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MASTER OF SCIENCE (M.Sc.) THESIS

Amount of nutrient in the soil and above ground biomass and its effect on different sward-height patches under different grazing regimes

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DIPLOMA THESIS ASSIGNMENT

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Thesis title

Amount of nutrients in soil and in the above-ground biomass and its effect on different sward-height patches under different grazing regimes

Objectives of thesis

The grazing process is characterized by the animal factors of selectivity of grazing, deposition of excreta and treading, with these factors affecting the growth and botanical composition of pastures. This behaviour creates spatial heterogeneity in the sward patchiness with the mean canopy height being shorter in the more frequently grazed patches than in the less grazed patches. Furthermore, excretion of dung and urine by grazing animals leads to a localized accumulation of nutrients.

This thesis builds on a long-term project and it is focused on vegetation structure of pastures in relation to the differences in amount of nutrients in soil and in the above-ground biomass. The particular objectives of thesis are:

- to find out how the mosaic sward structure on pastures is affected by amount of nutrients (N, P, K, Ca, Mg) in soil
- to find out how the mosaic sward structure on pastures is affected by amount of nutrients (P, K, Ca, Mg) in above-ground biomass
- to evaluate these effects according to the plant species composition and different grazing intensity

Methodology

This work is a part of a long-term Oldřichov Grazing Experiment in Jizera Mountains. The research proceeds on continuously stocked pasture from May to October from 1998. Two contrasting stocking densities of heifers were applied (intensive and extensive grazing). Samples of the above-ground biomass from three sward height categories (with exact species composition) as well as the samples of the soil from those particular plots will be analysed in an accredited laboratory. The amount of available nutrients and the digestibility of plant biomass will be investigated. 48 soil samples and 48 biomass samples will be analysed (3 sward height categories x 4 samples from each category x 2 repetitions x 2 grazing intensities).

Schedule for processing

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- discussion, conclusions – 15.3.2014
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The proposed extent of the thesis

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semi-natural grassland, cattle grazing, patchiness, nutrients

Recommended information sources

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DECLARATION

I hereby declare that I, **FRED APAU FREMPONG** solely authored this master thesis as one of the prerequisite requirements for the MSc. degree at the Faculty of Environmental Sciences, Czech University of Life Sciences, Prague.

I have carried out different studies connected to my thesis on my own; therefore I declare that I only used those sources that are referenced in the work.

Prague, 20th April 2014.

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FRED APAU FREMPONG

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I dedicate this thesis to Freda Apau Frempong.

Abstract

The nutrient in herbage and soils in different sward height patches under different grazing intensities were studied in an upland area in the northern part of the Czech Republic.

Three types of non-grazed patches were identified and studied under intesive and extensive grazing: 1) non-grazed patches with feaces under intensive grazing treatment-IGF; 2) non-grazed patches with feaces under extensive grazing treatment – EGF; 3) non-grazed patches without feaces under extensive grazing treatment – EGNF. Non-grazed patches were identified under intesive and extensive grazing, which were designed in two randomised block. Totally were samples taken from four plots. Four separate above-ground herbage biomass samples were taken from each plot, dried and analysed in accredited laboratory for P, K, Ca, Mg, and N. After that, under each herbage sample soil samples were taken at 10cm in depth, after removing plant biomass. Soil chemical analyses were performed in an accredited laboratory to determine content of P, K, Ca, Mg, Cox, Nt, and pH/CaCl2.

It was realized that the different sward height patches had no effect on P, K, Ca, Mg, Nt, Cox and pH/CaCl2 in soil but rather had influence on P, K, Mg, and N in the above-ground plant biomass. Correlation analyses revealed that, there was found a relationship between the amount of nutrients in herbage and in soil (P, K, Ca, Mg, and N) The study found that N, P and K in herbage was affected by Nt, P and K in soil respectively. We can conclude that the feaces had key effect on non grazed patches creation and herbage nutrient content under extensive and intensive grazing management however no effect on soil nutrient content was revealed.

Keywords: Grassland, Cattle grazing, Patches, Nutrients, Biomass, Herbage, Grazing intensity, Soil nutrients, Sward height,

Abstrakt

Živiny v rostlinách a půdě v rozdílných výškových ploškách v různé pastevní intenzitě byly studovány v podhorské oblasti v severní části České republiky. Tři typy výškových plošek byly identifikovány a studovány pod intenzivní a extenzivní pastvou: 1) nespásané plošky s výkalem při intenzivní pastvě – IGF; 2) nespásané plošky s výkalem při extenzivní pastvě – EGF; 3) nespásané plošky bez výkalu při extenzivní pastvě. Plošky byly identifikovány v extenzivní a extenzivní experimentální pastvině, která byla uspořádána do dvou znárodněných bloků. Celkem tedy byly vzorky odebírány ve 4 oplůtcích Čtyři vzorky nadzemní rostlinné biomasy byly odebrány z každého oplůtku, usušeny a analyzovány v akreditované laboratoři na P, K, Ca, Mg, a N. Po té byly pod každém rostlinném vzorku odebrán vzorek půdy z hloubky 10 cm po odstranění rostlinných zbytků. Chemická analýza půdy byla provedena v akreditované laboratoři na obsah P, K, Ca, Mg, Cox, Nt, a pH/CaCl2.

Bylo zjištěno, rozdílné výškové plošky neměly žádný vliv na P, K, Ca, Mg, Nt, Cox a pH/CaCl2 v půdě ale měli vliv na obsah P, K, Mg, a N v rostlinách. Korelační analýza odhalila vztah mezi obsahem živin v půdě a rostlinách (P, K, Ca, Mg, a N). Studie ukázala, že obsah N, P a K v rostlinách byl ovlivněn obsahem Nt, P a K v půdě. Závěrem můžeme říci, že efekt výkalu měl klíčový vliv na tvorbu a obsah živin v rostlinách nespasených plošek při intenzivní a extenzivní pastvě, ale neměl žádný vliv na obsah živin v půdě.

Klíčová slova: Travní porost, Pastva skotu, Plošky, Živiny, Biomasa, Rostliny, Intenzita pastvy, Živiny v půdě, Výška porostu

CHAPTER 1

1.1. INTRODUCTION

The traditional ways of grassland cultivation, which have been in use for hundreds of years, and have resulted in a high diversity of plants and invertebrates in nutrient-poor, semi natural grasslands (Zoller et al. 1986; Baur et al. 1996; Wilmanns 1998) were either treated more intensively or, in many cases, abandoned.

Grasslands are vital elements of the historical landscape of Europe and of crucial importance in biodiversity conservation (Nösberger & Rodriguez 1996; Wallis De Vries et al. 2002). Grasslands play an important role in the land use of Europe, the 38.1% of all agricultural lands (474.3 million ha) are grasslands (FAOSTAT). Most grassland in Europe is managed by mowing or grazing which is important for animal husbandry and support farmer livelihood.

Grasslands provide pertinent ecosystem services such as recreation, sport and tourism (Isselstein et al. 2005). Grassland biodiversity is a crucial element of the total biodiversity of rural landscapes (Nösberger & Rodriguez 1996). The species richness of plants is very high in many grassland types, both in the form of a high overall richness and a high richness at small spatial scales (Eriksson et al. 2002).

The frequent application of fertilizers (Tilman 1993), substantial nitrogen input from atmospheric deposition (Bakker & Berendse 1999) and commercial seeding (e.g. commercial seed mixtures and/or energie grasses) result in an increased biomass production but decreased species richness (Bakker & Berendse 1999; Pfadenhauer & Grootjans 1999).

These days, approximately 20% of the agriculturally used area in the European Union is managed under agri-environmental schemes (Rounsewell et al. 2005).

There are many grassland restoration techniques or practices in use depending on the type of disturbance and level of degradation the area is subjected to. If basic grassland vegetation is still present but former management altered and the grassland is impoverished or abandoned, the major aim is to recover its former species richness by restoration. One of the most frequently applied restoration methods is to resume the traditional management (e.g. mowing or low levels of grazing). (Kiehl et al. 2010).

The management of grazing affects not only herbage accumulation but also grazing efficiency.

Grasslands in Europe make an important contribution to the total biodiversity of rural landscapes (Nosberger and Rodriguez, 1996). A considerable proportion of plant and animal species live in grasslands predominantly and are rarely found in other vegetation types. Grazing management is therefore an important factor influencing grassland flora as well as fauna.

Extensive grazing with beef cattle offers opportunities for the restoration of biodiversity in formerly intensively used grasslands (Isselstein et al., 2007).

The effect that grazing has on vegetation is explained primarily by visible, aboveground changes in the vegetation and litter structure due to defoliation & trampling. Freely grazing animals distribute manure/fertilizers inefficiently; excreta tend to be deposited most heavily where the forage is produced and consumed (Simpson and Stobbs, 1981).

Nutrient may affect plant production, nutritional quality and resistance to herbivores and defoliation tolerance (Lambers Chapin and Pons 1998, Milchunas, Lauenroth and Burke 1998). Herbivores move nutrient directly by ingestion, retention and excretion and indirectly by modifying mineralization, dry deposition, leaching and erosion.

The degree to which a plant or pasture is grazed during a grazing event is referred to as the intensity of grazing. The greater the intensity of grazing, the greater the rate of forage utilization, and the greater the harvest efficiency. Grazing intensities are evaluated based on the relationship between pregrazing and post grazing forage heights.
Grazing intensity can also be referred generally to the quantitative animal forage demand placed upon the standing forage, and the resulting level if defoliation made during the grazing.
There is extensive research in the area of grassland and management regimes, but only a few hand linked these two to nutrients in above-ground biomass and soil.

1.2. AIM OF STUDY

This thesis build on a long term project and it focus on vegetation structure of pasture in relation to the differences in amount of nutrients in soil and above-ground biomass. The influence of different grazing intensity would be examined on the level of nutrient in the soil and above-ground biomass, with comparative analysis in patches with and without Feaces.

The objective of this study is to evaluate the nutrient level in above-ground biomass (with respect to Nitrogen-N, Phosphorus-P, Potassium-K, Calcium-Ca, Magnesium-Mg) in the ungrazed patches (with and without feaces) and also nutrient in soils (with respect to Phosphorus-P, Potassium-K, Calcium-Ca, Magnesium-Mg, Total Nitrogen-Nt, Carbon-Cox and pH/$CaCl_2$) at these same spot of ungrazed patches.

The study is specifically looks to find out if nutrient in herbage is affected by nutrient in soil (H_1) and also if treatments applied have effect on nutrients measured (H_1).
The study seeks to verify the dynamic relationship that exists between the different nutrients in soil and try to compare them with the nutrients in herbage.

The study also was to conduct analyses on the effect that the different treatments or management regimes will have on plant available nutrient (in soil) and then also nutrient in herbage. We will therefore compare and contrast all the above relationship and come out with a analyses how each nutrient and treatment performed in the 2 blocks and in the 4 different replications.

CHAPTER 2

2.1. LITERATURE REVIEW

Grazing generally describes a type of feeding, in which herbivores feed on plants (like grasses), and also on other multicellular autotrophs (like algae). Grazing differs from true predation because the organism being eaten from is not generally killed, and it differs from parasitism as the two organisms do not live together.

Grazing management is an important factor influencing grassland flora as well as fauna.

The grazing process is characterized by the animal factors with respect to selectivity of grazing, deposition of excreta and treading. And these factors affect the growth and botanical composition of pastures both separately of grazing and interdependently. To obtain optimum nutrient intakes, which control potential levels of animal production, the herbage on offer to grazing animals must be sufficient to satisfy appetite, be acceptable and of high feeding value. (Milan 2005)

A large proportion of the nutrients ingested by grazing stock are excreted in dung and urine. Excretion off the pasture, and the leaching, volatilization and immobilization of N from urine and patches are sources of loss from the soil fertility/grazed pastures nitrogen cycle. Urine deposition covers large area of the pasture in contrast to dung, and contains higher levels of available nitrogen and potassium so it's considered of value in stimulating pasture growth. The adverse effects of treading (hoof trampling), which increase as grassland use is intensified, may be kept at acceptable levels by management that is designed to maintain dense, vigorous and long-term sward of tolerant pasture species (Frame 1992).

When grazing increases, plant diversity primarily reduce by competition (Collins et al, 1998), and the spatial distribution of grazing may not matter. But grazing can also affect plant diversity by creating environmental heterogeneity at different spatial scales (McNaughton 1983**).**

Grazing offers a potentially important tool for conservation management because of its influence on habitat structure and biodiversity (Collins et al. 1998).

In this study, the influence of two grazing intensities, nutrient level in above-ground biomass and soils immediately below the above-ground biomass was studied.

The general idea is to look at the amount of nutrient in the above ground biomass in patches with and without Feaces.

2.2. Grazing Systems

Grazing systems are controlled grazing management practices that manipulate livestock to systematically control periods of grazing, deferment, or rest. An important consideration in creating grazing system is to select the best season of grazing or rest:

A grazing system regulates the length and timing of grazing periods in order to achieve the desired results with respect to forage and livestock production. Grazing systems must be tailored to fit the climate, soils, and vegetation of a given area as well as the objectives of the landowner.

A good grazing system is simple and flexible, and it provides for adequate utilization of forage, uniform distribution of livestock, and economic practicality.

Some objectives of a grazing system include:

- Carry out deferment, or rest, over a period of time so that preferred forage plants can replenish energy storage in the roots and restore vigor.
- To obtain uniform forage use within each land unit. Here, it important to note the rule of "use half and leave half". This allows enough leaves to remain for the grass to maintain healthy roots for the next year's growth.
- Allow management of livestock, forage plants, and other components of the grazing system so that production is increased or maintained on a sustained yield basis. The most commonly stated benefit of grazing systems is improved range condition resulting from increased plant vigor, seed production, and maintenance of preferred forage. These improved conditions increase forage yield and quality, thereby increasing animal production. The benefits gained from a grazing system will depend heavily on the site and forage species (Demers and Clausen, 2002).

Grazing period - The season and number of days during which a pasture is grazed.

Deferment - A delay of grazing (or a period of non-grazing) in a pasture until the key forage species set seed and seeds mature.

Rest - A period of non-grazing for a full year.

2.2.1. Rotational grazing system

Rotational stocking is the movement of livestock between pastures during the grazing season, concentrating their feeding on one pasture for a few days and then moving them to a new field that is ready to be grazed. Rotational grazing systems are sometime called paddock grazing systems.

Alternatively, paddock grazing can be referred to as a system of grazing management where livestock are grazed on a rotational basis within a large number of paddocks. Typically a paddock may be utilized for just a single day before the stock is moved on. The grazed paddock is allowed to rest and regrow for a suitable length of time. The time needed depends on the forage species and growing conditions.

The goal of rotational grazing management is to allow plants to produce large volumes of high quality leaf material by setting:

- Frequency
- Intensity and timing
- Duration of grazing

Under rotational grazing the area is divided into a series of fields or paddocks, which are, grazed in sequence each use being followed by a rest period. The period of time a pasture is allowed to recover between successive grazing is referred to as the rest period. The total length of the grazing plus rest period is called the rotational grazing cycle. A number of rotational methods are possible, varying from fairly rigid to extremely flexible, though all control access of stock to sward. Rotational grazing allows good forward budgeting of forage supply since the areas of growing grass in their various stages can be clearly seen and the amount of grass presented to the stock closely controlled. A high degree of management flexibility to match variability in grass growth is possible, including close integration with conservation; this entails regular monitoring of the sward and frequent decision-making to maintain herbage nutritive value at a high level (Frame 1992).

Advantages ascribed to rotational grazing include:

- Uniform areas (soil, slope) are camped separately so that areas with different production potentials can be treated separately to maximize production.
- Efficient utilization of the pasture is possible because varying periods of stay or different sized camps can be used to attain the required degree of utilization, or leader and follower herds can be used.
- Herbage of the desired quality (age of regrowth) can be offered to animals by adjusting the number of camps or the period of regrowth following utilization.
- During periods of drought or slow growth of the pasture, herbage can be rationed to the animals.
- Excess growth can be used for hay, silage or set aside for forage.
- It is easy to control the degree of defoliation to ensure that the pastures are maintained at high growth rates.
- The adverse effects that may result from applying nitrogen (high nitrate nitrogen in the herbage or spilling of fertilizers) can be reduced.
- With irrigated pastures the adverse effects of puddling and foot rot can be reduced by irrigating once the animals are removed from a camp.
- There is regular "informal inspection" of animals as they are moved from one camp to another and "unhealthy" animals can be spotted easily.
- Lick troughs are usually moved with the animals and shortages are easily noticed.

The disadvantages of rotational grazing include:

- Increased fencing and watering costs.
- Increased managerial time required.
- Application of fertilizer and establishment of the pasture could be a problem with small areas (well-designed electric fencing can help to alleviate these problems).
- Access, to each camp, by animals and machinery could be a problem.
- Increased labor is required to move stock and lick troughs.
- Compared with continuous grazing, animals are disturbed relatively frequently.

2.2.2. Continuous grazing system

Continuous grazing, Set stocking, or Continuous stocking is the grazing of one pasture for a long period. It occurs when a group of stock has access to just one area of grassland for the whole season and in a pure sense is only found in extensive grazing systems.

Frame (1992) describes this as free-range, uncontrolled grazing of stock on fields for a prolonged period, often the whole grazing season. Stocking rates may vary during this time; where they remain fixed for a particular period the term set stocking is sometime used. When grass is scarce, notably in the spring, the grazed area may be augmented by a buffer grazing area.

In general, all continuously grazed pastures are grazed during whole the vegetation period (Klapp 1971). They often are characterized by a heterogeneous mosaic of the sward structure, in which heavily utilized areas alternate with lightly or not at all utilized patches and a transitional zone of intermediate utilization (Hirata 2000, Cid Brizuela 1998).

Right at the onset of a continuous grazing season, defoliation takes place only in parts of the total area, because animals are not able to remove the exact quantity of herbage in when the objective is to obtaining a uniform sward. The grazing animals initially don’t show strong selective behavior, but instead graze randomly across the undisturbed, homogeneous sward. This initial uneven utilization is theoretically given a greater opportunity to develop in the case of high surplus of forage or low stocking rate, or of course any combination of them. If a pattern of sward heights is created, the animals prefer the heavily grazed low areas above taller. (Illius et al. 1987). This selective grazing was demonstrated to be due to resulting nutritional differences in such areas. Lower patches are marked by regrowing young biomass rich of leaves and therefore showing high digestibility and nutrient content. Tall patches on the other hand are rather characterized by high amounts of mature and stemy herbage and higher proportion of senescent plant material. Digestibility and nutrient content therefore are lower in these (Bakker et al. 1983, Illius et al. 1987).

The term continuous stocking is preferred to continuous grazing since individual tillers or leaves are not continuously grazed but in effect rotationally defoliated within the sward. The frequency of defoliation depends on the stocking rate, since stocks have free access to all the grazing area. Continuous stocking encourages the formation of a dense, well-tillered sward, with up to 20,000 to 30,000 tillers per square meter, which makes for long-term stability, resistance to poaching damage, prevention of weed ingrowths and tolerance of drought.

Continuous stocking often results in poor forage utilization in the spring when plant regrowth is rapid. If the animals are stocked to use the spring flush, there will not be enough forage during the summer to meet the herd's needs. When the pasture is stocked properly for summer forage production the manager should clip the pasture to remove grass seed heads and weeds. If the pasture is overstocked animal gains will be lower and the pasture will be overgrazed. This results in lower forage production and an open sward that is subject to erosion and weed invasion.

The advantages of continuous grazing include the following:

- Least management input of all the grazing systems, since the animals are placed in a camp and remain there for the growing season of the pasture.
- Least cost of all the systems with one boundary fence and possibly only one watering point.
- Least disturbance to animals since the animals does not need to be moved from one camp to another.
- Easy to keep grazing records.
- At light stocking rates good production per animal can be expected.

Disadvantages of continuous grazing include:

- The precise stocking rate needs to be known, otherwise it may be necessary to add animals or remove animals as the pasture growth rate varies over the season, or an area may have to be closed off.
- Seasonal fluctuations in yield are difficult to cater for (herbage cannot be rationed and it is difficult to make hay or forage in sections).
- Herbage cannot be rationed during drought periods.
- Area selection (particularly with sheep) leads to inefficient pasture growth rates and inefficient pasture utilization (some areas are defoliated severely and repeatedly while other areas may be rejected and become moribund).
- Application of fertilizer, particularly nitrogen, can cause distinct poisoning problems, both from the high nitrate content in the herbage following fertilization and from fertilizer lumps and spills during application.
- Since the animals are not moved from camp to camp, continuous grazing tends to lead to complacency and the animals often are not "seen" for extended periods, with the result that sick animals or animals in poor condition often are noticed

only after the "poor" condition has become so severe that it has affected profitability.

- Supervision of licks and water points is often neglected.

2.2.3. Strip grazing system

Strip grazing is regarded as a refinement of rotational grazing, and it is a management system that involves giving livestock fresh allocation of pasture every day. It is usually organized within a paddock grazing system and the animals are controlled by the use of electric fence.

Strip grazing systems are often employed where there is a significant excess of forage early in the season and where providing the livestock with access to a larger area would result in waste – for example through trampling or spoilage by dung. Strip grazing systems are widely used in the dairy sectors and for beef and sheep, where these animals are being provided with root crops as their forage.

2.3. Botanical Composition

Extensive grazing with beef cattle offers opportunities for the restoration of biodiversity in formerly intensively used grasslands (Isselstein *et al*., 2001

The biodiversity of grasslands, and the forage nutritive value, are influenced by various factors, among them are the effects of fertilization and the effects of defoliation are very important (Nösberger and Rodriguez 1996).

The composition and diversity of the community may also be influenced by grazing livestock. In particular, animals may significantly influence the physical structure of the community through the partial or complete destruction of the canopy of competitive and dominant species. This may arise either directly, through the effects of defoliation, or indirectly, through the effects of the treading, urine scorch and burrowing or scraping by livestock (Grime 1979). The effect of this disturbance is to create a niche which opportunistic ‘ruderal’ species can exploit free from competition (Grime 1979, Smith and Rushton 1994).

Grazing animals can also influence the spatial diversity and botanical composition of a pasture community. That animals are selective in their grazing habit is well established (e.g. Gibb et al. 1989). This behavior creates spatial heterogeneity in the canopy architecture of the community, with the mean canopy height being shorter in the more frequently grazed patches than in the less grazed patches. This difference in canopy architecture creates niches for plants of contrasting growth habit (Putman et al. 1991) and leads to the establishment of a mosaic of sub habitats within the pasture communities. Furthermore, excretion of dung and urine by grazing animals leads to a localized accumulation of nutrients. The elevated fertility of the affected areas will favor more competitive species, such as *Lolium perenne* and *Trifolium repens*. The patchy distribution of excreta will create further sub habitats, which ad to the spatial diversity of the pasture community.

2.3.1. Sward Structure

Structure is the physical organization or pattern of a system from, the habitat complexity as measured within communities to the pattern of patches and other elements on a landscape scale (Nösberger and Rodriguez 1996).

Features of the structural differences of pastures are due to decisions made by grazing animals on when and where place a bite. Grazing intensity is a key management variable that influences the structure and composition of pastures. A decrease in grazing intensity is assumed to favor biodiversity as a result of the increased heterogeneity of pastures (Grime, 1979).

2.4. Patch grazing

Patch grazing (which is synonym to spot grazing) is the close and often repeated grazing of small patches or even individual plants, while adjacent but similar patches or individual plants of the same species are left ungrazed or only lightly grazed (Willms et al. 1988).

Patch grazing is an inefficient utilization of forage since a significant portion of the major forage plants are not grazed, or grazed only after they have deteriorated from weathering, while others are damage by repeated close grazing.

Defoliation and other effects can be the cause of patch grazing. Nearby patches of grazed and ungrazed vegetation frequently emerge, not because the animal cannot search the whole area, but because of factors affecting preference for individual plants or clusters of plants over others (Kothmann 1984). Patch grazing is a frequent occurrence on sites with high plant density and productivity and with species of relatively lower palatability, especially when grazed only during advanced growth stages. Ungrazed patches of perennial forage plants in one year tend to be perpetuated as ungrazed patches the following year. However, under summer season, long grazing in the mixed prairie with steers, the development of ungrazed patches depended mostly on not being grazed at the beginning of the grazing season (Ring et al. 1985).

Patch grazing often occurs when forage supply exceeds livestock demand and grazing animals have the luxury of choice to graze selectively and is more characteristic of season-long stocking (Kothmann 1984).

Distinct patches of ungrazed vegetation surrounded by areas of grazed vegetation are even found on short grass range under both light and moderate grazing and to a lesser extent under heavy grazing (Klipple and Costello 1960).

It is a common observation that some individual plants in a population of a given species are utilized much more intensively than others. Wolf plant is a term that refers to individual plants of a species generally considered palatable but still remains ungrazed when exposed to grazing. It is mostly a matter of chance that these individual plants have access to more soil resources or receive less utilization (Caldwell 1984).

The problem is minimal on arid and semiarid rangelands, except in animal concentration areas at water, permanent supplemental feeding areas, and under shade, but can be severe on meadows and highly productive grassland. Under Intensive pasture system in temperate areas, where a grazing season may be 180 days, up to 45% of the area may be covered with herbage rejected by cattle by the end of the grazing season (Simpson and Stobbs 1981).

The spatial distribution of the patches can affect diet selection by grazing animals and so probably their impact on grasslands (Dumont et al. 2000).

The reduction in herbage intake and animal production associated with the fouling from dung appears greatest at intermediate grazing pressures but minimal at either very low or very high grazing pressure. With very low grazing intensity, herbage intake would not be affected because there is plenty of unfouled forage. With very high grazing intensity, herbage intake would not be affected because intake of all animals is depressed by low herbage availability, and this overrides the tendency to reject on affected spots.

Smell seems to be an important consideration when it comes to the rejection of a grass type.

Sheep show only minimal aversion to herbage around their own Feaces, except around sheep camps where it is often very dense (Arnold and Dudzinski 1978). Whereas cattle reject forage growing in proximity to cattle dung but will graze close to sheep dung, sheep will accept forage growing close to dung from either species (Forbes and Hondgson 1985).

2.4.1. Cover

Cover is the projection of plants or plant parts on the soil surface. Measurements of cover can be expressed either as the percentage of the soil surface covered by the plants or plant parts or can be broken down into the species or groups of species. It can be measured as either basal cover or canopy cover (Whalley and Hardy 2000).

2.4.2. Basal cover

The basal cover represents the proportion of the ground occupied by the bases (where they are rooted to the ground) of the individual species. Because measurements are made at ground level, there cannot be any overlap and so the total cannot be more than 100%. Again, the percentage of the area occupied by bare ground, litter or stones can be estimated simultaneously. This may be particularly in semiarid and arid grasslands, where the percentage plant basal cover may be quite small.

Basal cover is a more stable property of vegetation than canopy cover. It is less affected by prior grazing or seasonal conditions, particularly with perennial species.

2.4.3. Canopy cover

Canopy cover is the projection of the plant canopies on to the soil surface, usually expressed as a percentage. The canopy cover of an area of grassland can change dramatically in a very short period of time, e.g. by grazing or fire, and regrowth may be slow or rapid, or may be stable, e.g. the canopy cover of the shrub component of semi-arid grass/shrub communities. Because the canopies of different individuals and different species can overlap, the total can add up to more than 100%.

Canopy cover is related to sward structure. The percentage of area covered by bare ground, stones or litter can also be estimated at the same time.

Measurement of canopy cover in grassland can often be difficult because the grass leaves may have a vertical or near vertical orientation. The very act of walking about in the grassland can often cause these leaves to become horizontal and therefore effectively increase the canopy cover. Care must be taken that canopy cover is not substantially affected by sampling activities.

The usual method of estimating canopy cover is to use a point quadrate frame, such as Levy Bridge (Levy and Madden 1933, Brown 1954), where the points can be slowly lowered through the vegetation and hits of individual leaves recorded. Where the leaves of individual species can be identified from their morphology, the contribution of the leaves of different species to the canopy cover can estimate. The use of point quadrates to estimate canopy cover in tall grasses is impossible in windy weather and when the height is more than 0.5 m.

Norman and Campbell (1989) defined canopy structure as the amount and organization of aboveground plant material.

2.4.4. Techniques in measuring sward canopy

Sward height and density are the two main characteristics influencing herbage mass and its visual appraisal. Both have featured separately or together in a large number of techniques for estimating herbage mass. The speed and simplicity of sward height observations is advantageous for taking numerous measurements on non-uniform grazed sward; however height measurements are most accurate in short swards of simple botanical composition and uniform density. Progressive overestimation of herbage mass occurs with increasing sward height because a high proportion of herbage is concentrated in the lower layers of the sward (Frame 1993).

Castle (1976) described one version of a settling-plate instrument and its evaluation on both cut and grazed sward. His method is quick, allowing 50 readings per 15 minutes in

a field of 2.5 ha, minimal training is necessary and the instrument can be made easily and cheaply.
Earle and McGowan (1979) described an automatic rising-plate meter, in which sward height correlated linearly with herbage dry matter mass cut to ground level.

2.5. The Effects of Grazing on Vegetation

The effects of grazing on vegetation tend to be explained primarily by visible, aboveground changes in the vegetation and litter structure due to defoliation and trampling. Tissue loss and modified light profiles may be major causes of changes in establishment, growth, competitive success and longevity (Ritchie and Olff 1999).
Short-term effects of dung and urine are also apparent. Long term changes in the nutrient availability are less easy to asses (Milchunas and Lauenroth 1993). Nevertheless they might play a key role, especially in nutrient- poor environments (Berendse 1985, Jefferies Klein and Shaver 1994, Jefferies 1999). Nutrient may affect plant production, nutritional quality and resistance to herbivores and defoliation tolerance (Lambers Chapin and Pons 1998, Milchunas, Lauenroth and Burke 1998). Herbivores move nutrient directly by ingestion, retention and excretion and indirectly by modifying mineralization, dry deposition, leaching and erosion. They change pathways (De Mazancourt et al. 1998), flow rates (Pastor et al. 1993) and pools (Milchunas and Lauenroth 1993). Positive nutrient-mediated feedback may stabilize or intensify the grazing pressure on grazing lawns (McNaughton 1984). Negative feedback may induce abandonment after declines in production and nutritional quality, and an increase in the intrinsic resistance.

Freely grazing animals distribute fertilizers inefficiently; excreta tend to be deposited most heavily where the forage is produced and consumed (Simpson and Stobbs, 1981). A lower nutrient availability might induce higher lignin and tannin concentrations according to the carbon-nutrient ratio hypothesis (Bryant, Chapin and Klein 1983, Hobbie 1992, Iason and Hester, 1993). Neighboring plants may provide associational resistance or associational palatability (Huntley 1991, Hester et al. 1999, Olff et al. 1999).
Plants have several anti-herbivore defenses including high concentrations of silica in lower leaves, growing meristems, high levels of the fiber and low levels of protein and a variety of defense compounds (Vicari and Bazely 1993). Several plant traits confer resistance to both herbivory and environmental stress. For example, high tissue density, tough, fibrous leaves and high concentration of secondary compounds confer resistance to herbivores and stress (Chapin 1980; Chapin et al. 1990, Grubb 1992). In addition, many traits allowing to with stand grazing may actually be adaptation to a semi-arid environmental (Coughenour 1995).

2.6. Effects of Grazing on Soil

All grazing land receives treading to a greater or lesser extent as a natural consequence of grazing. Treading of soil by grazing animals has the potential of being deleterious to soil in the following ways:

a) Compacting the soil,
b) Penetrating and disrupting the soil surface,
c) Reducing infiltration,
d) Vertical displacement of soil on steep slopes,
e) Developing animal traits, and
f) Increasing erosion.

The interaction of many site, soil, weather, and vegetation factors will determine the severity of hoof action on the soil; the effects will range from inconsequential, or less commonly beneficial, to very destructive.

Livestock grazing affects watershed hydrologic properties by potentially removing protective vegetation as well as causing trampling disturbances. Reductions in the vegetation cover may:

a) Increase the impact of raindrops,
b) Decrease soil organic matter and soil aggregates,
c) Increase surface soil crusting, and
d) Decrease water infiltration rates (Blackburn 1983).

These effects may cause increased runoff, reduced soil water content, and increased erosion. Historically some grazing studies have only led to an erroneous conclusion that livestock grazing is necessary synonymous to heavy damage to watershed.

Freely grazing animals inefficiently distribute excreta, both manure and urine; excreta is deposited most heavily where animals spend the most time rather than where the forage is produced and consumed. Thus, forage producing parts of the grazing unit become progressively more deficient in soil nutrients removal being greatest on sites most selected for grazing, while animal concentration areas near water, salt feeding areas, bed grounds, shade, and selected level areas are enhanced with soil nutrients. Urine is particularly involved in the redistribution of nitrogen but also potassium, magnesium, and sulfur, while a large assortment of minerals including phosphorous and potassium are passed through the manure (Gerrish et al. 1995). The fertilizer effects are primarily found on the immediate area covered by Feaces and urine with lesser effects out to 2 to 3 times this area.

Fecal nitrogen is largely insoluble and becomes available to plants only after incorporation into the soil by soil fauna and mineralization by microorganisms; the nitrogen in urine returns to the soil more rapidly than through senescence-decomposition pathways, but this also introduces the potential for greater nutrient losses (Lauenroth et al. 1994).

About 75% of the nitrogen and phosphorous and from 80 to 90 % of the potassium normally passes through the animal, but the losses are both irregular and substantial. While only minimal amounts of nitrogen and other nutrients are exposed from the site as animal tissue, high stocking rates and forage utilization efficiency can gradually deplete soil nutrients. Even higher nutrient losses may result nitrogen volatilization, nutrient redistribution to unproductive sites, and water transport through leaching and soil erosion from accumulations sites. However, the general conclusion is that grazing does not seriously increase nutrient losses from grazed ecosystems. The management goal should be keep manure evenly distributed over the grazing land unit to maintain soil fertility (Heady and Child 1994). Areas receiving excess excreta often received excess trampling as well; while providing extra fertility, the combined effects may be to dramatically alter vegetation composition and permit the entry of undesirable weedy vegetation.

2.6.1. Nutrients in dung and urine

There are major differences between nutrient in dung and urine and in amounts and availability for plant growth. Dung mainly consists of indigested herbage cellulose and lignin residues, waste mineral matter and living or dead ruminant micro-organisms together with their metabolic products. The water content is around is 85% in cow dung and 65% in sheep dung. Considerable quantities of silica may be present as a result of eating soil-contaminated herbage, although ingested soil also supplies some minerals. Urine is largely (90%) water, plus nitrogenous compounds from the breakdown of protein, sugar substances and other end products of metabolism, with some mineral matter. The proportion of excreted N in urine increases with increasing N in the diet. A typical analysis of the major elements in dung and urine is shown in table 2d.

Of the total nutrients excreted, dung contains 20 to 30% of the nitrogen, almost 10% of the phosphorous and calcium, 10 to 20% of the potassium and 30 to 40% of the magnesium and sulphur. Since dung and urine are deposited in small patches, there is a very high local concentration of nutrients in these patches. Estimates for the three major nutrients place the localized rates at 700 to 800 kg $N.ha^{-1}$, 250 to 500 kg $P_2O_5.ha^{-1}$ to 400 kg $K_2O.ha^{-1}$ for dung and 300 to 450 kg $N.ha^{-1}$, 25 to 50 kg $P_2O_5.ha^{-1}$ 700 to 800 kg $K_2O.ha^{-1}$ for urine. Value can also be ascribed to other nutrients, including trace elements.

Table 2d. Major elements in dung and urine		
Elements	**Dung (g.kg^{-1} DM)**	**Urine (g.kg^{-1})**
Nitrogen	20	10
Phosphorous	10	0,3
Potassium	10	10
Calcium	10	0,6

In urine, nitrogen and potassium are almost all in readily available form. Because of rapid hydrolysis of urea, which constitutes the major fraction of urinary nitrogen, and the high local pH engendered, is lost by volatilization of ammonia. Weather is again important, since rainfall causes leaching of the urea, and of nitrites and nitrates from ammonia nitrification, while volatilization is increased under hot, dry conditions (Frame 1992).

2.6.2. Nitrogen and phosphorous in grasslands soils

The requirements, roles and functions of N and P in pasture management for both plants and animals are well known and have been reviewed extensively over the years (Whitehead 1995, Tunney et al. 1997). The behavior of the two nutrients within ecosystems is quite different. Substantial amounts of the N, on the one hand, are either mobile or have the potential to be converted into mobile forms, and N is therefore considered to be 'non-conservative'. Most of the P, on the other hand, is immobile and regarded as being a 'conservative' nutritive in most circumstances. Their functions and requirements in plant and animal biomass are well defined and will not be discussed further here. Recent research has centered on their environmental impact 'downstream' from farming systems and these issues have been widely discussed and debated (Jarvis and Pain 1997, Tunney et al. 1997, Jarvis 1998).

2.6.3. Role of the grazing animal

On grasslands, animal productivity is a function of herbage accumulation, quality and efficiency of harvest by the grazing animal.

Large herbivores may have profound effects on grasslands particularly if grazing is intensive and occurs for a long duration. Cattle have preferred plant species which tend to disappear from intensively grazed pastures (decreasers) while other less palatable species may increase (increasers).

Large grazers can also affect the system by compacting soil, trampling the vegetation, and depositing urine and Feaces.

Other herbivores besides domestic livestock are usually present as well, though they tend to be less conspicuous than cattle. These can include antelope, ground squirrels, prairie dogs, rabbits, voles, and insects. Below ground, grasses are eaten by nematodes, micro arthropods (e.g., mites), macro arthropods (e.g., immature insects), and gophers.

In fact, there is evidence those nematodes may consume more plant biomass than any above-ground grazer, including cattle.

Grazing has been an immediate impact on soil N pools. First, the physiological controls over uptake of N by roots are severely disrupted when shoots are removed (frequently in the case of intensively grazed sward) and uptake does not return to normal patterns for a number of days afterwards (Jarvis and Macduff 1989), depending on the severity of the defoliation. There will also be an increase in the leakage of N and C compounds into rhizosphere of the plants, with consequences for the microbial populations there and their activities (Dawson et al. 2000). Over the long term, this will affect overall activities throughout the rooting zone soil, with implications for soil quality and functional sustainability.

An evaluation of grazing effects on vegetation structure and nutrient transfer (N and P) made in native grasslands in the flooding pampas of Argentina (Chaneton et al. 1996) showed that grazing:

- Generated a relocation of N and P in plants pools (80-90% and 63-75%, respectively in belowground biomass in grazed and ungrazed pastures;
- Resulted in less P in graminaceous plants than in forbs ; and
- Resulted in greater nutrient uptake (by 30-50%), concomitant with enhanced mineralization rates and generally accelerated cycling rates.

Perhaps of even greater significance to nutrient cycling within grazed systems is the return of nutrient (especially N) in excreta. Ingested N is poorly utilized by ruminants, with only small proportions of intake being incorporated in body tissues or products. ‘Harvest’ of N into product is therefore lower than in arable agriculture and much is excreted into dung and urine and deposited in localized, discrete areas in pastures. The amounts of N excreted depend very much on the N inputs to the system and the content in the diet; whereas excretion in dung remains relatively constant, that in urea is responsive to N intake (Jarvis et al. 1989).

Excreta returned to the sward, especially urine, create ‘hot spots’ of high N (and other nutrient) content, activity and potential for immediate transfer from the system. Some of this may be volatilized as NH_3 or denitrified, but it will almost always be in excess of immediate local crops demands for N. There will also be an immediate impact on soil microbial processes and activities.

2.7.1. Intensively used grassland

Natural grasslands deriving from forest where utilized by uncontrolled grazing for an indefinite period, but normally the whole grazing season. The soil was transformed to arable crop husbandry while herds and flocks transumed with their herdsmen and shepherds from one place to another to graze what the natural grasslands could offer.

The history of intensive agriculture starts only around the middle of the 16th century when forage legumes were introduced into arable crop rotation (Giardini and Cinti 1985). After Second World War grassland production was largely based on fertilizers-nitrogen (N) and re-seeding of improved species in the north-western European counties and productivity increases markedly (Frame et al. 1995). In Czech Republic, grasslands improvement continued until the change of the political regime in 1989. In many cases the improvement was not successful and led to the infestation of meadows by weedy species like *Rumex obtusifolius, R, crispus, Taraxacum spp., Elytrigia repens, Holcus mollis* (Pavlů et al. 2003).

Intensive grazing systems may involve some form of rotational grazing such as strip or paddock grazing, or continuous stocking. Studies of both the carbon balance of sward and the rate of growth of individual tillers led to grazing management based on sward surface height (Parsons et al. 1991). On highly productive grasslands, intensive use may include grazing and cutting for hay reasons.

2.7.2. Extensively used grassland

Extensive use of grasslands is mostly practiced on shallow soils, in difficult climatic conditions and with severe lie of the land.

Everywhere in Europe, measures potentially useful for the environment including grassland in land use plans are being adopted. Some important plant communities depend, for their survival, on extensive farming. For example, if species-rich hay meadows are cut when mature, their nutritive value is low but it allows seed shedding to replenish soil seed reserves. However, this system can be adopted only in extensive systems and feeding animals with low nutritional demands.

2.7.3. Compressed Sward Height Method (CSHM) by Rising Plate Meter (Castle 1976)

This method is most suitable for measuring productivity and large scale monitoring points. These methods were adopted from Correll's (2001) thesis. The Rising-Plate-Meter is an instrument consists of two light and linked horizontal discs and an upright cm-marked shaft (1.20 m), all made of aluminum. The discs are fastened horizontally to the shaft, but are still able to glide freely up and down in the vertical plane. In use, the shaft was held upright above the sward-canopy and then gently lowered to the ground, allowing the larger bottom disc to settle to a certain height position on the vegetation. The sward height then was read with an accuracy of 0.5 cm from the relative position of the upper, smaller disc to the shaft. As the lower disc was 30 cm in diameter and both discs including the three small linking rods together weighed exactly 200 g, a pressure of 2·8 kg/ m^2 was applied to the sward during the measurement. The determined height nevertheless does not only depend upon the real herbage height, but is additionally influenced by other parameters, mainly disc pressure, number of tillers present and the rigidity of leaves or tillers supporting the disc (Virkajärvi 1999). It is therefore often referred to as Sward-Height-Density, summarizing the afore mentioned factors in the term ‘density’. This magnitude is usually well-correlated to the corresponding standing herbage mass (HM) and, according to its nature, is called Compressed-Surface-Height (CSH, e.g. Frame 1993).

CHAPTER 3

3.1. MATERIALS AND METHOD

3.2. Description of Study Site

The study was performed on an experimental pasture site of the Research Station for Grasslands Ecosystems, Liberec, Czech Republic, during the vegetation period of May to October 2013. The research pasture is located close to the small village of Oldřichov at the south – western part of the Jizera hills, better known Giant Mountains (Krkonoše), lat. 50° 50' N, long. 15 06' E

3.3. Ecological Characteristics

The climate in the district of Oldřichov is mainly characterized by long snowy winters, and relatively wet summers. It is nevertheless also influenced by the warmer and dryer condition of the neighboring South–Eastern German lowland region.). The mountains form the natural frontier to Germany and Poland. The site is 420m above sea level. The average total annual precipitation in the region is 803 mm and the mean annual temperature is 7.2°C.

The experimental plots were established in 1998 on an earlier occasionally cut or mulched meadow**.** Situated on a south west exposed slope, the bedrock is formed of biotic granite and overlain by a typical brown soil (cambisol). The soil shows a weak acid pH-value (pH (H_2O) =6.25; ph (KCl) =5.45) and at the research site it is predominantly quite shallow. The botanical state of the site initially (before the start of the whole trial) was classified as mesofile meadow, belonging to the phylosociological union of *Arrhenatherion* (Moravec et al. 1995). The most dominant species were determined to be common bent grass (*Agrostis capillaries*), meadow foxtail (*Alopecurus pratensis*) red fescue *Festuca rubra*, ground elder (*Aegopodium podagraria*) and hedge bedstraw (*Galium album*) Pavlů et al. (2001). The nomenclature of species is according to Kubát et al. (2002).

3.4. Experimental Design

The experimental plot was divided into 8 small managed paddocks by electric fences.

Next to the experimental units, two small control plots remained unmanaged and also fenced.

The experiment was arranged in 2 completely randomized blocks.

Three type of non-grazed patches were identified and studied:

- Non-grazed patches with feaces under intensive grazing treatment- IGF
- Non-grazed patches with feaces under extensive grazing treatment - EGF
- Non-grazed patches without feaces under extensive grazing treatment – EGNF

There were 4 replications

The paddock area for each IGF, EGF and EGNF plot was approximately 0.35 ha, whereas the control area was 0.12 ha only. The pasture was continuously stocked with growing heifers (Holstein breed) of 150–220 kg initial live-weights.

3.6.1 Method 1:

Places with adequate above-ground biomass of ungrazed patches (with feaces and without feaces) were selected and sward heights recorded (with an accuracy of 0.5 cm) by use of the Rising-Plate-Meter which is an instrument made of aluminum. Four separate above-ground biomass samples were collected from these ungrazed patches on 2 different patch types – those with feaces and those without feaces.

The samples were oven dried at 80°C until an even consistency of dry matter obtained. The dried sample was grinded and approximately 500grams was packaged and sent accredited laboratory, (Ekolabˇ Zamberk) for analysis

3.6.2 Method 2:

In each plot, four separate soil samples were taken at 10cm in depth, after removing plant biomass. Soil chemical analyses were performed in an accredited laboratory to determine content of P, K, Ca, Mg, Cox, Nt, and pH/$CaCl_2$.

3.6.3 Statistical Analyses

A single-factor ANOVA was used to evaluate the effect of treatment on the individual amount of nutrient in herbage and soil, considering patches with Feaces and patches with No Feaces, in block 1 and block 2.

The relationships between nutrient in herbage, and soil were analyzed by linear regression analysis. All analyses were performed in Statistica 9.0 program (www.statsoft.cz).

CHAPTER 4

4.1. RESULTS

4.2. Relationship between nutrients and treatments applied

The relationship between nutrients in herbage and treatment were analysed by linear regression analysis. All analysis was performed with the Statistica 9.0 programme.

The figures below are results of nutrients that show differences between herbage and soil, all the other figures are represented in appendices.

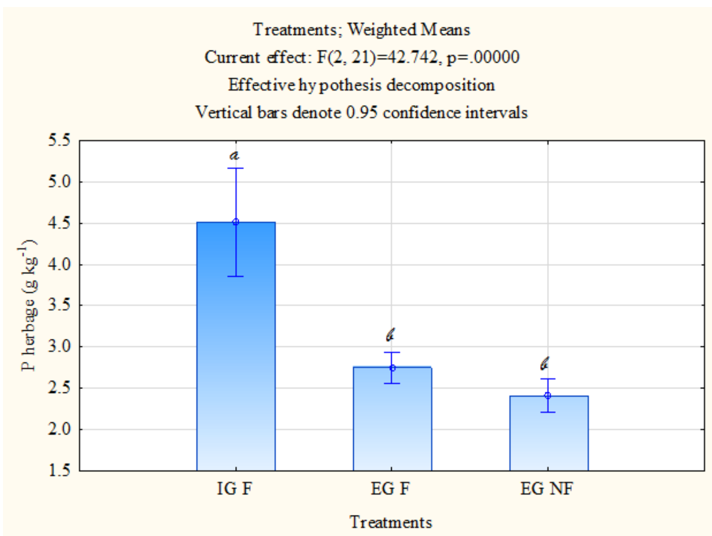

Figure 8a. – Relationship between Phosphorus in Herbage and treatments applied

From Figure 8a, there are differences existing between the treatment means of IGF and EGF on Phosphorus in herbage. Differences also exist between the effect of IGF and EGNF on herbage, however, non-significant differences was recorded between EGF and EGNF. This was in consistency with results recorded in the post hoc Tukey test shown in Appendix T 3a.

4.2.1. Relationship between Phosphorus in Herbage and treatments applied

In Figure 8a, the data show $F(2, 21) = 42.742$, $p<0.05$, we Reject the Null Hypothesis (and Accept the Alternate Hypothesis), and say that the various treatments applied have significant effect on the Phosphorus measured.

Post hoc comparisons using the Tukey HSD test indicated (Appendix T 3a, & Figure 8a) that the value for IGF & EGF, and IGF & EGNF ($p<0.05$) was significantly different. This difference is not due to chance.

However, the EGF & EGNF ($p>0.05$), did not significantly differ from each other.

This is in accordance with Pavlu et. al (2012), which states that, "Effect of treatment on plant available P concentration in the soil and in the total aboveground biomass was only marginally significant".

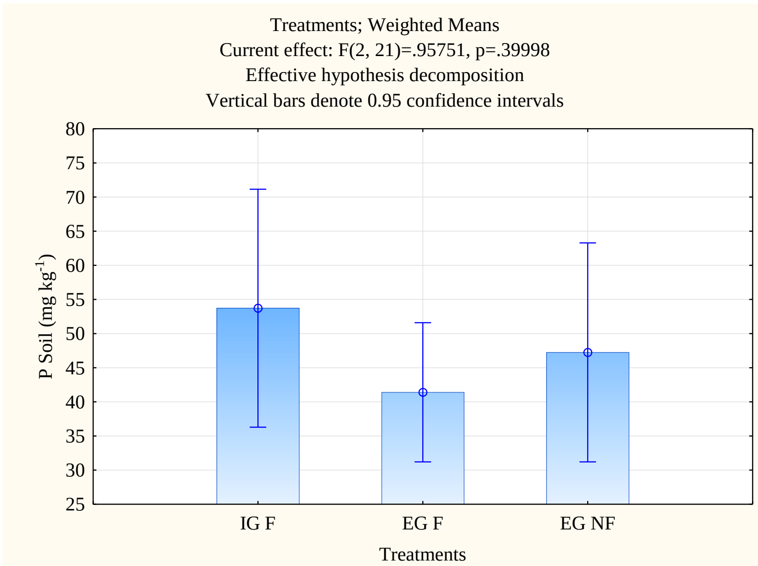

Figure 8b. – Relationship between Phosphorus in Soil and treatments applied

4.2.2. Relationship between Phosphorus in Soil and treatments applied

In Figure 8b, the data show F (2, 21) =0.95751, p > (0.05), we Reject the Alternate Hypothesis (and Accept the Null Hypothesis), and say that the various treatments applied have no significant effect on the nutrient measured. In other words, no significant differences between the treatments means and Phosphorus in Soil

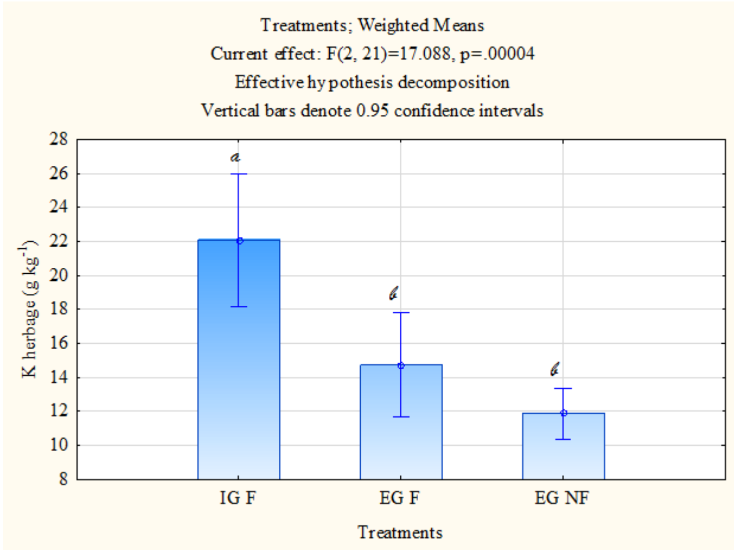

Figure 9a. – Relationship between Potassium in Herbage and treatments applied

4.2.3. Relationship between Potassium in Herbage and treatments applied

In Figure 9a, the data show F (2, 21) =17.088, $p<0.05$, we Reject the Null Hypothesis (and Accept the Alternate Hypothesis), and say that the various treatments applied have significant effect on the Potassium measured.

Post hoc comparisons using the Tukey HSD test indicated (Appendix T 4a, & Figure 9a) that the value for IGF & EGF, and IGF & EGNF ($p<0.05$) was significantly different. However, the EGF & EGNF ($p>0.05$), did not significantly differ from each other.

There is difference existing between the treatment means of IGF and EGF on Potassium in herbage. Differences also exist between the effect of IGF and EGNF on herbage, however, no significant differences was recorded between EGF and EGNF. This was in consistency with results recorded in the post hoc Tukey test in Table Appendix T 4a.

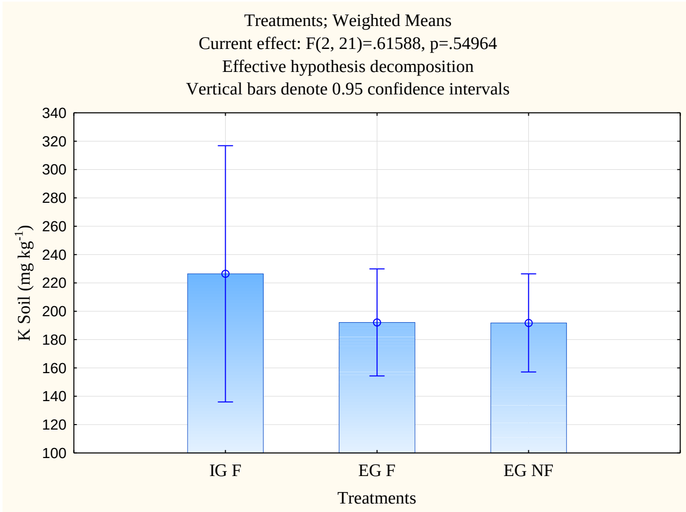

Figure 9b. – Relationship between Potassium in Soil and treatments applied

4.2.4. Relationship between Potassium in Soil and treatments applied

In Figure 9b, the data show F (2, 21) =0.61588 p>0.05, we Reject the Alternate Hypothesis (and Accept the Null Hypothesis), and say that the various treatments applied have no significant effect on the potassium measured.

4.2.5. Relationship between Calcium Herbage and treatments applied

In Appendix F 10a, the data show F (2, 21) =1.6466, p>0.05, we Reject the Alternate Hypothesis and (Accept the Null Hypothesis), and say that, the various treatments applied have no significant effect on the Calcium measured.

This is in accordance with the results of Pavlu (2013), who sad that “Concentrations of Ca were not affected by the different treatments”

4.2.6. Relationship between Calcium Soil and treatments applied

In Appendix F 10b, the data show F (2, 21) =0.375482, p>0.05, we Reject the Alternate Hypothesis (and Accept the Null Hypothesis), and say that, the various treatments applied have no significant effect on the Calcium measured.

This is in accordance with the results of Pavlu (2013) who sad that “Concentrations of Ca were not affected by the different treatments

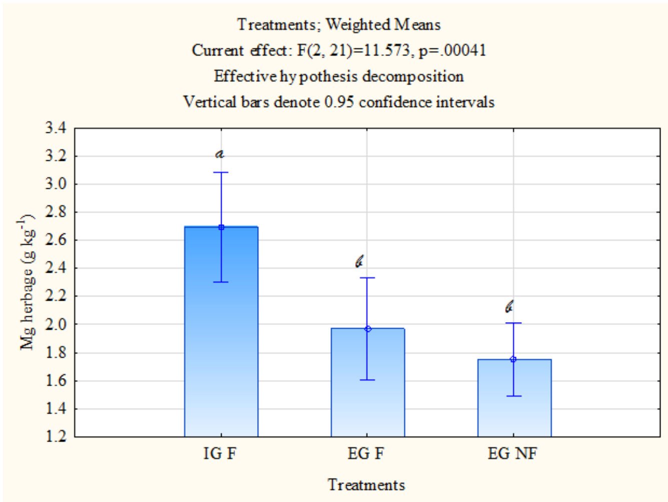

Figure 11a. – Relationship between Magnesium Herbage and treatments applied

4.2.7. Relationship between Magnesium Herbage and treatments applied

In Figure 11a, the data show F (2, 21) =11.573, $p<0.05$, we Reject the Null Hypothesis (and Accept the Alternate Hypothesis), and say that, the various treatments applied have significant effect on the Herbage measured.

Post hoc comparisons using the Tukey HSD test indicated (Appendix T 6a, & Figure 11a) that the value for IGF & EGF, and IGF & EGNF ($p<0.05$) was significantly different. However, the EGF & EGNF ($p>0.05$), did not significantly differ from each other.

There is difference existing between the treatment means of IGF and EGF on Magnesium in herbage. Differences also exist between the effect of IGF and EGNF on herbage, however, no significant differences was recorded between EGF and EGNF. This was in consistency with results recorded in the post hoc Tukey test in Table Appendix T 6a.

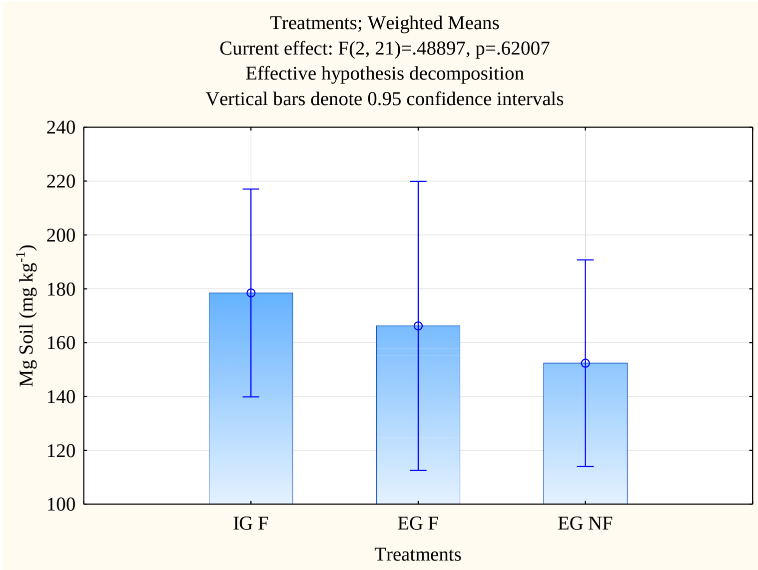

Figure 11b. – Relationship between Magnesium Soil and treatments applied

4.2.8. Relationship between Magnesium Soil and treatments applied

In Figure 11b, the data show F (2, 21) =0.48897, p>0.05, we Reject the Alternate Hypothesis (and Accept the Null Hypothesis), and say that, the various treatments applied have no significant effect on the Magnesium measured. This is in accordance with the results of Pavlu (2013) who sad that "Concentrations of Mg were not affected by the different treatments"

There are generally no significant differences between the treatments means of Magnesium in Soil.

4.3. Relationship between nutrient in Herbage and nutrient in Soil

The relationship between nutrients in herbage and nutrients in the soil were analyzed by linear regression analysis. All analysis was performed with the Statistica 9.0 programme.

The Pearson correlation was used to reveal that, there was a relationship between the amount of nutrients in herbage and in soil (P, K, Ca, Mg, and N.) at the same place. There was however no relationship found for any of the other tested nutrients (p=0.0558, r=0.3955; p=0.223, r-0.5927; p=0.0205, r=.4701; p=0.0223, r=0.4643; p=0.3853, r=0.1856) for P, K, Ca, Mg, N. respectively (Figures 1-5)

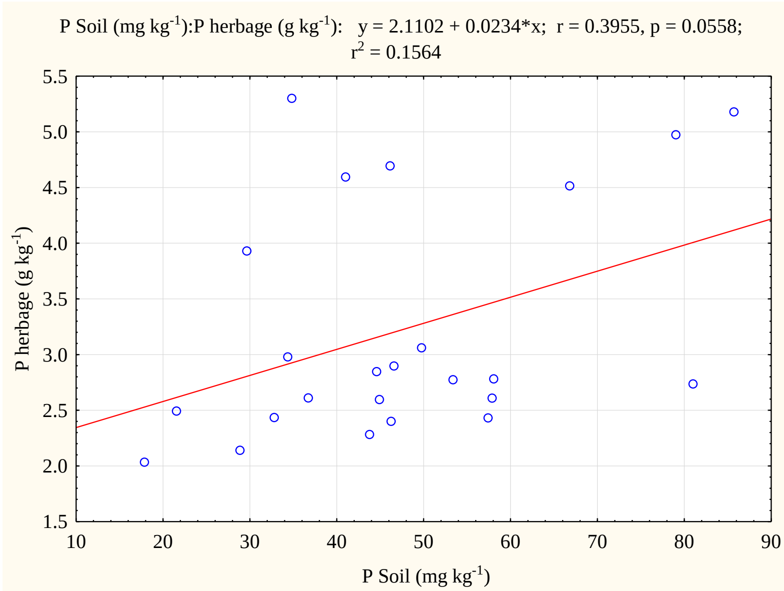

Figure1. – Relationship between Phosphorus in Herbage and Phosphorus in Soil

4.3.1. Relationship between Phosphorus in Herbage and Phosphorus in Soil

In Figure 1, the correlation (39%) is not strong enough to conclude that Phosphorus in the soil influence Phosphorus in herbage. The p value (0.0558) >α (0.05) and so was Not Significant.

So we Accept alternative hypothesis, and say that, P in herbage is affected by P in soil and Reject the null hypothesis, which says that P in herbage is not affected by P in soil.

The coefficient of determination $r^2 = 0.1564$ (15%), indicates a very weak relationship or no relationship between P in Herbage and P in soil, thus, we conclude that there is no relationship between the amount of P in Soil to P in Herbage.

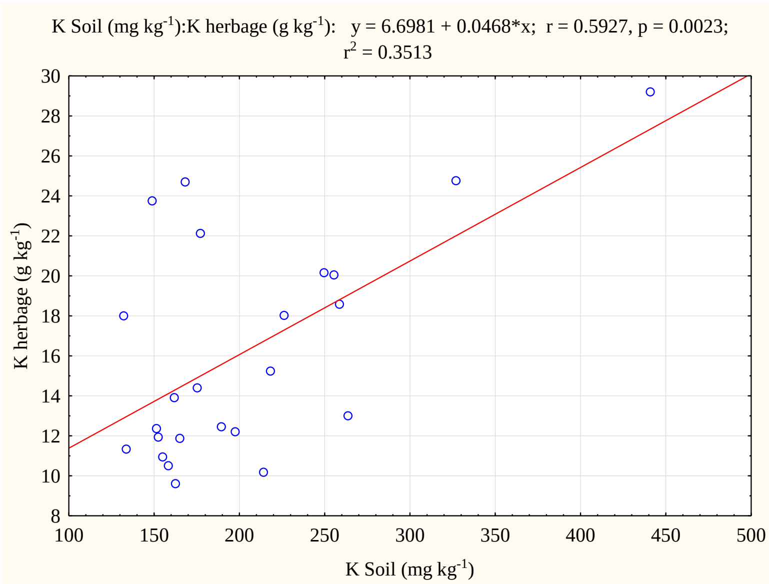

Figure2. – Relationship between Potassium in Herbage and Potassium in Soil

4.3.2. Relationship between Potassium in Herbage and Potassium in Soil

In Figure 2, there is a slightly strong correlation (59%) to conclude that Potassium in the soil influence Potassium in herbage. The p value (0.0223) <α (0.05) and so there was a Significant association between the dependent and independent variables.

This result is in accordance to Schaffers (2002), who reported that, K is the only nutrient which shows a strong relationship between plant-available soil and biomass concentrations.

So we Accept alternate hypothesis, and say that, K in herbage is affected by K in soil and Reject null hypothesis, which says that K in herbage is not affected by K in soil.

Furthermore, with r^2 of 0.3513, there is a low linear relationship or no relationship between the amount of K in the herbage and K in the soil.

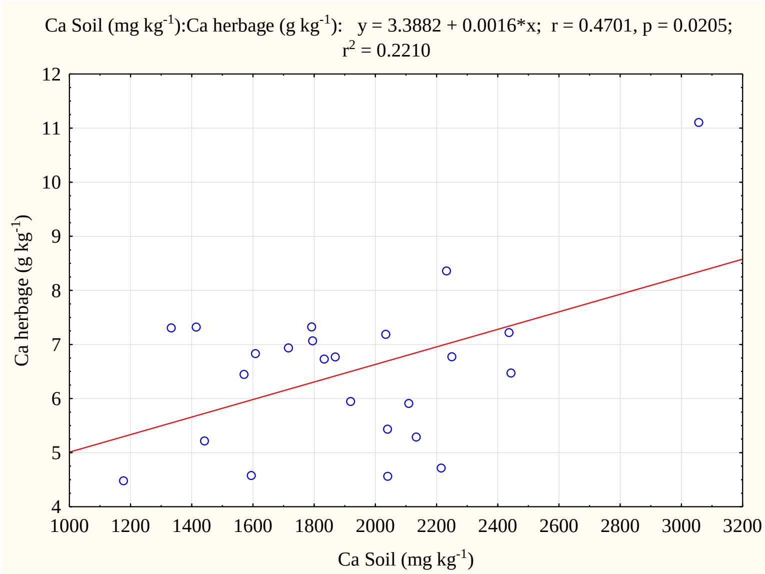

Figure3. – Relationship between Calcium in Herbage and Calcium in Soil

4.3.3. Relationship between Calcium in Herbage and Calcium in Soil

In Figure 3, there is a slight correlation (47%) that Calcium in the soil influence Calcium in herbage - P (0.0205) <α (0.05). it is thus Significant.

So we accept the null hypothesis, and say that, Ca in herbage is not affected by Ca in soil and Reject alternate hypothesis, which says that Ca in herbage is affected by Ca in soil.

The coefficient of determination (r^2) of 0.2210 (22%) depicts a weak predictive effects or no relationship of Ca in the soil on the Ca in herbage.

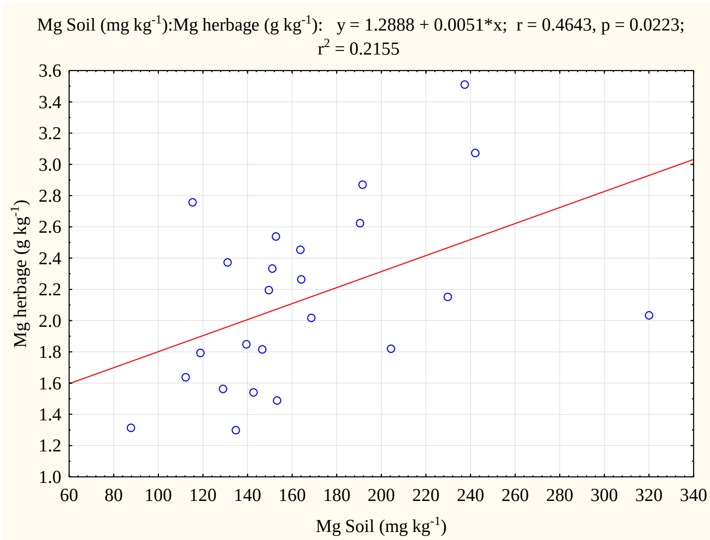

Figure4. – Relationship between Magnesium in Herbage and Magnesium in Soil

4.3.4. Relationship between Magnesium in Herbage and Magnesium in Soil

In Figure 4, there is a slight correlation (46%) that Magnesium in the soil influence Magnesium in herbage - P (0.0223) <α (0.05), which indicates a significant relationship. So we Accept null hypothesis, and say that, Mg in herbage is not affected by Mg in soil and Reject alternate hypothesis, which says that Mg in herbage is affected by Mg in soil With coefficient of determination (r^2) = 0.2155 (21%), we can say there is no relationship between the amount of Mg in Soil to Mg in Herbage.

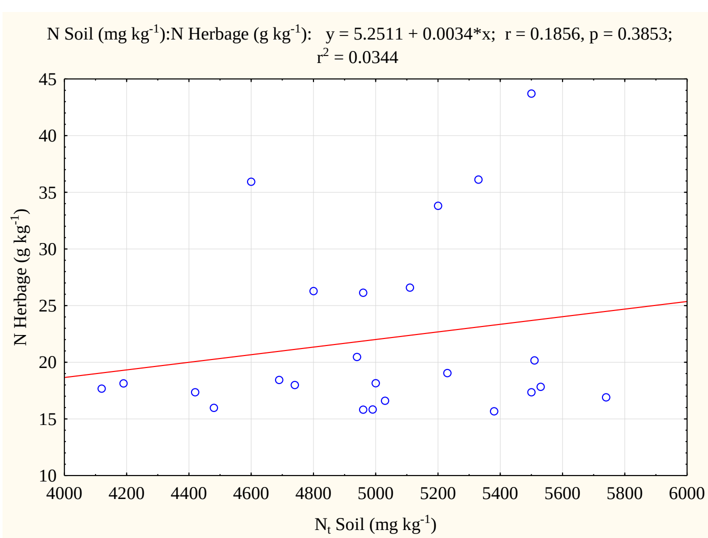

Figure5. – Relationship between Nitrogen in Herbage and Total Nitrogen in Soil

4.3.5. Relationship between Nitrogen in Herbage and Total Nitrogen in Soil

In Figure 5, there is virtually no correlation (18%) to say that Total Nitrogen in the soil influence Nitrogen in herbage - p (0.3853) >α (0.05), indicates that is Not Significant

So we Reject null hypothesis, which says that, Nitrogen in herbage is affected by Total Nitrogen in soil and Accept alternate hypothesis, which says that Nitrogen in herbage is not affected by Total Nitrogen in soil.

This is consistent with the works of other authors which says, N and P in herbage concentrations do not depend predominantly on their availability in the soil (Hejcman et al., 2010d; Janssens et al., 1998; Koerselman and Meuleman, 1996).

With r2 = 0.0344, we can say there is no relationship between the amount of Nt in Soil to N in Herbage

4.3.6. Relationship between Nitrogen Herbage and treatments applied

In Figure 12, data show F (2, 21) =1.9736, p<0.05, we Reject the Null Hypothesis (and Accept the Alternate Hypothesis), and say that, the various treatments applied have **significant** effect on the Nitrogen measured.

4.4. Relationship between Total Nitrogen in Soil and treatments applied

In Figure 15, the data show F (2, 21) =0.38002, p>0.05, we Reject the Alternate Hypothesis (and Accept the Null Hypothesis), and say that, the various treatments applied have no significant effect on the total Nitrogen measured.

4.5. Relationship between pH/$CaCl_2$ in Soil and treatments applied

In Appendix F 13, the data show F (2, 21) =1.9736, p>0.05, we Reject the Alternate Hypothesis (and Accept the Null Hypothesis), and say that, the various treatments applied have no significant effect on the pH/$CaCl_2$ measured.

4.5. Relationship between COx in Soil and treatments applied

In Appendix F 14, the data show F (2, 21) =1.6983, p>0.05, we Reject the Alternate Hypothesis (and Accept the Null Hypothesis), and say that, the various treatments applied have no significant effect on the COx measured.

CHAPTER 5

5.1 DISCUSSION

In the current results, we discern there are changes in the soil nutrient partly due to organic matter concentrations, pH, moisture, temperature, texture, but most importantly, it is directly due to the presence of feaces on the patches.

The changes observed in herbage would also be attributed to the presence of feaces which was absorbed by the sward, or adhesion of feaces to herbage at the time of cutting them to the laboratory. As we know, accumulation of feaces in grassland patches leads to accumulation of nutrient element in the soil, some of which are toxic and unpalatable to grazing animals. Thus resulting in ungrazed patches. Urine deposition produce an increase in herbage N and K and decrease in P and Mg.

Some of these variations arise from the physical environment and others may be from differences in past treatment.

No strong evidence of dependency or relationship between nutrients in soil pools, and the nutrients in aboveground biomass was observed.

We found that the N and P content in the soil is not an indicator of their availability on same levels in herbage. This is to say that their higher levels in soil does not mean high levels in herbage. But it have bearing on other factors like soil pH, moisture content of soil etc.

Result came out that, there was virtually no effect on patch type (more especially IGF) on plant-available concentrations of P, Ca and Mg is in agreement with other grassland management studies (Hansson and Fogelfors, 2000; Hejcman et al., 2010a; Ilmarinen and Mikola, 2009; Köhleret al., 2001; Øien and Moen, 2001; Perring et al., 2009; Schafferset al., 1998).

The fact that N in herbage is not affected by Total Nitrogen in soil, was in consistent with the works of other authors which says, N and P in herbage concentrations do not depend predominantly on their availability in the soil (Hejcman et al., 2010d; Janssens et al., 1998; Koerselman and Meuleman, 1996).

We found that, the various treatments applied have no significant effect on the Ca measured in both soil and above-ground biomass. This is in accordance with the results of Pavlu (2013), who sad that “Concentrations of Ca were not affected by the different treatments”

Generally, the study conclude that the relationship between P in herbage and treatments applied had significant effect, in accordance with Pavlu et. al (2012), which states that, “Effect of treatment on plant available P concentration in the soil and in the total above-ground biomass was only marginally significant”.

There was also a relationship between the amount of nutrients in herbage and in soil (P, K, Ca, Mg, and N.) at the same place. Figure 1-5. Schaffers (2002), also reported that, K shows a strong relationship between plant-available soil and biomass concentrations.

The accumulation of K into herbage was sufficient enough that plant available K in soil was not affected by feaces presence-it is the same nearly for all nutrients – See Figure 2, & 9b.

The patch type IGF was sufficient significantly to decrease plant-available concentrations of K in the soil. The lower levels of K availability in IGF is in accordance with results obtained from several other grassland studies (Alfaro et al., 2003, 2004; Koerselman et al., 1990; Schaffers et al., 1998). It is possible explain this with characteristic of soil with high organic matter and low clay content not being able to release bigger amounts of K in weathering of clay minerals so as to compensate for the K removed by IGF.

The same result of a substantial decrease in the concentration of K under the IGF, despite "very high" K concentrations in the soil, was recorded by Hejcman et al. (2010a) Pavlu, L. et. al. (2011a), recorded a significant effect of treatment on P and K, and this study also recorded significant effect of treatments on P and K. The significant effect was only found in IGF & EGF, IGF & EGNF, however, no significant differences occurred in EGF & EGNF – Figure 8a and 9a.

The results obtained in Figures 1, 2, 8a, 9a 11a and 12, indicates that treatments applied does not influences soil and herbage nutrient properties, which conflict with the work of Hejcman et al., 2010a; Klimes and Klimesová, 2002; Köhler et al., 2001; Øien and Moen, 2001;Pavlu et al., 2011a,. They all agreed that, "The management regime influences soil and herbage nutrient properties". Possible reason for this could be the varying sample sizes used in study. Further investigation is recommended for this area.

CHAPTER 6

CONCLUSION

Although non-significant differences in plant available phosphorus, potassium, magnesium and total nitrogen in soil, the study recorded, the highest content phosphorus, potassium, magnesium and nitrogen in herbage under IGF patches.

The different type of patches had no effect on calcium content in the soil nor herbage.

Also, there wasn't any effect of the different type of patches on pH and Cox in soil.

The study revealed significant linear relationship between plant available phosphorus, potassium, magnesium and calcium in soil and phosphorus, potassium, magnesium and calcium in herbage.

No relationship between total nitrogen in soil and nitrogen content in herbage.

The main effect of feaces under non grazed patches was revealed directly on majority of studied nutrients in herbage.

The feaces had key effect on non-grazed patches creation under extensive and intensive grazing management however no effect on soil nutrient content was revealed.

The study concludes that, generally treatments applied expectedly had no significant influence on P, K, Ca, Mg, Nt, COx and pH/$CaCl_2$ in soil. However, there was significant influence of treatments on the nutrients levels of P, K, Mg, and N in herbage. Abd lastly, N, P and K in herbage was affected by Nt, P and K in soil respectively. However, this was not the case in Ca, Mg, Cox and pH/$CaCl_2$.

CHAPTER 7

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CHAPTER 8

APPENDICES:

APPENDIX Ta - DATA OF NUTRIENT IN HERBAGE - BLOCK 1 AND BLOCK 2							
treatment	block	replic	N	P	K	Ca	Mg
IG F	1	1	26.13	4.514319	24.6974	6.732156	2.869816
IG F	1	2	43.71	4.694512	24.76342	6.473982	2.372661
IG F	1	3	33.81	5.300365	20.05686	6.775342	3.073015
IG F	1	4	36.12	3.929955	29.19848	5.946387	2.623047
IG F	2	1	35.94	4.97335	23.75279	4.578775	2.333962
IG F	2	2	26.59	5.1798	22.1276	6.771407	3.510781
IG F	2	3	16.6	2.898116	13.91335	4.56495	2.016892
IG F	2	4	26.28	4.595382	18.00833	7.30564	2.757172
EG F	1	1	18.44	2.781667	11.93395	6.83117	2.4531
EG F	1	2	18.14	2.845981	12.36523	11.10358	1.793102
EG F	1	3	20.47	2.610868	20.15841	6.447041	2.034301
EG F	1	4	18	2.435231	10.50964	7.321119	2.263917
EG F	2	1	20.16	3.061905	11.87097	7.220271	2.538135
EG F	2	2	19.05	2.979809	14.39937	7.188681	1.815113
EG F	2	3	17.36	2.773992	18.582	4.71468	1.298553
EG F	2	4	17.83	2.493513	18.02444	7.066839	1.562614
EG NF	1	1	15.98	2.0336	9.604471	4.479518	1.540381
EG NF	1	2	18.15	2.609388	10.17744	6.939414	2.194874
EG NF	1	3	17.68	2.400875	15.23945	5.909884	1.820411
EG NF	1	4	15.82	2.431417	12.20848	8.358995	2.151986
EG NF	2	1	17.36	2.736362	12.44775	7.325767	1.848159
EG NF	2	2	16.91	2.281893	13.00808	5.43399	1.488806
EG NF	2	3	15.83	2.597109	10.94989	5.215695	1.314276
EG NF	2	4	15.67	2.141762	11.33941	5.288573	1.637793

APPENDIX Tb - DATA OF NUTRIENT IN SOIL - BLOCK 1 AND BLOCK 2

treatment	block	replic	pH/$CaCl_2$	P	K	Ca	Mg	Cox	Nt
IG F	1	1	5.7	66.78976	168.1899	1833.013	191.5995	49100	4960
IG F	1	2	5.55	46.13961	326.952	2442.82	131.0968	52200	5500
IG F	1	3	5.69	34.81115	255.4281	2249.994	242.1118	50700	5200
IG F	1	4	5.37	29.6414	440.8743	1918.964	190.4184	54600	5330
IG F	2	1	5.4	79.04201	148.8067	1594.707	151.1248	45400	4600
IG F	2	2	5.5	85.7192	177.1473	1868.732	237.3491	49800	5110
IG F	2	3	5.51	46.58297	161.8071	2040.189	168.6094	50500	5030
IG F	2	4	5.19	41.00309	132.1738	1332.821	115.3725	46400	4800
EG F	1	1	5.21	58.06539	152.4417	1607.686	163.737	51100	4690
EG F	1	2	6.93	44.58628	151.374	3056.728	118.8729	45900	4190
EG F	1	3	5.95	36.71243	249.5964	1570.485	320.0124	56500	4940
EG F	1	4	5.22	32.80406	158.3495	1414.289	164.1275	50600	4740
EG F	2	1	5.52	49.74476	165.117	2436.613	152.7605	58400	5510
EG F	2	2	5.36	34.3524	175.2844	2034.021	146.5793	54500	5230
EG F	2	3	5.44	53.38284	258.6785	2214.731	134.7609	55100	5500
EG F	2	4	5.33	21.54812	226.1321	1794.822	129.0072	58300	5530
EG NF	1	1	5.08	17.85684	162.544	1176.62	142.6802	47000	4480
EG NF	1	2	5.14	57.88205	214.0735	1715.748	149.5759	58000	5000
EG NF	1	3	5.46	46.25385	218.2295	2108.898	204.3334	44100	4120
EG NF	1	4	5.46	57.41288	197.5143	2232.281	229.7648	49800	4960
EG NF	2	1	5.2	80.99002	189.4835	1791.308	139.4651	51800	4420
EG NF	2	2	5.3	43.76649	263.6366	2039.896	153.2358	60600	5740
EG NF	2	3	5.1	44.91019	154.9819	1441.126	87.76264	53900	4990
EG NF	2	4	5.39	28.84987	133.6622	2133.553	112.2347	55300	5380

Appendix T1-Statistical analysis of measured nutrients from treatments application in both soil and herbage				
Measured nutrients		**R2**	**F**	**p**
Phosphorus	Soil	0.08	0.96	>0.05
	Herbage	0.80	42.74	<0.05
Potassium	Soil	0.06	0.62	>0.05
	Herbage	0.62	17.09	<0.05
Calcium	Soil	0.03	0.38	>0.05
	Herbage	0.13	1.65	>0.05
Magnesium	Soil	0.04	0.49	>0.05
	Herbage	0.52	11.57	<0.05
Total Nitrogen	Soil	0.03	0.38	>0.05
Nitrogen	Herbage	0.64	18.90	<0.05
pH/$CaCl_2$	Soil	0.15	1.97	>0.05
CO_x	Soil	0.13	1.69	>0.05

Significant (p<0.05) : Non Significant (p>0.05)

Appendix T 2a - Weighted means (±SD) of measured nutrients from treatments application in both soil and herbage (Blocks 1 and 2)				
Treatments	**Phosphorus**		**Potassium**	
	Soil	**Herbage**	**Soil**	**Herbage**
IG F	53.715±19.516	4.51±0.800	226.422±67.230	22.064±4.072
EG F	41.399±12.912	2.747±0.218	192.121±45.909	14.73±3.757
EG NF	47.24±20.465	2.403±0.257	191.265±41.154	11.871±1.750

Appendix T 2b - Weighted means (±SD) of measured nutrients from treatments application in both soil and herbage (Blocks 1 and 2)				
Treatments	**Calcium**		**Magnesium**	
	Soil	**Herbage**	**Soil**	**Herbage**
IG F	1910.155±297.867	6.143±0.910	178.46±48.297	2.694±0.474
EG F	2016.172±519.892	7.236±1.685	166.232±49.489	1.969±0.409
EG NF	1829.292±392.316	6.118±1.324	152.381±203.056	1.749±0.533

Appendix T 2c - Weighted means (±SD) of measured nutrients from treatments application in both soil and herbage (Blocks 1 and 2)				
Treatments	**Nitrogen**		**pH/$CaCl_2$**	**CO_x**
	Soil-Nt	**Herbage-N**	**Soil**	**Soil**
IG F	5066.25±229.331	30.647±7.567	5.488±0.151	49837.5±1294.816
EG F	5041.25±230.533	18.681±1.206	5.619±0.832	53800±3200.768
EG NF	4886.25±492.35	16.674±1.001	5.266±0.164	52562.5±4870.319

Appendix T 3a - Tukey HSD test for Phosphorus in Herbage (g kg^{-1})			
Treatments	**4.5107 IGF MEAN**	**2.7479 EGF MEAN**	**2.4041 EG NF MEAN**
IG F	-	$p<0.05$	
EG F	$p<0.05$	-	$p>0.05$
EG NF		$p>0.05$	-

Significant $p<0.05$: Non Significant ($p>0.05$)

Appendix T 3b - Tukey HSD test for Phosphorus in Soil (mg kg^{-1})

Treatments	53.716 IGF MEAN	41.400 EGF MEAN	47.240 EG NF MEAN
IG F	-	$p>0.05$	
EG F	$p>0.05$	-	$p>0.05$
EG NF		$p>0.05$	-

Significant $p<0.05$: Non Significant ($p>0.05$)

Appendix T 4a - Tukey HSD test for Potassium in Herbage (g kg^{-1})

Treatments	22.065 IGF MEAN	14.731 EGF MEAN	11.872 EG NF MEAN
IG F	-	$p<0.05$	
EG F	$p<0.05$	-	$p>0.05$
EG NF		$p>0.05$	-

Significant $p<0.05$: Non Significant ($p>0.05$)

Appendix T 4b - Tukey HSD test for Potassium in Soil (mg kg^{-1})

Treatments	226.42 IGF MEAN	192.12 EGF MEAN	191.77 EG NF MEAN
IG F	-	$p>0.05$	
EG F	$p>0.05$	-	$p>0.05$
EG NF		$p>0.05$	-

Significant $p<0.05$: Non Significant ($p>0.05$)

Appendix T 5a - Tukey HSD test for Calcium in Herbage (g kg^{-1})

Treatments	6.1436 IGF MEAN	7.2367 EGF MEAN	6.1190 EG NF MEAN
IG F	-	$p>0.05$	
EG F	$p>0.05$	-	$p>0.05$
EG NF		$p>0.05$	-

Significant $p<0.05$: Non Significant ($p>0.05$)

Appendix T 5b - Tukey HSD test for Calcium Soil (mg kg^{-1})			
Treatments	**1910.2** **IGF MEAN**	**2016.2** **EGF MEAN**	**1829.9** **EG NF MEAN**
IG F	-	$p>0.05$	
EG F	$p>0.05$	-	$p>0.05$
EG NF		$p>0.05$	-

Significant $p<0.05$: Non Significant ($p>0.05$)

Appendix T 6a - Tukey HSD test for Magnesium in Herbage (g kg^{-1})			
Treatments	**2.6947** **IGF MEAN**	**1.9699** **EGF MEAN**	**1.7496** **EG NF MEAN**
IG F	-	$p<0.05$	
EG F	$p<0.05$	-	$p>0.05$
EG NF		$p>0.05$	-

Significant $p<0.05$: Non Significant ($p>0.05$)

Appendix T 6b - Tukey HSD test for Magnesium in Soil (mg kg^{-1})			
Treatments	**178.46** **IGF MEAN**	**166.23** **EGF MEAN**	**152.38** **EG NF MEAN**
IG F	-	$p>0.05$	
EG F	$p>0.05$	-	$p>0.05$
EG NF		$p>0.05$	-

Significant $p<0.05$: Non Significant ($p>0.05$)

Appendix T 7 - Tukey HSD test for pH/$CaCl_2$ in Soil			
Treatments	**5.4887** **IGF MEAN**	**5.6200** **EGF MEAN**	**5.2662** **EG NF MEAN**
IG F	-	$p>0.05$	
EG F	$p>0.05$	-	$p>0.05$
EG NF		$p>0.05$	-

Significant $p<0.05$: Non Significant ($p>0.05$)

Appendix T 8 - Tukey HSD test for CO_x in Soil			
Treatments	**49838** **IGF MEAN**	**53800** **EGF MEAN**	**52562** **EG NF MEAN**
IG F	-	p>0.05	
EG F	p>0.05	-	p>0.05
EG NF		p>0.05	-

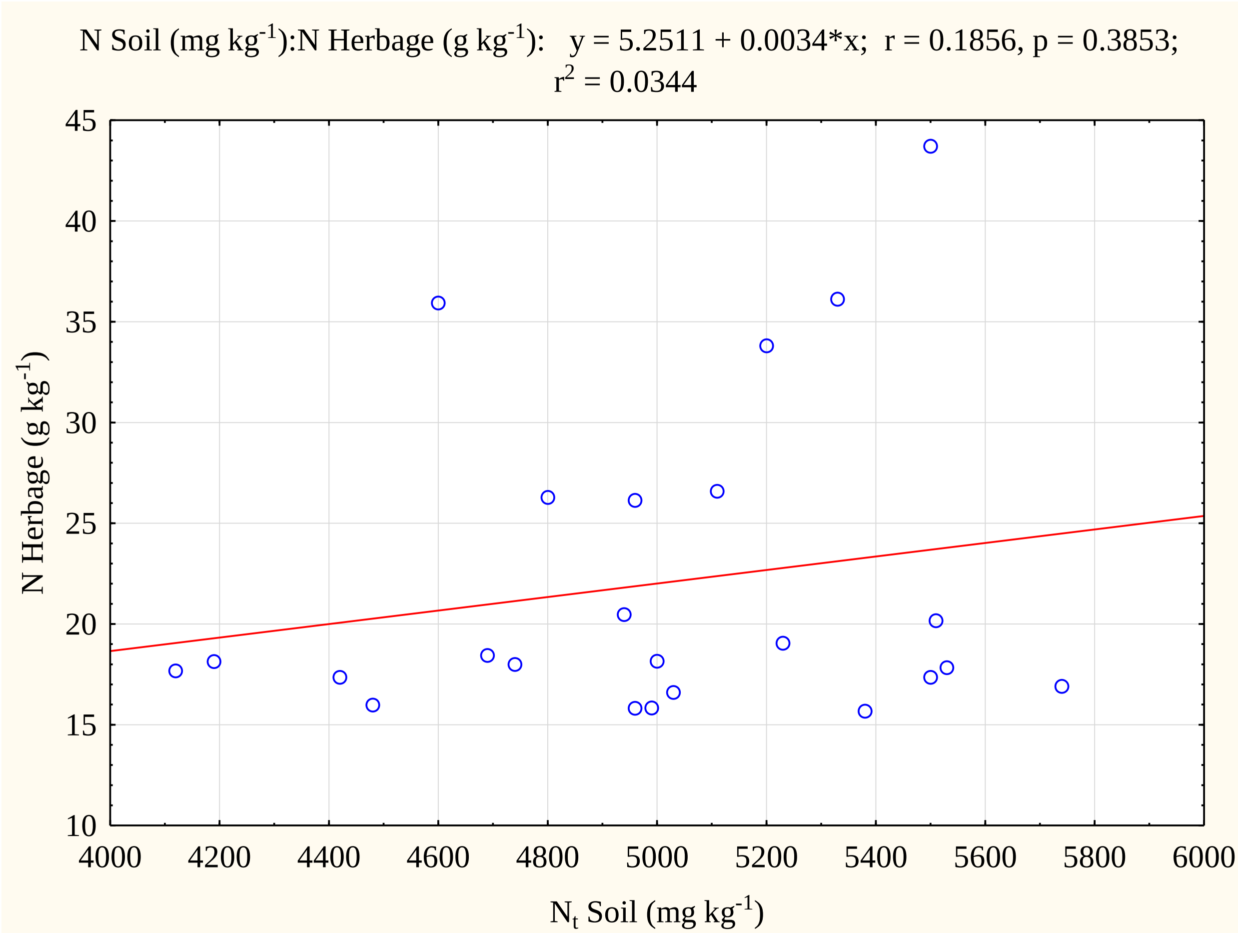
Significant p<0.05: Non Significant (p>0.05)

Appendix T 9a - Tukey HSD test for Nitrogen in Herbage ($g\ kg^{-1}$)			
Treatments	**30.647** **IGF MEAN**	**18.681** **EGF MEAN**	**16.675** **EG NF MEAN**
IG F	-	p<0.05	
EG F	p<0.05	-	p>0.05
EG NF		p>0.05	-

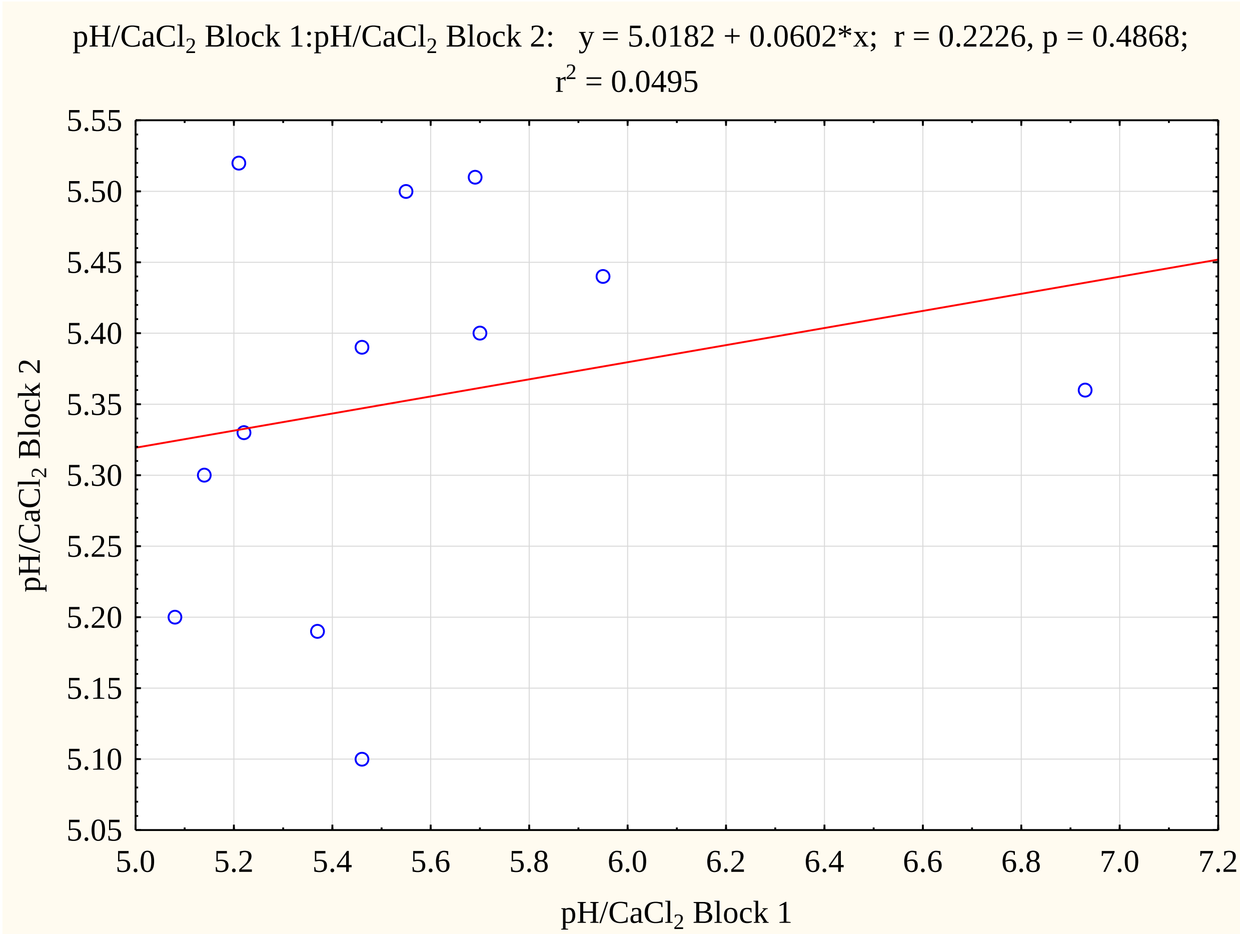
Significant p<0.05: Non Significant (p>0.05)

Appendix T 9b - Tukey HSD test for Total Nitrogen in Soil ($mg\ kg^{-1}$)			
Treatments	**5066.3** **IGF MEAN**	**5041.3** **EGF MEAN**	**4886.3** **EG NF MEAN**
IG F	-	p>0.05	
EG F	p>0.05	-	p>0.05
EG NF		p>0.05	-

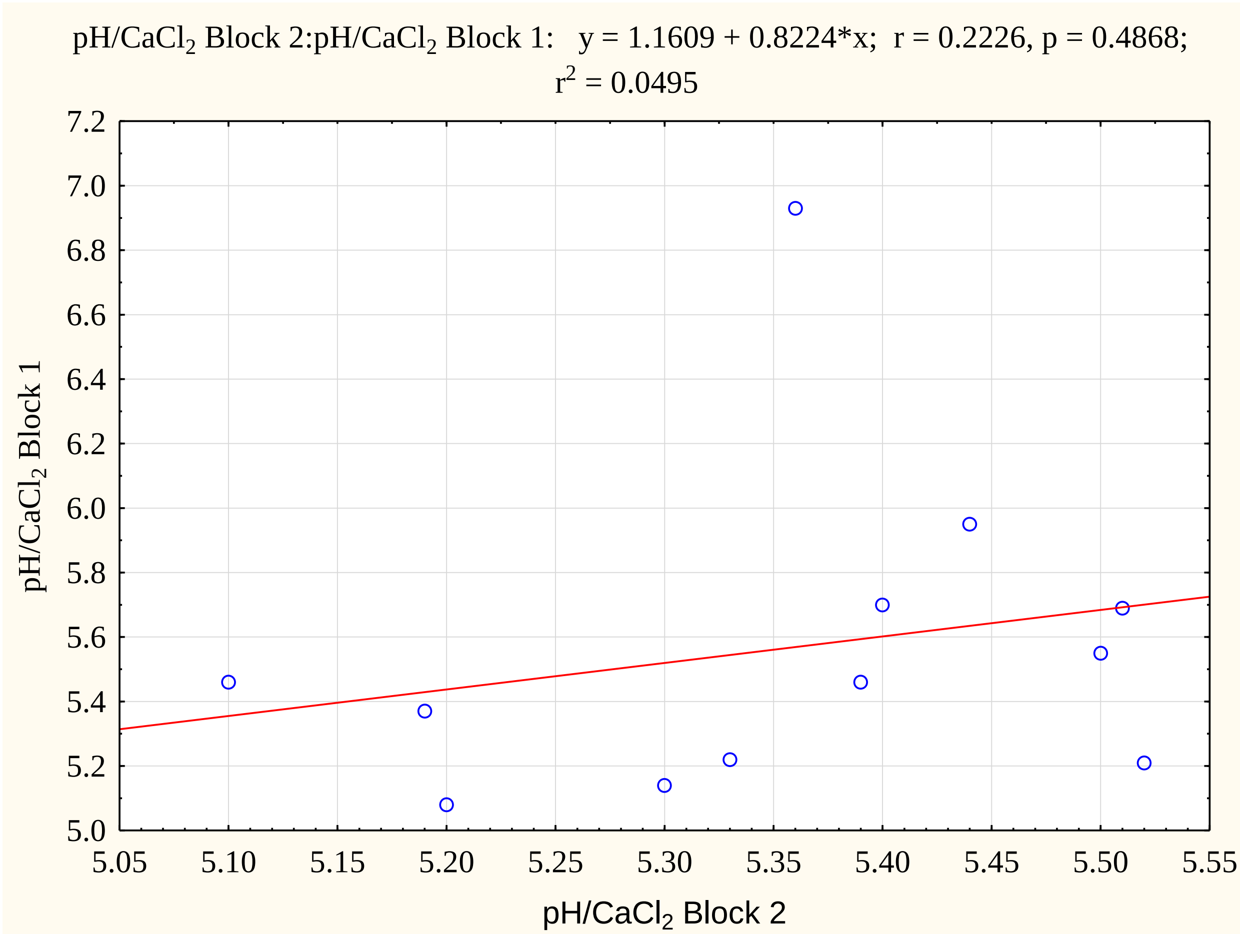
Significant p<0.05: Non Significant (p>0.05)



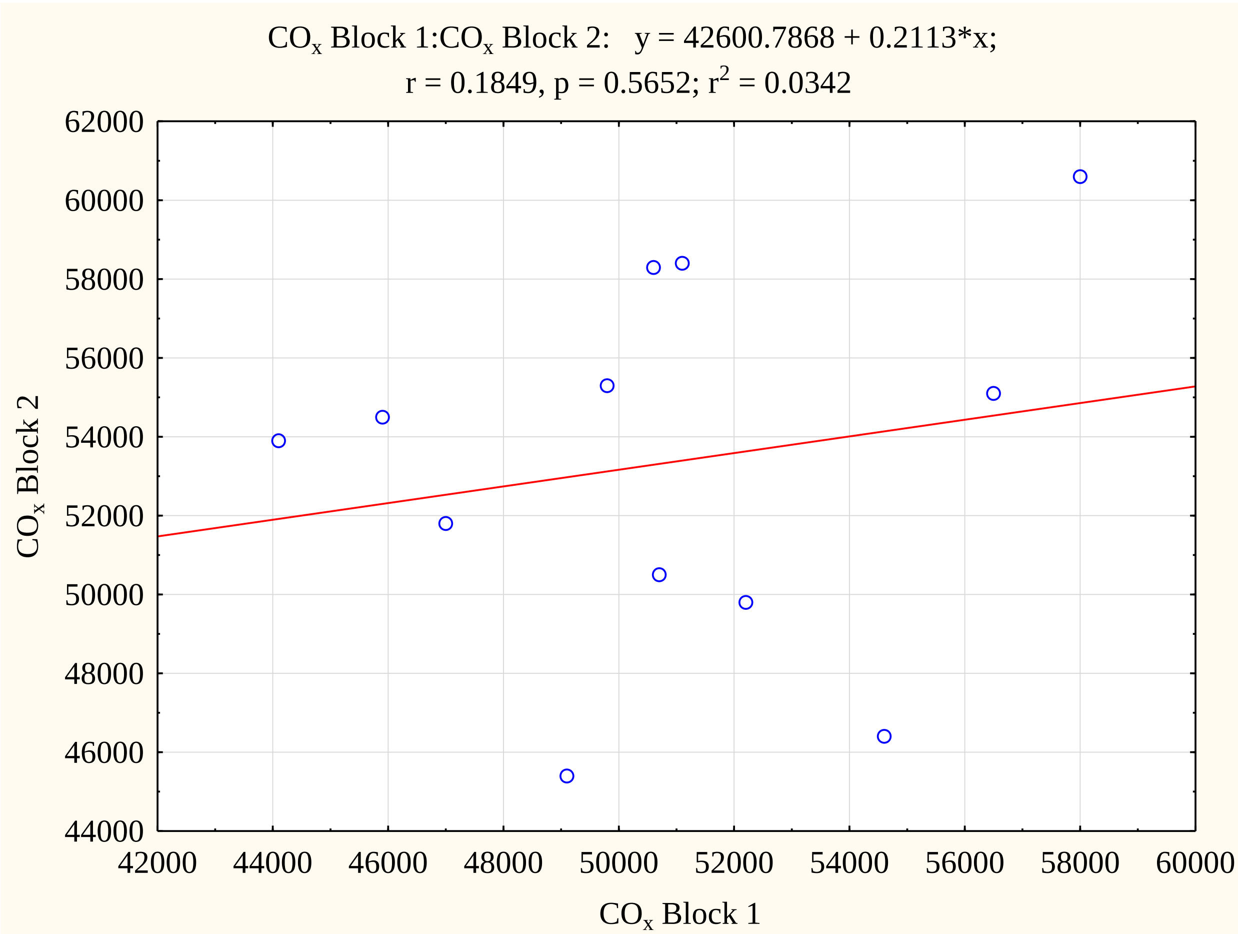
Appendix F 5. – Relationship between Nitrogen in Herbage and Total Nitrogen in Soil



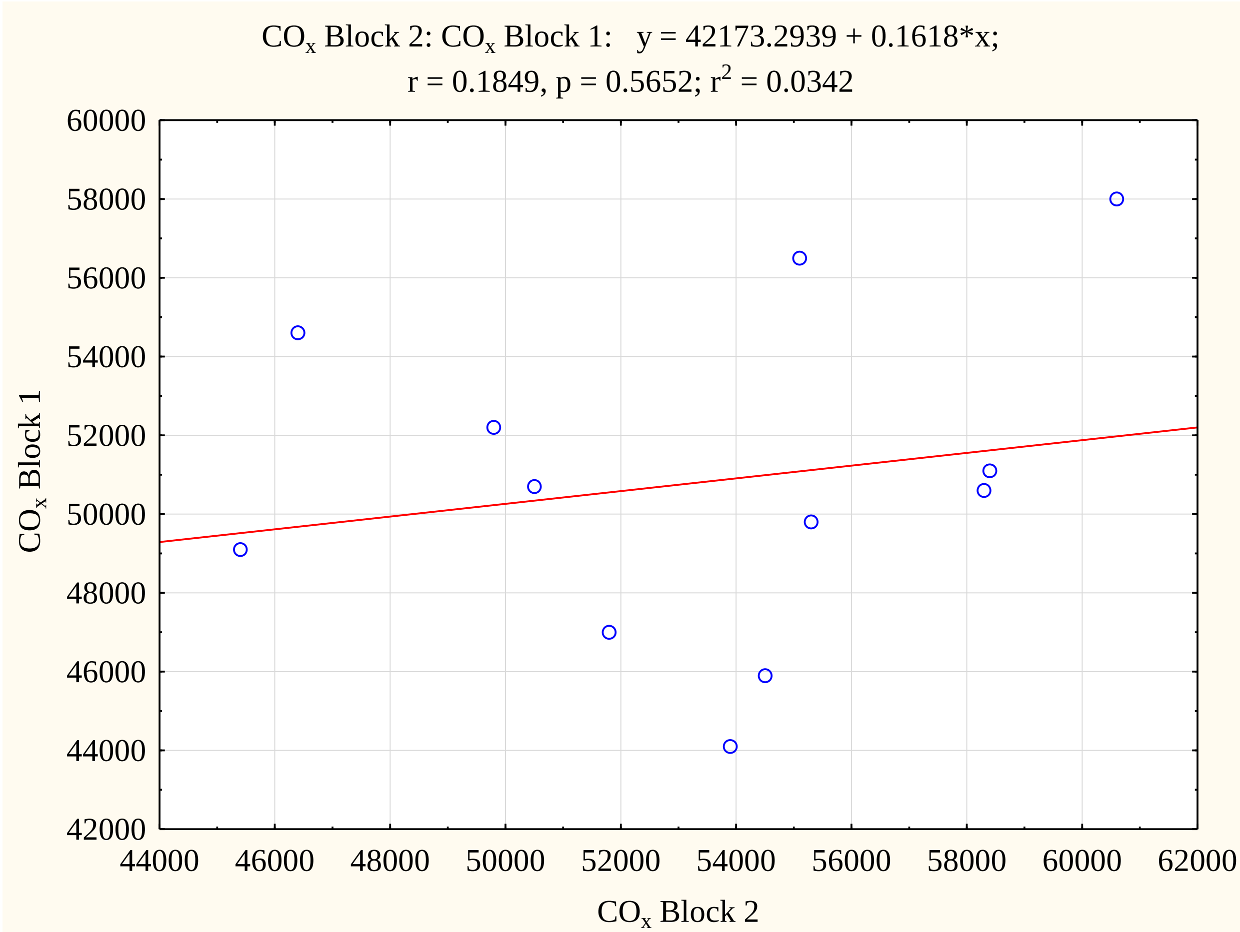
Appendix F 6a. – Relationship between pH/$CaCl_2$ in soil in block2 and block 1

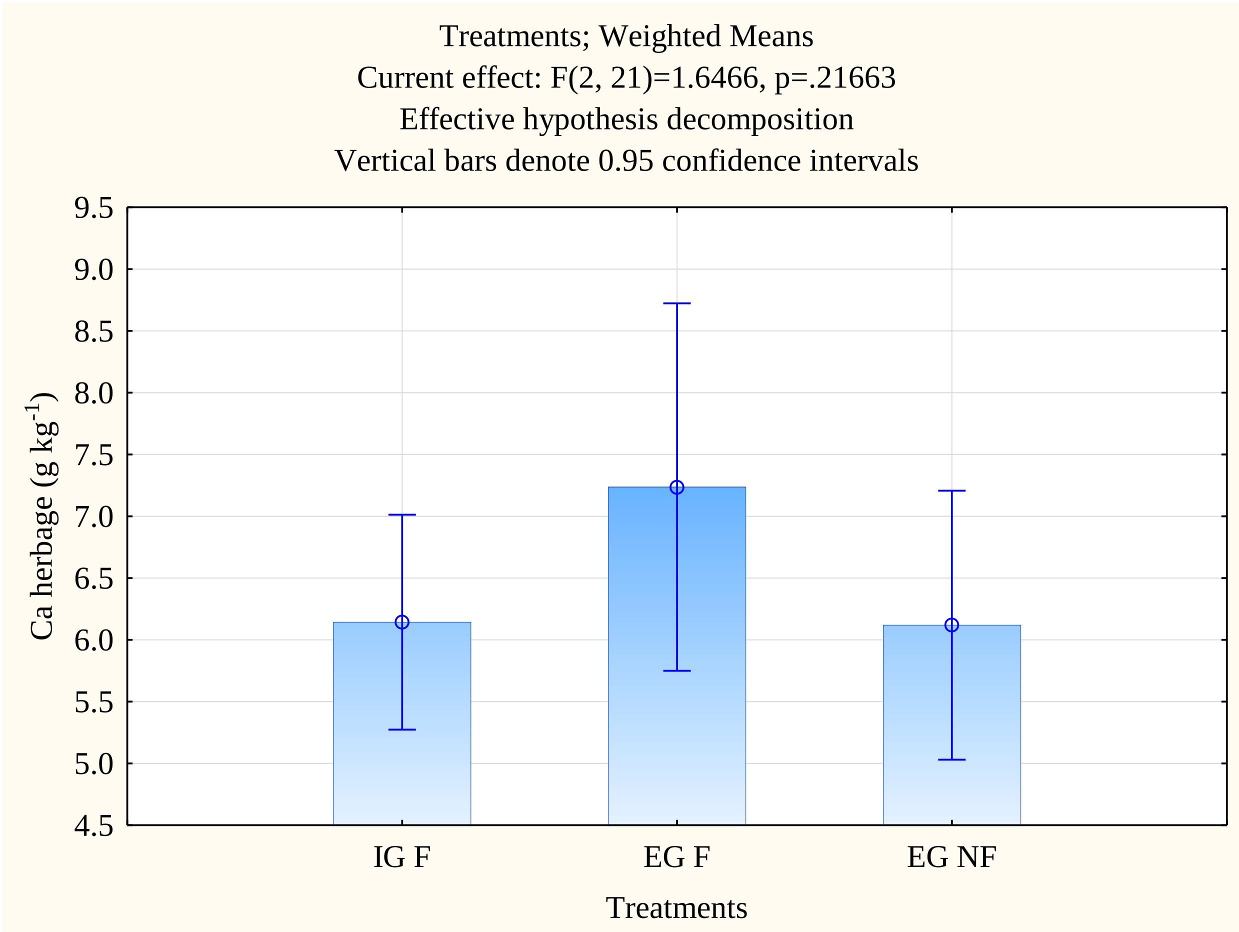


Appendix F 6a. – Relationship between pH/$CaCl_2$ in soil in block 1 and block 2

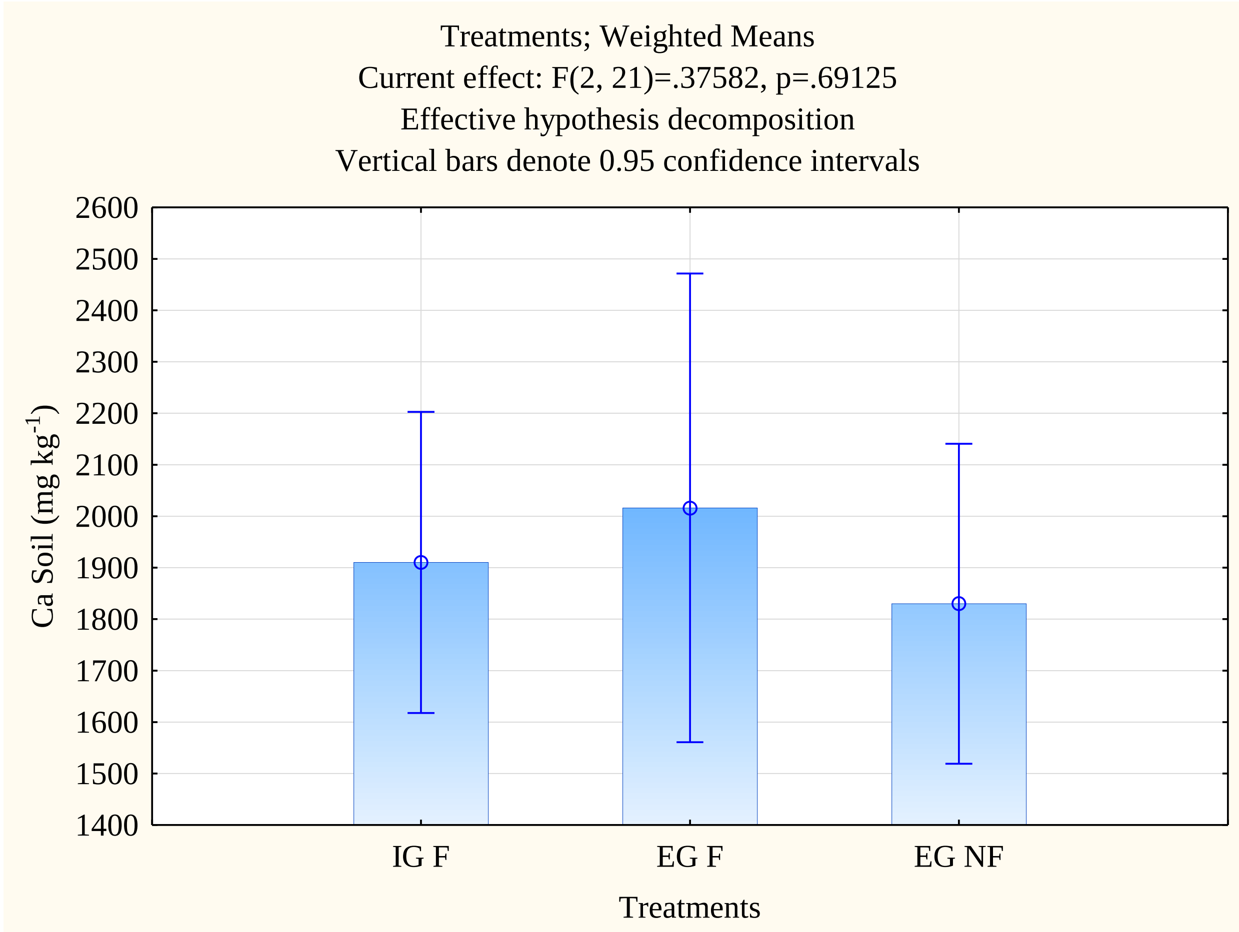


Appendix F 7a. – Relationship between CO_x in soil in block 2 and block 1

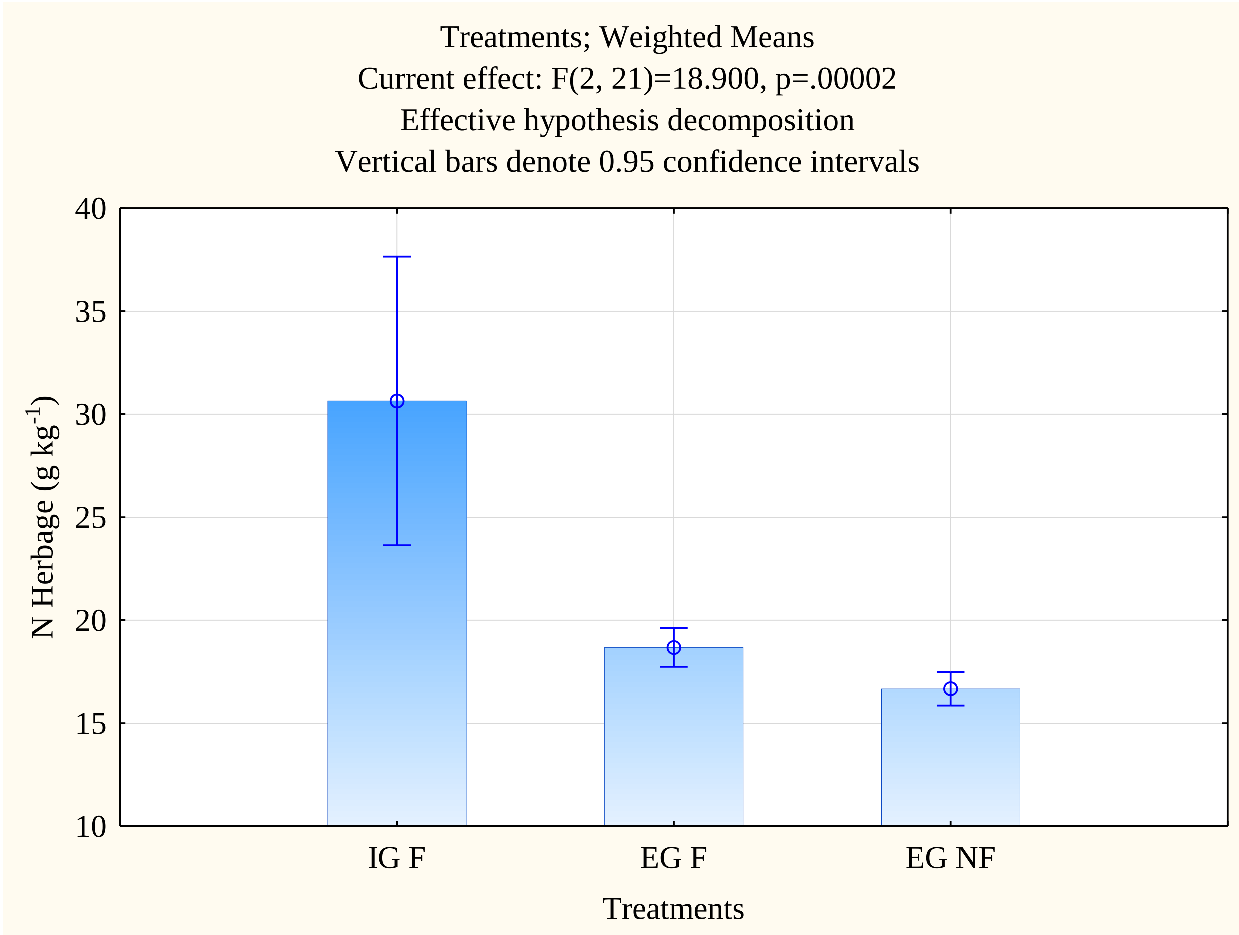

COx Block 2: COx Block 1: y = 42173.2939 + 0.1618*x;
r = 0.1849, p = 0.5652; r2 = 0.0342
60000
58000
56000
54000
52000
50000
48000
46000
44000
42000
44000
46000
48000
50000
52000
54000
56000
58000
60000
62000
COx Block 1
COx Block 2



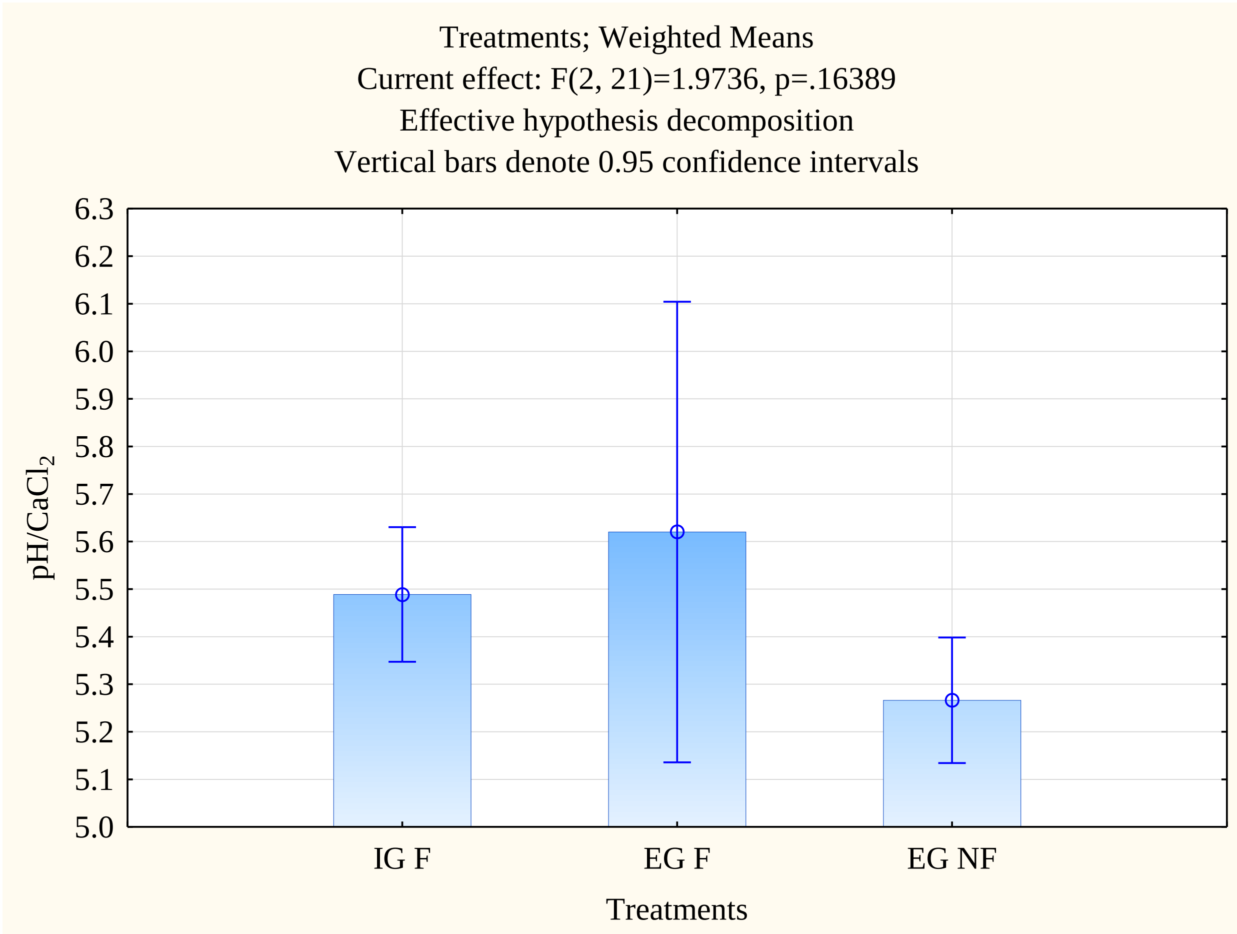
Appendix F 10a. – Relationship between Calcium Herbage and treatments applied



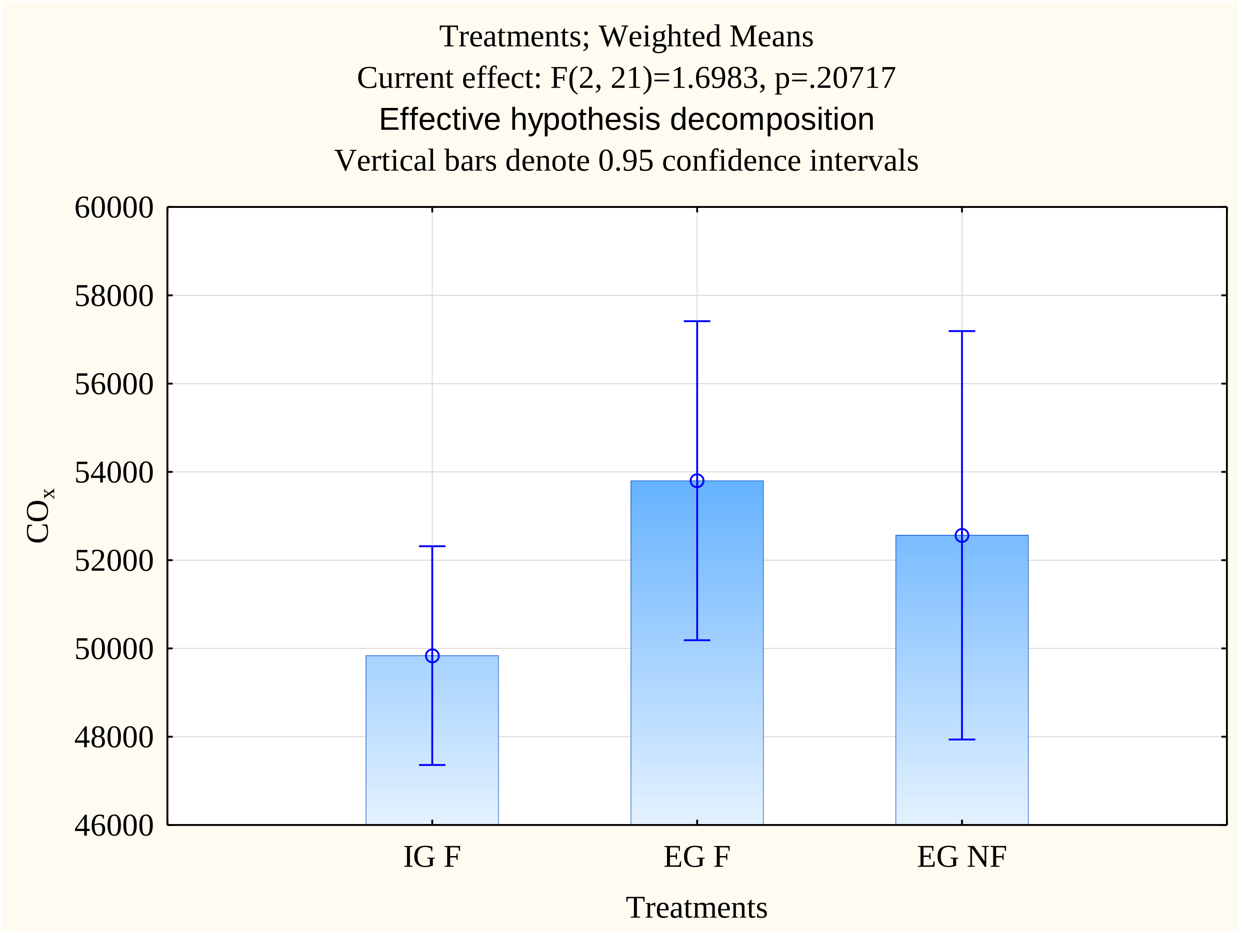
Appendix F 10b. – Relationship between Calcium Soil and treatments applied



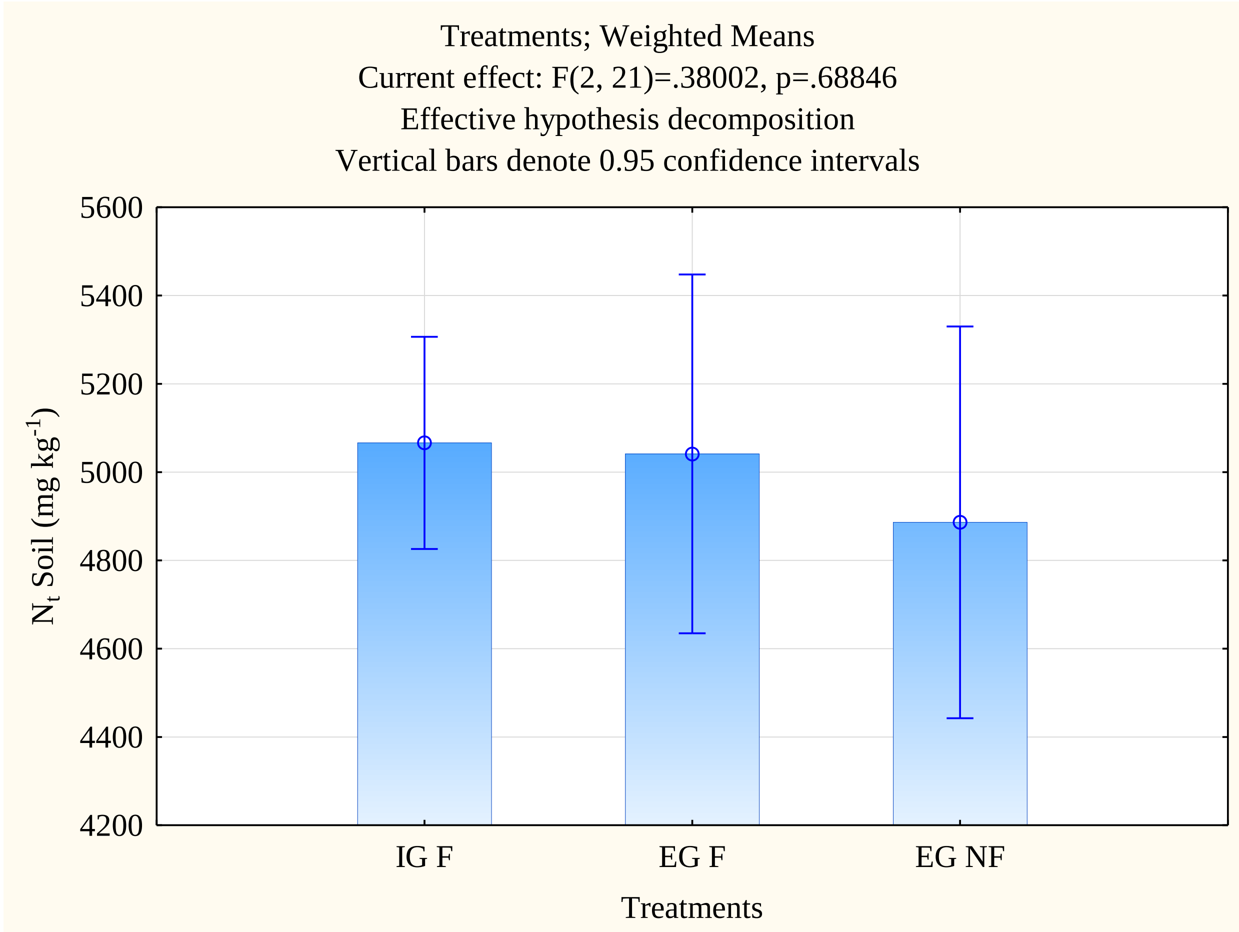
Appendix F 12. – Relationship between Nitrogen Herbage and treatments applied



Appendix F 13. – Relationship between pH/$CaCl_2$ in Soil and treatments applied



Appendix F 14. – Relationship between COx in Soil and treatments applied



Appendix F 15. – Relationship between Nt in Soil and treatments applied