ORGANIC MANURE EFFECTS ON SELECTED SOIL PROPERTIES, WATER USE EFFICIENCY AND GRAIN YIELD OF SUNFLOWER

BY

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Declaration

I, Mokgolo Matome Josphinos (11582892), hereby declare that this dissertation hereby submitted to the University of Venda for the degree of Master of Science in Agriculture (Soil Science) has not been previously submitted for any degree to any other university.

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Table of Contents

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Dedication

I dedicate this dissertation to my mother Noko Maggie Mokgolo and my late father Phuti Dalson Mokgolo whose silent presence has guided my effort, and my daughter Rethabile whom I was blessed with during the writing of this dissertation.

List of Acronyms

AI	Aridity Index
ANOVA	Analysis of Variance
BD	Bulk density
CEC	Cation exchange capacity
CM	Cattle manure
CS	Cropping season
D	Drainage
DAFF	Department of Agriculture, Forestry and Fisheries
DAP	Days after planting
EC	Electrical conductivity
ET	Evapotranspiration
FC	Field capacity
GY	Grain yield
HI	Harvest index
I	Cumulative infiltration
LA	Leaf area
LAI	Leaf area index
LSD	Least significant differences
m	mass
MMI	Mapfura-Makhura Incubator
NWM	Neutron water meter
ns	not significant
OM	Organic manure
PAW	Plant available water

PM	Poultry manure
P	Precipitation
PR	Palm residues
RCBD	Randomised complete block design
R	Runoff
OC	Organic carbon
SWRC	Soil water retention characteristics
SPSS	Statistical package for the social science
V	Volume
WU	Water use
WUE	Water use efficiency
WP	Wilting point

List of symbols

Ca	Calcium
K	Potassium
Mg	Magnesium
N	Nitrogen
Na	Sodium
P	Phosphorus
Zn	Zinc
Θg	Gravimetric water content
Θv	Volumetric water content
Θ_{FC}	Volumetric water content at field capacity
Θ_{WP}	Volumetric water content at wilting point
z	soil layer thickness
ΔS	Change in soil water content
Y	Observation of the treatment
μ	Overall mean
i	treatment
ε	random error

List of figures

List of tables

List of equations

Abstract

The application of organic manures as alternatives to reduce the use of mineral fertilizers is considered a good agricultural practice for smallholder farmers. However, the effect of organic manure on soil properties and crop yield depends upon its application rate and chemical composition. Climatic seasonal variability within the study area could adversely affect crop production. The amount of rainfall and temperature are among the most important factors that determines crop production. This field experiment was carried out during the 2013/2014 and 2014/2015 cropping seasons at the University of Venda experimental farm which is located about 2 km west of Thohoyandou town in the Vhembe District, Limpopo Province.

The main objective of this study was to determine the effect of three types of organic manure (cattle, poultry and their combination (1:1)) on yield and water use efficiency of sunflower (*Helianthus annuus* L.) and selected soil physical and chemical properties under rainfed conditions. The experiment was a randomized complete block design (RCBD) with four treatments and four replications (control (C_0), cattle manure (CM), poultry manure (PM) and their combination (CM + PM)). All organic manures were applied 21 days before planting at a rate equivalent to 20 t ha^{-1}. The manures were incorporated in the soil using a hoe to an approximate depth of 10 cm.

Crop water use (WU) and water use efficiency (WUE) were determined using the water balance equation. Rainfall was measured using three standard rain gauges installed on the experimental site. Change in soil moisture storage was determined by monitoring soil moisture content weekly using a neutron water meter (NWM), calibrated on the experimental site.

Data on sunflower dry matter and leaf area index (LAI) was collected at flower bud stage, flowering stage and at grain maturity stage. Plant height and stem girth were also determined at the same developmental stages. Grain yield was measured at physiological maturity.

Analysis of variance (ANOVA) was carried out using SPSS software. Due to seasonal variability encountered during the two cropping seasons, particularly in terms of rainfall, further analysis of two factors (viz. cropping season and organic manure) and their interaction were performed. The differences between treatment means were separated using the least significant differences (LSD) procedure.

The results showed that organic manure application had no significant effect on soil physical properties. Poultry manure application resulted in lowest bulk density (BD) with a decrease of 32% in the top layer (0 – 20 cm) compared to control. Cattle manure + PM and CM application decreased BD in the top layer by 14% and 9% compared to control, respectively. Poultry manure and CM recorded almost the highest similar stable aggregate fractions at all soil depths. Poultry manure recorded the highest final infiltration rate and cumulative infiltration followed by CM and CM + PM. The control treatment retained the highest mean water content compared to other treatments at both field capacity (FC) and wilting point (WP). Cattle manure + PM and PM recorded the least mean water content among others at FC and WP respectively. This could be as a result of increased micropores by organic manure application on a clayey soil which allowed an ease movement of water that control treatment which had no manure application.

Total N, Ca, and Zn were significantly different between treatments in the first cropping season while K, Na, CEC and Zn were significantly different in second cropping season. pH recorded no significant difference in all treatments in both cropping seasons. CM + PM recorded the highest OC at top layer (0 – 20 cm) in both cropping seasons compared to other treatments.

Dry matter yield and LAI at flower bud, flowering and maturity stages increased with the application of different manures compared to the C_0. Organic manure application showed a significant ($p<0.05$) effect on dry matter at all growth stages in the second cropping season. Organic manure had a significant effect on LAI only at flower bud stage of the first cropping season, with PM and CM + PM recording the highest similar value of 1.31. The manure application also showed a significant ($P<0.05$) effect on plant height and stem girth at all growing stages in the second cropping season, whereas in the first cropping season the significant effect was only in the flower bud stage for both parameters.

Grain yield was significantly affected by the manure application in the second cropping season. Manure application in the second cropping season resulted in an increase in the grain yield compared to the first cropping season, except for PM where the grain yield decreased significantly by 167.92% from the first cropping season. Then high grain yield in the second cropping season could be as a result of high WUE reported.

The manure application had a significant effect ($p<0.05$) on water use efficiency (WUE) in the second cropping season. The WUE recorded the highest values under CM and CM + PM treatments in second cropping season than in first cropping season, while PM recorded the highest WUE value in the first cropping season. Generally, organic manures used obtained higher grain yield and WUE compared to control.

Keywords: *Organic manure, smallholder farmers, sunflower and water use efficiency*

1. INTRODUCTION

1.1 Background

In southern Africa, crop production is not only limited by shortage of water alone, but also by poor soil fertility. The poor soil fertility and scarce water resources inhibit farmers to prepare large portions of land to plant crops due to high risk of crop failure associated with arid and semi-arid environments (Kundhlande et al., 2004). In most parts of Limpopo Province, South Africa, crop yields are low and continue to decline in the smallholder sector. This can be explained by declining soil fertility and water scarcity which has been identified as major production constraints to the smallholder farmers. The situation is aggravated by the continuous monoculture system of maize and sorghum which are the staple food crops in relatively wetter and drier areas, respectively. Farmers have identified soil erosion, poor soil type, lack of fertilizer and lack of manure as factors that greatly contribute to low soil fertility (Ramaru et al., 2000).

Vhembe District is one among five districts in Limpopo Province. The district is characterized by high levels of poverty, mostly in rural areas. Most farmers also keep livestock, mainly cattle, goats and poultry. Use of organic manures is highly encouraged in the area because it is available due to the presence of high livestock population while inorganic fertilizers are less available and costly, and cannot be afforded by smallholder farmers in the area. Most of the smallholder farmers in Vhembe District experience low crop yields because they do not use fertilizers due to limited financial resources (Magandini, 2005).

Animal manures such as cattle manure (CM) and PM are excellent fertilizers for crops and forages. Manure contains nitrogen, phosphate, potash and micronutrients that are essential for plant growth. Also applying manure to the farmland can increase water retention capacity, improve tilth, reduce water and wind erosion, improve soil aeration and promote beneficial organisms particularly in sandy soil (Manson and Miles, 2005). The positive role of soil organic matter includes facilitation of soil structural aggregation, infiltration, microbial nutrition, and enhanced mineral nutrient uptake in plants (Brady and Weil, 2002). Improved aggregate stability facilitates water infiltration and hence increases the plant available water content and decreases run-off and erosion.

Worldwide, especially in organic and sustainable agriculture, manure is used as a source of organic matter to improve soil quality as well as the traditional source of crop nutrients (Kumar et al., 2006).

In South African smallholder farming, cattle and goats produce the bulk of the manure accumulating in kraals but in some cases, sheep are also important. Increasingly, smallholder farmers also make use of poultry manure (PM) purchased from large- and small- scale poultry production units (Van Averbeke, 2008). Mbah and Mbagwu (2006) reported that application of organic manure increased cation exchange capacity (CEC) of soils thus indicating greater nutrient retention capacity of soils.

Sunflower (*Helianthus annuus* L.) over the years has emerged as an important ornamental and oilseed crop in the world. It is a successful crop both in irrigated and in rainfed areas and grow well, when planted in areas with adequate sunlight, light-textured and well drained sandy loam soil (Aduayi et al., 2002).

In South Africa, the largest area of farmland planted with field crops is maize, followed by wheat and to a lesser extent, sugar cane and sunflower seed. South Africa is the world's 12th largest producer of sunflower seed, which is produced in the Free State, North West, on the Mpumalanga Highveld and in Limpopo Province. An area of 397 700 ha was planted in 2009/2010 agricultural season, producing 509 000 ton (DAFF, 2012a). The South African annual production of sunflower grain ranges between 500 000 and 700 000 tons. The fluctuations in production levels are mainly caused by uncertain price expectations and high input cost. The average yield ranges from 1.2 to 1.8 t ha^{-1} under dry land (DAFF, 2010).

In Limpopo Province, sunflower and soya bean are major grain crops for the production of biodiesel. Mapfura-Makhura Incubator (MMI) is a registered non-profit making company aiming to provide small scale farmers (incubatees) with training to enhance their technical skills, business and managerial skill to optimize the yields of the two crops required for edible oil and biodiesel production. All incubatees forms a primary base for the supply of sunflower and soya bean feedstock in to the biodiesel plant and are also supported to do both rotational crop production and intercropping as a way of ensuring food security.

Water scarcity is reported to be the main cause of crop failure in rainfed agriculture. Irrigation is currently consuming the largest quantity of available water resources (both ground and surface water) (Leenhardt and Gonzales, 2004). Research results indicate that at current levels of water utilization, a food shortage is likely to occur in the near future. The solution to this problem lies in improving the water use efficiency in the agricultural sector. Improving crop water use efficiency will save water for environmental flow requirements and industrial consumption (Sally and Kamara, 2003).

One of the factors required for optimum yield of crops is adequate nutrients in the soil and its proper management. Organic amendments are cheap sources of improving nutrient status of the soil. Research results have shown that compost and other organic manures can serve as soil amendments to improve soil nutrient status and water holding capacity particularly in sandy soils (Roe et al., 1997). They stabilize soil pH, increase soil organic matter and ultimately improve plant growth and yield.

The main aim of this study was to investigate the application of three organic manures on sunflower grain yield, water use efficiency and selected soil physical and chemical properties under rainfed in the Limpopo province.

1.2 Problem Statement

Sunflower is a drought tolerant crop, almost entirely cultivated in heavy soils of all districts in Limpopo Province. The production of sunflower by smallholder farmers in the province is relatively low. By the year 2002, the estimated total output was 526 tons which was the lowest among the main field crops produced in Limpopo Province (Thomas, 2003). In 2009, the sunflower seed production in the province was 90 000 tons (DAFF, 2011). Water scarcity is one of the problems affecting agriculture in South Africa in general and Limpopo Province in particular. The province is a relatively dry area, with an average annual rainfall ranging between 300 and 600 mm (M'Marete, 2003). The rainfall pattern is erratic and severe droughts are experienced once every eight years (Thomas, 2003). Most soils in Vhembe District are fragile and low in plant nutrients. The nutrient recycling mechanisms that sustain soil fertility are insufficient to support increased production without fertilizers (Odhiambo and Magandini, 2008). Low agricultural crop production in the province is attributed to low rainfall coupled with poor soil fertility. The use of adequate organic manures may alleviate the problem of declining soil fertility and hence lead to increased crop yields. Increasing water use efficiency, thereby increasing the output of a given crop per unit volume (m^3) of water used, is a possible solution to scarce water resources, in addition to drought tolerant crops such as sunflower. In order to increase sunflower production, this study was therefore designed to investigate the application of three organic manures on sunflower grain yield, water use efficiency and selected soil physical and chemical properties under rainfed in the Limpopo province so as to advise farmers appropriately on the use of manures for soil fertility management.

1.3 Motivation of the Study

Much of the arable land in the Limpopo Province is inherently infertile and subject to unreliable rainfall leading to low crop productivity (Ramaru et al., 2000). Research into more drought resistant crops such as sunflower that are suitable for Limpopo Province should be conducted under rainfed conditions with the aim of improving food production and water use efficiency in the agricultural sector (Oni et al., 2003). There is little information regarding the grain yield, water use and water use efficiency of sunflower when fertilized with poultry manure, cattle manure and CM + PM manure under rainfed conditions. Increased yield at high water use efficiency will increase the income of the smallholder farmers so that they can have a better livelihood thereby reducing poverty in most rural areas of Limpopo Province.

1.4 Research Objectives

1.4.1 Main objective

The main objective of this study is to determine the effect of two organic manures and their combination on selected soil properties, yield and water use efficiency of sunflower.

1.4.2 Specific objectives

(1) To determine the effect of organic manure on selected soil properties.

(2) To determine the effect of organic manure on water use efficiency.

(3) To determine the effect of organic manure on sunflower yield.

1.5 Hypotheses

(1) Cattle manure, poultry manure and their combination increases grain yield, water use and water use efficiency of sunflower and

(2) Cattle manure, poultry manure and the combination of the two manures improves soil physical and chemical properties.

2. LITERATURE REVIEW

2.1 Effects of organic manure on soil physical properties

Materechera (2009) reported improved aggregate stability, reduced soil strength and bulk density and increased bambara nut (*Voandzeia subterranean* L.) growth and yield after applying 5 t ha^{-1} of cattle manure (CM) on a hard setting and crusting chromic Luvisol in South Africa. Application of poultry manure (PM) at a rate of 10 t ha^{-1} reduced soil bulk density and temperature, while total porosity and moisture content increased (Ojeniyi et al., 2013). Application of 20 t ha^{-1} CM increased aggregate stability by 33 % compared to control (0 t ha^{-1}) (Nciizah, 2011).

Brar et al. (2015) conducted a field experiment on the effect of long term use of organic and inorganic fertilizers on soil physical properties and soil organic carbon. The authors found that the highest infiltration rate and cumulative infiltration (I) was observed under the application of CM + NPK where more stable aggregation was measured. Khalid et al. (2014) found that the application of 9 t ha^{-1} PM + NPK recorded the lowest infiltration value of 159 mm at one hour duration on a sandy soil, whereas the control gave the highest value of 257 mm. The authors further concluded that the infiltration amount was reduced as the amount of PM application increased, which showed that PM had the ability to reduce the rapid rate of water entry into the sandy soil. Dunjana (2012) observed that on the short-term (2 years), clay field's infiltration rates were increased by 30% with 20 t ha^{-1} CM applications over control, while no changes in steady state infiltration rates were observed with manure application on sandy soils after 6 years (long-term).

The study by Olatunji et al. (2012) showed that the application of PM improved aggregate stability with increasing rate of application. Their study showed that PM applied, helped in sustaining aggregate stability with improved soil fertility. Bakayoko et al. (2013) also reported that CM (10 t ha^{-1}) had improved water retention and aggregate stability than the control.

The addition of CM at a rate of 0, 5, 15 and 25 t ha^{-1} resulted in significant ($p<0.01$) increases in soil organic carbon, macro-aggregate stability and aggregate protected carbon in clay soils from at least the 5 t ha^{-1} CM rate. Aggregate protected carbon in clay soils was significantly higher from the 15 and 25 t ha^{-1} CM rates compared to the 5 t ha^{-1} CM treatment. In contrast, only soil organic carbon was significantly ($p<0.05$) increased with the addition of CM on the sandy soils, while bulk density, macro-aggregate stability and aggregate protected carbon were not significantly changed. Bulk density was also not significantly ($p>0.05$) different on the clay soils. A significant and positive linear relationship ($r^2 = 0.85$) was found between soil organic carbon and macro-aggregate stability, while an r^2 value of 0.82 was obtained between soil organic carbon and aggregate protected carbon on the clay soils. However, no regressions were performed on data from the sandy soils because of the lack of significant changes in soil physical properties (Dunjana et al., 2012).

Rasouzadeh and Yaghoubi (2010) concluded that application of CM (30 and 60 t ha^{-1}) restore the damaged soil structure thereby increasing infiltration, size of aggregates, available water capacity, hydraulic conductivity and decreasing bulk density.

Tekwa et al. (2010) investigated CM application during the rainy months. Four application levels (0, 25, 50, and 75 t ha^{-1}) were studied over a period of four months. Data showed that CM had no effect on the soil densities (particle and bulk densities). Both sand and silt content of untreated control were significantly different ($p<0.05$) from all the treatment levels. The CM recorded a significant effect on clay proportion, especially at increased levels of application rate. The influence of CM on soil porosity also significantly varied between the treatments, especially from the untreated control. The soil water retention capacity did not show significant difference between the control and a plot treated with 25 t ha^{-1} of CM, but was significantly influenced at higher levels (50 and 75 t ha^{-1}) of CM application.

Lawal and Girei (2013) recorded higher sand fraction in plots treated with CM + Urea although statistically similar with other treatments except for urea, CM + NPK and control plots under long term use of CM and mineral fertilizer. Though the clay fraction was not significantly ($p>0.05$) affected by CM and NPK, plots amended with CM + NPK recorded the highest mean clay fraction. The infiltration rate had a significant difference ($p<0.01$) among the treatments means with plot treated with CM and their combination possessing better rate than the no amendment plots except for CM + NPK plot which was statistically equal with the control. Lawal and Girei (2013) further observed that CM and mineral fertilizer had no significant effect on the soil water retention capacity at 30 kPa (field capacity). However, the plot amended with CM + NPK retained the highest mean moisture at field capacity relative to other treatments. At 1500 kPa, the effect of cattle manure and mineral fertilizers on soil moisture retention capacity was highly significant ($p<0.01$) where plot treated with urea and CM + NPK recorded the highest mean moisture retention relative to the plot with no amendment.

2.2 Effects of organic manure on soil chemical properties

The effects of animal manures on selected soil properties were studied in the laboratory by Ano and Agwu (2005). Poultry manure (PM) and cattle manure (CM) were added at 10, 20, 30 and 40 t ha^{-1} to an acidic Ultisol. The amended soils were incubated at 70% water holding capacity for three weeks. The treatments increased soil pH with PM having the greatest effect than CM. Animal manures also reduced exchangeable acidity and increased exchangeable Ca and Mg. The authors found that all the manures did not improve soil organic carbon. Brar et al. (2015) found that the addition of CM had no significant changes in pH compared to other fertilizer treatments except control.

Ullah et al. (2008) reported that soil pH decreased with organic manure (CM at 22.9 t ha^{-1} and PM at 5 t ha^{-1}) application and combined application (organic and inorganic fertilizers) but increased with only chemical fertilizer application. The authors further found that in all cases, the nutrient availability increased and the highest availability of N, P and S was from PM and the highest availability of K was from CM followed by PM.

Ayuba et al. (2005) reported that two application rates of CM (15 and 30 t ha^{-1}) and two application rates of PM (10 and 20 t ha^{-1}) increased the soil pH, organic matter, N, available P, exchangeable K, Ca and Mg relative to control.

Kaur et al. (2005) reported that the application of cattle manure and poultry manure alone or in combination with chemical fertilizers improved the soil organic C, total N, P, and K status. Adeniyan et al. (2011) investigated the effects of different organic manures and NPK fertilizer for improvement of soil chemical properties and maize traits and concluded that application of organic manures enhanced soil organic carbon, total N, available P, and exchangeable K better than NPK fertilizer. However, the application of chemical fertilizer achieved the highest amount of dry matter and yield of maize.

Olatunji et al. (2012) applied poultry manure of 0 kg, 50 kg, 100 kg and 200 kg on a 4 m x 4 m plot and found that available phosphorus, potassium, and organic matter improved with increasing rate of application of poultry manure.

The study by Okonwu and Mensah (2012) reported that PM application (0, 1, 2, 3, 4 and 5 t ha^{-1}) increased nutrient content (N, P, K, Ca, Na and Mg) of the soil. Among the treatments, 5 t ha^{-1} of PM had the highest value for N, Mg, organic matter, and OC while 2 t ha^{-1} PM gave the highest value for K, Ca and Na content of the soil. The available P, Ca, Mg, organic matter and OC were quite high at 4 t ha^{-1} PM. The control showed the least for all nutrients assessed in the soil. The pH value for the control was 5.78 and increased to 7.21 when 3 t ha^{-1} of PM was applied. Their study recommended an application rate of 5 t ha^{-1} for the improvement of the soil nutrients. Studies have shown that PM increased soil organic matter, nitrogen, pH, phosphorus and CEC (Adeniyan and Ojeniyi, 2003; Mbah and Mbagwu, 2006; Ayeni et al, 2008)

Gholamhoseini et al. (2012) reported that the highest and lowest rates of nitrate leaching were obtained from the full irrigation and urea (36 kg ha^{-1}) and full irrigation and urea + CM with 21% Zeolite (11 kg ha^{-1}) treatment combinations, respectively. Fertilizing only with urea resulted in the highest nitrate leaching across both irrigation regimes, while the integrated treatments (urea + CM with w/w% zeolite) significantly decreased nitrate leaching, compared to the urea treatment, particularly with full irrigation. Addition of zeolite to the CM also decreased P leaching but not as much as for nitrate leaching. Gholamhoseini et al. (2012) concluded that amending soil with manure and zeolite can be a beneficial approach for decreasing chemical fertilizer application rates and improving the sustainability of agricultural systems.

The study by Dikinya and Mufwanzala (2010) reported that PM application, irrespective of the application rate did not change the pH or acidity of the Luvic Calcisol. However, substantial pH increase or response with increasing application rate of PM was observed in the case of Ferralic Arenosol and Vertic Luvisols, whereas the amount of exchangeable bases increased with increasing application rate for all the soil types.

2.3 Effects of organic manure on sunflower water use and water use efficiency

Water use efficiency (WUE) represents a given level of biomass or grain yield per unit of water use (WU) by the crop (Hatfield et al., 2001). Cattle manure (CM) application at 25 t ha^{-1} per year results in increased crop water use efficiency or water productivity over no manure application on both clay and sandy soils (Dunjana, 2012). Filho et al. (2013) evaluated water use, water use efficiency and yield components of sunflower cultivated in two types of soil (Fluvisol and Haplic Luvisol) subjected to increasing doses (5, 10, 15 and 20% v/v) of cattle manure. Their results showed that the sunflower was positively affected by cattle manure application, increasing the production components and the water use efficiency, regardless of the type of soil. Except for the 1000 seeds weight and the water use efficiency, the type of soil significantly affected the water use, the number and weight of seeds per plant. Regarding the efficiency of the water use, a significant effect ($p<0.01$) was only observed on doses of cattle manure applied on soil (increasing with the increasing dose). The efficiency of water use increased at a rate of 0.03 g L^{-1} per percentage unit of cattle manure increased, totaling 1.349 g L^{-1} for 20% of manure. According to the data on biomass production and water use of the sunflower, Filho et al. (2013) noticed that the efficiency of water use, although not significant, was increased by the doses of manure in both soils, i.e., sunflower plants showed greater ability to reverse the volume of water consumed in the production of dry matter.

Soriano et al. (2004) conducted two field experiments to investigate the effects of early and late planting dates on the components of water-limited crop productivity of sunflower; namely, water use, water use efficiency (WUE) and harvest index (HI) of sunflower. The results were generalized by simulating rain-fed sunflower yields, under early and late plantings. For the two years, water use of early plantings was higher than that of late plantings, but the response of WUE and harvest index to planting date was not the same in the two experiments. In the simulation exercise, water use and water use efficiency of early plantings were consistently higher than those of late plantings, while there were no differences in the HI for the two planting dates. Soriano et al. (2004) concluded that early plantings of sunflower increased rain fed yields by increasing both water use and water use efficiency, while the impact of planting date on HI very much depends on the crop water stress pattern, which is quite variable from year to year even in the predictable Mediterranean environment (Soriano et al. 2004).

Gholamhoseini et al. (2012) found that limited irrigation and combination of urea + cattle manure with 21% Zeolite had maximum irrigation water use efficiency in the second growing season (0.81 kg m^{-3}), while the minimum value was found for the full irrigation and urea in the first growing season (0.48 kg m^{-3}).

2.4 Effects of organic manure on sunflower growth and yield

Wabekwa et al. (2014) conducted an experiment to evaluate the performance of sunflower under various poultry manure (PM) application rates (0, 2, 4, 6 and 8 t ha^{-1}) during 2010 and 2011 rain seasons. The authors reported significant ($p<0.05$) increase in growth variables such as grain yield per head, plant height, head diameter and plant dry matter as application rate of PM increased up to 6 to 8 t ha^{-1}.

Esmaeilian et al. (2012) found that application of cattle manure (CM) (30 t ha^{-1}) resulted in maximum grain yield (3752 kg ha^{-1}) which was statistically equal to that of PM (10 t ha^{-1}). Adebayo et al. (2012) reported that organic amendments (PM, CM and composted organic waste of different combinations on dry weight basis: cassava/poultry manure at a ratio 3:1 and elephant grass/poultry manure at a ratio of 3:1) all at rate of 5 t ha^{-1} had no significant effect on flower diameter and head weight of sunflower in the first planting, but CM application recorded the highest value for all parameters (yield and dry matter partitioning to stem, root and leaves). In the second planting season, all organic amendments had significant effects on the flower diameter and head weight of sunflower. CM significantly recorded the highest flower diameter (12.13 cm) and head weight (3.93 kg). These values were closely followed by cassava/poultry manure 3:1 for both parameters measured. The application of organic amendment at 5 t h^{-1} had no significant effect on dry matter content of sunflower in the first planting but cassava/poultry manure 3:1 and elephant grass/poultry manure 3:1 significantly recorded low dry matter content of root and stem in the second planting. The authors concluded that the performance of CM and cassava/poultry manure 3:1 over the amendments and control at this application rate may be as a result of the higher nitrogen content in both treatments.

Helmy and Ramadan (2009) stated that dry matter yields at vegetative and flowering stages of sunflower were increased with the application of three different organic nitrogen sources: CM, PM and palm residues (PR), all applied at 119.0 kg N ha^{-1} and their combination (CM + PM, CM + PR and PM + PR) compared to the control treatment. Sunflower yield and its components i.e., head weight, seed weight per head, seed yield, straw yield and crop index were significantly increased due to the addition of organic N sources individually or combined. The relative values of seed and straw yield due to the treatments over the control were as follows: 142.0(CM), 224.0 (PM), 217.5 (PR), 188.6 (CM + PM), 154.4 (CM + PR) and 175.1% (PM + PR) for seed and 195.5 (PM), 327.7 (PM), 261.6 (PR), 270.0 (CM + PM), 185.6 (CM + PR) and 152.7% (PM + PR) for straw. The 100 seed weight showed an increase but not significant. When organic manures were added individually, the PM was superior followed by PR and then CM for both seed and straw yield. Comparing the combination of the used organic manures, the data present the following descending order: CM + PM > PM + PR > CM + PR for seed and CM + PM >CM+PR > PM+PR for straw.

Buriro et al. (2015) conducted a study on the impact of organic and inorganic manures on sunflower yield and yield components and reported that 6 t ha^{-1} PM + 75% NPK had taller plants with an average height of 201 cm and thicker plants with a stem girth of 3.71 cm. Accordingly with the same manure inputs, highest number of average leaves per plant (20.70), head diameter (19.49 cm), seeds per head (1650.91) and weight of seeds per head (66.04 g) were recorded. The same manure inputs (6 t ha^{-1} PM + 75% NPK) further recorded the highest grain yield of 2017.74 kg ha^{-1} followed by 8 t ha^{-1} + 50% NPK, goat/sheep manure 6 t ha^{-1} + 75% NPK and goat/sheep manure 8 t ha^{-1} + 50% NPK with 1997.74 , 1994.70 and 1962.53 kg grain yield ha^{-1}, respectively.

Incorporation of CM by Rasool et al. (2013) at 10 and 20 t ha^{-1} significantly improved sunflower growth parameters over the control. The dry matter production with 10 t ha^{-1} CM was 9.5% higher over control. The authors further observed that application of 10 and 20 t ha^{-1} of CM increased sunflower grain yield by 9 and 15%, respectively over control. This might be due to better crop growth, facilitated by the improvement in soil physical, chemical and biological properties as well as plant nutrition with the addition of organic manure (Rasool et al., 2013).

Filho et al. (2013) reported that the increase in the production components of sunflower was affected by CM application. The CM used as treatments were previously tanned and mixed with the soil in the following proportion: 5% (1.5 L of manure + 28.5 L of soil), 10% (3 L of manure + 27 L of soil), 15% (4.5 L of manure + 25.5 L of soil) and 20% (6 L of manure + 24 L of soil). The yield components of sunflower were influenced at 1% probability by cattle manure and the two soil types (Fluvissol and Haplic Luvisol). The mass of 1000 seeds increased with the increase of the doses of CM. The increase in the weight of 1000 seeds reached the maximum weight of 30.63 g when fertilized with the highest dose (20%) of manure. It was observed that the growth of the plants cultivated in Fluvisol was positively affected by the increase of the doses of the manure, reaching the maximum of 1126 seeds. On the other hand, the number of seeds per plant cultivated in Haplic Luvisol reached a maximum of 1428 seeds per plant with the dose of 20% cattle manure.

Gholamhoseini et al. (2012) conducted an experiment to determine the effects of applying CM combined with zeolite and chemical fertilizer on sunflower yield and quality and nutrient leaching fewer than two irrigation regimes on a sandy soil in a semi-arid region. Irrigation regimes were full irrigation and limited irrigation. Their results showed that limited irrigation significantly decreased dry matter yield by 10% in the first growing season and 9% in the second growing season. Dry matter and seed yield were considerably improved by the application of manure + zeolite in both years, but the impact of their application was greater in the second growing season than in the first. In both growing seasons, the maximum seed protein content was achieved with the urea + CM with 21% Zeolite treatment, while minimum seed protein content was observed in the urea + CM with 0% zeolite and urea only for first and second growing seasons, respectively.

2.5 Production levels of sunflower

The production of sunflower, which is an important source of vegetable oil in South Africa, is most prevalent in the summer rainfall areas. During the 2010/2011 production season, South Africa was recorded as the 9th largest sunflower producer in the world (USDA, 2011). South Africa produced 500 000 to 800 000 tons of sunflower seed per year between 2005 and 2010 (USDA, 2011). In 2013/2014 production season, 19 farmers (incubatees) from Sekhukhune, Waterberg, and Capricorn district of Limpopo Province each produced an average sunflower grain yield of 3.6 t ha^{-1} (MMI, 2014). The same amount of yield was obtained in the previous production season (2012/2013 season) by largely increased 62 incubatees.

2.6 Sunflower production areas

Sunflower seed is produced mostly in eight out of the nine provinces of South Africa. Traditionally, the North West and Free State Provinces produced a significant amount of sunflower seed. Sunflower seed can be planted from the beginning of November to the end of December, which is almost the same time for maize plantings (DAFF, 2012b).

Generally, it was observed that during the five-year period between 2006 and 2010, the production of sunflower seed experienced a downturn in almost all the major producing provinces. The Free State Province consistently experienced a downward trend in sunflower seed production during this period except in 2008, while another major producer, the North West Province, also had a similar experience. The same trend was observed in other provinces such as Limpopo and Mpumalanga (DAFF, 2012b). The actual production of sunflower grain during the 2009/2010 production season showed that the Free State and the North West provinces were the major producers of this crop, followed by Limpopo, Mpumalanga and Gauteng provinces. Very small quantities of sunflower grain were produced in the Western, Eastern and Northern Cape provinces of South Africa (DAFF, 2012b).

2.7 Uses of sunflower

Sunflower can be used as edible oil in the form of margarine, salad dressing oil and cooking oil. In Limpopo Province, Mapfura-Makhura Incubator (MMI) Company uses sunflower grain extract for the edible oil and biodiesel production. It can also be used as snacks. The non-dehulled or partly dehulled sunflower meal can be used as feed for ruminant animals, pigs and poultry because of its high protein percentage of 28% to 42%. Sunflower can be used as silage for animal feeds. Sunflower silage is richer in nutrients than maize but lower than alfalfa hay (Agele and Taiwo, 2013; DAFF, 2010).

Sunflower can be used in certain paints, varnishes and plastics because of good semi-drying properties without colour modification associated with oils high in linolenic acid. Sunflower can also be used to manufacture soaps and detergents. Other industrial uses of sunflower include the production of agrochemicals or pesticides, surfactants, adhesives, fabric softeners, lubricants and coatings. A future high-potential use will be on diesel engines as the world is striving for a non-polluted environment (DAFF, 2010).

3. MATERIALS AND METHODS

3.1 Description of the study site

A field experiment was conducted during the 2013/2014 and 2014/2015 cropping seasons at the University of Venda experimental farm (22°58' S; 30°26' E). The University of Venda is located in Thulamela Municipality and it is about 2 km west of Thohoyandou Town in Vhembe District, Limpopo Province. The site is 596 m above sea level (Mzezewa and van Rensburg, 2011). Figure 1 presents a map showing the location of the study site.

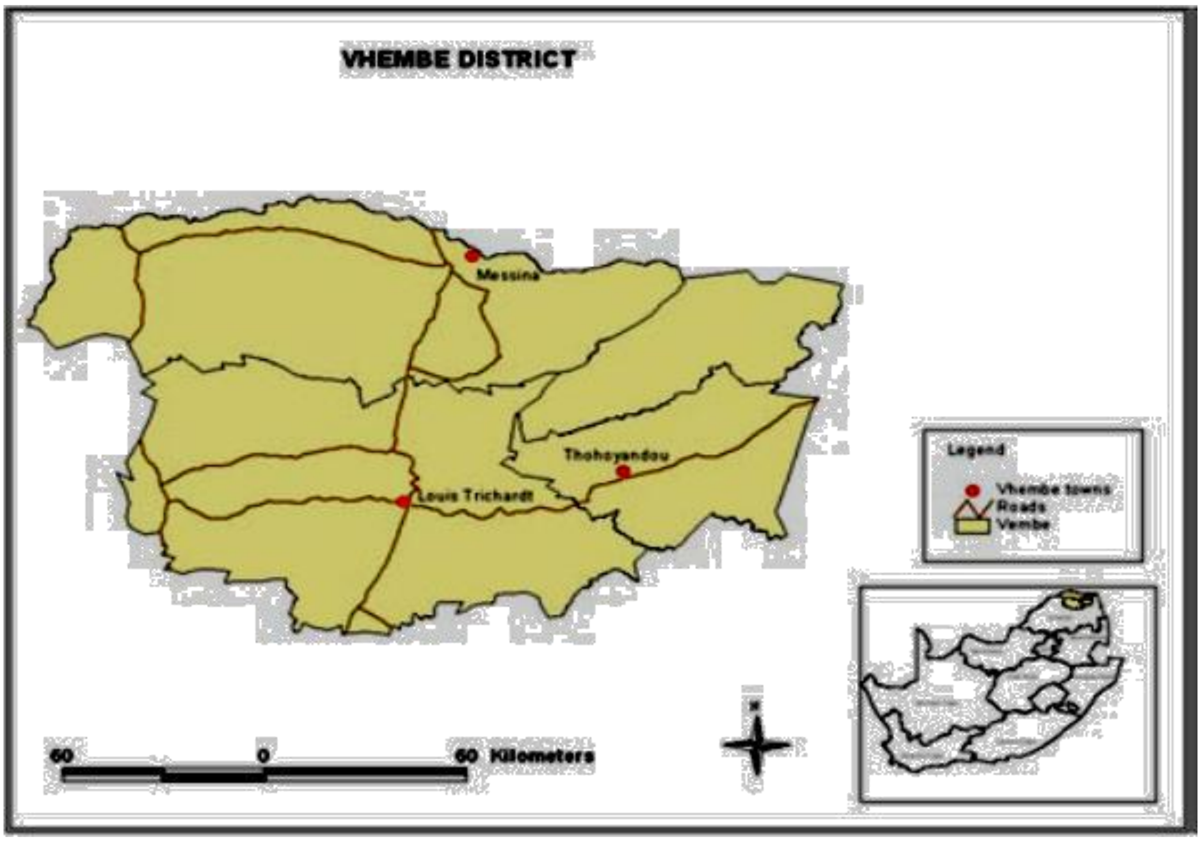


Figure 1: A location of the study area (adapted from Mzezewa and van Rensburg, 2011)

The experimental area falls within the eastern part of the lowveld, which forms part of the greater Limpopo River basin. The study site receives about 781 mm annual rainfall and it is highly seasonal with 85% occurring between October and March (summer). The highest evaporative demand also occurs from October to March. The mean annual aridity index (AI) is 0.52 (Mzezewa and van Rensburg, 2011), causing the area to fall on the borderline between semi-arid and sub-humid according to the UNESCO classification criteria.

The soil at the experimental site was described and classified as Shortlands form according to the Soil Classification Working Group, (1991). The soil is deep (>1200 mm) characterized by a weak angular and subangular structure in a dry state (Figure 2.). The soil profile was uniform with no limitation of water movement and plant roots penetration. The entire profile had a munsell colour notation of 10R3/3 in a moist state (dark reddish brown or dusky red) (Revised Standard Soil Color Charts, 1967). The soil was characterized by well drained clays with slightly acidic average pH of 5.72 which makes the soil suitable for agricultural production especially for deep rooted drought tolerant crops. The soil falls under mesotrophic soils, with no calcareousness and belongs to the *Bayala family*.

Figure 2: Vertical view of the soil profile at the study site

3.2 Soil profile description

A soil profile of 1.2 m deep was described according to the procedure specified by the South African Agricultural Research Council-Institute for Soil, Climate and Water. The profile was classified according to the Soil Classification-A Taxonomic System for South Africa (Soil Classification Working Group, 1991). Bulk density samples were also collected during the description of the soil profile for the calibration of neutron water meter (NWM) from the following depths: 0 - 300 mm, 300 - 600 mm, 600 - 900 mm and 900 - 1200 mm.

3.3 Organic manure sources and application

The organic matter sources comprised of cattle manure (obtained from a nearby smallholder farmers' kraal), poultry manure (obtained from the University of Venda broilers house), and the combination of two manures at a ratio of 1:1 on dry weight basis. Before manure application, the two organic matter sources were analyzed (i.e. pH, organic matter content, total nitrogen, extractable P and Zn, exchangeable Ca, Mg, Na and K, and CEC). Each manure type and their combination was applied at a rate of 20 t ha^{-1}, except for control plots where no manure was applied. The manures were applied to the soil 21 days before planting (Okorogbona et al., 2011; Mehdizadeh et al., 2013), to allow sufficient time to react with the soil. The manures were incorporated in the soil using hand hoe to an approximate depth of 10 cm.

3.4 Land preparation and experimental layout

The experimental site was ploughed using a disc plough at the beginning of the first cropping season only, followed by manual seed-bed preparation and plots demarcation before planting. The land preparation for second cropping season in each plot was done manually in order to retain the previous season's demarcated plots and also to protect the access tubes. The field layout was a randomized complete block design (RCBD) with a total of 16 plots, with individual plot measuring 36 m^2 (6 x 6 m). The plots were 1 m apart from each other to avoid encroachment of organic manure, therefore the area of the whole experimental site was 841 m^2 including 1 m length separating the plots. Four treatments were applied (control, poultry manure, cattle manure and the combination of manures 1:1) and replicated four times.

3.5 Planting density and spacing

A landrace sunflower seed collected from local farmers was planted. Two seeds were planted per hole at a spacing of 0.3 m (intra row spacing) and 1 m (inter row spacing) at an approximate depth of 2.5 cm. Planting was done on 8th December 2013 and 28 November 2014 for first and second cropping seasons respectively. The seedlings were thinned to one stand per hole after two weeks of emergence. The plant density after thinning was approximately 33 333 plants ha^{-1}. Pests were controlled with Malathion 50% EC and weeds were controlled manually throughout the growing season.

3.6 Soil sampling and analysis

Each season before manure application and planting, three soil samples were randomly collected at two depth intervals (0 – 20 cm for top soil and 20 – 30 cm for subsoil) using a soil auger. Samples from the same depths were bulked, dried, sieved (2 mm) and stored in a laboratory plastic bag for subsequent physical and chemical analysis. At the end of each cropping season, the representative soil samples from each plot at the same depths were collected for analysis.

3.7 Soil physical properties

3.7.1 Bulk density determination

Bulk density was determined using the core method (Blake and Hartge, 1986). The soil surface was cleared to remove any debris or obstacles before sampling. The soil samples were taken using a 98.17 cm^3 core ring (5 cm inner diameter and 5 cm height) with cylindrical core sampler. The core ring was fitted on the cylindrical core sampler, placed against the soil surface and carefully pressed downwards in to the soil until the core ring is sufficiently filled with soil. The samples were collected from two soil depths (0 – 200 mm and 200 – 300 mm). The core ring was then excavated from the soil with the aid of cylindrical core sampler. Both ends of the core ring were trimmed with a trowel and put on the caps. The samples were then taken to the laboratory and dried in an oven at 105 ^{o}C for 24 hours. Bulk density was calculated using the following equation:

$$BD = m/V \tag{1}$$

Where BD is dry bulk density in g cm^{-3}, m is the mass of the dry soil in g and V is the volume of the soil in cm^{-3}.

Particle size distribution analysis was carried out by Bouyoucos hydrometer method (Bouyoucos, 1936) using sodium hexametaphosphate (calgon) as the dispersant. Aggregate stability was determined by a wet sieving method (Nimmo and Perkins, 2002).

3.7.2 Soil water retention characteristics determination

Soil water retention characteristics (SWRC) were determined in the laboratory on soil cores using pressure membrane apparatus (Hillel, 2003). The core samples were collected as described in bulk density determination section. The 98.17 cm^3 core rings containing the soil samples were arranged on the porous ceramic plates. Each ceramic plate was assigned to a certain pressure; 10 kPa (field capacity) and 850 kPa (maximum lab pressure representative of permanent wilting point, since the pressure plates couldn't go higher than 850 kPa). The ceramic plates and core rings containing the soil samples were then saturated for 24 hours in order to substitute air in the pores of the soils with water. The ceramic plates and rings were inserted into the pressure plate apparatus according to their respective pressure.

The pressure plates were closed by uniformly tightening nuts and turned on as to allow the air pressure inside the apparatus to rise to the designated pressures. The apparatus was left until equilibrium had been reached. The point of equilibrium was noticed by observing at what point does water being expelled from the pressure plate stop. The samples were weighed immediately for each pressure and then placed into an oven at 105 degrees Celsius to allow drying for 24 hours.

The samples were then weighed after oven drying and the amount of mass change between pressure equilibrium mass and oven dried mass was calculated. The gravimetric water content of the samples was then determined by weighing the sample immediately after taking it out of the saturation chamber. The volumetric water content (ϴv) value for each sample was then calculated by multiplying the gravimetric water content by the BD value. Plant available water capacity (mm) was then calculated using the following equation:

$$PAWC = (\Theta_{FC} - \Theta_{wp}) \times z \qquad (2)$$

Where Θ_{FC} is the volumetric water content at field capacity (%), Θ_{wp} is the volumetric water content at wilting point (%), and z is the depth (mm).

3.7.3 Infiltration measurements

Infiltration rate was determined in the field using a double ring infiltrometer method under dry soils following the procedure described in Bouwer (1986). The standard double ring infiltrometer consisted of two pairs of inner and outer rings, a driving plate, an impact absorbing hammer, measuring bridge and measuring rods with float (Figure 3). The inner ring measured the following diameter x thickness x height (28 x 0.5 x 25 cm) while the outer measured 53 x 0.5 x 25 cm. Before the installations of the infiltration rings, small obstacles such as stones or twigs were cleared. The driving plate was put on top of the rings and the impact-absorbing hammer was used to simultaneously inserting the infiltration rings about 5 cm vertically in to the soil. During the installation the soil disturbance was kept as little as possible. The measuring bridge and measuring rod with a float were then placed on the inner ring insuring that no any obstacles may hamper free movement of the float. The set of rings was filled with approximately 25 litres of water. After filling the water in the rings, the measurements were started by recording the time and water level in the inner ring as indicated on the measuring rod in mm. The measurements were started with the shorter time interval of 1 minute and finished by measuring with longer time interval of 30 minutes. The measurements were stopped only when the infiltration rate had reached almost a constant value (i.e. steady state). After the measurements the rings were carefully removed from the ground and cleaned with water. The cumulative time and time interval were determined by calculating the differences of the time reading on the clock. The infiltration was determined by calculating the water level differences. The infiltration rate (mm h^{-1}) was calculated by dividing infiltration by the time interval. The cumulative infiltration (I) was determined by adding up the total amount of water infiltrating the soil from the beginning until the end of the measurement. The infiltration curve was plotted out of the calculated infiltration rate on the y- axis of the graph and the cumulative time on the x-axis.

Figure 3: Installed double ring infiltrometer measuring water infiltration on the study site.

3.8 Change in soil moisture content

Change in soil water content (ΔS) was measured using a NWM calibrated on site, Model 503DR CPN Hydroprobe (Campbell Pacific Nuclear, California and USA) on a weekly basis from planting to harvest. The frequency of measurements was increased with frequent rainfall events. Before each measurement, the standard count of NWM for the day was determined with NWM mounted on a 1 m tall access tube in three replicates. Two aluminum access tubes were installed to a depth of 1200 mm in each plot including controls. One tube was installed between the rows and another within the rows. Readings were taken from the following depths: 0 - 300, 300 - 600, 600 - 900, and 900 - 1200 mm.

3.9 Soil chemical properties

Soil pH was measured (in supernatant suspension of a 1:2.5 soil: water) using a pH/EC/TDS Multi-meter probe (McLean, 1982). Total nitrogen (N) was determined by using micro Kjeldahl method (Bremner, 1996). Available phosphorous (P) was determined by Bray 1 method (Bray and Kurtz, 1945). Zn was extracted with 0.1M HCL and determined by atomic absorption spectrometry. Potassium (K), Calcium (Ca), Magnesium (Mg) and sodium (Na) extraction were done by 1M ammonium acetate at pH 7 and exchangeable cations were determined by using atomic absorption spectrometry. Organic carbon was determined by using Walkley-Black procedures (Walkley and Black, 1934). Cation exchange capacity (CEC) was determined by ammonium acetate method (Rhoades, 1982).

3.10 Calibration of the NWM

Calibration on site of the NWM (Model 503DR CPN Hydroprobe, Campbell Pacific Nuclear, California and USA) was performed using methods described in Evett and Steiner (1995). Calibrations involved creating a two site plots (wet site and dry site). The two plots measured 5 m x 5 m. The two sites were prepared by clearing debris and other obstacles. At each site, two aluminium access tubes were installed in the plot to a depth of 1200 mm and the two tubes were placed 2 m apart in each plot. A wet site plot was bermed before ponding by irrigation to field capacity.

Prior to taking counts in the access tubes, three standard counts were taken with the NWM mounted at 1 m above the soil surface to avoid any influence of soil wetness, and with the probe locked in its shield. Counts (60 s counts) were taken from the depths as mentioned in the previous section. Count ratios were calculated by dividing each depth count by the mean of the standard counts. Three soil samples were taken close to each access tube at each depth of reading for determination of gravimetric water content (θg). Gravimetric water content was converted to volumetric water content using the bulk density values determined earlier from the respective depths (Figure 4a and 4b), as

$$\Theta v = \Theta g \times BD \times z \qquad (3)$$

Where Θv is the volumetric water content ($mm^3\ mm^{-3}$), Θg is the gravimetric water content ($g\ g^{-1}$), BD is the bulk density ($g\ cm^{-3}$) and z is the soil layer thickness (mm). Calibration equations were calculated for the soil layers by linear regression of NWM count ratio vs. volumetric water contents.

a b

Figure 4: (a) Three gravimetric soil samples taken around each access tube at each depth of a $5 \times 5\ m^2$ wet plot. (b) Soil bulk density taken at each depth during soil profile description.

3.11 Crop water use and water use efficiency

Water balance components were determined under dry-land conditions using the water balance equation as follows:

$$\Delta S = P - (R + D + ET) \qquad (4)$$

Where ΔS is change in soil moisture storage, P is precipitation, R is runoff, D is drainage, and ET is evapotranspiration (all in mm). R and D were neglected because they were considered small relative to other components (Hillel, 1998). ET was calculated after the simplification of equation (4) as:

$$ET = P - \Delta S \ldots\ldots (5)$$

Water use efficiency (WUE) was calculated using total grain yield per unit ET, as follows:

$$WUE = GY/ET \ldots\ldots (6)$$

Where WUE is the water use efficiency (kg ha^{-1} mm^{-1}), and GY is the grain yield (kg ha^{-1}).

Meteorological data were recorded in both cropping seasons by an automatic weather station located approximately 60 m from the experimental site.

Precipitation was measured using three standard rain gauges installed in the experimental site. Precipitation was taken as the average rainfall.

3.12 Biomass sampling and yield determination

3.12.1 Dry matter and leaf area index

Plant samples were collected for above ground dry matter at flower bud stage for the first sampling. The second and third plant samplings were done at flowering stage and grain maturity stage, respectively, for both growing seasons (Table 1). Plants in the second outer rows were sampled over one meter row length starting at 0.3 m from each row. Plant samples were partitioned into leaves, heads and stems, and thereafter dry matter was determined and expressed in kilograms per hectare. In addition to dry matter determination, leaves were also used for leaf area (LA) measurement, with a leaf area meter (LI-COR model 3100) prior to drying. Leaf area meter was first calibrated using square-shaped papers of known area. Leaf area index (LAI) was then determined by dividing LA by total area of sampled plants. Samples were dried at 65°C for 72 hours and dry mass was measured using an electronic scale (Sartorius PMA 7500).

Table 1: Planting and sampling dates of the entire experiment

Growth/sampling stages	1st cropping season (2013/14)	2nd cropping season (2014/2015)
Planting	08th December 2013	28 November 2014
Flower bud	22nd January 2014 (45 DAP)	09th January 2015 (42 DAP)
Flowering	21st February 2014 (75 DAP)	07th February 2015 (71 DAP)
Grain maturity/Harvest	29th March 2014 (111 DAP)	21st February 2015 (85 DAP)

3.12.2 Plant height and stem girth determination

Plant height and stem girth at flower bud stage, flowering stage and grain maturity stage were measured from two marked plants (second and fourth plants) from each of the two central rows and an average was obtained. A total number of four plants per plot were used to determine the plant height and stem girth. Measurement was taken by using a tiny rope and tape measure. The plant height was measured from the base of the plant to the tip of the top most leaf.

3.12.3 Grain yield

At physiological maturity, two middle rows (i.e. rows with access tubes) were harvested for yield component determination. All sunflower heads were then measured for head diameter (cm), head dry matter (g head^{-1}) and the weight of 100 seeds. Grain yield was determined after threshing. Seeds were dried at 65°C in the oven for 24 hours. Seed weight was adjusted to 13% moisture content.

3.13 Statistical analysis

Data collected was analyzed using analysis of variance (ANOVA) for randomized complete block design (RCBD) using IBM SPSS version 20 (IBM, 2011). Due to seasonal variability encountered during the two cropping seasons, particularly in terms of rainfall, further analysis of two factors (viz. cropping season and organic manure) and their interaction were performed. The differences between the treatment means were separated using the least significant differences (LSD) procedure. The mathematical model that describes the relationship between the response and treatment for the One-way ANOVA was used, given by:

$$Y_{ij} = \mu + I_i + \varepsilon_{ij} \quad (7)$$

Where Y_{ij} represents the *j*-th observation ($j = 1,2,\ldots n_i$) on the *i*-th treatment ($i = 1,2,\ldots,k$ levels). μ is the common effect for the whole experiment (overall mean), I_i represents the *i*- th treatment effect and εij represents the random error present in the *j*-th observation on the *i*- th treatment.

4. RESULTS

4.1 Pre-cropping selected average soil physical and chemical properties

The soil was generally acidic and dominated by clayey soil with low bulk density (Table 2a and Table 2b). The soils are high in clay content (average of 60.5%). The bulk density increased with the soil depth, whereas the aggregate stability decreased with soil depth. The major nutrients content of the soil were insufficient and were dominated by Ca followed by Mg, K and Na, in that order (Table 2b). The OC and N content of the soil were higher, decreasing with depth. The CEC of the sub soil was 14.22 cmol(+) kg^{-1}, which caused the soil to fall under mesotrophic soils regardless of higher CEC in the top soil (Table 2b).

Table 2. Pre-cropping selected average soil physical and chemical properties.

(a)

Soil physical properties								
Depth (cm)	Particle size (%)			Bulk density (g cm^{-3})	Aggregate stability (g g^{-1})	Water retention		
	Sand (2.0–0.05 mm)	Silt (0.05– 0.002 mm)	Clay (<0.002 mm)			FC (10 kPa)	WP (1500 kPa)	PAW (mm)
0 – 20	22	18	60	0.98	0.64	29.46	6.35	4622
20–30	21	18	61	1.12	0.47	30.34	5.57	2477

(b)

Soil chemical properties										
Depth (cm)	pH (H_2O)	Organic carbon (%)	Total N (%)	Available P (mg/kg)	K (cmol (+)/kg)	Ca (cmol (+)/kg)	Mg (cmol (+)/kg)	Na (cmol (+)/kg)	CEC cmol (+)/kg)	Zn (mg/kg)
0 – 20	5.72	1.57	0.081	1.63	0.54	6.82	2.41	0.12	22.53	2.60
20 – 30	5.48	1.11	0.039	1.53	0.41	6.12	1.84	0.10	14.22	1.04

4.2 Chemical properties of the organic manure

Table 3 shows results of organic manure analysis. The pH of poultry manure (PM) was neutral, whereas cattle manure (CM) was found to be slightly alkaline. Organic carbon content was found to be high in PM than CM, where total N content and CEC was found to be higher in CM than PM (Table 3). PM had the highest P content and CM had the lowest P content. The manures also differed in K concentration, with CM recording double the concentration compared to PM. Ca content of PM was found to be six times higher than CM, while Mg content of the two manures were nearly the same (Table 3). The C/N ratio of PM was found to be higher than CM (Table 3).

Table 3. Chemical properties of the organic manures used in the experiment

Organic manure sources	pH (H_2O)	Total C (%)	Total N (%)	CEC (cmol kg^{-1})	P (g kg^{-1})	K (g kg^{-1})	Na (g kg^{-1})	Ca (g kg^{-1})	Mg (g kg^{-1})	C/N ratio
CM	8.21	27	1.96	36.62	3.37	22.54	2.94	15.53	7.98	13.8:1
PM	7.02	31.9	1.61	22.14	9.68	11.21	2.18	90.59	6.58	19.8:1

4.3 Climatic conditions

The temperature was generally similar in both cropping seasons, while rainfall varied between the two seasons (Table 4). The total rainfall received in the first cropping season (2013/2014) was about three-times greater than second cropping season (2014/2015). The temperature remained the same during the two cropping seasons with maximum temperature slightly higher in second cropping season. The mean maximum temperature (T_{max}) was around 30^{o}C while the mean minimum temperature (T_{min}) was about 20^{o}C during the cropping period (Table 4).

The highest rainfall received in the 2013/2014 season was in January (458 mm) where 37% (171 mm) of rainfall was received in 1 day. Unlike January, rainfall in February was evenly distributed throughout the month with nearly the same number of rainy days (Table 4). The month of March had a total rainfall of 192 mm with 99% (190.5 mm) of this rainfall occurred within the first 13 days of the month. For the second cropping season, most of the rainfall occurred in December with frequent rainfall occurring at the middle and towards the end of the month.

Table 4. Monthly meteorological data during 2013/2014 and 2014/2015 cropping seasons.

		2013/2014		
Month	**Max temp.**	**Min temp.**	**Total rainfall (mm)**	**No. of rainy days**
December	26.74	18.59	269[a]	12.0
January	27.99	19.98	458	17.0
February	27.22	19.47	275	16.0
March	27.73	19.49	192[b]	12.0
Total	**27.42**	**19.38**	**1195**	**57.0**
		2014/2015		
November	28.44	19.74	50[a]	3.0
December	30.49	18.99	313	16.0
January	31.20	19.40	56	12.0
February	32.94	19.22	16[b]	8.0
Total	**30.77**	**19.34**	**434.85**	**39.0**

[a] rainfall received on or after planting

[b] rainfall received on or before harvest

4.4 Effect of organic manure on soil physical properties

Bulk density (BD) showed no significant difference in two years cropping period. Poultry manure (PM) application recorded a decrease of 32% BD in the top layer compared to control (Table 5). CM + PM and cattle manure (CM) application decreased BD in the top layer by 14% and 9% compared to control, respectively. BD at sub layers also showed no significant difference but recorded high values in all treatments compared to top layers, with CM + PM recording the lowest (Table 5).

Organic manure (OM) application had no significant effect on aggregate stability, but CM and PM application recorded almost the highest similar stable fractions at all soil depths (Table 5). CM + PM recorded the lowest aggregate stability compared to other treatments.

Table 5: Effect of organic manure on soil physical properties

Treatment	Bulk density (g cm^{3})		Aggregate stability (g g^{-1})		Final infiltration rate (mm hr^{-1})	Cumulative infiltration (mm)
Depth (cm)	0 - 20	20 – 30	0 – 20	20 - 30		
Control	0.97	0.97	0.36	0.36	16.8a	101.3a
CM	0.88	1.00	0.40	0.47	24b	151.2b
PM	0.66	1.02	0.41	0.47	28.1b	185.8b
CM + PM	0.83	0.85	0.35	0.34	17.4a	121.8a

Means in the same column followed by the same letter are not significant different

The infiltration curves have a general shape in all treatments, starting with high infiltration rates followed by a rapid decrease with time until the steady state infiltration rate (final infiltration rate) is attained (Figure 5). Generally, steady state infiltration rates in all treatments were attained after 100 minutes of the infiltration process. The final infiltration rates and cumulative infiltration are presented in Table 5. Poultry manure (PM) had the highest final infiltration rate (28.1 mm hr^{-1}) and cumulative infiltration over the other treatments (Table 5). There was no significant increase observed with addition of CM + PM as compared to control. The final infiltration rate of CM + PM was 3.6% higher than the control, whereas PM and CM increased by 67% and 43%, respectively, over control. The cumulative infiltration values were higher in the manure application compared to control (Figure 6). Both the final infiltration rate (i) and cumulative infiltration (I) were highest in PM followed by CM, CM + PM and control treatments.

Figure 5: Effect of organic manure on infiltration rate

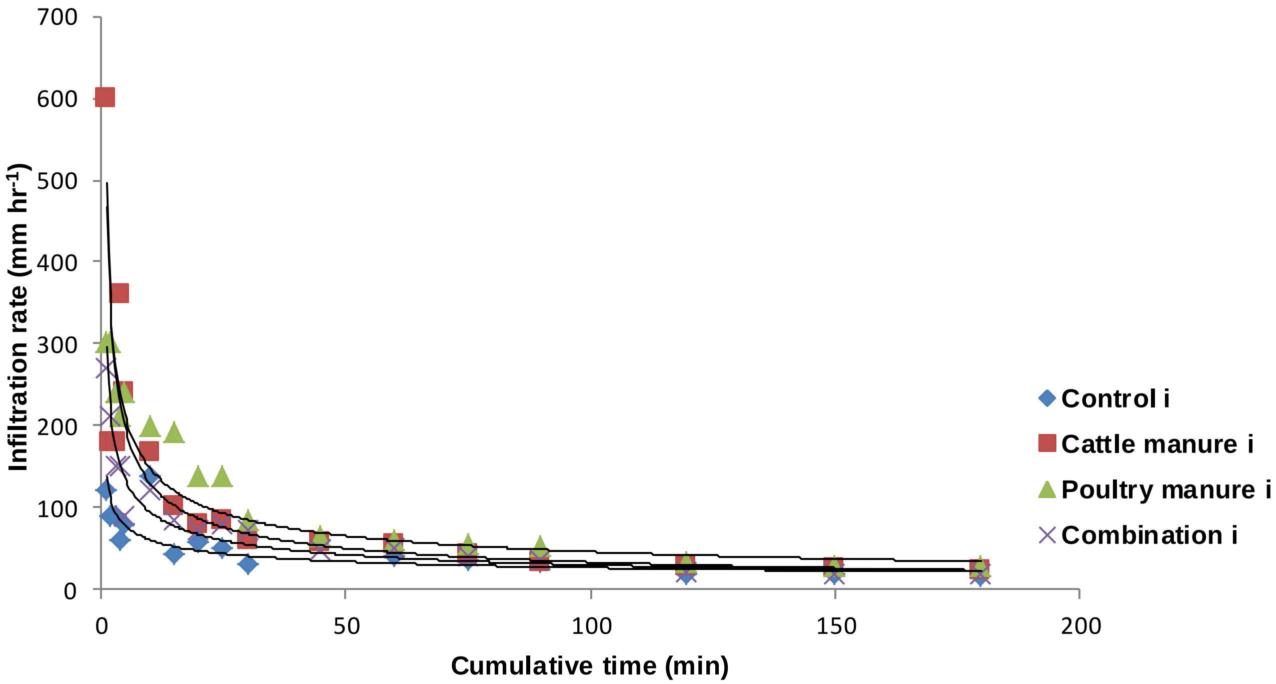
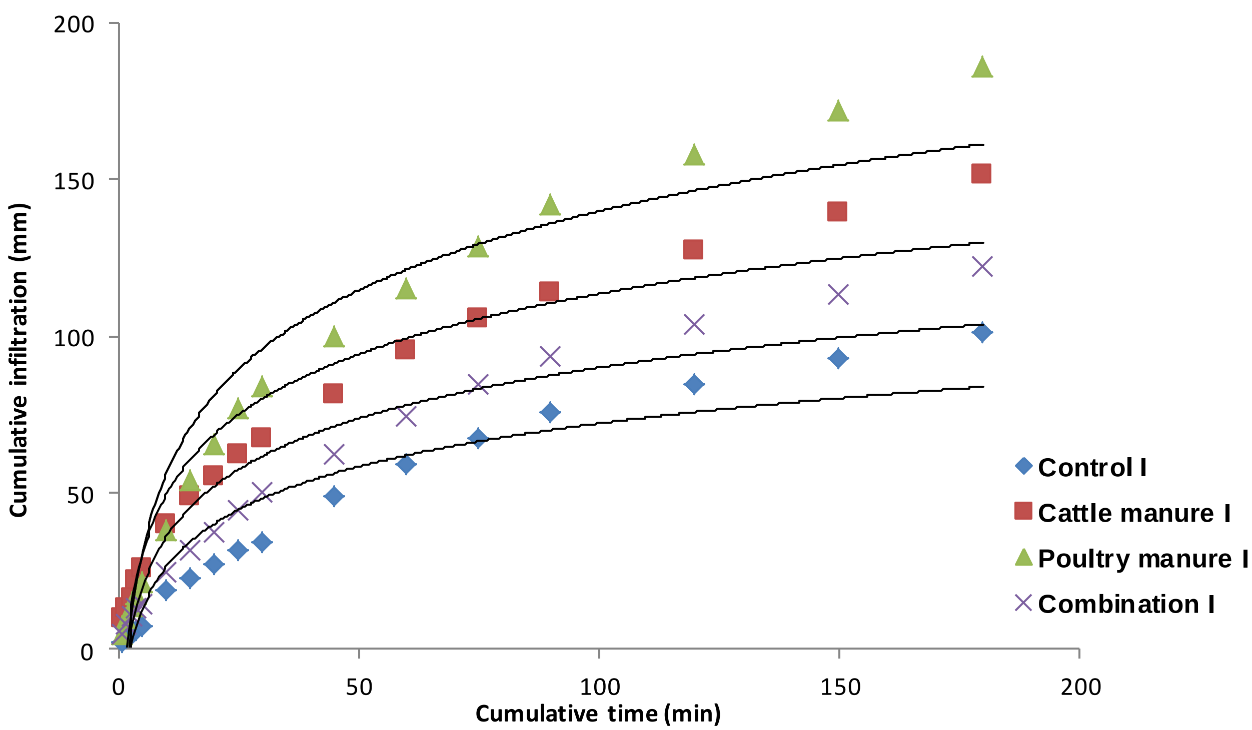


Figure 6: Effect of organic manure on cumulative infiltration



The effect of organic manure on soil water retention capacity is shown in Table 6. Organic manures had no significant effect on the water retention capacity at both 10 kPa (field capacity) and 850 kPa (wilting point). However, the control treatment retained the highest mean water content compared to other treatments at both field capacity (FC) and wilting point (WP). CM + PM and PM recorded the least mean water content among others at FC and WP respectively (Table 6).

Table 6. Effect of organic manure on plant available water

Treatment	Depth (mm)	Θ_{FC} (10 kPa) $cm^3\ cm^{-3}$	Θ_{WP} (850 kPa) $cm^3\ cm^{-3}$	PAW (%)	PAW (mm)
Control	300	0.2919	0.2235	6.84	2052
CM	300	0.2729	0.2221	5.08	1524
PM	300	0.2527	0.1930	5.97	1791
CM + PM	300	0.2511	0.2007	5.04	1512

Means in the same column followed by the same letter are not significant different

4.5 Effect of organic manure application on soil chemical properties

The results showed that total N, Ca and Zn were significantly different between treatments in the first cropping season while K, Na, CEC and Zn were significantly different in the second cropping season (Table 7). No significant difference in pH values was recorded in all treatments. The highest pH was recorded by CM + PM (6.27) in the top layer in the first cropping season (Table 7). In the second cropping season, cattle manure (CM) recorded the highest pH of 5.95 and 5.81 in the 0 – 20 cm and 20 – 30 cm depth, respectively.

CM + PM recorded the highest OC at top layer in both cropping seasons compared to other treatments. CM + PM application increased OC by 45% in the second cropping season compared to control. CM recorded the lowest OC in the first cropping season in both depths. The OC values of manure treatment recorded in the second cropping season were higher than the OC recorded in first cropping season, except for control treatment were the OC decreased with cropping season (Table 7).

Organic manure application resulted in a significant difference on total N and CEC in the first and second cropping seasons respectively, at 20 – 30 cm depth. Both parameters recorded the highest values in the second cropping season compared to first cropping season, except for control treatment where the CEC was higher in the first cropping season (Table 7).

Potassium and Na showed a significant difference ($p<0.05$) among the treatments in the second cropping season. The values of K, Ca and Mg increased with the cropping season under different treatments except for Na which decreased under control treatment. The values of K, Ca and Mg were higher in the 0 – 20 cm depth layer than the 20 – 30 cm depth layer under all treatments in both cropping season (Table 7).

Table 7. Effect of organic manure on soil chemical properties for 2013/2014 and 2014/2015 cropping seasons

Treatment	Depth	pH(H_2O)	OC (%)	Total N (%)	Available P (mg/kg)	Extractable cations (cmol(+)/kg) K	Ca	Mg	Na	CEC (cmol/kg)	Zn (mg/kg)
1st cropping season											
Control	0 – 20	5.27	1.71	0.045	7.59	0.4	6.743	2.162	0.068	18.151	1.90
	20 -30	5.50	1.15	0.032a	7.05	0.294	5.336b	1.883	0.075	15.818	0.95b
CM	0 – 20	5.74	1.47	0.050	9.25	0.647	8.462	2.696	0.081	19.104	3.34
	20 -30	5.92	1.00	0.049b	8.20	0.499	7.785a	2.328	0.075	20.393	1.93a
PM	0 – 20	6.25	1.92	0.042	31	0.643	5.548	1.937	0.051	13.482	10.98
	20 -30	6.00	1.60	0.030a	8.45	0.412	4.363c	1.610	0.057	15.394	1.85a
CM + PM	0 – 20	6.27	1.96	0.037	8.49	0.572	5.629	2.119	0.087	16.126	5.64
	20 -30	5.13	1.53	0.031a	7.58	0.370	4.490c	1.845	0.079	13.232	1.20b
2nd Cropping season											
Control	0 – 20	3.98	1.50	0.057	1.94	0.42a	7.17	2.36	0.063a	17.72c	1.94b
	20 -30	5.00	1.25	0.049	1.51	0.33	6.16	2.16	0.070c	15.61a	1.51c
CM	0 – 20	5.95	2.00	0.065	2.67	1.07b	8.72	2.98	0.095b	20.97c	3.51b
	20 -30	5.81	1.67	0.058	0.69	0.68	7.55	2.47	0.104d	18.14b	2.11c
PM	0 – 20	5.40	1.75	0.057	30.27	0.98b	6.29	2.23	0.064a	15.63c	10.38a
	20 -30	4.62	1.21	0.045	11.30	0.66	4.95	1.79	0.077c	15.62a	4.71c
CM + PM	0 – 20	4.72	2.18	0.078	29.40	1.42b	7.50	3.10	0.079a	17.22c	10.63a
	20 -30	3.79	1.66	0.058	6.61	0.98	6.21	2.47	0.098d	18.03b	4.69c
CS	0 – 20	$p < 0.05$	ns	$p < 0.05$	ns	$p < 0.05$	ns	ns	ns	ns	ns
	20 -30	$p < 0.05$	ns	$p < 0.05$	ns	$p < 0.05$	ns	ns	$p < 0.05$	ns	$p < 0.05$
OM	0 – 20	$p < 0.05$	ns	ns	$p < 0.05$	$p < 0.05$	ns	ns	ns	$p < 0.05$	$p < 0.05$
	20 -30	ns	ns	ns	ns	ns	$p < 0.05$	ns	ns	$p < 0.05$	ns
CS * OM	0 – 20	$p < 0.05$	ns	ns	ns	ns	ns	ns	ns	ns	ns
	20 -30	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Means in the same column followed by the same letter are not significant different

(ns= not significant; CS = cropping season; OM = organic manure)

4.6 Effect of organic manure on biomass and yield

Response of dry matter (partitioned into leaves, stems and heads), leaf area and leaf area index of sunflower on organic manure are shown in Table 8. Data shows that dry matter yields at flower bud, flowering and maturity stages were increased with the application of different organic manures and their combination compared to the control treatment for both cropping seasons. The highest dry matter yield was observed from the application of PM at flower bud stage of first (2571.4 kg ha^{-1}) and second (1141.7 kg ha^{-1}) cropping seasons (Table 8). In the flowering stage of the second cropping season the highest value of dry matter (6127.4 kg ha^{-1}) was also observed under PM treatment. Poultry manure increased ($p<0.05$) dry matter yield at flower bud stage by 1022.4 kg ha^{-1} and 617.1 kg ha^{-1} in the first and second cropping seasons, respectively, over control.

Organic manure had a significant effect on leaf area index (LAI) only at flower bud stage of the first cropping season with PM and CM + PM recording the highest similar values at flower bud stage (Table 8). In the second cropping season, the organic manure had significant effect on LAI at flower bud and flowering stages with all treatments significantly different from control. Generally, the use of organic manures led to higher LAI compared with no manure application. The interaction between cropping season and organic manure was not significant at all growing stages of LAI in both seasons.

Table 8: Effect of organic manure on dry matter and LAI

	1st cropping season					
	Dry matter (kg ha^{-1})			LAI		
Treatments	Flower bud	Flowering	Maturity	Flower bud	Flowering	Maturity
Control	1549.0b	4285.1	5152.8	0.66a	1.70	1.10
CM	2110.3a	6969.5	7209.7	1.08b	2.21	1.63
PM	2571.4a	6515.0	6955.6	1.31c	2.42	1.40
CM + PM	2485.4a	7446.4	7275.5	1.31c	2.43	1.20
	2nd cropping season					
Control	524.6a	2869.7b	3416.1b	0.53a	1.63a	1.28
CM	704.8b	5395.7a	8751.1a	0.99b	2.09b	1.75
PM	1141.7c	6127.4a	8408.9a	1.22b	2.21b	1.79
CM + PM	967.3d	5914.5a	9414.7a	1.13b	2.33b	1.49
CS	p<0.05	p<0.05	ns	ns	ns	p<0.05
OM	p<0.05	p<0.05	p<0.05	p<0.05	p<0.05	p<0.05
CS * OM	ns	ns	<0.05	ns	ns	ns

Means in the same column followed by the same letter are not significant different

(ns= not significant; CS = cropping season; OM = organic manure)

The effects of organic manure on plant height and stem girth are shown in Table 9. The application of organic manure showed an increase in plant height and stem girth in both cropping season as compared to control. The manure application showed a significant effect ($p<0.05$) on plant height and stem girth in all growing stages in the second cropping season, whereas in the first cropping season the significant effect was in the flower bud stage for both parameters. Poultry manure recorded the highest plant height in all growing stages for both cropping seasons. Cattle manure + PM (7.28, 10.48 and 11.01 cm) and PM (7.05, 10.21 and 10.28 cm) recorded the highest stem girth in all growing stages for first and second cropping seasons respectively.

Table 9: Effect of organic manure on plant height and stem girth determination

	1st cropping season					
	Plant height(cm)			Stem girth (cm)		
Treatments	Flower bud	Flowering	Maturity	Flower bud	Flowering	Maturing
Control	54.69a	184.63a	186.50a	4.51b	8.21a	8.45a
CM	83.06b	172.13a	183.81a	6.88a	10.09a	9.74a
PM	106.75c	204.25a	209.13a	7.24a	10.00a	10.49a
CM + PM	90.88d	201.75a	205.69a	7.28a	10.48a	11.01a
	2nd cropping season					
Control	39.31b	150.86a	152.75a	4.00b	6.19a	6.25a
CM	90.75a	179.13b	182.06b	6.56a	9.56b	9.69b
PM	100.00a	198.31c	199.38c	7.05a	10.21b	10.28b
CM + PM	88.63a	188.88d	189.75d	6.45a	8.56c	8.63c
CS	ns	p<0.05	p<0.05	ns	ns	p<0.05
OM	p<0.05	p<0.05	p<0.05	p<0.05	p<0.05	p<0.05
CS * OM	ns	ns	ns	ns	ns	ns

Means in the same column followed by the same letter are not significant different

(ns= not significant; CS = cropping season; OM = organic manure)

The highest grain yield was recorded under PM (3289.39 kg ha^{-1}) in the first cropping season which was 465% higher than control (Table 10). Cattle manure and CM + PM application recorded no statistical difference between each other and had higher quantity of grain yield in the second cropping season (Table 10). Organic manure application in the second cropping season resulted in a higher grain yield compared to first cropping season, except for PM which consequently decreased by 168% from the first cropping season. From the results, it has been observed that the values recorded in the first cropping season for head diameter and head dry matter are higher than the values recorded in the second cropping season (Table 10). Cattle manure recorded the highest head diameter (22.81 cm) in the first cropping season whereas CM + PM recorded the highest value (20.50 cm) in the second cropping season. There was a significant effect ($p<0.05$) on head dry matter in both cropping seasons. Poultry manure (49.27 g head^{-1}) and CM + PM (32.50 g head^{-1}) recorded the highest head dry matter values in the first and second cropping season, respectively. There was no statistical difference among the treatments for 100 seed weight.

Table 10: Grain yield, head diameter, head dry matter and 100 seed weight

1st cropping season				
Treatment	Grain yield (kg ha^{-1})	Head diameter (cm)	Head dry matter (g head^{-1})	100 seed weight (g)
Control	582.47	19.79	27.38a	5.26
CM	1173.20	22.81	42.63b	6.08
PM	3289.39	22.28	49.27c	5.29
CM + PM	1336.49	20.53	34.71d	5.55
2nd cropping season				
Control	968.35a	12.84b	12.06b	4.59
CM	1646.14b	19.88a	27.32a	5.28
PM	1227.75c	20.25a	29.28a	5.45
CM + PM	1647.29b	20.50a	32.50a	5.24
CS	ns	$p< 0.05$	$p< 0.05$	ns
OM	ns	$p< 0.05$	$p< 0.05$	ns
CS * OM	ns	$p< 0.05$	$p< 0.05$	ns

Means in the same column followed by the same letter are not significant different

ns= not significant

4.7 Crop water use and water use efficiency

4.7.1 Calibration of NWM

The following calibration equations were derived for each respective soil layer. The equations showed strong relationships between volumetric water content (ϴv) and NWM count ratios (C_R) with high (>0.8) correlation coefficient (R^2).

$\Theta_{v\ (0-30\ cm)} = 0.6965_{CR} + 0.0655\ (r^2 = 0.9083)$ (8)

$\Theta_{v\ (30-60\ cm)} = 0.5504_{CR} + 0.4715\ (r^2 = 0.9055)$ (9)

$\Theta_{v\ (60-90\ cm)} = 0.5099_{CR} - 0.0935\ (r^2 = 0.9049)$ (10)

$\Theta_{v\ (90-120\ cm)} = 0.2692_{CR} - 0.0935\ (r^2 = 0.9057)$ (11)

4.7.2 Effect of organic manure on WU and WUE

The application of organic manure had no significant effect on water use (WU) of sunflower in both cropping seasons. The first cropping season recorded the highest average WU of 1148.21 mm. Cattle manure + PM and PM recorded the highest WU in the first cropping season and second cropping season, respectively (Table 11). The organic manure application had a significant effect ($p<0.05$) on WUE in the second cropping season. Unlike the WU, the water use efficiency (WUE) recorded the highest values in second cropping season than first cropping season, except for PM which recorded the highest WUE value in the first cropping season than the second cropping season. Statistically, CM and manure combination (CM + PM) treatments had similar WUE in the second cropping season. Similarly, PM and control treatments had no significant difference on WUE. The cropping seasons had a significant effect ($p<0.05$) on both

WU and WUE of sunflower. There was no interaction between cropping season and organic manure on both WU and WUE of sunflower in both seasons.

Table11: Effect of organic manure on WU and WUE of sunflower

	1st cropping season		2nd cropping season	
Treatment	WU (mm)	WUE (kg ha^{-1} mm^{-1})	WU (mm)	WUE (kg ha^{-1} mm^{-1})
Control	1147.21	0.51	449.22	2.15a
CM	1144.83	1.03	481.77	3.40b
PM	1149.28	2.85	503.76	2.46a
CM + PM	1151.51	1.16	485.91	3.39b
CS	p<0.05	p<0.05	p<0.05	p<0.05
OM	ns	ns	ns	ns
CS * OM	ns	ns	ns	ns

Means in the same column followed by the same letter are not significant different

(ns= not significant; CS = cropping season; OM = organic manure)

5. DISCUSSION

5.1 Effect of organic manure on soil physical properties

Although non-significant, poultry manure (PM) application resulted in lowest soil bulk density (BD), especially in the top layer, followed by CM + PM, CM and control in that order (Table 5). The results are in contrast to the findings by Ojeniyi et al. (2013) who observed a significant decrease in BD at 0 – 15 cm depth under PM application in a three year field experiment on an alfisol, which resulted in increased water infiltration and retention leading to reduction in soil temperature. Lack of significant difference in BD among treatments could be attributed to insufficient organic manure (OM) applied or slow effectiveness of OM to alter BD significantly. Slow alteration by BD was reported by Brar et al. (2015) and Cebula (2013). Ibrahim and Fadni (2013) reported no significant difference in BD after applying 10 t ha^{-1} of CM, PM and CM + PM on a sandy soil, with CM recording the lowest BD followed by PM then CM + PM in both 0 – 20 cm and 20 – 40 cm soil depth. Tadesse et al. (2013) also reported non-significant difference in BD at 0 – 20 cm soil depth after applying 7.5 and 15 t ha^{-1} of CM, with 15 t ha^{-1} rates recording the lowest BD value on a vertisol soil of 71.25% clay content. Boateng et al. (2006) reported a slight decrease of BD at 0 – 20 cm soil depth after PM application rate of 0, 2, 4, 6 and 8 t ha^{-1} on a Ferric Acrisol.

There was no significant difference in aggregate stability among all treatments. This is contrary to previous reports that showed an increase in aggregate stability under CM application compared to control treatment (Cebula, 2013; Nciizah, 2011; and Materechera, 2009). Olatunji et al. (2012) found that 31 and 125 t ha^{-1} PM application rates increased aggregate stability compared to 0 t ha^{-1}. Cattle manure + PM recorded the lowest aggregate stability as compared to control treatment as this was unexpected. Olatunji et al. (2012) also observed the unexpected results due to quantity of organic manure applied, where he found that aggregate stability increase was not progressive after applying 62 t ha^{-1} of PM but increased progressively after application of 31 t ha^{-1} PM and 125 t ha^{-1} PM. The authors further explained that these observations could be due to the bonding effect of the organic carbon that is being released to the soil from the manure. This observation is further illustrated by final infiltration rate where the difference (3.6%) between control and CM + PM is not significant (Table 5). Lack of significant response in most soil physical properties may be that the rate of organic manure (20 t ha^{-1}) applied was not sufficient enough or the term of the experiment was not long enough to observe any significant changes in soil physical properties as previously reported (Olatunji et al., 2012; Cebula, 2013).

The infiltration results showed that at the beginning, the infiltration rate was rapid and then subsequently decreased with time until a steady state was reached (Figure 5). This trend was attributed to the initial high capacity of infiltration associated with dry soil followed by a diminished constant infiltration rate due to soil saturation, in accordance with the theory of infiltration (Hillel, 2003). Initially, CM recorded high infiltration rate than other treatments (Figure 5). Brar et al. (2015) recorded rapid initial infiltration rate under CM application on a sandy loam soil texture. After 10 minutes duration, the PM treatment recorded the highest infiltration rate until a steady state was reached, followed by CM (Figure 5). This is shown by high final infiltration rate of 28.1 mm hr^{-1} (Table 5). The increase in infiltration rate under PM application may be due to increase in porosity as a result of relatively low BD brought about by PM application (Table 5) and high OC in PM (Table 3). However, there was no significant difference in final infiltration rates found among treatments. Similar to the findings of this study, Mubarak et al. (2009) observed that there was no significant difference among treatments after organic manure application on a sandy soil. The ability of the soil to transmit water depends on the soil particle arrangement and aggregate stability. After three hours, the PM treatment recorded the highest infiltration value of 185.8 mm compared to the control (101.3 mm) (Table 5). This could be attributed to more stable aggregation and reduced BD. Meanwhile, the application of CM and CM + PM recorded the final infiltration of 151.2 mm and 120 mm, respectively. This indicates an additive effect of CM as found by Rasoulzadeh and Yaghoubi (2010) who reported that by applying CM, cumulative infiltration increases with the increasing rate.

The amount of plant available soil water is influenced by the texture, organic matter content and structure of the soil (Brady and Weil, 2002). The application of organic manure showed no significant difference among treatments, but control treatment retained slightly higher water content. This observation could be that the organic manure applied treatments resulted in increased micropores of the clayey soil than control treatment which allowed an ease movement of water, hence decreased BD and increased infiltration rate (Table 5). Contrary to the findings in this study, Sommerfeldt and Chang (1986) reported that water retention decreases with increasing organic matter content in clayey soil and increases with increasing organic matter content in sandy soils. Furthermore, Lawal and Girei (2013) observed higher PAW under CM than control treatment on a leached tropical ferruginous soil (sandy). Tadesse et al. (2013) also reported that application of 15 t ha^{-1} of CM significantly increased water retention over control (0 t ha^{-1}) under vertisols with clay content of 71%. An increase in plant available water after addition of PM has been reported by Boateng et al. (2006) and Fubara-Manuel et al. (2013) under sandy soils. Meanwhile, Rasoulzadeh and Yaghoubi (2010) reported a decrease in available water capacity with the application of 30 and 60 t ha^{-1} but the statistical results showed that available water capacity was just significantly ($P<0.05$) affected by the application of 60 t ha^{-1}.

5.2 Effect of organic manure on soil chemical properties

Organic manure application showed that the pH was not significantly different between the treatments, which is in agreement with the findings of Dikinya and Mufwanzala (2010) and Magagula et al. (2010) who found that the application of CM and PM, respectively, did not significantly change the pH of the soils irrespective of the application rate.

The OC recorded the highest values in the 0 – 20 cm depth than the 20 – 30 cm depth in all treatments under both cropping seasons (Table 7). Similar to the results obtained in this study, Ibrahim and Fadni (2013) recorded the highest OC in CM + PM in 0 – 2 cm depth than CM and PM. An increased OC under the application of organic manure compared to control was observed by Okonwu and Mensah (2012) and Roy and Kashem (2014). The authors further observed that the organic manure application increased the OC, available P and extractable Zn. The OC, available P and Zn were found to be higher in PM treatment than other treatments.

Cattle manure recorded the highest values of total N and CEC in both cropping season and this may be due to the fact that the cattle manure used had a higher total N and CEC than the PM (Table 3). Ibrahim and Fadni (2013) reported that organic manures increased CEC for all treatments with CM + PM increasing CEC by 51.04% over control, while CM and PM increasing CEC by 28.64 and 32.10%, respectively. Application of organic manure significantly improved available P in both cropping seasons. Poultry manure recorded the highest P in both cropping season than other treatment (Table 7), and this may be due to the fact that poultry manure applied had higher P than cattle manure (Table 3). Magagula et al. (2010) and Ullah et al. (2008) also reported a higher P under PM treatments.

Similar to the finding of this study, Ullah et al. (2008) reported that CM application had the highest availability of K in the soil than PM application. Sodium recorded the highest values in the 20 – 30 cm depth than 0 – 20 cm depth under all treatments in the second cropping season, which may be due to the fact that it is easily leachable from topsoil to the subsoil.

5.3 Effect of organic manure on biomass and yield

Organic manure application showed a significant effect ($p<0.05$) on dry matter yield at all stages in the second cropping season than in the first growing season where the effect was only at flower bud stage. Wabekwa et al. (2014) reported that application of 6 and 8 t ha^{-1} poultry manure showed no significant difference in mean dry weight at all growing stages. An increase in dry matter yield under application of PM at flower bud and flowering stages was reported by Helmy and Ramadan (2009). The dry matter yield recorded in the first cropping season in this study were higher than the values obtained in the second cropping season at flower bud and flowering stages (Table 8). This observation may be as a result of the amount of rainfall received, in which the first cropping season crops received more rainfall at the two growing stages compared to the second cropping season (Table 4). The observation may also be as a result of late sampling in the first cropping season (45 and 75 days after planting) compared to 42 and 71 days after planting (DAP) for the second growing season. In contrast, the dry matter yield values in the second cropping season were higher than those of first cropping season at maturity stage except for control treatment (Table 8). This decrease in the dry matter in the first cropping season at maturity stage may be due to the excess rainfall experienced towards the end of the second cropping season that may have caused the fungal diseases on plants as evidenced by plant wilt. This is also shown by a decrease in LAI at maturity stage in the first cropping season and by an average dry matter increase of 47.7% from flowering to maturity in the second cropping season in a period of 14 days, compared to 5.5% increases in first cropping season in a period of 36 days. Adebayo et al. (2012) observed that the values of growth parameters (dry matter weight, plant height and plant girth) obtained during low rainfall season were generally higher than the values obtained during high rainfall season as disease and pest infestation were very low during low rainfall season.

It was observed that plant height and stem girth values obtained in the first cropping season were generally higher than the second planting. Poultry manure recorded the highest values of plant height in both cropping seasons throughout all the three growing stages (Table 9). Similar observation was reported by Adebayo et al. (2012). Adebayo et al. (2012) further reported that the PM application recorded the highest plant height compared to CM and control treatments. The highest mean plant height (171.64 cm) of sunflower under 8 t ha^{-1} of PM after 10 weeks of planting was reported by Wabekwa et al. (2014). Poultry manure application also recorded the highest sunflower stem girth in the second cropping season throughout the three growing stages (Table 9), unlike in the first cropping season where the combination (CM + PM) application recorded the highest values of sunflower stem girth throughout the three growing stages (Table 9). The highest values recorded by PM could be attributed to the high values of primary (macro) nutrients (P and K) obtained (Table 3). The two primary nutrients are well known to be essential for improving quality of grains, fruits and vegetables and increasing WUE, photosynthesis, and disease resistance and they are also essential for plant cell division and enlargement.

5.4 Effect of organic manure on grain yield, head diameter, head dry matter and 100 seed weight

The application of organic manure showed a significant effect ($p<0.05$) on the grain yield in the second cropping season. Similar to the findings of this study, Munir et al. (2007) recorded highest grain yield under PM application in the first cropping season. Cattle manure and CM +

PM application statistically recorded the same and the highest quantity of grain yield of 1646.14 and 1647.29 kg ha^{-1}, respectively, in the second cropping season. Esmaeilian et al. (2011) observed the highest grain yield under CM, which were statistically equal to that of PM. Rasool et al. (2013) also observed 15% increase of grain yield over control after application of 20 t ha^{-1} cattle manure. Organic manure application in the second cropping season (low rainfall) resulted in a higher grain yield compared to the first cropping season as was previously reported by Adebayo et al. (2012). However, PM application in the second cropping season resulted in a significant decrease of grain yield by 2061.64 kg ha^{-1} (167.92%) from the first cropping season (Table 10). The decrease in yield of sunflower under PM is also shown by a decrease in dry matter at grain maturity stage of second cropping season (Table 8). The significant decrease in grain yield observed under poultry manure application may be an indication that poultry manure has low water retention capacity since in the second cropping season the rainfall was low, therefore the crops may have experienced water stress, hence low grain yield. This is also shown by its low WUE of 2.46 kg ha^{-1} mm^{-1} in the second cropping season (Table 11). The lowest grain yield of 582.47 and 968.35 kg ha^{-1} were obtained in the control treatment in the first and second cropping seasons, respectively. Similar findings were also reported by Esmaeilian et al. (2011), who observed that the control treatment recorded the lowest grain yield compared with CM and PM treatment.

Organic manure application showed a significant effect ($p<0.05$) on head diameter in the second cropping season only in agreement with earlier findings by Esmaeilian et al. (2011). The application of organic manure in the first cropping season recorded the highest head diameter compared to second cropping season in all treatments. Both cropping seasons and organic manure had a significant effect on head diameter. The organic manure contributed to a significant increase in head diameter over control in the second cropping season compared to first cropping season, supporting the findings of Wabekwa et al. (2014). Cattle manure recorded the highest head diameter (22.81 cm) in the first cropping season as previously reported (Esmaeilian et al., 2011) whereas in the second cropping season, CM + PM recorded the highest head diameter of 20.50 cm (Table 10). The lower values of head diameter and head dry matter recorded in the second growing season may be due to the low rainfall received in the second cropping season. The highest head dry matter value (49.27 g $head^{-1}$) was recorded by poultry manure application in the first cropping season compared to other treatments. In the second cropping season, manure combination (CM + PM) recorded the highest value followed by poultry manure application. This implies that poultry manure application had an effect on head dry matter. There was an interaction between cropping season and organic manure. The 100 seed weight showed an increase but was not significantly affected by organic manure application in both cropping seasons. Similar results were observed by Helmy and Ramadan (2009).

5.5 Effect of organic manure on sunflower WU and WUE

Generally, it was observed that, WU in the first cropping season was higher than WU in the second cropping season. The higher WU in first cropping season could be associated with the 174% higher total rainfall received in the first cropping season as compared to second cropping season.

The results of this study showed that CM and CM + PM statistically had similar and high WUE in the second cropping season. Filho et al. (2013) reported that WUE of sunflower was significantly increased by CM application. Yassen et al. (2006) found that application of CM had more pronounced effect on increasing grain WUE values compared to composted sunflower residues. The authors further observed the same trend in case of biomass WUE values after using both organic manures. Even though WUE was not significantly affected by organic manure application in the first cropping season, PM recorded the highest value of WUE (2.85 kg ha^{-1} mm^{-1}). High WUE recorded by PM in the first cropping season can be associated with the highest grain yield obtained. Even though the WU in the first cropping season was higher than the WU in the second cropping season, the WUE was higher in the second cropping season than in the first cropping season except for PM (Table 11). The high grain yield by control, CM and CM + PM in the second cropping season resulted in high WUE as compared to the first cropping season (Table 11). Water use efficiency was high under low rainfall season where high grain yield was obtained. Similar to the findings of this study, Olalde et al. (2001) reported high total biomass production under low rainfall experimental site which resulted in high WUE.

6. CONCLUSIONS AND RECOMMENDATIONS

Application of the three organic manures served as a good source of organic amendment for the improvement of soil fertility and plant nutrition over control. Poultry manure recorded the lowest bulk density and highest aggregate stability. Furthermore, PM resulted in highest final infiltration rate and cumulative infiltration. Lacks of significant difference in soil physical properties among treatments could be attributed to insufficient organic manure applied or slow response of organic manure within the cropping period. The improved soil physical properties could be as a result of high total C possessed by poultry manure used. Organic manure had no significant effect on plant available water (PAW). This was also attributed to low quantities of OM applied. Zinc, total N, Ca, K, Na and CEC were significantly affected by application of organic manures. CM recorded the highest values of total N and CEC in both cropping season, this may be due to the fact that cattle manure used had higher total N and CEC than PM. Sodium recorded the highest values in the 20 – 30 cm depth than 0 – 20 cm depth in the second cropping season under all treatments, which may be due to the fact that it is easily leachable. Even though OC and available P were not significantly affected by organic manure, they both recorded the highest values especially under PM and CM + PM treatments.

Generally, use of the three organic manures led to higher grain yield, yield components and WUE compared to control in both cropping seasons. Lack of positive response by dry matter, grain yield and WUE at maturity stage of the first cropping season may be due to excess rainfall experienced towards the end of cropping season resulting in fungal diseases, hence causing a decrease in LAI at maturity.

From the results of this study, organic manure used could be recommended to improve sunflower grain yield, soil bulk density, aggregate stability, infiltration rate and cumulative infiltration of a clayey soil. It may also be recommended that in order to get a significant influence of organic manure on soil physical properties, further similar long term studies on organic manure should be conducted. Based on the results of this study PM can be recommended as the first choice among the manure used for local smallholder farmers under evenly distributed rainfall. It should however be noted that for recommendations to be made across sites, based on grain yield and WUE, climatic conditions and soil type have to be considered, therefore the results obtained in this study are only valid for the specified soil and climatic conditions.

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8. APPENDICES

8.1 Appendix A: Soil profile description of the study site

Location	: University of Venda experimental farm		
Coordinates	: 22°58' S; 30°26' E		
Altitude	: 596 m		
Slope	: Gentle undulating slope		
Soil form and family	: Shortlands; *Bayala*		
Land use	: Agronomic field crops		
Terrain unit	: foot slope		
Surface rockiness	: None		
Calcareousness	: Non - calcareous		
Described by	: Mokgolo M.J.		
Horizon	**Depth (mm)**	**Description**	**Diagnostic horizon**
A	0 – 300	Dark reddish brown (10R3/3); Clay soil; weak angular and subangular structure; slightly hard (dry); friable (moist); good permeability and well drained; few roots;	Orthic
B1	300 – 600	Dark reddish brown (10R3/3); Clay soil; weak angular and subangular structure; slightly hard (dry); friable (moist); good permeability and well drained; few roots; slightly sticky and plastic (wet); no clear transition	Red structured B
B2	600 – 900	Dark reddish brown (10R3/3); Clay soil; weak angular and subangular structure; slightly hard (dry); friable (moist); good permeability and well drained;	Red structured B

		occasional few fine roots; slightly sticky and plastic (wet); no clear transition	
B3	900 - 1200	Dark reddish brown (10R3/3); Clay soil; weak angular and subangular structure; slightly hard (dry); friable (moist); good permeability and well drained; occasional few fine roots; slightly sticky and plastic (wet); no clear transition	Red tructured B

8.2 Appendix B: Effect of organic manure on infiltration rate and cumulative infiltration

	Infiltration rate (mm hr^{-1})				Cumulative infiltration (mm)			
Cum. time (min)	Control	Cattle	Poultry	Combination	Control	Cattle	Poultry	Combination
1	120	600	300	270	2	10	5	4,5
2	90	180	300	210	3,5	13	10	8
3	90	180	240	150	5	16	14	10,5
4	60	360	210	150	6	22	17,5	13
5	78	240	240	90	7,3	26	21,5	14,5
10	138	168	198	120	18,8	40	38	24,5
15	42	102	192	84	22,3	48,5	54	31,5
20	57,6	78	138	72	27,1	55	65,5	37,5
25	50,4	84	138	78	31,3	62	77	44
30	30	60	84	72	33,8	67	84	50
45	60	58,2	64,2	48	48,8	81,5	100	62
60	40,2	54	60	49,8	58,8	95	115	74,5
75	34,2	42	54	40,2	67,3	105,5	128,5	84,5
90	31,8	31,8	52,2	36	75,3	113,5	141,5	93,5
120	18	27	31,8	19,8	84,3	127	157,5	103,5
150	17,4	24,6	28,7	19,2	92,9	139,2	171,8	113
180	16,8	24	28,1	17,4	101,3	151,2	185,8	121,8

8.3 Appendix C: Determination volumetric water content for dry end and wet end NWM calibration

DRY END CAL

ACCESS TUBE #1

	REP 1				REP 2				REP 3		
DEPTH (cm)	θ_g (w/w)	DB	θ_v		θ_g	DB	θ_v		θ_g	DB	θ_v
0-30	0,1827	1,09	**0,1991**		0,1699	1,2	**0,2039**		0,1617	1,11	**0,1795**
30-60	0,2088	1,26	**0,2631**		0,2073	1,21	**0,2508**		0,1788	1,21	**0,2163**
60-90	0,2775	1,16	**0,3219**		0,2695	1,07	**0,2884**		0,2575	1,06	**0,273**
90-120	0,2703	1,04	**0,2811**		0,279	0,97	**0,2706**		0,2846	1,09	**0,3102**

DRY END CAL

ACCESS TUBE #2

	REP 1				REP 2				REP 3		
DEPTH (cm)	θ_g	DB	θ_v		θ_g	DB	θ_v		θ_g	DB	θ_v
0-30	0,1825	1,09	**0,1989**		0,2056	1,2	**0,2467**		0,1696	1,11	**0,1883**
30-60	0,2014	1,26	**0,2538**		0,2325	1,21	**0,2813**		0,2055	1,21	**0,2487**
60-90	0,2513	1,16	**0,2915**		0,2537	1,07	**0,2715**		0,2456	1,06	**0,2603**
90-120	0,2769	1,04	**0,288**		0,2902	0,97	**0,2815**		0,276	1,09	**0,3008**

WET END CAL

ACCESS TUBE #1

	REP 1				REP 2				REP 3		
DEPTH (cm)	θ_g	DB	θ_v		θ_g	DB	θ_v		θ_g	DB	θ_v
0-30	0,3654	1,09	**0,3983**		0,3872	1,2	**0,4646**		0,4063	1,11	**0,451**
30-60	0,3589	1,26	**0,4522**		0,4109	1,21	**0,4972**		0,3642	1,21	**0,4407**
60-90	0,413	1,16	**0,4791**		0,4255	1,07	**0,4553**		0,4309	1,06	**0,4568**
90-120	0,3674	1,04	**0,3821**		0,363	0,97	**0,3521**		0,3779	1,09	**0,4119**

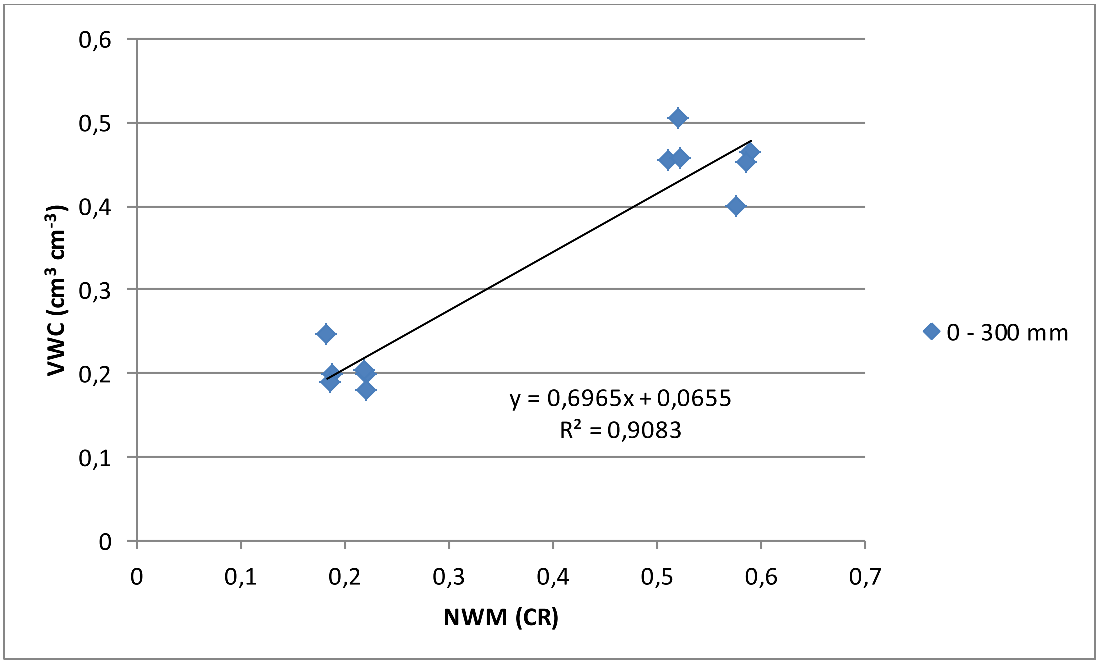
WET END CAL

ACCESS TUBE #2

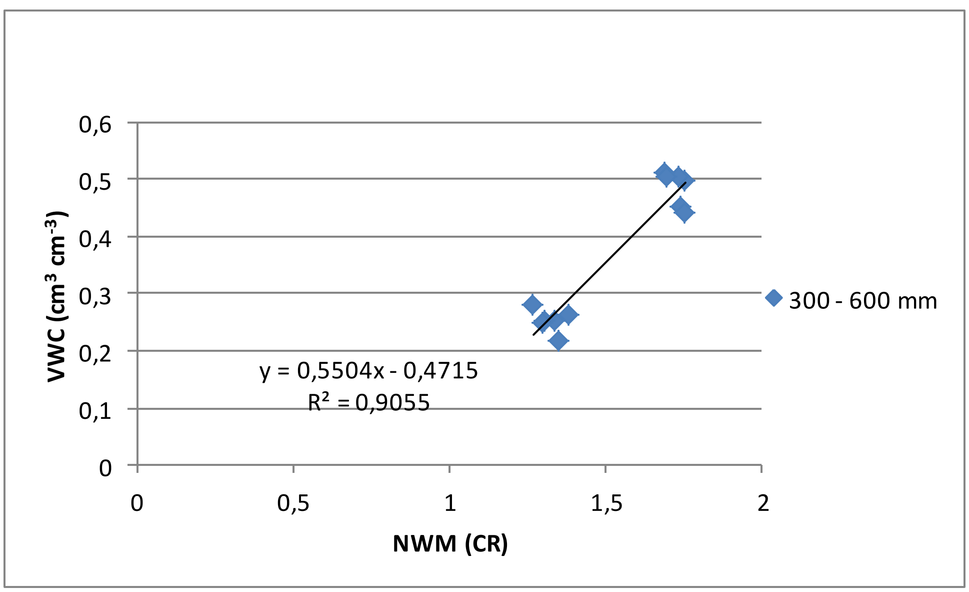
	REP 1				REP 2				REP 3		
DEPTH (cm)	θ_g	DB	θ_v		θ_g	DB	θ_v		θ_g	DB	θ_v
0-30	0,4174	1,09	**0,455**		0,4201	1,2	**0,5041**		0,4113	1,11	**0,4565**
30-60	0,3991	1,26	**0,5029**		0,4228	1,21	**0,5116**		0,4159	1,21	**0,5032**
60-90	0,3651	1,16	**0,4235**		0,3851	1,07	**0,4121**		0,3692	1,06	**0,3914**
90-120	0,3944	1,04	**0,4102**		0,4179	0,97	**0,4054**		0,3846	1,09	**0,4192**

8.4 Appendix D: NWM calibration graphs

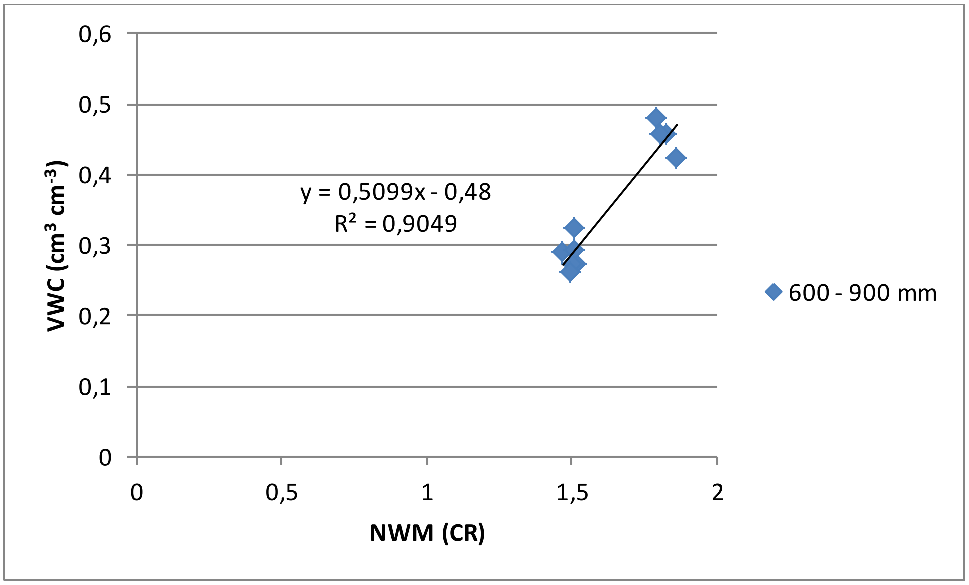
0 – 300 mm depth: $\Theta_{v\,(0-300\ mm)} = 0.6965_{CR} - 0.0655$



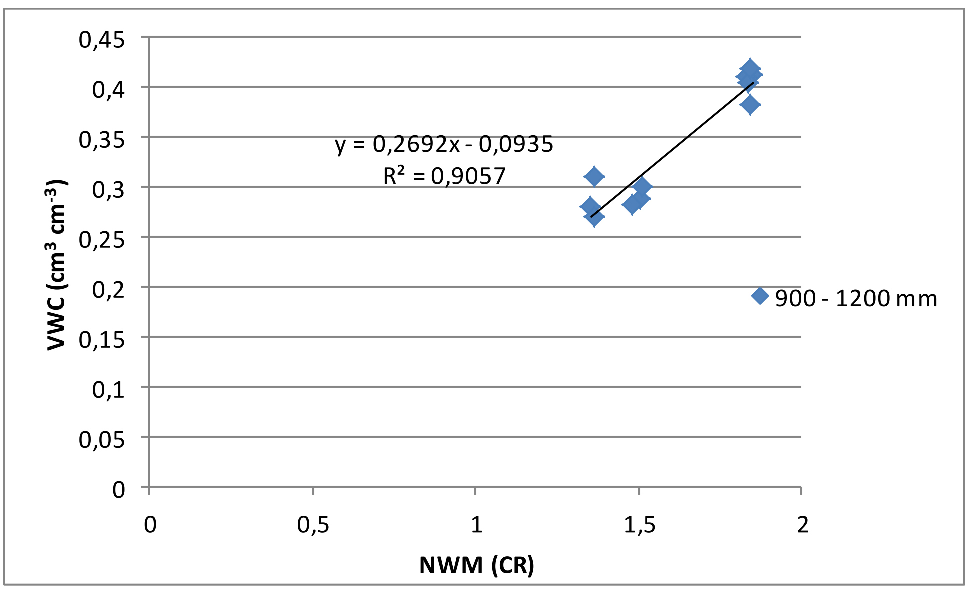
300 – 600 mm depth: $\Theta_{v\,(300-600\ mm)} = 0.5504_{CR} - 0.4715$



600 – 900 mm depth: $\Theta_{v\,(600-900\,mm)} = 0.5099_{CR} - 0.48$



900 – 1200 mm depth: $\Theta_{v\,(900-1200\,mm)} = 0.2692_{CR} - 0.0935$



8.5 Appendix E: Measurements of weekly soil water content

First cropping season

10 December 2013

Average standard count: 7516

			UNIT COUNTS				COUNT RATIO			
Treatments	Rep	Access tube	0-30 cm	30-60 cm	60-90 cm	90-120 cm	0-30 cm	30-60 cm	60-90 cm	90-120 cm
CM	1	Inter	1757,445	12920,96	13662,69	13385,46	0,233827	1,719127	1,817815	1,780928
	1	Intra	1532,556	12371,94	13481,63	13377,08	0,203906	1,646081	1,793724	1,779813
PM	1	Inter	1663,307	13659,42	14203,33	13891,48	0,221302	1,817378	1,889746	1,848255
	1	Intra	1858,905	13666,7	14073,64	13756,69	0,247326	1,818348	1,87249	1,83032
CM + PM	1	Inter	1825,425	13431,36	13759,97	13860,15	0,242872	1,787035	1,830756	1,844086
	1	Intra	2029,366	13928,28	13862,34	13730,46	0,270006	1,85315	1,844377	1,82683
Control	1	Inter	1385,12	12428,41	12725,33	13179,26	0,18429	1,653594	1,693098	1,753493
	1	Intra	1576,492	12909,67	13134,45	13351,94	0,209751	1,717625	1,747531	1,776469
CM	2	Inter	1641,339	13295,47	13290,37	13459,77	0,218379	1,768956	1,768277	1,790816
	2	Intra	1485,524	12594,54	13437,55	13654,32	0,197648	1,675697	1,787859	1,8167
PM	2	Inter	1642,396	12464,84	14275,46	14348,69	0,21852	1,658441	1,899343	1,909086
	2	Intra	1439,475	12478,69	13655,04	14340,31	0,191521	1,660283	1,816797	1,907971
CM + PM	2	Inter	1817,046	13420,06	14170,91	13982,56	0,241757	1,785533	1,885432	1,860372
	2	Intra	1612,049	13330,08	13653,22	13164,68	0,214482	1,77356	1,816554	1,751554
Control	2	Inter	1628,807	12861,58	13945,04	13618,61	0,216712	1,711226	1,85538	1,81195
	2	Intra	1704,11	13037,17	13368,7	12683,43	0,226731	1,73459	1,778698	1,687524
CM	3	Inter	1738,61	12243,34	14048,5	14432,48	0,231321	1,628971	1,869146	1,920234
	3	Intra	1851,583	12650,28	14425,92	14622,65	0,246352	1,683113	1,919362	1,945536
PM	3	Inter	1911,184	12877,97	14261,98	13904,23	0,254282	1,713408	1,89755	1,849951
	3	Intra	1830,635	13524,62	14101,69	13910,43	0,243565	1,799444	1,876223	1,850775
CM + PM	3	Inter	1948,817	12829,88	13803,68	14142,49	0,259289	1,707009	1,836573	1,881651
	3	Intra	1692,598	12949,38	14166,54	13874,72	0,225199	1,722908	1,88485	1,846025
Control	3	Inter	1644,472	12049,89	13837,2	13792,39	0,218796	1,603232	1,841032	1,83507
	3	Intra	1402,898	12335,15	14227,38	14477,29	0,186655	1,641185	1,892945	1,926196
CM	4	Inter	421,8626	12295,44	15177,13	14851,8	0,056129	1,635902	2,01931	1,976025
	4	Intra	1603,706	12400	13852,86	13864,52	0,213372	1,649813	1,843117	1,844668
PM	4	Inter	1644,472	12667,76	14189,85	13735,92	0,218796	1,68544	1,887953	1,827557
	4	Intra	1666,44	13346,84	14284,94	13879,1	0,221719	1,77579	1,900604	1,846607
CM + PM	4	Inter	1864,115	14173,82	14031,74	14374,92	0,24802	1,88582	1,866916	1,912576
	4	Intra	1750,122	13829,91	14294,41	14097,68	0,232853	1,840063	1,901864	1,875689
Control	4	Inter	1480,278	12938,81	13447,02	13949,04	0,19695	1,721502	1,78912	1,855913
	4	Intra	1709,32	12975,24	13689,65	13922,08	0,227424	1,726349	1,821402	1,852326

CM: Cattle manure; PM: Poultry manure

19 December 2013

Average standard count: 7761

			UNIT COUNTS				COUNT RATIO			
Treatments	Rep	Access tube	0-30 cm	30-60 cm	60-90 cm	90-120 cm	0-30 cm	30-60 cm	60-90 cm	90-120 cm
CM	1	Inter	6285,053	12738,44	13460,87	13021,15	0,809825	1,64134	1,734424	1,677766
	1	Intra	1965,211	12442,99	13311,86	13046,65	0,253216	1,603271	1,715225	1,681052
PM	1	Inter	2062,445	13472,89	13964,34	13599,67	0,265745	1,735973	1,799297	1,752309
	1	Intra	1931,804	13434,64	13814,25	13326,07	0,248912	1,731045	1,779957	1,717056
CM + PM	1	Inter	2009,802	13224,79	13575,26	13430,27	0,258962	1,704006	1,749164	1,730481
	1	Intra	2018,91	13722,08	13500,21	13336,27	0,260135	1,768081	1,739494	1,71837
Control	1	Inter	949,2596	12236,06	12429,51	12578,51	0,122312	1,576608	1,601534	1,620733
	1	intra	1835,553	12930,07	12792,36	13001,84	0,23651	1,666031	1,648287	1,675279
CM	2	Inter	1948,015	13067,78	13125,34	13173,06	0,251001	1,683775	1,691192	1,697341
	2	intra	1884,188	12608,02	13270,33	13229,89	0,242776	1,624535	1,709874	1,704664
PM	2	Inter	1902,404	12320,21	13960,34	14064,53	0,245124	1,587452	1,798781	1,812206
	2	intra	1897,34	13013,49	13570,16	13798,95	0,244471	1,676781	1,748507	1,777986
CM + PM	2	Inter	2057,381	13432,45	13907,51	13555,95	0,265092	1,730763	1,791974	1,746676
	2	intra	1925,72	13140,64	13417,15	12874,33	0,248128	1,693163	1,728791	1,658849
Control	2	Inter	1918,616	12668,86	13629,91	13262,32	0,247212	1,632374	1,756205	1,708841
	2	intra	2042,19	13008,03	13143,92	12543,17	0,263135	1,676077	1,693586	1,61618
CM	3	Inter	2203,251	12112,56	13819,35	14007,7	0,283888	1,560695	1,780614	1,804883
	3	intra	2045,25	12491,44	14172	14226,65	0,263529	1,609514	1,826053	1,833095
PM	3	Inter	1944,955	12608,75	14043,4	13742,48	0,250606	1,624629	1,809483	1,77071
	3	intra	2186,056	13272,52	13921,72	13735,19	0,281672	1,710156	1,793805	1,769771
CM + PM	3	Inter	2146,528	12771,96	13768,71	13910,43	0,276579	1,645659	1,77409	1,79235
	3	intra	1885,208	12844,82	13792,03	13539,92	0,242908	1,655047	1,777094	1,744611
Control	3	Inter	1979,383	11991,97	13724,99	13382,9	0,255042	1,545158	1,768457	1,724379
	3	intra	1932,824	12243,34	13829,55	14167,99	0,249043	1,577547	1,781929	1,825537
CM	4	Inter	490,4112	12287,79	14764,37	14514,09	0,063189	1,583274	1,90238	1,870131
	4	intra	1778,83	12115,47	13605,5	13628,09	0,229201	1,561071	1,75306	1,75597
PM	4	Inter	1914,572	12497,63	14082,74	13346,47	0,246691	1,610312	1,814553	1,719685
	4	intra	2110,061	12994,91	14103,15	13510,41	0,27188	1,674387	1,817182	1,740808
CM + PM	4	Inter	1847,721	14004,78	13863,79	14076,55	0,238078	1,804507	1,786341	1,813755
	4	intra	1978,399	13506,41	14052,51	13785,83	0,254915	1,740292	1,810657	1,776296
Control	4	Inter	1838,613	12815,67	13299,84	13639,01	0,236904	1,651292	1,713676	1,757379
	4	intra	2019,93	12943,18	13486	13601,49	0,260267	1,667721	1,737663	1,752544

CM: Cattle manure; PM: Poultry manure

26 December 2013

Average standard count: 7027

			UNIT COUNTS				COUNT RATIO			
Treatments	Rep	Access tube	0-30 cm	30-60 cm	60-90 cm	90-120 cm	0-30 cm	30-60 cm	60-90 cm	90-120 cm
CM	1	Inter	1602,577	12315,11	13080,89	12838,99	0,22806	1,752542	1,861519	1,827094
	1	intra	1590,445	11912,91	12996,74	12871,41	0,226333	1,695306	1,849543	1,831708
PM	1	Inter	1825,425	13153,03	13637,92	13274,34	0,259773	1,871784	1,940789	1,889048
	1	intra	1759,594	12997,83	13440,47	13111,49	0,250405	1,849698	1,912689	1,865874
CM + PM	1	Inter	1810,233	12905,66	13142,82	13240,1	0,257611	1,836582	1,870332	1,884175
	1	intra	1746,443	13280,53	13190,18	13186,18	0,248533	1,889929	1,877072	1,876502
Control	1	Inter	794,2821	11615,27	12152,27	12481,24	0,113033	1,652949	1,729368	1,776183
	1	intra	1530,662	12401,45	12610,93	12912,94	0,217826	1,764829	1,79464	1,837618
CM	2	Inter	1491,171	12677,97	13025,15	12976,7	0,212206	1,804179	1,853587	1,846691
	2	intra	1518,53	11991,97	13115,5	13178,16	0,216099	1,706556	1,866444	1,875361
PM	2	Inter	1681,596	11842,24	13888,2	13845,58	0,239305	1,685248	1,976406	1,97034
	2	intra	1507,383	11805,81	13241,92	13689,65	0,214513	1,680064	1,884434	1,948151
CM + PM	2	Inter	1729,211	12927,88	13632,09	13308,95	0,246081	1,839744	1,939959	1,893973
	2	intra	1410,148	12549	13151,93	12643,36	0,200676	1,785826	1,871628	1,799254
Control	2	Inter	1451,68	12148,99	13442,65	12988,72	0,206586	1,728901	1,913	1,848402
	2	intra	1608,661	12382,15	12906,75	12260,47	0,228926	1,762081	1,836737	1,744765
CM	3	Inter	1562,065	11577,75	13679,45	13770,9	0,222295	1,647609	1,946699	1,959712
	3	intra	1568,149	11974,85	13918,8	14042,31	0,223161	1,704119	1,980761	1,998336
PM	3	Inter	1509,386	12257,55	13752,68	13439,37	0,214798	1,744351	1,95712	1,912534
	3	intra	1604,617	12704,2	13572,35	13400,03	0,22835	1,807912	1,931457	1,906934
CM + PM	3	Inter	1618,789	12343,53	13402,21	13728,27	0,230367	1,756586	1,907245	1,953646
	3	intra	1545,854	12404,37	13635,01	13397,84	0,219988	1,765244	1,940374	1,906623
Control	3	Inter	1341,257	11373,01	13312,96	13239	0,190872	1,618473	1,894544	1,884019
	3	intra	1344,281	11498,69	13693,66	14174,91	0,191302	1,636359	1,948721	2,017207
CM	4	Inter	418,4927	11467,36	14615,37	14201,15	0,059555	1,6319	2,079887	2,02094
	4	intra	1441,552	11590,86	13207,67	13361,41	0,205145	1,649475	1,879561	1,901439
PM	4	Inter	1466,871	12012,37	13748,31	13114,41	0,208748	1,709459	1,956497	1,866288
	4	intra	1609,681	12543,17	13801,13	13322,07	0,229071	1,784996	1,964015	1,89584
CM + PM	4	Inter	1603,597	13480,9	13485,28	13889,3	0,228205	1,918444	1,919066	1,976561
	4	intra	1606,657	12997,83	13658,32	13727,18	0,228641	1,849698	1,943692	1,953491
Control	4	Inter	1395,94	12386,15	12956,3	13416,06	0,198654	1,762652	1,843788	1,909215
	4	intra	1420,276	12362,84	13302,76	13516,61	0,202117	1,759334	1,893092	1,923524

CM: Cattle manure; PM: Poultry manure

09 January 2014

Average standard count: STD 8146

			UNIT COUNTS				COUNT RATIO			
Treatments	Rep	Access tube	0-30 cm	30-60 cm	60-90 cm	90-120 cm	0-30 cm	30-60 cm	60-90 cm	90-120 cm
CM	1	Inter	1795,515	12480,14	12764,67	12525,32	0,220417	1,532058	1,566986	1,537604
	1	intra	1945,429	12095,8	12626,96	12465,57	0,23882	1,484876	1,550081	1,530269
PM	1	Inter	1949,254	13056,85	13296,93	12937,35	0,23929	1,602854	1,632326	1,588185
	1	intra	1951,185	13009,49	13094,01	12744,27	0,239527	1,59704	1,607416	1,564482
CM + PM	1	Inter	2044,412	12774,14	12869,23	12873,24	0,250971	1,568149	1,579822	1,580314
	1	intra	2026,16	13130,8	12866,31	12719,5	0,248731	1,611933	1,579464	1,561441
Control	1	Inter	1642,724	11954,45	11945,7	12065,92	0,20166	1,467523	1,46645	1,481208
	1	intra	1801,271	12543,53	12156,27	12471,4	0,221123	1,53984	1,4923	1,530985
CM	2	Inter	1854,133	12706,02	12344,62	12516,58	0,227613	1,559786	1,515421	1,53653
	2	intra	1892,567	12504,92	12652,1	12697,27	0,232331	1,535099	1,553167	1,558713
PM	2	Inter	1961,75	12028,4	13329,72	13274,7	0,240824	1,476602	1,636351	1,629598
	2	intra	1691,723	12019,66	12821,14	13120,24	0,207675	1,475529	1,573918	1,610636
CM + PM	2	Inter	1874,316	12863,4	13289,28	12899,1	0,23009	1,579106	1,631387	1,583489
	2	intra	1710,012	12920,23	12848,1	12162,83	0,20992	1,586083	1,577228	1,493105
Control	2	Inter	1733,073	12357,01	13060,49	12728,97	0,212751	1,516942	1,603301	1,562604
	2	intra	1934,864	12785,8	12711,85	11958,45	0,237523	1,56958	1,560502	1,468015
CM	3	Inter	2008,855	11778,48	13157,76	13543,93	0,246606	1,445922	1,615242	1,662648
	3	intra	1740,76	12106,36	13530,45	13490,01	0,213695	1,486173	1,660993	1,656029
PM	3	Inter	2054,03	12344,62	13198,93	13018,23	0,252152	1,515421	1,620296	1,598113
	3	intra	2128,021	12786,53	13162,5	12974,15	0,261235	1,56967	1,615823	1,592702
CM + PM	3	Inter	2216,403	12341,71	12974,88	13249,93	0,272085	1,515063	1,592791	1,626557
	3	intra	1784,003	12527,14	13174,88	12979,98	0,219004	1,537827	1,617344	1,593417
Control	3	Inter	1764,768	11612,36	12985,44	12819,32	0,216642	1,425529	1,594088	1,573695
	3	intra	1693,654	11815,28	13225,89	13604,41	0,207912	1,450439	1,623605	1,670072
CM	4	Inter	446,3661	12098,71	14073,27	13771,62	0,054796	1,485234	1,72763	1,6906
	4	intra	1734,02	11926,76	12910,76	13049,93	0,212868	1,464124	1,58492	1,602004
PM	4	Inter	1861,82	12101,63	13289,28	12789,44	0,228556	1,485591	1,631387	1,570027
	4	intra	1708,081	12585,79	13362,14	12966,5	0,209683	1,545028	1,640331	1,591763
CM + PM	4	Inter	1788,812	13549,76	13149,75	13379,63	0,219594	1,663363	1,614258	1,642478
	4	intra	1897,376	12899,1	13258,31	13099,84	0,232921	1,583489	1,627585	1,608131
Control	4	Inter	1569,716	12345,71	12820,41	13015,32	0,192698	1,515555	1,573829	1,597755
	4	intra	1980,986	12376,32	12768,31	13006,57	0,243185	1,519312	1,567434	1,596682

CM: Cattle manure; PM: Poultry manure

16 January 2014

Average standard count: 8348

			UNIT COUNTS				COUNT RATIO			
Treatments	Rep	Access tube	0-30 cm	30-60 cm	60-90 cm	90-120 cm	0-30 cm	30-60 cm	60-90 cm	90-120 cm
CM	1	Inter	1362,023	11558,08	12217,48	11958,45	0,163156	1,384532	1,463521	1,432493
	1	intra	1415,722	10966,44	12010,18	11986,5	0,169588	1,31366	1,43869	1,435853
PM	1	Inter	1422,316	11893,24	12685,62	12423,68	0,170378	1,424682	1,519599	1,488222
	1	intra	1537,22	11865,92	12590,53	12220,39	0,184142	1,421408	1,508209	1,463871
CM + PM	1	Inter	1401,587	11799,98	12318,03	12359,56	0,167895	1,41351	1,475566	1,480541
	1	intra	1394,046	12024,39	12303,09	12212,74	0,166992	1,440392	1,473777	1,462954
Control	1	Inter	1176,48	11097,59	11284,84	11636,4	0,14093	1,329371	1,351802	1,393915
	1	intra	1349,782	11543,14	11729,3	12031,68	0,161689	1,382743	1,405043	1,441265
CM	2	Inter	1217,902	11962,1	11967,92	12130,77	0,145891	1,43293	1,433628	1,453135
	2	intra	1395,94	11540,95	12159,92	12285,24	0,167219	1,382481	1,456626	1,471639
PM	2	Inter	1275,39	10934,38	12726,05	12915,5	0,152778	1,30982	1,524443	1,547136
	2	intra	1258,413	11091,03	12402,91	12498	0,150744	1,328585	1,485734	1,497125
CM + PM	2	Inter	1395,94	11984,68	12723,14	12451	0,167219	1,435635	1,524094	1,491495
	2	intra	1328,106	11945,34	12301,27	11751,16	0,159093	1,430922	1,473559	1,407662
Control	2	Inter	1303,624	11417,82	12553,74	12158,82	0,15616	1,367731	1,503802	1,456495
	2	intra	1411,933	11667,37	11979,95	11424,37	0,169134	1,397624	1,435068	1,368516
CM	3	Inter	1443,993	11000,32	12563,21	13014,22	0,172975	1,317719	1,504936	1,558963
	3	intra	1363,917	11296,14	12996,37	13083,81	0,163383	1,353155	1,556825	1,567298
PM	3	Inter	1518,385	11540,95	12837,17	12496,17	0,181886	1,382481	1,537754	1,496906
	3	intra	1620,1	11573,01	12632,79	12434,97	0,19407	1,386322	1,513272	1,489575
CM + PM	3	Inter	1550,408	11522,37	12533,7	12731,52	0,185722	1,380256	1,501401	1,525098
	3	intra	1348,835	11063,71	12397,45	12478,32	0,161576	1,325312	1,48508	1,494768
Control	3	Inter	1153,856	10750,77	12481,24	12392,71	0,138219	1,287825	1,495117	1,484512
	3	intra	1234,879	11115,44	12903,11	13139,55	0,147925	1,331509	1,545653	1,573975
CM	4	Inter	379,6318	10911,06	13512,6	13282,72	0,045476	1,307027	1,618663	1,591126
	4	intra	1284,789	10838,56	12470,67	12733,7	0,153904	1,298343	1,493852	1,52536
PM	4	Inter	1308,324	11038,93	12560,29	12255	0,156723	1,322345	1,504587	1,468016
	4	intra	1229,232	11681,58	12805,11	12426,59	0,147249	1,399326	1,533913	1,488571
CM + PM	4	Inter	1332,842	12701,65	12569,76	12936,99	0,15966	1,52152	1,505722	1,549711
	4	intra	1379	12026,21	12722,41	12746,82	0,165189	1,44061	1,524007	1,526931
Control	4	Inter	1141,615	11593,78	12157	12421,86	0,136753	1,388809	1,456277	1,488004
	4	intra	1516,49	11533,67	12238,97	12537,71	0,181659	1,381608	1,466096	1,501881

CM: Cattle manure; PM: Poultry manure

23 January 2014

Average standard count: 8219

			UNIT COUNTS				COUNT RATIO			
Treatments	Rep	Access tube	0-30 cm	30-60 cm	60-90 cm	90-120 cm	0-30 cm	30-60 cm	60-90 cm	90-120 cm
CM	1	Inter	1095,239	10330,35	11902,71	11927,85	0,133257	1,256887	1,448195	1,451253
	1	intra	1154,002	10247,65	11499,42	11875,75	0,140407	1,246825	1,399127	1,444915
PM	1	Inter	1120,303	10887,75	12260,1	12289,97	0,136307	1,324704	1,491678	1,495313
	1	intra	1164,567	10880,1	12174,49	12086,69	0,141692	1,323774	1,481262	1,470579
CM + PM	1	Inter	1081,759	10603,95	11854,62	12217,84	0,131617	1,290175	1,442344	1,486536
	1	intra	1183,839	11201,78	12124,21	12150,08	0,144037	1,362913	1,475145	1,478292
Control	1	Inter	602,2543	9954,748	11155,51	11631,3	0,073276	1,211187	1,357284	1,415172
	1	intra	1160,742	10857,14	11907,45	12080,13	0,141227	1,320981	1,448771	1,469781
CM	2	Inter	1040,374	10888,84	12080,13	12076,12	0,126582	1,324837	1,469781	1,469294
	2	intra	1066,349	10488,1	11978,85	12282,32	0,129742	1,27608	1,457459	1,494382
PM	2	Inter	968,1309	9822,868	12757,02	13025,52	0,117792	1,195141	1,552138	1,584806
	2	intra	1060,593	10045,46	11916,19	12475,77	0,129042	1,222224	1,449835	1,517919
CM + PM	2	Inter	1130,868	10665,52	12457,56	12333,33	0,137592	1,297666	1,515702	1,500587
	2	intra	1067,332	10569,34	12147,53	11823,66	0,129862	1,285964	1,477981	1,438576
Control	2	Inter	1094,291	10322,7	12519,85	12255,37	0,133142	1,255956	1,523282	1,491102
	2	intra	1296,483	10579,9	11694,69	11281,56	0,157742	1,28725	1,422885	1,37262
CM	3	Inter	1063,471	9997,372	12897,64	13076,52	0,129392	1,216373	1,569247	1,591011
	3	intra	1133,783	10578,81	13156,67	13266,33	0,137947	1,287117	1,600763	1,614105
PM	3	Inter	1096,222	10096,46	12753,01	12696,18	0,133377	1,22843	1,55165	1,544735
	3	intra	1205,989	10649,12	12191,61	12348,63	0,146732	1,295671	1,483345	1,502449
CM + PM	3	Inter	1128,937	10336,18	12560,29	12815,67	0,137357	1,257596	1,528202	1,559274
	3	intra	1176,152	10045,46	12028,04	12218,57	0,143102	1,222224	1,463443	1,486625
Control	3	Inter	992,2118	10132,9	12584,7	12562,48	0,120722	1,232862	1,531172	1,528468
	3	intra	1062,524	10679,72	12940,63	13384,73	0,129277	1,299395	1,574478	1,62851
CM	4	Inter	355,7549	9250,901	13234,63	13248,11	0,043284	1,125551	1,610248	1,611888
	4	intra	1105,84	9698,638	12072,12	12686,71	0,134547	1,180027	1,468806	1,543583
PM	4	Inter	1115,458	9940,54	12098,35	12182,14	0,135717	1,209459	1,471998	1,482192
	4	intra	1084,674	10442,92	12868,5	12411,29	0,131971	1,270583	1,565701	1,510073
CM + PM	4	Inter	1149,193	11613,82	12538,43	13085,26	0,139822	1,413045	1,525543	1,592075
	4	intra	1221,399	11171,91	12355,19	12778,88	0,148607	1,359278	1,503247	1,554797
Control	4	Inter	1178,046	10656,77	12071,39	12596	0,143332	1,296602	1,468717	1,532546
	4	intra	1268,577	10584,64	12241,89	12574,87	0,154347	1,287826	1,489462	1,529975

CM: Cattle manure; PM: Poultry manure

30 January 2014

Average standard count: 8208

			UNIT COUNTS				COUNT RATIO			
Treatments	Rep	Access tube	0-30 cm	30-60 cm	60-90 cm	90-120 cm	0-30 cm	30-60 cm	60-90 cm	90-120 cm
CM	1	Inter	1897,267	12129,31	12919,87	12727,15	0,231149	1,477743	1,574058	1,550578
	1	intra	1747,754	11766,83	12714,03	12210,56	0,212933	1,43358	1,54898	1,487641
PM	1	Inter	1871,401	12761,03	13231,35	12992,73	0,227997	1,554706	1,612007	1,582935
	1	intra	1849,36	12833,89	13083,81	12814,58	0,225312	1,563583	1,594031	1,561231
CM + PM	1	Inter	1771,726	12483,06	12834,62	12899,83	0,215854	1,520841	1,563672	1,571617
	1	intra	1815,807	13003,29	12809,85	12822,23	0,221224	1,584222	1,560654	1,562163
Control	1	Inter	1593,433	11804,35	11798,52	12101,63	0,194132	1,438152	1,437442	1,47437
	1	intra	1781,307	12340,98	12413,84	12471,4	0,217021	1,50353	1,512407	1,51942
CM	2	Inter	1593,433	12420,76	12452,09	12472,49	0,194132	1,513251	1,517068	1,519553
	2	intra	1697,917	12217,48	12579,6	12812,76	0,206861	1,488484	1,532603	1,561009
PM	2	Inter	1720,905	11775,57	13290,01	13358,86	0,209662	1,434645	1,619153	1,627541
	2	intra	1508,148	11722,74	12758,84	13048,47	0,183741	1,42821	1,55444	1,589726
CM + PM	2	Inter	1801,417	12614,21	13237,18	12912,22	0,219471	1,536819	1,612717	1,573126
	2	intra	1693,108	12606,56	12647,73	11881,95	0,206275	1,535887	1,540902	1,447606
Control	2	Inter	1809,104	12038,24	13055,03	12762,85	0,220407	1,466647	1,590525	1,554928
	2	intra	2119,605	12290,34	12610,57	12050,62	0,258237	1,497361	1,536375	1,468156
CM	3	Inter	1922,186	11503,43	12939,18	13441,19	0,234184	1,40149	1,57641	1,637572
	3	intra	1872,348	11803,26	13295,83	13366,51	0,228113	1,438019	1,619863	1,628474
PM	3	Inter	1947,105	11912,55	13188,36	12984,35	0,23722	1,451334	1,606769	1,581914
	3	intra	2191,666	12198,17	12976,33	12516,58	0,267016	1,486132	1,580937	1,524924
CM + PM	3	Inter	2018,036	12063,01	13034,99	13083,81	0,245862	1,469665	1,588083	1,594031
	3	intra	1912,605	12351,54	13085,63	12961,03	0,233017	1,504818	1,594253	1,579073
Control	3	Inter	1712,307	11350,06	13050,29	12860,48	0,208614	1,382804	1,589948	1,566823
	3	intra	1712,307	11626,93	13220,06	13682,73	0,208614	1,416536	1,610631	1,667
CM	4	Inter	436,639	11802,53	14010,61	13852,5	0,053197	1,43793	1,706946	1,687683
	4	intra	1703,673	11682,67	12681,24	13225,52	0,207562	1,423327	1,544986	1,611297
PM	4	Inter	1810,998	11717,28	13149,02	12869,23	0,220638	1,427544	1,601976	1,567888
	4	intra	1569,497	12236,79	13310,04	12982,16	0,191216	1,490836	1,621594	1,581648
CM + PM	4	Inter	1798,539	13244,83	13119,14	13424,07	0,21912	1,613649	1,598336	1,635486
	4	intra	1774,604	12741,72	13097,29	13141,37	0,216204	1,552354	1,595673	1,601044
Control	4	Inter	1839,743	12302,73	12729,33	12945	0,22414	1,49887	1,550845	1,57712
	4	intra	1977,78	12221,12	12758,84	13110,77	0,240958	1,488928	1,55444	1,597315

CM: Cattle manure; PM: Poultry manure

06 February 2014

Average standard count: 8311

			UNIT COUNTS				COUNT RATIO			
Treatments	Rep	Access tube	0-30 cm	30-60 cm	60-90 cm	90-120 cm	0-30 cm	30-60 cm	60-90 cm	90-120 cm
CM	1	Inter	1658,061	11919,47	12488,16	12246,26	0,199502	1,43418	1,502606	1,4735
	1	intra	1573,578	11462,99	12283,05	12200,72	0,189337	1,379255	1,477927	1,468021
PM	1	Inter	1827,028	12497,63	12942,82	12616,4	0,219833	1,503746	1,557312	1,518036
	1	intra	1703,636	12375,22	12730,06	12472,13	0,204986	1,489017	1,531712	1,500677
CM + PM	1	Inter	1622,942	12294,35	12652,46	12664,85	0,195276	1,479286	1,522376	1,523866
	1	intra	1662,797	12626,6	12629,51	12492,9	0,200072	1,519263	1,519614	1,503176
Control	1	Inter	1348,616	11363,53	11513,27	11856,08	0,162269	1,367288	1,385305	1,426553
	1	intra	1653,325	12027,67	12136,96	12245,16	0,198932	1,447199	1,460349	1,473368
CM	2	Inter	1449,239	12252,82	12261,19	12320,21	0,174376	1,474289	1,475297	1,482398
	2	intra	1579,297	11906,36	12424,41	12506,38	0,190025	1,432602	1,494935	1,504798
PM	2	Inter	1626,73	11462,26	12996,01	13040,45	0,195732	1,379168	1,563712	1,569059
	2	intra	1426,469	11652,8	12581,06	12869,59	0,171636	1,402093	1,513784	1,548501
CM + PM	2	Inter	1753	12468,12	12953,38	12726,42	0,210925	1,500195	1,558583	1,531274
	2	intra	1669,464	12254,64	12423,68	11963,19	0,200874	1,474508	1,494847	1,43944
Control	2	Inter	1554,597	11777,39	12777,79	12417,85	0,187053	1,417085	1,537455	1,494146
	2	intra	1749,175	12060,1	12325,68	11669,92	0,210465	1,4511	1,483056	1,404153
CM	3	Inter	1472,955	11130,74	12903,84	13216,05	0,17723	1,339278	1,552621	1,590188
	3	intra	1597,331	11515,09	13131,53	13240,82	0,192195	1,385524	1,580018	1,593169
PM	3	Inter	1667,57	11716,55	12936,26	12743,54	0,200646	1,409764	1,556523	1,533334
	3	intra	1482,464	11846,61	12828,79	12681,97	0,178374	1,425413	1,543592	1,525926
CM + PM	3	Inter	1777,664	11911,82	12586,89	13029,16	0,213893	1,43326	1,514485	1,567701
	3	intra	1667,57	11849,52	13039,72	12666,67	0,200646	1,425764	1,568972	1,524085
Control	3	Inter	1390,403	11144,22	12730,06	12516,58	0,167297	1,3409	1,531712	1,506025
	3	intra	1422,462	11384,3	13044,46	13299,84	0,171154	1,369787	1,569542	1,60027
CM	4	Inter	406,0989	11459,35	13783,65	13500,94	0,048863	1,378817	1,658482	1,624467
	4	intra	1540,389	11465,91	12606,92	12847	0,185343	1,379606	1,516896	1,545783
PM	4	Inter	1628,625	11630,94	12965,77	12515,85	0,19596	1,399463	1,560073	1,505938
	4	intra	1474,886	11915,83	13188,73	12653,19	0,177462	1,433742	1,5869	1,522463
CM + PM	4	Inter	1440,714	12982,53	12862,31	13177,43	0,17335	1,56209	1,547624	1,585541
	4	intra	1627,678	12504,19	12903,84	12942,82	0,195846	1,504535	1,552621	1,557312
Control	4	Inter	1581,192	12054,27	12319,12	12732,98	0,190253	1,450399	1,482267	1,532063
	4	intra	1833,659	11889,23	12508,2	12735,89	0,22063	1,430542	1,505017	1,532414

CM: Cattle manure; PM: Poultry manure

13 February 2014

Average standard count: 8055

			UNIT COUNTS				COUNT RATIO			
Treatments	Rep	Access tube	0-30 cm	30-60 cm	60-90 cm	90-120 cm	0-30 cm	30-60 cm	60-90 cm	90-120 cm
CM	1	Inter	1496,162	12427,32	13122,79	12889,26	0,185743	1,542808	1,629148	1,600157
	1	Intra	1529,678	11859	13004,02	12974,51	0,189904	1,472253	1,614404	1,61074
PM	1	Inter	1792,528	13017,14	13700,22	13288,91	0,222536	1,616032	1,700834	1,649772
	1	Intra	1696,132	12885,99	13601,86	13081,98	0,210569	1,59975	1,688623	1,624083
CM + PM	1	Inter	1622,031	12777,42	12993,82	13290,01	0,201369	1,586272	1,613137	1,649908
	1	Intra	1579,407	12959,21	13297,29	13179,62	0,196078	1,608841	1,650812	1,636204
Control	1	Inter	1330,729	11936,23	12101,63	12506,38	0,165205	1,481841	1,502375	1,552623
	1	Intra	1653,507	12672,14	12624,41	13038,27	0,205277	1,573201	1,567276	1,618655
CM	2	Inter	1430,112	12908,57	12836,44	12936,99	0,177543	1,602554	1,593599	1,606082
	2	intra	1523,558	12503,46	13030,25	13277,98	0,189144	1,552261	1,61766	1,648415
PM	2	Inter	1578,387	11818,19	13362,14	13843,39	0,195951	1,467187	1,658863	1,718609
	2	intra	1395,685	11984,68	13190,55	13620,07	0,173269	1,487856	1,63756	1,690884
CM + PM	2	Inter	1575,326	12872,87	13699,13	13390,56	0,195571	1,598122	1,700698	1,66239
	2	intra	1559,078	12602,92	13298,38	12579,6	0,193554	1,564608	1,650948	1,561713
Control	2	Inter	1462,682	12284,15	13390,56	13231,35	0,181587	1,525034	1,66239	1,642626
	2	intra	1605,783	12445,54	13083,08	12339,16	0,199352	1,54507	1,624218	1,531863
CM	3	Inter	1394,665	11491,41	13400,76	14070,72	0,173143	1,426618	1,663657	1,746831
	3	intra	1595,618	12080,13	13654,32	14058,34	0,19809	1,499706	1,695135	1,745293
PM	3	Inter	1727,571	12018,2	13637,19	13499,12	0,214472	1,492017	1,69301	1,675868
	3	intra	1545,89	12026,58	13337,73	13298,38	0,191917	1,493058	1,655832	1,650948
CM + PM	3	Inter	1821,964	12340,98	13190,55	13595,66	0,22619	1,532089	1,63756	1,687854
	3	intra	1612,887	11708,9	13657,59	13327,53	0,200234	1,453619	1,695542	1,654566
Control	3	Inter	1318,561	11626,57	13323,52	13333,72	0,163695	1,443397	1,654069	1,655335
	3	intra	1361,185	11847,7	13613,88	14216,81	0,168986	1,470851	1,690115	1,764967
CM	4	Inter	427,4074	11635,67	14256,52	14227,01	0,053061	1,444528	1,769897	1,766234
	4	intra	1498,202	11706,71	13161,04	13524,62	0,185997	1,453348	1,633897	1,679034
PM	4	Inter	1624,071	12136,24	13650,31	13244,47	0,201623	1,506671	1,694638	1,644254
	4	intra	1477,91	12522,77	13946,86	13341,74	0,183477	1,554658	1,731453	1,65633
CM + PM	4	Inter	1533,722	13458,68	13728,64	14070,72	0,190406	1,670848	1,704362	1,746831
	4	intra	1557,074	12747,18	13620,8	13567,25	0,193305	1,582518	1,690974	1,684326
Control	4	Inter	1515,434	12438,61	12817,13	13264,87	0,188136	1,54421	1,591202	1,646787
	4	intra	1779,34	12291,43	13208,76	13593,48	0,220899	1,525938	1,639822	1,687582

CM: Cattle manure; PM: Poultry manure

19 February 2014

Average standard count: 8225

			UNIT COUNTS				COUNT RATIO			
Treatments	Rep	Access tube	0-30 cm	30-60 cm	60-90 cm	90-120 cm	0-30 cm	30-60 cm	60-90 cm	90-120 cm
CM	1	Inter	1459,366	11801,8	12325,68	12068,84	0,177431	1,434869	1,498563	1,467336
	1	Intra	1402,498	11211,98	12235,69	12043,34	0,170516	1,363159	1,487622	1,464236
PM	1	Inter	1772,09	12410,2	12911,49	12554,1	0,215452	1,508839	1,569786	1,526334
	1	Intra	1501,991	12191,25	12637,53	12423,68	0,182613	1,482218	1,536477	1,510477
CM + PM	1	Inter	1593,943	12021,48	12393,8	12479,42	0,193792	1,461578	1,506845	1,517254
	1	Intra	1535,179	12308,55	12462,29	12354,09	0,186648	1,496481	1,515172	1,502017
Control	1	Inter	1229,05	11446,23	11321,27	11748,61	0,149429	1,391639	1,376447	1,428402
	1	Intra	1579,698	12062,28	11894,33	12191,25	0,192061	1,466539	1,44612	1,482218
CM	2	Inter	1304,571	12024,39	12093,61	12136,96	0,15861	1,461932	1,470348	1,475619
	2	Intra	1444,175	11850,98	12232,05	12345,71	0,175584	1,440849	1,487179	1,500999
PM	2	Inter	1454,63	11256,79	12656,47	12998,56	0,176855	1,368607	1,538781	1,580372
	2	Intra	1319,107	11361,71	12181,77	12657,56	0,160378	1,381363	1,481067	1,538914
CM + PM	2	Inter	1600,573	12222,58	12966,5	8454,155	0,194599	1,486028	1,576474	1,027861
	2	Intra	1523,813	7727,356	10755,5	11843,33	0,185266	0,939496	1,30766	1,439919
Control	2	Inter	1320,054	11648,06	12550,46	12382,51	0,160493	1,416178	1,525891	1,505472
	2	Intra	1451,789	11789,41	12327,5	11550,43	0,176509	1,433363	1,498784	1,404307
CM	3	Inter	1389,237	10883,37	9809,388	12973,78	0,168904	1,323207	1,192631	1,57736
	3	Intra	1414,811	11511,44	12919,87	13240,1	0,172014	1,399568	1,570804	1,609738
PM	3	Inter	1584,434	11430,2	12820,41	12664,85	0,192636	1,38969	1,558712	1,539799
	3	Intra	1511,463	11479,39	12510,38	12527,51	0,183764	1,39567	1,521019	1,523101
CM + PM	3	Inter	2392,838	11679,39	12567,21	12790,17	0,290923	1,419987	1,527929	1,555036
	3	Intra	1502,938	11048,04	12815,67	12445,9	0,182728	1,343227	1,558137	1,513179
Control	3	Inter	1058,48	9963,127	11632,03	12390,16	0,128691	1,211322	1,414229	1,506402
	3	Intra	1047,332	11325,28	12801,83	10552,58	0,127335	1,376934	1,556454	1,282989
CM	4	Inter	363,8098	11027,28	13420,43	13373,8	0,044232	1,340702	1,631663	1,625994
	4	Intra	1393,973	11088,84	12499,09	12641,17	0,16948	1,348188	1,519646	1,53692
PM	4	Inter	1462,208	11504,16	12807,3	12393,8	0,177776	1,398682	1,557118	1,506845
	4	Intra	1396,814	11867,01	12954,84	12468,85	0,169825	1,442798	1,575057	1,51597
CM + PM	4	Inter	2977,592	12589,07	12678,33	13011,67	0,362017	1,530586	1,541438	1,581966
	4	Intra	1396,814	12001,44	12758,84	12741,72	0,169825	1,459142	1,551227	1,549145
Control	4	Inter	1474,522	11822,57	12071,75	12363,57	0,179273	1,437394	1,46769	1,503169
	4	Intra	1594,89	11655,71	12342,8	12644,08	0,193908	1,417108	1,500644	1,537275

CM: Cattle manure; PM: Poultry manure

28 February 2014

Average standard count: 8195

			UNIT COUNTS				COUNT RATIO			
Treatments	Rep	Access tube	0-30 cm	30-60 cm	60-90 cm	90-120 cm	0-30 cm	30-60 cm	60-90 cm	90-120 cm
CM	1	Inter	1557,803	10843,3	11940,24	11855,35	0,190092	1,32316	1,457015	1,446657
	1	intra	1485,415	10768,98	11911,82	11919,47	0,181259	1,314092	1,453547	1,454481
PM	1	Inter	1541,628	11606,89	12412,75	12073,57	0,188118	1,416338	1,514673	1,473286
	1	intra	1598,751	11479,39	12390,89	12120,21	0,195089	1,400779	1,512006	1,478976
CM + PM	1	Inter	1630,191	11340,22	11785,04	12054,63	0,198925	1,383797	1,438077	1,470974
	1	intra	1544,469	11465,18	11973,75	11977,4	0,188465	1,399045	1,461105	1,461549
Control	1	Inter	884,4853	10737,29	10948,95	11435,67	0,10793	1,310224	1,336052	1,395445
	1	intra	1678,754	11509,62	11624,02	11838,23	0,204851	1,404469	1,418428	1,444567
CM	2	Inter	2383,512	11281,2	11761,36	12098,35	0,290849	1,376596	1,435187	1,476308
	2	intra	1658,753	11225,83	12051,72	12149,72	0,20241	1,369838	1,470618	1,482577
PM	2	Inter	1645,42	10731,82	12462,29	12926,79	0,200783	1,309557	1,520719	1,577399
	2	intra	1341,621	10759,51	11911,82	12503,1	0,163712	1,312936	1,453547	1,525698
CM + PM	2	Inter	1554,961	11641,14	12367,94	12198,53	0,189745	1,420517	1,509205	1,488534
	2	intra	1594,963	11536,58	12257,55	11702,34	0,194626	1,407759	1,495735	1,427986
Control	2	Inter	1551,136	10760,24	12183,96	12021,11	0,189278	1,313025	1,486755	1,466884
	2	intra	1539,697	10992,67	12094,7	11267,72	0,187882	1,341387	1,475864	1,374951
CM	3	Inter	1538,75	10235,63	12363,93	12940,27	0,187767	1,249009	1,508716	1,579044
	3	intra	1389,237	10673,53	12618,22	13013,49	0,169522	1,302444	1,539746	1,58798
PM	3	Inter	1589,243	10585	12464,12	12388,7	0,193928	1,291642	1,520941	1,511739
	3	intra	1330,182	10848,76	11965,01	12070,66	0,162316	1,323827	1,460038	1,47293
CM + PM	3	Inter	1733,036	10826,18	12041,15	12552,64	0,211475	1,321071	1,469329	1,531744
	3	intra	1413,063	10361,32	12239,34	11969,02	0,17243	1,264346	1,493513	1,460527
Control	3	Inter	1763,529	10243,28	12213,47	12329,68	0,215196	1,249943	1,490356	1,504537
	3	intra	1316,848	10597,39	12668,86	13302,03	0,160689	1,293153	1,545925	1,623188
CM	4	Inter	385,468	9990,814	13150,84	13230,62	0,047037	1,219135	1,604739	1,614475
	4	intra	1465,414	10155,48	12040,42	12457,56	0,178818	1,239229	1,46924	1,520141
PM	4	Inter	1641,631	10806,14	12396,35	12064,1	0,200321	1,318626	1,512673	1,47213
	4	intra	1388,29	11119,45	12655,38	12173,76	0,169407	1,356857	1,54428	1,485511
CM + PM	4	Inter	1545,416	11916,56	12320,21	12787,99	0,18858	1,454125	1,503382	1,560462
	4	intra	1367,342	11323,1	12192,7	12452,46	0,166851	1,381708	1,487822	1,519519
Control	4	Inter	1544,469	10865,89	11387,94	12300,18	0,188465	1,325917	1,389621	1,500937
	4	intra	1490,187	10963,16	12099,44	12472,49	0,181841	1,337786	1,476442	1,521964

CM: Cattle manure; PM: Poultry manure

07 March 2014

Average standard count: 8289

			UNIT COUNTS				COUNT RATIO			
Treatments	Rep	Access tube	0-30 cm	30-60 cm	60-90 cm	90-120 cm	0-30 cm	30-60 cm	60-90 cm	90-120 cm
CM	1	Inter	1874,826	12098,71	12619,31	11982,13	0,226182	1,459611	1,522417	1,445546
	1	intra	1767,718	11806,9	12620,04	12367,21	0,213261	1,424406	1,522504	1,492002
PM	1	Inter	1900,437	12664,85	13038,27	12447,72	0,229272	1,52791	1,57296	1,501716
	1	intra	1832,165	12730,06	12937,72	12690,35	0,221036	1,535778	1,56083	1,530987
CM + PM	1	Inter	2003,755	12356,64	12681,61	12677,97	0,241737	1,490728	1,529932	1,529493
	1	intra	1932,642	12954,84	12592,72	12328,23	0,233157	1,562895	1,519208	1,4873
Control	1	Inter	1525,052	11610,54	10953,69	11359,53	0,183985	1,400716	1,321473	1,370434
	1	intra	1772,454	12324,58	12224,03	12386,88	0,213832	1,48686	1,47473	1,494376
CM	2	Inter	1652,086	12343,53	12264,84	12269,57	0,199311	1,489146	1,479652	1,480224
	2	intra	1747,827	12284,51	12504,55	12640,08	0,210861	1,482026	1,508572	1,524922
PM	2	Inter	1843,531	11750,8	12872,14	13122,42	0,222407	1,417637	1,552919	1,583113
	2	intra	1625,528	12005,81	12431,69	12894	0,196107	1,448403	1,499782	1,555556
CM + PM	2	Inter	1787,61	12702,74	13147,2	12853,2	0,21566	1,532481	1,586102	1,550633
	2	intra	1799,013	12590,89	12685,62	12081,59	0,217036	1,518988	1,530416	1,457545
Control	2	Inter	1799,013	11909,27	11978,49	11807,63	0,217036	1,436756	1,445107	1,424494
	2	intra	1919,381	12162,47	12689,26	11844,79	0,231558	1,467302	1,530855	1,428977
CM	3	Inter	1767,718	11480,84	12610,57	12855,38	0,213261	1,38507	1,521362	1,550897
	3	intra	1696,605	11887,41	12994,55	13286,73	0,204682	1,434119	1,567686	1,602935
PM	3	Inter	1882,403	11888,51	13033,53	12662,66	0,227097	1,434251	1,572389	1,527647
	3	intra	1697,589	12221,12	12908,21	12588,71	0,2048	1,474378	1,55727	1,518725
CM + PM	3	Inter	1935,483	11976,67	12417,48	12811,67	0,2335	1,444887	1,498068	1,545623
	3	intra	1689,027	11739,5	12895,09	12077,95	0,203767	1,416275	1,555688	1,457105
Control	3	Inter	1727,899	11179,19	12592,72	12331,87	0,208457	1,348678	1,519208	1,487739
	3	intra	1506,107	11637,13	12919,87	13408,77	0,1817	1,403925	1,558676	1,617658
CM	4	Inter	445,3824	11605,8	13759,6	13535,92	0,053732	1,400145	1,659983	1,632997
	4	intra	1710,85	11610,54	12747,18	12845,91	0,2064	1,400716	1,537843	1,549754
PM	4	Inter	1821,746	11801,07	13131,17	12805,11	0,219779	1,423703	1,584168	1,544832
	4	intra	1781,927	12301,63	13355,58	12612,75	0,214975	1,484091	1,611242	1,521625
CM + PM	4	Inter	1951,003	12372,31	13526,81	12266,66	0,235373	1,492618	1,631899	1,479872
	4	intra	1804,259	12332,23	12913,31	12709,66	0,217669	1,487783	1,557885	1,533316
Control	4	Inter	1902,331	12112,92	12471,4	12497,27	0,229501	1,461325	1,504572	1,507693
	4	intra	1981,933	12170,85	12506,38	12569,04	0,239104	1,468313	1,508792	1,516351

CM: Cattle manure; PM: Poultry manure

19 March 2014

Average standard count: 7092

			UNIT COUNTS				COUNT RATIO			
Treatments	Rep	Access tube	0-30 cm	30-60 cm	60-90 cm	90-120 cm	0-30 cm	30-60 cm	60-90 cm	90-120 cm
CM	1	Inter	1809,286	13074,33	13725,36	13439,74	0,255117	1,843533	1,935329	1,895056
	1	intra	1749,649	12857,57	13534,82	13385,46	0,246707	1,812968	1,908463	1,887402
PM	1	Inter	1745,459	13759,97	14321	13758,14	0,246117	1,940209	2,019318	1,939953
	1	intra	1739,157	13645,94	14037,57	13782,19	0,245228	1,924131	1,979353	1,943343
CM + PM	1	Inter	1808,266	13438,64	13671,07	13852,14	0,254973	1,894902	1,927675	1,953206
	1	intra	1685,785	13593,48	13697,3	13643,75	0,237702	1,916734	1,931374	1,923823
Control	1	Inter	1514,086	12561,39	12513,3	12908,94	0,213492	1,771205	1,764424	1,820211
	1	intra	1937,013	13217,87	13295,11	13314,05	0,273127	1,863772	1,874662	1,877334
CM	2	Inter	1502,574	13335,91	13479,45	13498,39	0,211869	1,880416	1,900655	1,903326
	2	intra	1462,791	13438,64	13692,93	13676,17	0,206259	1,894902	1,930758	1,928395
PM	2	Inter	1849,069	12797,09	14048,86	14453,98	0,260726	1,804441	1,980945	2,038068
	2	intra	1616,676	12634,61	13695,12	14000,77	0,227958	1,78153	1,931066	1,974165
CM + PM	2	Inter	1745,459	13636,46	14123,18	13935,93	0,246117	1,922795	1,991425	1,965021
	2	intra	1716,132	13674,35	13811,33	13160,31	0,241981	1,928138	1,947453	1,855656
Control	2	Inter	1720,322	12759,21	13901,32	13505,68	0,242572	1,799098	1,960141	1,904354
	2	intra	1842,803	13232,44	13667,07	12808,39	0,259842	1,865827	1,92711	1,806033
CM	3	Inter	1643,889	12297,63	14055,42	14415,36	0,231795	1,734014	1,98187	2,032623
	3	intra	1493,138	12840,81	14338,85	14610,99	0,210538	1,810605	2,021835	2,060208
PM	3	Inter	1856,428	12660,84	14204,79	13955,96	0,261764	1,785229	2,002931	1,967846
	3	intra	1513,029	12961,4	13988,39	13908,6	0,213343	1,827608	1,972418	1,961168
CM + PM	3	Inter	1879,452	13072,15	13828,09	14243,77	0,26501	1,843225	1,949816	2,008428
	3	intra	1560,135	12289,25	14197,5	13860,52	0,219985	1,732832	2,001904	1,954387
Control	3	Inter	1778,939	12170,85	13848,86	13811,33	0,250837	1,716137	1,952744	1,947453
	3	intra	1460,714	12473,59	14040,48	14667,83	0,205966	1,758825	1,979764	2,068221
CM	4	Inter	78,668	12161,37	15053,99	14929,4	0,011092	1,714802	2,122673	2,105104
	4	intra	1602,03	12675,41	13957,79	14185,12	0,225893	1,787284	1,968103	2,000157
PM	4	Inter	1826,044	12675,41	14190,22	13688,93	0,257479	1,787284	2,000876	1,930193
	4	intra	1665,894	13391,65	14458,35	13691,11	0,234898	1,888275	2,038684	1,930501
CM + PM	4	Inter	1909,799	14162,16	14235,39	14531,57	0,269289	1,996921	2,007246	2,049009
	4	intra	1618,789	13507,86	14132,65	14196,77	0,228256	1,904662	1,99276	2,001801
Control	4	Inter	1572,703	13192,74	13437,55	13827	0,221757	1,860228	1,894748	1,949661
	4	intra	1722,398	12981,07	13797,85	13900,23	0,242865	1,830382	1,945552	1,959987

CM: Cattle manure; PM: Poultry manure

Secondary cropping season

28 November 2014

Average standard count: 7295

			UNIT COUNTS				COUNT RATIO			
Treatments	Rep	Access tube	0-30 cm	30-60 cm	60-90 cm	90-120 cm	0-30 cm	30-60 cm	60-90 cm	90-120 cm
CM	1	Inter	3068	10729	11307	11372	0,420562	1,470733	1,549966	1,558876
	1	intra	3430	12039	11752	11004	0,470185	1,650308	1,610966	1,50843
PM	1	Inter	2342	11776	11944	11403	0,321042	1,614256	1,637286	1,563125
	1	intra	2414	11849	11836	11174	0,330912	1,624263	1,622481	1,531734
CM + PM	1	Inter	2400	10905	11380	11264	0,328992	1,494859	1,559973	1,544071
	1	intra	2687	11765	12021	11161	0,368334	1,612748	1,647841	1,529952
Control	1	Inter	1618	10295	10017	10819	0,221796	1,411241	1,373132	1,483071
	1	intra	2044	10615	11077	11090	0,280192	1,455106	1,518437	1,520219
CM	2	Inter	1872	9976	10976	11498	0,256614	1,367512	1,504592	1,576148
	2	intra	2107	10758	11706	11514	0,288828	1,474709	1,604661	1,578341
PM	2	Inter	2090	11422	12087	12266	0,286498	1,56573	1,656888	1,681426
	2	intra	2775	12056	12256	12390	0,380398	1,652639	1,680055	1,698424
CM + PM	2	Inter	2928	12167	12026	11516	0,401371	1,667855	1,648526	1,578615
	2	intra	2892	11512	11688	10799	0,396436	1,578067	1,602193	1,480329
Control	2	Inter	2265	10318	12004	11292	0,310487	1,414393	1,645511	1,54791
	2	intra	2637	10683	11269	10264	0,36148	1,464428	1,544757	1,406991
CM	3	Inter	2685	10024	11632	12091	0,36806	1,374092	1,594517	1,657437
	3	intra	2466	11381	12561	12319	0,33804	1,56011	1,721864	1,688691
PM	3	Inter	2933	13060	13828	12495	0,402056	1,790267	1,895545	1,712817
	3	intra	2706	12220	12976	12818	0,370939	1,67512	1,778753	1,757094
CM + PM	3	Inter	1862	10652	11586	11522	0,255243	1,460178	1,588211	1,579438
	3	intra	2218	10011	11898	11628	0,304044	1,37231	1,63098	1,593968
Control	3	Inter	2150	9117	11461	11638	0,294722	1,24976	1,571076	1,595339
	3	intra	1088	9260	11680	12291	0,149143	1,269363	1,601097	1,684853
CM	4	Inter	2399	10461	12292	12528	0,328855	1,433996	1,68499	1,717341
	4	intra	2340	9818	11671	12007	0,320768	1,345853	1,599863	1,645922
PM	4	Inter	2235	10105	11819	11557	0,306374	1,385195	1,620151	1,584236
	4	intra	2816	10534	13657	12788	0,386018	1,444003	1,872104	1,752981
CM + PM	4	Inter	1932	13108	13229	12400	0,264839	1,796847	1,813434	1,699794
	4	intra	2649	12583	12204	11393	0,363125	1,72488	1,672927	1,561755
Control	4	Inter	2486	11000	10989	11904	0,340781	1,507882	1,506374	1,631803
	4	intra	2519	10852	11738	11750	0,345305	1,487594	1,609047	1,610692

CM: Cattle manure; PM: Poultry manure

04 December 2014

Average standard count: 7428

			UNIT COUNTS				COUNT RATIO			
Treatments	Rep	Access tube	0-30 cm	30-60 cm	60-90 cm	90-120 cm	0-30 cm	30-60 cm	60-90 cm	90-120 cm
CM	1	Inter	2552	11799	12760	11462	0,343565	1,588449	1,717824	1,54308
	1	intra	2728	11982	13030	12892	0,367259	1,613086	1,754173	1,735595
PM	1	Inter	2371	12822	13427	12118	0,319198	1,726171	1,80762	1,631395
	1	intra	2366	12510	13314	11658	0,318525	1,684168	1,792407	1,569467
CM + PM	1	Inter	2565	12465	12842	11493	0,345315	1,67811	1,728864	1,547254
	1	intra	2399	12839	13087	11108	0,322967	1,72846	1,761847	1,495423
Control	1	Inter	1575	11489	10436	10989	0,212036	1,546715	1,404954	1,479402
	1	intra	2699	12298	11657	11117	0,363355	1,655627	1,569332	1,496634
CM	2	Inter	2400	11302	11174	12269	0,323102	1,52154	1,504308	1,651723
	2	intra	2801	12615	11845	12058	0,377087	1,698304	1,594642	1,623317
PM	2	Inter	2217	11764	13012	11996	0,298465	1,583737	1,75175	1,61497
	2	intra	2223	12491	13644	13916	0,299273	1,68161	1,836834	1,873452
CM + PM	2	Inter	2725	12713	13496	11787	0,366855	1,711497	1,816909	1,586834
	2	intra	2672	12831	13099	10905	0,35972	1,727383	1,763463	1,468094
Control	2	Inter	2537	12754	13889	12853	0,341546	1,717017	1,869817	1,730345
	2	intra	3158	11326	12333	10728	0,425148	1,524771	1,660339	1,444265
CM	3	Inter	2450	11310	12589	12287	0,329833	1,522617	1,694803	1,654146
	3	intra	2155	12052	13588	13498	0,290118	1,622509	1,829295	1,817178
PM	3	Inter	2596	12609	14242	13867	0,349488	1,697496	1,91734	1,866855
	3	intra	2330	12279	13278	13389	0,313678	1,653069	1,787561	1,802504
CM + PM	3	Inter	2403	12197	12232	11870	0,323506	1,64203	1,646742	1,598008
	3	intra	2412	11378	12536	11877	0,324717	1,531772	1,687668	1,59895
Control	3	Inter	2502	10925	11565	12658	0,336834	1,470786	1,556947	1,704093
	3	intra	2348	11770	13025	12609	0,316101	1,584545	1,7535	1,697496
CM	4	Inter	2319	11745	13461	12563	0,312197	1,581179	1,812197	1,691303
	4	intra	2394	11807	12419	12444	0,322294	1,589526	1,671917	1,675283
PM	4	Inter	2226	11880	12480	11622	0,299677	1,599354	1,680129	1,56462
	4	intra	2247	12343	12988	11895	0,302504	1,661686	1,748519	1,601373
CM + PM	4	Inter	2446	13212	13808	13703	0,329295	1,778675	1,858912	1,844777
	4	intra	2506	13088	13564	12644	0,337372	1,761982	1,826064	1,702208
Control	4	Inter	2692	12227	12735	12236	0,362412	1,646069	1,714459	1,647281
	4	intra	2479	12334	12105	11765	0,333737	1,660474	1,629645	1,583872

CM: Cattle manure; PM: Poultry manure

11 December 2014

Average standard count: 7431

			UNIT COUNTS				COUNT RATIO			
Treatments	Rep	Access tube	0-30 cm	30-60 cm	60-90 cm	90-120 cm	0-30 cm	30-60 cm	60-90 cm	90-120 cm
CM	1	Inter	2258	11595	12533	12021	0,303862	1,560355	1,686583	1,617683
	1	intra	2289	12005	12574	12812	0,308034	1,61553	1,692101	1,724129
PM	1	Inter	1972	12844	13349	12538	0,265375	1,728435	1,796393	1,687256
	1	intra	2122	12283	13015	11865	0,28556	1,65294	1,751447	1,59669
CM + PM	1	Inter	2224	12296	12405	11374	0,299287	1,65469	1,669358	1,530615
	1	intra	2106	12547	12890	11549	0,283407	1,688467	1,734625	1,554165
Control	1	Inter	1873	10718	10370	11057	0,252052	1,442336	1,395505	1,487956
	1	intra	2082	11910	11474	11032	0,280178	1,602745	1,544072	1,484592
CM	2	Inter	1785	11300	11506	11758	0,24021	1,520657	1,548378	1,58229
	2	intra	2100	12714	11896	11553	0,2826	1,710941	1,600861	1,554703
PM	2	Inter	1889	10704	13050	12974	0,254205	1,440452	1,756157	1,745929
	2	intra	1803	12115	13434	13578	0,242632	1,630332	1,807832	1,82721
CM + PM	2	Inter	2303	12528	13226	11934	0,309918	1,68591	1,779841	1,605975
	2	intra	2274	12414	13021	11203	0,306015	1,670569	1,752254	1,507603
Control	2	Inter	2107	12787	13228	12358	0,283542	1,720764	1,78011	1,663033
	2	intra	2407	12007	12284	10508	0,323913	1,615799	1,653075	1,414076
CM	3	Inter	1917	10924	12802	12239	0,257973	1,470058	1,722783	1,647019
	3	intra	1757	11557	13312	13455	0,236442	1,555242	1,791414	1,810658
PM	3	Inter	2192	12439	14290	13577	0,29498	1,673934	1,923025	1,827076
	3	intra	1980	12209	13310	13391	0,266451	1,642982	1,791145	1,802045
CM + PM	3	Inter	2036	10369	12031	11579	0,273987	1,395371	1,619028	1,558202
	3	intra	2136	11484	12516	11818	0,287444	1,545418	1,684296	1,590365
Control	3	Inter	2022	10502	11769	11617	0,272103	1,413269	1,583771	1,563316
	3	intra	1958	11199	12507	12574	0,263491	1,507065	1,683084	1,692101
CM	4	Inter	1701	10728	13359	12838	0,228906	1,443682	1,797739	1,727628
	4	intra	1896	11197	12488	12501	0,255147	1,506796	1,680528	1,682277
PM	4	Inter	1667	11449	12378	11761	0,224331	1,540708	1,665725	1,582694
	4	intra	2102	11858	12874	11824	0,282869	1,595748	1,732472	1,591172
CM + PM	4	Inter	1970	13145	13639	13168	0,265106	1,768941	1,835419	1,772036
	4	intra	2264	12754	13312	13016	0,30467	1,716324	1,791414	1,751581
Control	4	Inter	2165	12110	11828	12034	0,291347	1,62966	1,59171	1,619432
	4	intra	2265	12154	12169	11749	0,304804	1,635581	1,637599	1,581079

CM: Cattle manure; PM: Poultry manure

20 December 2014

Average standard count: 7419

			UNIT COUNTS				COUNT RATIO			
Treatments	Rep	Access tube	0-30 cm	30-60 cm	60-90 cm	90-120 cm	0-30 cm	30-60 cm	60-90 cm	90-120 cm
CM	1	Inter	2386	12145	12998	13527	0,321607	1,637013	1,751988	1,823292
	1	intra	2709	12276	12994	12836	0,365144	1,65467	1,751449	1,730152
PM	1	Inter	2263	12972	13617	13389	0,305028	1,748484	1,835423	1,804691
	1	intra	2734	12584	13564	13264	0,368513	1,696185	1,828279	1,787842
CM + PM	1	Inter	2785	12783	12995	13159	0,375388	1,723008	1,751584	1,773689
	1	intra	2428	12750	13246	13110	0,327268	1,71856	1,785416	1,767085
Control	1	Inter	2513	10871	11761	13061	0,338725	1,465292	1,585254	1,76048
	1	intra	2467	12286	12433	12858	0,332525	1,656018	1,675832	1,733118
CM	2	Inter	2453	12197	13109	13488	0,330638	1,644022	1,76695	1,818035
	2	intra	2676	13026	12838	13152	0,360696	1,755762	1,730422	1,772746
PM	2	Inter	2415	12040	13306	13498	0,325516	1,62286	1,793503	1,819383
	2	intra	2429	12527	13701	14096	0,327403	1,688502	1,846745	1,899987
CM + PM	2	Inter	2746	12929	13703	13243	0,370131	1,742688	1,847014	1,785011
	2	intra	2596	12822	13202	12462	0,349912	1,728265	1,779485	1,679741
Control	2	Inter	2523	13047	13663	13380	0,340073	1,758593	1,841623	1,803478
	2	intra	2955	12441	12915	12225	0,398302	1,676911	1,740801	1,647796
CM	3	Inter	2366	11169	13203	13675	0,318911	1,505459	1,77962	1,84324
	3	intra	2212	11978	13612	13733	0,298153	1,614503	1,834749	1,851058
PM	3	Inter	2820	13031	14158	14314	0,380105	1,756436	1,908343	1,929371
	3	intra	2487	12506	13362	13587	0,33522	1,685672	1,801051	1,831379
CM + PM	3	Inter	2569	12313	13348	12964	0,346273	1,659658	1,799164	1,747405
	3	intra	2633	12114	13788	13407	0,3549	1,632835	1,858471	1,807117
Control	3	Inter	2772	11095	13277	13659	0,373635	1,495485	1,789594	1,841084
	3	intra	2121	11747	13619	14096	0,285888	1,583367	1,835692	1,899987
CM	4	Inter	2219	11219	14250	14138	0,299097	1,512198	1,920744	1,905648
	4	intra	2476	11636	13712	14095	0,333738	1,568405	1,848228	1,899852
PM	4	Inter	2173	11986	14039	13656	0,292897	1,615582	1,892304	1,840679
	4	intra	2408	12100	13652	13731	0,324572	1,630948	1,84014	1,850789
CM + PM	4	Inter	2745	13454	13685	13767	0,369996	1,813452	1,844588	1,855641
	4	intra	2595	12909	13706	13633	0,349778	1,739992	1,847419	1,837579
Control	4	Inter	1571	12749	12813	13411	0,211754	1,718426	1,727052	1,807656
	4	intra	2742	12575	13020	13692	0,369592	1,694972	1,754953	1,845532

CM: Cattle manure; PM: Poultry manure

03 January 2015

Average standard count: 7417

			UNIT COUNTS				COUNT RATIO			
Treatments	Rep	Access tube	0-30 cm	30-60 cm	60-90 cm	90-120 cm	0-30 cm	30-60 cm	60-90 cm	90-120 cm
CM	1	Inter	1935	11261	12892	13438	0,260887	1,518269	1,738169	1,811784
	1	intra	2287	11813	12981	13151	0,308346	1,592692	1,750169	1,773089
PM	1	Inter	1938	11803	13764	13012	0,261292	1,591344	1,855737	1,754348
	1	intra	2017	11821	13360	12928	0,271943	1,593771	1,801267	1,743023
CM + PM	1	Inter	2108	21807	12831	13217	0,284212	2,940138	1,729945	1,781987
	1	intra	1831	12970	13199	13983	0,246865	1,748685	1,77956	1,885264
Control	1	Inter	1803	10112	12022	13656	0,24309	1,363354	1,620871	1,841176
	1	intra	4532	12810	12970	12891	0,611029	1,727113	1,748685	1,738034
CM	2	Inter	1833	11672	13219	13511	0,247135	1,573682	1,782257	1,821626
	2	intra	4713	12387	12819	13812	0,635432	1,670082	1,728327	1,862208
PM	2	Inter	1209	11131	13875	13891	0,163004	1,500742	1,870702	1,87286
	2	intra	2016	11833	13793	14111	0,271808	1,595389	1,859647	1,902521
CM + PM	2	Inter	2101	12538	13606	13767	0,283268	1,690441	1,834434	1,856141
	2	intra	5673	12569	12578	12877	0,764865	1,69462	1,695834	1,736147
Control	2	Inter	2618	12138	13889	13773	0,352973	1,636511	1,87259	1,85695
	2	intra	2609	11988	12890	12126	0,351759	1,616287	1,737899	1,634893
CM	3	Inter	1973	11361	13971	13789	0,266011	1,531751	1,883646	1,859107
	3	intra	1810	11473	13861	13891	0,244034	1,546852	1,868815	1,87286
PM	3	Inter	2175	11895	14784	13892	0,293245	1,603748	1,993259	1,872994
	3	intra	1919	11009	12893	13432	0,25873	1,484293	1,738304	1,810975
CM + PM	3	Inter	2115	11612	13871	13724	0,285156	1,565593	1,870163	1,850344
	3	intra	1821	10988	13018	13827	0,245517	1,481462	1,755157	1,864231
Control	3	Inter	2017	11431	13903	13674	0,271943	1,541189	1,874478	1,843603
	3	intra	1383	11801	13454	14151	0,186464	1,591075	1,813941	1,907914
CM	4	Inter	1151	9653	13819	14282	0,155184	1,30147	1,863152	1,925576
	4	intra	2013	11091	13876	13283	0,271404	1,495349	1,870837	1,790886
PM	4	Inter	2132	11383	13681	13827	0,287448	1,534718	1,844546	1,864231
	4	intra	1831	11532	13818	13607	0,246865	1,554807	1,863017	1,834569
CM + PM	4	Inter	2014	12713	13811	13871	0,271538	1,714035	1,862074	1,870163
	4	intra	1634	12810	13786	13621	0,220305	1,727113	1,858703	1,836457
Control	4	Inter	2289	12457	13072	13553	0,308615	1,67952	1,762438	1,827289
	4	intra	2131	12013	13112	13607	0,287313	1,619658	1,767831	1,834569

CM: Cattle manure; PM: Poultry manure

08 January 2015

Average standard count: 7411

			UNIT COUNTS				COUNT RATIO			
Treatments	Rep	Access tube	0-30 cm	30-60 cm	60-90 cm	90-120 cm	0-30 cm	30-60 cm	60-90 cm	90-120 cm
CM	1	Inter	1805	11129	12624	13126	0,243557	1,501687	1,703414	1,771151
	1	Intra	2259	11522	12440	12505	0,304817	1,554716	1,678586	1,687357
PM	1	Inter	1886	11714	13248	12928	0,254487	1,580623	1,787613	1,744434
	1	Intra	1905	11399	13214	12688	0,25705	1,538119	1,783025	1,71205
CM + PM	1	Inter	2019	11574	12659	12967	0,272433	1,561733	1,708137	1,749696
	1	Intra	1749	11972	13136	13083	0,236001	1,615437	1,7725	1,765349
Control	1	Inter	1701	9950	12015	13142	0,229524	1,342599	1,621239	1,77331
	1	Intra	4631	12108	12507	12558	0,624882	1,633788	1,687627	1,694508
CM	2	Inter	1761	11154	12977	13416	0,23762	1,50506	1,751046	1,810282
	2	Intra	4839	12280	12590	13205	0,652948	1,656996	1,698826	1,781811
PM	2	Inter	1736	10947	13167	13392	0,234246	1,477129	1,776683	1,807044
	2	Intra	2063	11680	13445	14015	0,27837	1,576036	1,814195	1,891108
CM + PM	2	Inter	2018	12329	13470	13237	0,272298	1,663608	1,817568	1,786129
	2	Intra	5577	12239	12870	12303	0,75253	1,651464	1,736608	1,6601
Control	2	Inter	2513	12765	13577	13156	0,339091	1,72244	1,832006	1,775199
	2	Intra	2609	11568	12739	11988	0,352044	1,560923	1,718931	1,617595
CM	3	Inter	1861	11006	13078	13666	0,251113	1,48509	1,764674	1,844016
	3	Intra	1645	11211	13346	13554	0,221967	1,512751	1,800837	1,828903
PM	3	Inter	2072	11671	14629	13762	0,279584	1,574821	1,973958	1,856969
	3	Intra	1818	11169	12759	13117	0,245311	1,507084	1,72163	1,769937
CM + PM	3	Inter	2010	11014	13116	13042	0,271218	1,486169	1,769802	1,759816
	3	Intra	1630	10532	12916	13401	0,219943	1,421131	1,742815	1,808258
Control	3	Inter	1913	10964	13399	13438	0,25813	1,479422	1,807988	1,813251
	3	Intra	1252	11263	13210	14023	0,168938	1,519768	1,782485	1,892187
CM	4	Inter	1013	9653	13582	14182	0,136689	1,302523	1,832681	1,913642
	4	Intra	1991	10936	13313	13831	0,268655	1,475644	1,796384	1,86628
PM	4	Inter	1787	11022	13708	13354	0,241128	1,487249	1,849683	1,801916
	4	Intra	2058	11319	13592	13483	0,277695	1,527324	1,83403	1,819323
CM + PM	4	Inter	1831	12515	13456	13520	0,247065	1,688706	1,815679	1,824315
	4	Intra	1533	12383	13469	13409	0,206855	1,670895	1,817434	1,809337
Control	4	Inter	2211	12202	12826	13372	0,29834	1,646471	1,730671	1,804345
	4	Intra	2028	11966	12832	13305	0,273647	1,614627	1,73148	1,795304

CM: Cattle manure; PM: Poultry manure

17 January 2015

Average standard count: 7406

			UNIT COUNTS				COUNT RATIO			
Treatments	Rep	Access tube	0-30 cm	30-60 cm	60-90 cm	90-120 cm	0-30 cm	30-60 cm	60-90 cm	90-120 cm
CM	1	Inter	2278	10329	11877	12411	0,307588	1,39468	1,6037	1,675803
	1	Intra	2678	10996	11304	11902	0,361599	1,484742	1,52633	1,607075
PM	1	Inter	2536	11689	12191	12180	0,342425	1,578315	1,646098	1,644612
	1	Intra	2268	11611	12145	12265	0,306238	1,567783	1,639887	1,65609
CM + PM	1	Inter	2734	11069	11548	12415	0,36916	1,494599	1,559276	1,676344
	1	Intra	6531	12259	12250	12212	0,881853	1,65528	1,654064	1,648933
Control	1	Inter	2331	9283	11535	12708	0,314745	1,253443	1,557521	1,715906
	1	Intra	5780	11784	11934	12200	0,780448	1,591142	1,611396	1,647313
CM	2	Inter	2386	10869	12500	12795	0,322171	1,467594	1,687821	1,727653
	2	Intra	5440	12148	12041	12682	0,73454	1,640292	1,625844	1,712395
PM	2	Inter	2320	10330	12163	13126	0,31326	1,394815	1,642317	1,772347
	2	Intra	2558	11396	12655	13125	0,345396	1,538752	1,70875	1,772212
CM + PM	2	Inter	2563	11560	12539	12634	0,346071	1,560897	1,693087	1,705914
	2	Intra	5624	11917	12223	11832	0,759384	1,609101	1,650419	1,597624
Control	2	Inter	2888	11712	12642	12779	0,389954	1,58142	1,706994	1,725493
	2	Intra	3470	11747	12214	11613	0,468539	1,586146	1,649203	1,568053
CM	3	Inter	2307	10114	12974	13600	0,311504	1,365649	1,751823	1,836349
	3	Intra	6867	10839	13090	13268	0,927221	1,463543	1,767486	1,79152
PM	3	Inter	2534	10943	13251	13023	0,342155	1,477586	1,789225	1,758439
	3	Intra	2331	11002	12243	12248	0,314745	1,485552	1,653119	1,653794
CM + PM	3	Inter	2421	10584	12314	12489	0,326897	1,429112	1,662706	1,686335
	3	Intra	4907	10273	12373	12411	0,662571	1,387119	1,670672	1,675803
Control	3	Inter	1430	10131	13324	13209	0,193087	1,367945	1,799082	1,783554
	3	Intra	1759	11111	13025	13751	0,23751	1,50027	1,758709	1,856738
CM	4	Inter	2213	10276	12846	13214	0,298812	1,387524	1,73454	1,784229
	4	Intra	2301	10069	12324	12753	0,310694	1,359573	1,664056	1,721982
PM	4	Inter	2174	10417	12589	12570	0,293546	1,406562	1,699838	1,697272
	4	Intra	2344	10668	12750	12735	0,3165	1,440454	1,721577	1,719552
CM + PM	4	Inter	2260	11990	12623	13091	0,305158	1,618958	1,704429	1,767621
	4	Intra	2547	12034	12236	12906	0,34391	1,624899	1,652174	1,742641
Control	4	Inter	3090	11401	12362	13003	0,417229	1,539427	1,669187	1,755739
	4	Intra	2770	11359	12589	13056	0,374021	1,533756	1,699838	1,762895

CM: Cattle manure; PM: Poultry manure

22 January 2015

Average standard count: 7476

			UNIT COUNTS				COUNT RATIO			
Treatments	Rep	Access tube	0-30 cm	30-60 cm	60-90 cm	90-120 cm	0-30 cm	30-60 cm	60-90 cm	90-120 cm
CM	1	Inter	2021	10038	11537	11667	0,270332	1,342697	1,543205	1,560594
	1	Intra	2318	10783	11431	11456	0,310059	1,442349	1,529026	1,53237
PM	1	Inter	2024	11233	12301	13213	0,270733	1,502541	1,645399	1,767389
	1	Intra	2136	11245	11956	11573	0,285714	1,504147	1,599251	1,54802
CM + PM	1	Inter	1621	9478	11237	12358	0,216827	1,26779	1,503077	1,653023
	1	Intra	2613	11101	11464	11345	0,349518	1,484885	1,53344	1,517523
Control	1	Inter	2018	10036	11356	11211	0,26993	1,342429	1,518994	1,499599
	1	Intra	4212	11783	11348	10145	0,563403	1,57611	1,517924	1,357009
CM	2	Inter	1917	10515	11963	12022	0,256421	1,406501	1,600187	1,608079
	2	Intra	3612	11663	11507	11973	0,483146	1,560059	1,539192	1,601525
PM	2	Inter	1807	11334	11997	12486	0,241707	1,516051	1,604735	1,670144
	2	Intra	2012	11198	12564	12412	0,269128	1,49786	1,680578	1,660246
CM + PM	2	Inter	2017	11283	11837	11644	0,269797	1,50923	1,583333	1,557517
	2	Intra	2234	11621	11984	11335	0,298823	1,554441	1,602996	1,516185
Control	2	Inter	2439	11862	11673	11861	0,326244	1,586677	1,561396	1,586544
	2	Intra	2138	11227	11724	10786	0,285982	1,501739	1,568218	1,44275
CM	3	Inter	1881	9976	12143	12228	0,251605	1,334403	1,624264	1,635634
	3	Intra	3212	9990	11467	12644	0,429642	1,336276	1,533842	1,691279
PM	3	Inter	1807	10783	12453	11974	0,241707	1,442349	1,66573	1,601659
	3	Intra	2113	10641	12001	11886	0,282638	1,423355	1,60527	1,589888
CM + PM	3	Inter	2018	10125	12268	11723	0,26993	1,354334	1,640984	1,568085
	3	Intra	1326	10363	12400	11887	0,177368	1,386169	1,658641	1,590021
Control	3	Inter	2361	18325	12847	12915	0,315811	2,451177	1,718432	1,727528
	3	Intra	1892	13142	12336	13123	0,253077	1,757892	1,65008	1,75535
CM	4	Inter	2012	18102	12366	12724	0,269128	2,421348	1,654093	1,70198
	4	Intra	1908	10012	11824	12415	0,255217	1,339219	1,581594	1,660647
PM	4	Inter	1776	10322	12405	11862	0,23756	1,380685	1,65931	1,586677
	4	Intra	1872	10463	12541	11910	0,250401	1,399545	1,677501	1,593098
CM + PM	4	Inter	2136	11766	11989	12062	0,285714	1,573836	1,603665	1,61343
	4	Intra	2015	11892	11567	11984	0,269529	1,59069	1,547218	1,602996
Control	4	Inter	2346	10813	11728	12678	0,313804	1,446362	1,568753	1,695827
	4	Intra	2441	10900	11956	12341	0,326512	1,457999	1,599251	1,650749

CM: Cattle manure; PM: Poultry manure

28 January 2015

Average standard count: 5948

			UNIT COUNTS				COUNT RATIO			
Treatments	Rep	Access tube	0-30 cm	30-60 cm	60-90 cm	90-120 cm	0-30 cm	30-60 cm	60-90 cm	90-120 cm
CM	1	Inter	1833	9953	11343	11567	0,308171	1,673336	1,907028	1,944687
	1	intra	2186	10509	11252	11298	0,367518	1,766812	1,891728	1,899462
PM	1	Inter	1965	11120	12108	11426	0,330363	1,869536	2,035642	1,920982
	1	intra	2016	11047	11901	11268	0,338937	1,857263	2,000841	1,894418
CM + PM	1	Inter	1221	8938	10667	11791	0,205279	1,50269	1,793376	1,982347
	1	intra	3682	11054	11219	11299	0,619032	1,85844	1,88618	1,89963
Control	1	Inter	1969	10598	11326	11144	0,331036	1,781775	1,904169	1,873571
	1	intra	5634	11600	11905	11070	0,947209	1,950235	2,001513	1,86113
CM	2	Inter	1708	10315	11848	11992	0,287155	1,734196	1,99193	2,01614
	2	intra	4418	11565	11402	11671	0,742771	1,944351	1,916947	1,962172
PM	2	Inter	1582	10128	11832	12339	0,265972	1,702757	1,98924	2,074479
	2	intra	1809	10653	12272	12380	0,304136	1,791022	2,063215	2,081372
CM + PM	2	Inter	1976	11003	11968	11421	0,332213	1,849866	2,012105	1,920141
	2	intra	3042	11410	11828	10826	0,511432	1,918292	1,988568	1,820108
Control	2	Inter	2551	11289	11890	11512	0,428884	1,897949	1,998991	1,93544
	2	intra	2316	10783	11668	10458	0,389375	1,812878	1,961668	1,758238
CM	3	Inter	1630	9235	12239	12471	0,274042	1,552623	2,057666	2,096671
	3	intra	4262	10681	12543	12143	0,716543	1,79573	2,108776	2,041527
PM	3	Inter	1678	10528	12764	12243	0,282112	1,770007	2,145931	2,058339
	3	intra	1961	10546	11963	11603	0,329691	1,773033	2,011264	1,95074
CM + PM	3	Inter	1862	10146	12073	11819	0,313046	1,705783	2,029758	1,987054
	3	intra	1309	9789	12241	11661	0,220074	1,645763	2,058003	1,960491
Control	3	Inter	2533	9653	12718	12830	0,425857	1,622898	2,138198	2,157028
	3	intra	1449	9915	12245	12990	0,243611	1,666947	2,058675	2,183927
CM	4	Inter	1819	7667	12230	12604	0,305817	1,289005	2,056153	2,119032
	4	intra	1847	9682	11794	12199	0,310525	1,627774	1,982851	2,050941
PM	4	Inter	1986	10224	12220	11602	0,333894	1,718897	2,054472	1,950572
	4	intra	1713	10201	12350	11710	0,287996	1,71503	2,076328	1,968729
CM + PM	4	Inter	1997	11504	11976	11831	0,335743	1,934095	2,01345	1,989072
	4	intra	1980	11624	11905	11171	0,332885	1,95427	2,001513	1,87811
Control	4	Inter	1810	10717	11662	12560	0,304304	1,801782	1,960659	2,111634
	4	intra	2219	10767	12009	12109	0,373067	1,810188	2,018998	2,03581

CM: Cattle manure; PM: Poultry manure

05 February 2015

Average standard count: 6534

			UNIT COUNTS				COUNT RATIO			
Treatments	Rep	Access tube	0-30 cm	30-60 cm	60-90 cm	90-120 cm	0-30 cm	30-60 cm	60-90 cm	90-120 cm
CM	1	Inter	1886	10047	11571	11524	0,288644	1,537649	1,770891	1,763698
	1	Intra	2098	10497	11187	11009	0,32109	1,60652	1,712121	1,684879
PM	1	Inter	1882	11009	12036	11377	0,288032	1,684879	1,842057	1,7412
	1	Intra	1979	10992	11833	11248	0,302877	1,682277	1,810989	1,721457
CM + PM	1	Inter	1879	10733	11266	11288	0,287573	1,642639	1,724212	1,727579
	1	Intra	1464	11307	11775	11358	0,224059	1,730487	1,802112	1,738292
Control	1	Inter	1651	8935	10897	11468	0,252678	1,367463	1,667738	1,755127
	1	Intra	2559	10810	11055	11218	0,391644	1,654423	1,691919	1,716866
CM	2	Inter	2532	10246	11763	11744	0,387511	1,568105	1,800275	1,797368
	2	Intra	4397	11653	11463	11749	0,672942	1,78344	1,754362	1,798133
PM	2	Inter	1745	10187	11983	12236	0,267065	1,559076	1,833946	1,872666
	2	Intra	1972	10731	12065	12500	0,301806	1,642332	1,846495	1,91307
CM + PM	2	Inter	1905	10957	11934	11425	0,291552	1,676921	1,826446	1,748546
	2	Intra	3897	11400	11792	10908	0,596419	1,74472	1,804714	1,669421
Control	2	Inter	2381	11294	12004	11345	0,364402	1,728497	1,837159	1,736302
	2	Intra	2506	10855	11399	10524	0,383532	1,66131	1,744567	1,610652
CM	3	Inter	1629	9295	11859	12520	0,249311	1,422559	1,814968	1,916131
	3	Intra	1816	10141	11932	12744	0,277931	1,552036	1,82614	1,950413
PM	3	Inter	1770	10657	12714	11964	0,270891	1,631007	1,945822	1,831038
	3	Intra	1910	10814	12433	12071	0,292317	1,655035	1,902816	1,847414
CM + PM	3	Inter	1610	10200	11860	11890	0,246403	1,561065	1,815121	1,819712
	3	Intra	1406	10027	11995	11625	0,215182	1,534588	1,835782	1,779155
Control	3	Inter	2413	9714	12497	12345	0,369299	1,486685	1,912611	1,889348
	3	Intra	1459	9924	12420	12861	0,223294	1,518825	1,900826	1,96832
CM	4	Inter	2071	7965	12179	12486	0,316957	1,219008	1,863942	1,910927
	4	Intra	1795	9433	11654	12108	0,274717	1,443679	1,783594	1,853076
PM	4	Inter	1864	10268	12118	11429	0,285277	1,571472	1,854607	1,749158
	4	Intra	1654	10474	12344	11619	0,253137	1,603	1,889195	1,778237
CM + PM	4	Inter	1917	11677	11913	11708	0,293388	1,787114	1,823232	1,791858
	4	Intra	2063	11555	12183	11431	0,315733	1,768442	1,864555	1,749464
Control	4	Inter	1678	10667	11404	12100	0,256811	1,632537	1,745332	1,851852
	4	Intra	2177	10750	11820	11990	0,33318	1,64524	1,808999	1,835017

CM: Cattle manure; PM: Poultry manure

13 February 2015

Average standard count: 6460

			UNIT COUNTS				COUNT RATIO			
Treatments	Rep	Access tube	0-30 cm	30-60 cm	60-90 cm	90-120 cm	0-30 cm	30-60 cm	60-90 cm	90-120 cm
CM	1	Inter	1822	10886	11348	11359	0,282043	1,685139	1,756656	1,758359
	1	Intra	1531	10212	12653	11107	0,236997	1,580805	1,958669	1,71935
PM	1	Inter	2119	11893	11337	11912	0,328019	1,841022	1,754954	1,843963
	1	Intra	2231	10444	11451	10234	0,345356	1,616718	1,772601	1,584211
CM + PM	1	Inter	1816	11341	11267	11367	0,281115	1,755573	1,744118	1,759598
	1	Intra	1645	11900	11467	11364	0,254644	1,842105	1,775077	1,759133
Control	1	Inter	1213	18233	10012	11367	0,187771	2,822446	1,549845	1,759598
	1	Intra	1815	10153	11457	11692	0,28096	1,571672	1,773529	1,809907
CM	2	Inter	1627	10155	11265	11617	0,251858	1,571981	1,743808	1,798297
	2	Intra	4215	11312	12587	11018	0,652477	1,751084	1,948452	1,705573
PM	2	Inter	1838	10010	11334	12872	0,28452	1,549536	1,754489	1,99257
	2	Intra	1867	10895	12138	12011	0,289009	1,686533	1,878947	1,859288
CM + PM	2	Inter	1810	10781	11356	11633	0,280186	1,668885	1,757895	1,800774
	2	Intra	1751	11321	12111	11892	0,271053	1,752477	1,874768	1,840867
Control	2	Inter	2015	10119	11234	12478	0,31192	1,566409	1,739009	1,931579
	2	Intra	2312	10489	12237	12914	0,357895	1,623684	1,894272	1,999071
CM	3	Inter	1813	11149	12372	12003	0,28065	1,725851	1,91517	1,85805
	3	Intra	1645	10128	11645	12035	0,254644	1,567802	1,802632	1,863003
PM	3	Inter	2261	10217	11332	12841	0,35	1,581579	1,75418	1,987771
	3	Intra	2122	10887	11293	11702	0,328483	1,685294	1,748142	1,811455
CM + PM	3	Inter	1820	10531	11127	12843	0,281734	1,630186	1,722446	1,98808
	3	Intra	1415	10178	11826	11227	0,21904	1,575542	1,83065	1,737926
Control	3	Inter	1843	10012	11817	12388	0,285294	1,549845	1,829257	1,917647
	3	Intra	1434	10567	11455	12634	0,221981	1,635759	1,77322	1,955728
CM	4	Inter	1423	9854	10571	11322	0,220279	1,525387	1,636378	1,752632
	4	Intra	1663	10125	11633	11401	0,25743	1,567337	1,800774	1,764861
PM	4	Inter	1832	10327	11514	11583	0,283591	1,598607	1,782353	1,793034
	4	Intra	2612	11327	11289	11981	0,404334	1,753406	1,747523	1,854644
CM + PM	4	Inter	1701	11234	11973	11421	0,263313	1,739009	1,853406	1,767957
	4	Intra	1912	10531	11109	11003	0,295975	1,630186	1,719659	1,703251
Control	4	Inter	1823	11015	11366	11879	0,282198	1,705108	1,759443	1,838854
	4	Intra	2118	11138	11087	11368	0,327864	1,724149	1,716254	1,759752

CM: Cattle manure; PM: Poultry manure

21 February 2015

Average standard count: 7431

			UNIT COUNTS				COUNT RATIO			
Treatments	Rep	Access tube	0-30 cm	30-60 cm	60-90 cm	90-120 cm	0-30 cm	30-60 cm	60-90 cm	90-120 cm
CM	1	Inter	1655	9731	11407	11284	0,222716	1,309514	1,535056	1,518504
	1	Intra	2080	10597	11307	11262	0,279908	1,426053	1,521599	1,515543
PM	1	Inter	2048	11087	11971	11299	0,275602	1,491993	1,610954	1,520522
	1	Intra	1952	10794	11860	10953	0,262683	1,452564	1,596017	1,47396
CM + PM	1	Inter	1778	10602	11281	11163	0,239268	1,426726	1,5181	1,50222
	1	Intra	1465	11082	11766	11222	0,197147	1,49132	1,583367	1,51016
Control	1	Inter	1059	8692	10700	11497	0,142511	1,169695	1,439914	1,547167
	1	Intra	1612	10379	11628	11123	0,216929	1,396716	1,564796	1,496838
CM	2	Inter	1557	9969	11777	11946	0,209528	1,341542	1,584847	1,60759
	2	Intra	3905	11472	11455	11661	0,525501	1,543803	1,541515	1,569237
PM	2	Inter	1630	10043	11936	12183	0,219351	1,3515	1,606244	1,639483
	2	Intra	1732	10617	12491	12365	0,233078	1,428744	1,680931	1,663975
CM + PM	2	Inter	2013	10958	11888	11338	0,270892	1,474633	1,599785	1,52577
	2	Intra	2701	11273	11718	10630	0,363477	1,517023	1,576908	1,430494
Control	2	Inter	2241	11323	11916	11484	0,301574	1,523752	1,603553	1,545418
	2	Intra	2299	10681	11295	10410	0,30938	1,437357	1,519984	1,400888
CM	3	Inter	1652	9454	12082	12220	0,222312	1,272238	1,625892	1,644462
	3	Intra	1416	10487	12397	12163	0,190553	1,41125	1,668282	1,636792
PM	3	Inter	1800	10739	12537	12056	0,242229	1,445162	1,687122	1,622393
	3	Intra	1849	10541	11747	11393	0,248823	1,418517	1,58081	1,533172
CM + PM	3	Inter	1712	10036	11706	11630	0,230386	1,350558	1,575293	1,565065
	3	Intra	1346	9739	12178	11458	0,181133	1,310591	1,63881	1,541919
Control	3	Inter	1702	9205	12182	11750	0,229041	1,23873	1,639349	1,581214
	3	Intra	1312	9515	12231	12645	0,176558	1,280447	1,645943	1,701655
CM	4	Inter	1215	7649	12078	12716	0,163504	1,029337	1,625353	1,71121
	4	Intra	1716	9256	11699	12084	0,230925	1,245593	1,574351	1,626161
PM	4	Inter	1663	10263	12151	11418	0,223792	1,381106	1,635177	1,536536
	4	Intra	2555	10292	12297	11671	0,34383	1,385009	1,654824	1,570583
CM + PM	4	Inter	2002	11706	12156	11381	0,269412	1,575293	1,63585	1,531557
	4	Intra	2099	11627	11749	11001	0,282465	1,564662	1,581079	1,48042
Control	4	Inter	1631	10828	11226	11905	0,219486	1,457139	1,510698	1,602072
	4	Intra	2151	10869	11745	11964	0,289463	1,462656	1,580541	1,610012

CM: Cattle manure; PM: Poultry manure