Growers of Organic Food Yukon

Yukon Legume Study (2005-2009)

Final Report

Prepared by Lisa Werther

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Contents

Introduction

The Legume cultivation plays an essential role as forage and green manure in organic agriculture. Cultivation of legumes in colder regions can be very challenging which is mostly related to climate factors, soil temperature or inadequate species adaptation. Although soil fertility is also essential for a successful legume growth, no study in North America has so far analyzed the influence of nutrient conditions on plant fertility in detail. Studies conducted n Alaska, Yukon and North Alberta concerned themselves mostly with nitrogen fixation, bacteria survival and functioning in cold conditions and legume winter hardiness. The most extensive studies of legume persistence have been conducted in Alaska. It has shown that the persistence of legumes was poor as were yields and measured crude protein. This weak establishment could be caused by cold climate and/or inadequate soil conditions. Kinsey reports that soils in Alaska and the Yukon tend to have low amounts of available potassium in relation to calcium and magnesium. Potassium and also phosphorous are essential for developing winter hardiness in alfalfa, and other legumes.

To analyze the influence of soil conditions on the establishment and fertility of legumes closely, a five years study in the Yukon with the participation of various farms was launched.

The purpose of this experiment was to test the hypothesis that "the limiting factors of successful legume growth in the Yukon are soil nutrient balance and adequate fertility".

The focal point of this study is on the spatial and temporal development of legume growth under consideration of given soil conditions.

Therefore the following questions need to be answered:

1. Is there a difference in **performance of the plants**, **microbial community and organic matter** in between treatments, the 4 different farms and in between the 6 species?

3. How did the **plant growth** (biomass) change over the time period of 5 years?

4. How did the **organic matter** change over the time period of 5 years?

2. Which are the most **important influences** on plant growth (biomass and crude protein) and Organic matter?

Material and Methods:

Study side:

The experiment was carried out on four different farms in the Yukon: Aurora Mountain farm, Lendrum/Ross Farm, Mc'Clintock Valley farm, Wild blue Yonder family (Gillespie) farm, Partridge creek (Buerge) Farm and the farm of Grant Dowdell and Karen Digby.

Aurora Mountain, M' Clintock Valley farm and Grant Dowdell farm participated continuously (2005-2009) in the experiment whereas the Partridge Creek farm attended the study only in 2005.The data of this farm is not accounted for in this study. Lendrum Ross has allocated his farm for the experiment from 2006 and 2009. The Wild Blue Yonder Family farm participated from 2005 to 2006.
Information about locations and conditions are described in the following and were extracted from the "legume report 2008".

Aurora Mountain Farm is located along the Takhini River Road and the plot site is situated in a corner of a grain field and bordered on the other side by a pine and lichen–dominated, open boreal forest. The plot is not irrigated and the general soil composition is primarily clay/silt. The plot is fenced since the mid-2007 season and three sides are reinforced with smaller gauge wire, though gopher incidence continues to be a major deterrent of crop growth throughout the season. The pH at this site ranges from 8.1 to 8.4.

M'Clintock Valley Farm is accessed from the M'Clintock Valley Road near Marsh Lake and the plot site is situated between cultivated vegetable plots and a potato field, and uncultivated pasture on the two other sides. The soil is primarily a sandy/ loam base with a pH value ranging from 6.3 to 6.8. This site is also characterized by a predominance of horsetail (*Equisetum spp.*) growth throughout the plots at the site.

The Lendurm/Ross Farm is located along Lake LaBerge and the fenced legume plots are bordered by a newly cultivated vegetable plot, a fenced goat pasture, and an uncultivated pine/ spruce and juniper dominated terrain. The site is irrigated with Tyvek tubing and has a gradual sloping grade from east to west with the amended blocks situated at the top of the grade and the unamended blocks at the bottom. The soil is primarily clay/silt with a pH that ranges from 7.0 to 7.6.

The Dowdell/Digby Farm is located about 20 minutes by power boat, upstream of Dawson on an island otherwise dominated by mixed boreal forest of spruce, alder, and willow with a lush understory of deciduous shrubs. The fenced legume plots are located between fallow fields and goat pasture and are also situated on a gradual slope that finds the amended blocks at the top (east) and the non-amended at the bottom (west). The soil at the plot is a silty clay loam with a pH that ranges from 8.0 to 8.4.

Gillespie Farm is located on the north side of Tagish Lake. The study site was located on a low-lying, weathered inter-lacustrine fluvio-glacial silt deposit. Weathering of the silt parent has produced a silt loam approximately 8 to 10 inches deep. The plot site was located on a 20 year-old stand of brome hay. Soil conditions in this area could be characterise as being borderline sodic, exacerbated by high magnesium levels, contributing to poor drainage, low porosity, low air exchange levels, and ephemeral anaerobic conditions. Brome hay stand was patchy in this area. Polar salt grass dominated areas with highest sodium levels.

Climate:

The climate varied in between the years and among the different farms. A detailed description of all the climate data (Precipitation, Frost and Growing degree days (GDD)) per farm is listed in the *Appendix A-D*.

Fig. 1 clearly shows that the years 2009, 2007 and 2005 had on average the most "Growing degree days (GDD)" in the analysis period. The fewest average number of "Growing degree days (GDD)" were recorded in 2008. The year 2008 and 2005 had on average the highest amounts of total annual precipitation. The lowest amounts of total annual precipitation were recorded in 2009. The most frost days were listed in 2005 and 2009 and very few in 2006.

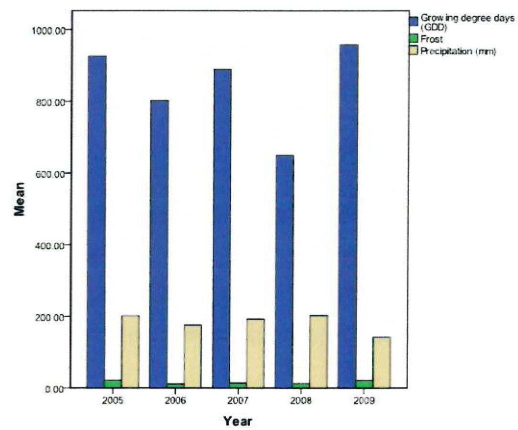


Figure 1: Yearly mean GDD, Freeze and precipitation (reference period 2005-2009)

Experimental design:

For every farm an area (block) of 15 *11 meters was selected. Each of the block included 12 plots of 3*3 meters (randomized block design, see Picture 1), separate by one foot buffer strip. Half of the 12 blocks of each farm underwent a soil treatment recommended by *Kinsey Agricultural Services, Inc* to analyze the influence of soil nutrients. The rest of the blocks did not receive any treatments and is considered to be a control group.

Picture 1: Randomized block design

The layout of the plots and legume assignment is exhibited in Fig. 2. For every treatment only one sample per species existed. The treatments for the particular years and farms are listed in the Appendix E-Q.

Treatments were applied every year using different concentrations based on the soil analysis from the last growing season. The first soil treatments were conducted in 2006.

Treatment	Treatment	No Treatment	No Treatment
1 (Alfalfa)	2 (Red Clover)	3 (Sweet clover)	4 (White clover)
5 (Field peas)	6 (Alsike)	7 (Alfalfa)	8 (Alsike clover)
9 (White Clover)	10 (Sweet Clover)	11 (Red Clover)	12 (Field peas)

15 metres × 11 metres

Figure 2: Plot layout and legume assignment (2005-2009)

Six different legume species (1 annual and 5 perennial) have been planted on every block per farm. The following species were selected for the study: *Alfalfa, White Clover, Red Clover, Alsike, Sweet Clover and Field peas*. The species were chosen because it was known that they grow satisfactorily in the Yukon and the seeds were locally available.

Morphological and ecological characteristic of the selected species:

Common red clover

Red clover is an herbaceous, short lived perennial plant, with variable size, growing to 20–80 cm tall. It is widely grown as a fodder crop, valued for its nitrogen fixation which increases soil fertility. For these reasons it is often used as a green manure crop. (Wikipedia, 2010)

Picture 2: Red clover

Common alsike clover

Alsike clover is a plant species of the genus *Trifolium* in the pea family *Fabaceae*. The plant is 30–60 cm tall and is grown as a hay or silage fodder.

Picture 3: Alsike clover

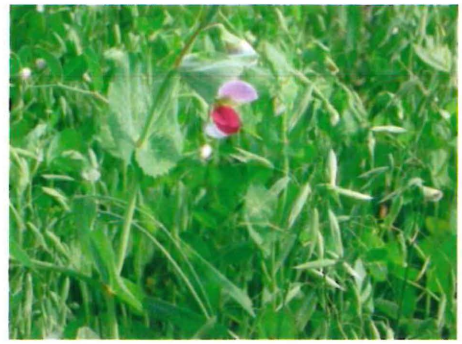
Common sweet clover

Sweet clover, *Melilotus*, is a genus in the family Fabaceae. Sweetclover is a biennial, occasionally annual plant in the pea family that can attain a height of 2 m but is usually less than 1 m. It rapidly colonizes gravelly well-drained soils. *Melilotus* is often used as a green manure and sometimes as silage, it is a common rotational crop for soil building in the prairies. It is especially valuable in heavy soils because of its deep rooting. It should be turned into the soil when 8 to 10 inches tall.

Picture 4: Sweet clover

Common field peas

A pea is most commonly the small spherical seed or the seed-pod of the legume *Pisum sativum*. *P.* sativum is an annual plant, having a one year life cycle. It is a cool season crop grown in many parts of the world. Field peas are grown as a fodder crop or for seed production. (Wikipedia, 2010)



Picture 5: Field peas

Ladino white clover

White clover has been widely introduced worldwide as a pasture crop. It is a herbaceous perennial plant. It is low growing, The stems function as stolons, so white clover often forms mats with the stems creeping as much as 18 cm a year, and rooting at the nodules cool season perennial legume

Picture 6: White clover

Peace alfalfa

Alfalfa is a flowering plant in the pea family *Fabaceae* cultivated as one of the most important forage crops. It is widely grown throughout the world as forage for cattle, and is most often harvested as hay, but can also be made into silage, grazed, or fed as greenchop. (Wikipedia, 2010) Alfalfa has the highest feeding value of all common hay crops, being used less frequently as pasture. Alfalfa is a cool season perennial legume. The plant grows to a height of up to 1 metre, and has a deep root system sometimes stretching to 4.5 metres. This makes it very resilient, especially to droughts (Wikipedia, 2010)

Picture 7: Alfalfa

Data collection:

a.) Soil sampling and analyses:

Soil from each block was sampled at the end of the season (last visit) of each year, except for 2006.

Following information derived from the "legume report 2007": A soil sampling probe was used to collect soil samples to a depth of 15 cm. Twelve soil cores were collected per block; consisting of four cores per row by three rows and evenly spaced throughout the block. The 12 soil cores collected per block were combined to form one sample, placed in a labeled plastic bag and shipped to *Kinsey Agricultural Services Inc.* for analysis.

In 2008 soil samples of all Alfalfa Plots were also examined for microbial communities at each study site. The purpose of this type of soil analysis was to determine the biological activity taking place in the root zone.

b.) Vegetative assessment:

Information on vegetative assessment of the legumes was collected every year from 2005-2009 and from every farm up to 3 times. The following data were gathered on every visit (1-3). Information derived from the "legume report 2008 and 2007":

Aerial Cover: To obtain percent of foliar cover a visual assessment of crop growth in each block was completed and the percentage of the crop area, bare ground and weed cover was recorded to equal 100 percent.

Height Assessment: To obtain height assessment an average of four (2008), ten (2007) measurements were taken at each block based on random sampling; four, ten plants were each measured from soil level to the uppermost stem growth and recorded.

Stage of Growth: To obtain stage of growth a visual inspection of each block was completed and the percentage of leaf, bud, flower, green seed and mature seed was determined and recorded to equal 100 percent.

Root Nodule: Root nodules were collected on the third visit. The sample procedure followed field assessment criteria established by W.A. Rice (1977) where nodulation was scored by evaluating the colour of Nodules, number of Nodules per plant, position of Nodules and size of Nodules.

For **biomass** collection a 50 cm by 50 cm sampling square was randomly placed near centre of each block. In this square all vegetation was cut at 6 cm to 8 cm from ground level. The biomass was dried and sent to the **Central testing lab** to analyze the crude protein content. Biomass and dry matter are indicated in g per 50 cm^2. Crude protein is listed as percentage (%) of dry matter and was also converted in (g/50cm2) per 50 cm^2.

Statistical analysis:

The data of the legume study were analyzed with the **SPSS 17** software. The statistical analysis evaluates the spatial (different farms) and temporal (years with different climatic conditions) variability over a certain time span of 5 years.

1. Comparative Analysis of spatial variability (Treatment, Farm, Species):

With the aid of comparative analysis (Analysis of variance (ANOVA), T-Test, Kruskal-Wallis, Mann-Whitney U Test) differences between "treatments, farms and species" were analyzed. Hence those factors were selected, which demonstrated plant growth or rather the performance of the plant. In the following: ***biomass (g/50cm2), dry matter (g/50cm2), crude protein content (%), protein (g/50cm2) and vegetation assessment data (see page 7).***
The microbial community and the organic matter (%) were also analyzed for significant differences between "farms, treatments and species".

The data was tested for normal distribution for each analysis. In the case that all data were normally distributed parametric tests like "ANOVA" and "T-Test" could be conducted. If not, data were improved by a log transformation (Lg10). Should even the transformation fail to achieve a normal distribution then all data has to be evaluated with non-parametric tests (i.e. Kruskal Wallis, Mann Whitney U Test). The dependent variable is in any case the „**plant performance, soil organic matter (OM) and soil microbial community**" whereas as independent variables „ **treatments, farms and species** "were selected.

1a.Analyses between treatments:

The analyses were conducted **every year** for **every farm**. Plant performance, OM and microbial community (for 2008) were analyzed.

The result should demonstrate if soil improvement has any influence on the plant performance, soil OM and soil microbial community.

1b .Analyses between farms:

These analyses compared the plant performance, soil OM and soil microbial community between **all farms per year**.

The analyses should demonstrate which of the four farms was best suited for the establishment of legumes and if the location has any influence on the accumulation of soil OM and soil microbial community.

1c. Analyses between species:

For this analysis the performance of all species was compared **for every farm**.

The analysis allowed us to conclude which of the six species established itself best on the particular farm. An annual comparison was not possible because due to lack of repetitions maximal only two values (Performance|Soil treatment; Performance|No Treatment) existed.

2. Comparative Analysis of temporal variability (2006-2009):

This part of the study demonstrated the temporal changes of the Biomass (g/50cm2), Crude protein (%), soil OM (%) and "Estimated Nitrogen release" (ENR). The parameters Biomass and Crude protein were chosen for this analysis because they are the most important indicators of crop success. The OM and ENR were important parameter for the sustainment of soil fertility. The ENR is a calculated estimate of how much nitrogen will be released through the growing season from the OM or humus-like materials.

The data was tested for normal distribution for each analysis. In the case that all data was normally distributed parametric tests like "ANOVA" and "T-Test" could be conducted. If not, data was improved by a log transformation (Lg10). Should even the transformation fail to achieve a normal distribution then all data has to be evaluated with non-parametric tests (i.e. Kruskal Wallis, Mann Whitney). The "Biomass (g/50cm2), Crude protein (%), OM (%), ENR" preselected by treatment was used as dependent variable and the "year "as independent variable.

3. Influence factors

Subsequently the relationship between the variables *Biomass, Crude Protein and OM* (dependent) and the *microbial community, root nodulation, climatic conditions and soil conditions* (independent variables) can be verified with the aid of a **Pearson correlation analysis.**

A correlation analysis is a statistical technique that can show whether and how strongly pairs of variables are related. The main result of a correlation is called the **correlation coefficient** (or "r"). It ranges from -1.0 to +1.0. The closer r is to +1 or -1, the more closely the two variables are related.
If r is close to 0, it means there is no relationship between the variables. If r is positive, it means that as one variable gets larger the other gets larger. If r is negative it means that as one gets larger, the other gets smaller (often called an "inverse" correlation).

4. Soils

4a. Soil fertility per farm

The end of the study also addressed the soil fertility of the analyzed areas. This data was not statistically interpreted but described with the aid of graphics.

4b.Temporal variability of soil fertility:

This part of the study demonstrated the temporal changes of soil fertility. This data was not statistically interpreted but described with the aid of graphics.

Results:

1. Comparative Analysis of spatial variability (Treatment, Farm, Species):

1a). Analyses between treatments (entire period): Plant performance

M' Clintock farm:

The analysis for the entire period has shown that significant differences existed between treatments in *biomass* (g/50cm^2) (p=0,025), *crude protein* (%) (p=0,004), *protein* (g/50cm^2) (p=0,033) and the root nodules (p=0,043). Results are shown in Fig. 3-6.

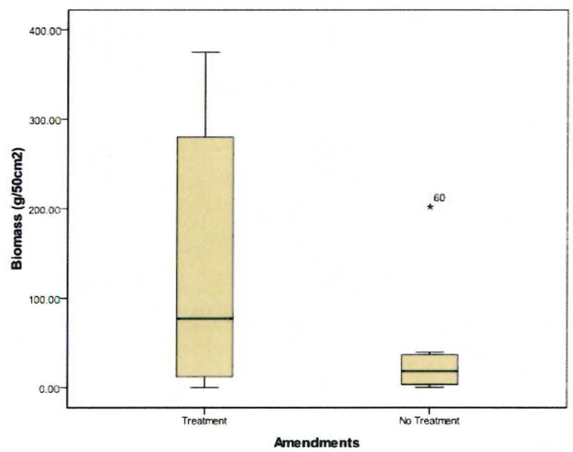


Figure 3; Average biomass (g/50cm2) per amendment

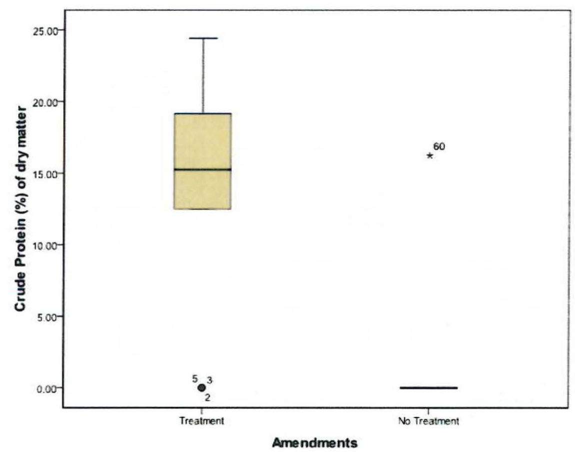


Figure 4; Average crude protein (%) per Amendment

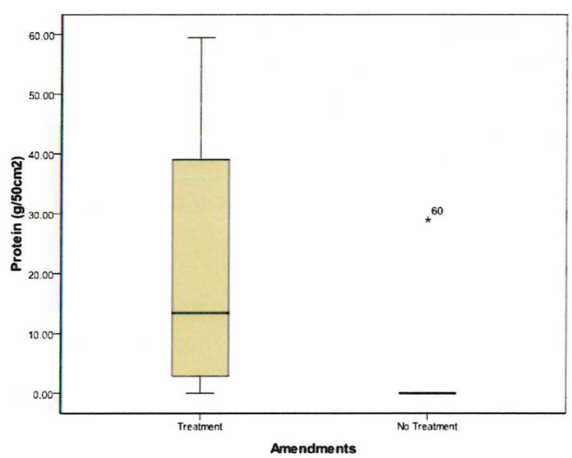


Figure 5; Average protein (g/50cm2) per amendment

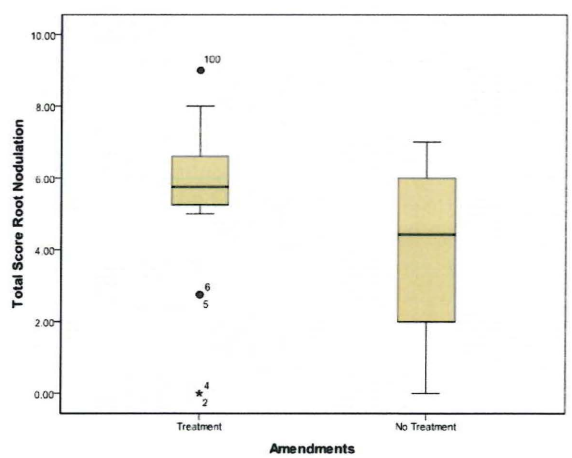


Figure 6: Average total score of root nodulation

No significant differences in performance between treatments could be detected on the Dowdell, Aurora and Lendrum farm.

1a.) Analyses between treatments (entire period): Organic matter (OM)

Dowdell farm:

Organic matter showed significant differences (p=0,021) between treatments. OM (%) was higher on treated plots than on untreated plots (Fig.7)

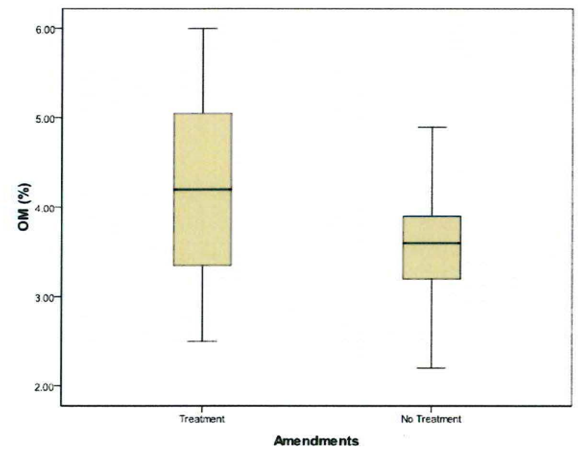


Figure 7; Mean OM (%) per amendment

Aurora farm:

Organic matter differed significantly (p=0,006) between treatments. OM (%) was higher on untreated plots than on treated plots (Fig.8)

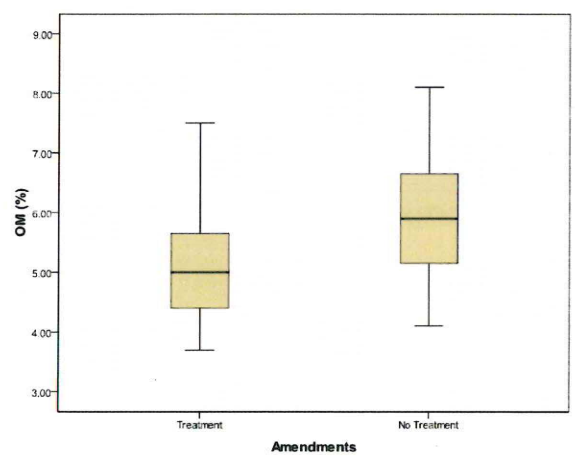


Figure 8: Average OM (%) per amendment

1a.) Analyses between treatments (single years): Plant performance

M' Clintock farm:

The analysis of the particular years has shown that *plant biomass* ($g/50cm^2$) in the years 2007 (Z=2,294,p=0,003) and 2008 (F=0,006,p=0,019) has significantly differed in between treatments. In 2007 as well as 2008 *biomass* ($g/50cm^2$) was higher in treated areas than in untreated areas (Fig.9,11). A significant difference (F=0,002, p=0,031) between the *percentage of crop area* (Visit3) per plot was established in 2007. Here again soil improvement lead to a positive result (Fig.10). The analysis for 2005 could not be conducted due to the lack of viable data. For 2006 no significant differences were noted, but it should be mentioned that only two biomass values existed. 2006 showed a tendency (F=67,993,p=0,063) for a significant difference in relation to the *percentage of crop* area per plot.

The analysis of the *root nodules* indicated that no significant differences between both treatments existed. 2006 and 2007 showed a slight tendency (F=1,384,p=0,076; F=12,49, p=0,071) for a significant difference. Here the values of the treated areas were higher which infers to a positive influence.

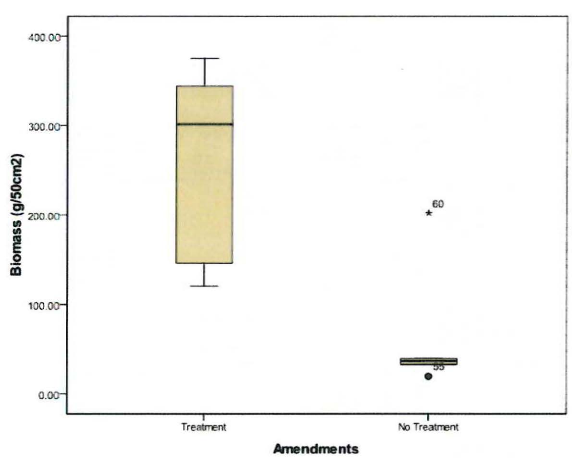


Figure 9: Biomass ($g/50cm^2$) of legumes per treatment,2007

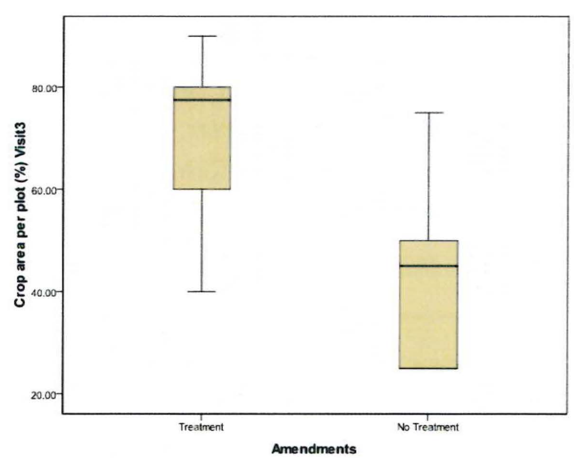


Figure 10: Crop area per plot (%) per treatment,2007

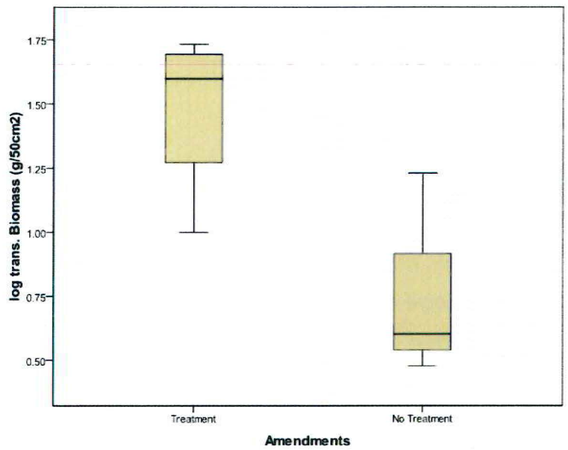


Figure 11: log transformed Biomass (g/50cm2) of legumes per treatment,2008

Dowdell farm:

For 2007 significant differences (F=1,422, p=0,007) between treatments in the *percentage of crude protein* was detected. It was higher on the treated plots than in the untreated plots (Fig.12). The analysis for the *root nodules* also showed a significant difference (F=0,p=0,004) in 2007 between the treatments. Soil treatment affected *root nodules* significantly positively (Fig.13). The rest of the years showed no significant differences in plant performance and root nodule count between treatments. The analysis for 2005 could not be conducted due to lack of data.

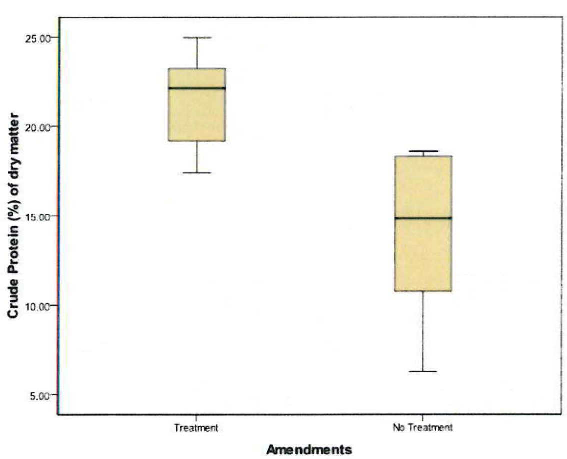


Figure 12: Crude protein (%) of dry matter per treatment,2007

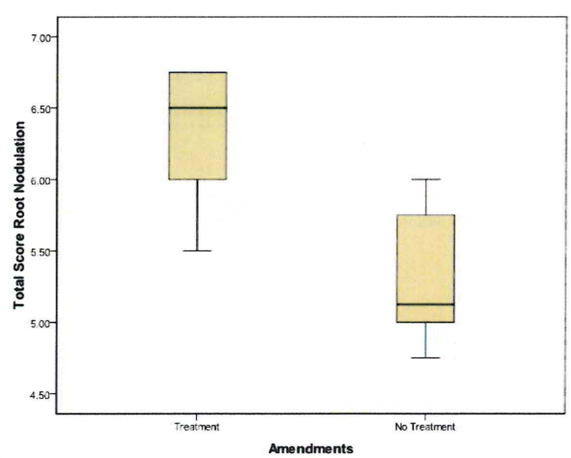


Figure 13: Total score root nodulation per treatment,2007

Aurora farm:

The annual analysis in plant performance for the Aurora farm showed no significant difference between treatments. The sample count per group (biomass ($g/50cm^2$), crude Protein (%), protein ($g/50cm^2$), dry matter (%)) was very low in 2009 (two values each) which renders a statistical analysis impossible.
Soil treatment did not affect the development of root nodules.

Lendrum farm:

The annual analysis of plant performance for the Lendrum farm did not show any significant difference between treatments. In 2006 only the values for "height" (visit 2 and 3) were included since no values for biomass (g/50cm2), crude protein (%), protein (g/50cm2) and dry matter (%) existed.

The results of the root nodule analysis have demonstrated that the development of *root nodules* for 2007 differs significantly between treatments. An improvement of the areas here though seemed to have a negative effect on the *root nodules*. Fig.14 shows clearly that there were (multiple) zero values and only one value (2) for "Treatment ". The remaining years exhibited no significant differences.

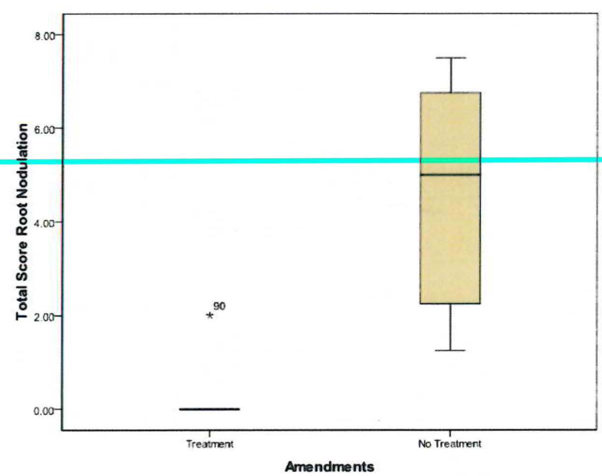


Figure 14: Total Score Root Nodulation per treatment,2007

Gillespie farm:

Since the Gillespie farm participated only two years in the project, analyses could only be conducted in 2005 and 2006. Both analyses showed no significant differences between the amendments. 2006 only included the value "height" (visit 2 and 3) and "crop area (%) per plot" (visit 2 and 3) since no values for biomass ($g/50cm^2$), crude protein (%), protein ($g/50cm^2$) and dry matter (%) existed.
Soil treatment did not affect the development of root nodules.

1a.) Analyses between treatments (single years): *Organic matter (%)*

M' Clintock farm:

The results of the annual comparison have demonstrated that no significant differences on organic matter (%) existed between treated and untreated plots.

Dowdell farm:

For the Dowdell farm two significant results could be identified. The organic matter (%) differed between untreated and treated plots in 2007 (F=0,889, p= 0,048) and 2009 (F=0,002, p<0,001). In both cases organic matter (%) was significantly higher on treated plots than on untreated plots (Fig.15,16).

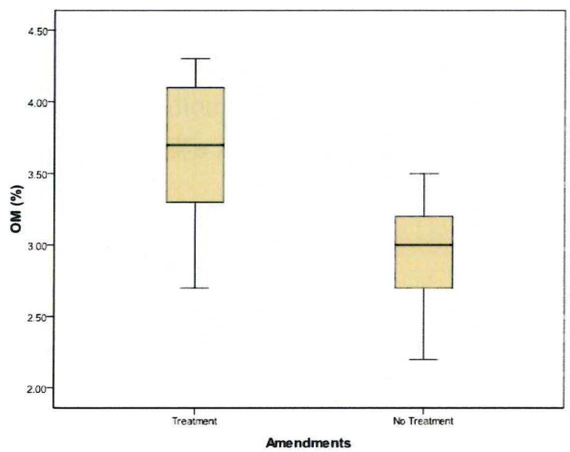


Figure 15: Average OM (%) per Treatment, 2007

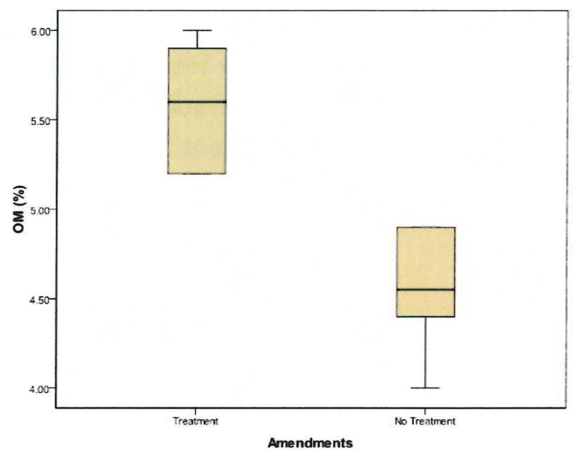


Figure 16: Average OM (%) pro Treatment, 2009

Aurora farm:

The results of the annual comparison displayed that there was no significant difference between organic matter (%) on untreated or treated blocks. A tendency (F=1.011, p=0,052) for a significant result could only be identified for 2009. In this case organic matter was higher on untreated plots than on treated plots.

Lendrum farm:

No significant differences of organic matter (%) between treated and untreated plots were found for the particular years.

1a). Analyses between treatments (2008): Microbial community

First all data was tested for normal distribution (Treatment, No Treatment) then a "T-Test" was conducted. No significant differences in microbial community (for all farms) between amendments (four samples per amendment) had been identified.
Results are described in Fig. 17-19.

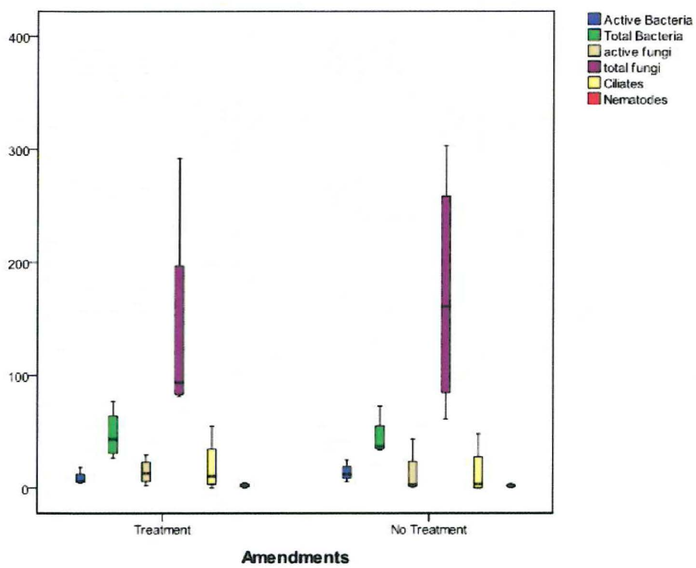


Figure 17: Average count on active and total bacteria (μg/g), active and total fungi (μg/g), ciliates (numbers/g) and nematodes (numbers/g) per treatment

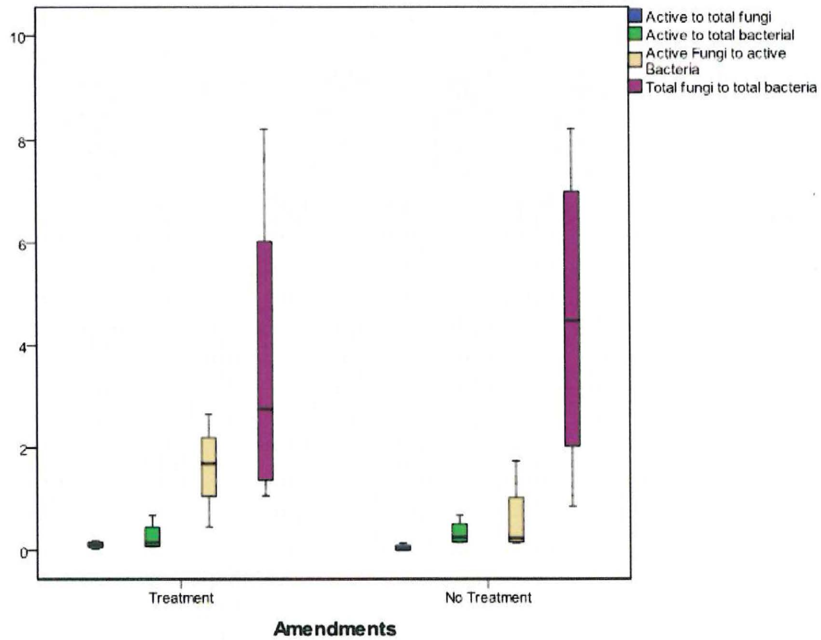


Figure 18: Average proportion (bacteria and fungi) per treatment per treatment

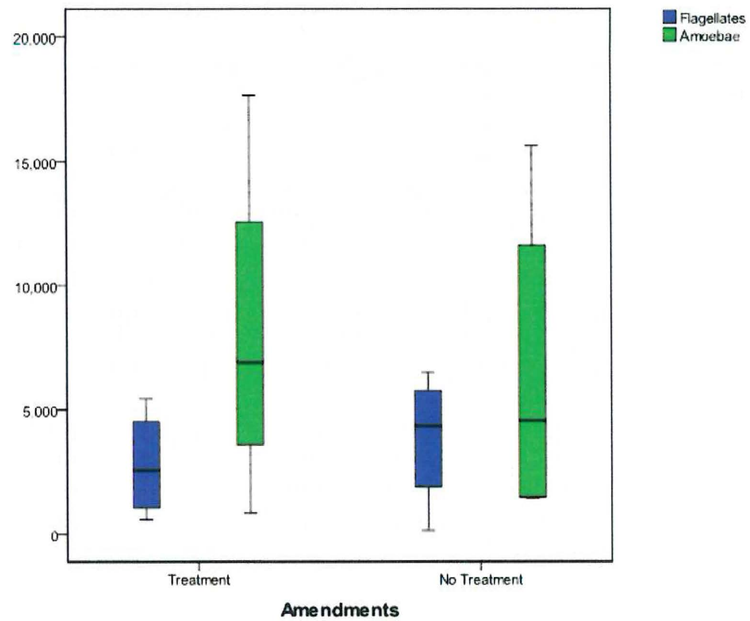


Figure 19: Average count on flagellates (numbers/g) and amoebas (numbers/g)

Discussion:

It can be ascertained for the **entire period** that soil improvement on the M' Clintock farm had a positive effect on plant performance (biomass (g/50cm^2), crude protein (%), protein (g/50cm^2) and root nodulation). The soil treatment also affected the soil OM (%) positively on Dowdell farm and negatively on Aurora farm.

The **annual analyses** for the Aurora and Gillespie farm have demonstrated that an improvement of soil conditions had no significant influence on plant performance. On the Dowdell farm three significant differences (for crude protein (%), OM and root nodules) could be detected in 2007 and one significant difference (OM (%)) in 2009 whereas on the M' Clintock farm two significant differences (biomass (g/50cm2) and crop area (%) per plot) were found in 2007 and one significant difference (biomass (g/50cm20)) in 2008. All the significant results have shown that soil condition improvement had a positive influence on legume performance. A negative development through soil improvement demonstrated the Lendrum farm. Here the development of root nodules was lower than on untreated areas.

Soil improvement didn't have an influence on microbial community.

1.b) Analyses between farms

The following data was used to analyze plant performance: biomass (g/50cm^2), crude protein (%), protein (g/50cm^2) and dry matter (g/50cm^2). Additional data on stage of growth, aerial cover, height and root nodules are available in three replicates, since they were collected three times a year.

The analyses on plant performance were partitioned in individual years (2005-2009). In the following the particular farms which plant performance significantly differed from each other are listed.

First year (2005):

No analysis due to lack of data.

Second year (2006):

a.) Performance of plants

The analyses were conducted with a Kruskal Wallis test with the data "height (visit 2 and 3)" and "crop area per plot (visit 2 and 3)" in order to compare the farms among each other. An analysis of variance (ANOVA) could not be applied because the variances were not homogeneous distributed. A T-test with biomass (g/50cm^2), crude protein (%), protein (g/50cm^2) and dry matter (%) data could also be conducted for *Dowdell* and *Aurora* farms. The remaining farms did not provide enough data for a conclusive test.

Significant results between farms for the data "height" visit 2 and 3, "crop area per plot (%)" visit 2 and 3 and root nodules are demonstrated in Fig.20-24 and are as follows:

Lendrum and Aurora farm: height (cm) visit 2 (p=0,001) and 3 (p<0,001), crop area per plot (%) visit2 (p<0,001) and 3 (p<0,001),
Lendrum and Dowdell farm: height (cm) visit 2 (p<0,001) and 3 (p<0,001), crop area per plot (%) visit 2 (p<0,001) and 3 (p<0,001), root nodule (p<0,001).
Lendrum and M' Clintock farm: height (cm) visit 2 (p<0,001) and 3 (p<0,001), crop area per plot (%) Visit 2 (p<0,001) and 3 (p<0,001), root nodule (p<0,001).
Lendrum and Gillespie farm: height (cm) visit 2 (p=0,024) and 3 (p<0,001), crop area per plot (%) visit 2 (p=0,014) and visit 3 (p<0,001),
M' Clintock and Dowdell farm: height (cm) visit 2 (p=0,001) and 3 (p<0,001), crop area per plot (%) visit2 (p<0,001) and 3 (p<0,001),
M' Clintock and Aurora farm: crop area per plot (%) visit 2 (p=0,007) and 3 (p=0,002),
M' Clintock and Gillespie farm: crop area per plot (%) visit 2 (p=0,005),
Dowdell and Aurora farm: height (cm) visit 2 (p=0,003) and 3 (p=0,002), crop area per plot (%) visit2 (p<0,001) and 3 (p<0,001),
Dowdell and Gillespie farm: height (cm) visit 2 (p=0,001) and 3 (p<0,001), crop area per plot (%) visit2 (p<0,001) and 3 (p<0,001),
Aurora and Gillespie farm: height (cm) visit 2 (p=0,001) and 3 (p=0,017), crop area per plot (%) visit 3 (p<0,001),

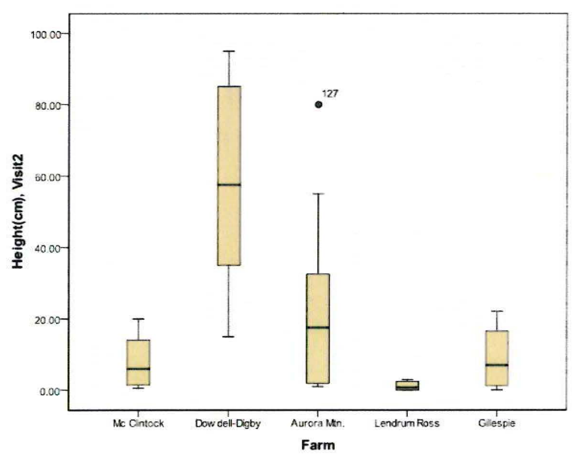


Figure 20: Average plant height (Visit 2) per farm, 2006

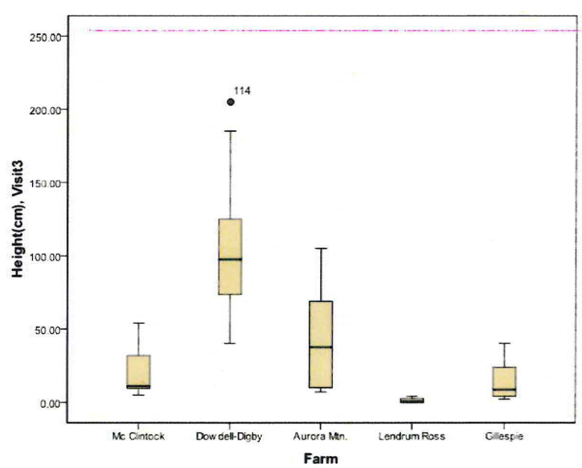


Figure 21: Average plant height (Visit 3) per farm, 2006

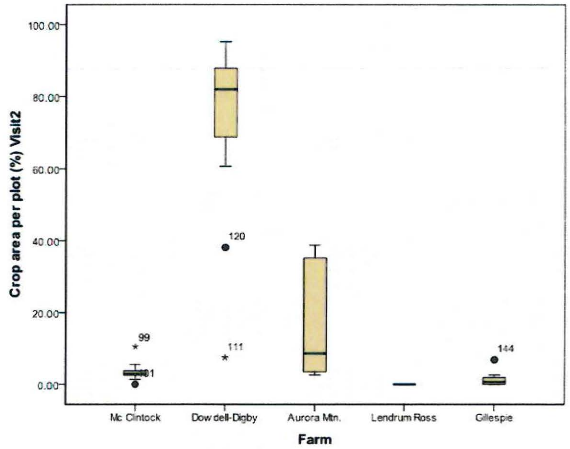


Figure 22: Average percentage of crop area (%) (Visit 2),2006

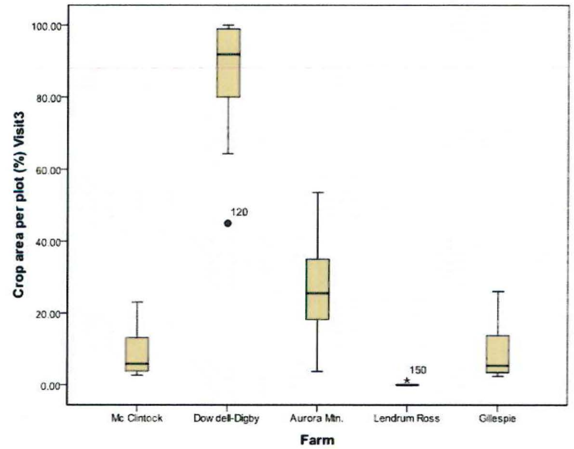


Figure 23: Average percentage of crop area (%) (Visit3),2006

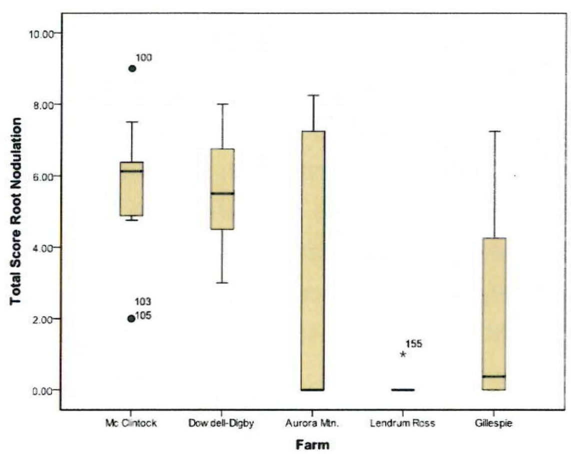


Figure 24: Average total root nodulation per farm, 2006

The "T-Test" results showed significant differences in *biomass* (g/50cm^2) and *dry matter* (g/50cm^2) for the *Dowdell* and *Aurora* farm. The Dowdell plants had higher values in biomass (g/50cm^2) and dry matter (g/50cm^2) than the Aurora plants (Fig.25,26).

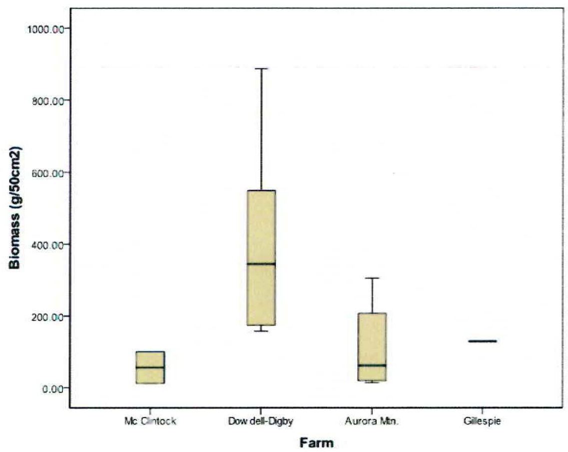


Figure 25: Average biomass (g/50cm2) per Farm (2006)

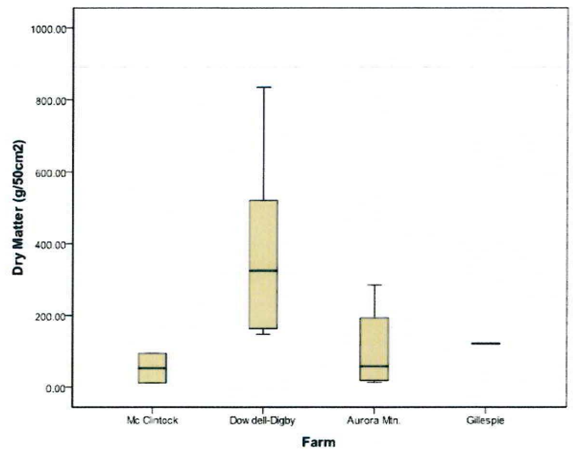


Figure 26: Average dry matter (g/50cm2) per Farm (2006)

Discussion:

The analyses have demonstrated that the *Dowdell* and *Lendrum* farm significantly distinguished themselves in "*height*" and the "*percentage of crop area per plot*" from the remaining Aurora, M'Clintock and Gillespie farms. In this regard the Dowdell farm excels as the farm with the highest averages whereas the Lendrum farm had the lowest averages of all farms (Fig.20-24). Plants on M' Clintock and Gillespie farms had about the same height (Fig.20,21). The crop area per plot (%) (Visit2 und 3) was larger on the Aurora farm than on Gillespie and M' Clintock but smaller than on the Dowdell farm.

These results indicate that the legumes developed very well on the Dowdell farm on the Lendrum farm rather not. The plant growth on the Gillespie and M' Clintock farm was considered equally positive but not as good as on the Aurora farm.

The farms distinguished themselves furthermore in root nodules from each other. Legumes on M' Clintock and Dowdell farm possessed significantly more root nodules than legumes on the Lendrum farm (Fig.24)

Third year (2007):

a.) Performance of plants

The following data was log transformed (LG10) (biomass (g/50cm^2), height (cm) Visit2, protein (g/50cm^2)) and evaluated with an analysis of variance (ANOVA) with the rest of the data (height (cm) visit 3, dry matter (g/50cm2), flower (%) visit 3 and crop area per plot (%) visit 2.

The data Crude protein (%), crop area per plot (%) visit 3, bud (%) visit 2 and 3, flower (%) visit 2, leaf (%) visit 2 and 3, green and mature seeds (%) visit 3 was treated with a non parametrical Kruskal Wallis test.

Significant results between the farms are demonstrated in Fig. 27-36 and are as follows:

M' Clintock and Dowdell: biomass (g/50cm2)(p=0,009); dry matter (g/50cm2) (p=0,037); crop area per plot (%) visit 2 (p=0,047) and 3 (p=0,003); height (cm)visit2 (p=0,010) and 3 (p=0,015); green seeds (%) visit 3 (p<0,001); leaf (%) visit 3 (p<0,001)
M' Clintock and Lendrum: crop area per plot (%) visit 3 (p<0,001), root nodules (p<0,001)
Dowdell and Lendrum: height (cm) visit 3 (p=0,045); leaf (%) visit 3 (p<0,001); height (cm) visit 2 (p=0,002); green seeds (%) visit 3 (p<0,001), root nodules (p<0,001)
Dowdell and Aurora: leaf (%) visit 3 (p<0,001); green seeds (%) visit 3 (p<0,001); protein (g/50cm2) (p<0,001);height (cm) visit 2 (p=0,019)
Lendrum and Aurora: protein (g/50cm2) (p=0,040)
Aurora and M' Clintock: protein (g/50cm2) (p=0,017)

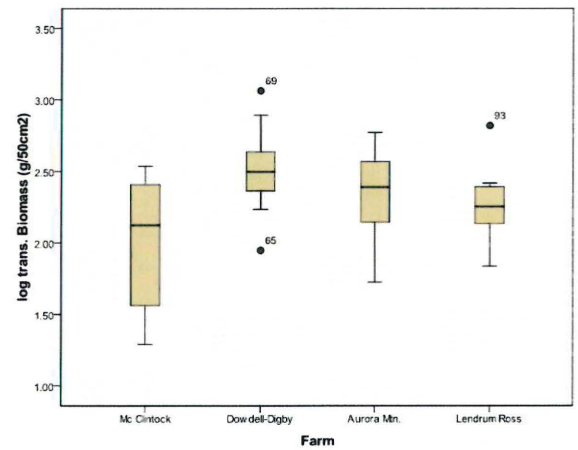


Figure 27: Average log trans. biomass (g/50cm2) per farm, 2007

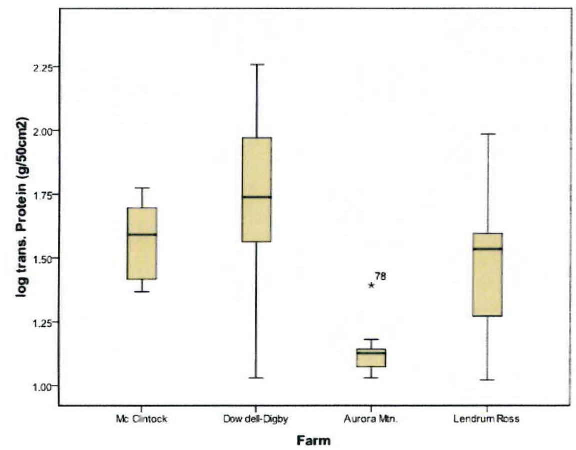


Figure 28: Average log trans. protein (g/50cm2) per farm, 2007

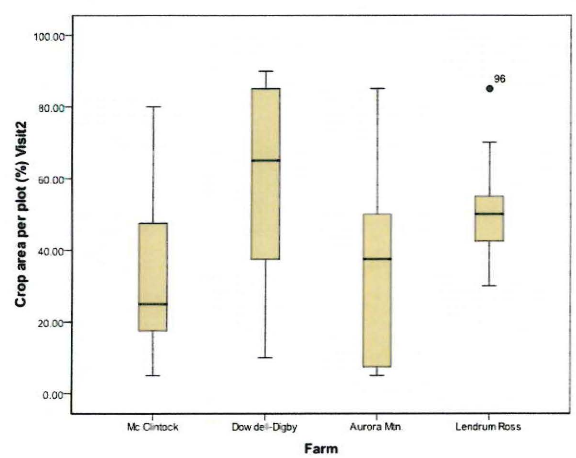


Figure 29: Average crop area (%) (Visit2) per farm,2007

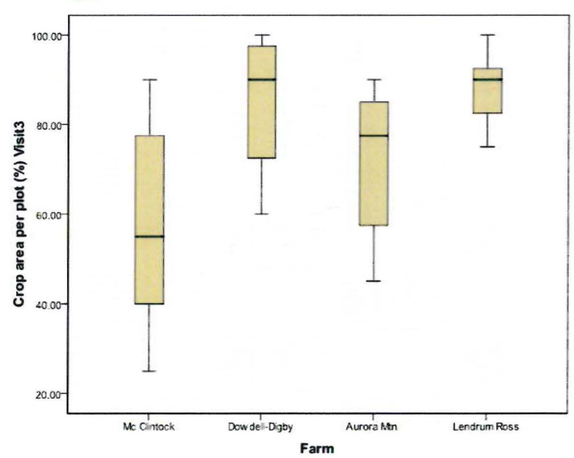


Figure 30: Average crop area (%)(Visit3) per farm,2007

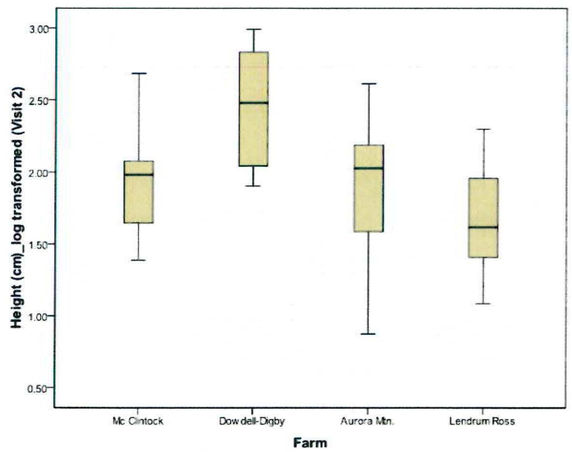


Figure 31: Average log trans. plant height (cm) per farm, 2007

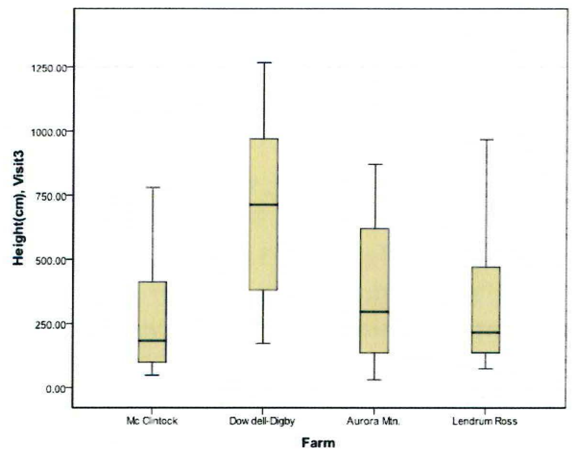


Figure 32: Average plant height (cm) per farm, 2007

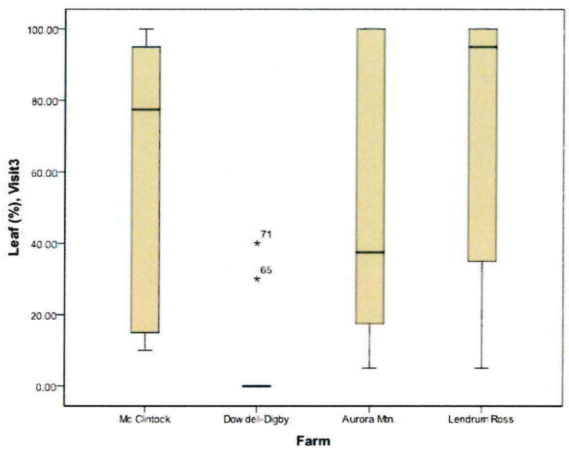


Figure 33: Average percentual leaf part per farm, 2007

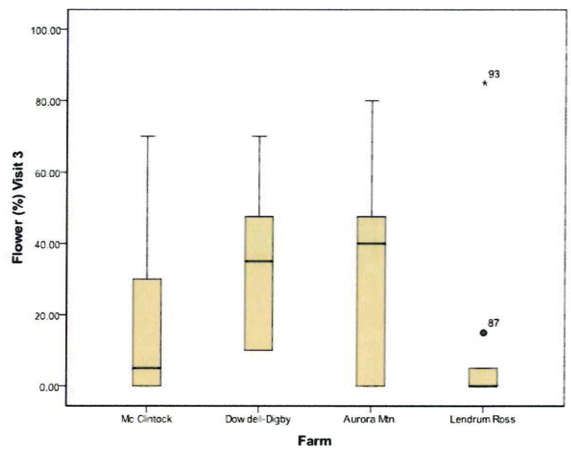


Figure 34: Average percentual flower part per farm, 2007

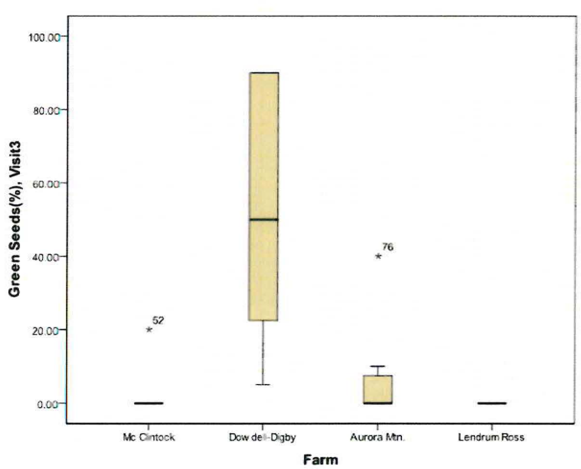


Figure 35: Average green seed part (%) per farm,2007

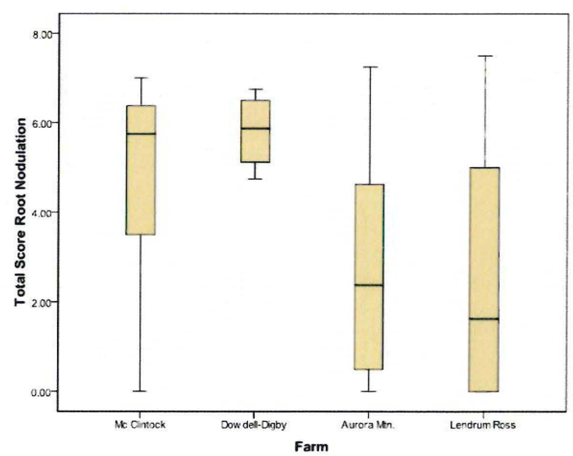


Figure 36: Average total root nodulation per farm, 2007

b.) Organic matter (OM):

As demonstrated in Fig.37 the M' Clintock farm differs extremely in OM (%) from all the other farms. The OM (%) is here significantly lower than on the Dowdell ($F=4{,}725, p<0{,}001$), Lendrum ($F=10{,}920, p<0{,}001$) and Aurora ($F=8{,}797, p<0{,}001$) farms. Dowdell also distinguished itself from Aurora ($F=5{,}905$, $p<0{,}001$) and Lendrum ($F=3{,}825, p<0{,}001$) farm. The soil on these farms showed higher OM (%) than soil on the Dowdell farm (Fig.37)

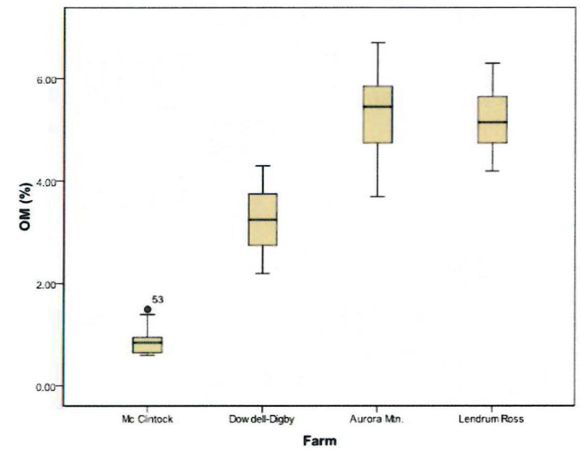


Figure 37: Average OM (%) per farm

Discussion:

The results show clearly that most of the significant differences existed between the Dowdell and the M' Clintock, Lendrum and Aurora farms. Plants on the Dowdell farm exhibited higher biomass ($g/50cm^2$) values (Fig.27) in comparison to M' Clintock farm and they were also larger on the 2nd and 3rd visit Fig. (31,32). Even in comparison to the Lendrum and Aurora farms, Dowdell plants were significantly larger (Fig.31).

The analysis of the plant protein content (g/50cm2) proofed that legumes on Aurora farm possessed significantly less protein (g/50cm2) than plants on Lendrum, M' Clintock and Dowdell (Fig.28).

The results and graphic demonstration of the "crop area per plot (%)" (Fig.29,30) reveal that plants developed much better on Dowdell and Lendrum farms than plants on the M' Clintock farm.

It is quite peculiar that the "Leaf (%)" part of legumes on the M' Clintock, Aurora and Lendrum farm was significantly higher than on the Dowdell farm. This indicates that M' Clintock and Lendrum showed the highest percentage (Fig.33). A subsequently consideration of the green seed percentage (Fig.35) demonstrated clearly that Dowdell plants produced significantly more green seeds than plants on any other farms. This concludes to the fact that plants who grew on these farms invested less into production. A cause for this could be lack of nutrients due to poor soil conditions, bad climatic conditions or other disturbances such as damage through feeding animals.

Legumes on M' Clintock farm were able to produce more root nodules than legumes on Aurora and M' Clintock farm (Fig.36).

Soil on Lendrum and Aurora farm showed significantly more OM (%) than Dowdell and M' Clintock farms (Fig.37). In comparison to M' Clintock, Dowdell demonstrated significantly more OM (%).

Fourth year (2008):

a.) Performance of Plants

The data biomass (g/50cm2), protein (g/50cm2), crude protein (%) und dry matter (g/50cm2) were log transformed for the analyses so that homogeneous variances could be produced in order to apply an analysis of variance (ANOVA).

Significant results between the farms are demonstrated in Fig. 38-48 as follows:

M' Clintock and Dowdell: biomass (g/50cm2) (p=0,002), protein (g/50cm2) (p=0,029), crop area per plot (%) visit 2 (p<0,001) and 3 (p<0,001); height (cm) visit 2 (p=0,028) and 3 (p=0,001), leaf (%) visit 3 (p=0,001), flower (%) visit 3 (p=0,004), green seeds (%) visit 3 (p=0,012)
M' Clintock and Aurora: biomass (g/50cm2) (p=0,013)
M' Clintock and Lendrum: biomass (g/50cm2) (p<0,001), protein (g/50cm2)(p<0,001), dry matter (p=0,003), leaf (%) visit 2 (p<0,001) and 3 (p<0,001), height (cm) visit 2 (pp=0,001) and 3 (p=0,010), green seeds visit 3 (p=0,033)
Dowdell and Lendrum: protein (g/50cm2) (p=0,001)
Aurora and Lendrum: protein (g/50cm2) (p=0,004), leaf (%) visit 2 (p=0,003) and 3 (p<0,001), height (cm) visit 2 (p=0,003) and 3 (p=0,001), flower (%) visit 3 (p=0,028), root nodule. (p=0,015)
Dowdell and Aurora: crop area per plot (%) visit 3 (p<0,001), height (cm) visit 2 (p=0,024) and 3 (p<0,001), flower (%) visit 3 (p<0,001), green seed (%) visit 3 (p=0,005), Tendency for crop area per plot (%) visit 2 (p=0,052), leaf (%) visit 3 (p=0,060) and root nodule. (p=0,026)

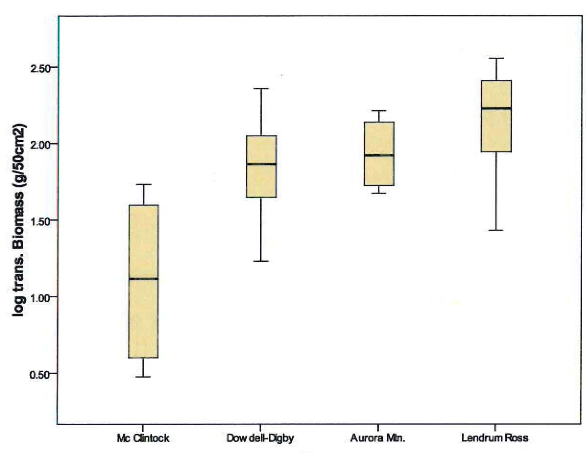


Figure 38: Average log trans. biomass per farm, 2008

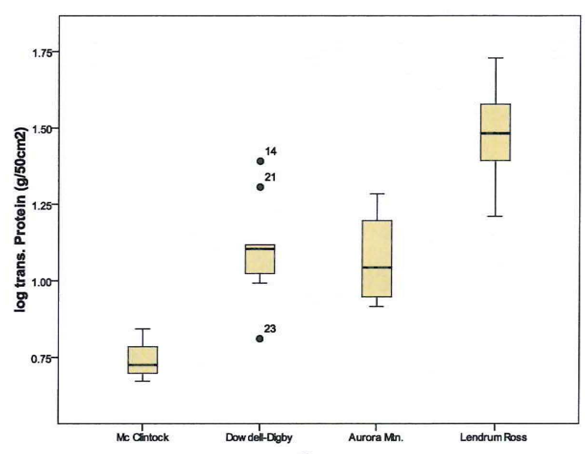


Figure 39: Average log trans. protein per farm, 2008

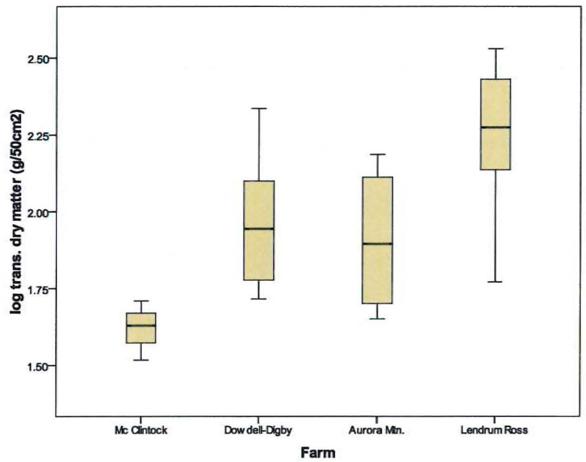


Figure 40: Average log trans. dry matter (g/50cm2) per farm,2008

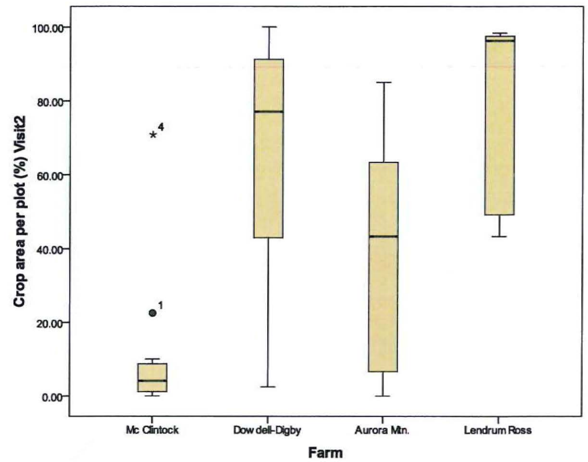


Figure 41: Average legume part (Visit2) per farm 2008

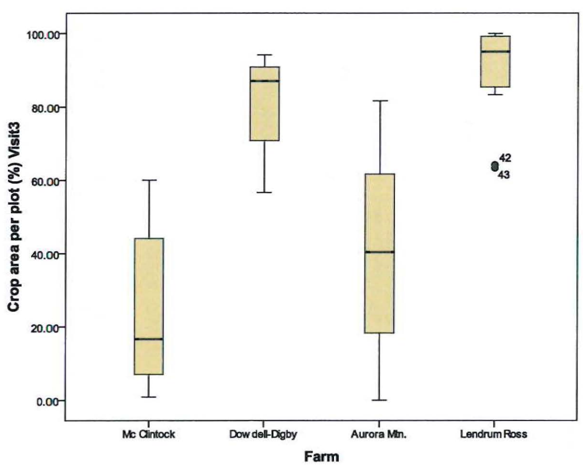


Figure 42: Average crop area (%) (Visit 3) per farm, 2008

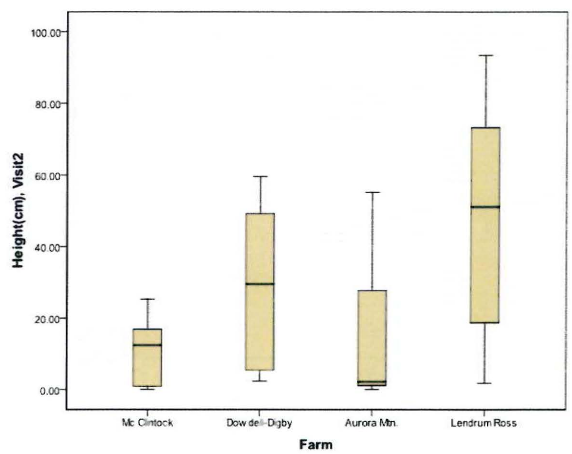


Figure 43: Average plant height (Visit2) per farm, 2008

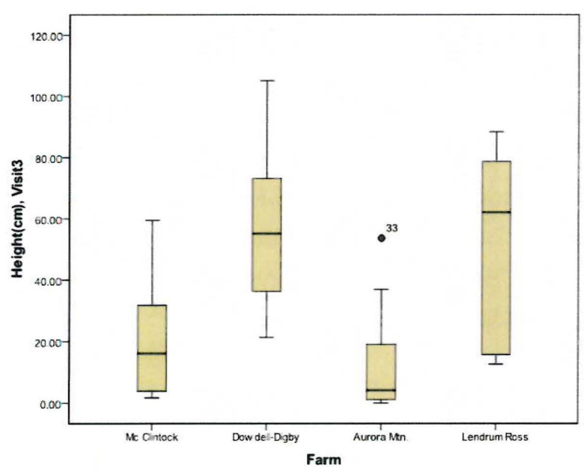


Figure 44: Average plant height (cm) per farm (2008)

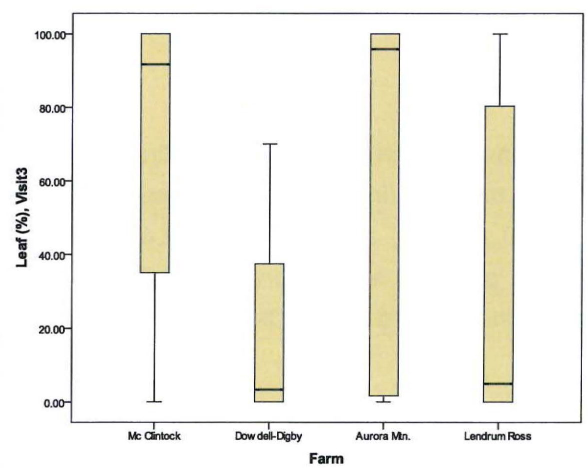


Figure 45: Average leaf part (%) per farm, 2008

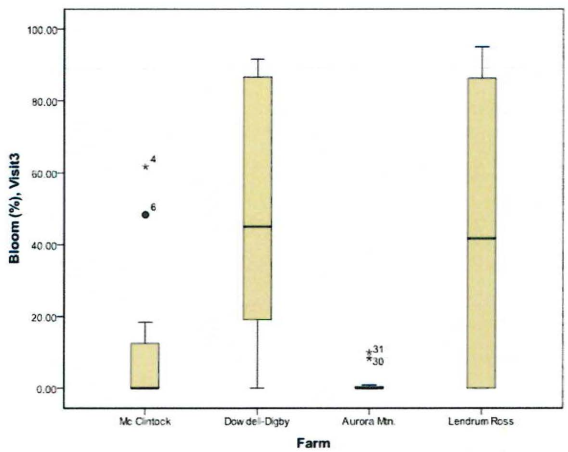


Figure 46: Average flower part (%) per farm, 2008

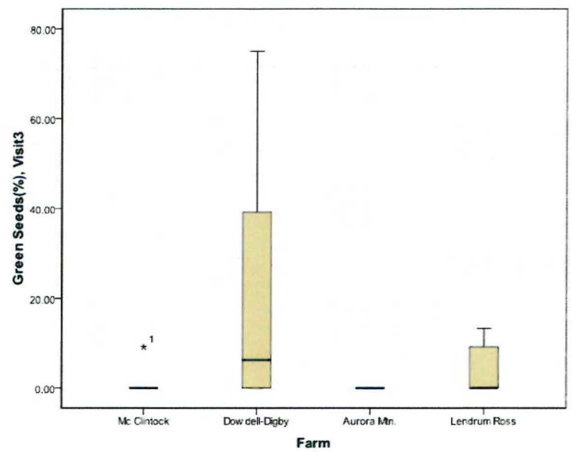


Figure 47: Average green seed part (%) per farm, 2008

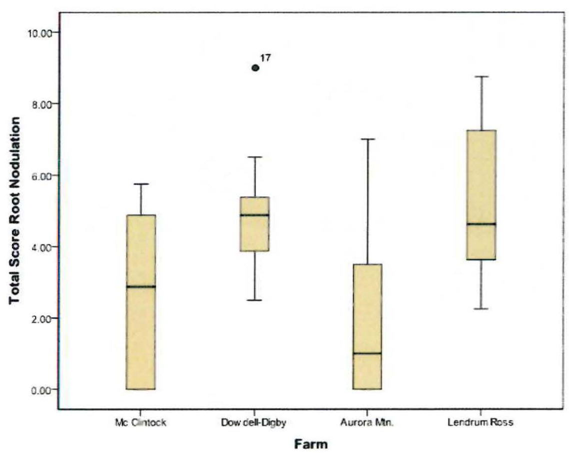


Figure 48: Average root nodulation count per farm, 2008

b.) Organic matter

As demonstrated in Fig.49 the M' Clintock farm differs clearly in OM (%) from all the other farms. OM (%) on M' Clintock farm is significantly lower than on Dowdell (F=2,348,p<0,001), Lendrum (F=10,920,p<0,001) and Aurora (F=12,463,p<0,001) farms. Dowdell also sets itself apart from Aurora (F=5,905, p<0,001) and Lendrum (F=3,825,p<0,001) farms. The particular soil on Aurora and Lendrum farms demonstrated higher OM (%) than soil on the Dowdell farm (Fig.49).

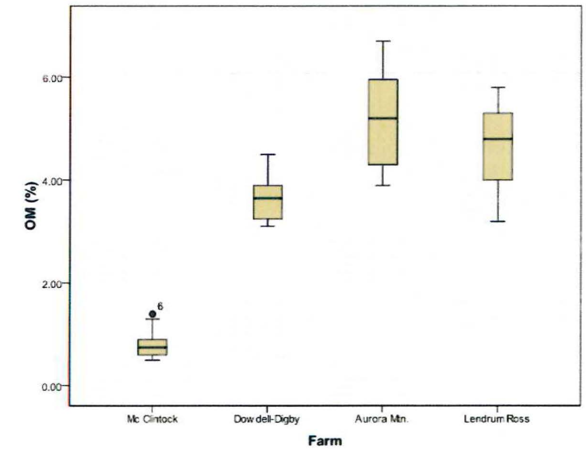


Figure 49: Average OM (%) per farm

c.) Microbial community

There were no significant differences in microbial community between the farms. Fig.50-54 are displayed to indicate tendencies.

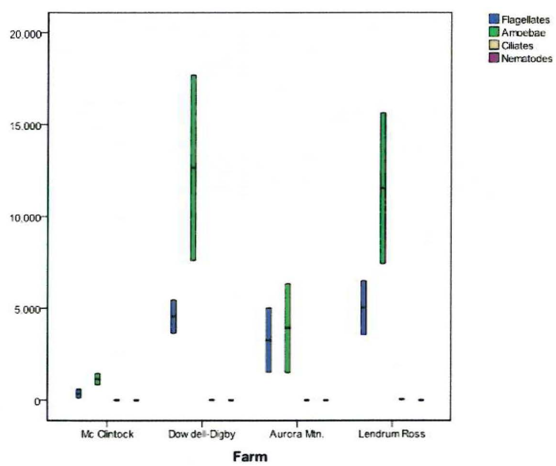


Figure 50: Average count of flagellates (number/g), amoebas (number/g),ciliates (numbers/g) and nematodes (numbers/g)per farm

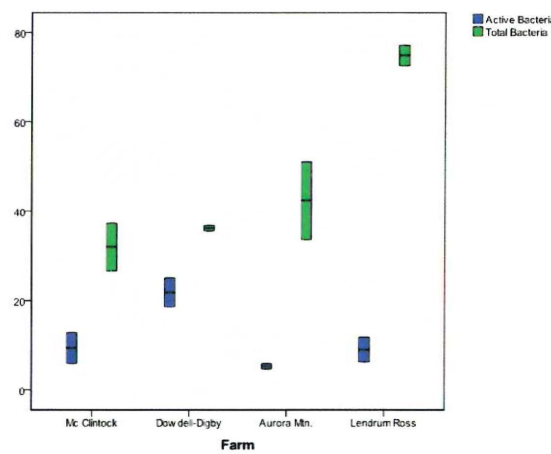


Figure 51: Average count of active und total bacteria (µg/g) per per farm

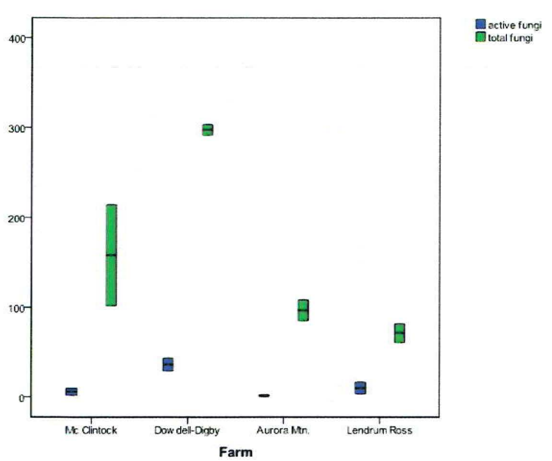


Figure 52: Average count of active und total fungal (µg/g) per farm

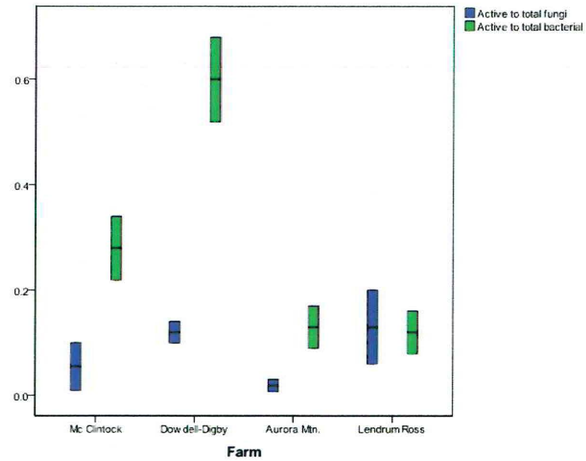


Figure 53: Average proportions of act. to tot. Fungal and act. to tot. bacteria per farm

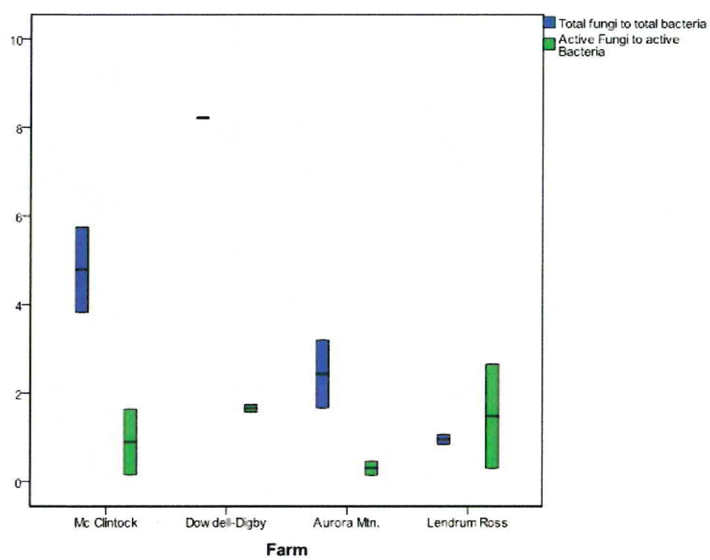


Figure 54: Average proportions of tot. Fungal to tot. bacteria and act. Fungal to act. bacteria per farm

Discussion:

The results show clearly that the Lendrum and Dowdell farms are significantly different in relation to plant performance compared to M' Clintock and Aurora farms. Plants on Lendrum and Dowdell farms were larger (Fig.43,44) than plants on both other farms and possessed a higher percentual crop area per plot (Fig.41,42). The Dowdell and Lendrum farm differ among each other only in protein content. In general plants seem to have developed better on Dowdell and Lendrum farms than on Aurora and M' Clintock farms. Clearly the M' Clintock farm exhibits the lowest values for biomass (g/50cm^2), dry matter (g/50cm^2), protein (g/50cm^2) content and percentual crop area (Fig38-42). But M' Clintock possesses significantly higher values in percentual leaf parts than Dowdell and Lendrum farm as does Aurora farm (Fig.45) and shows a tendency to a significant difference in percentual leaf parts to the Dowdell farm. Considering the flower (%) (Fig.46) and green seeds values (Fig.47) it becomes quite clear, that plants on Dowdell and Lendrum farms have developed more buds and seeds than both other farms. Dowdell and Lendrum plants seem to have invested more into production (buds and seeds) than M' Clintock and Aurora farms.

Legumes on Lendrum and Dowdell farms formed significantly more root nodules than legumes on Aurora farm (Fig.48)

Soil on Lendrum and Aurora farms showed significantly more OM (%) than on Dowdell and M' Clintock farms (Fig.49). Dowdell farm displayed significantly more OM (%) in comparison to M' Clintock.

It substantiated the fact that the microbial community did not demonstrate to be significantly different between the farms. It should be mentioned though that the data consisted only of two samples per farm therefore the result cannot be regarded as meaningful.

Fifth year (2009):

a.) Performance of Plants

The analyses with the data for biomass (g/50cm^2), crude protein (%), protein (g/50cm^2), dry matter (g/50cm^2) were conducted with a T-Test only for the Dowdell, Aurora and Lendrum farm because no data was available from the M' Clintock farm.
The rest of the data was applied to a "Kruskal Wallis Test" and subsequently to a "Mann Whitney Test", to show which farms differ significantly from each other.

The results demonstrated no significant differences in biomass (g/50cm^2), crude protein (%), protein (g/50cm^2), dry matter (g/50cm^2) and crop area per plot (%).The "Kruskal Wallis" results have indicated that differences in leaf (%) visit 2 and 3, flower (%) visit 2 and 3, crop area per plot (%) visit 1 and 2, height (cm) visit 1 and 2 and bud (%) visit 2 existed.

Significant results between farms are demonstrated in Fig. 55-65 and are as follows:

M' Clintock and Dowdell: leaf (%) visit 2 (p=0,012) and 3 (p=0,013), crop area per plot (%) visit 1 (p=0,009) and 2, bud (%) visit2 (p=0,028), height (cm) visit 1 (p=0,011) and 2 (p<0,001)
M' Clintock and Aurora: height (cm) visit 2 (p=0,042)
M' Clintock and Lendrum: leaf (%) visit 2 (p=0,010) and 3 (p=0,001), crop area per plot (%) visit 2 (p=0,010) and 1 (p=0,007), bud (%) visit 2 (p=0,014), height (%) visit 2 (p=0,002) and 1 (p=0,009
Dowdell and Lendrum: No significant differences
Dowdell and Aurora: flower (%) (p=0,022)
Aurora and Lendrum: crop area per plot (%) visit 1 (p=0,035) and height (cm) visit 1(p=0,029)

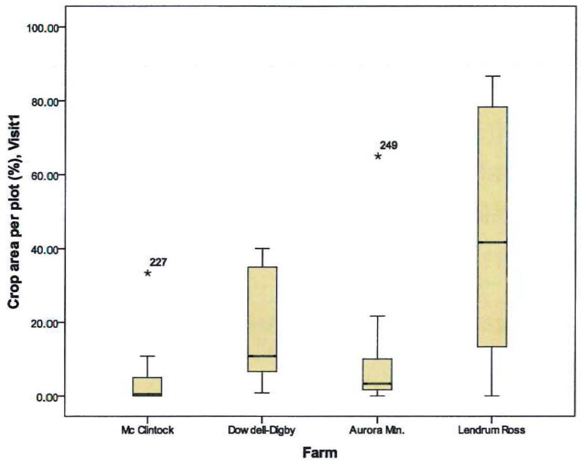


Figure 55: Average crop area part (%) per farm (2009)

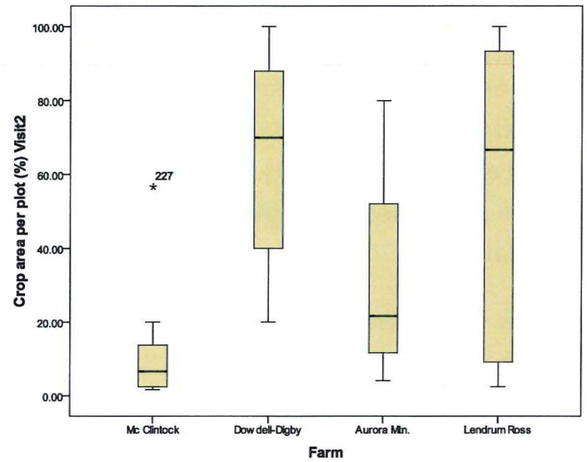


Figure 56: Average crop area part (%) per farm (2009)

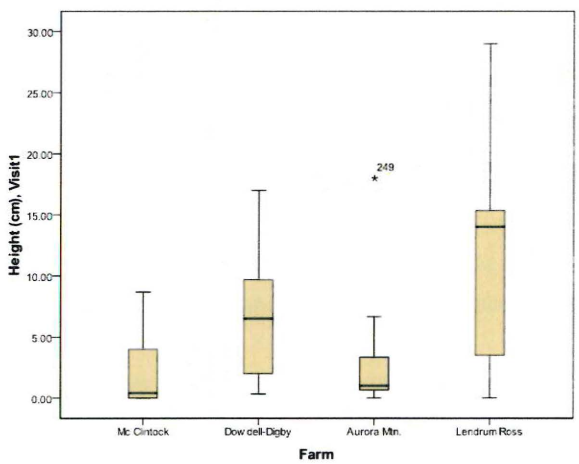


Figure 57: Average plant height (cm) per farm (2009)

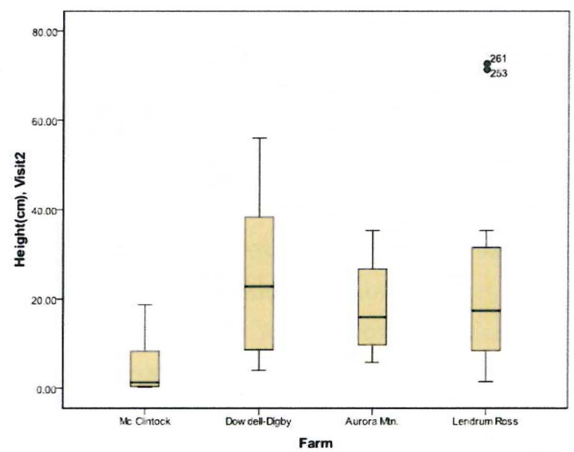


Figure 58: Average plant height (cm) per farm (2009)

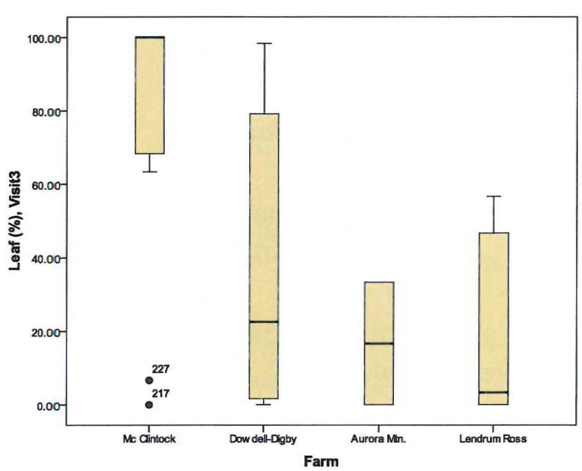


Figure 59: Average leaf part (%) per farm (2009)

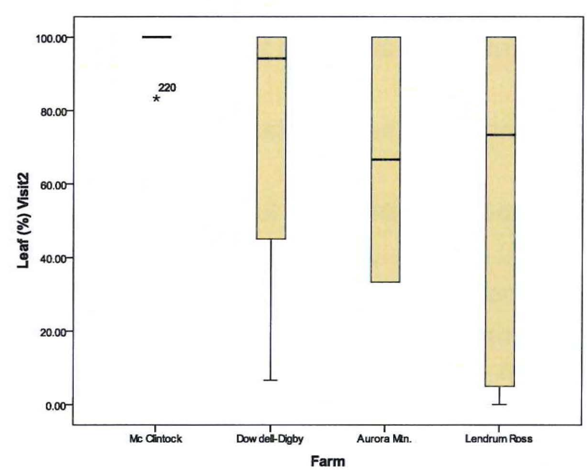


Figure 60: Average leaf part (%) per farm (2009)

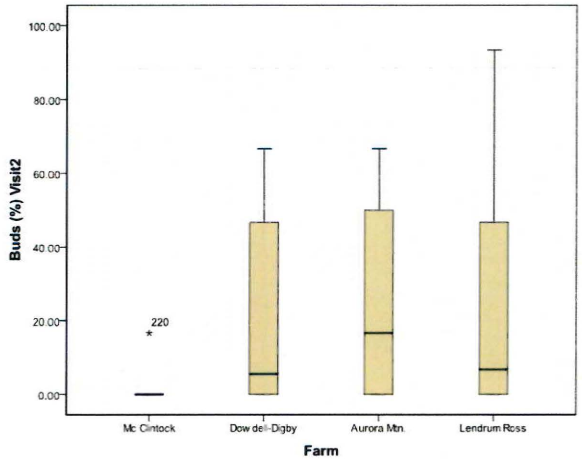


Figure 61: Average buds part (%) per farm (2009)

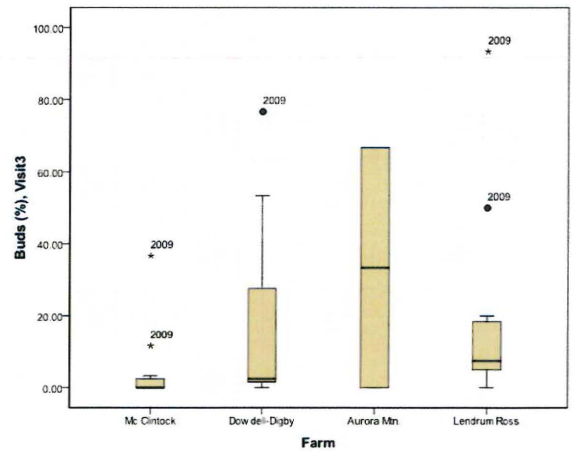


Figure 62: Average buds part (%) per farm (2009)

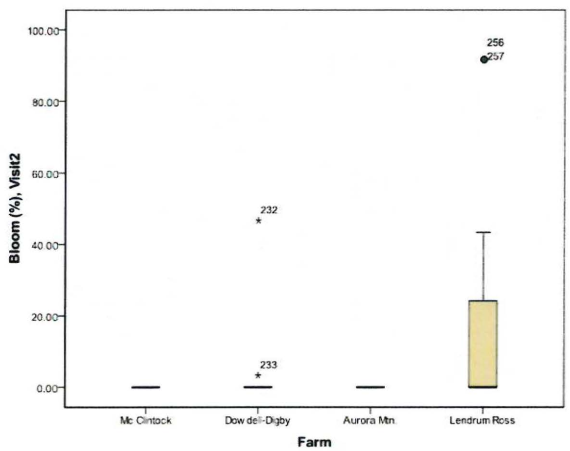


Figure 63: Average flower part (%) per farm 2009

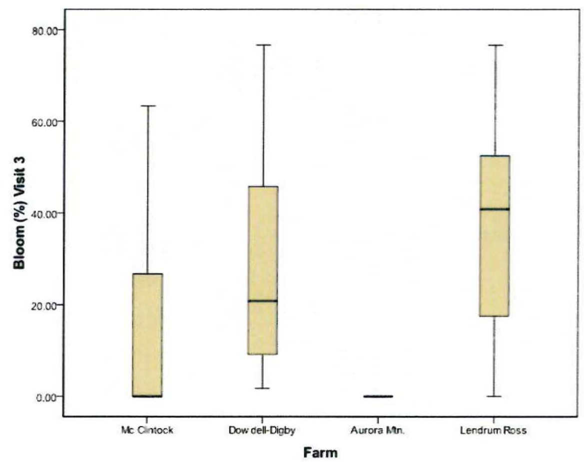


Figure 64: Average flower part (%) per Farm 2009

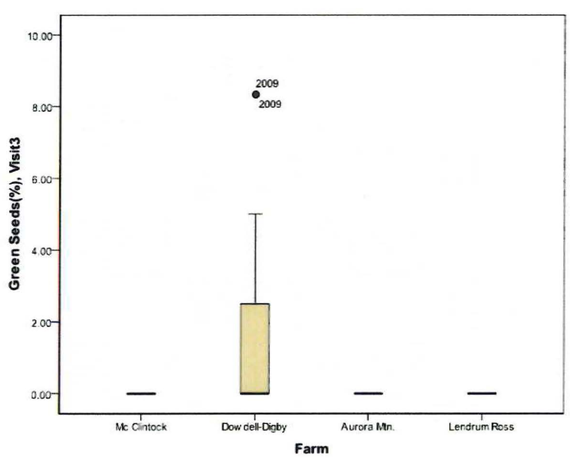


Figure 65: Average green seed part (%) per farm (2009)

b.) Organic matter

The M' Clintock farm distinguished itself significantly ($p<0,001$) in OM (%) from all other farms. OM (%) is here lower than on Dowdell, Lendrum and Aurora farms (Fig.66). The Dowdell farm furthermore differs significantly from Aurora ($p=0,008$) and Lendrum ($p<0,001$) farms.

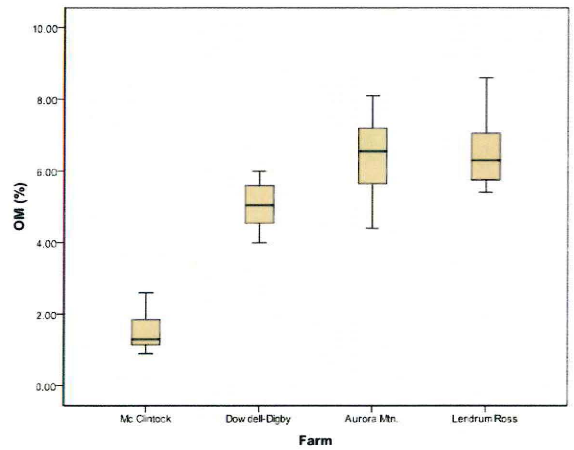


Figure 66: Average OM (%) per farm

Discussion:

The results showed clearly that Lendrum and Dowdell farms are significantly different in relation to plant performance from the M' Clintock farm. There was no significant difference among each other though (Dowdell and Lendrum). Plants seemed to have developed better on Dowdell and Lendrum farms than on the M' Clintock farm. Also M' Clintock displayed the lowest values of all farms in crop area per plot (%) visit 1 (Fig.55) and 2 (Fig.56), height visit 2 (Fig.58), bud visit 2 (Fig.61) and the highest value in percentual leaf part (Fig.59,60).

Considering the percentual bud part (Fig.62) and the flower part (Fig.64) it clearly demonstrated that the plants on the M' Clintock and Lendrum farm developed buds but no seeds (Fig.65). Aurora farm plants on the other hand developed buds which did not bloom and accordingly did not develop seeds either. The only plants which were able to develop seeds were found on the Dowdell farm (Fig. 65).

The nodule count did not show any significant difference between farms.

Soil on Lendrum and Aurora farms possessed significantly more OM (%) than on Dowdell and M' Clintock farms (Fig.66). Also significantly more OM (%) was detected on the Dowdell farm compared to M' Clintock farm.

1c.) Analyses between species (entire period): Performance of plants

M' Clintock farm:

The data biomass (g/50cm^2), crude protein (%) and protein (g/50cm^2) was evaluated with the analysis of variance (ANOVA) and the data height (cm) visit 1, 2 and 3, mature seeds (%) visit1, 2 and 3, green Seeds (%) visit 1,2 and 3, height (cm) visit 1,2 and 3, green (%) visit 1,2 and 3, buds (%) visit 1,2and 3, bloom (%) visit 1,2 and 3 with a non parametrical Kruskal Wallis test. No significant differences could be seen between the species.

Dowdell farm:

Data was evaluated with a non parametrical Kruskal Wallis test. It clearly demonstrated that a tendency to a significant difference in *biomass* (g/50cm^2) content (χ^2=10,694, p= 0,058) and *protein* (g/50cm^2) content (χ^2=10,279, p=0,068) existed between species. Therefore the data was once again researched into using a "Mann Whitney Test" (non parametrical).

It clearly showed that Alfalfa and White clover significantly distinguish themselves from each other in *protein* content (Z=-2,739, p=0,005) and *biomass* (-3,046, p=0,001). Red clover also differed significantly from White clover in *biomass* (Z=-2,205, p=0,028) and *protein* content (Z=-2,212, p=0,028). Alfalfa and Red clover exhibited higher values in *biomass* (g/50cm^2) than White clover (Fig.67). Significant differences were also detected in biomass (Z=-2,205, p=0,028) of Alsike and White clover and in *protein* content (Z=-2,317, p=0,021) of Field peas and White clover. White clover had the lowest values in biomass (g/50cm^2) and protein (g/50cm^2) content (Fig.67,68).
White clover plants were significant smaller (Height Visit3) than Alfalfa (Z=-2,102, p=0,038), Field peas (Z=-2,102, p=0,038) and Sweet peas (Z=-2,207, p=0,028) (Fig.69). Sweet clover plants had significant more buds than White clover (F-2,812, p=0,002), Alfalfa (Z=-2,903, p=0,002), Red Clover (Z=-2,817, p=0,002), Alsike (Z=-2,903,p=0,002) and Field peas (F=-2,085, p=0,041) (Fig.70).

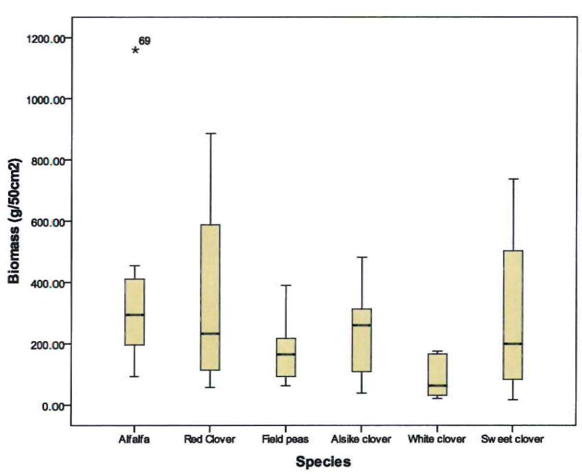


Figure 67: Average biomass (g/50cm2) per species

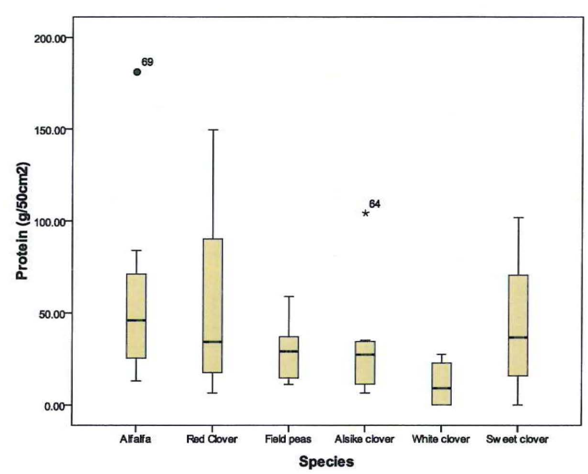


Figure 68: Average protein (g/50cm2) per species

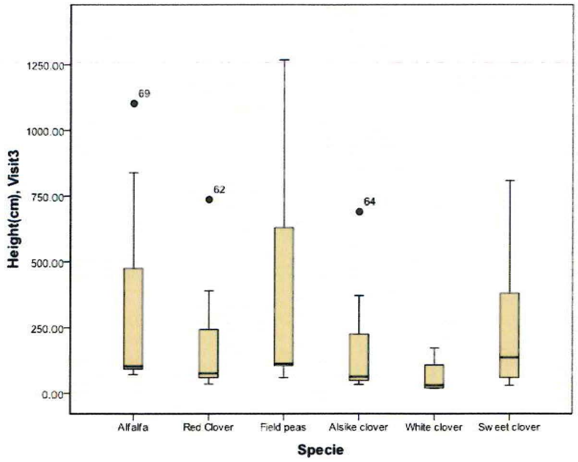


Figure 69: Average plant height (cm) per species

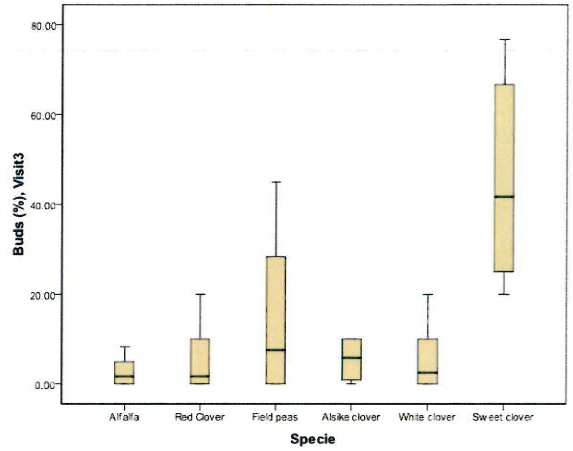


Figure 70: Average bud part (%) per species

Aurora farm:

Data was evaluated with a non parametrical Test ("Kruskal Wallis"). It indicated that the species differed significantly in their *protein* content (g/50cm^2) among each other. Plants of the species Sweet clover possess significantly more *protein* (g/50cm^2) than the species Red clover (Z=-2,567,p=0,009) und Field peas (Z=-2,379, p=0,017) (Fig.71). There is also a tendency for a significant difference in protein content (g/50cm^2) between White clover (p=0,071) and Alsike (p=0,052) visible.

The root nodule analysis data showed that Alfalfa possessed significantly more *nodules* than Red clover (F=-3,188, p<0,001), Field peas (F=-2,567, p< 0,001), White Clover (Z=-3,289, p<0,001) und Alsike (F=-2,381,p<0,018). Sweet clover had significantly more nodules than Red clover (F=-3,008,p<0,001), Field peas (F=-3,090,p<0,001), Alsike (F=-2,176,p<0,035) and White clover (F=-3,160, p=0,007). The results of the root nodules count are displayed in Fig.72.

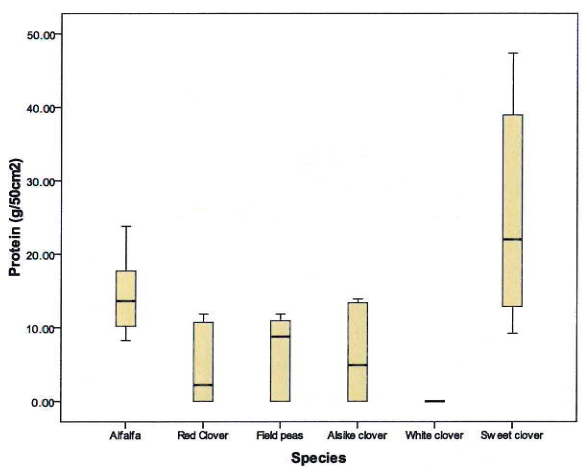


Figure 71: Average protein content (g/50cm2) per species

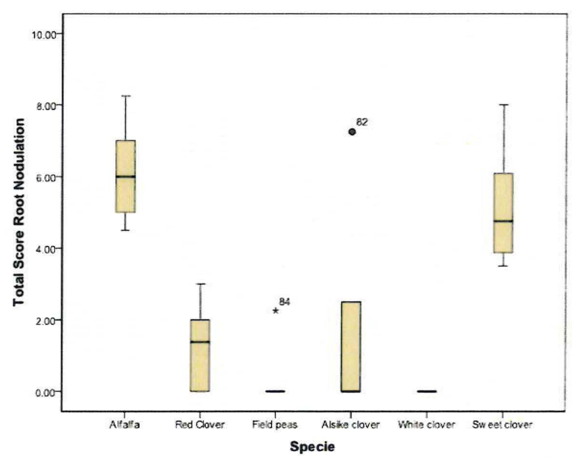


Figure 72: Average root nod. count per species

Lendrum:

Data was evaluated with a non Kruskal Wallis parametrical test. Significant results were further analyzed using a "Mann Whitney Test".

Significant differences in *biomass (g/50cm²) and dry matter* (g/50cm²) between the species Alfalfa and White clover (p=0,009) Alfalfa and Alsike (p=0,002), Alfalfa and Field peas (p=0,002) were detected. Alfalfa possessed the highest biomass (g/50cm²) and dry matter *(g/50cm²)* values and White clover the lowest (Fig.73,74)

Additional significant differences were found between species in the *protein content (g/50cm²)*. The species Alfalfa and White Clover (p=0,009), Alfalfa and Alsike (p=0,002), Alfalfa and Field peas (p=0,004) differed significantly from each other. Alfalfa plants showed the highest whereas White clover the lowest values in protein content *(g/50cm²) (Fig.75)*. Significant differences between Sweet clover und Red clover (p=0,002), Sweet peas and Field peas (p=0,002), Sweet clover and Alsike (p=0,002), Sweet clover and White (p=0,002), Alsike and Alfalfa (p=0,026) could also be found among the percentual *bud* part (Visit3). Sweet clover possessed the highest bud count (Fig.76).

There were significant differences in the *flower* part (Visit 3), between Alfalfa and Sweet clover (p=0,015) and Alfalfa und White clover (p=0,041). More Alfalfa plants bloomed than any other plant species (Fig.77).

The percentual *leaf* part (Visit3) between Field peas and Sweet clover (p=0,002), White and Sweet clover (p=0,001), White and Alfalfa (p=0,002), Alfalfa and Field peas (p=0,008), Alfalfa und Sweet clover (p=0,002) was significantly different. The percentual leaf part of the Field peas and White clover was larger than among all other species (Fig.78).

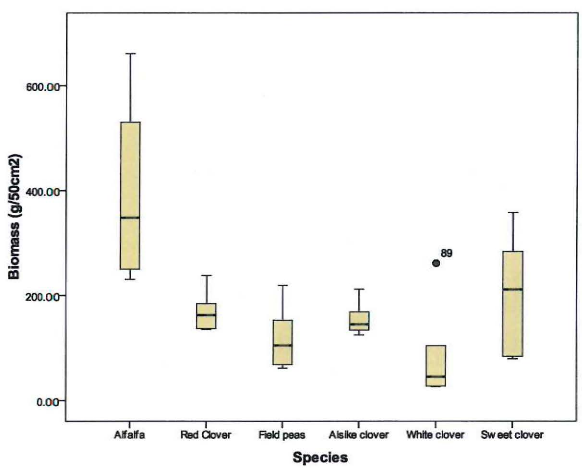


Figure 73: Average Biomass (g/50cm²) per species

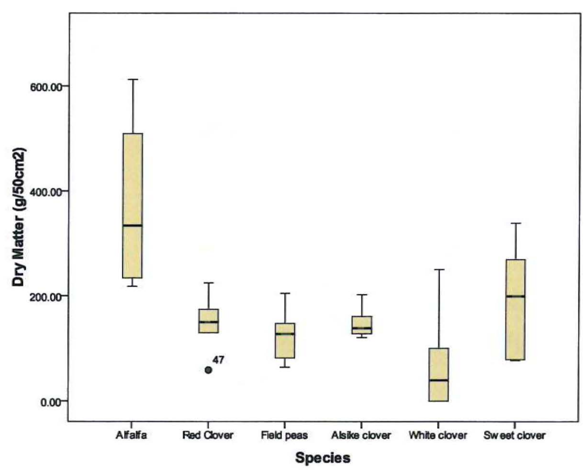


Figure 74: Average dry matter (g/50cm²)

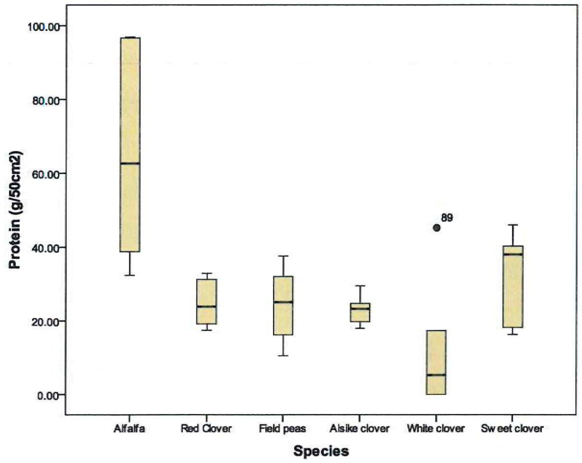


Figure 75: Average protein content (g/50cm2) per species

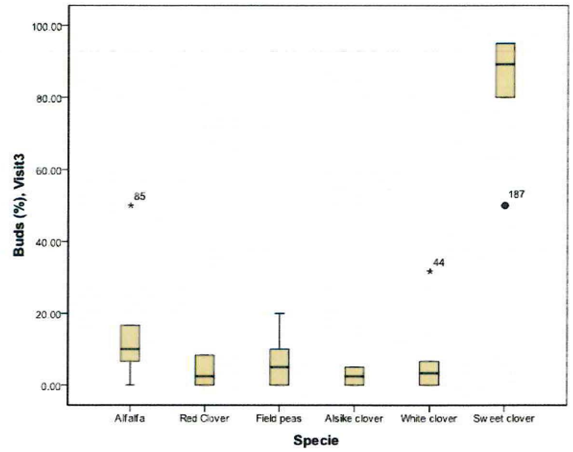


Figure 76: Average bud part (%) per species

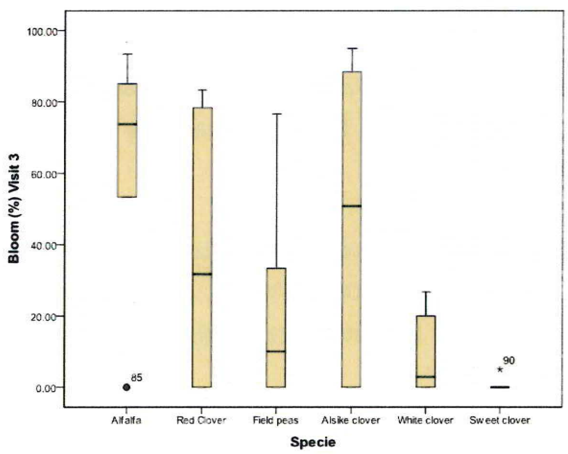


Figure 77: Average flower part (%) per species

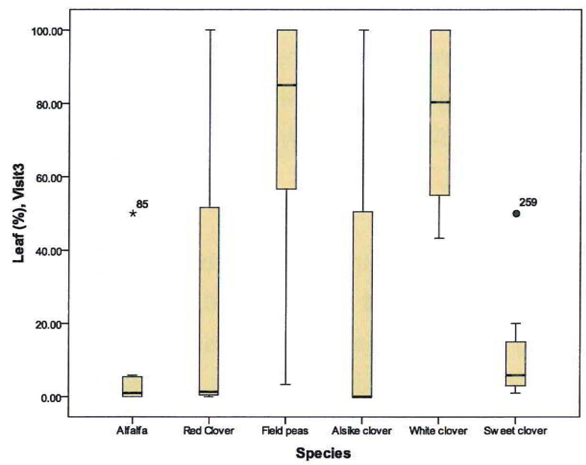


Figure 78: Average leaf part (%) per species

Gillespie

Not enough samples

1c.) Analyses between species (entire period): Organic matter (OM)

No significant differences in OM (%) between species and farms could be found.

2. Comparative Analysis of temporal variability (2006-2009):

Temporal development of biomass, crude protein, Organic matter (%)and ENR under consideration of treatments.

The following chapter describes the temporal development of biomass (g/50cm^2), crude protein (%), OM (%) and ENR per farm on areas with and without treatments. It should be mentioned that biomass (g/50cm^2) and crude protein (%) as well as OM (%) and ENR are correlated to each other (Chap.3: Influence factors). The combined and paired description should serve a better visualization.
The factor *ENR* poses an "estimate of the amount of nitrogen (lbs/acre)" that will be released from the organic matter over the season. Therefore, as the % OM increases, so will the ENR. This calculation is based on the "rule of thumb" that organic matter contains 5% nitrogen.

2a.) Biomass and Crude protein

M' Clintock :

It is now evident that crude protein (%) was significantly lower in 2008 compared to 2006 (p=0,004) and 2007 (p=0,038) on treated plots (Fig.80). The untreated plots did not provide enough data for a statistical analysis.

The average annual biomass (g/50 cm^2) was significantly higher in 2007 compared to 2006 (p=0,039) and 2008 (p=0,007) on treated plots. A significant difference between 2007 und 2008 (p=0,003) was found on untreated plots. The results are described in Fig.79.

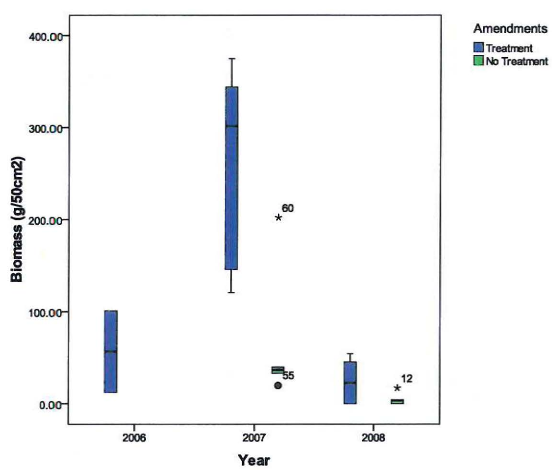


Figure 79: Average biomass (g/50cm2) per year

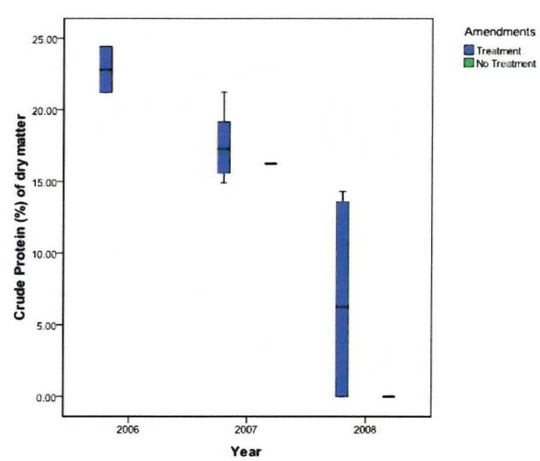


Figure 80: Average Crude protein content (%) per year

Dowdell:

The results showed that crude protein (%) was significantly higher on treated plots in 2007 compared to 2006 (p=0,016) and 2008(p=0,001). No significant differences could be detected on plots without treatment (Fig.82).

The average annual biomass (g/50cm^2) was significantly lower on treated plots in 2008 compared to 2006 (p=0,037) and 2007 (p=0,045). On untreated plots biomass (g/50cm2) was significantly lower in 2008 compared to 2006 (p=0,004) and 2007 (p=0,005) and lower in 2009 compared to 2006 (p=0,013) and 2007 (p=0,014). Results are described in Fig 81.

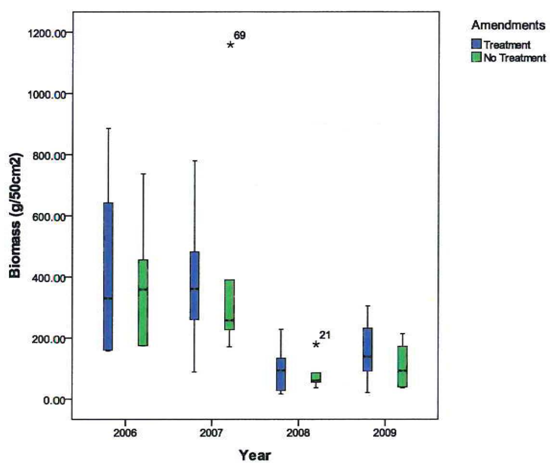


Figure 81: Average biomass (g/50cm2) per year

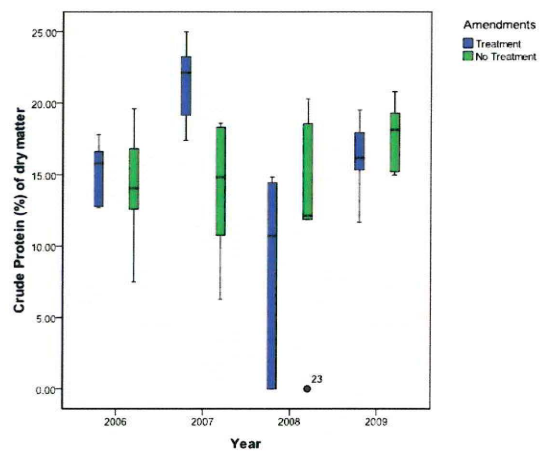


Figure 82: Average Crude protein content (%) per year

Aurora:

A significant difference on treated plots was found for crude protein (%) between 2007 und 2008 (p=0,012) and 2006 und 2008 (p=0,011). For both years crude protein (%) was lower in 2008. On untreated plots crude protein (%) was significantly lower in 2008 compared to 2006 (p=0,017) (Fig.84).

The average annual biomass (g/50 cm^2) was significantly lower in 2008 compared to 2007 on treated plots and lower in 2008 compared to 2006 (p=0,017) and 2007 (p=0,034) on untreated plots.
Results are described in Fig.83.

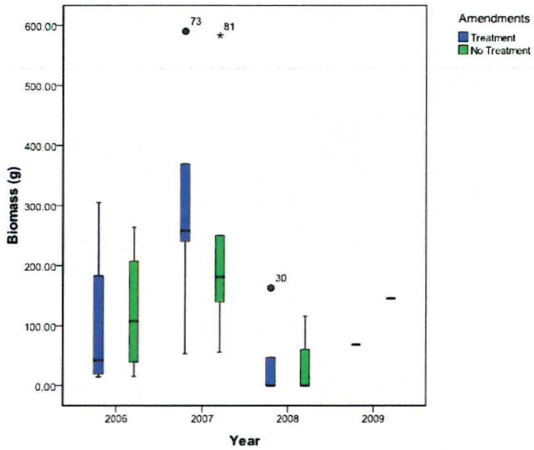


Figure 83: Average biomass (g/50cm2) per year

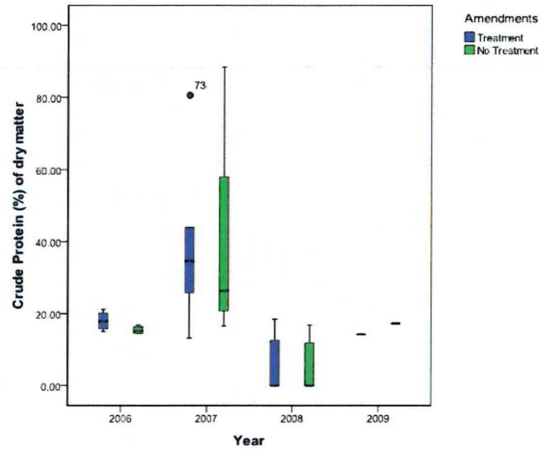


Figure 84: Average crude protein (%) per year

Lendrum:

No significant differences on treated or untreated plots for biomass (g/50cm^2) and crude protein (%) could be detected between the years. The results are described in Fig.85,86.

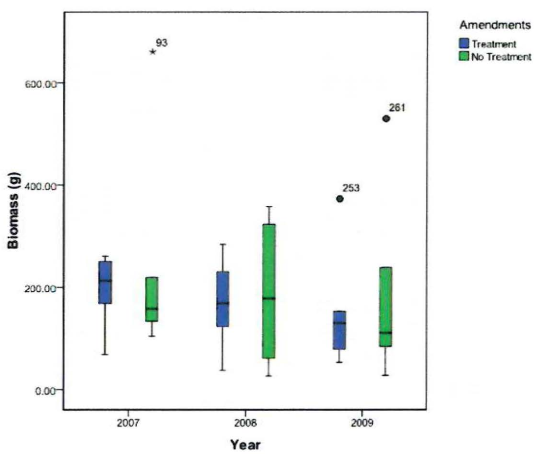


Figure 85: Average biomass (g/50cm2) per year

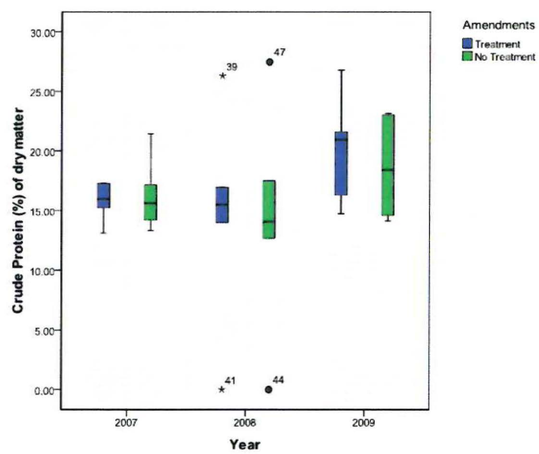


Figure 86: Average crude protein (%) per year

2b.) Organic matter (OM) and ENR

M' Clintock

OM (%) and ENR were significantly higher on untreated plots in 2009 compared to 2008 (Om: p=0,035, ENR: p=0,015). There was no significant difference in OM (%) and ENR on treated plots between the years. The results are described in Fig. 87,88.

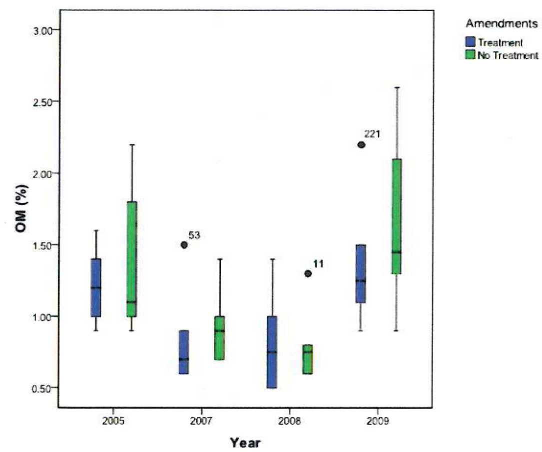


Figure 87: Average OM (%) per year

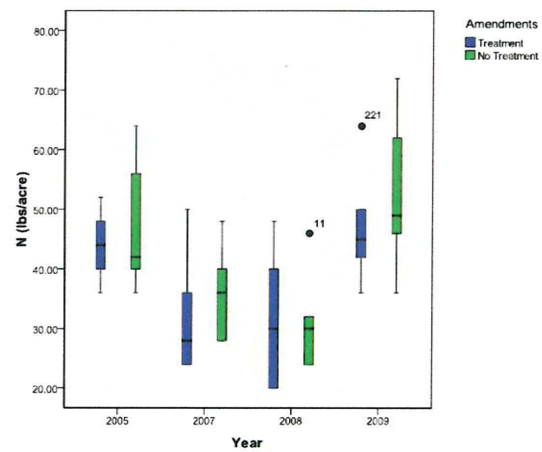


Figure 88: Average N (lbs/acre) per year

Dowdell:

OM (%) and ENR were significantly higher on treated and untreated plots in 2009 compared to 2005 (p=0,002), 2007 (p=0,002) and 2008 (p=0,002). The results are described in Fig.89,90.

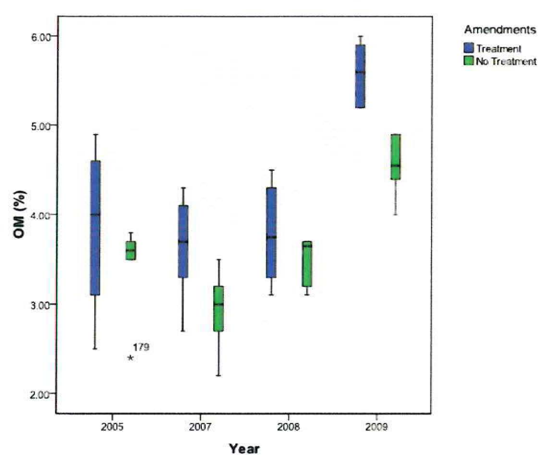


Figure 89: Average Om (%) per year

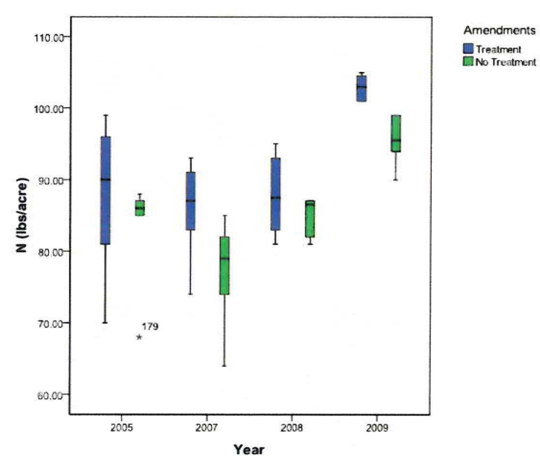


Figure 90: Average N (lbs/acre) per year

Aurora:

A significant difference in OM (%) (p=0,014) and ENR (p=0,031) could be found on untreated plots between 2005 and 2009, whereas OM (%) was higher in 2009. The results are described in Fig.91,92.

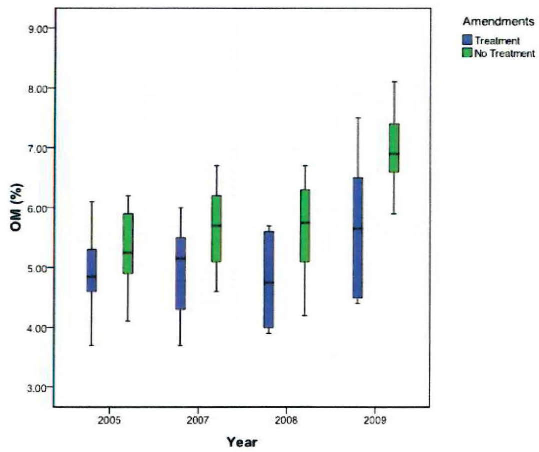


Figure 91: Average OM (%) per year

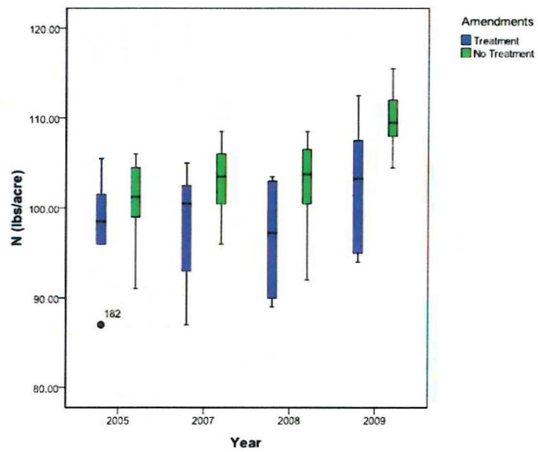


Figure 92: Average N (lbs/acre) per year

Lendrum:

OM (%) and ENR were significantly higher in 2009 compared to 2008 (OM: p=0,004, ENR: p=0,003) on treated plots. A tendency (p=0,051) to a significant result for OM (%) could be found between 2007 and 2009.

Significant differences in OM (%) and ENR on untreated plots were detected in 2009 und 2007 (OM: p=0,016, ENR: p=0,026) and 2008 (OM and ENR: p=0,002), whereas OM (%) was higher in 2009The results are described in Fig.93,94.

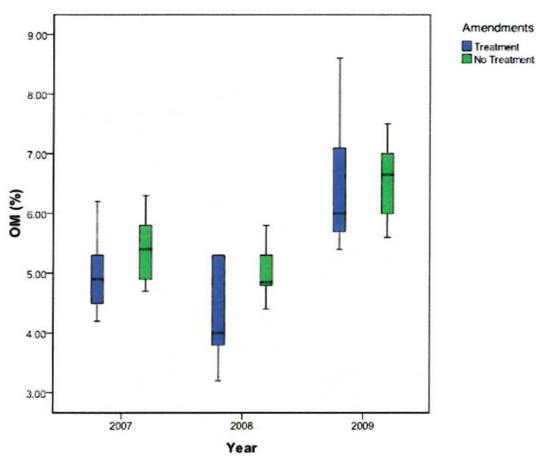


Figure 93: Average OM (%) per year

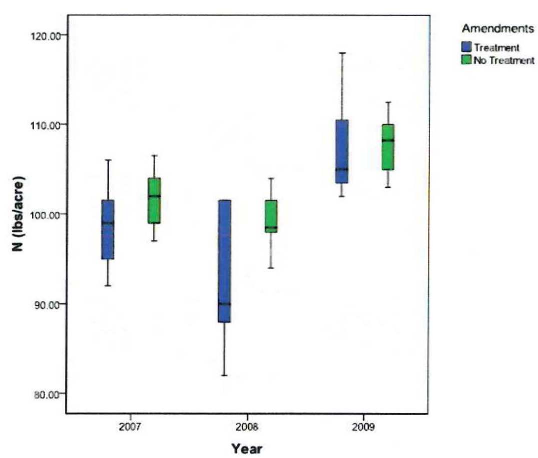


Figure 94: Average N (lbs/acre) per year

Discussion:

Biomass und Crude protein

Contemplating the charts makes it quite evident that the annual circle has a strong influence on biomass and crude protein. The result show clearly that average annual *biomass* (g/50 cm^2) was significantly **lower in 2008 than in 2007** on treated and untreated plots on Dowdell, M' Clintock and Aurora farms. *Crude protein* (%) was significantly **lower in 2008** compared to 2007 on treated plots but no significant differences were found on untreated plots. Lendrum farm showed no significant difference in biomass and crude protein content on treated or untreated plots.

The decrease of biomass and crude protein in 2008 may be connected to the average number of "Growing degree days (GDD)" which were the fewest in the whole period and to the amounts of total annual precipitation (mm) which were the highest in the whole period.

Organic matter (OM) und ENR

The results demonstrate clearly that *OM and ENR* differ significantly on Dowdell and Aurora between 2005 and 2009. The percentual OM and ENR was **higher in 2009 than in 2005**. This could be observed on the Dowdell farm on treated and untreated plots and on the Aurora farm only on untreated plots. The increase of OM (%) occurred on the Aurora farm continuously over the years compared to the Dowdell farm.

A strong increase of *OM and ENR* could be observed on all farms (except Aurora farm) between **2008 and 2009**. OM and ENR increased on treated and untreated plots on Lendrum and Dowdell farms, on M' Clintock only on untreated plots.

3. Influence factors:

The following chapter deals with the relationship between **OM (%), crude protein (%), total score root nodulation** and

1.) Microbial community, root nodulation and plant parameters
2.) Soil parameters (PH, TEC, Soil temperature, soluble nutrients)
3.) Climatic parameters (Rainfall, freeze, temperature)

The following describes the results for 1.) Microbial community, root nodulation and plant parameters:

OM (%): The organic matter (%) was positively influenced by the crude protein (r= 0,266, p=0,005) (Fig. 96) and flagellates (**r=0,757**, p=0,030) (Fig.95).

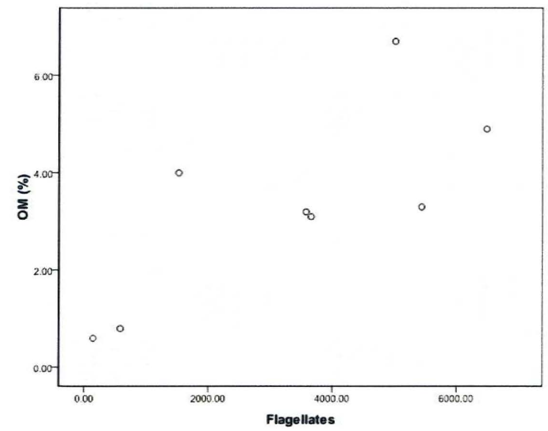


Figure 95: Relation between OM(%) and flagellates (numbers/g)

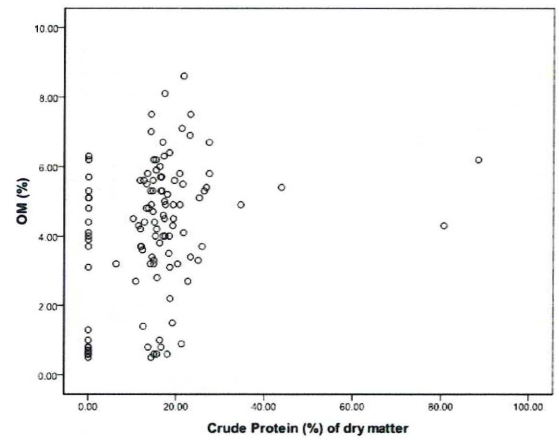


Figure 96: Relation between OM(%) and crude protein ($g/50cm^2$)

Biomass ($g/50cm^2$): Biomass ($g/50cm^2$) was positively influenced by root nodulation (r=0,224, p=0,007) (Fig.97), total bacteria (µg/g) (**r=0,775**, p=0,024) (Fig.98) and the ciliates (numbers/g) (**r=0,854**, p=0,007) (Fig.99). A negative relation could be determined for the species (r=-0,206, p=0,013) (Fig.100). There was also a positive correlation between biomass and crude protein (%) (r=0,397, p<0,001) (Fig.101) and the protein ($g/50cm^2$) (**r=0,897**, p<0,001) (Fig.101,102).

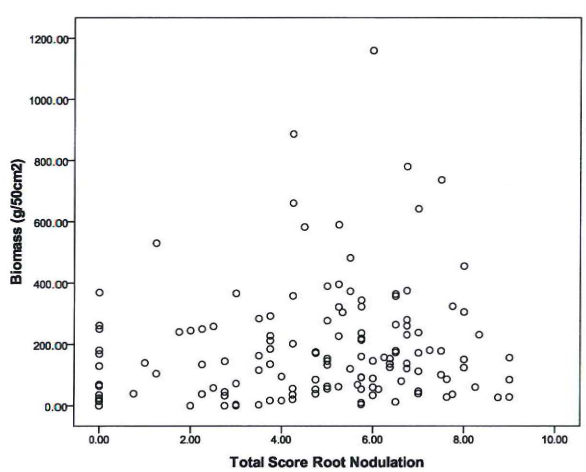


Figure 97: Relation between biomass (g/50cm2) and root nodules

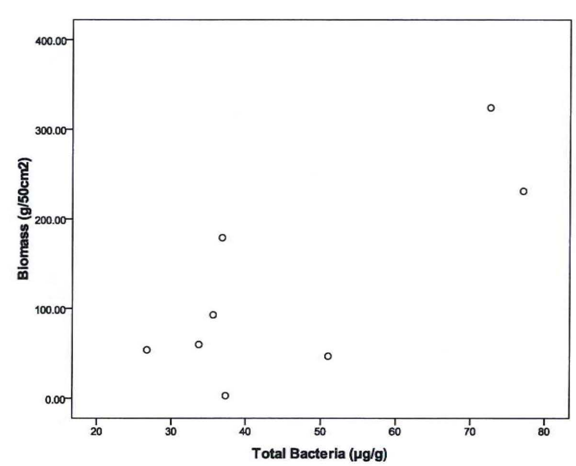


Figure 98: Relation between biomass (g/50cm2) and total amount of Bacteria (µg/g)

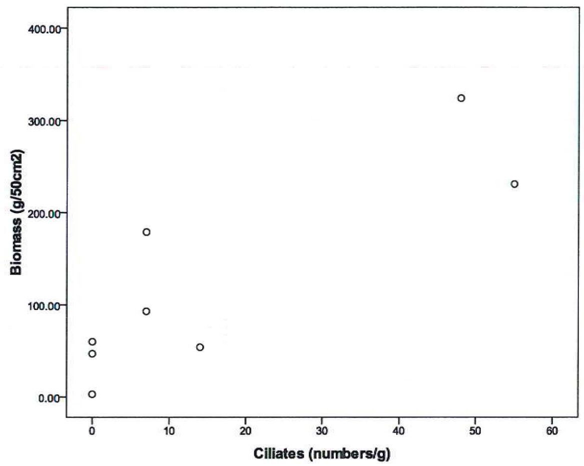


Figure 99: Relation between biomass (g/50cm2) and amount of ciliates (numbers/g)

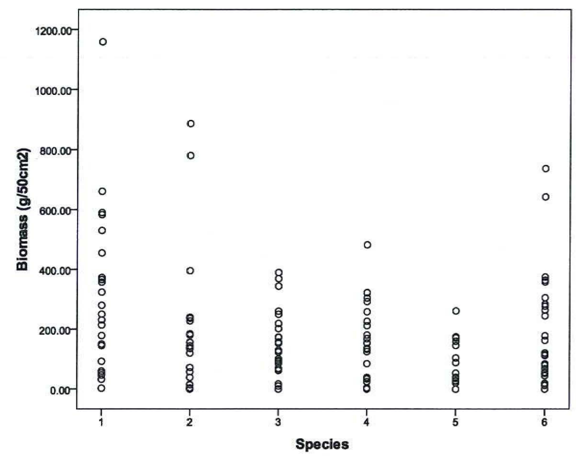


Figure 100: Relation between species (1=Alfalfa,2=Red clover,3=Field peas, 4=Alsike, 5=White clover,6=Sweet clover) and biomass (g/50cm2)

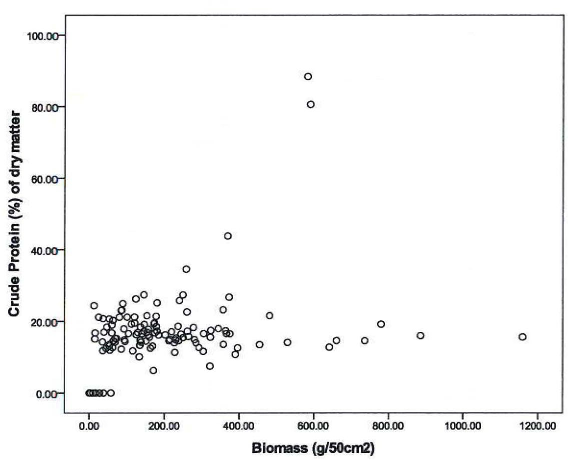


Figure 101: Relation between biomass (g/50cm2) and the crude protein (%)

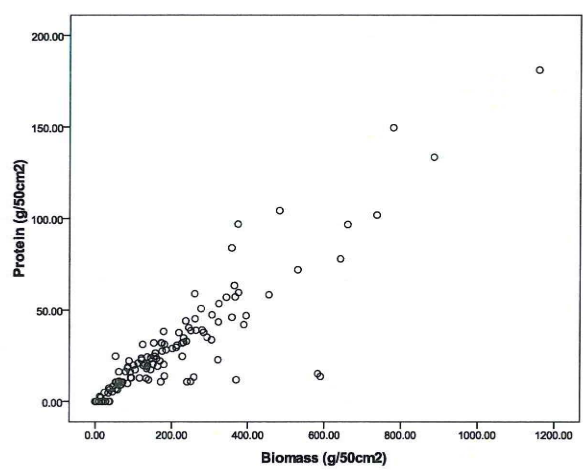


Figure 102: Relation between biomass (g/50cm2) and protein (g/50cm2

Crude protein (%): Crude protein was positively influenced by root nodulation (r=0,205, p=0,017), biomass (r=0,397, p<0,001), protein (r=0,176, p=0,041) und negatively by the species (r=-0,184, p=0,032)

Root Nodulation: The amount of root nodules is positively correlated to biomass and crude protein.

The following describes the results for 2.) Soil parameters (PH, TEC, Soil Temperature, soluble nutrients)

OM (%): Organic matter (OM) was negatively influenced by soil temperature (r=-0,404, p<0,001) (Fig.103). Another negative relation was detected between OM and Cu (r=-0,402, p<0,001) and Fe (**r=-0,801**, p<0,001) (Fig.104). PH value (r=0,567, p<0,001) (Fig. 105) and TEC (**r=0,792**, p<0,001) (Fig.106) had a positive influence on OM. And an additional positive correlation existed between **N (r=0,952**, p< 0,001) (Fig.107), K (r=0,437, p<0,001), S (r=0,479, p<0,001), Na (r=0,693, p<0,001), Ca (r=0,682, p<0,001), **Mg (r=0,725**, p<0,001) (Fig.108) , Zn (r=0,222, p<0,002), B (r=0,274, p<0,001) and Mn (r=0,195, p=0,007).

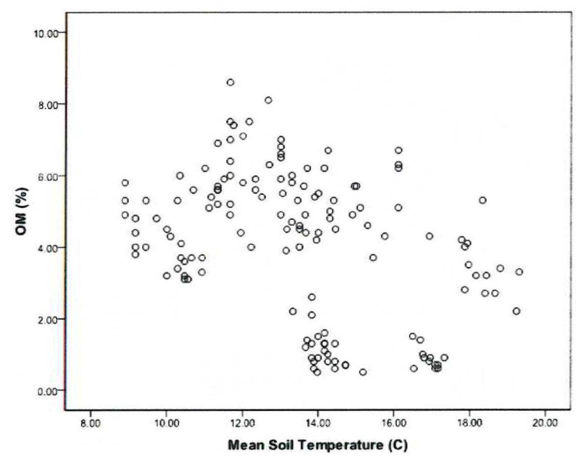


Figure 103: Relation between mean soil temp. (C) and OM (%)

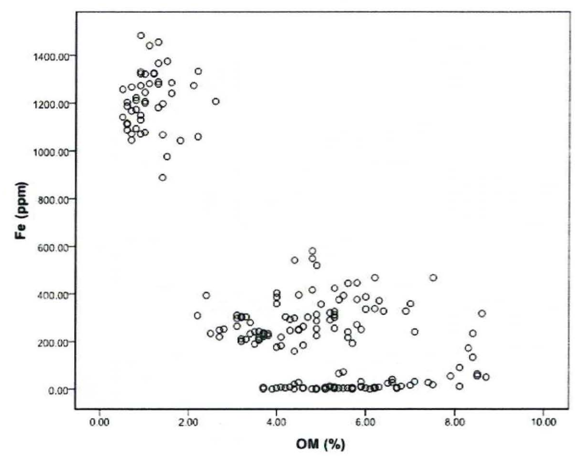


Figure 104: Relation between OM (%) und Fe (ppm)

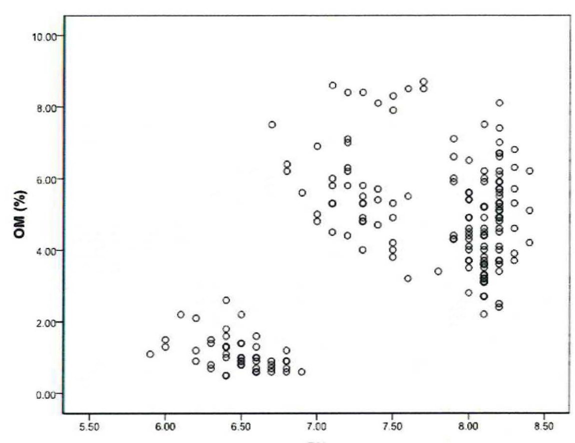


Figure 105: Relation between PH and OM (%)

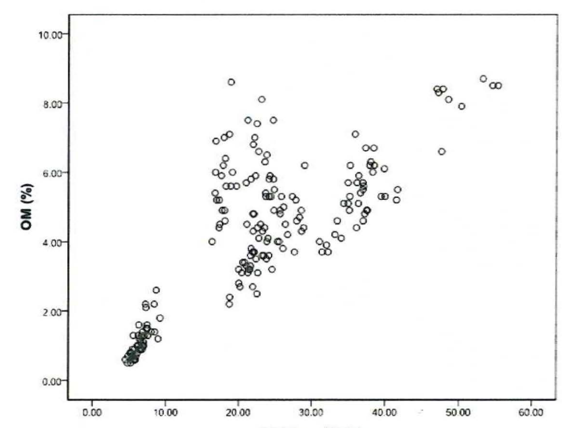


Figure 106: Relation between OM (%) und TEC (meq/100g)

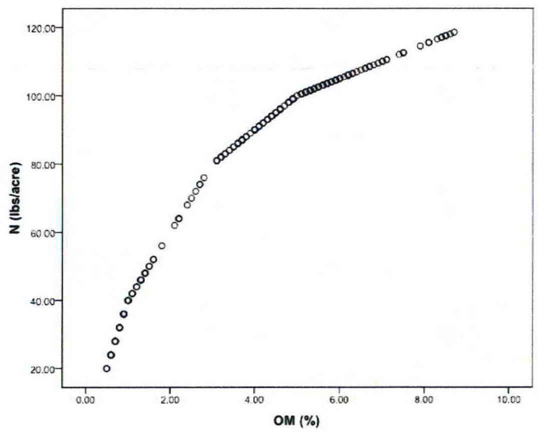


Figure 107: Relation between OM (%) and N (lbs/acre)

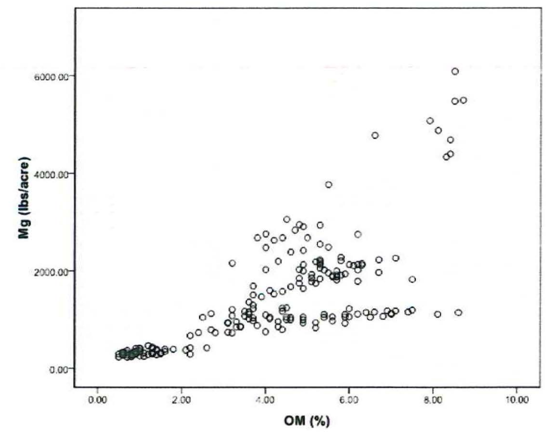


Figure 108: Relation between OM (%) und Mg (lbs/acre)

Biomass (g/50cm2): Biomass was positively influenced by soil temperature (r=0,194, p=0,020), Zn (r=0,205, p=0,025) and Mn (r=0,336, p<0,001)

Crude protein (%): Crude protein was positively related to TEC (r=0,223, p=0,018), N (r=0,268, p=0,004), Na (r=0,215, p=0,023), Mg (r=0,206, p=0,030) and Fe(r=-0,272,p<0,001).

Root nodulation: Root Nodules were negatively influenced by TEC (r=-0,261, p=0,001), Na (r=-0,234, p=0,004), Ca (r=-0,206, p=0,012), and Mg (r=-0,258, p=0,002). A positive relation could be determined for Zn (r=0,170, p=0,031) und Mn (r=0,321, p<0,001).

The following describes the results for 3.) Climatic factors (rainfall, freeze and temperature):

OM (%): No correlation between Organic matter (%) and climatic factors could be detected.

Biomass (g/50cm2): Biomass was positively influenced by the amount of "Growing degree days (GDD)"(r= 0,571, p=0,021) (Fig.109).

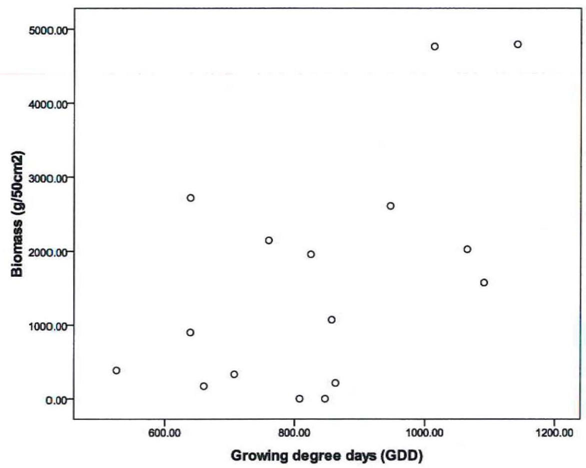


Figure 109: Relation between GDD and Biomass (g/50cm2)

Crude protein (%): No significant relation between crude protein (%) and climatic factors could be detected.

Discussion:

The results of the correlation analysis showed the most important relationship between biomass (g/50cm^2), OM (%), root nodulation and crude protein (%) and the influence factors (Microbial community, root nodulation, plant parameters, soil parameters (PH, TEC, soil temperature, soluble nutrients, climatic parameters (Rainfall, freeze and temperature)).

It appeared that **biomass** (g/50cm^2) was positively influenced by the amount of nodules, the total bacteria, the ciliates, the amount of "Growing degree days (GDD)" and the soil content of Mn and Zn.
Biomass was negatively influenced by soil temperature. The choice of species also had an effect on biomass (see 1.3).

The content of **Crude protein (%)** in plants was positively related to the amount of nodules and the soil type (TEC). The more nodules were formed by Rhizobium the higher was the crude protein (%) part in the plant. The more clay the soil contained the less nodules were formed.
The soil content of N (lbs/acre), Mg (lbs/acre) and Na (lbs/acre) had a positive impact on the crude protein (%) impact of the plant. The content of Fe on the other hand has a rather negative effect. The selection of species also seemed to have an influence on crude protein content.

To generate **OM (%)** in soil the number of flagellates, crude protein (%), the soil type (TEC), the pH value and the soil temperature (C) are very important factors. Soil with higher TEC and pH value generated more OM than soil with lower TEC and pH value. An increase of soil temperature seemed to have a negative effect on OM in the soil. Out of the positive relation between OM (%) and the soluble nutrients (except Fe) we can conclude that an increase of OM (%) also lead to an increase of the above mentioned soluble nutrients.

4. Soils:

4a.) Soil fertility per farm:

A statistical comparison of soil parameter between the farms was not conducted. The soil parameters were graphically demonstrated (Fig. 110-117) and interpreted under consideration of treatments.

Treated blocks

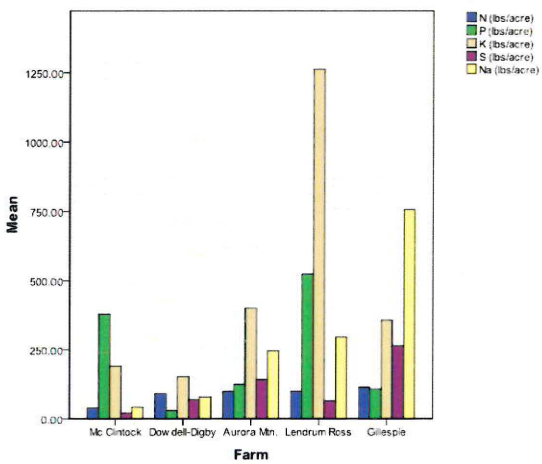


Figure 110: Average N, P, K, S, Na (lbs/acre) soil content per farm

Untreated blocks

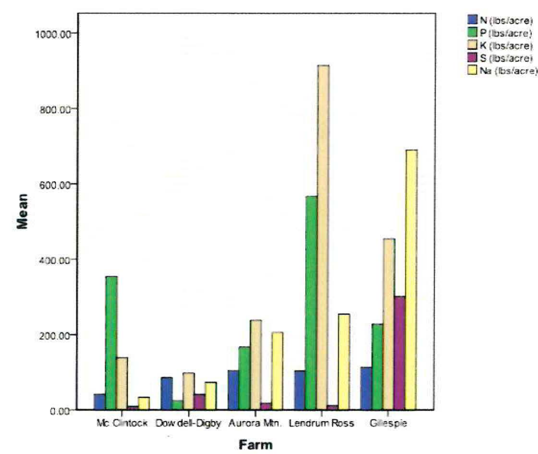


Figure 111: Average N, P, K, S, Na (lbs/acre) soil content per farm

Treated blocks

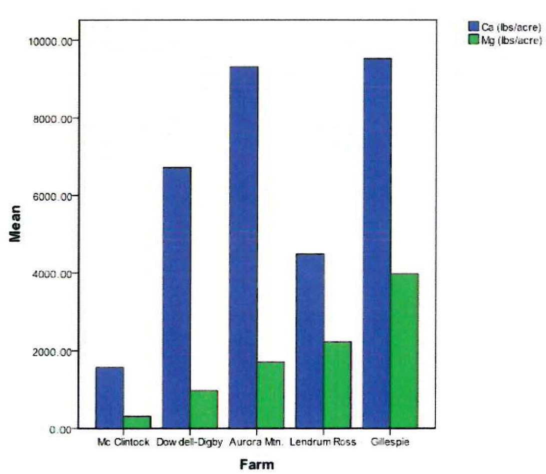


Figure 112: Average Ca, Mg (lbs/acre) soil content per farm

Untreated blocks

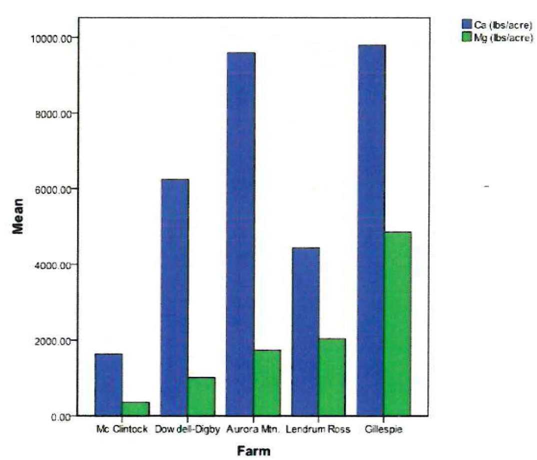


Figure 113: Average Ca, Mg (lbs/acre) soil content per farm

Treated blocks

Untreated blocks

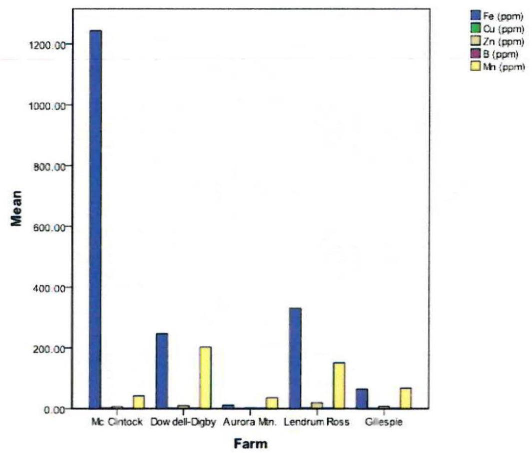


Figure 114: Average Fe,Cu,Zn,B,Mn (ppm) soil content per farm

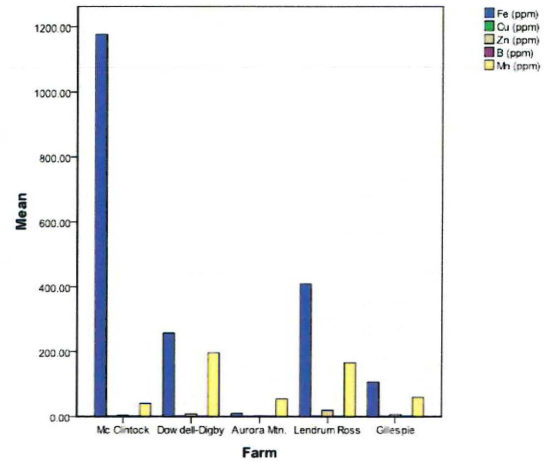


Figure 115: Average Fe,Cu,Zn,B,Mn (ppm) soil content per farm

Treated blocks

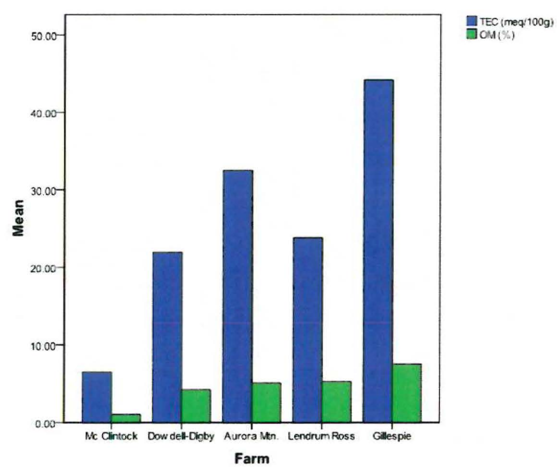


Figure 116: Average OM (%) and average TEC (meq/100g) values per farm

Untreated blocks

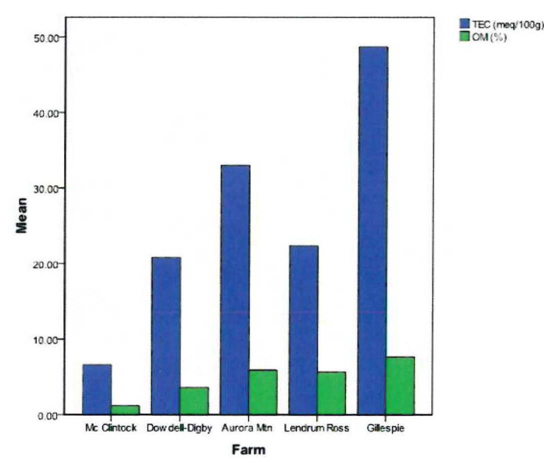


Figure 117: Average OM (%) und average TEC (meq/100g) values per farm

Discussion:

Iron (Fe): Mean Fe (ppm) values on M' Clintock farm were very high compared to Lendrum (three times as high as on treated blocks but less than three times as high on untreated blocks), Dowdell, Aurora and Gillespie farm. The lowest Fe values (under 100 ppm) were observed on Aurora and Gillespie farm (treated and untreated plots). Results are shown in Fig.114,115.

Potassium (K): Mean K (lbs/acre) values were very high on Lendrum farm on treated (1262 lbs/acre) and untreated (914 lbs/acre) plots. On treated plots values were more than six times higher compared to Dowdell (152 lbs/acre) and M' Clintock (190 lbs/acre) farm and about three times as high as on Gillespie (355 lbs/acre) farm and on Aurora (400 lbs/acre) farm. Differences were even bigger on untreated plots except for Gillespie and Lendrum farm. Results are shown in Fig.110,111.

Phosphor (P): The highest mean P (lbs/acre) values were observed on Lendrum farm (treated and untreated plots), followed by M' Clintock. Lower mean soil P (lbs/acre) values were found on Aurora and Gillespie farm, whereas on untreated plots the Gillespie farm showed higher P (lbs/acre) values than the Aurora farm. Dowdell had the lowest mean P (lbs/acre) values on treated and untreated plots. Results are shown in Fig.110,111.

Sulfur(S): Gillespie exhibits on average the highest S (lbs/acre) values (two times as much as Aurora (140 lbs/acre) on treated plots and more than 15 times as much as Aurora (17 lbs/acre) on untreated blocks). Mean soil S (lbs/acre) values were higher on treated blocks than on untreated blocks except for Gillespie. Results are shown in Fig.110,111.

Sodium (Na): Differences in mean Na (lbs/acre) values between farms on treated and untreated plots were high. On treated plots mean Na (lbs/acre) values on Gillespie farm (755 lbs/acre) were more than two times higher than on Lendrum farm (295 lbs/acre). In untreated plots Na (lbs/acre) values were considerably lower but the proportion of Na (lbs/acre) between the farms stayed the same.
Results are shown in Fig.110,111.

Magnesium (Mg): Gillespie had the highest mean Mg (lbs/acre) values (3975 treated - 4862 untreated) followed by Lendrum (2228 treated - 2037 untreated), Aurora (1704 treated-1728 untreated), Dowdell (967 treated -1007 untreated) and M' Clintock (307 treated- 355 untreated). Mg (lbs/acre) values on untreated were slightly higher than on treated except on Lendrum where Mg (lbs/acre) values were higher on treated than on untreated. Results are shown in Fig.112,113.

Calcium (Ca): Mean Ca (lbs/acre) values were quite diverse between farms. Gillespie and Aurora showed the highest values (about 9500) on treated and untreated plots whereas M' Clintock leveled at about 1500 lbs/acre. Results are shown in Fig.112,113.

Calcium (lbs/acre) values were slightly higher on Gillespie, Aurora and M' Clintock on untreated blocks and on Lendrum and Dowdell on treated blocks.

Organic matter (OM): The most OM (%) was accumulated on Gillespie farm (around 7,5%) on treated and untreated plots. Lendrum, Dowdell and Aurora farm accumulated almost the same amount of OM (%) in the soil (around 5%). The lowest OM (%) was observed on the M' Clintock farm (around 1%). On all farms (except the Dowdell farm) OM (%) was higher on untreated plots.

Total Exchange Capacity (TEC): The Gillespie and Aurora farm had the highest mean TEC (meq/100g) values compared to the other farms on treated and untreated plots. Here, mean TEC (meq/100g) values were higher on untreated plots (Gillespie 49 meq/100g-Aurora 33 meq/100g) than on treated plots (Gillespie 44 meq/100g-Aurora 32 meq/100g). Mean TEC (meq/100g) values on Dowdell and Lendrum farm were similar to each other and were higher on treated plots (Dowdell 22meq/100g-Lendrum 24meq/100g) than on untreated plots (Dowdell 21meq/100g-Lendrum 22meq/100g). The lowest mean TEC (meq/100g) values on treated and untreated plots (6,5 meq/100g) were found on M' Clintock farm.

4b.) Temporal changes of soil nutrient content (per farm):

M' Clintock

Treated blocks

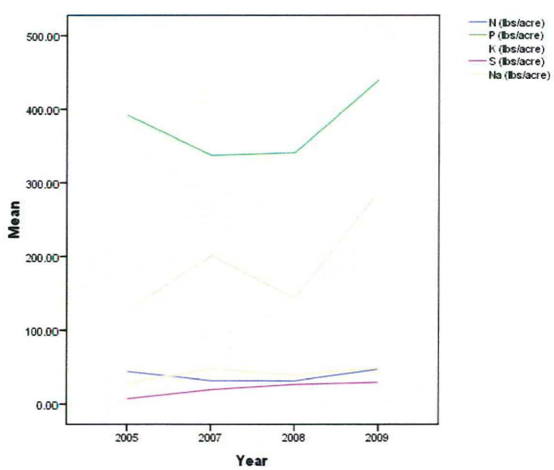


Figure 118: Temporal change of average N, P, K, S, Na (lbs/acre) soil content

Untreated blocks

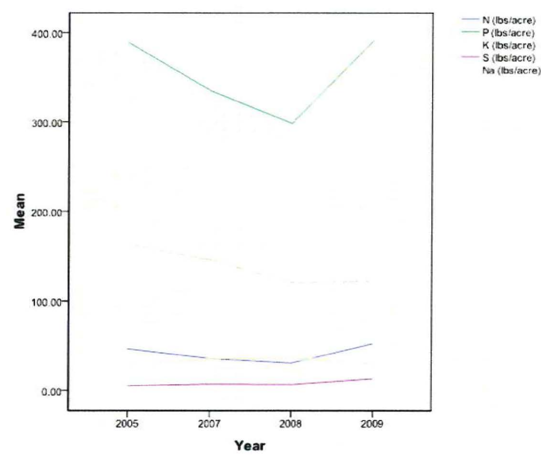


Figure 119: Temporal change of average N, P, K, S, Na (lbs/acre) soil content

Treated blocks

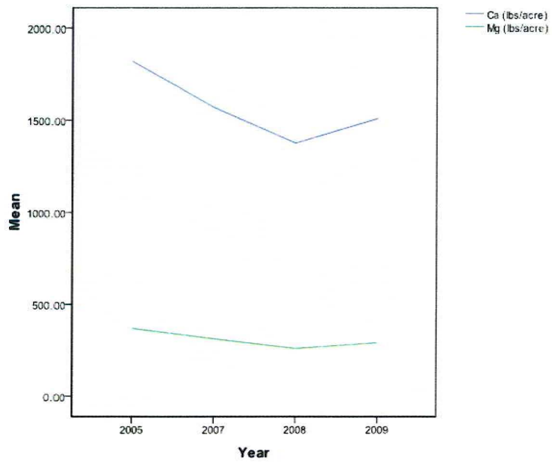


Figure 120: Temporal change of average Ca, Mg (lbs/acre) soil content

Untreated blocks

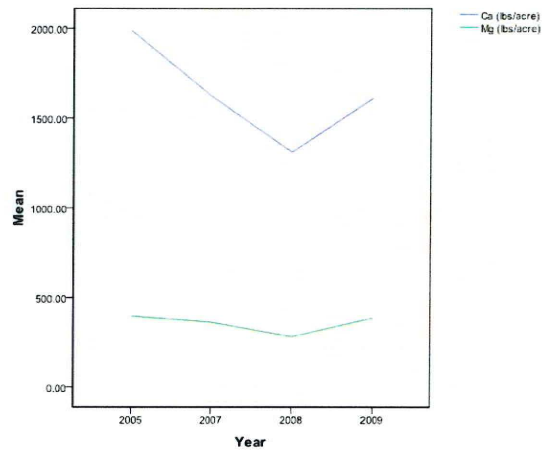


Figure 121: Temporal change of average Ca, Mg (lbs/acre) soil content

Treated blocks

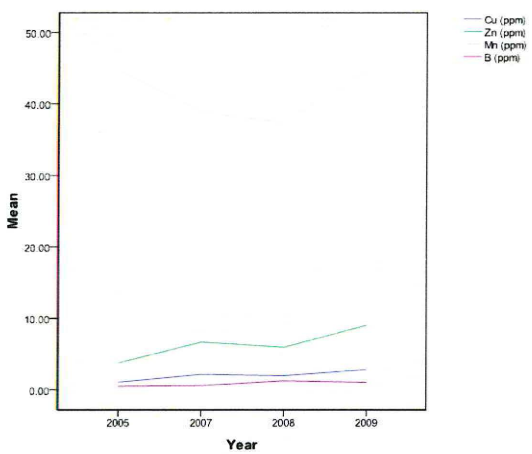


Figure 122: Temporal change of average Cu, Zn, Mn,B (lbs/acre) soil content

Untreated blocks

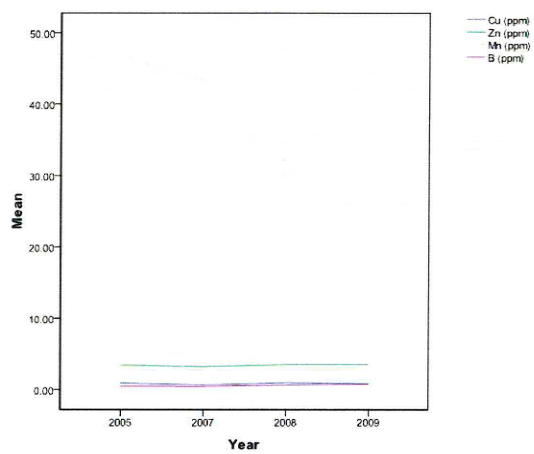


Figure 123: Temporal change of average Cu, Zn, Mn,B (lbs/acre) soil content

Discussion:

On the untreated plots the **Na- , N- and S** (lbs/acre) contents have increased compared to their initial contents **(Fig).** No changes were observed for **Mg and P** (lbs/acre) contents but a decrease in **Ca and K** (lbs/acre) contents was found. Results are shown in Fig.119,121.

On the treated plots **P, Na and S** (lbs/acre) contents have increased compared to their initial contents, **Ca and Mg** (lbs/acre) contents have decreased on the other hand. Results are shown in Fig.118,120.

Dowdell

Treated blocks

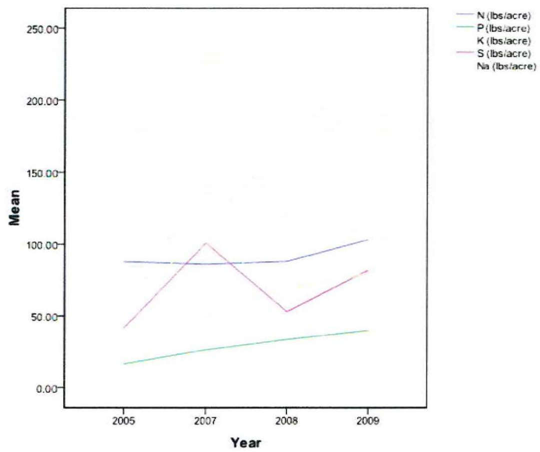


Figure 124: Temporal change in average, N, P, K, S, Na (lbs/acre) soil content

Untreated blocks

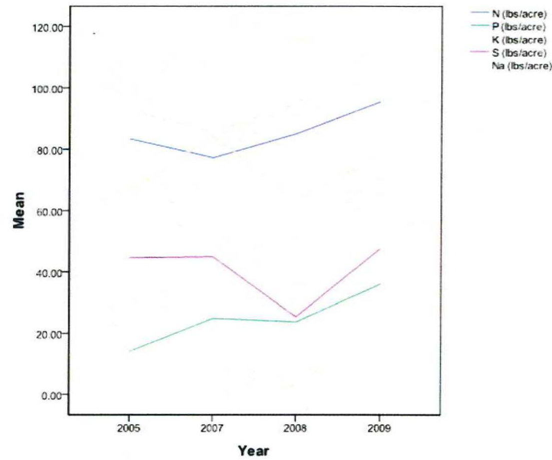


Figure 125: Temporal change in average N, P, K, S, Na (lbs/acre) soil content

Treated blocks

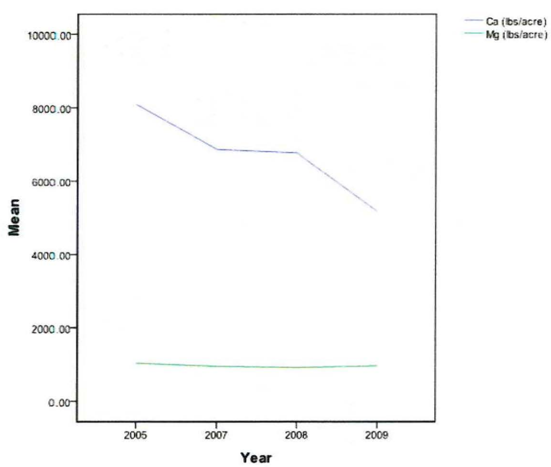


Figure 126: Temporal change in average, Ca, Mg (lbs/acre) soil content

Untreated blocks

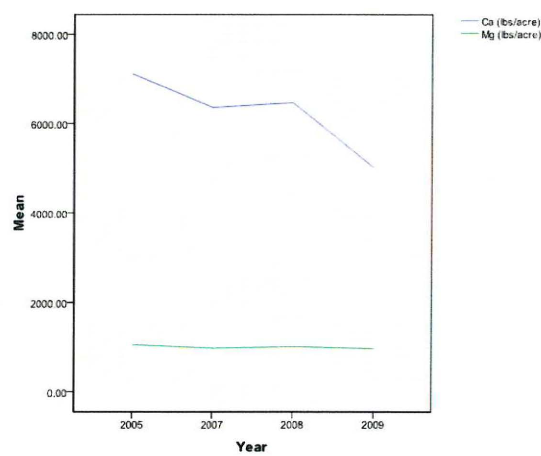


Figure 127: Temporal change in average Ca, Mg (lbs/acre) soil content

Treated blocks

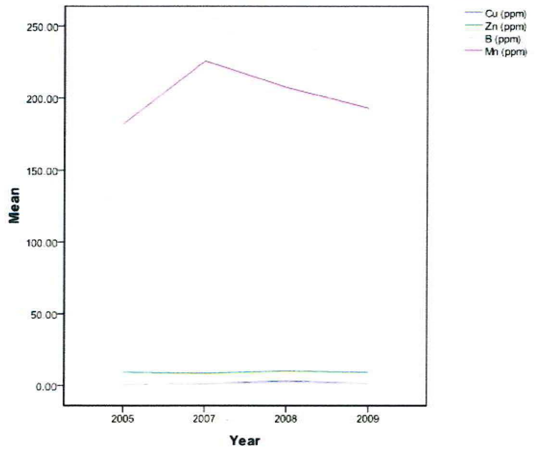


Figure 128: Temporal change in average Cu, Zn, B, Mn (ppm) soil content

Untreated blocks

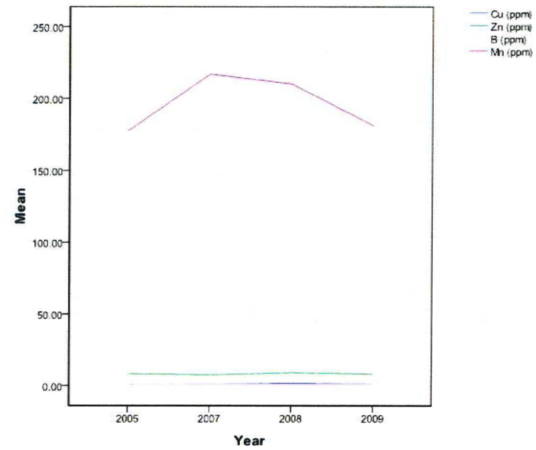


Figure 129: Temporal change in average Cu, Zn, B, Mn (ppm) soil content

Discussion:

On the untreated plots **P, K, Na, N** (lbs/acre) contents have increased compared to the initial soil (Fig). Little changes were observed for **S, Mg (lbs/acre) and Mn (ppm). Ca** (lbs/acre) contents have decreased. Results are shown in Fig.125,127,129.

On treated plots **P, K , Na, N, S** (lbs/acre) contents have increased compared to their initial contents. **Mg (lbs/acre) and Mn** (ppm) values on the other hand have not changed, Ca (lbs/acre) values have even decreased compared to the initial soil values. Results are shown in Fig.124,126,128.

Aurora

Treated blocks

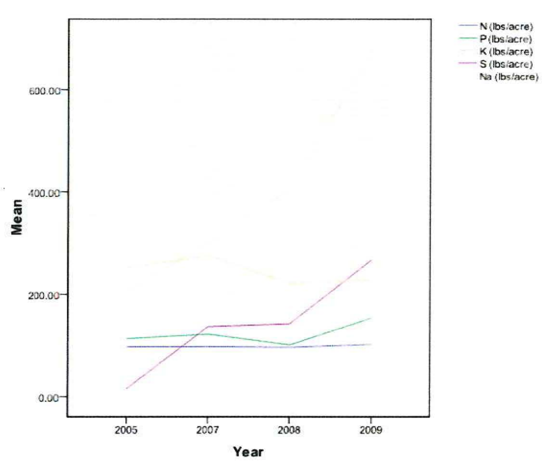


Figure 130: Temporal Change of average N, P, K,S,Na (lbs/acre) soil content

Untreated blocks

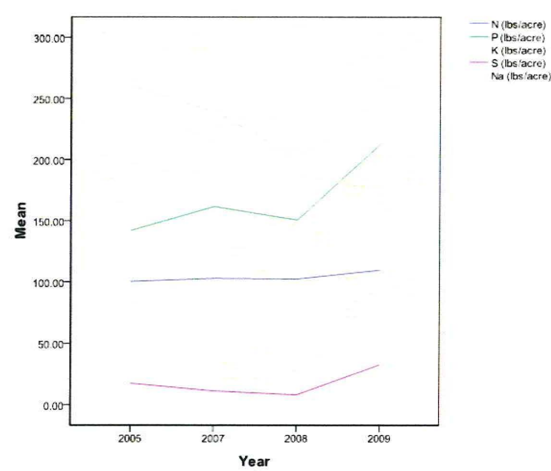


Figure 131: Temporal Change of average N, P,K,S,Na (lbs/acre) soil content

Treated blocks

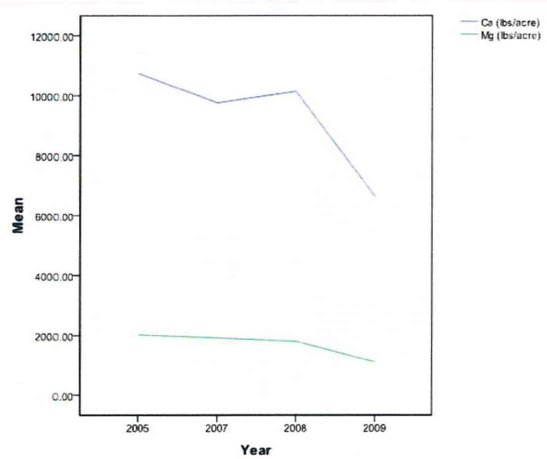


Figure 132: Temporal Change of average Ca, Mg (lbs/acre) soil content

Untreated blocks

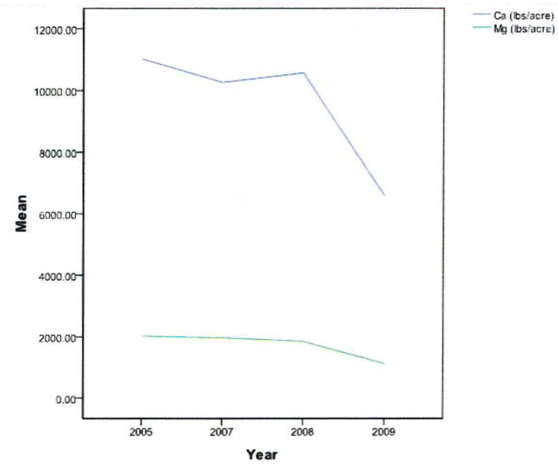


Figure 133: Temporal Change of average Ca, Mg (lbs/acre) soil content

Treated blocks

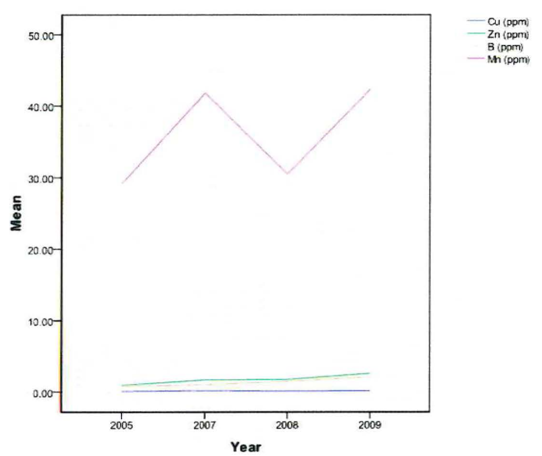


Figure 134: Temporal change of average Cu, Zn, B, Mn (ppm) soil content

Untreated blocks

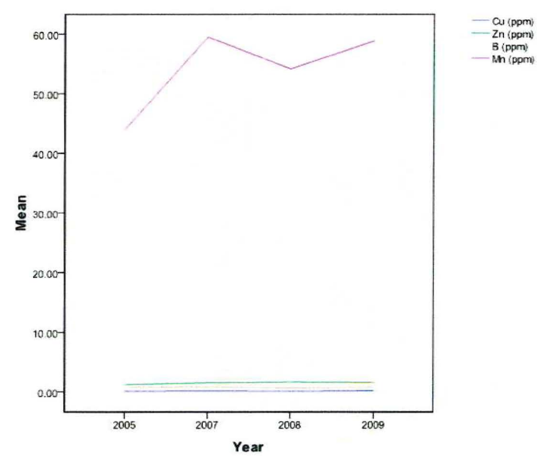


Figure 135: Temporal change of average Cu, Zn, B, Mn (ppm) soil content

Discussion:

On untreated plots **P, Mn, N, S** (lbs/acre) contents have increased compared to their initial contents (Fig). **Ca, K, Na, Mg** (lbs/acre) values on the other hand have decreased. Results are shown in Fig.130,132,134.

On **treated blocks P, K, N, S und Mn** (lbs/acre) contents have increased compared to their initial contents whereas **Ca, Mg and Na** (lbs/acre) values have decreased. Results are shown in Fig.131,133,135.

Lendrum

Treated blocks

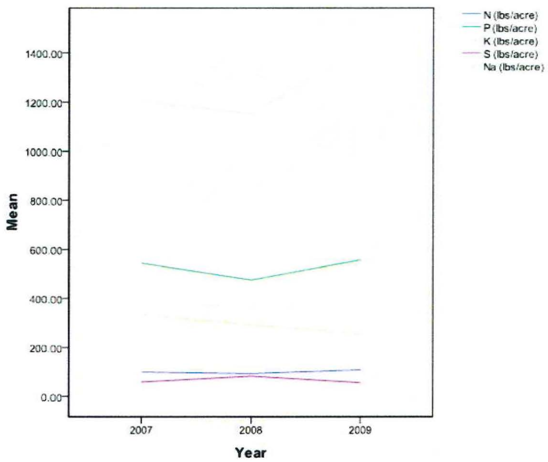


Figure 136: Temporal change of average N,P,K,S,Na (lbs/acre) soil content

Untreated blocks

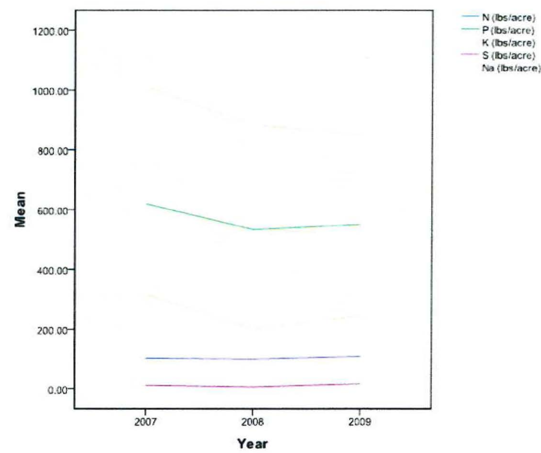


Figure 137: Temporal change of average N,P,K,S,Na (lbs/acre) soil content

Treated blocks

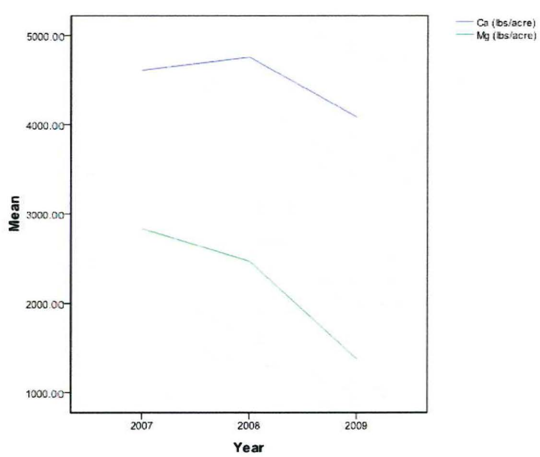


Figure 138: Temporal change of average Ca, Mg (lbs/acre) soil content

Untreated blocks

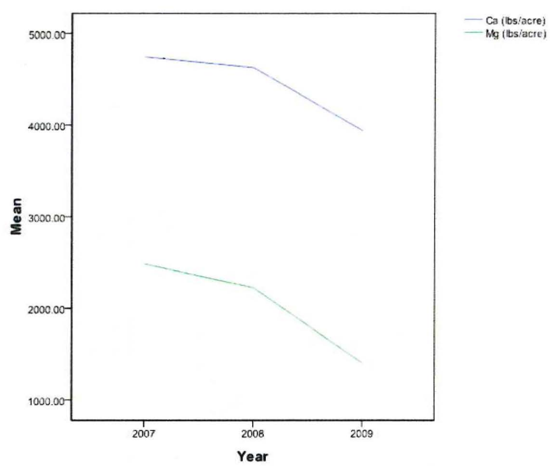


Figure 139: Temporal change of average Ca, Mg (lbs/acre) soil content

Treated blocks *Untreated blocks*

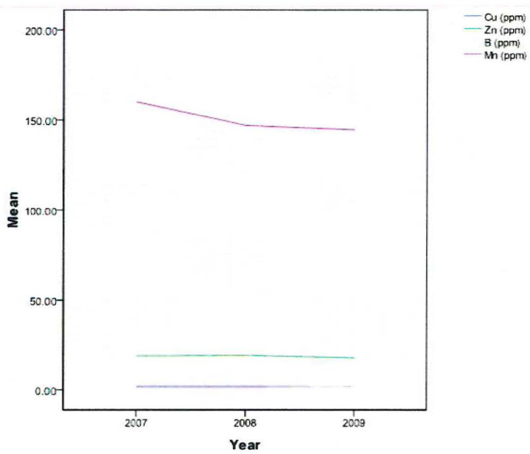


Figure 140: Temporal change of average Cu, Zn,B,Mn (ppm) soil content

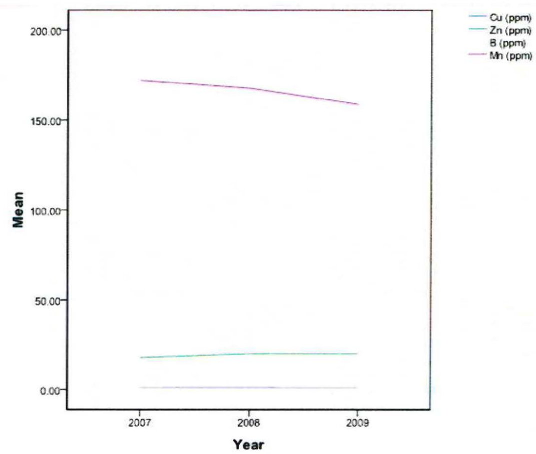


Figure 141: Temporal change of average Cu,Zn, B,Mn (ppm) soil content

Discussion:

On **untreated** plots **N** (lbs/acre) **and Zn** (ppm) contents have slightly increased compared to their initial contents. **P, K, Na, Ca, Mg** (lbs/acre) **and Mn** (ppm) contents have decreased and **S** (lbs/acre) values have not changed at all. Results are shown in Fig.137,139,141.

On treated plots **N, P** (lbs/acre) values have slightly increased. **K** (lbs/acre) contents have increased even more since the initial contents of 2005. **Na** (lbs/acre) **and Mn** (ppm) contents have decreased compared to their initial soil values and **S** (lbs/acre) **and Zn** (ppm) values have remotely changed. Results are shown in Fig.136,138,140.

Summary:

The summary relates to the initial questions of the study.

1. Is there a difference in performance of the plants, microbial community and organic matter in between treatments, the 4 different farms and in between the 6 species?

Treatments:

The results for the entire period have shown that soil treatment affected biomass (g/50 cm^2), crude protein (%), protein (g/50cm^2) and the root nodules significantly positive on the MC Clintock farm but it is quite noticeable that the improved plots did not lead to an annual increase in performance every year (only in 2007 and 2008). Thus the "improved" soil conditions did not seem to have a big influence on the establishment and growth of legumes. On the Mc Clintock farm it should be considered due to the improper sandy/loam soil conditions (very low nutrient holding capacity, see Appendix R), to improve the particular plots with artificial fertilizer prior to the cultivation of legumes, to benefit the initial establishment and growth.

The microbial community did not seem to be different between treatments. It should be mentioned that the data relates only to 2008 and thus we only had a very low amount of samples.

No differences in OM (%) between treatments were detected on Mc Clintock and Lendrum farms. An Improvement of plots had a significantly positive effect on OM (%) on the Dowdell farm and a significantly negative effect on the Aurora farm.

Farms:

Plant performance was very different between the farms and the years. The Dowdell farm had the highest performance on average in 2006 and 2007. Dowdell, Lendrum and Aurora farms did not show much of a difference in performance in 2008 and 2009 whereas the Lendrum and Dowdell farms were considered to be more productive. Mc Clintock farm showed the lowest performance in all the years (except 2006).

The microbial community did not exhibit any significant difference between farms. Since only 2 samples per farm were available for testing it makes a statistical analysis obsolete. The results would be inconclusive.

OM (%) differed significantly between farms. Soil on Lendrum and Aurora farm showed significantly more OM (%) than Dowdell and Mc Clintock farms. Also significantly more OM (%) was detected on the Dowdell farm compared to the Mc Clintock farm.

Species:

It could be ascertained that species regarding their biomass (g/50cm^2) and crude protein (%) parts have developed differently on the farms.

The Field peas on the Mc Clintock farm reached higher values of biomass (g/50cm^2) and crude protein (%) on average than all the other species. The Dowdell farm showed that *Alfalfa, Red clover und Alsike clover* had significantly higher biomass (g/50cm^2) values than White clover. *Alfalfa, Red Clover and Field peas* also demonstrated a significant difference on average in protein (g/50cm^2) content compared to White clover. In this category White clover had always the lowest values.

On the Aurora farm Sweet clover and Alfalfa seemed to have the highest values in biomass (g/50cm^2) and protein (g/50cm^2) content on average. Alfalfa and Sweet clover were significantly different in their protein content (g/50cm^2) compared to Red clover and Field peas. The highest content in biomass (g/50cm^2) and protein (g/50cm^2) showed the species Alfalfa on Lendrum farm. The plants significantly distinguished themselves in biomass (g/50cm^2) and protein (g/50cm^2) content from White clover, Alsike and Field peas. It should be mentioned that these are the average values per species for the entire period of analysis. However biomass (g/50cm^2) and crude protein (%) values of the particular species are subject to variation. This means that for example Alfalfa has achieved on average (entire period) the highest value in biomass (g/50cm^2) (on Lendrum farm) but might not have the highest biomass (g/50cm^2) values every year.

It should also be mentioned that Sweet clover (due to extensive growth) was cut every year during the phase of analysis. Therefore it is difficult to compare this species performance with other analyzed species.

No differences in OM (%) between species could be observed.

2. How did the plants growth (biomass) change over the time period of 5 years?

The results showed strong fluctuations in biomass (g/50cm^2) values in the course of the period of analysis. They indicated clearly that Dowdell, Mc Clintock and Aurora farms displayed a significant decrease in biomass (g/50cm^2) and crude protein (%) on treated plots in 2008 compared to 2007. No significant differences in crude protein (%) could be detected on untreated plots. However on Dowdell, Aurora und Mc Clintock farms biomass differed significantly on untreated plots. Lendrum farm did not show any significant differences in biomass (g/50cm^2) and crude protein (%) on treated and untreated plots. 2007 was on average the best year for all the farms.

3. How did the organic matter (OM) change over the time period of 5 years?

OM (%) has significantly increased in 2009 on Aurora and Dowdell farms compared to 2005. This could be contemplated on the Dowdell farm on treated and untreated plots, on the Aurora farm however only on untreated plots. Compared to the Aurora farm OM (%) on Dowdell farm did not increase continuously over the years.

Between **2008 and 2009** OM (%) increased intensely on all farms (except Aurora). On Lendrum and Dowdell farms OM (%) increased on treated and untreated plots whereas on Mc Clintock farm only on untreated plots.

4. Which are the most important influences on plant growth (biomass and crude protein) and organic matter?

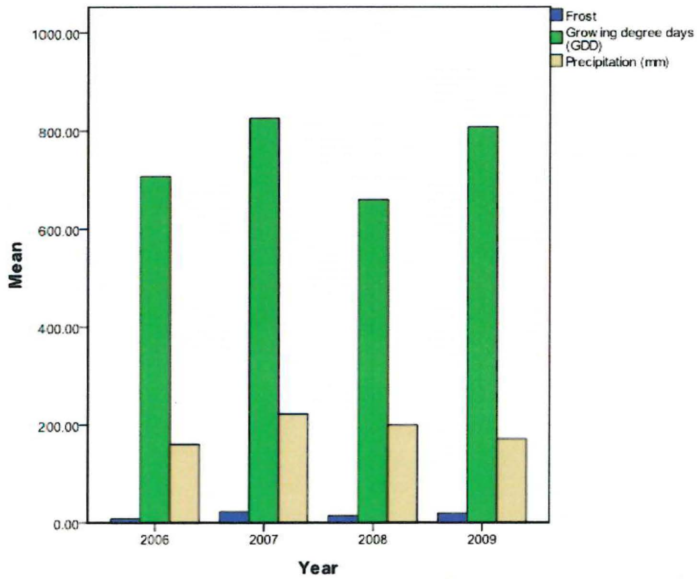
It appeared that **biomass** (g/50cm^2) was positively influenced by the amount of root nodules, the total bacteria (µg/g), the ciliates (numbers/g), the temperature (C) and soil content of Mn (ppm) and Zn (ppm) and negatively by soil temperature (C). The selection of species was another decisive factor to determine the amount of biomass (see species above).

The content of plant **crude protein** (%) depended on the amount of nodules and the soil type (TEC). The more nodules were formed by Rhizobium the higher is the crude protein (%) part in the plant. The more clay the soil contained the less nodules were formed.
The soil content of N, Mg and Na (lbs/acre) has a positive effect on crude protein (%) content in plants; the content of Fe on the other hand seemed to have a rather negative influence. The selection of species appeared to be an additional factor in generating crude protein content (see species above)

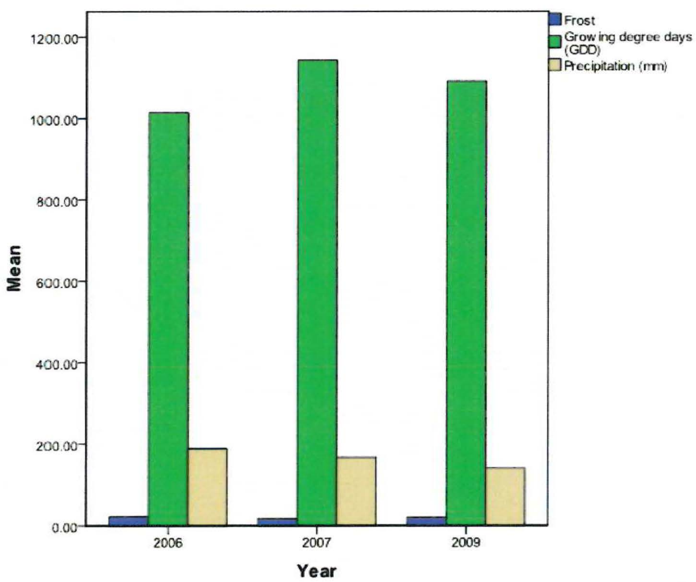
The amount of flagellates (numbers/g), the soil type (TEC), the pH value and the soil temperature (C) were very important for the generation of **OM (%).** Soil with high TEC and pH values generated more OM (%) than soil with low TEC and pH values. An increase of soil temperature (C) appeared to have a negative effect on OM (%). Out of the positive relation between OM (%) and soluble nutrients (except Fe) we can conclude that an increase of OM (%) also lead to an increase of above mentioned soluble nutrients.

Appendixes:

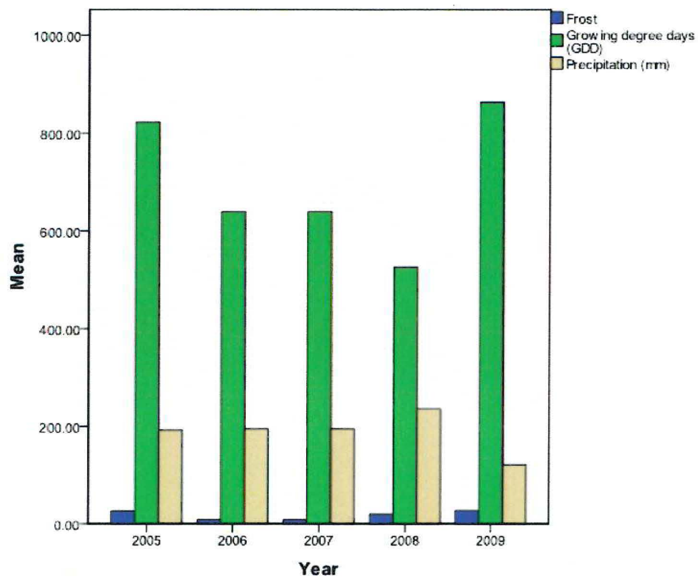
Appendix A: Climate data (Precipitation (mm), freeze, GDD), M' Clintock farm



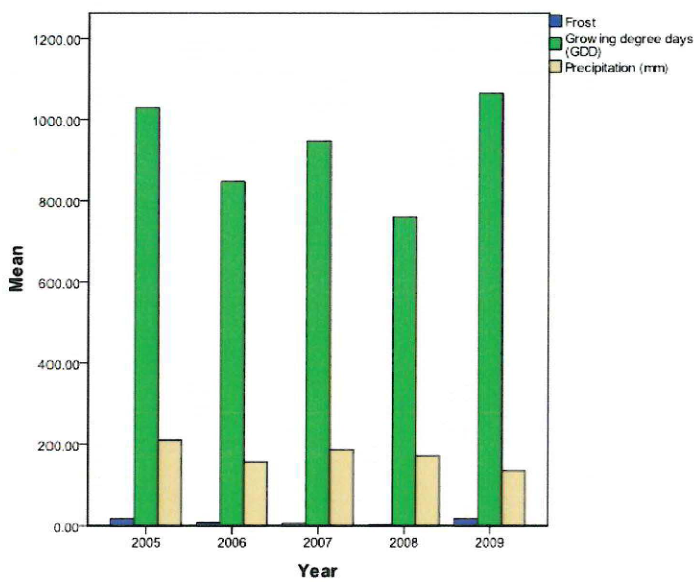
Appendix B: Climate data (Precipitation (mm), freeze, GDD), Dowdell farm



Appendix C: Climate data (Precipitation (mm), freeze, GDD), Aurora farm



Appendix D: Climate data (Precipitation (mm), freeze, GDD), Lendrum farm



Appendix E: Soil applications 2006, Dowdell

Recommended Amendment	Application Date	Block1*	Block2*	Block5*	Block6*	Block9*	Block10*
Sulfur 90-92%	10-Jun-06	39.9	9.6	35	24.7	9.6	9.6
Soft Rock Phosphate							
Calcium Carbonate							
Gypsum							
Magnesium Sulfate							
Potassium Sulfate	10-Jun-06	197.9	197.9	197.9	197.9	197.9	197.9
Borax 11%	Scheduled Apr-07	19.9	19.9	19.9	19.9	19.9	19.9
Ferrous Sulfate					120.9		307.9
Manganese Sulfate							
Copper Sulfate	10-Jun-06	24.7	19.9	19.9	24.7	24.7	24.7
Zinc Sulfate							
		*Recommended Quantity in Grams/ 9 sq. m Block					

Appendix F: Soil application 2006,Gillespie

Recommended Amendment	Application Date	*Block 1	*Block 2	*Block 5	*Block 6	*Block 9	*Block 10
Sulfur 90-92%							
Soft Rock Phosphate	23-Jun-06	505.8	505.8	505.8	505.8	505.8	505.8
Calcium Carbonate	12-Sep-06	4035.3	3078.7	3023.7	3023.7	3023.7	3023.7
Gypsum							
Magnesium Sulfate							
Potassium Sulfate	23-Jun-06	197.9	307.9	197.9	197.9	197.9	197.9
Borax 11%	12-Sep-06	19.9	19.9	19.9	19.9	19.9	19.9
Ferrous Sulfate		**406.8	**274.9		**208.9		**296.9
Manganese Sulfate							
Copper Sulfate	23-Jun-06	30.2	30.2	30.2	24.7	30.2	30.2
Zinc Sulfate	26-Jul-06	19.9	19.9				9.6
		*Recommended Quantity in Grams/ 9 sq. m Block					
		**unable to apply due to sustained wind					

Appendix G: Soil application 2006,M' Clintock

Recommended Amendment	Application Date	*Block 1	*Block 2	*Block 5	*Block 6	*Block 9	*Block 10
Sulfur 90-92%	20-Jul-06	77	99	110	99	110	99
Soft Rock Phosphate	20-Jul-06	505.8		505.8	505.8	505.8	505.8
Calcium Carbonate							
Gypsum				659.7		560.8	
Magnesium Sulfate							
Potassium Sulfate	20-Jul-06	197.9	197.9	197.9	197.9	197.9	197.9
Borax 11%	26-Aug-06	19.9	19.9	19.9	19.9	19.9	19.9
Ferrous Sulfate							
Manganese Sulfate					39.9		
Copper Sulfate	20-Jul-06	15.1	15.1	15.1	15.1	19.9	19.9
Zinc Sulfate	20-Jul-06	35	35	35	35	35	35
		*Recommended Quantity in Grams/ 9 sq. m Block					

Appendix H: Soil application 2006, Aurora

Recommended Amendment	Application Date	*Block 1	*Block 2	*Block 5	*Block 6	*Block 9	*Block 10
Sulfur 90-92%	16-Jun-06	88	99	77	77	66	66
Soft Rock Phosphate	16-Jun-06	505.8					
Calcium Carbonate							
Gypsum		**2023.1					
Magnesium Sulfate							
Potassium Sulfate	16-Jun-06	197.9	197.9	197.9	197.9	197.9	197.9
Borax 11%	21-Aug-06	19.9	19.9	19.9	19.9	19.9	19.9
Ferrous Sulfate	25-Sep-06	384.8	362.8	406.8	406.8	348.8	406.8
Manganese Sulfate	25-Sep-06	15.1	164.9	120.9	99	66	15.1
Copper Sulfate	16-Jun-06	35	35	35	35	35	35
Zinc Sulfate	17-Jul-06	30.2	35	35	35	35	35

Appendix I: Soil application 2007,Dowdell, M' Clintock , Aurora, Lendrum (figure from Legume report 2007**)**

Grant Dowdell's Farm	
0.06 kg	Elemental Sulphur
1.1 kg	Rock Phosphate
1.8 kg	Potassium Sulfate
0.03 kg	Borax
0.3 kg	Iron Sulfate
M'Clintock Valley Farm	
0.15 kg	Elemental Sulphur
1.1 kg	Rock Phosphate
1.8 kg	Potassium Sulfate
Aurora Mountain Farm	
0.15 kg	Elemental Sulphur
1.1 kg	Rock Phospate
1.8 kg	Potassium Sulfate
Lendrum/Ross Farm	
0.4 kg	Elemental Sulphur
3 kg	Rock Phosphate
12 kg	Calcium Carbonate
1 kg	Potassium Sulfate
0.12 kg	Borax
0.05 kg	Copper Sulfate
0.1 kg	Zinc Sulfate

Appendix J: Soil application 2008, M' Clintock

Recommended Amendment	Block 1a	Block 2c	Block 5f	Block 6d	Block 9b	Block 10e
SULFUR 90-92% (a)	**1.75 Lbs**	**1.5 Lbs**	**1.25 Lbs**	**2 Lbs**	**1 Lbs**	**1.75 Lbs**
SFT RK PHOSPHATE	**11.5 Lbs**	**11.5 Lbs**	**11.5 Lbs**	**11.5 Lbs**	**11.5 Lbs**	**7 Lbs**
CALCIUM CARB (a)					**9.25 Lbs**	
POT SULFATE 0-0-50	**2.75 Lbs**	**4.5 Lbs**	**5.75 Lbs**	**5.75 Lbs**	**4.5 Lbs**	**4.5 Lbs**
BORAX 11% (b)	**7.25 oz**	**7.25 oz**	**7.25 oz**	**7.25 oz**	**7.25 oz**	**7.25 oz**
MANG SULF 28%	**1.5 Lbs**		**1.75 Lbs**	**14.5 oz**		
CU SULFATE 23%			**3.5 oz**		**3.5 oz**	
ZINC SULFATE 36%	**9 oz**	**5.5 oz**	**9 oz**	**3.5 oz**	**3.5 oz**	

Appendix K: Soil application 2008, Dowdell

Recommended Amendment	Block 1a	Block 2c	Block 5f	Block 6d	Block 9b	Block 10e
POT SULFATE 0-0-50 (a)	**4.5 Lbs**	**4.5 Lbs**	**4.5 Lbs**	**4.5 Lbs**	**5.75 Lbs**	**4.5 Lbs**
BORAX 11%	**7.25 oz**	**7.25 oz**	**7.25 oz**	**7.25 oz**	**7.25 oz**	**7.25 oz**
FE SULFATE 21% (b) (c)		**5.25 Lbs**		**9.25 Lbs**		**9.25 Lbs**
CU SULFATE 23%	**5.5 oz**	**5.5 oz**	**5.5 oz**	**7.25 oz**	**5.5 oz**	**7.25 oz**

Appendix L: Soil application 2008, Aurora

Recommended Amendment	Block 1a	Block 2c	Block 5f	Block 6d	Block 9b	Block 10e
SFT RK PHOSPHATE	**11.5 Lbs**		**11.5 Lbs**			
GYPSUM (a)	**46 Lbs**					
POT SULFATE 0-0-50 (b)	**9.25 Lbs**	**8.5 Lbs**	**5.75 Lbs**	**8.5 Lbs**	**9.75 Lbs**	**8 Lbs**
BORAX 11%	**7.25 oz**	**7.25 oz**	**7.25 oz**	**7.25 oz**	**7.25 oz**	**7.25 oz**
FE SULFATE 21% (c) (d) (e)	**9.25 Lbs**	**9.25 Lbs**	**9.25 Lbs**	**9.25 Lbs**	**9.25 Lbs**	**9.25 Lbs**
MANG SULF 28% (d)		**3.25 Lbs**				
CU SULFATE 23%	**11 oz**	**11 oz**	**11 oz**	**11 oz**	**11 oz**	**12.75 oz**
ZINC SULFATE 36%	**9 oz**	**11 oz**	**9 oz**	**12.75 oz**	**12.75 oz**	**12.75 oz**
SULFUR 90-92%				**9 oz**		

Appendix M: Soil application 2008, Lendrum

Recommended Amendment	Block 1a	Block 2c	Block 5f	Block 6d	Block 9b	Block 10e
SULFUR 90-92%		9 oz		7.25 oz	1.25 Lbs	
CALCIUM CARB (a)	91.75 Lbs	91.75 Lbs	103.25 Lbs	91.75 Lbs	103.25 Lbs	103.25 Lbs
POT SULFATE 0-0-50	4.5 Lbs	4.5 Lbs		5.75 Lbs		5.75 Lbs
CU SULFATE 23%	3.5 oz	1.75 oz	7.25 oz	7.25 oz	1.75 oz	
SFT RK PHOSPHATE				11.5 Lbs		

Appendix N: Soil application 2009 Dowdell

Rcommended Amendment*	Block 1A	Block 2C	Block 5F	Block 6D	Block 9B	Block 10E
Sufur	13.4		8.8		6.7	8.8
Pot. Sulfate	136.7	156.2	146.5	200.2	166.0	156.2

Appendix O: Soil application 2009 M'Clintock

Recommended Amendment	Block 1 A	Block 2C	Block 5F	Block 6D	Block 9B	Block 10E
Sulfur	24.4	19.5	24.4	19.5	11.0	29.2
Rk. Phosphate	136.7		180.6	136.7	136.7	
Pot. Sulfate	7.9	87.8	156.2	87.8	68.4	68.4
Borax	6.7	8.8		8.8		8.8
Mang. Sulfate	34.2	43.9	63.5	34.2	29.3	48.8
Cu. Sulfate	2.1	4.3	8.8	4.3	8.8	4.3
Zinc Sulfate	13.4	8.8	11.0	4.3	8.8	8.8

Appendix P: Soil application 2009 Aurora

Recommended Amendment	Block 1A	Block 2C	Block 5F	Block 6D	Block 9B	Block 10E
Pot. Sulfate	156.2	146.5	224.6	224.6	112.3	112.3
Iron Sulfate	90*	90*	90*	90*	90*	40*
Cu. Sulfate	15.6	13.4	15.6	15.6	15.6	15.6
Zinc Sulfate	13.4	15.6	15.6	15.6	15.6	11.0
Mang. Sulfate	73.2		53.7	53.7	29.3	
Borax			8.8	8.8	8.8	
*180.6 required, more amendment unavailable						

Appendix Q: Soil application 2009 Lendrum

Recommended Amendment	Block 1A	Block 2C	Block 5F	Block 6D	Block 9B	Block 10E
Pot. Sulfate	87.8	8.8				87.9
Borax	8.8					
Rk. Phosphate		224.6		224.6	224.6	224.6
Calcium Carb.		537.1		537.1	224.6	
Cu. Sulfate		2.1	8.8	2.1	2.1	8.8

Appendix R:

Rating	CEC (meq/100g)	Comment
Very Low	0-10	Very low nutrient holding capacity indicating sandy soils with little or no clay or organic matter. Nutrients will be easily leached and foliar applied nutrients are strongly recommended.
Slightly low	10-15	Slightly low nutrient holding capacity indicating a more loamy mineral soil. Leaching may still be a problem and therefore foliar applications should be considered.
Normal range	15-40	Adequate to high nutrient holding capacity indicating soils with increasing clay content.
High	+ 40	Very high level normally found in very heavy soils with a high clay content or soils with a high organic matter level. Nutrients can be bound very tightly to the soil particles and availability can be restricted.

CEC values for different soils aus http://www.yaravita.com/pmedia/analysis-tech-cationexchange.pdf