UNIVERSIDAD DE VALLADOLID

Edafoclimatic Monitoring

Evaluation of Pasture: Production and Quality

Fertilization Effects

in

VALLE DEL NANSA
and
PEÑARRUBIA

INSTITUTO UNIVERSITARIO EN GESTIÓN FORESTAL SOSTENIBLE
IUGFS

TUTHOR:
JULIÁN GONZALO
VºBº:

AUTHOR:
MARIA JESÚS SERRA

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Abstract

This master thesis exposes the preliminary results of the forage project promoted by Fundación Marcelino Botín and developed by Universidad de Valladolid. The main aim of this project is the improvement of the economical yield of livestock exploitations in Valle del Nansa and Peñarrubia through the enhancement of production and quality of pasture and homemade forage. The conclusions extracted from the enhancement experiments will be integrated in a functional model, dynamically calibrated and able to define grass production and its quality that will be constructed as a next objective in the project. This work is based in the behavior observed in ten different experimental plots.

In this first step, meteorological variables (PAR radiation, precipitation, temperature and relative humidity in air) and soil variables (Volumetric Water Content, soil temperature and soil water potential) have been monitored. Three different weathers with significant differences have been described. These differences between weathers can be easily explained due to different altitudes in the valley.

Meanwhile, a complete phenology grass cycle has been traced analyzing production and quality. Production has been checked to grow along with time while in terms of quality a peak has been detected among day 32 and 64 of the vegetative period and from then it descends gradually. These aspects are basic when selecting a harvesting date.

Finally, a fertilization plan has been developed in which different products and doses have been tested analyzing its effects in grass production and quality. Control treatment has proved to be the worst in terms of productivity but for one exception. The use of farmyard manure turns to have positive or negative depending on C/N ratio and meteorological variables. The most productive fertilizer and its dose has been 400 kg/ha ENTEC 24-8-7 even over 600 kg/ha of the same product. No positive effects have been detected in the use of HUMIBIO neither in quality or productive values.

Resumen

Esta master tesis expone los resultados preliminares del Proyecto de Pastos y Forrajes promovido por la Fundación Botín y desarrollado por la Universidad de Valladolid cuyo objetivo principal es el incremento del rendimiento económico de las explotaciones ganaderas del Valle del Nansa y Peñarrubia a través de la mejora en la producción y calidad de los pastos y forrajes de elaboración propia. Las conclusiones de los ensayos de mejora aquí descritas se integrarán en un modelo funcional de producción y calidad de hierba de calibración dinámica que se desarrollará como siguiente objetivo dentro de dicho Proyecto. Este trabajo se fundamenta en el comportamiento observado en 10 parcelas experimentales.

En un primer paso, se han monitorizado las variables meteorológicas (radiación PAR, precipitación, temperatura y humedad relativa) y edáficas (Contenido volumétrico de agua en suelo, temperatura del suelo y potencial hídrico) de 10 parcelas del Valle del Nansa y Peñarrubia. Se han observado tres microclimas diferentes en el valle con importantes diferencias fácilmente explicables dado el gradiente altitudinal y con sus consecuencias en las características del suelo.

Paralelamente se ha realizado un seguimiento de un ciclo productivo completo de la hierba, analizando calidad y producción. La producción crece continuamente con el tiempo mientras que se ha detectado el pico de máxima calidad entre el día 32 y el 64 del periodo vegetativo, descendiendo gradualmente desde entonces. Estos aspectos son básicos a la hora de seleccionar el momento de aprovechamiento óptimo.

Finalmente se ha desarrollado un plan de fertilización en el que se han analizado los efectos de los diferentes productos fertilizantes y dosis sobre la calidad y la cantidad del pasto. El tratamiento Control ha demostrado ser el peor en todos los casos en términos productivos salvo una excepción. El uso de estiércol ha tenido efectos positivos o negativos dependiendo de la relación C/N y de las variables meteorológicas. El fertilizante y la dosis más productiva ha sido 400 kg/ha de ENTEC 24-8-7 por encima de 600 kg/ha del mismo producto. No se ha encontrado en el empleo de HUMIBIO ninguna mejora en el pasto ni en términos cuantitativos ni cualitativos.

Keywords: Grassland, Fertilization, Phenology, Dry Matter

1.-State of the art

Farming activities have been taking place in Coordillera Cantábrica since Neolithic period. This anthropic activity prolonged for centuries has strongly determined its landscape configuration (Millán, 2006). The landscape is composed of small parcels for agriculture and livestock exploitations and scarce forests spots resulting in an extremely segmented territory. In fact, in Cantabria, the size of 71% of the fields is smaller than 20 ha (MAPyA, 2003). Economy is mainly based of livestock production (intended for both milk or meat production) (Martínez Gómez, 2007) and almost 93% of agriculture is used as a feeding resource for cattle (MAPyA, 2003).

From the 532.134 ha that conform Cantabria, 331.691 ha (over 62% of the area) are intended to grasslands and meadows. Another 1.5% of the territory is destined to arable crops, mostly forage crops, in which according to precipitation regime, hardly ever extra irrigation is needed (MAPyA, 2003).

The importance of herbaceous pasture in Cantabria that has been detailed above is not reflected in scientific production. While numerous studies about cattle fitness and requirements have been made along the years (Ramos *et al.*, 1998; Cerdeño and Mantecón, 2003) hardly no importance has been given to the basic element for the development of cattle: grass.

Even though there have been some investigations about this topic, the information was extremely disperse. It was not until 2007 when a compilation of all available data was done by Centro de Investigación y Formación Agraria de Cantabria (CIFA) as a consequence of a previous national project called "Tipificación, Cartografía y Evaluación de los Pastos Españoles" carried out by Sociedad Española para el Estudio de los Pastos (SEEP).

Concerning to Universidad de Valladolid, the Grupo de Modelización de Sistemas Pascícolas, nowadays included in the Instituto Universitario de Investigación en Gestión Forestal Sostenible, has been carrying out several studies in the south slope of Coordillera Cantábrica (León and Palencia). These studies, financed by different projects and contracts with government administration sectors, pursued a liable characterization and management of pasture in this area. Furthermore, the permanent collaboration with Centro Tecnológico Agrario y Agroalimentario – Itagra, ct, located in the same campus as Escuela Técnica Superior de Ingenierías Agrarias (Campus de la Yutera) has enabled these projects with laboratory services in order to obtain complete forage, soil and meat analysis. This collaboration, key when developing integrated projects, was also crucial in 2007 when a net of permanent plots was finally established in order to monitor pasture in Coordillera Cantábrica.

Specifically in Valle del Nansa and Peñarrubia (Cantabria), where this work takes place, no previous studies about pasture had been done but for some carried out by CIFA concerning mountain grasslands. This continued until in 2008 Fundación Marcelino Botín started a development plan which main objective is to firmly promote the economy of this territory.

Fundación Marcelino Botín started this project as a possible solution to an emerging problem: the loss of rural population and the important consequences this would mean in economic sectors like agriculture and livestock activities. The need to improve life conditions has caused a massive migration from rural sites to cities. In Valle del Nansa, this is reflected in a decrease of 10% of the local population in the last five years (INE, 2010). Agriculture and livestock exploitations have been abandoned or relegated to a secondary job or just a hobby.

The only way to stop this trend or to even invert it and fix rural population is to improve economical yield of rural activities. Technology is far ahead of the practices that are actually being carried out in the fields but communication between farmers and scientists is difficult. This is why a pilot project involving farmers firmly interested in improving is the main road to obtain this task.

As the principal aim of the project is to improve economy, it was precisely the main economic activity that should be improved: livestock production. But this time the whole system would be involved, this means grass production, meat production and the establishment of adequate sanity measures.

From this theory three different and combined projects were defined in 2010: The first one, concerning animal production, is actually being carried out by Ángel Ruiz Mantecón from Estación Agrícola Experimental (CSIC). On the other hand Christian Gortázar from Instituto de Investigación en Recursos Cinegéticos (IREC), started a project to determine principal vectors of diseases and to establish preventive measures. Finally, a forage project was defined permitting the development of a complete system of production and commercialization of beef cattle meat certified in Valle del Nansa and Peñarrubia. The responsible for this last project is Julián Gonzálo from Departamento de Producción Vegetal, Universidad de Valladolid (Campus de Palencia). The general idea is to establish a rearing system with a carefully determined diet based in homemade silage.

This master thesis focuses on the forage project, which is carefully explained below:

The first step in this ambitious project was taken in 2008 and consisted in obtaining a general characterization of the area (types of pasture and distribution) and in recollecting information about conservation techniques and forage products obtained in the valley.

Mainly, this work out lighted two problems:

- Grasslands in Valle del Nansa lack of all kind of cares but from the use of farmyard manure. This means that no amendments, fertilization processes or seedling is done. The result is a progressive reduction of grasslands production and also the loss of species of pastoral interest (Ruiz, 2008; Longland, 2010)
- Harvesting is done too late in the summer obtaining more biomass production in detriment of quality. The reason is the strict climatic conditions necessary to make hay. Although the forage obtained has medium ingestible and digestible values, these are very low in terms of protein. The direct consequence of low

nutritive values in homemade forage is the need of big inversions in other alimentary products (mainly lucerne hay and concentrates) in order to complete cattle feeding requirements.(Ruiz, 2008; Longland, 2010)

Taking this into account, in 2010, the Instituto Universitario de Investigación en Gestión Forestal Sostenible de la Universidad de Valladolid along with Itagra ct and staff from the Institute for Grassland and Environmental Research in Aberystwyth (Gales) started to develop the forage project. As a general view, the project pursues a significant reduction of costs in complementary feeding products for livestock. The main road to obtain this task is to carefully organize pasture management from the beginning. This way, the forage project proposes the creation of a grass production model which can be easily calibrated by few variables. According to this, during the development of the project, two tasks should be completed. First of all, the necessary data to calibrate the model should be recollected. Secondly, all the different activities involved in the management the grass should be organized.

To start with the project will concern the activities that take place previously to the exploitation of the resource: this means a soil amendment and fertilization plan, encouraging the correct use of farmyard manure and a seeding plan in order to increase the presence of species of interest.

Then, next part will involve the management related with the exploitation system: grazing or harvesting and optimum dates for each of both. This part will focus on the necessity of an earlier harvest.

Finally, a drastic change in the conservation processes will be analyzed proposing Big Bale Silage (BBS) as an alternative to hay. The use of additives in order to guarantee silage quality will also be studied.

While these three points are being developed, the different variables needed to calibrate the production model will be carefully monitored.

This master thesis consists on some of the aspects included in the forage project as a first approach to the final objective. Specifically it focuses on those aspects related with fertilization recommendations, management of the pasture system (grazing, harvesting and optimum dates) and the monitoring techniques.

Fertilization is the principal technique to be used when looking for an increase of grass production. To establish a fertilization regime in extensive farm exploitations requires a complete fertility management inside the farm. This idea became important in Spain in 1986 with Mombiela´s work (Mombiela, 1986). Today, almost twenty five years later, it is still a very pursued task that involves a complex balance of nutrient inputs and outputs: On one hand, current contributions coming from soil amendments and the use of farmyard manure that reintroduce nutrients from concentrates and external forage into the system. On the other hand, estimations of nutrient extraction by leaching, grazing or harvesting are also necessary. In order to obtain this information, it is essential to analyse soil characteristics every 4-5 years (Piñeiro Andión *et al.*, 2010) and to organize the different corrections needed depending on production. If soil presents low pH values, fertilization must be combined with proper liming practices in order to make it more effective and to improve grass quality.

Nitrogen (N) is the main component that enables fertilizers to increase grass production although it must be accompanied by phosphorus (P) and potassium (K) in order to obtain good quality grass. Some studies have shown that extensive farms exploitations are autonomous in terms of these two components (P and K) given hardly none is lost by leaching and three quarters of the P-K fraction eaten by cattle is back into the system through defecations. Anyway, an exact dose of phosphorus and potassium has been proposed according to the quantity of this nutrients found in the grass (Farrugia *et al.*, 2000).

Fertilization (N-P-K) has shown some negative effects in clover production especially in *Trifolium pratense* and *Trifolium repens (García et al., 2003)*. These two legumes are generally the main protein components in grass so this characteristic must be carefully analysed when using fertilizers.

On the other hand, organizing the exploitation system requires a deep knowledge of grass phenology especially when and optimum harvesting date must be recommended. Grass phenology is closely related with soil characteristics and climatic conditions reason for which both of them have been deeply analysed in this master thesis.

Soil chemical characteristics have strong influence in nutrient contents in grass. In similar soils to the ones located in Valle del Nansa also positioned in Coordillera Cantábrica, strong relation has been found between soil pH and calcium and potassium absorption (Afif and Oliveira, 2009). This justifies the recommendation of establishing limestone amendments. pH also influences nutrient availability in soils.

In terms of soil characteristics not only chemical analyses have been done, but also Volumetric Water Content (VWC), soil temperature and soil water potential have been continuously registered (every 30 minutes) during one year. Something similar has been done with grass phenology, whose quality values have been followed for one complete productive cycle.

As a result, this thesis aims to determine whether the use of fertilization is productively recommendable or not and the ideal dose and product for each situation. Quantifying the increase in grass production that can be obtained in each case is a first step to make an economic evaluation. This evaluation supposes a complex task as all costs should be included from the product till the application. The advantage of fertilization is the increase of grass production which must also be included in the economic balance as a reduction of costs in complementary food.

The thesis also pretends to determine the effects weather and soil variables have in grass phenology in an attempt of enable us to predict the optimum dates of for grazing or harvesting. In case of harvesting, one or two harvests might be recommended. While generally, given the fast growth of grasses, the first harvest shows higher production than the rest, the second one, as legumes grow better in this second stage, show better quality. A delay in the first harvesting date not only means a reduction in the quality of the product but also a delay in the growing period of the second harvest (Bochi *et al.*, 2003).

2.-Objectives

General

- To obtain a significant increase of homemade forage quality and quantity as an alternative to more expensive and external forage (lucerne hay and concentrates).

Specific

- Monitoring during one year of soil parameters with strong influence in grass phenology: temperature, volumetric water content and water potential index. Chemical analysis in order to obtain nutrient availability will also be carried out.
- Monitoring during one year of climatic parameters with strong influence in both soil characteristics and grass phenology: Temperature, Relative humidity in air, Photosynthetic Activity Radiation (PAR) and Precipitation.
- Tracing one complete phenology grass cycle (from March until harvesting date) obtaining quality and quantity data finally obtaining an optimum harvesting date based on soil characteristics and climatic conditions.
- Determination of an optimum fertilization regimen (product and dose) according to the farmer´s necessities and to the environmental characteristics.

3.-Materials and methods

Brief introduction to the valley

Valle del Nansa is located in the west side of Cantabria, northern Spain (see *Figure 3.1*). The region lies between latitudes 43º 2´- 43º 20´ North and longitudes 4º 21´ y 4º 37´ West.

The valley is named Nansa after the principal river that flows through it from south to north. This river belongs to “Cuenca Hidrográfica Norte” and starts its way in Sierra de Peña Labra. After very few kilometres it is dammed up in “La Cohilla”, which was built in 1950 by “Saltos the Nansa” with the aim of producing hydraulic energy. Finally, after 46 km through the valley the river reaches the sea “Mar Cantábrico”.

The total area where the project is developed includes 420 km^2. This territory is not only composed by the five Valle del Nansa municipalities (Herrerías, Lamason, Río Nansa, Tudanca y Polaciones) but it also includes Peñarrubia.

The altitude in the valley is very variable depending on latitude. This way, it is 93 meters above sea level in the north limit of the valley while it reaches 2175 at the south end. Orography is very rough as the torrential river causes steep slopes all around the valley.

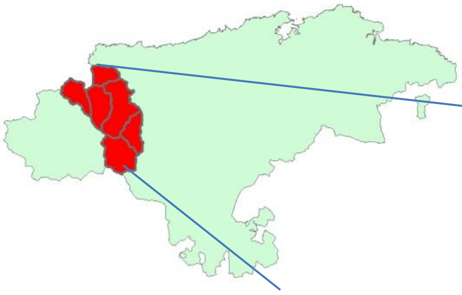
Concerning to climate, it is a typical oceanic weather with high precipitation regime and soft temperatures due to the proximity of the sea. Nevertheless, altitude strongly determines nuances in the territory so temperature and precipitation ranges are very variable. The lowest sites, which are also the nearest to the sea, are characterized by high precipitation regimes between 1200 and 1500 mm per year. Soft temperatures in winter and summer accompany this rain regime with an annual average between 12 and 15^{o}C. On the other hand, the highest sites, farther from the sea show more extreme weather conditions. Precipitation is lower (900-1300mm per year) and although temperature averages are similar, there are strong contrasts between the winter and the summer. Climate will be more profoundly analysed in paragraph *Results and Discussion.*

<u>*Experimental plots*</u>

The criterion followed to select the plots included in the project was based in two statements. First of all, the fields selected belong to farmers firmly interested in the project and willing to incorporate the recommended improvements in their farms. Secondly, different altitudes, climatic conditions, soil characteristics, exploitation systems and pasture species existing in the valley should be represented by the plots included in the study.

Finally ten different plots were selected including grasslands all over Valle del Nansa and at least one plot per municipality (see *Figure 3.1*).

In an attempt to integrate farmers in the project, the different experiences have taken place in 1000 m^2 of their own fields while the rest of the field has been treated as normally.



This way, the farmer can directly see the results obtained in his property and is more likely to change to the new measures. All plots but for Tudanca and Río Seco, have 1000 m^2 and only one fertilization dose has been experienced. When possible, 4000 m^2 have been delimitated opening the possibility of analysing different treatments which will be later explained.

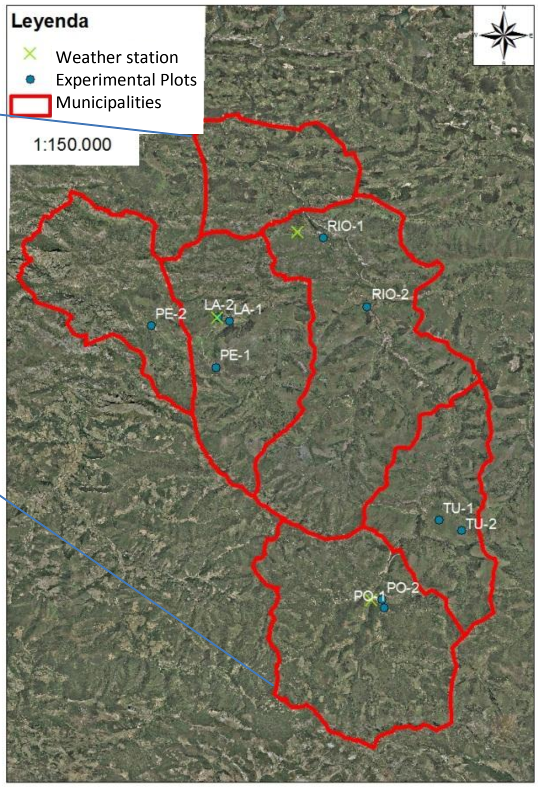


Fig 3.1: Location of the experimental plots

Monitoring

From 15th November 2010 until today meteorological and soil parameters have been monitored. To reach this objective thirteen dataloggers EM50 (Decagon Devices Inc.) with different probes have been installed in the experimental plots. These instruments record one data every thirty minutes. The measurement recorded is not the value the parameter reaches in the moment it is taken but an average result of thirty values recorded (one per minute) until

Fig 3.2: Probe´s set up

the definitive measurement is memorized.

All the dataloggers EM50 installed in the valley were carefully isolated using hermetic boxes sealed with silicone and both into hermetic plastic bags. An envelope filled in with Silicagel is also included in the hermetic box to avoid possible moisture coming from condensation. All the external connections between the probes and the dataloggers were protected with 21 mm corrugated cable. In the top side of the hermetic box, a cable USB was installed to make possible the connection between the computer and the datalogger (see *Figure 3.2*).

Dataloggers were checked once every 21 days to guarantee that they worked properly. As they had to support hard conditions, they had to be repaired several times

A. Meteorological monitoring

Three weather stations have been strategically located in Valle del Nansa as shown in *Figure 3.1* continuously measuring Temperature, Relative humidity in air, Photosynthetic Activity Radiation (PAR) and Precipitation.

Fig 3.2: Weather station

Each station is composed of one datalogger EM50 and three different probes: one pluviometer (ECRN-100) with precision of 0.2mm, one temperature and relative humidity sensor (EHR) and finally a radiation probe (QSO-PAR) with a measurement interval between 0-1750 W/m^2 and precision of 2%.

The probes must be positioned 1.30m above the ground reason for which a structure of that height is needed when putting them in the field. To hold this structure a concrete formwork was used. The whole can be observed in *Figure 3.3*.

Once the area were each weather station should be located had been selected, the exact place was picked somewhere near a farmer´s house, in order to guarantee that no person would interfere with the stations and in a clear area so no structure would influence the measurements.

Each month the datalogger stores 4464 data per variable but for August and November that are not fully monitored. This makes a total of 13160 per variable and station. To make this information valuable it is mandatory to organize it properly.

The first step was to check for impossible values. Temperatures over 50 ^{o}C were eliminated from the data as wrong values and also all relative humidity values over 1.

Once this was done, a climodiagram was built as a general characterization of each weather and as a visual way to observe the principal differences between them. To make it easier to understand, data from November and December 2010 has been located after August 2011. There are two missing months in the climograms (September and October) as no data about them has still been stored. The average temperature of every month was built from 4464 data (48 data per day). To calculate month precipitation simply consisted in adding all precipitation from the beginning of the month until the end.

For further analysis, all the data was daily compared. To make this possible, every day has been labelled with a numeric value, starting from 17/11/2010 that is labelled 1 until 22/08/2011 that is labelled 277. Temperature averages were daily calculated using 48 data and plotted. A regression line was done to observe the different tendencies for the three weathers. Exact the same procedure was done with relative humidity in air. Finally, the 48 data concerning precipitation was added, plotted and compared for the three weather stations.

B. Soil monitoring

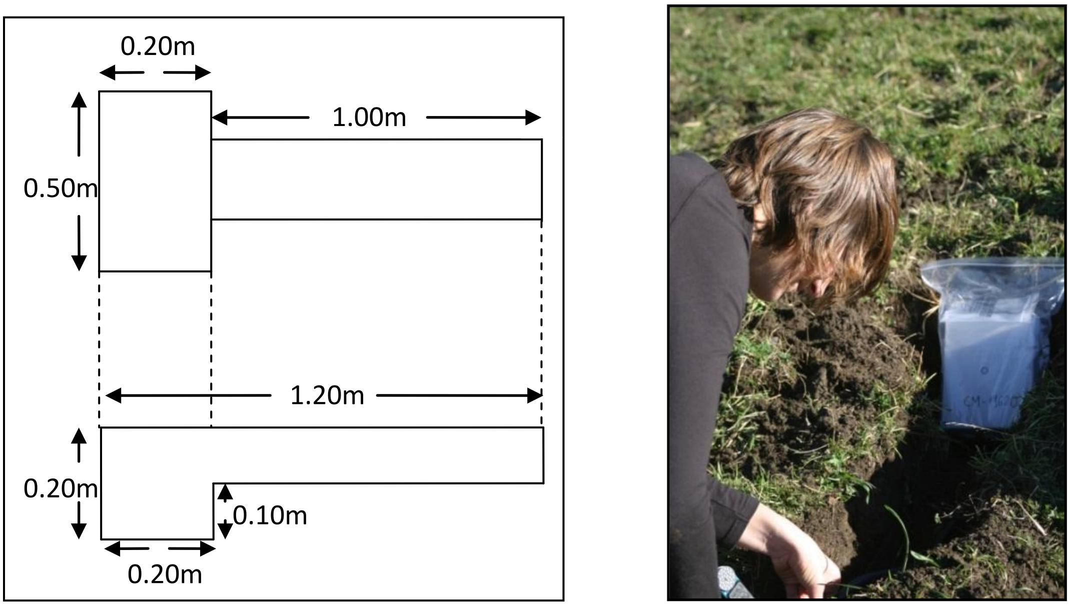
The first step taken to obtain soil information was the recollection of soil samples from the ten different experimental plots. As the project pretends to determine soil conditions for pasture, only the 20 first centimeters were analyzed obtaining pH, changeable aluminum, conductivity, textural analysis (clay, lime and sand), Organic Matter (OM), Carbonates, Active limestone and assimilable phosphorus, potassium, magnesium and sodium.

The analyses were done in August 2010 and to pick up each sample four different holes were made per each 1000 m^2. The responsible for the analysis is Itagra ct. who also offered an interpretation of the results according to the level of each variable in soil.

The conclusions were very similar in all the different experimental plots: First of all, we are dealing with Acid to Very Acid soils with no detectable carbonates. Concerning to OM, always High or Very High levels are reached in almost all the experimental plots presumably due to the incorrect use of farmyard manure. Finally, the nutrients available in soil were always determined as Low or Very low but for some exceptions in Ca and Mg. These deficiencies have a strong negative effect in the growth of legumes and generally mean grasslands dominated by grasses or other types of species (San Miguel Ayanz, 2001).

Once chemical analyses had been finalized, one datalogger EM50 was installed in each experimental plot. Two different probes were connected to each datalogger. The first probe is responsible for the measurements of temperature and volumetric water content (5TM Moisture/Temp) while the second is intended to obtain water potential index (MPS-1 Water Potential).

As this time the dataloggers are located in quite isolated places, the only way to avoid different kinds of interferences by animals or people (voluntary or involuntary) is to bury the whole complex. This is also useful as the probes anyway needed to be underground. The probes were buried 10cm and located following the slope while the box was located in vertical position in a 20 cm hole. A scheme is shown in *Figure 3.3.*



Scheme of the hole done to bury the probes

Installing the probe in the fields

Fig 3.3: Installation of Probes in the fields

A period of five days has been considered as necessary for the probes to stabilize in soil and for so the measures taken during the first five has not been considered in the analysis.

Soil data has been treated very similarly too climatic data although it was first analyzed separatedly plot by plot, and secondly associated to a weather station.

C. Herbage monitoring

Herbage production and quality has been closely followed during one complete production cycle. The most common tool to check the quantity and quality of a feeding element is the use of bromatological analyses. With this aim, every 21 days a herbage sample has been taken and analyzed obtaining the total weight of the sample, Crude protein, Crude fiber, Acid Detergent Fiber (ADF), Neutral Detergent Fiber (NDF), Total carbohydrates, Starch, Phosphorus (P), Potassium (K), Calcium (Ca), Sodium (Na), Magnessium (Mg), Dry Matter Intake (DMI)

Fig 3.4: Herbivore exclusion cage

When picking a herbage sample it must be representative of the whole grassland that wants to be characterized. All herbage samples must be properly identified with the origin, date, phenology of the grassland and grass height.

The first step to guarantee that the herbage sample shows a real value of the grassland potential production is to guarantee that no animals, whether cattle or wildlife animals, are feeding from the site selected. As a solution to this problem, one herbivore exclusion cage (*Figure 3.4*) was installed in each of the experimental plots and labeled as shown in *Figure 3.5*. Periodical harvests have been done under the cages dimensioned with 0.5625 m^2 in the baseline. When harvesting, the first 5cm of the grass are not taken as cattle cannot reach this grass. Once the area under the cage was harvested, the cage was moved to a different place in the grassland. Last harvest was done at the same time the whole grassland was harvested or grazed.

Fig 3.5: Label of an herbivore exclusion cage

The quantity of grass was calculated using the fresh weight of the sample, the area where it had been harvested and the moisture percentage to obtain Dry Matter (DM) values (Eq1):

Eq1

$$DM\left(\frac{kg}{ha}\right) = \frac{Fresh\ Weight\ (g) * [100 - Moisture\ (\%)]}{Area\ (m^2) * 10}$$

DM values are good indicators of production in grasslands instead of Fresh Matter values as moisture in grass is very variable depending on weather and soil conditions.

To find a numeric value to characterize pasture quality is more difficult as it can be defined very differently depending on aim and authors. To decide the best indicator to be used is a very hard task as there are a lot of variables to play with. Some authors compare separately the different principles one by one to obtain a final conclusion based on the whole (Ramírez et al., 2010).

Finally, in this master thesis the evaluation system selected is proposed by FEDNA (Fundación Española para el desarrollo de la Nutrición Animal) and officially adopted by *American Forage and Grassland Council*. This criterion uses an equation which defines pasture quality as a combination of its Digestibility and Ingestibility. The concept is simple:

Digestibility defines the yield an animal can extract from the grass. This value is closely related with Acid Detergent Fiber (ADF), an indicator of lignin content in the grass. Lignin difficults digestion and for so, the higher ADF(%) values are, the lower Digestibility ratio (see Eq2)

Eq2

$$Digestibility(\%) = \left[[88.9 - (0.779 * ADF(\%))]\right]$$

On the other hand, Ingestibility defines the quantity a ruminant can voluntarily eat and it depends on Neutral Detergent Fiber (NDF). NDF refers to the structural components of the plant (cellulose, hemicellulose, lignin…), so the bigger it is the lower value the Ingestibility.

Eq3

$$Ingestibility(\%) = \frac{120}{NDF\ (\%)}$$

Combining this two concepts defines pasture quality as a measure of how much can an animal eat (Ingestibility) and how much of that food that the animal has eaten, is really going to be taken advantage in its organism without eliminating it through defecation (see Eq4).

Eq4

$$Relative\ Value = \frac{Digestibility\ (\%) * Ingestibility(\%)}{1.29}$$

<u>Fertilization experiments</u>

Fertilization experiments were determined by two variables: available area and results obtained in soil chemical analysis.

Each treatment requires at least 1000 m^2 to be applied. This extension is necessary as it is the minimum area to obtain at least two bales in order to continue the experiment with the analysis of Big Bale Silage (BBS), the new conservational method proposed (see *State of the Art*). This way, even though it is very interesting to try all different treatments and doses in all the fields, generally space has not permitted this choice. The experimental plots have been consequently divided in two groups: one group in which only one fertilization dose has been tried and compared with a control treatment and another where 4000 m^2 have been delimited and fenced and where four different treatments (including control) have been experimented.

The fertilization plan has been developed according to the Spanish fertility guidelines in grasslands intended for forage crops (Piñeiro Andión *et al.*, 2010). The fertilization regime has been detailed below, separating nutrient by nutrient.

A. Nitrogen

The inadequate use of nitrogen in fertilization regimes, generally applying a higher dose than needed chasing increased productions, can easily cause important impacts. If the vegetation and the soil structure cannot rapidly fix the inorganic nitrogen applied, it will be lost by leaching with the risk of causing a serious eutrophication problem.

As it was previously said, there has been evidence that nitrogen fertilization is related with a reduction of clover in pasture (García *et al.*, 2003) and it strongly determines the balance legume/grass (González, 1982).

The nitrogen dose used in grasslands intended for forage varies depending on the specific production aim and the particularities of each field. In grasslands under ecological grants no inorganic nitrogen can be applied. For all the rest the dose varies depending on the desired legume/grasses balance and it can ascend to 400 kg N/ ha if only grasses to ensilage are desired with and estimated production of 10 t/ha (Piñeiro Andión *et al.*, 2010).

The experimental plots belong to fields were, although legumes are present, main production is due to grasses. In this case and with and estimated production of 10 t/ha, Spanish fertility guidelines recommends a double application of 60-70 kg/N per ha. The first application should be made at the end of winter and the second one after the first grazing (never later than June).

It is also important to keep in mind the results obtained from soil chemical analysis and the strategy selected by the farmer (ecological or not) before definitively determining the fertilization dose. Although nitrogen levels are whether high or very high in all the experimental plots this refers to organic nitrogen, still not available as nutrient for the plants.

B. Phosphorus and potassium

Although nitrogen is the most important element in a crop in yield terms, fertility is closely related with phosphorus and potassium contents in soil. When doing a phosphoric and potassic fertilization, the main aim is first to reach a determined level of fertility (establishment level) and after the objective is to maintain this level. During the first stage the contribution dose must be higher than the amount of phosphorus and potassium extracted while during the second contributions must be approximately the same amount that is extracted (Piñeiro Andión *et al.*, 2010).

To determine the doses that should be applied in soil for each of these components again Piñeiro Andion´s recommendations for 10 t DM per ha and year have been used. These recommendations depend on the exploitation system and on the initial contents of P and K in soil. Piñeiro determines five different qualitative levels (very low, low, medium high or very high) depending on K and P contents in soil. *Table 1* shows the quantity P and K obtained in the chemical analysis of soil for each experimental plot, the correspondent qualitative level and the recommended dose, assuming grazing as the exploitation system given generally grazing and harvesting are combined. In grazing systems nutrient return via cattle defecations is very intense. Generally, phosphorus and potassium inputs (concentrates, feeding condiments and outside forage) are offset with the outputs (grazing and leaching). This is more remarkable as neither of them suffer gaseous losses (Farrugia *et al.*, 2000). These assumptions allow a drastic reduction in phosphorus and potassium doses when applied in grazing systems.

Table 1: Phosphorus and Potassium levels and recommended fertilization dose

EXPERIMENTAL PLOT	Assimilable phosphorus			Assimilable potassium		
	mg/kg	Level	Recommended dose (kg P_2O_5/ha)	mg/kg	Level	Recommended dose (kg K_2O/ha)
PO-1	6.1	Low	70	127	Low	60
PO-2	7.2	Low	70	156	Low	60
TU-1	<4	Very Low	80	75	Low	60
TU-2	nd	Very Low	80	75	Low	60
RIO-1	<4	Very Low	80	108	Low	60
RIO-2	<4	Very Low	80	145	Low	60
LA-1	<4	Very Low	80	152	Low	60
LA-2	<4	Very Low	80	256	Medium	30
PE-1	<4	Very low	80	137	Low	60
PE-2	5.5	Low	70	99	Low	60

*nd: non detectable

As it is noticeable all the phosphoric values are whether low or very low while potassium is always low but for LA-2. This supports that phosphoric and potassium fertilization is recommended in all the experimental plots.

When using potassic fertilizers it is important to keep in mind that potassium is a mobile ion in soils and significant amounts can be lost by leaching (Quemener, 1986). Rainfall seems to be the factor that most strongly affects potassium leaching so application of manures or mineral fertilizers should be avoided before heavy rainfall (Alfaro *et al.*, 2004). The use of combined fertilization N-K also reduces potassium losses by leaching (Alfaro *et al.*, 2004). It is also recommended to at least divide the highest doses (60-120 ppm) in two or three turns, one after each grazing/harvesting period.

No potassium should be applied before the first grazing period is finished in order to avoid the risk of hypomagnesemia, a ruminant's disease that causes unbalance between K, Ca and Mg. The dose applied just after the winter should not be very high. Otherwise potassium concentration in grasses will be unnecessarily high, phenomenon called *luxury consumption*, without a visible increase in production. Luxury consumption reduces potassium levels in soil which will affect next harvests. Clovers are the most affected species by this reduction as they can hardly compete with grasses in low potassium situations (Piñeiro Andión *et al.*, 2010).

C. pH correction

Soil chemical analysis revealed all soils to be Acid or Very Acid. The main reason that plants scarcely grow in acid soils is the presence of exchangeable aluminium in soil complex (Piñeiro Andión *et al.*, 2010). This makes aluminium the most important element to neutralise. Aluminium rate in soil complex has been used as an acid indicator in Spain since the XX century (Mombiela and Mateo, 1984).

One of the most common ways to calculate which quantity of $CaCO_3$ is appropriate to neutralise high levels of exchangeable aluminium was proposed by Kamprath (Kamprath, 1970) and discussed by McLean (Mc Lean, 1982). These authors suggest incorporating as many tons of $CaCO_3$ per hectare as cmol/ckg of exchangeable aluminium is detected in the soil complex. If we are dealing with very toxicity sensitive crops the dose of $CaCO_3$ applied should be multiplied per 1.5 or even doubled (Lema and Rodríguez, 2006).

In this project, after evaluating pH, we have determined total aluminium in screened dry soil samples. Exchangeable aluminium extracted with KCl 0.1M, ratio 1:5, has also been estimated by Quantitative Analysis of Aluminum by Optical Emission Spectrometry with Inductively Coupled Argon Plasma (ICP-OES).

Piñeiro Andión, following the same procedure than above, provides a recommended liming dose to correct acidity. If very active materials such as CaO or $Ca(OH)_2$ are used with a dose over 2 t/ha the application times should be divided in two different turns to prevent from burning the herbage.

Table 2 shows the results obtained in soil chemical analysis concerning total aluminium, exchangeable aluminium, the percentage of exchangeable aluminium and the correspondant liming dose. When the percentage of exchangeable aluminium reaches significant values liming is recommended. If the product to be used is CaO, the liming dose corresponds to the exchangeable aluminium measured in cmol/ckg while it is multiplied per 1.5 in case the product used is $CaCO_3$.

Table 2: Aluminium levels and liming recommendations

EXPERIMENTAL PLOT	pH	Total Aluminium (g/kg)	Exchangeable Aluminium (cmol/ckg)	% Exchangeable Aluminium	Liming dose	
					CaO (t/ha)	$CaCO_3$ (t/ha)
PO-1	5,55	11,54	0,021	0,318	-	-
PO-2	5,45	11,7	0,021	0,233	-	-
TU-1	4,73	25,03	1,981	43,516	2	3,5
TU-2	4,9	19,09	1,116	17,335	1	1,5
RIO-1	5,77	10,94	0,021	0,326	-	-
RIO-2	5,94	14,74	0,021	0,158	-	-
LAM-1	5,99	13,61	0,021	0,172	-	-
LAM-2	5,87	5,67	0,021	0, 8162	-	-
PE-1	4,97	14,84	1,174	18,58	1	1,5
PE-2	6,53	28,67	0,021	0,114	-	-

4.-Results and Discussion

Meteorological data

Three different types of weathers have been profoundly characterized as a result of the monitoring carried out from 17 November 2010 until 15 August 2011.

As it can be observed in *Figure 4.1* the three different weathers analyzed show important differences in terms of temperature and precipitation regime, although under Gaussen criterion, none of them show any dry month (period in which two times temperature shows higher values than precipitation).

Weather 1 is associated to the weather station located in Polaciones, the highest site included in this study. This is reflected in the weather which is determined by the coldest temperatures all over the year and the lowest precipitation regime as it is exposed in *Figure 4.1*. On the other hand, weather 2 correspond to the lowest site, nearest to the coast, shows higher temperatures all along the year and the precipitation regime is far over the other two. Finally, weather 3, situated at a medium altitude, has consequently intermediate characteristics as it will be later detailed.

In this same figure (*Fig 4.1*), it can be appreciated how rain is softly distributed along the year while temperatures show a clear summer peak.

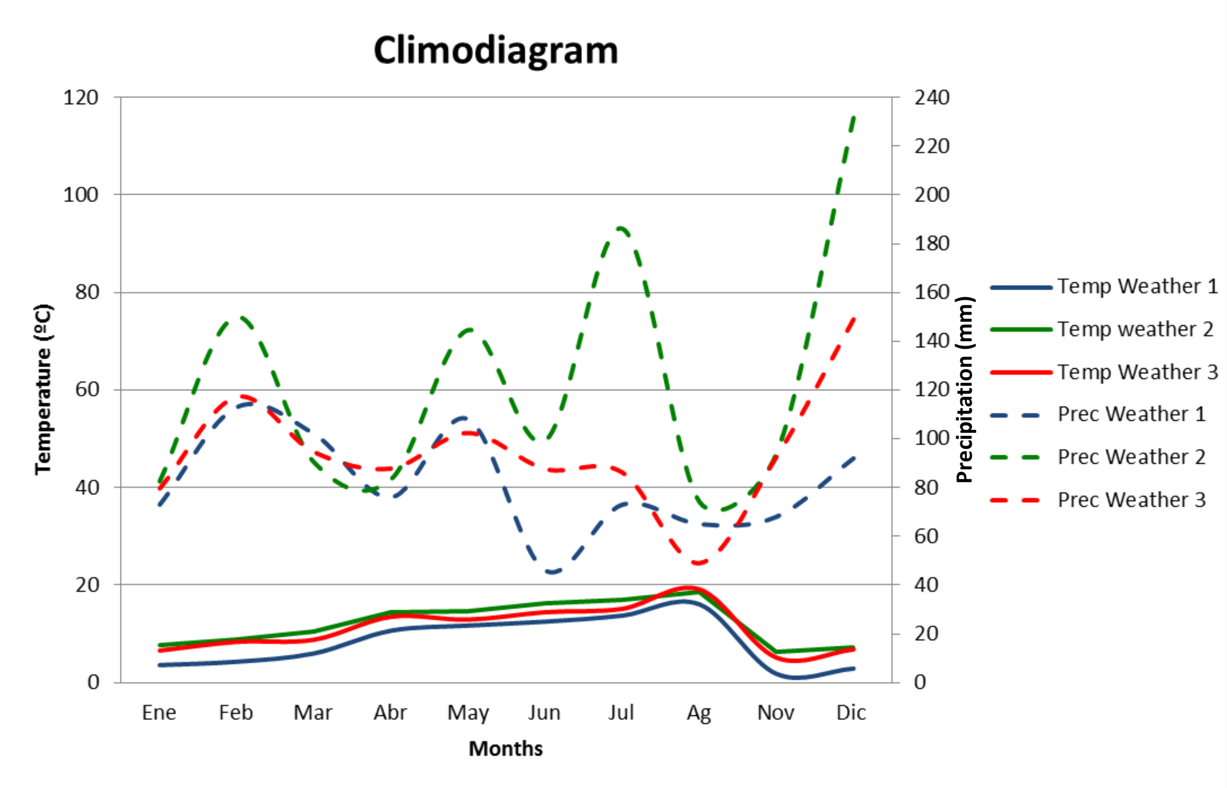


Fig 4.1: Climodiagram of the three different weathers

Figures 4.2, 4.3 and *4.4* show the general tendency of the three weathers for each variable with a regression line included.

Figure 4.2 exposes the behavior of temperature. As it can be easily observe, although weather 1 and weather 2 are the most different attending to temperature values, their behavior during the year is similar (parallel lines). This does not occur with weather 3 that starts the graph being very similar to weather 2 (in November) and seems to be lower limited by weather 1 to which is similar during the summer. To sum up, weather 1 and 2 show similar behavior during the year while weather 3 moves between them, starting in November being similar to weather 2 and ending up in summer being similar to weather 1. The behavior of temperature was predictable due to the different altitudes and the effects in atmospheric pressure. Highest station (Weather 1) show lowest temperatures coinciding with the lowest atmospheric pressure and *vice versa* occurs with lowest station (Weather 2), in which the temperature is the highest as the pressure so.

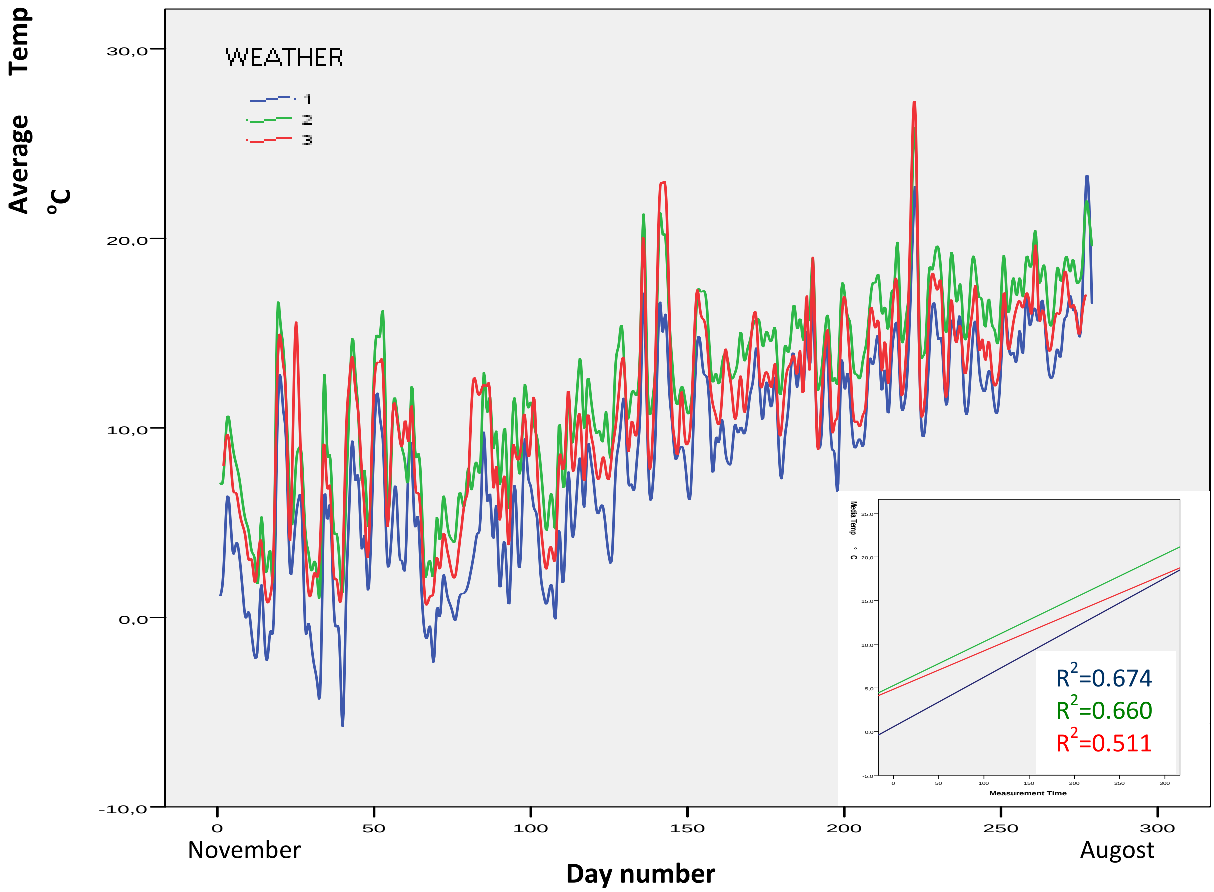


Fig 4.2: Daily average for temperature.

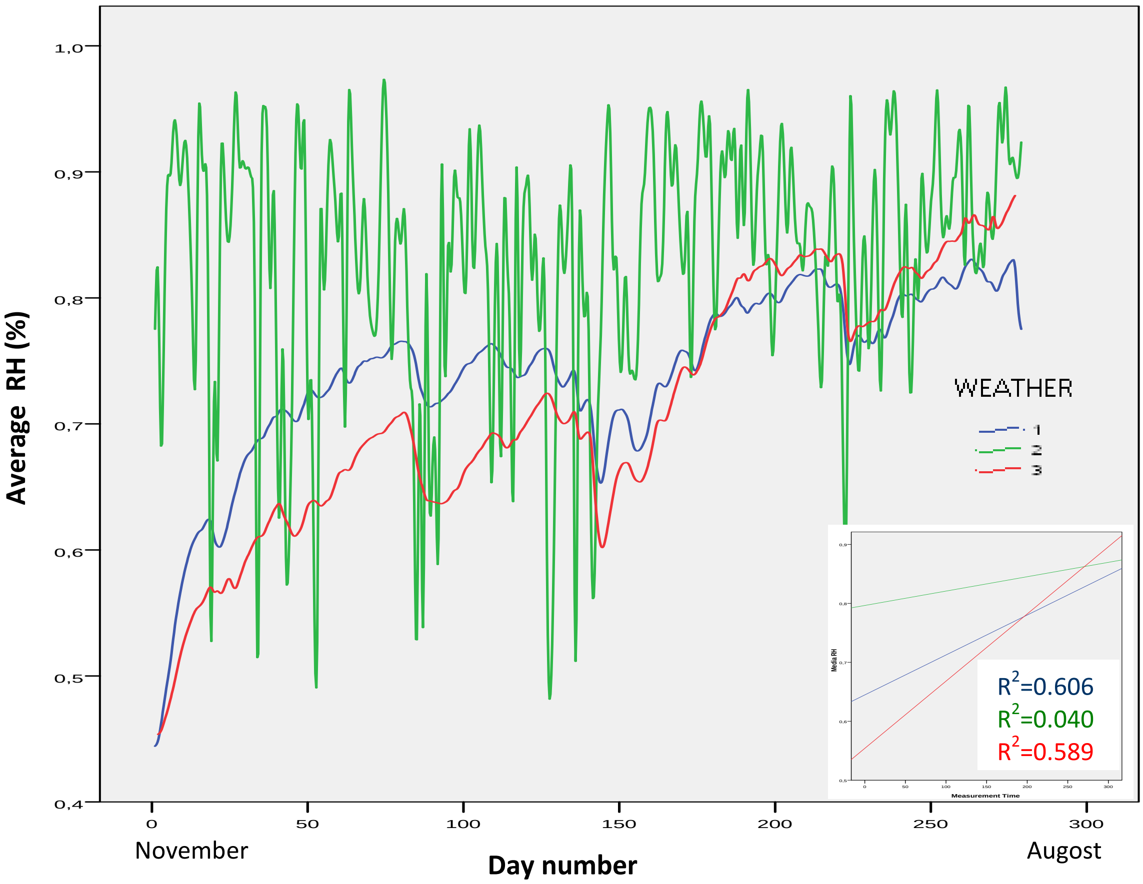


Fig 4.3: Daily average for RH. Comparison of the three weathers

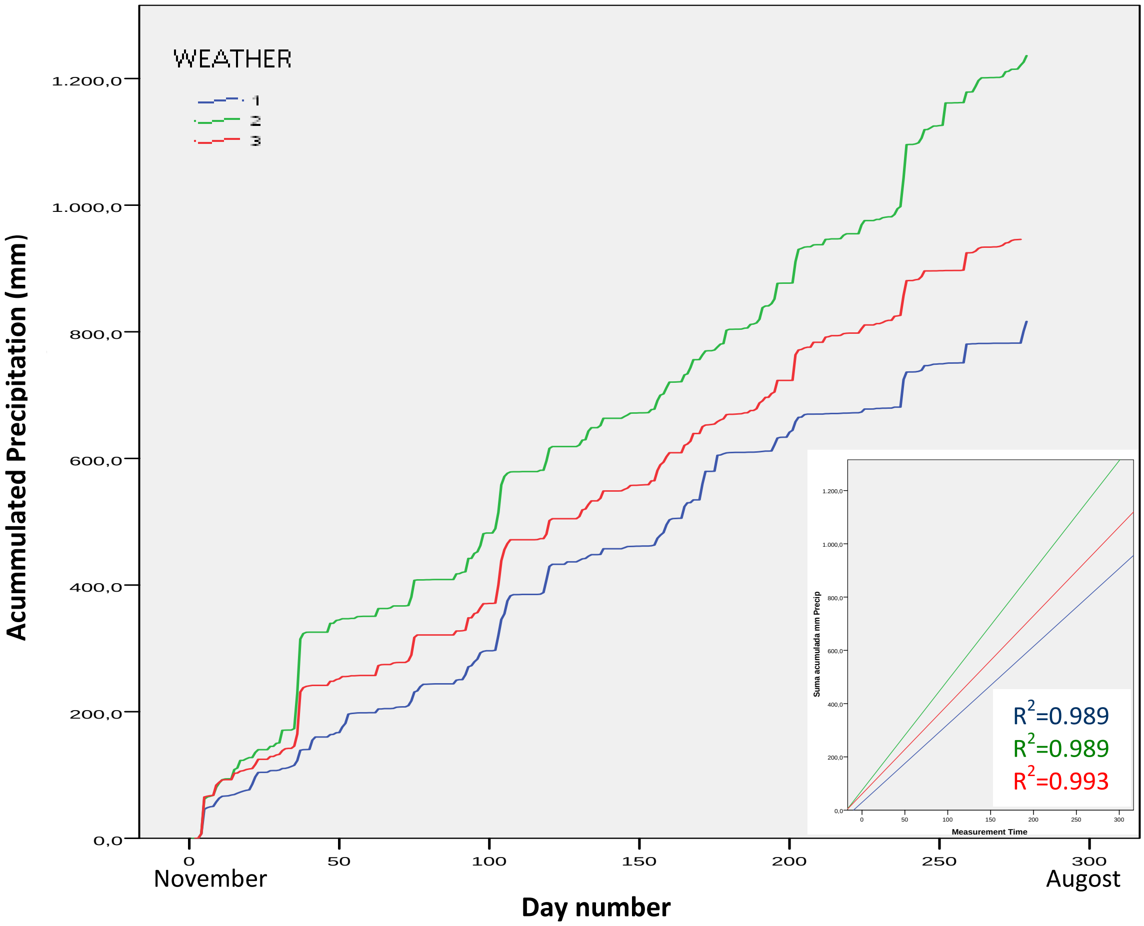


Fig 4.4: Daily accumulated precipitation. Comparison of the three weathers

In *Figure 4.3* the same graph has been constructed, this time in terms of Relative Humidity in air. In this case, while weather 1 and 3 show a similar behavior during the year, weather 2 shows an erratic conduct that causes a very low R^2 in the regression line. Anyway it is obvious that relative humidity in weather 2 is always higher than relative humidity in weather 1 and 3. This is probably because it is the nearest weather station to the coast. Concerning to weather 1 and 3, relative humidity in weather 3 is always lower than weather 1 but for last period in spring. The general tendency of both is to increase with time, which can be related with the raise of temperature shown in *Figure 4.2.*

Finally, in *Figure 4.4* the accumulated precipitation daily added is exposed. This graph has the highest R^2 compared with Figures 4.2 and 4.3 as precipitation grows lineally. It clearly defines weather 2 as the one with more precipitation, growing this difference as time goes through. Weather 1 is the one with less precipitation while weather 3 shows again intermediate conditions. Altitude is the main responsible for this differences that will definitively have an effect in pasture growth. Air moves from the sea into the continent and suffers condensation phenomena losing water conform it climbs higher into Coordillera Cantábrica

The data recollected in this study about meteorological parameters is huge and means the first step to calibrate the grass production model in Nansa Valley. Although the extension of this master thesis does not permit a further analysis of the data an example of the level of detail available wants to be exposed. Data has been divided in four seasons and *Figure 4.5* shows an average Spring day. Every half an hour an average value of temperature coming from the period between 21th March to 21th June has been used to characterize a typical spring day in the valley for each different weather analyzed. The graph can be easily interpreted as temperatures grow in the central times of the day and reach a minimum very early in the morning. As it is expectable, weather 1 corresponds to the lowest temperatures while weather 2 shows the highest values.

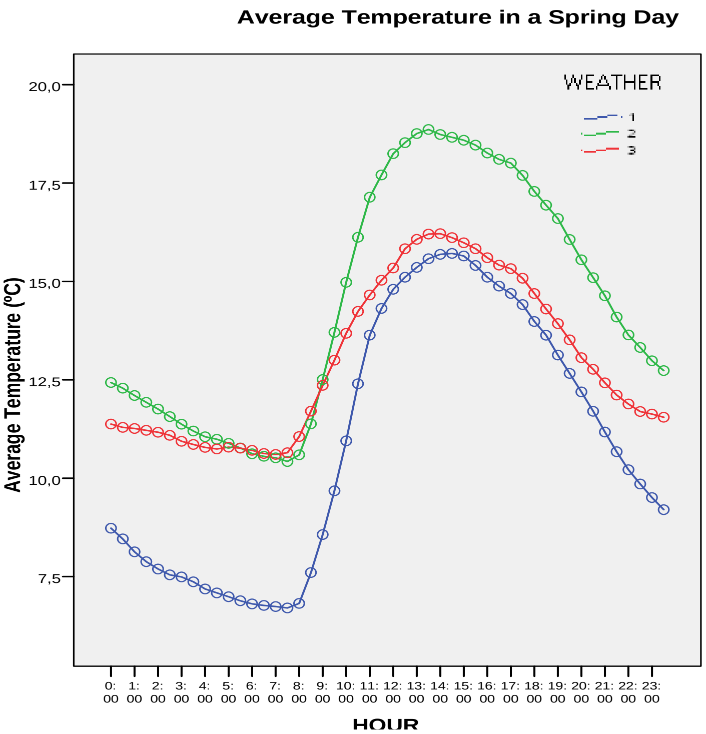


Fig 4.5: Daily fluctuation of Temperature in a spring day

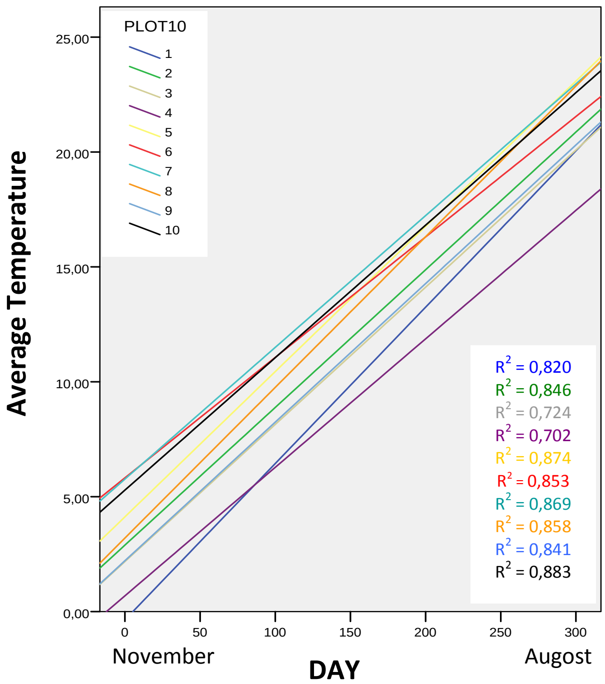
<u>Soil data</u>

Chemical results of soils were exposed in *Matherials and Methods* as it was necessary to understand the fertilization explications. In this point, the physic characteristics of soil, stored by dataloggers will be described.

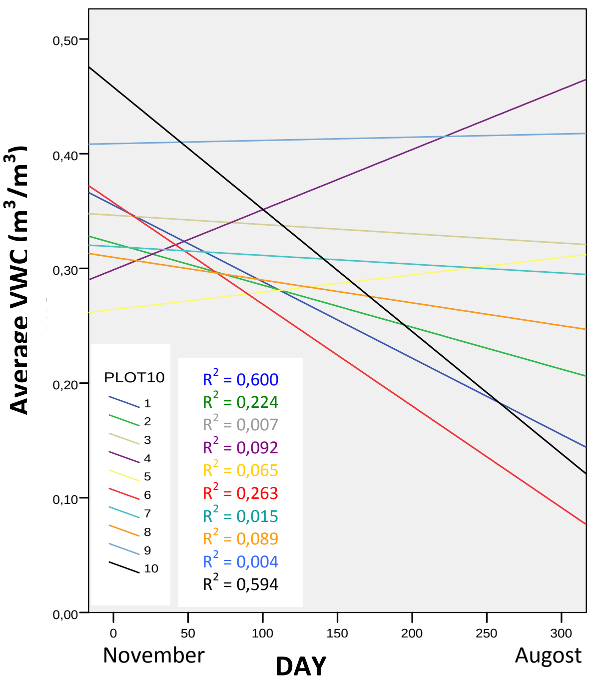
First of all an initial characterization of the three parameters monitored can be observed in *Figure 4.6*.

*Figure 4.6*A shows a similar behavior in terms of soil temperature in the ten experimental plots. During the first dates included in the study temperature in soil shows the lowest value and it lineally grows as time goes through. This is logical attending to the temperature tendency in the three weathers that was exposed in *Figure 4.2*.

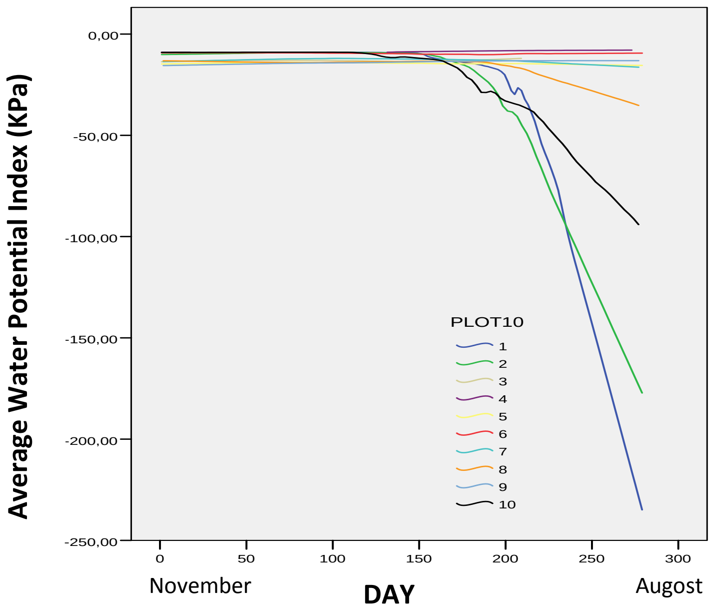
According to Volumetric Water Content (VWC), regression lines show very low R^2 but for PE-2 and PO-1 that reach acceptable values. No conclusions will be obtained from the rest of the tendency lines. In this two experimental plots, VWC decreases fastly as summer gets nearer (see *Figure 4.6B*).



A. Soil temperature in ten different experimental plots



B. Volume Water Content in ten different experimental plots



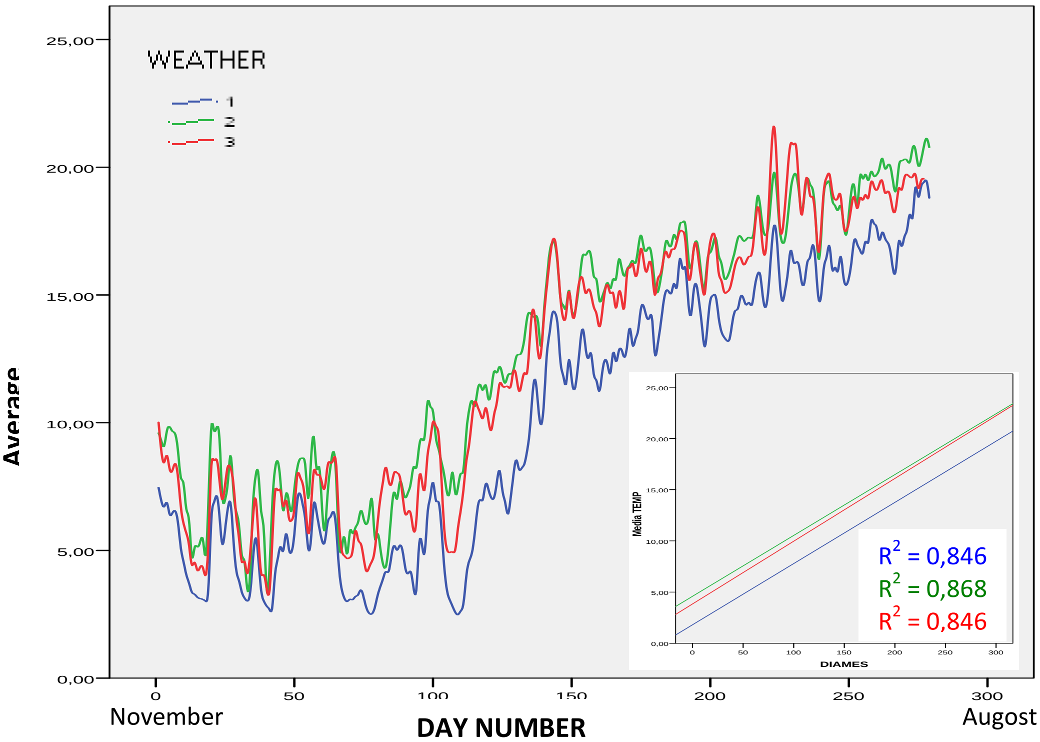
C. Water potencial index in ten different experimental plots

Fig 4.6: Soil parameters evolution during the year

Water potential index is very low until summer, when it exponentially grows in some experimental plots (PO-1, PO-2 and PE-1) as it can be checked in *Figure 4.6C*. This is probably justified by the fast descent VWC shows in those plots. Different textures in the experimental soils revealed in soil chemical analyses have strong influence in VWC and water potential index and for so should be taken into account in farther studies.

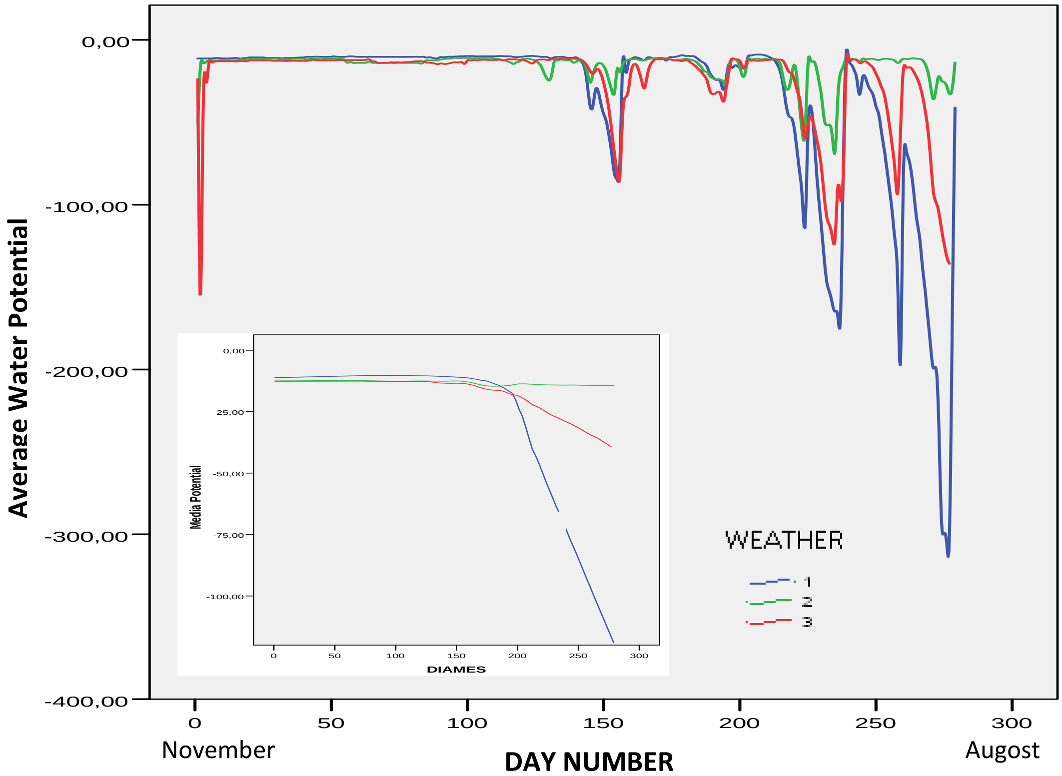
Although there are some differences in the behavior of different experimental plots belonging to the same weather station, it is interesting to see how weather influences soil parameters creating groups with different characteristics. This way, clusters have been created according to the distance of experimental plots to weather stations (see *Figure 3.1*). PO-1, PO-2, TU-1 and TU-2 form the first group correspondent to Weather 1, RIO-1 and RIO-2 correspondent to Weather 2 and finally, Weather 3 includes LA.1, LA-2, PE-1 and PE-2.

First of all, *Figure 4.7* shows how in temperature terms the daily averages of soil temperatures analyzed separately by weathers follow the same canon. The interesting point is that RIO-1 and RIO-2, the group included in Weather 2, show the highest temperature regime. This coincides exactly with the observation in *Figure 4.2*, in which it can be observed how weather 2 is the warmest. The same occurs with weather 1 (the coldest) which also corresponds to the coldest soils and similarly with plots included in weather 3.



4.7: Soil Temperature grouped by different weathers

In terms of Water Potential Index (see *Figure 4.8*) it also works: Soils in weather 2, characterized by high precipitation regime, show a very low potential index during all year. This is remarked by the fact that summer in Weather 2 had very high precipitation in difference with the other two weathers (see *Figure 4.1)*.Again, highest Water Potential Index coincides with Weather 1, the lowest precipitation regime.



4.8: Soil Temperature grouped by different weathers

<u>Herbage data</u>

According to grass production and quality all experimental plots have shown a similar behavior even though dates vary depending on the different experimental plots. If there are no limitations in terms of water, nutrients and light, DM constantly grows along with days in the vegetative period. Meanwhile the quality of pasture reaches a peak from which it starts to descend. This result had previously been found in several publications related with pasture phenology (San Miguel Ayanz, 2001; Ramírez *et al.*, 2010).

In all the experimental plots, independently of the weather they belong to, there are no problems in terms of water availability as it can be checked in *Figure 4.1.*

In the graphs included in *Figure 4.9,* DM and relative quality values of pasture quality has been represented per each experimental plot. The start of vegetative period has been considered to be as the spring, 21th March.

*A*s it can be observed in *Figure 4.9,* DM grows along with time in all the experimental plots but for very few exceptions. These exceptions are mainly related to the productive irregularities in grasslands. It is important to remember that the herbage sample comes from under a cage which was moved after each harvest causing these differences. When this happens although the set of values are a good representation of the production of the whole grassland, they cannot be observed as an evolution of the growth. A secondary reason for this event can be the different moisture conditions in which each sample was recollected. Little variations in moisture strongly influences the result of DM content (see *Eq1*).

Quality of pasture starts to descend between day 35 and day 62 of vegetative period in all experimental plots but for PE-1. These days coincide with 26th April and 24th May. Differences between dates are mainly caused by different altitudes related with plant phenology and its maturation processes.

Descend in quality along with time is easily explained if the criterion followed to determine quality is taken into account. Quality grows at the same time as Digestibility and Ingestibility. These two parameters are inversely proportional to NDF and ADF. The increment in NDF and ADF content in grass grows along with age due to the physiological changes that occur in the plant that reduces the cytoplasmic content in the cells while it increments the fiber components (Nogueira Filho, 1995).

The optimum relative quality value of the grass varies from 180 reached in Tudanca to 120 found in Polaciones. In the middle Peñarrubia, Rionansa, and Lamasón with 161,159 and 130. It is important to remember that these values refer to the peak of quality as a reference that enables us to compare the quality of the different experimental plots. This quality will decrease in harvesting date so it cannot be used as a reference of forage quality in these grasslands.

Comparing production values at the moment when the quality peak is reached, changes the order of municipalities to the opposite. Polaciones shows the highest production values while Tudanca is the less productive grassland in terms of kg of DM/ha. If the values are compared at harvesting date the same result is found. This is explained again by the way quality is defined in this master thesis. As it was described above, the highest values NDF and ADF reach, the lowest quality is. On the other hand, fiber is the main structural component in pasture and for so, one of the main components of DM. It is a possibility that higher values of DM will mean higher values of fiber and consequently lower quality values.

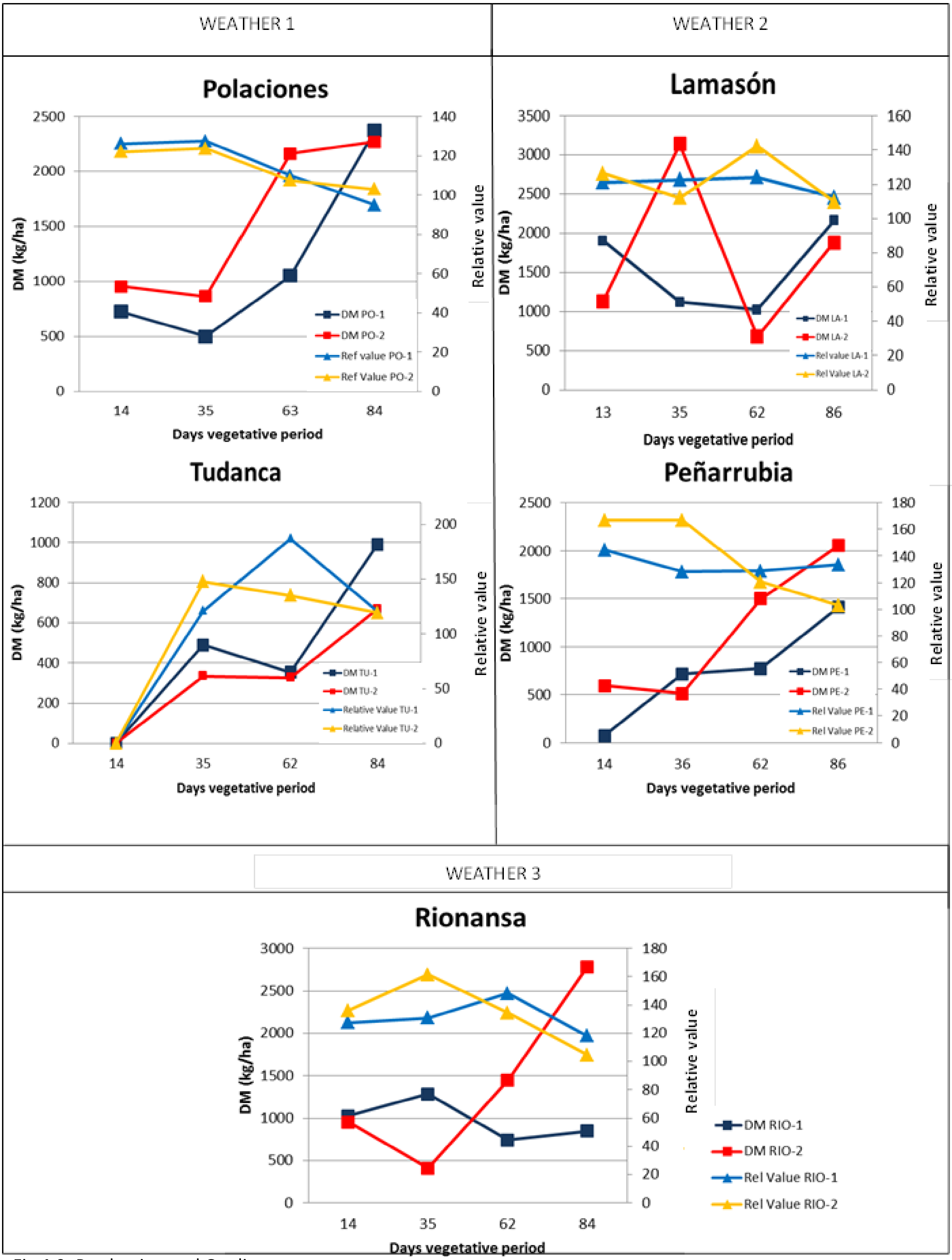


Fig 4.9: Production and Quality

Crude protein, which can be also used as a quality indicator, has also been checked to constantly descent from the same point as the relative quality value analyzed in all the different experimental plots. This is due to mobilization of nutrients inverted in flowering processes.

To propose a harvesting date has to be separately analyzed for each case. Harvesting too early supposes a very important loss in terms of DM while if it is done too late, the forage will be voluminous but not nutritive. As a general indication, production must be at least over 1000 kg DM/ha to compensate the harvesting effort. On the other hand, relative quality values varying from 120-100 are described as acceptable in *American Forage and Grassland Council* descending to an inferior class from relative values under 100. This justifies the recommendation of harvesting with relative quality values over a hundred. By these two principles, it is easy to check the recommended date in each experimental plot using the graphs in *Figure 4.9*.

Nevertheless, it is important to remember that harvesting dates have to be flexible as machines and weather conditions have to be appropriate to carry out the job.

Fertilization plan

After the previous premises about fertilization explained in *Materials and Methods* a final fertilization plan was designed to fulfill all the requirements.

Fertilization applications have been separated in two different turns as it is exposed in *Table 3*, one to be applied in spring and the second one in autumn. Spring fertilization had already been done when this thesis was redacted.

The spring fertilization was done very early in spring before the vegetative period was started. In order to distribute nitrogen dose along the different harvests or grazing periods without the need of doing two different applications during the season, the product selected was ENTEC 24-8-7 (Composition: Total nitrogen 24% from which 13´5% is Ammonia N and 10´5% nitric N; Phosphorus 8% from which 5'2% is soluble in water; potassium 7%; DMPP 0'8% from N Ammonia). N Ammonia changes to nitric N helped by the action of *Nitrosomonas spp.* This action is retarded by DMPP (3, 4-dimetilpirazol phosphate), distributing in time nitrogen available in soil (COMPOAgricultura, 2006) and simulating two different applications. The double application of 60-70 kgN per ha previously determined, requires an ENTEC application of 600 kg/ha (which is equivalent to 144 kgN/ha). This dose involves 48 kgP/ha and 42 kgK/ha which, taking into account that the recommended dose for these elements is around 80 and 60 kg/ha respectively, reaches over half of it. The second half will be applied in autumn fertilization. As it is necessary that high doses of P and K are applied separately, this is not an inconvenient but an advantage.

In order to select the product to be used in autumn, the first requirement was that it should have slightly higher proportion of P than K due to the necessities that should still be fulfilled. At the same time, products that included other principal nutrients such as Ca or Mg which had also turned to be Very Low or Low in soil chemical analysis was positively valuated. The content in Ca would also help to increase pH values in those cases were the use of $CaCo_3$ has not been recommended as it would improve nutrient´s absorbance by plants. The final choice was IMANTHOMAS 0-14-8 with the following composition: 14% P_2O_5, 8% K_2O, 15% CaO, 4% MgO and 20% SO_3 and slights of Zink, Boron and Manganese (IMAN, 2004).

Taking into account the P and K provided in the spring fertilization, the doses applied in autumn should include around 30 kgP/ha and 18 kgK/ha. According to this the dose selected was 225 kg IMANTHOMAS per ha. No different doses will be tested as the best absorbance of nutrients wants to be guaranteed in all treatments. As IMANTHOMAS contains CaO, this dose might be modified according to liming necessities that will be defined before autumn fertilization time.

As Ecological strategy allows hardly any inorganic nitrogen application (inferior to 8%), a different product needed to be selected for this strategy. HUMIBIO turned to be the final election as its composition is the one with highest inorganic nitrogen permitted. Its composition (Nitrogen 7% from which 6% is Organic nitrogen and 1% is Ammonia N; Phosphorus 12%; Potassium 2%; Organic Carbon 35%; humic acids 8%) needs sometimes high doses to be effective (FERTINAGRO, 2006). The recommended dose for this product varies from 400 kg/ha to 1300 kg/ha and so an intermediate value was selected: 600 kg/ha.

Although generally the area available permitted only one treatment to be studied, in TU-1 + TU-2 and RIO-2 4000 m^2 enabled four treatments to be analyzed including control. Taking advantage of this a lower dose of ENTEC was tested (400 kg/ha) and also farmyard manure as a cheaper alternative to increase production.

There are some particularities in fertilization experiments according to the different situations. First of all, common practices that farmers applied normally in their fields should also be analyzed to test which treatment worked the best. This happened in PO-1, were farmyard manure was also included in the study excluding control treatment. It also happened in LA-1 and LA-2 were different doses of cattle slurry and fertilizer P-K 14 14 was commonly used by the farmer and for so included in the study.

On the other hand, in PO-2 the extremely elevated moisture in soil did not permit the fertilization application.

Table 3: Fertilization plan

EXPERIMENTAL PLOT	Strategy	Area (m^2)	Spring				Autumn
PO-1	Ecological	1000 1000	30 t/ha FARMYARD MANURE		600 kg/ha HUMIBIO		225 kg/ha IMANTHOMAS
PO-2	Ecological	1000	CONTROL				225 kg/ha IMANTHOMAS
TU-1+TU-2	Not ecological Fenced Field	4000	CONTROL	400 kg/ha ENTEC 24-8-7	600 kg/ha ENTEC 24-8-7	30 t/ha FARMYARD MANURE	225 kg/ha IMANTHOMAS 2 t/ha $CaCo_3$
RIO-1	Not ecological	1000	CONTROL		600 kg/ha ENTEC 24-8-7		225 kg/ha IMANTHOMAS
RIO-2	Not ecological Fenced Field	4000	30 t/ha FARMYARD MANURE	CONTROL	400 kg/ha ENTEC 24-8-7	600 kg/ha ENTEC 24-8-7	225 kg/ha IMANTHOMAS
LAM-1	Not ecological	1000	40 m^3 CATTLE SLURRY		40 m^3 CATTLE SLURRY+600 kg/ha ENTEC		225 kg/ha IMANTHOMAS
LAM-2	Not ecological	1000	40 m3/ha CATTLE SLURRY	400 kg/ha fertilizer P-K 14 14	600 kg/ha ENTEC 24-8-7	Control	225 kg/ha IMANTHOMAS
PE-1	Not ecological	1000	CONTROL		600 kg/ha ENTEC 24-8-7		225 kg/ha IMANTHOMAS
PE-2	Not ecological	1000	CONTROL		600 kg/ha ENTEC 24-8-7		225 kg/ha IMANTHOMAS 1.5 t/ha $CaCO_3$

Pasture chemical analyses take very long and were not totally finished when this thesis was being redacted. Anyway, a first approach to the results is included as a first view of fertilizers effects.

All the herbage samples used to evaluate treatments effects correspond to harvesting dates even though generally an intermediate sample was taken. In this master thesis, the results for TU-1+TU-2 and PO-1 correspond to the intermediate sample, as there was no possibility of including last analysis. TU-1+TU-2 and PO-1 are located in the highest sites, which involves a delay in the harvesting date (Harvest was done in August) making it impossible to include the final results. *Figure 4.10* shows a compilation of all the fertilization results available when this thesis was being redacted.

Referring to the fenced field experiments (*Figure 4.10A*), a similar behavior in terms of production can be observed for all the treatments but for farmyard manure.

Control treatment shows better production results in RIO-2 than in TU-1+TU-2. This is mainly explained because herbage sample from RIO-2 was taken at harvesting date while, even though it was taken the same day from TU-1+TU-2, grass phenology and growth is delayed as these sites situated at a higher altitude.

Farmyard manure seems to have a positive effect in RIO-2, while it is negative in TU-1+TU-2. There are two reasons to explain this difference. First of all, the farmyard manure used in each field was different and belonged to a different farmer. Analysis of both revealed a higher C/N relation in the one used in TU-1+TU-2. While farmyard manure used in RIO-2 had C/N=17´81, the one used in TU-1+TU-2 had C/N=18´61. The relation C/N can be used as an indicator of mineralization being the best values between 10-15 and getting worse as it grows (Manzanera, 2004). Not only the farmyard manure used in Tudanca had a worse C/N relation but also climatic conditions do not accompany. An application of farmyard manure in spring requires specific weather conditions to decompose and change organic nitrogen into inorganic and available for plants. Weather conditions in RIO-2 are farther more adequate for this aim than weather conditions in TU-1+TU-2, reason for which, farmyard manure should be applied in autumn in these higher fields.

Fertilization treatments, ENTEC40 (400 kgENTEC/ha) and ENTEC60 (600 kgENTEC/ha) enormously increase production almost doubling it when comparing to Control treatment. On the other hand, when comparing ENTEC40 and ENTEC60 in both cases (TU-1+TU-2 and RIO-2) ENTEC60 seems to have a negative effect reaching optimum values when using ENTEC40 treatment. Even though this is very interesting as better results are obtained from lower doses of fertilizer, there is an explication for this behavior. Fertilizers containing N ammonia, may cause a soil acidification when applied as the chemical reaction that changes ammonia into nitric and nitrates generates ion H^+ (Bernier and Alfaro, 2006). This way, the acidification will be more significant the higher the dose of ENTEC is applied. Acidification can drive some nutrients to become not available for plants and as ENTEC60 would have cause lower pH values consequently it may have worse productive values.

In terms of quality of pasture the rule changes. Control quality value for TU-1+TU-2 is very high while it is comparatively low in RIO-2. The justification for this is probably again the different phenology moment in which the two herbage samples were taken (TU-1+TU-2 is not the sample taken at harvesting but an intermediate sample while RIO-2 is taken at harvesting date). Anyway, it is still possible to compare the effect that treatments have on quality. ENTEC60 seems to obtain a similar quality value in all the experimental plots where it has been tested (including experiments done in Peñarrubia and Lamasón). This value that varies between 100 and 120 is correspondent with Forage Quality Type 2 according to *American Forage and Grassland Council.* Whether this means an improvement in quality or not depends on the initial values that can be checked in Control. This way all treatments suppose a decrease in quality for TU-1+TU-2 while they mean higher values in RIO-2.

Another clarification must be done according to the quality reached with ENTEC treatments. Descend of pH value detailed above caused the areas where it had been applied to be covered with *Holcus lanatus.* This species is characteristic to have an optimum range of pH among 5 – 7´5 but it lives under lower pH values. Although it has acceptable ranges of quality (attending to ADF and NDF) palatability is mediocre (Estero, 2004). Relative quality values found in the ENTEC treatments match these characteristics and are mainly due to this species as it is the protagonist in the grass.

These results are confirmed in Peñarrubia (*Figure 4.7C*) were identical behavior in production was shown in PE-1 and PE-2. Fertilization increased in over 1000 kg/ha production in both experimental plots. According to quality, similar values to those observed for treatment ENTEC60 are observed in PE-1and PE-2.

In Lamasón a lot of different experiments were done as the farmer used very different practices (*Figure 4.10B*). ENTEC60 + CATTLE SLURRY, tried in LA-1, obtains the highest production values found (over 6000 kg per ha). In LA-2, CATTLE SLURRY obtains the best result getting even over ENTEC60. ENTEC60 obtains similar production values as the fertilization commonly used by the farmer (PK 14-14) both of them over Control values.

In terms of quality, again LA-1 and LA-2 show the typical value obtained in all the experiments for ENTEC60 (between 100 and 120) while the highest quality value is obtained by PK 14-14. The reason for this is simple. Legumes are very demanding in P (San Miguel Ayanz, 2001) and this kind of fertilization enables them to effectively compete with grasses obtaining a better quality product.

Finally, in Polaciones (*Figure 4.10D*), were a different fertilizing product was tried due to its ecological strategy, no positive results were obtained. Both, production and quality seemed to be negatively affected by fertilizer although the reduction shown in quality is not very significative. It is important to remember, that herbage samples in this case, came from an intermediate date one month earlier the harvesting date. It is possible that farther analysis show different results. Another possible explication is that organic nitrogen contained in HUMIBIO has still not been incorporated to soil.

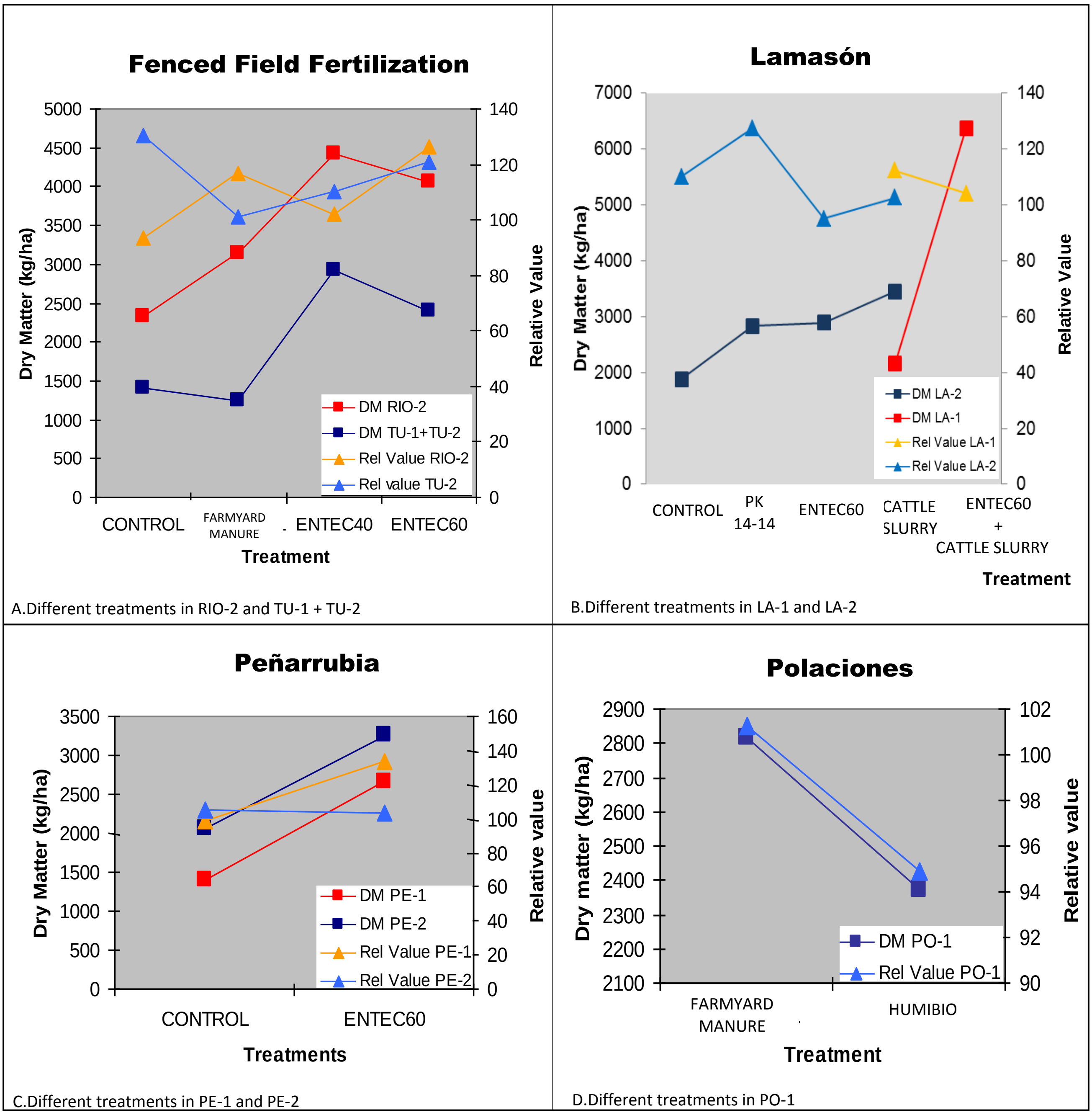


Fig 4.10: Effects of fertilization in different experimental plots

5.-Conclusions

- Valle del Nansa is a very heterogeneous territory. Monitoring techniques used in the valley from November 2010 have proved to be very effective and have obtained very useful and detailed data that will be profoundly analyzed in further publications.
- Different weather stations show variation in terms of temperature and precipitation regime. These differences are not anomalous taking into account the different altitudes at which they are located. Soil parameters monitored show a normal behavior in terms of Water Potential Index and Temperature according to the nearest weather station. Soil and weather conditions in Valle del Nansa are appropriate for pasture.
- Production grows inversely to quality along with time. While production grows continuously, quality reaches a peak from which it starts to descend gradually.
- Harvests should not be done before production reaches values over 1000 kgDM/ha and never after relative quality values are under 100. As a personal experience, harvesting dates cannot be strictly fixed as climatic conditions do not accompany and machine availability is also limited.
- Fertilization with ENTEC, independently of the dose applied, has demonstrated to be very effective in productive terms almost duplicating DM values. ENTEC40 (400 kg ENTEC/ha) seems to have better results in terms of kgDM/ha than ENTEC60 (600 kg ENTEC/ha).Fertilization with ENTEC drives to a relative quality value in pasture that varies among 100 to 120. This corresponds to a medium quality of forage, type 2 according to *American Forage and Grassland Council.*
- Nitrogen fertilization must be done very early in spring. Another complementary fertilization in some circumstances accompanied with liming should be carried out in autumn to make spring fertilization more effective.
- It is important to remember that the most important effort must be done in transferring these results to the farmers and make sure they interiorize them, other ways this work will be lost.

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