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Full Length Research Paper

Insitu assessment of soil nitrate-nitrogen in the pigeon pea-groundnut intercropping-maize rotation system: Implications on Nitrogen management for increased maize productivity

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Abstract

Assessment of soil nitrate nitrogen (NO_3^-–N) was conducted in a pigeon pea-groundnut intercrop-maize rotation cropping system at Chitedze Agricultural Research Station (S 130 59' 23.2", E 0330 38' 36.8") in the 2012/2013 cropping season. In the 2011/2012 cropping season, eight treatments replicated three times in a randomized complete block design, with monocultures and intercrops of either of the two pigeon pea varieties, long (ICEAP 04000) and medium duration (ICEAP 00557) plus groundnut (CG 7) were planted. At harvest, the legume biomass was ploughed into the soil in some of the treatment plots. Maize was then planted in the 2012/2013 cropping season and NO_3^-–N data was collected from emergence over a period of three weeks. This was done before top dressing with urea. The results of the study seem to suggest that there was high NO_3^-–N in the soil solution in all the treatment plots over the study period (106.4 mg l^{-1} to 463.1 mg l^{-1}). It was observed however, that the level of soil NO_3^-–N in most cases was statistically the same ($p>0.05$) across the treatment plots. In general, mean soil NO_3^-–N was higher in the sub than top soil. This was attributable to the soil texture which is predominantly sandy clay loam with low to medium level of SOM, both in the top (mean=0.9-1.6%) and sub soil (mean=1.1-1.6%). Leaching of NO_3^- is high under such soil conditions. It is likely that the level of mean soil NO_3^-–N, into the season, in treatment plots which had no biomass buried under would decline faster than in treatment plots where biomass was incorporated, mostly due to uptake by the maize crop and leaching losses. This may last longer into the season for the latter treatment plots, but may not last until the end of the cropping cycle. For the Malawian smallholder farmers it implies that for this cropping system, N supplement from mineral fertilizer is not optional if reasonably high maize yield is to be realized.

Keywords: Groundnut biomass, Intercropping, Nitrate-nitrogen, Pigeon pea biomass.

INTRODUCTION

In Malawi maize yields are limited principally by nitrogen (N) defficiencies in soils under cultivation (Phiri *et al.*, 2010). To circumvert this impedement, use of mineral N fertilizer for increased yield has been advocated for decades. However, with escalation of the fertilizer prices on the market, this option has proved to be beyond reach of the resource poor smallholder farmers (Phiri *et al.,* 2010). Furthermore, the sole use of mineral fertilizers on many smallholder farms has led to general physical and chemical degradation of the soil (Maida, 2005). This has severely undermined the productivity of the soils in Malawi. To address the challenge, an array of soil rejuvinating technologies have been proposed. The premier method however, appears to be the large scale integration of legumes like the pigeon pea and groundnut in the maize production systems and the incorporation of their biomass into the soils (Bezner-Kerr, 2007). A systematic integrating of legumes into the predominantly maize production system has been proposed which is the pigeon pea-groundnut intercropping system in rotation with maize (Kanyama-Phiri *et al.,* 2008). Phiri *et al.* (2013), reported that the system can generate substantial amount of nitrogen rich biomass which upon incorporation into the soil, in a legume-cereal rotation system, the biomass can improve soil fertility thereby leading to increased maize yield. The increased soil fertility is attributable to increase in the soil's ability to retain nutrients, buffer soil pH and increase the soil's water holding capacity (Krull et al., 2004).

In this system the prime nutrient element, released by the buried, decomposing and mineralizing pigeon pea and groundnut residues, is the organically bound N. The soil microbe mediated process of decomposition and N mineralization, converts the organically bound N into plant available forms of ammonium (NH_4^+) which is also called ammonium nitrogen (NH_4^+–N), and nitrate (NO_3^-) which is also known as nitrate nitrogen (NO_3^-–N) (Deenik, 2006). Uwah *et al.* (2009) indicate that NO_3^- or NO_3^-–N is the major form of N absorbed by crops. Currently, in Malawi, little is know on the impact of the incorporation of pigeon pea and groundnut biomass on soil NO_3^-–N and the implication of this effect on maize production. A study therefore was conducted, to assess the effect of the biomass incorporation on soil NO_3^-–N in the pigeon pea-groundnut intercropping-maize rotation system. It was hypothesized that the assessment would help in the assertion of the implication of this effect on soil N management and maize production. Estimates of mineral fertilizer N required for maize production are function of expected yield, the amount of residual soil NO_3^-–N, SOM and other sources of N, timing of application and price of mineral fertilizer (Shapiro *et al.,* 2008). Residual NO_3^-–N in soil is an important N source for crops, and its amount correlates with crop yield (Ferguson *et al.,* 2002; Fan and Hao 2003).

MATERIALS AND METHODS

Study site

The study was conducted on-station at Chitedze Agricultural Research Station (S 13^0 59' 23.2", E 033^0 38' 36.8") in Lilongwe, Malawi. The site falls within the Lilongwe plain and receives an average annual rainfall of 875 mm. The rainy season starts in November and ends in April. The study was conducted in the 2012/2013 cropping season starting from December 2012 to January, 2013. During this period, a total of 175.9 mm of rainfall was recorded and the mean daily temperature ranged between 23.5^{0}C to 22.7^{0}C (Figure 1 and 2) for the months of December, 2012 and January, 2013, respectively. Baseline soil data collected in the first year of the study, indicate that the soil pH was acid to moderately acid both in the top (mean=5.4-5.7) and the sub soil (mean=5.4-5.6) in all the treatment plots, with mostly low to marginally adequate total nitrogen content both in the top (mean=0.08-0.14%) and the sub soil (mean=0.09-0.13%). The soil organic carbon content was medium in the top soil (mean=0.9-1.6%) as well as sub soil (mean=1.1-1.6%) across the treatment plots (Phiri *et al.,* 2013). This did not differ markedly with second season baseline soil data (Table 1).

Materials

Materials used include; biomass of a photo and thermo insensitive medium duration pigeon pea variety (ICEAP 00557, potential yield is up to 2.5 t ha^{-1}) which matures in 5-6 months, biomass of a long-duration pigeon pea variety (ICEAP 04000, potential yield is 1.6-2 t ha^{-1}) maturing in 8-9 months, biomass of groundnut (CG 7, potential yield is 3 t ha^{-1}), early maturing maize variety (SC 403 potential yield is 6 t ha^{-1}) and Triple Super Phosphate (TSP).

To generate data the following were used; Horiba NO_3^- meter for soil (B-342-Plate 1a), A digital pH meter (Fisher Scientific-Plate 1b), Hygrothermo (Plate 1c) bottled water (Hayat still purified water; NO_3^- 28 mg/l, pH 7.8, Ca 23 mg/l, Na 9 mg/l, K 7 mg/l, Cl 18 mg/l, SO_4 12, mg/l, HCO_3 82 mg/l, F <0.01 mg/l, plastic bottles, beakers, centrifuge tubes, soil auger, and a wash bottle.

Experimental design

The experiment involving eight treatments laid in a randomised complete design commenced in the 2011/2012 growing season, with pigeon pea and groundnut grown either as sole or intercrops in different treatment plots. The plot dimensions were 10 m x 20 m. Ridges were spaced at 75 cm apart. In the intercrop three pigeon pea seeds were planted per station at 90 cm apart while the groundnut was planted in between the pigeon pea planting stations at 15 cm apart, with one seed per station. In the pure stands three pigeon pea seeds were planted per station at 90 cm apart while the groundnut was planted at 15 cm apart, with one seed per station. Maize was planted on the ridges at 25 cm between planting stations with one seed per planting station. This

Plate 1a: Horiba NO_3^- meter for soil (B-342); Plate 1b: Digital pH meter (Fisher Scientific); Plate 1c: Hygrothermo

was done in January 2012. Two pigeon pea varieties were used in the study and these are medium duration pigeon pea and long duration pigeon pea. One of the treatment plots was planted with maize that was not fertilized. In the second season (2012/2013) all the plots were planted with maize. Planting for this season was done in December, 2012. For season one (2011/2012) the treatments were as follows: 1) Sole maize (control); 2) Medium duration pigeon pea (control); 3) Long duration pigeon pea (control); 4) Sole Groundnut (control); 5) Medium duration pigeon pea-groundnut intercrop; 6) Long duration pigeon pea-groundnut intercrop; 7) Medium duration pigeon pea-groundnut intercrop; 8) Long duration pigeon pea-groundnut intercrop. The medium duration pigeon pea-groundnut and long duration pigeon pea-groundnut intercrop was repeated (treatment 7 and 8) purposively. At harvest, the biomass in all the plots having the legumes, except plots with treatment 7, 8 and 1 (sole maize) had their biomass ploughed into the soil. Furthermore, later in the cropping season, this will allow for the comparison of the performance of maize between the plots with legume biomass incorporated into the soil and the plots with legume biomass removed from the field plus a plot where maize was grown without incorporating its biomass into the soil. In the 2012/2013 growing season all the plots were planted with maize.

A parallell trial along side the main trial was run in the second season with similar treatments to the first season for comparison of the perfomance of the legumes across seasons with the following treatments; 1) Long duration pigeon pea, 2) Medium duration pigeon pea, 3)Sole groundnut, 4)Sole groundnut + TSP-25 kg ha^{-1}, 5) Medium duration pigeon pea + TSP-25 kg ha^{-1}, 6) Long duration pigeon pea + TSP-25 kg ha^{-1}, 7) Long duration pigeon pea + groundnut, 8) Long duration pigeon pea + groundnut + TSP-25 kg ha^{-1}, 9) Medium duration pigeon pea + groundnut, 10) Medium duration pigeon pea + groundnut + TSP-25 kg ha^{-1} laid in RCBD replicated 3 times. The plot size was 3 m by six ridges spaced at 75 cm apart.

Data collection and analysis

Measurement

Soil pH, Soil Temperature and Soil Humidity Measurement

Soil pH_{H2O}, was measured insitu using a digital pH meter. This was calibrated before making the measurements. Soil temperature and humidity were measured using a hygrothermo. The assessment of these parameter was done on the top (0-20cm) and sub soil (20-40cm). Measurement was done on four positions within each plot for the respective soil depth. Means of the measurements for each parameter in the respective plots were computed thereafter. The data was subjected to the analysis of variance using GENSTAT. Means were separated using the least significant difference (LSD).

Soil Nitrate-Nitrogen

Soil NO_3^- level was to be assess after every three days for seven times from the emergence of maize using Horiba NO_3^- meter for soil (B-342). The assessment plan was to collect data for seven times after ever three days within the stated time frame. However incessant rains interrupted the process thereby elongating the exercise to three weeks and six days (16th December, 2012 to 10th January, 2013). Soil NO_3^- was measured on 16th, 20th, 24th, 29th December 2012 and 1st, 6th, and 10th January, 2013. The assessment was done on four different points in each treatment plot for the top (0-20cm) and sub soil (20-40cm). A soil paste was made from the top and sub soil (20-40cm) in centrifuge tubes. Added to the water used to make the slurry was 5.6 grams of calcium chrolide to 4.5 litre of distilled water. This was done inorder to stabilize the NO_3^- reading. The ratio of soil to water used to make the paste was 1:5. NO_3^- readings were corrected for this dilution by multiplying the values by five. This was adjusted further by subtracting the amount of NO_3^- detected in the distilled water (28 mg/l).

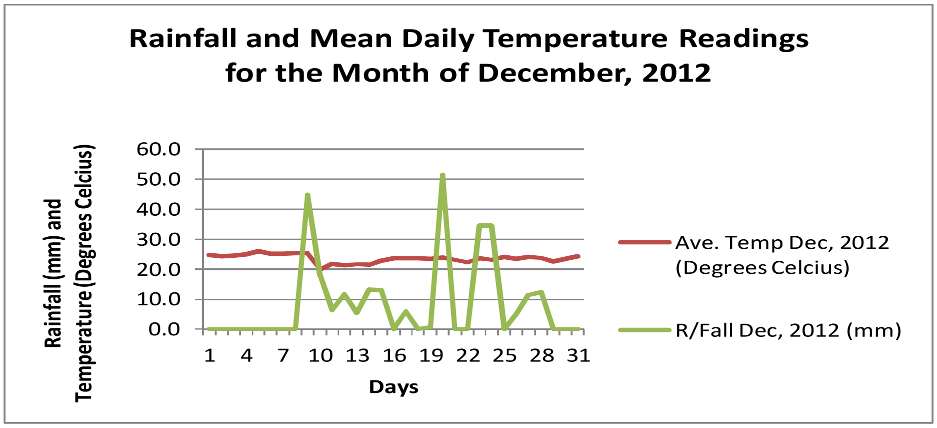


Figure 1a. Rainfall and Mean Daily Temperature Readings for the Month of December, 2012

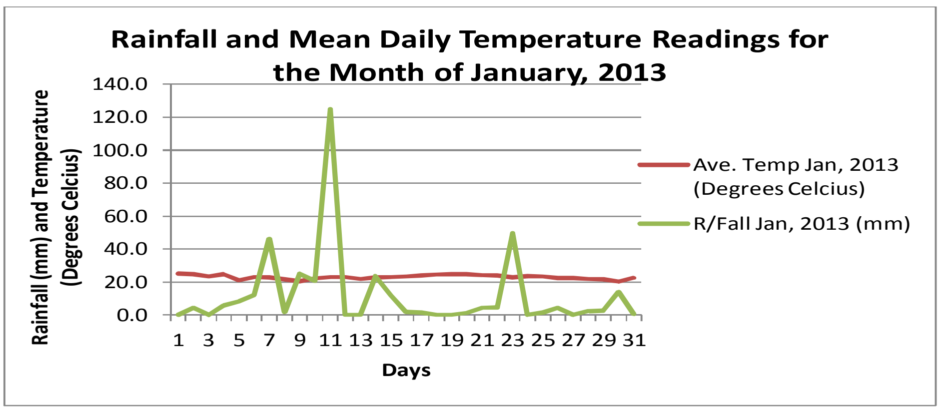


Figure 1b. Rainfall and Mean Daily Temperature Readings for the Month of January, 2013

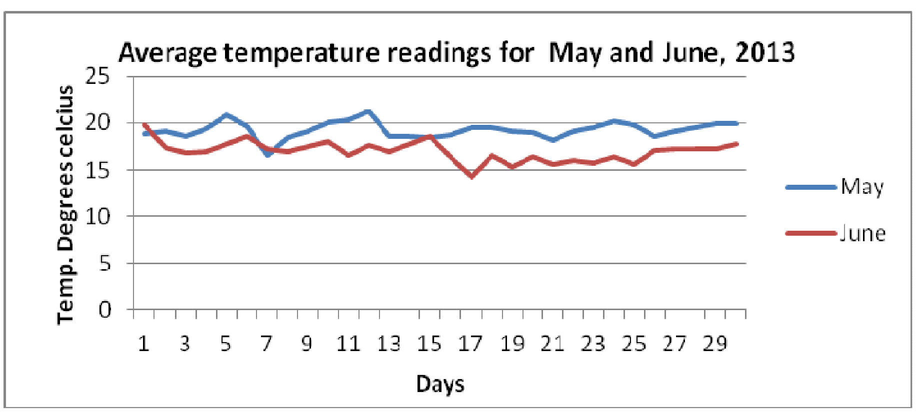


Figure 2. Mean Daily Temperature Readings for the Month of May and June, 2013

Calibration of the NO_3^- meter was done on each day before making measurements. Means of the NO_3^- level from the four points for the respective depth in each plot were computed. The corrected data was then transformed into NO_3^-–N by multiplying by a factor of 0.23. The data was subjected to the analysis of variance using GENSTAT. Means were separated using the least significant difference (LSD). In the parallel trial after harvest, the legume biomass was buried (one ridge in each treatment plot) in May, 2013 for one month. The ridges were watered at an interval of three days for a fortnight as a way of simulating wet soil conditions that prevail during the rainy season and also to facilitate decomposition and mineralization of the biomass. Composite soil samples for the top and sub soil were collected from all the plots. The composite samples were made from soil collected on five points on the ridge. Soil NO_3^-measurements, transformed to NO_3^-–N, were done on the samples using the meter. NO_3^-–N was perfomed on the samples using the KCL method (Miller and Sonon) inorder to compare values.

Daily rainfall and temperature reading for the data collection period

The study was conducted in the months of December, 2012, January, May and June, 2013. Daily rainfall and temperature data for these months were obtained from Chitedze Meteorogical Station. These were graphed (Figure 1a, 1b and 2). Higher and relatively consistent rainfall was recorded in the month of December, 2012 (98.1 mm) than January, 2013 (77.8 mm). Trace amount of rainfall was registered in May and June, 2013. The daily temperature ranged from18.5^{0}C to 28.4 ^{0}C in December, 2012 while in January, 2013 the daily temperature range was 18.6^{0}C to 26.7^{0}C. In May, 2013 the daily temperature ranged from12.4^{0}C to 26.1 ^{0}C while in June, 2013 the daily temperature range was 9.6^{0}C to 24.3^{0}C. On average, it was slightly warmer in December, 2012 (23.5 ^{0}C) than in January, 2013 (22.7 ^{0}C). It was cooler in May (19.25 ^{0}C) and June (16.95 ^{0}C), 2013.

RESULTS

Table 1 summarizes the soil pH, soil temperature and humidity as recorded on the first day of the assessment. Also included is second season data for total nitrogen and organic carbon content in the soil.The results indicate that the mean soil pH was acid to moderately acid both in the top (mean=5.4-5.7) and the sub soil (mean=5.4-5.6) in all the treatment plots. Total nitrogen was low both in the top (mean=0.09%) and sub soil (0.11%) to marginally adquate (0.12%-0.14%) in the two sampled levels. It is worth while to note that total N in the top soil was low in treatment plot 1 and 3. This was high in other treatment plots for this sampled depth. Organic carbon was marginally adequate both in the top (1.08-1.63%) and sub soil (1.17-1.55%). Soil temperature ranged from 25.9 ^{0}C to 27.2 ^{0}C in the top soil and 25.9 ^{0}C to 27.1 ^{0}C in the sub soil. Soil humidity ranged from 73.5% to 79.9% in the top soil and 74.7% to 81.0% in the sub soil.

Table 2 below show the estimated mean biomass yield for the legume monocultures and legume intecrops. The two pigeon pea varieties gave statistically similar mean yield of biomass. While the estimated mean biomass yield for the groundnut was higher the groundnut monoculture and the medium duration pigeon pea-groundnut intercrop. The long duration pigeon pea-groundnut intercrop yielded the lowest mean amount of biomass. All the biomass was ploughed under in treatment plot 2 to 6.

The figures below shows the level of soil nitrate-nitrogen measured over the period of three weeks and five days in the month of December, 2012 and January, 2013.

On the first day the mean amount of soil NO_3^-–N in the top soil ranged from 243.7 mg/l to 456.4 mg/l. Significant differences ($p>0.05$) were observed in the mean amount of soil NO_3^-–N across the treatment plots at this depth. A statistically higher ($p>0.05$) mean amount of soil NO_3^-–N was recorded in treatment plot 8 (456.4 mg/l) compared to the rest of the treatment plots.

In the sub soil there was no differences in the mean level of NO_3^-–N across treatment plots. This ranged from 249.6 mg/l to 444.9 mg/l. Except in treatment plot 3, 5 and 8, soil NO_3^-–N was higher in the sub soil than in the top soil.

On the second day of measurement, no statistical differences were observed in the mean level of soil NO_3^-–N across treatment plots both in the top and sub soil. This ranged from 161.7 mg/l to 369.2 mg/l in the top soil and 252.3 mg/l to 409.5 mg/l in the sub soil. All treatment plots apart from treatment plot 2 had higher mean NO_3^-–N in the sub soil than the top soil.

On the third day of data collection, the mean amount of soil NO_3^-–N in the top soil ranged from 149.6 mg/l to 300.3 mg/l. A Significantly higher ($p>0.05$) mean amount of soil NO_3^-–N was recorded in treatment plot 6 (300.3 mg/l) compared to the rest of the treatment plots.

In the sub soil there was no differences in the mean level of NO_3^-–N across treatment plots. This ranged from 198.8 mg/l to 410.4 mg/l. On this day, across all the treatment plots, soil NO_3^-–N was higher in the sub soil than in the top soil.

On the fourth day of measurement, no statistical differences were observed in the mean level of soil NO_3^-–N across treatment plots both in the top and sub soil. This ranged from 278.5 mg/l to 444.9 mg/l in the top soil and 276.9 mg/l to 443.3 mg/l in the sub soil. All treatment plots serve for treatment plot 1, 2 and 3 had higher mean NO_3^-–N in the sub soil than the top soil.

On day number five, the mean amount of NO_3^-–N ranged from 265.7 mg/l to 463.1 mg/l in the top soil and 294.5 mg/l to 452.6 mg/l in the sub soil. A Significantly higher ($p>0.05$) mean amount of soil NO_3^-–N was recorded in treatment plot 8 both in the top soil (463.1 mg/l) and sub soil (452.6 mg/l) compared to the rest of the treatment plots. Except for treatment plot 1, 2, 4 and 8 soil NO_3^-–N was higher in the sub soil than top soil.

On the sixth day of data collection, mean amount of NO_3^-–N ranged from 106.6 mg/l to 324.0 mg/l in the top soil and 139.9 mg/l to 375.0 mg/l in the sub soil. Statistical differences ($p>0.05$) were observed in the mean amount of soil NO_3^-–N in the top soil. This was

Table 1. Soil pH, soil organic carbon, total nitrogen, soil temperature and humidity

Treatment	pH_{H2O} 0-20 cm	pH_{H2O} 20-40 cm	%OC 0-20 cm	Total N (%) 20-40 cm	%OC 0-20 cm	Total N (%) 20-40 cm	Soil Temperature (^{0}C) 0-20 cm	Soil Temperature (^{0}C) 20-40 cm	Soil Humidity (%) 0-20 cm	Soil Humidity (%) 20-40 cm
1.Sole Maize	5.5	5.4	1.08	0.09[b]	1.42	0.12	26.2	26.2	75.7	77.8
2.Medium Duration Pigeon Pea	5.4	5.5	1.50	0.13[a]	1.36	0.12	26.9	26.7	73.6	75.0
3.Long Duration Pigeon Pea	5.6	5.5	1.10	0.07[b]	1.17	0.11	25.9	25.9	75.2	77.2
4.Sole Groundnut	5.5	5.4	1.28	0.11[a]	1.34	0.11	26.3	26.2	77.5	79.8
5.Medium Duration Pigeon Pea + Groundnuts	5.4	5.4	1.29	0.11[a]	1.32	0.11	26.1	25.9	77.6	80.9
6.Long Duration Pigeon Pea + Groundnuts	5.7	5.5	1.63	0.14[a]	1.35	0.11	27.2	26.9	73.5	74.7
7.Medium Duration Pigeon Pea + Groundnuts	5.6	5.6	1.31	0.12[a]	1.55	0.13	25.7	25.7	79.9	81.0
8.Long Duration Pigeon Pea + Groundnuts	5.6	5.5	1.58	0.14[a]	1.39	0.12	27.1	27.1	76.8	77.6
CV%	4.4	3.70	33.6	19.72	17.22	17.75	3.8	3.6	3.6	4.0
$LSD_{0.05}$	0.43	0.35	8.1	0.04	6.43	0.04	1.7	1.7	4.8	5.4

Number of replicates (N) = 3

Table 2. The Estimated amount of biomass produced by the legumes and incorporated into the soil

Treatment	Total Pigeon pea biomass (leaves plus twigs)	Groundnut Haulms (kg/ha)
1. Sole Maize	-	-
2. Medium duration Pigeon pea	2,034	-
3. Long duration Pigeon pea	2,636	-
4. Groundnut only	-	656[a]
5. Medium duration Pigeon pea + Groundnut	2,245	612[a]
6. Long duration Pigeon pea + Groundnut	2,593	479[b]
CV%	29.2	9.9
$LSD_{0.05}$	1,322	98.9

Means with different superscripts within a column are significantly different $p<0.05$; Number of replicates (N) = 3

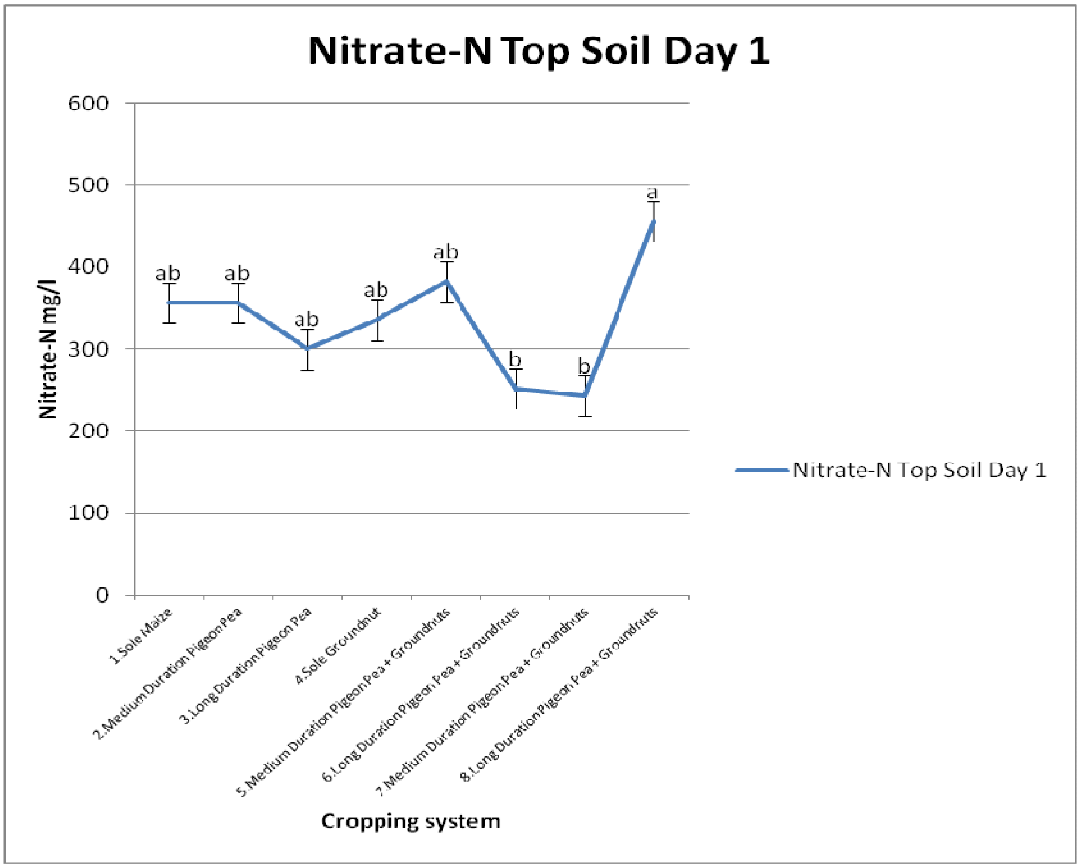


Figure 3. Nitrate-N top soil day 1

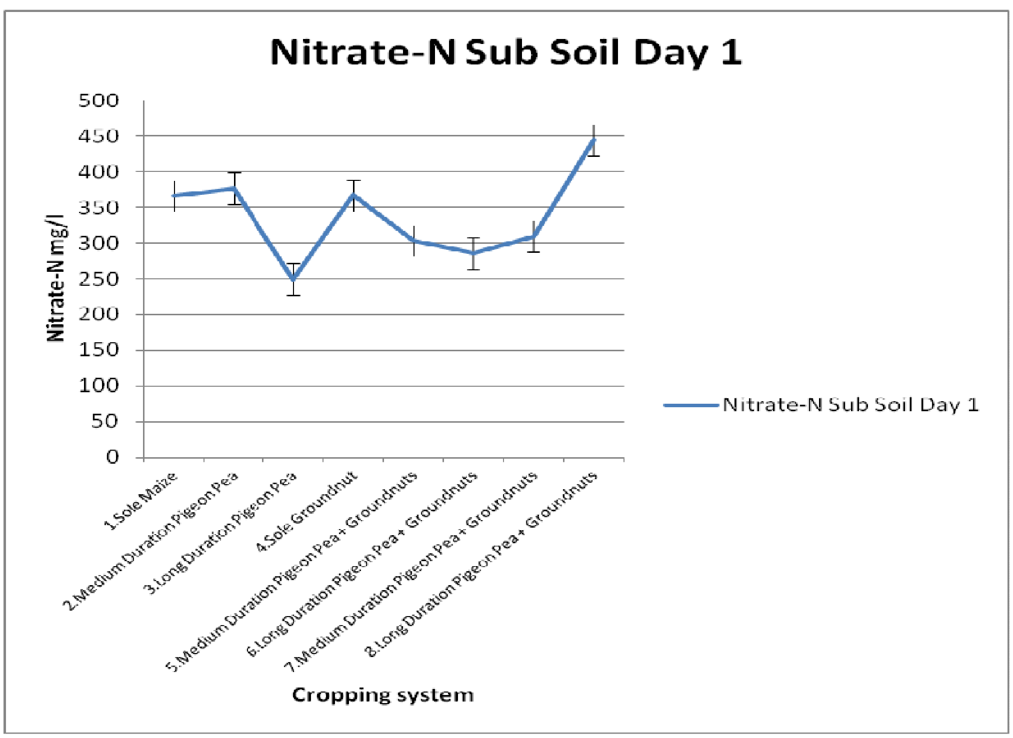


Figure 4. Nitrate-N sub soil day 1

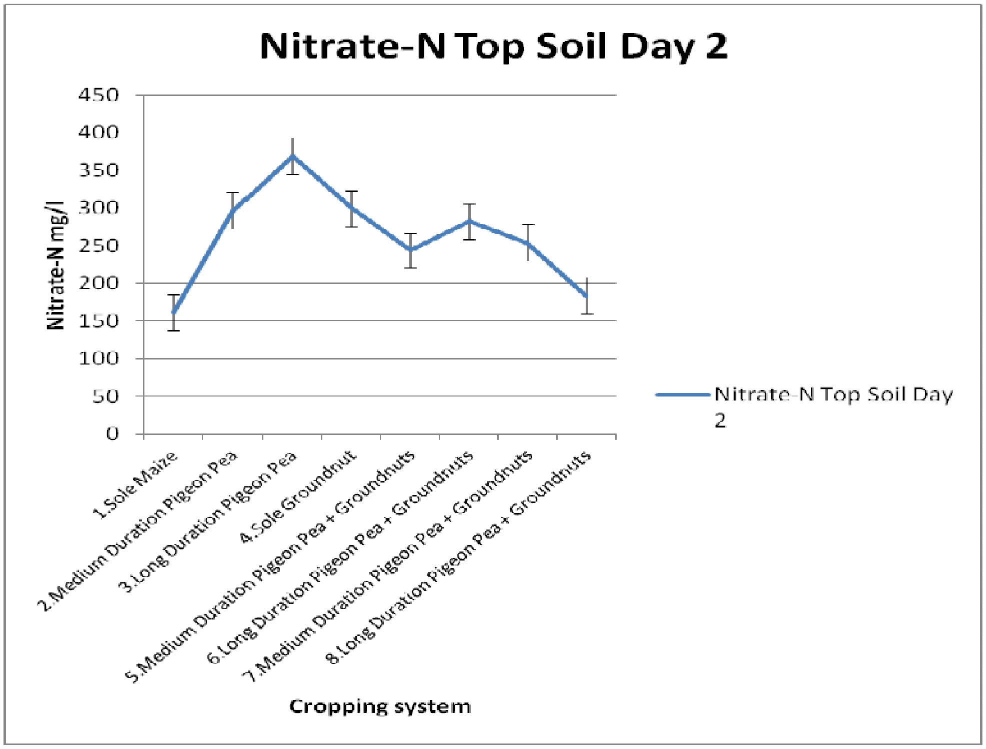


Figure 5. Nitrate-N top soil day 2

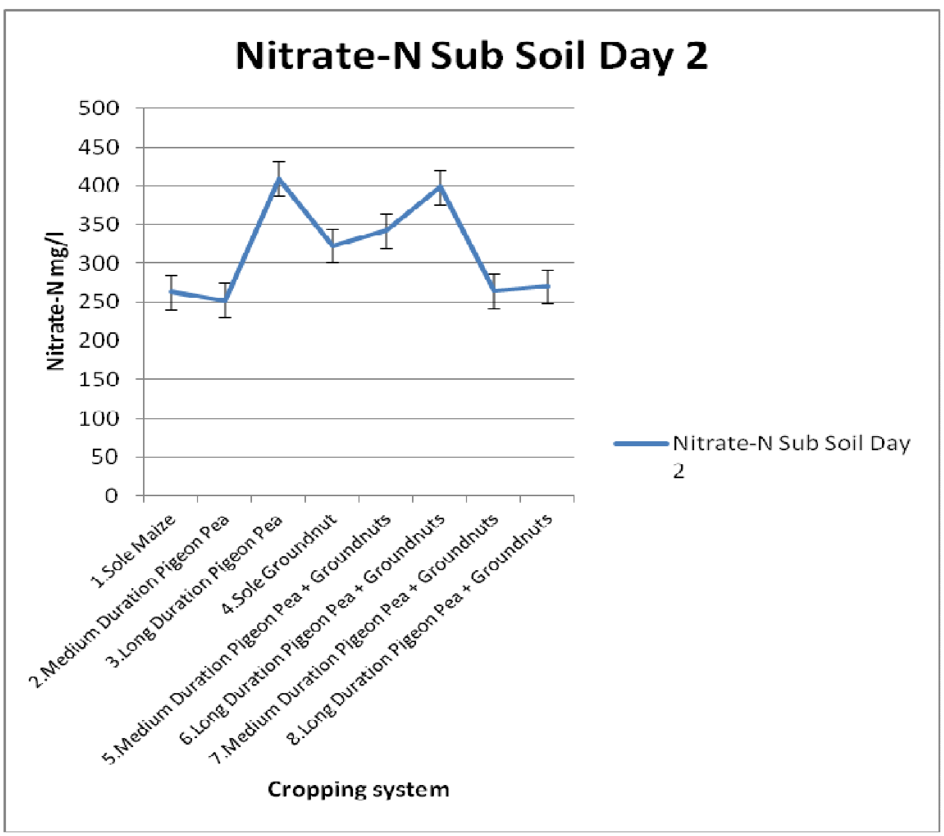


Figure 6. Nitrate-N sub soil day 2

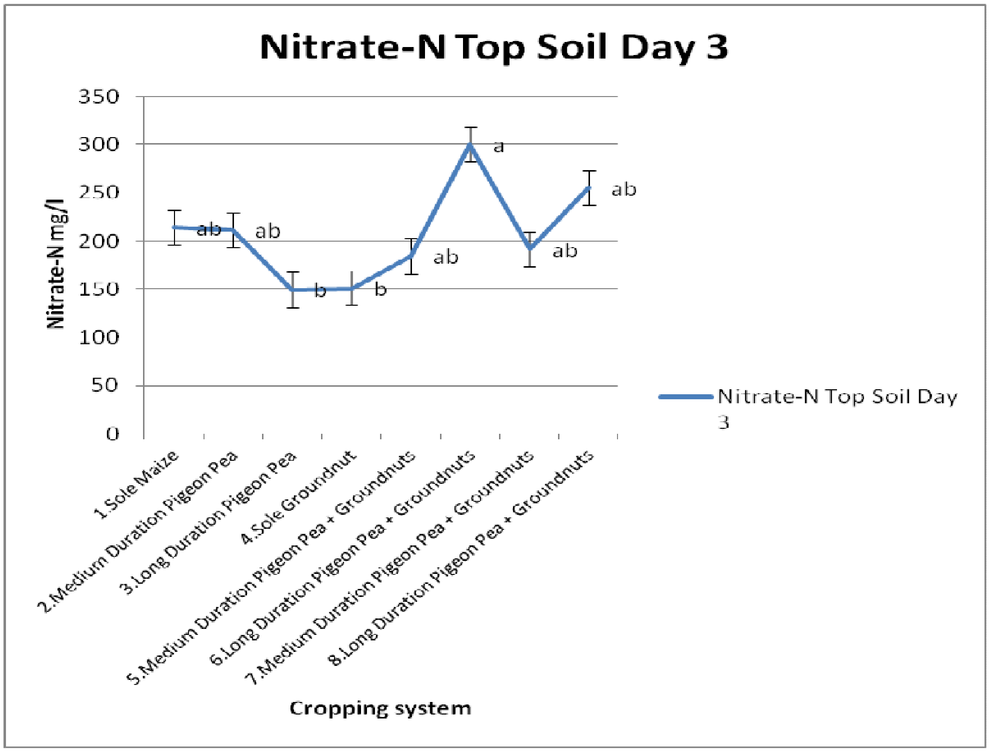


Figure 7. Nitrate-N top soil day 3

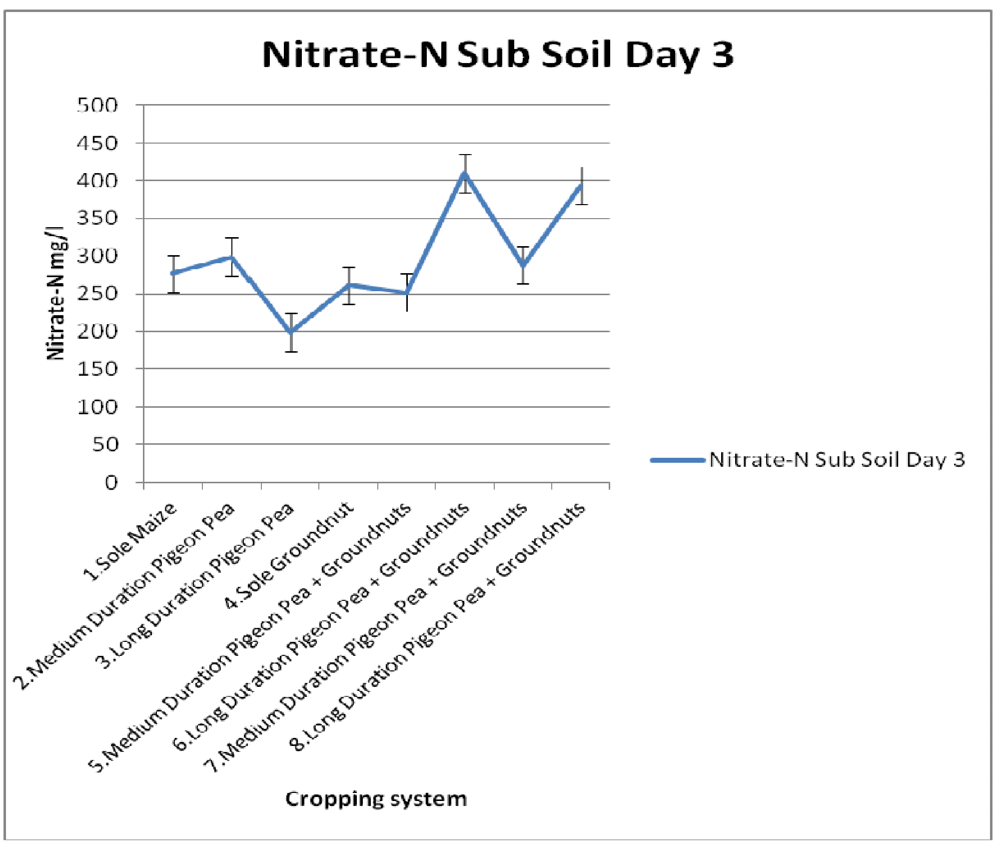


Figure 8. Nitrate-N sub soil day 3

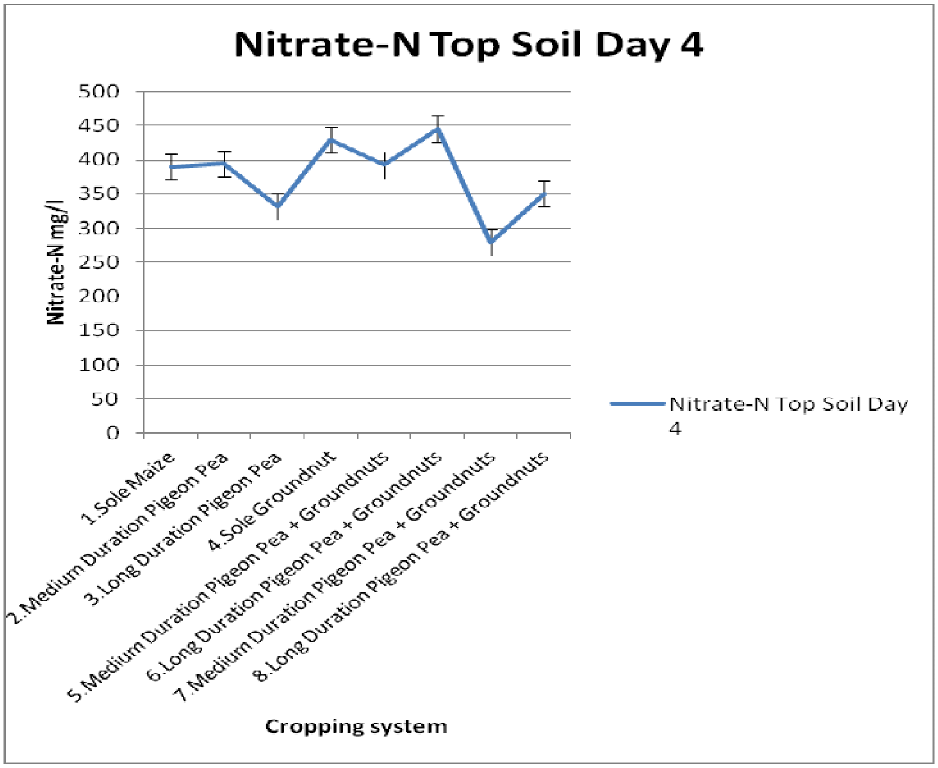


Figure 9. Nitrate-N top soil day 4

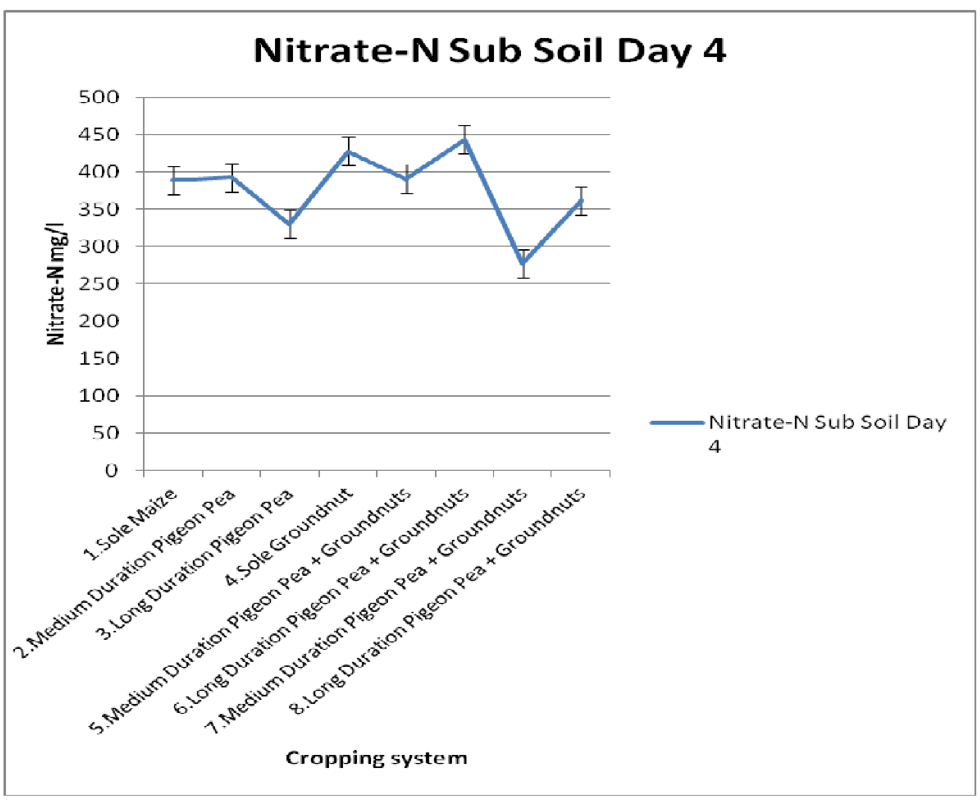


Figure 10. Nitrate-N sub soil day 4

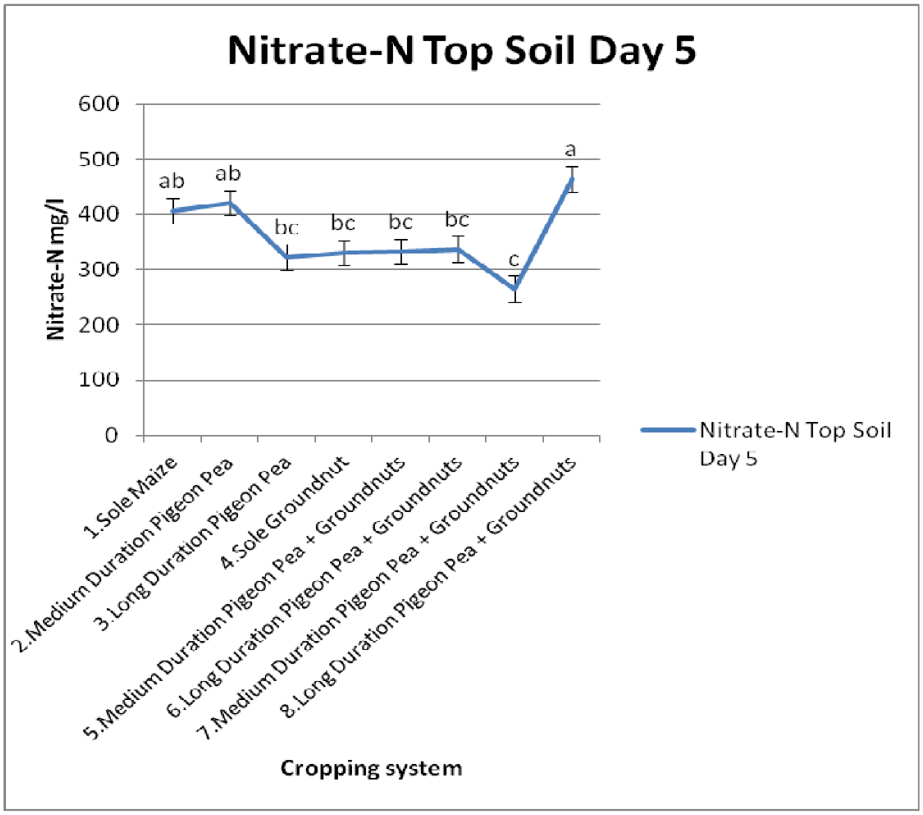


Figure 11. Nitrate-N sub soil day 5

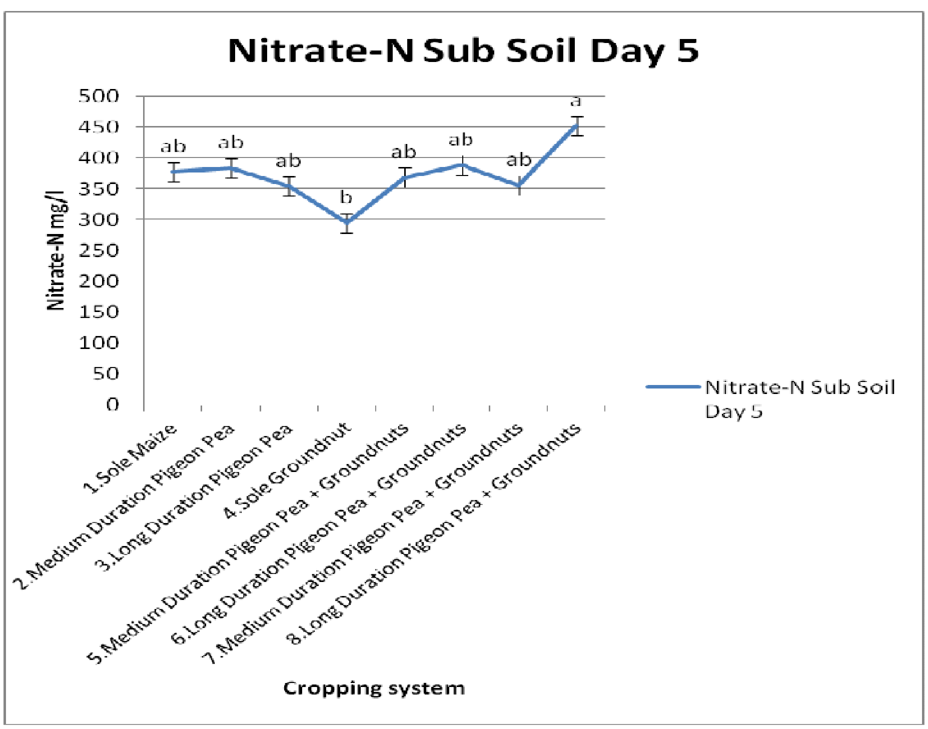


Figure 12. Nitrate-N sub soil day 5

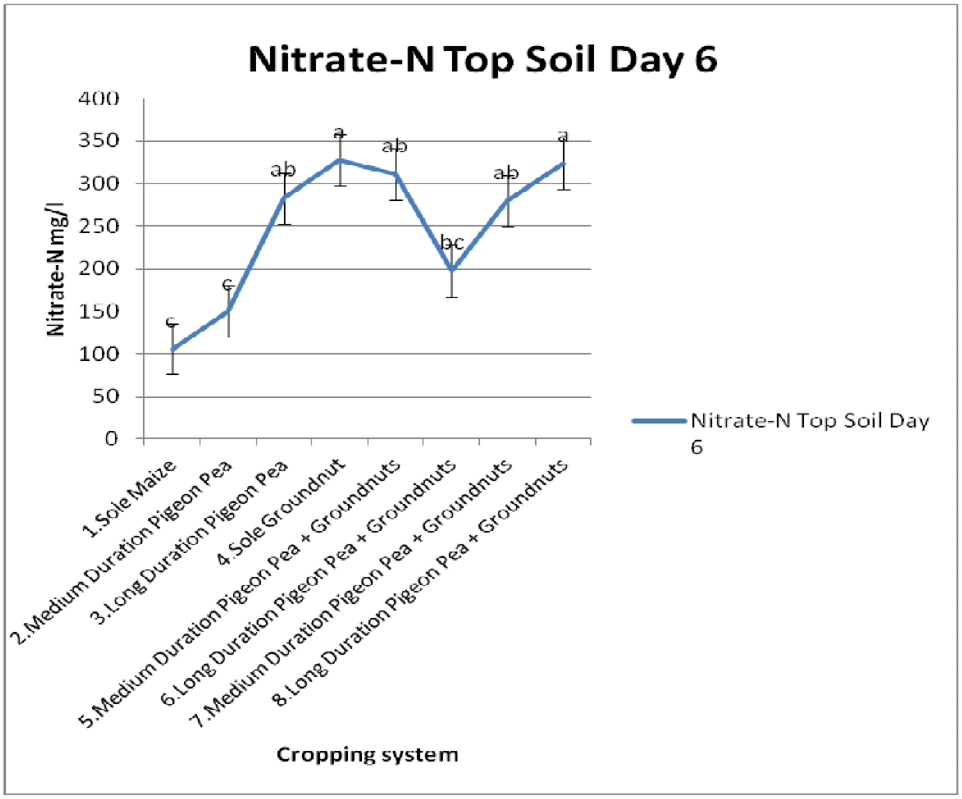


Figure 13. Nitrate-N top soil day 6

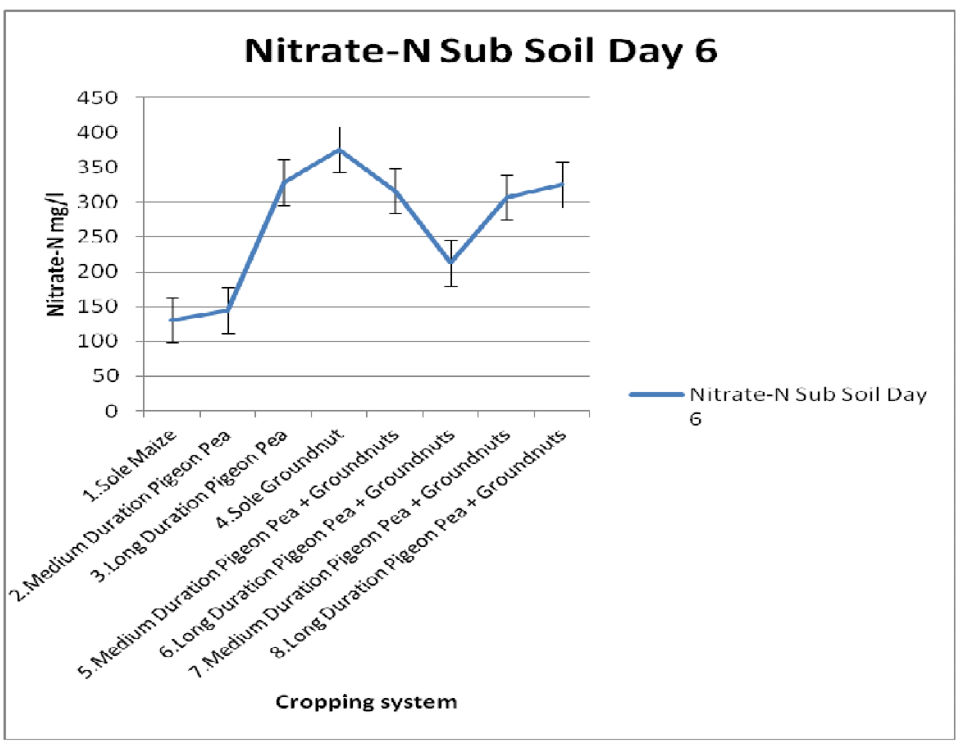


Figure 14. Nitrate-N sub soil day 6

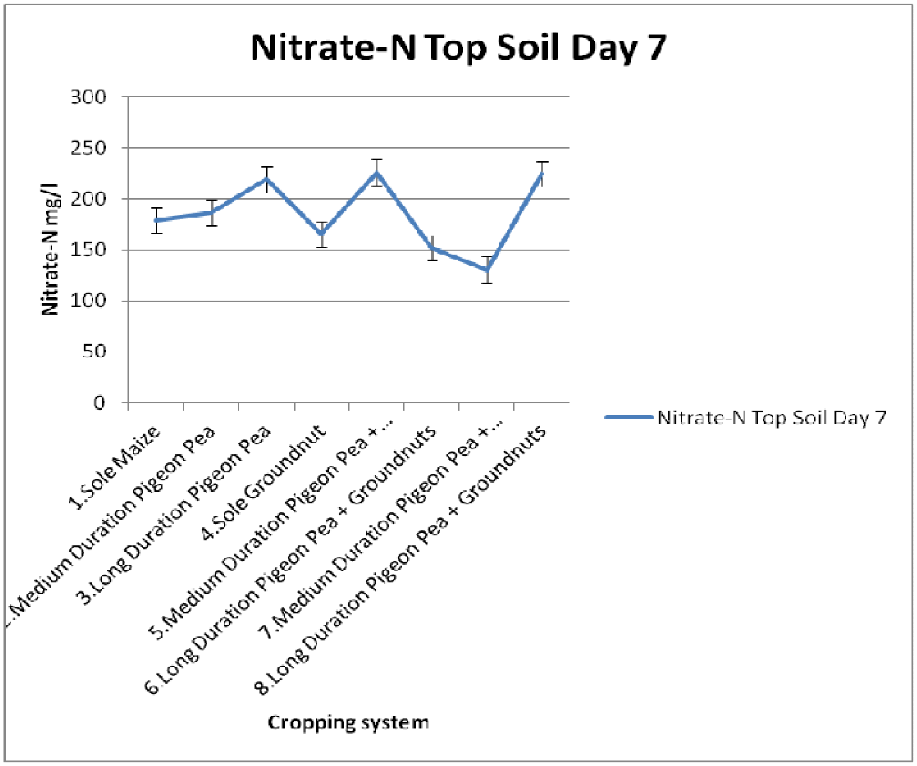


Figure 15. Nitrate-N top soil day 7

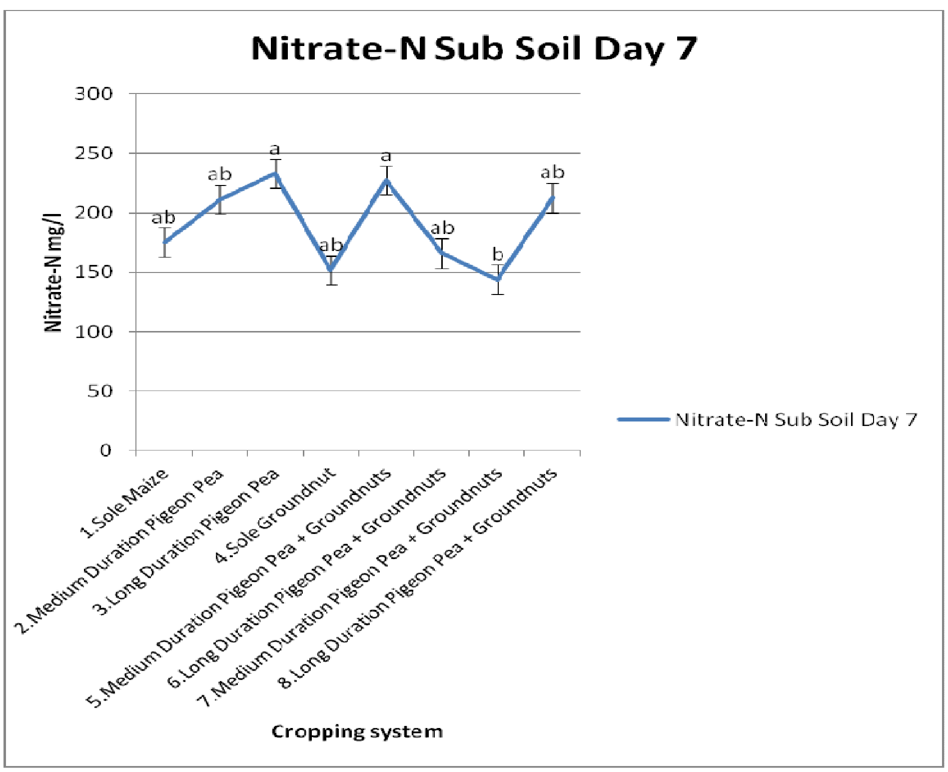


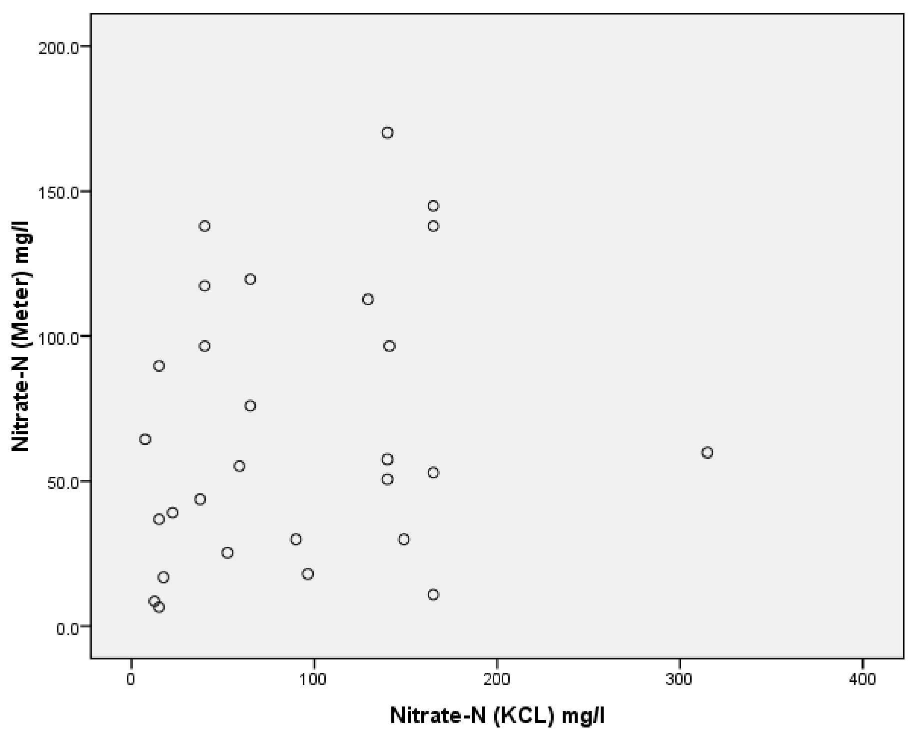
Figure 16. Nitrate-N sub soil day 7

Table 3. Nitrate nitrogen data from the nitrate meter and the KCL method

Treatment	NO_3^-–N (Meter) mg/l 0-20 cm	NO_3^-–N (KCL) mg/l 0-20 cm	NO_3^-–N (Meter) mg/l 20-40 cm	NO_3^-–N (KCL) mg/l 20-40 cm
1.Long Duration Pigeon pea + Groundnut + TSP-25 kg ha^{-1}	51.3	80.1	100.1	103.1
2.Medium Duration Pigeon pea + TSP-25 kg ha^{-1}	70.0	40.8	74.8	137.3
3.Groundnut	87.2	120.5	65.5	99.1
4.Medium Duration Pigeon pea + Groundnut	82.5	70.0	43.9	124.4
5.Long Duration Pigeon pea + Groundnut	17.5	103.0	84.0	88.9
6.Groundnut + TSP-25 kg ha^{-1}	40.0	128.0	70.2	91.4
7.Long Duration Pigeon pea + TSP-25 kg ha^{-1}	110.6	113.3	29.5	88.9
8.Medium Duration Pigeon pea + Groundnut + TSP-25 kg ha^{-1}	60.8	97.0	40.3	86.9
9.Long Duration Pigeon pea	53.9	45.8	70.2	126.4
10.Medium Duration Pigeon pea	107.4	104.2	81.1	138.9
$LSD_{0.05}$	82.8	132.4	114.6	144.7

Number of replicates (N) = 3

Correlation of NO_3^-–N data (Meter) and NO_3^-–N data (KCL): Top soil



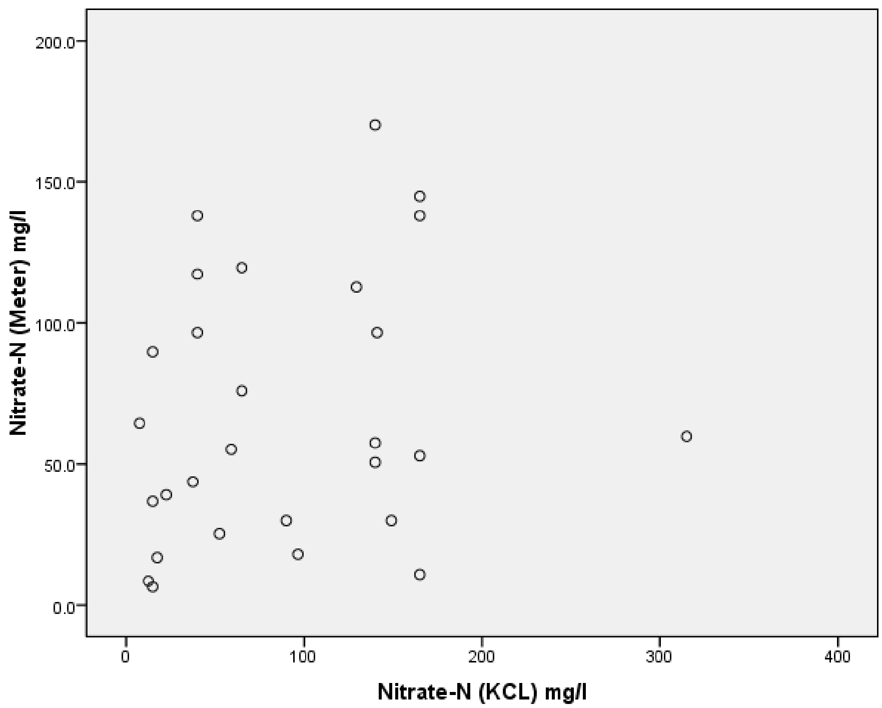
R sq=0.009

Figure 16: Correlation of NO_3^-–N data (Meter) and NO_3^-–N data (KCL): Top soil

significantly higher in treatment plot 4 (328.0 mg/l) and treatment plot 8 (324 mg/l). The lowest amount was recorded in treatment plot 1 (106.4 mg/l) and treatment plot 2 (150.1 mg/l). Except for treatment plot 2 soil NO_3^-–N was higher in the sub soil than top soil.

On the seventh day, no significance differences were observed in the mean amount of NO_3^-–N across treatment plots in the top soil. This ranged from 130.9 mg/l to 226.4 mg/l. In the sub soil this ranged from 144.0 mg/l to 233.1 mg/l. A Significantly higher (p>0.05) mean

Correlation of NO_3^-–N data (Meter) and NO_3^-–N data (KCL): Sub soil



R sq.= 0.071

Figure 17. Correlation of NO_3^-–N data (Meter) and NO_3^-–N data (KCL): Sub soil

amount of soil NO_3^-–N was recorded in treatment plot 3 (233.1 mg/l) and treatment plot 5 (227.4 mg/l). The lowest mean amount of NO_3^-–N was registered in treatment plot 7 (144.0 mg/l). Minus treatment plot 1, 4, and 8, soil NO_3^-–N was higher in the sub soil than top soil.

Nitrate nitrogen data from the meter and KCL method

The table 3 above show data generated from the parallel trial. In general, the amount of NO_3^-–N recorded was lower than data from the main trial (Figure 2-15). Analysis indicate that there is no linear correlation of the data obtained using the nitrate meter and data generated by the KCL method both for the top (R Sq.=0.009) and sub soil (R Sq. 0.071) with wide variation noted within the data sets. In general the KCL method gave higher readings of NO_3^-–N

DISCUSSION

The results of the study seem to suggest that the soil generally has high NO_3^-–N in the soil solution. The values obtained during the cropping season were higher than values reported by Uwah *et al.,* (2009). However the results obtained off season in the parallel trial using both the meter and the KCL method fall within the same range of values reported by Uwah *et al.,* (2009).

In general, the amount of NO_3^-–N recorded off season was lower than data from the main trial (Figure 2-15). This is explainable mainly interms of the prevailing temperature conditions at the time the measurements were done. It was warmer in January, 2013 (Figures 1a and 1b) and cooler in June, 2013 (Figure 2) when data was collected from the main trial and parallel trial, respectively. Most likely higher microbiological activity was present in January than in June, resulting into a higher rate of decomposition and mineralization of N from the buried biomass (Davidson *et al.,* 2006). This released more NO_3^- into the soil system culminating into higher NO_3^-–N readings. The opposite scenario held for the parallel trial. The lower temperature (Figure 2) reduced microbial activity and hence the rate of decomposition of the biomass and mineralization of N (Davidson *et al.,* 2006). The result of this is mirrored by the lower NO_3^-–N values that were recorded (Table 3). In general the KCL method gave higher readings of NO_3^-–N compared to the nitrate meter. This could be attributed to the differences in the extraction procedure for the two methods.

It was further observed however, that the level of mean soil NO_3^-–N in most cases was statistically the same (p>0.05) in treatment plots that had the legume biomass ploughed under and in treatment plots that did not have plant biomass ploughed under. This could be due to two reasons. Firstly, the soil on which the trial was mounted though not having high indigenous nitrogen content has been subjected to N fertilization and legume cropping over years. As such potential for having residual soil NO_3^-–N in soil solution is high (Shapiro *et al.,* 2008). This could possibly be the reason why the values of the parameter were consistently statistically the same ($p>0.05$) in treatment plots with biomass incorporated and treatment plots that did not have the biomass incorporated into the soil. Secondly, it is highly likely that the process of biomass decomposition and mineralization of the organically bound N from the incorporated legume biomass was gradual, due to warm soil conditions (Table 1), thus, this could not lead to spontenous increament in the level of mean soil NO_3^-–N in these treatment plots. It was also observed that largely, mean soil NO_3^-–N was higher in the sub soil than the top soil. This was attributable to the soil texture which is predominantly sandy clay loam with low to medium level of SOM. Leaching of NO_3^- is high under such soil conditions (Fan *et al.,* 2010). It is likely that the level of mean soil NO_3^-–N in the treatment plots which had no biomass buried under will decline faster as the season advances, than in the treatment plots where biomass was incorporated. This would come about mostly due to uptake by the maize crop, leaching losses and denitrification (Ju *et al.,* 2009). However, it is worthwhile to note that though the high level of mean NO_3^-–N may endure longer into the season, for the latter treatment plots, this may not last until the end of the cropping cycle.

CONCLUSION

The results of the study seem to suggest that the soil ingeneral has high NO_3^-–N in the soil solution attributable to residue N from fertilization and legume cropping over years. The mean soil NO_3^-–N was higher in the sub soil than the top soil. This was attributable to the soil texture which is predominantly sandy clay loam with low to medium level of SOM. Leaching of NO_3^- is high under such soil conditions. It was projected that soil NO_3^-–N levels in all the treatment plots will decline in all the treatment plots along the season. This for the Malawian smallholder farmers implies that in this cropping system N supplementation from mineral fertilizer is not optional if reasonably high maize yield is to be realized.

Comparative analysis of two nitrate analysis procedure indicated that the KCL method gave higher readings of NO_3^-–N compared to the nitrate meter. This was accrued to the differences in the extraction procedure for the two methods.

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REFERENCES

Bezner-Kerr R, Snapp S, Chirwa M, Shumba L, Msachi R (2007). Participatory Research on Legume Diversification with Malawian Smallholder Farmers for Improved Human Nutrition and Soil Fertility. *Experimental Agriculture* 43: 437–453.

Davidson EA, Janssens IA, Luo Y (2006). On variability of respiration in terrestrial ecosystems: moving beyond Q_{10}. *Global Change Biology* 12: 154-164.

Deenik J (2006). Soil and Crop Management. Nitrogen Mineralization Potential in Important Agricultural Soils of Hawai'i. *SCM-15.*

Fan J, Hao MD (2003). Nitrate accumulation in soil profile of dryland farmland. *J. Agro-Environ. Sci.* 22: 263-266 [in Chinese].

Fan J, Hao M, Malhi SS (2010). Accumulation of nitrate-N in the soil profile and its implications for the environment under dryland agriculture in northern China: A review. *Can. J. Soil Sci.* 90: 429-440.

Ferguson RB, Hergertb GW, Schepersc JS, Gotwayd CA, Cahoone JE, Petersonf TA (2002). Site-specific nitrogen management of irrigated maize, Yield and soil residual nitrate effects. *Soil Sci. Society Am. J.* 66: 544-553.

Ju XT, Xing GX, Chen XP, Zhang SL, Zhang LJ, Liu XJ, Cui ZL, Yin B, Christie P, Zhu ZL, Zhang FS (2009). Reducing environmental risk by improving N management in intensive Chinese agricultural systems. *PNAS* 106: 3041-3046.

Kanyama-Phiri, G.Y., Snapp, S., Wellard, K., Mhango, W., Phiri, A.T., Njoloma, J.P., Msusa Lowole HM, Dakishon L (2008). *Legume Best Bets to Improve Soil Quality and Family Nutrition.* Conference proceedings: M[c] Knight Foundation S/E African Community of Practice Meeting Lilongwe, Malawi October, 2008.

Krull ES, Skjemstad JO, Baldock JA (2004). Functions of soil organic matter and the

effect on soil properties. In: Grains Research and Development Corporation, pp. 129.

Maida JHA (2005). The role of soil science in agricultural production; *A paper presented at the launch of the book, elements of soil Chemistry and fertility, held at Bunda College of Agriculture on 23 November 2005.*

Miller R, Sonon L (2013). Soil Nitrate Nitrogen KCl Extraction/Cd-Reduction Method.

http://www.clemson.edu/agsrvlb/sera6/NitrateNitrogen3.doc. Site visited on 03/05/2013.

Phiri AT, Njoloma JP, Kanyama-Phiri GY, Sieglinde S, Lowole MW (2010). Maize yield Response to the Combined Application of Tundulu Rock Phosphate and Pigeon Pea in Kasungu, Central Malawi. *Afr. J. Agric. Res.* Vol. 5(11), pp., 1235-1242.

Phiri AT, Njoloma JP, Kanyama-Phiri GY, Sieglinde S, Lowole MW (2013). Effects of intercropping systems and the application of Tundulu Rock phosphate on groundnut grain yield in Central Malawi. International Journal of Plant and Animal Sciences Vol. 1 (1), pp. 011-020.

Shapiro CA, Ferguson RB, Hergert GW, Wortmann CS, Walters DT (2008). Suggestions for corn. University of Nebraska-Lincoln Extension.

Uwah EI, Abah J, Ndahi NP, Ogugbuaja VO (2009). Concentration levels of nitrate and nitrite in soils and some leafy vegetables obtained in Maiduguri, Nigeria. *J. Appl. Science in Environmental Sanitation*. Vol. 4(3), pp., 233-244.

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