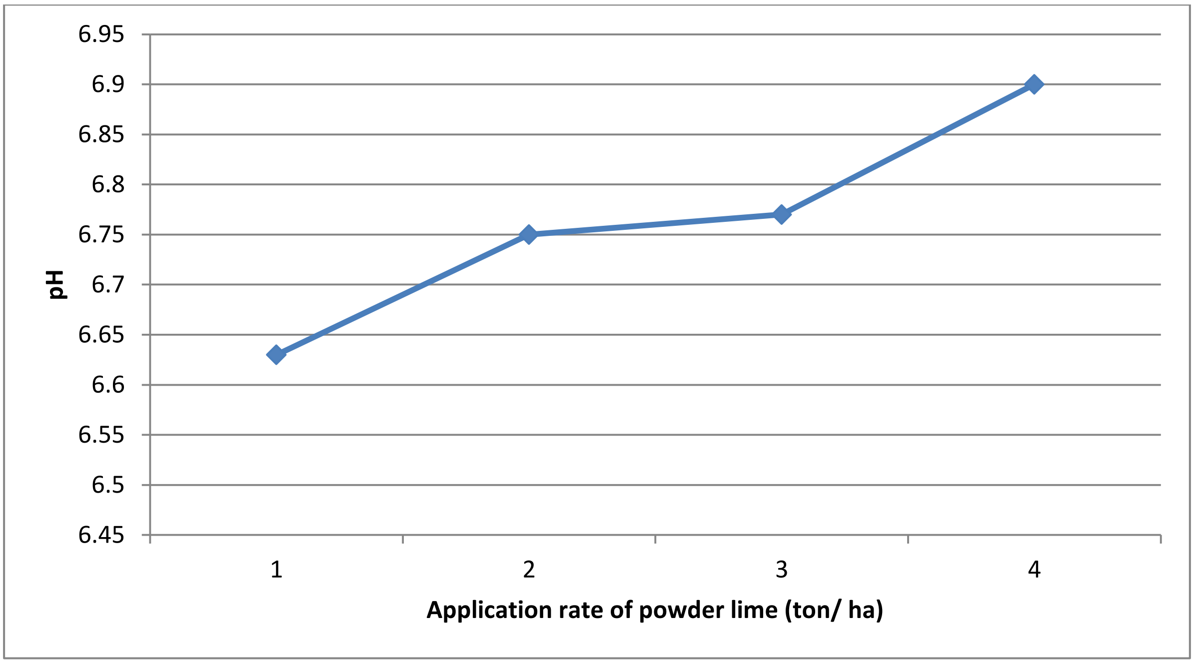


**Figure 2: Mean soil pH for the powder lime application at different application rates.**

3.3 Granular lime at different application rates

The analysis of variance (ANOVA) for the granular lime at different rates is given in Appendix 5. The coefficient of variation (CV) of 8.46% is good and the coefficient of determination ($R^2$) of 64% is average.

According to the analysis of variance (ANOVA) there was only a highly significant difference between the soil pH at different soil depths.

The mean soil pH at different depths for the granular lime is given in Table 3.

**Table 3: Mean soil pH at different depths with the granular lime**

| Soil depth (cm) | Soil pH |
|---|---|
| **5** | 5.98 |
| **15** | 4.98 |
| **25** | 4.99 |

$LSD_{Tukey}$ = 0.494 (0.01) CV = 8.46%

The least significant difference (LSD) between the different soil depths is 0.494. The 5cm differ highly significantly from the 15cm and 25cm, with no statistical difference between the 15cm and 25cm depths. The results are shown graphically in Figure 3.

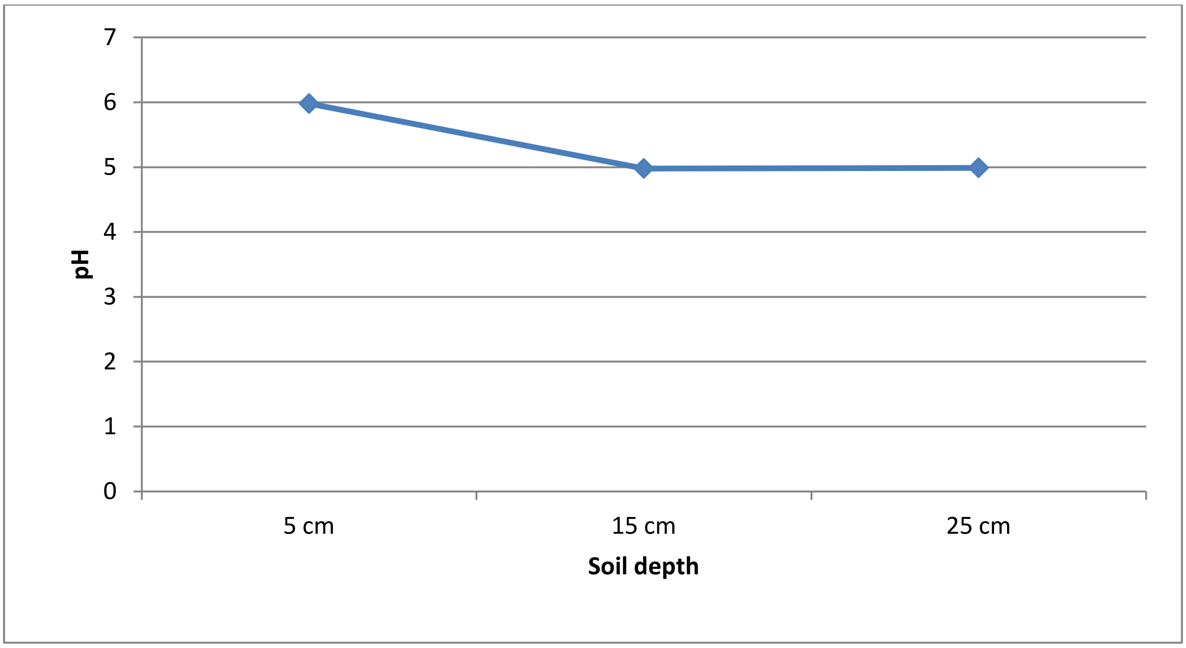


**Figure 3: Mean soil pH for the granular lime application at different soil depts.**

3.4 The cost of the lime

The cost of the powder lime, the "Marico" dolmitic lime obtained from Grasland was R233.70 per ton during 2016. This price includes VAT and excludes transport. The price of the granular dolomitic lime (DOLCA) was R211.30 for 50kg. If converted to 1 ton it would have cost R 4 226.00 per ton. The price includes VAT and excludes transport.

The granular lime cost 18 times as much as conventional powder lime. With the 1 ton per hectare comparison between the powder and granular lime, the granular lime's pH was significant lower at 5cm depth and it didn't even raise the pH at 15cm and 25cm depth. There is no financial sense in paying 18 times as much for a product that is performing worse than the much cheaper product.

## 4. Conclusion

With the results obtained from this study, the conclusion can be made that the granular lime is not as effective as the conventional powder lime in raising the pH of an acidic soil. The most important results show:

- There is a highly significant difference in pH between all soil depths, in the comparison between the 1 ton powder and 1 ton granular lime. It is important to keep in mind that with the granular lime all the lime is concentrated in a band at 5cm depth. Even for that concentration of granular lime at 5cm depth, the pH at 5cm depth is significant lower than at the same depth for the powder lime.
- For the granular lime there was a highly significant difference in pH between the 5cm depth and the depths of 15 and 25cm's. This show that the granular lime didn't have a neutralising affect in the soil 10cm below where it was applied.
- No statistical differences in pH for the different depths with the powder lime show that mixing the lime with the soil is necessary for raising the pH in the root zone.

The results obtained are expected if one keeps in mind that the fineness of the lime is important in effectively neutralizing the acidity of a soil. The fact that the granular lime is not incorporated or mixed into the soil, attribute that the pH was not neutralized lower down in the pot. The reason for this is that $Ca^{2+}$ as a divalent cation and its thin hydration sphere is being strongly adsorbed by the different clay minerals in the soil (Mengel & Kirkby, 1987:459). This makes $Ca^{2+}$ not as moveable as other cations in the soil. Therefore that agricultural lime had to be mixed and incorporated into the soil by means of a disk plough (Brady & Weil, 2008:390-391).

At the time of sampling at the end of the trial it was seen that the granular lime did not dissolved in the soil. The photo in Figure 4 shows that the granular lime is still intact in the soil after being in the soil for ± 3½ months. The undissolved lime explain why the soil pH at 15cm and deeper was significantly lower than at the top 5cm.

**Figure 4: Photo of undissolved granular lime in soil.**

## 5. Reference List


BRADY, N.C. & WEIL, R.R. 2008. The nature and properties of soils. 14th ed. Upper Saddle River N.J. : Pearson.

FSSA (The Fertilizer Society of South Africa). 2010. Fertilizer Handbook. Lynnwood Ridge : The fertilizer Society of South Africa. 298p.

MENGEL, K. & KIRKBY, E.A. 1987. Principles of plant nutrition. 4th ed. Bern : International Potash Institute. 687p.

PETERSEN, R.G. 1994. Agricultural field experiments: Design and analysis. New York : Marcel Dekker. 409p.

SSSSA (Soil Science Society of South Africa). 1990. Handbook of standard soil testing methods for advisory purposes. Pretoria. : The Soil Science Society of South Africa. 145p.

VAN DER WATT, H.V.H & VAN ROOYEN, T.H. 1990. A Glossary of Soil Science. Pretoria. : The Soil Science Society of South Africa. 356p.

# 6. Appendix

## Appendix 1: Soil Analysis of virgin soil used.

| **Property** | **Value** |
|---|---|
| **pH $_{(KCl)}$** | 4.0 |
| **pH $_{(H2O)}$** | 5.2 |
| **EC (mS.m$^{-1}$)** | 30 |
| **P $_{(Bray\ 1)}$ (mg.kg$^{-1}$)** | 2 |
| **CEC (cmol.kg$^{-1}$)** | 2.35 |
| **Exch Acid (cmol.kg$^{-1}$)** | 0.67 |
| **Acid saturation (%)** | 31.8 |
| | |
| **Sand (%)** | 75.1 |
| **Silt (%)** | 2.6 |
| **Clay (%)** | 22.3 |

| **Property** | | **Value** |
|---|---|---|
| **Ca** | **cmol.kg$^{-1}$** | 0.565 |
| | **mg.kg$^{-1}$** | 113 |
| **Mg** | **cmol.kg$^{-1}$** | 0.620 |
| | **mg.kg$^{-1}$** | 75 |
| **K** | **cmol.kg$^{-1}$** | 0.236 |
| | **mg.kg$^{-1}$** | 92 |
| **Na** | **cmol.kg$^{-1}$** | 0.013 |
| | **mg.kg$^{-1}$** | 3 |
| | | |
| | | |
| **Soil texture** | Sandy clay loam | |

## Appendix 2: Soil $pH_{(H_2O)}$ for the different treatments at the end of the trial.

| Lime | Amount (ton) | Replication | 5 cm | 15 cm | 25 cm |
|---|---|---|---|---|---|
| Powder | 1 | 1 | 6.6 | 6,6 | 6.7 |
| Powder | 1 | 2 | 6.7 | 6.6 | 6.6 |
| Powder | 1 | 3 | 6.6 | 6.6 | 6.4 |
| Powder | 1 | 4 | 6.8 | 6.8 | 6.5 |
| | | | | | |
| Powder | 2 | 1 | 6.9 | 6.8 | 6.8 |
| Powder | 2 | 2 | 6.8 | 6.7 | 6.7 |
| Powder | 2 | 3 | 6.7 | 6.5 | 6.7 |
| Powder | 2 | 4 | 6.8 | 6.8 | 6.8 |
| | | | | | |
| Powder | 3 | 1 | 6.7 | 6.6 | 6.7 |
| Powder | 3 | 2 | 6.8 | 6.9 | 6.7 |
| Powder | 3 | 3 | 6.7 | 6.7 | 6.7 |
| Powder | 3 | 4 | 7.1 | 6.7 | 6.9 |
| | | | | | |
| Powder | 4 | 1 | 7.0 | 6.9 | 6.9 |
| Powder | 4 | 2 | 6.8 | 6.9 | 6.9 |
| Powder | 4 | 3 | 6.7 | 6.9 | 6.7 |
| Powder | 4 | 4 | 7.0 | 6.9 | 6.9 |
| | | | | | |
| Granular | 0.5 | 1 | 6.3 | 5.4 | 5.4 |
| Granular | 0.5 | 2 | 5.6 | 5.6 | 5.5 |
| Granular | 0.5 | 3 | 5.9 | 4.7 | 5.5 |
| Granular | 0.5 | 4 | 5.8 | 4.9 | 5.8 |
| | | | | | |
| Granular | 0.75 | 1 | 6.6 | 4.9 | 4.7 |
| Granular | 0.75 | 2 | 6.9 | 4.9 | 4.9 |
| Granular | 0.75 | 3 | 5.8 | 5.4 | 5.6 |
| Granular | 0.75 | 4 | 5.7 | 4.8 | 4.7 |
| | | | | | |
| Granular | 1 | 1 | 5.6 | 4.7 | 4.6 |
| Granular | 1 | 2 | 6.0 | 4.7 | 4.5 |
| Granular | 1 | 3 | 6.4 | 4.8 | 4.7 |
| Granular | 1 | 4 | 6.4 | 5.0 | 4.4 |
| | | | | | |
| Granular | 1.5 | 1 | 5.6 | 5.0 | 5.5 |
| Granular | 1.5 | 2 | 6.9 | 5.2 | 5.1 |
| Granular | 1.5 | 3 | 5.7 | 5.1 | 5.0 |
| Granular | 1.5 | 4 | 4.5 | 4.5 | 4.4 |

**Appendix 3: Analysis of Variance of soil pH at different depths with 1 ton of powder and granular lime.**

| Source of Variation (Source) | Degrees of Freedom (df) | Sum of Squares (SS) | Mean Square (MS) | F | Significance |
|---|---|---|---|---|---|
| Type of lime | 1 | 13.0538 | 13.0538 | 357.37 | ** |
| Depth in soil | 2 | 3.1225 | 1.5613 | 42.74 | ** |
| Type of lime x Depth in soil | 2 | 2.4525 | 1.2263 | 33.57 | ** |
| Error | 18 | 0.6575 | 0.0365 | | |
| TOTAL | 23 | 19.2863 | | | |

Coefficient of variation (CV) = 3.25%   $R^2$ = 0.97

**** = Highly significant difference (1% level)**

*** = Significant difference (5% level)**

**ns = Not significant**

**Appendix 4: Analysis of Variance of soil pH at different depths with powder lime at different rates.**

| Source of Variation (Source) | Degrees of Freedom (df) | Sum of Squares (SS) | Mean Square (MS) | F | Significance |
|---|---|---|---|---|---|
| Amount of lime | 3 | 0.378 | 0.126 | 9.4 | ** |
| Depth in soil | 2 | 0.040 | 0.020 | 1.5 | ns |
| Amount of lime x Depth in soil | 6 | 0.041 | 0.007 | 0.5 | ns |
| Error | 36 | 0.480 | 0.013 | | |
| TOTAL | 47 | 0.939 | | | |

Coefficient of variation (CV) = 1.69%   $R^2$ = 0.49

**** = Highly significant difference (1% level)**

*** = Significant difference (5% level)**

**ns = Not significant**

**Appendix 5: Analysis of Variance of soil pH at different depths with granular lime at different rates.**

| Source of Variation (Source) | Degrees of Freedom (df) | Sum of Squares (SS) | Mean Square (MS) | F | Significance |
|---|---|---|---|---|---|
| Amount of lime | 3 | 0.942 | 0.314 | 1.553 | ns |
| Depth in soil | 2 | 10.668 | 5.334 | 26.368 | ** |
| Amount of lime x Depth in soil | 6 | 1.587 | 0.265 | 1.308 | ns |
| Error | 36 | 7.283 | 0.202 | | |
| TOTAL | 47 | 20.48 | | | |

Coefficient of variation (CV) = 8.46%   $R^2$ = 0.64

**** = Highly significant difference (1% level)**

*** = Significant difference (5% level)**

**ns = Not significant**