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THE RELATIONSHIP BETWEEN FERTILIZER DOSE, FEED VALUE AND ECONOMIC RETURN OF A GRASS-LEGUME FODDER CROP

Master Thesis

by

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Contents

ABSTRACT

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THE RELATIONSHIP BETWEEN FERTILIZER DOSE, FEED VALUE AND ECONOMIC RETURN OF A GRASS-LEGUME FODDER CROP

Beef cattle production in Romania is a widely spread form of subsistence farming, practiced especially in the undeveloped areas of the country. However, free-range grazing regimes do not provide quality feed for the cattle during the hot and dry summers characteristic to Romanian climate. Therefore, providing a forage supplement with good feeding value and which requires minimal labor and material input, is of great importance. To establish the economic and feed value potentials of an oat pea crop mixture, an experiment was conducted analyzing 6 levels of fertilizer regimes, in order to establish the economic threshold of the crop mixture and fertilizer levels. Observations regarding the robustness of the crop and its relationship with the environment recommend the crop as being robust and requiring minimum input of plant protection products. Furthermore, the plots subjected to minimum fertilizer inputs did not suffer from severe nutrient deficiencies, and they were not critically exposed to pathogens attacks. The economic threshold was reached by the control treatment, which required the lowest financial input, while the quantity of crude protein was not significantly reduced. There was no proportional increase in feed value correlated with an increase in nutrient availability.

Keywords: BEEF CATTLE, FEED VALUE, ECONOMIC, MIXED CROPPING.

1. Introduction

Beef cattle’s growing in Romania is a well-established and traditional activity, mostly practiced in the rural areas of the southern and eastern plains, and especially in the western mountainous areas. The production diversity, the low input concerning energy, labor and because of the nature of the forage being used, renders cattle growing a durable and sustainable activity for the Romanian rural population. It also has the potential of meeting the internal necessary of beef cattle production, being a source for commercial exchange and most importantly, ensuring workforce stability in the rural and mountainous areas of the country.

The objectives identified by the Romanian Ministry of Agriculture and Rural Development (MADR) in relation to cattle growing, are as follows:

- Raising the slaughter weight, which will determine a higher ratio of meat in the carcass;
- Supplementation of household income in the rural areas, by obtaining higher quality beef cattle production;
- Stimulating the development of competitive and efficient beef cattle exploitation facilities in the rural and in the less accessible mountainous areas of the country;

Although Romania has a large surface of pastures, and also a significant quantity of secondary bio-based products which can be used as forage for beef cattle production, a good domestic resource of animal genetic material, and a significant human resource, especially in the rural environment, beef cattle production is still far from the efficiency standards observed in other countries in the European Union.

Some of these drawbacks, as identified by the Romanian Ministry of Agriculture and Rural Development (MADR) in 2013, are summarized below:

- Weak organization of beef cattle farmers concerning the valorification of meat and other products which derive from beef cattle growing;
- The reduced size of the beef cattle growing facilities;
- The gradual deterioration of beef cattle production, attributed to unauthorized breeding, a raise in inbreeding incidents in isolated beef cattle effectives;
- The high cost of meat processing;
- And last but not least, <u>the low quality and productivity of forage</u>.

The dynamic of the beef cattle production in Romania, from 2001 to 2007 according to MADR, is presented in the table below.

Table 1-Dynamics of beef cattle production in Romania, 2001-2007

PRODUCT	UNIT	2001	2002	2003	2004	2005	2006	2007
Total beef cattle	Thousand cattle	2.800	2.878	2.897	2801	2862	2934	2819
Total beef cattle live weight	Thousand tons	295	319	378	391	383	318	333
Average slaughter weight	Kg/cattle	208	258	321	328	333	275	280

Source: MADR

Although the average slaughter weight is slowly increasing, it is still lagging behind the EU15 average slaughter weight, which has been, according to Eurostat, 321 kg/carcass, as of 2007.

One of the identified problems which are associated with the inefficiency of the beef cattle production sector in the rural areas of Romania is the use of low-quality forage. As such, this study aims to provide a viable low-cost alternative to commercial forage, by bringing into focus a mixed cropping culture of oats *(Avena sativa)* and forage peas *(Pisum sativum)*.

According to Moga et al., (1996), it is widely known and documented, that until the early 1990's, spring fresh forage, or "*borceag*", as it is called in Romania, has been one of the main forage crops, grown on extensive surfaces, for feeding livestock. In the Romanian classical agricultural technology of pre-1990 practices, it was followed by a second crop, usually silage maize, farmers taking advantage of the early harvesting of the oat peas mixture.

However, after 1990 and de-collectivization, as Moga et al. (1996) noted, the irrigated surfaces were reduced to such an extent, that applying this technology proved to be extremely difficult, due to the meteorological conditions present in Romania, namely late-summer (July-August) persistent drought, which proved to be an impediment for the normal development of silage maize.

Previous research being conducted in the late 1980's and early 2000's, (for example Drăgan and Dihoru, 2004; Veverca and Săbădeanu, 1984) lists the oats-peas forage's economic value as low, due to high seed price, expensive crop protection products used, and also due to disease and pest pressure. Thus, the authors recommend new culture systems that satisfy the requirements of livestock in terms of food have to be developed, in economically viable conditions, with reduced environmental impacts, and with respect to the principles of consumer standards.

Establishing a threshold of economic viability concerning the use of fertilizer is of utmost importance, especially in the context of rural subsistence farming, in the remote communities of Romania.

Along with trying to establish the economic viability threshold for the oat-peas mixture, this study will test the hypothesis that based only on a good fertilizer application strategy along with the nitrogen-fixing capacities of the legume used, the oats-peas crop mixture has the potential of providing a good nutritional value, comparable or superior to many products currently used in the feeding of beef cattle in Romania. Adding to that, the mixture will be subjected to low inputs of mechanical labor and crop protection products.

2. Literature review

Much has been written in the past four decades about the importance of having mixed crops on an agricultural field, a practice also known as intercropping.

Willey (1983) acknowledges the importance of intercropping, as safety insurance compared to monocropping, which is prone to increased risks of crop failure. The reasons behind the adoption of such cultivation practices are diverse.

As Willey (1983) mentions, a large proportion of growers are left with little choice but to cultivate a mixture of crop plants. One of the primary ideas is that they try to mitigate the risks of having a single crop on the ground, at a certain point in time. Single crops can fail completely, thus exposing the already fragile households to even more risks. Environmental conditions, such as prolonged drought periods, temperature shocks, pest dynamics, all constitute a risk in subsistence agriculture. Having two different crops on the ground, at the same time and in the same place, mitigates some of these risks, either by direct or indirect interactions. One of the main requirements of a intercropping system composed of two or more species is that at any point in time, it should present itself as being more efficient concerning the farmer's needs. Those needs can be expressed, as mentioned earlier, as a safety net for adverse environmental conditions, the ability of the system to provide different products in terms of food and feed, the system's resilience as a whole facing pests and diseases' pressure, as well as performing as a low acceptor of manual work and other material inputs.

These requirements may sound too demanding, in a world where a lot of the improvements concerning crop performance are expected to come from using more and more crop protection products, fertilizers and labour inputs. However, the mixed cropping system, composed of compatible species, is a prime example in illustrating how the interactions between the two species can lead to important benefits for the farmer.

Looking at the use of mixed cropping systems for improving forage feed quality, Anil et al. (1998), have noted that having a mixed crop presents concrete advantages when trying to supply a superior quantity of protein and other nutrients, in the dietary intake of cattle used for producing beef as well as milk.

Usually, in the highly advanced animal production systems, such as the one in the United Kingdom, which Anil et al. (1998) analyzed in their review, there are large quantities of cereals and other grasses which are being used for forage, and for good reasons. They contain good amounts of starch, sugars and carbohydrates, which provide an important amount of energy for the animals.

However, the cereal or grass based diet has one major drawback, and that is the low level of crude protein in its composition. This element is paramount in the production of beef cattle, and it has to be provided in a manner which is both efficient for the animal, but also cost-effective for the farmer. The obvious solution, as supplying the animal with commercial protein concentrates or other protein-rich additives, such as fish-meals, are both cost-ineffective and also not popular or accessible, in the case of the latter. (Anil et al., 1998).

Here is where the intercropping system shows its advantages of using a cereal, to satisfy the energetic and carbohydrate needs of the animal, and also using a legume, to provide a less expensive source of crude protein.

As Anil et al (1998) clearly point out in their review, having a mixed cropping in a temperate environment, comprised of a grass and a legume, proves to be a lot more efficient, in terms of radiation and light use efficiency, improved weed mitigation capacity and also a decrease in sensitivity to pest and diseases attacks. The conservation of resources, such as reducing soil erosion and water use efficiency is also mentioned by the authors.

In the next paragraphs, a number of studies are shown which point out the importance of using mixed cropping.

According to Tuna and Orak (2007), there are significant yield increases by using a mixture of a grass and a legume, than growing them separately. In their study conducted during 1999 and 2001, in the region of Tekirdag, Turkey, they analyzed a number of factors which are components of the yield, in vetch *(Vicia sativa L.)* and oat *(Avena sativa L.),* grown in either mixtures or as a sole crop, with different percentages of both species present in the various mixture systems. The authors analyzed factors such as the plant height, number of branches and pods, as well as dry matter weight.

Regarding plant height, Tuna and Orak (2007) clearly point out the advantages of mixed cropping, concerning the legume's performance, which reached its top height of 89.8 cm in the 75% vetch and 25% oat mix. The authors also illustrate that the average height of the vetch was decreasing proportionally with its percentage in the mixture, and had the lowest stand (57.8 cm) when it was grown as a single crop. However, they did find out that the oat plants performed better in terms of plant height, when they were grown as single crops; this is possibly attributed to inter-specific competition.

Investigating the dry yield and the herbage, Tuna and Orak (2007) found statistically significant differences between mixing percentages of the two crops. The mix of 25% vetch and 75% oat had yielded the highest quantity of herbage (29 tons/ha), while the single stand of vetch performed worse when this parameter was analyzed, yielding a mere 17.8 tons/ha, in the first year of the experiment. In the second year of the experiment, the sole crop stand of oat had the highest yield of 23.1 tons/ha, and the herbage yield of 75% vetch and 25% oat was the lowest, at 15.6 tons/ha. Overall however, the productivity of the mixed crops was higher than the sole cultivating of the vetch. As a consequence, the dry matter parameters followed the same pattern as the fresh weight measurements. It was also pointed out by the authors that the higher the percentage of vetch within the mixture, the lower the dry weight and fresh weight would be.

From the work of Tuna and Orak (2007), we can conclude therefore that this mixture comprising of vetch and oat is producing significant increases in forage mass. As the authors point out, the most successful mixture taking into account the local environmental conditions, proved to be the 75% vetch combined with the 25% oat.

To conclude, this study provides concrete evidence supporting the theories that a mixture of a legume and a cereal can perform better in providing a good forage quality, than either of the two cultivated separately.

The advantages of intercropping are expanding beyond the wellbeing of the crops themselves. Much research has also been directed into evaluating whether this system is also beneficial regarding agronomic aspects of plant cultivation, and especially into soil dynamics. This particular issue is of interest to our research topic, because as mentioned in the introduction of this Thesis, a lot of the agricultural activity involving the raising of the cattle is taking place in mountainous areas, where soil erosion is known to be an issue, not just in Romania, but throughout the world, where mountainous regions with high slopes are used for cultivation.

Wall et al. (1990), used the comparing methodology between a simple silage maize stand and a mixed grass-legume stand, where the same maize was used, along with an intermediate crop, the red clover *(Trifolium pratense).* The authors wanted to know if there is any effect on the soil runoff between the two different stands, and whether the possible differences could be attributed to the presence of the red clover legume. Concerned also about the inter-specific competition that might develop, the authors also looked at the yield of the maize plant and nitrogen consumption, both in solitary stand and in the mixed stand. Their results are summarized in the next paragraphs.

The authors have found a clear correlation between the presence of the red clover within the maize crop, when looking at yield parameters and also nitrogen consumption of each system. For example, when taking the maximum economic yield as a reference parameter, Wall et al. (1990) concluded that the maize-red clover stand needs roughly 42 kg/ha less nitrogen, than the single stands, in order to reach its maximum economic yield. They also concluded that under no nitrogen fertilization, and comparing the maize yield of the mixed stand with the maize yield of the single stand, there has been a statistically significant higher yield of silage maize biomass of the crop grown in the mixed stand, and the average of this difference was 30,2%. The maize-red clover stand, with and without added nitrogen, produced 34.8 t/ha and 26.3 t/ha respectively. The single maize stand, with and without added nitrogen, produced on average 35.0 t/ha, and 20.2 t/ha respectively. From these results, we can clearly see that the presence of the red clover in the stand did not only manifested no inter-specific competition regarding the maize yield under sufficient nitrogen supply, but it also positively influenced the yield of the maize crop, in the plots where no nitrogen was added, raising yields of up to 20% on average.

Concerning the other experimental objective, whether having a supplementary soil cover within the maize stand, the results were clear. Using a method called Guelph Rainfall Simulator 2, the authors collected data regarding runoff soil erosion, from their experimental sites, from both stands of single maize and mixed maize-red clover. Measurements taken in 1987, 1988 (2 assessment dates) and 1989, found that the volume of runoff water and soil was at any time higher from the maize stand, than from the maize-red clover stand. Concerning runoff and soil losses, the benefits of having a legume presence in the stand were obvious and significant. For instance, red clover presence manifested a 21-100% reduction in runoff, and 42-100% reduction in soil loss. The results of these measurements are presented in the figures below.

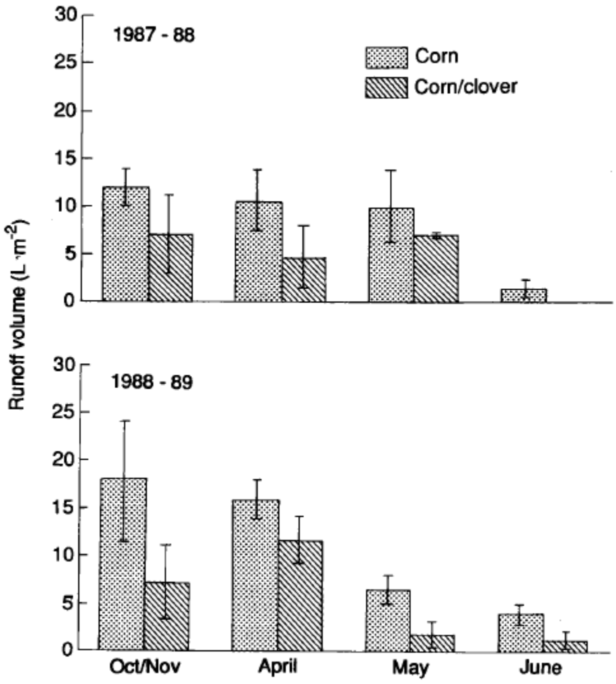

Figure 1. Average runoff in liters per meter square measured in the single maize and maize-red clover stands, at 8 assessment dates, during 1987-1989. (Source: Wall G. et al., 1991).

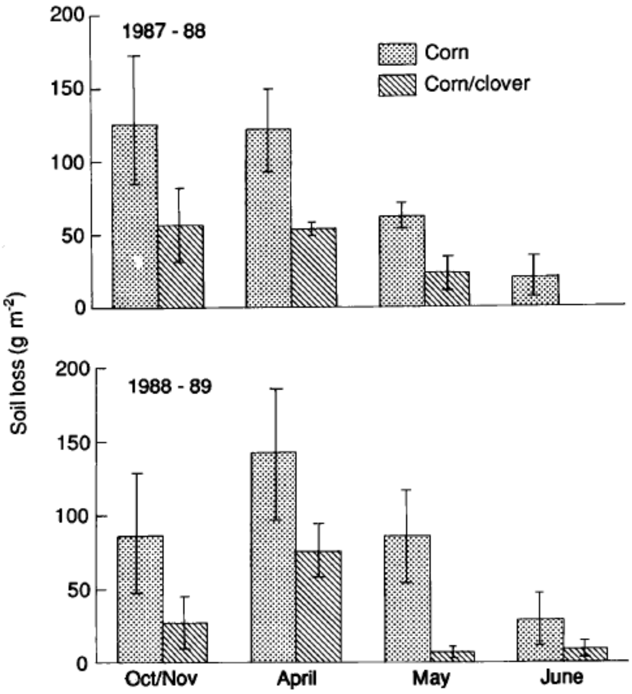

Figure 2. Average soil loss in grams per meter square measured in the single maize and maize-red clover stands, at 8 assessment dates, during 1987-1989. (Source: Wall G. et al., 1991).

From the above mentioned study, we can conclude that the benefit of a legume within a grass stand, reach beyond simple physiological implications, and it is extended into agronomical issues, helping the preservation of soil qualities.

Concerning practical aspects, the timeframe which is being exploited by the chosen crops coincides with an age-old problem of the Romanian rural livestock production. Exploiting the plant’s physiology, and the favorable climate conditions (mainly precipitation abundance) of the vegetation period, is at the center of the oat-peas mixed crop strategy.

As can it be noticed from the graph below, which details the average precipitation for the Romanian capital, there is a peak of precipitation in the three months of vegetation. Following, we see reductions of 50 to 70 percent in precipitation; therefore this climate trend is acting as a limiting factor regarding biomass accumulation and regenerative capacities of pastures. This is where the oats-pea crop mixture fills in the gap – providing high quality protein and carbohydrate nutrition for grazing animals, under limited availability of grazing possibilities.

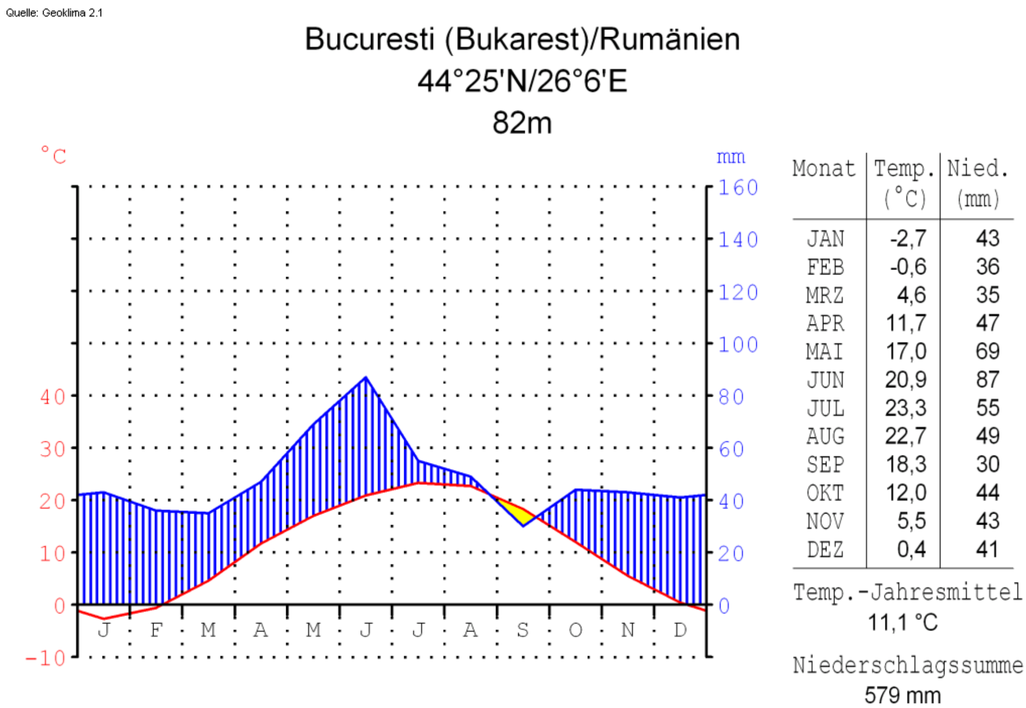

Figure 3. Climadiagram of the city of Bucharest, Romania

Source: http://en.wikipedia.org/wiki/File:Klimadiagramm-deutsch-Bucuresti_%28Bukarest%29-Rum%C3%A4nien.png

Aside biomass availability in critical periods, there are several other benefits of having forage available for consumption in the driest months of the summer. First of all, the animals are no longer required to be herded, guarded or attended during the day. Practices of immobilization have been around for generations, even on pastures, and trying to reduce the time of travelling, searching and free grazing of cattle, will have a direct impact on the weight gain of the animal.

L J Krysl (1993) shows the effect of diet supplementation on the behavior of grazing cattle, concerning energy expenditures, grazing time and biomass conversion into body weight. Protein supplements (regardless of type and timing) added to the diet of the cattle in the study, decreased average grazing time with an average of 1.5 hours per day, thus lowing energy expenditures and positively influencing body weight gain. Therefore, taking these results into account, it is of good agricultural practice to try to supplement the diet of free range grazing cattle with quality protein forage which will not present the health problems of grain feeding.

As being grass supplement forage, the oats-peas mixture does not promote the proliferation of pathogenic gut bacteria, such as various strains of E coli. These bacteria, which are known to cause hemorrhagic colitis after being ingested by humans, are present in the gut of cattle.

These particular strains are present in 30 to 80 percent of all cattle, with the prevalence depending mainly on diet and the abundance of diet grain.

As Callaway et al (2003) report, the high presence of O157:H7 is mainly attributed to the grain diet present in all of the industrial cattle producing facilities. Experiments which switched the pre-slaughter diet of grain-fed cattle to forage of barley, alfalfa or millet, showed a reduction of 1000 fold in pathogenic E coli populations within 5 days, while also reducing the bacteria’s ability to survive and recover after acidic shocks present in the human digestive system.

Therefore, we can conclude that fresh forage has also medical value, concerning the regulation of pathogenic E coli strains in beef cattle, which might occur due to grain feeding.

In conclusion, looking at prior studies, we can clearly see the agronomic value of mixed cropping, and also the value of fresh forage, concerning body weight accumulation, reduction of energy expenditures and medical value in fighting aggressive pathogenic bacteria.

3. Materials and Methods

3.1 Site specifications (geography, climate and soil characteristics)

The experiment has been conducted at the Ihinger Hof research station, owned by the University of Hohenheim. The geographic location is presented below.

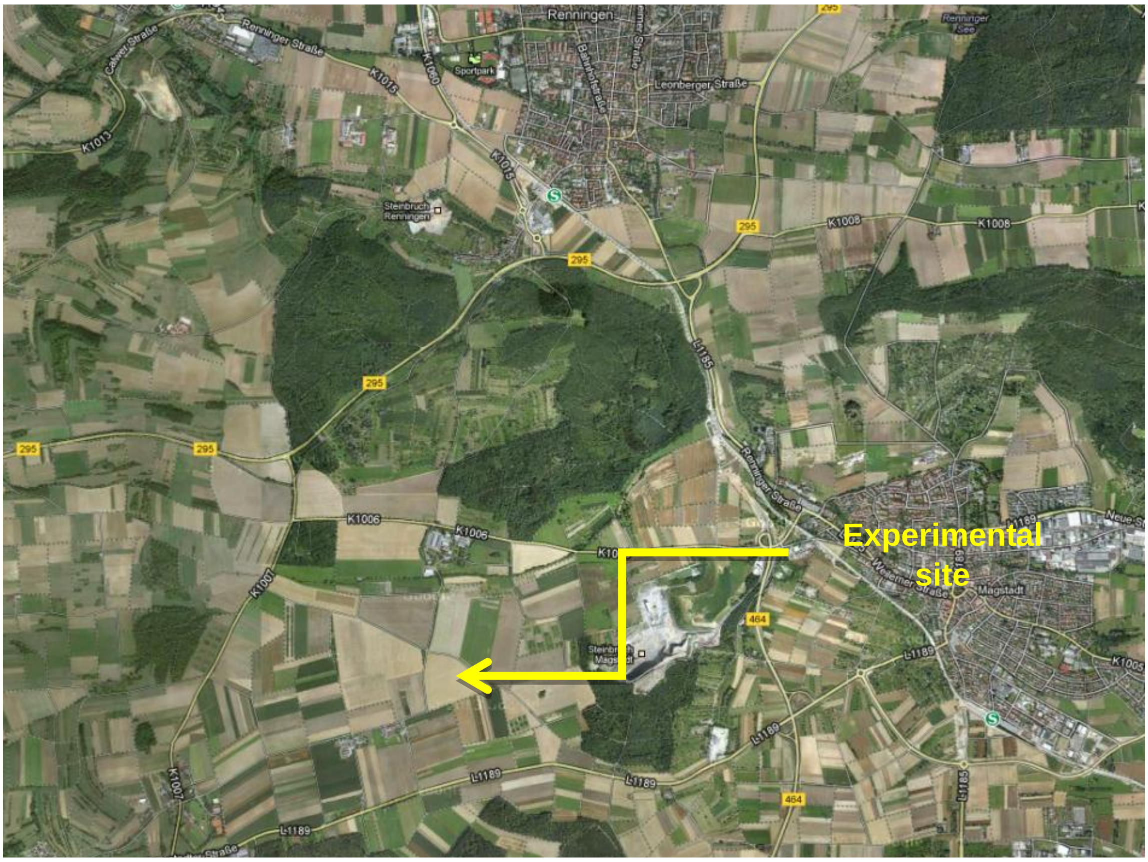

Image 1. Location of the Ihinger Hof experimental station. Reference local area´. (Image source: Google Maps)

Image 2 Location of the Ihinger Hof experimental station. Reference Germany. (Image source: Google Maps)

The experimental site is located on the administrative area of the town of Renningen, in the district of Böblingen, state of Baden Wurttemberg, Germany. The geographical coordinates of the town are 48.7656° N, 8.9367° E. (Google Maps).

As communicated by the Ihinger Hof staff, the experimental site is located on a clay soil, with good fertility and drainage conditions, and the altitude of the trial site ranges between 460 and 520 m.

Temperature mean of the period 1967 to 2009 at the Ihinger Hof weather station is 7.7^0 C. The temperature average of the last 10 years, between 2003 and 2013 is 9.2^0 C, and the mean precipitation of the last 10 years is 688 mm per year. The weather station is located on site, and its distance to the experimental plot is 0,5 km.

3.2 Experimental design

The experiment is laid out as a Randomized Complete Block. This particular design has the advantage of assuring that any heterogeneity of the trial site is being accounted for. The treatments are then distributed randomly within blocks, with the untreated included.

The layout of the experiment, including the treatment details, is listed in the image below.

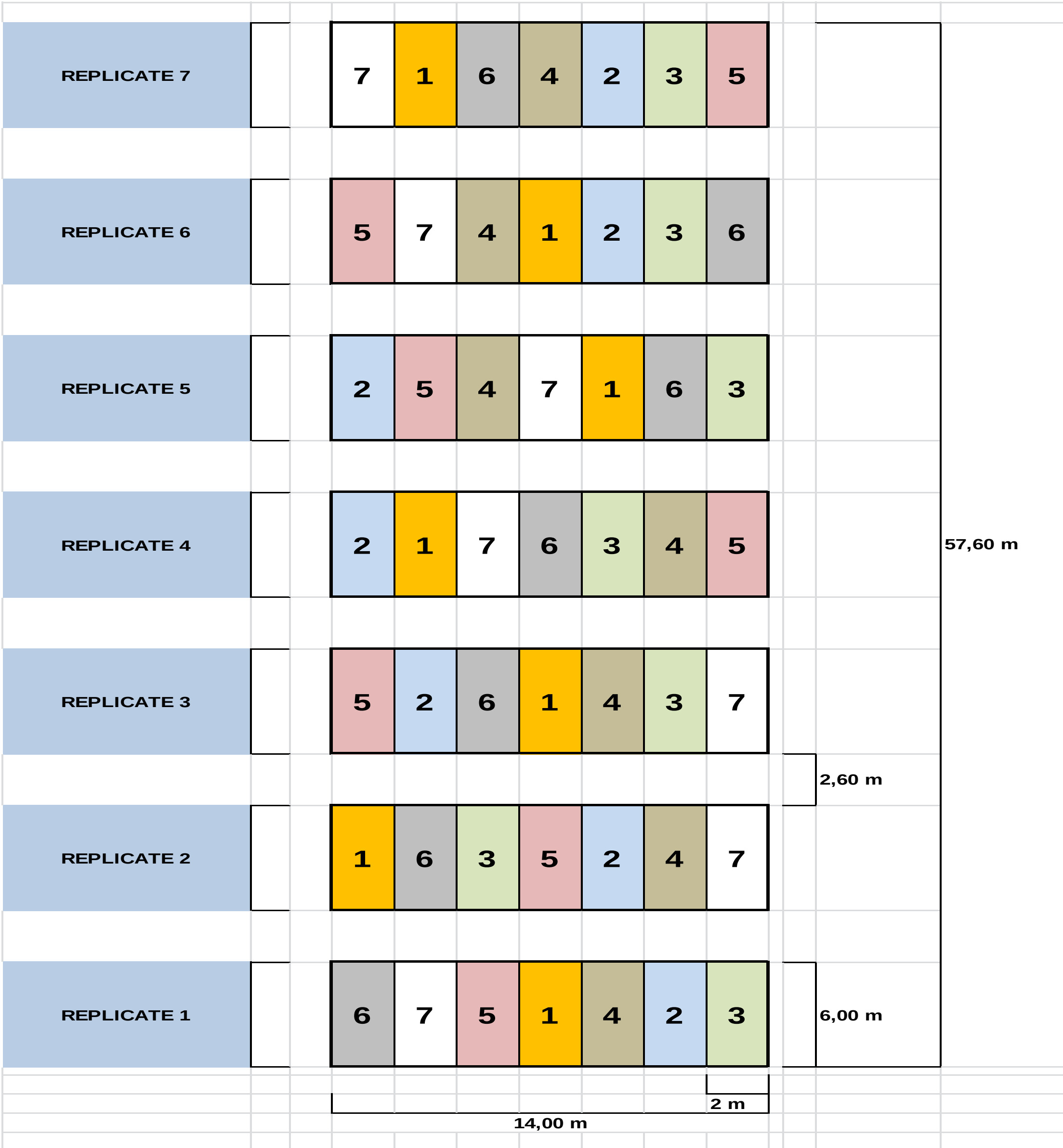

Image 3 Layout of the experiment and treatments. (1 = Control; 2 = 40 Kg N/ha; 3 = 120 Kg N/ha; 4 = 240 Kg N/ha; 5 = 35 Kg NPK/ha; 6 = 105 Kg NPK/ha; 7 = 210 Kg NPK/ha)

As it can be observed from the image above, the trial consists of seven treatments, with seven replicates each. The plot length is 6 meters, and its width is 1,5 meters, total surface of 9 m^2. The total cultivated area is 441 m^2.

3.3 Agronomic details

The agronomic details such as plant material, treatment details and maintenance work performed on the trial site are listed below.

3.3.1 Plant material

The plant material (seeds of *Avena sativa* and *Pisum sativum*) has been procured by the Ihinger Hof staff, and it has been selected as to be found on the Romanian seed market as well.

Table 2- Crop 1 description

Crop name	**OATS *(Avena sativa)* AVESA**
Cultivar	Scorpion
Origin	Saaten Union, Nordsaat Saatzucht GmbH, D-38895 Langenstein
TGW (g)	45,6
Germinability (%)	95
Planting date	April 5 2013
Planting rate (kg/ha)	90

Table 3- **Crop 2 description**

Crop Name	**PEAS *(Pisum sativum)* PIBSX**
Cultivar	Dolores
Origin	Saaten Union, Norddeutsche Pflanzensucht GmbH, D-23999 Malchow
TGW (g)	168
Purity (%)	99
Germinability (%)	96
Planting date	April 5 2013
Planting rate (kg/ha)	140

3.3.2 Treatment items

Table 4- **Tested items description**

Treatment Name	**Active ingredient(s)**	**Content of a.i. %**	**Formulation type**	**Application type**
KAS (Potassium Ammonium Sulphate)	N	27	Granules	Soil Surface
NPK (Complex fertilizer, containing Phosphorous, Nitrogen and Potassium)	N; P; K;	15; 15; 15	Granules	Soil Surface

Table 5- **Application quantities per hectare**

Treatment no.	Product / formulation	Rate of product/ha		Dosage a.i. In kg/ha	Timing
1	Control	-		-	Not treated
2	KAS 27 % N	40	kg/ha	10.8	Pre-emergence of crop
3	KAS 27 % N	120	kg/ha	32.4	
4	KAS 27 % N	240	kg/ha	64.8	
5	NPK 15-15-15	35	kg/ha	5.25 each	
6	NPK 15-15-15	105	kg/ha	15.75 each	
7	NPK 15-15-15	210	kg/ha	31.5 each	
Application	8 April 2013 (3 days after planting)				

Table 6- **Application quantities per plot**

Treatment no.	Product / formulation	Rate of product/plot		Timing
1	Control	-		Not treated
2	KAS 27 % N	0.13	kg/plot	Pre-emergence of crop
3	KAS 27 % N	0.40	kg/plot	
4	KAS 27 % N	0.80	kg/plot	
5	NPK 15-15-15	0.21	kg/plot	
6	NPK 15-15-15	0.63	kg/plot	
7	NPK 15-15-15	1.26	kg/plot	
Application	8 April 2013 (3 days after planting)			

Table 7- **Previous crop**

Year	Crop
2012	Triticale

Table 8- **Pesticide(s) applied to the trial area**

No.	Date	Treatment	Active Ingredient
1.	06 May 2013	Schneckekorn	Iron III-Phosphate
2.	06 May 2013	Trafo WG	Lambda Cyhalothrin

3.4 Observations and sampling methods

All field observations performed at the two evaluation dates, with the exception of the evaluation of tiller density in oats, were done according to the EPPO PP1 Standards, concerning the correct conduct of field experimental plots. The evaluation key is presented in the table below.

Table 9- **Evaluation descriptions (field)**

Eval. Number.	Evaluation Descriptions
1.Crop vigor	Full crop stand was visually assessed, on a 1-10 rating scale. 1 = no standing crop; 10 = healthiest crop on site. Values between 1 and 10 given as scoring value, estimating general crop vigor condition. Was done from one direction NW-SE.
2. Plant height	Plant height measurements of the standing crops were taken, of 3 plants per plot, and then the average per plot was calculated.
3. Photosynthetic activity	*Avena sativa:* Measurements taken of 5 random plants/plot. Each plant was sampled 3 times, the first fully unfurled leaf was chosen as sample part. SPAD measurements taken starting approx. 3 cm from top of leaf, with 3 cm between sampling spots on the leaf. 3 x 5 plants/plot;

	N=15 measurements; *Pisum sativum:* Measurements taken of 5 random plants/plot. Each plant was sampled 3 times; the first fully unfurled composed leaf pair and one of the first internode composed leaf were chosen as sample part. SPAD measurements taken randomly slightly off-centered on the leaf, to avoid nervure interference. 3 x 5 plants/plot; N=15 measurements;
4. Leaf area index	LAI measurements of the plots taken and the average per plot were calculated.

Source: EPPO PP1 Standards, http://pp1.eppo.int/.

The N_{min} measurements, concerning the nitrogen content in the soil left after harvest, were conducted on 27 June 2013, with borehole soil samples taken from 5 blocks. The samples were taken at standard depths of 20, 60 and 90 cm.

Data was logged into the field notebook, and all observations transferred into excel rating shells.

All laboratory observations and data collection were done according to the internal quality measures of Ihinger Hof. The evaluation key is presented below.

Table 10- Evaluation descriptions (laboratory)

Evaluation Number.	**Evaluation Descriptions**
1 Fresh weight	Total above-ground biomass, sampled and adjusted to cultivated surface (t/ha)
2 Dry weight	Total above-ground biomass, sampled and adjusted to moisture content and cultivated surface (t/ha)
3 Nitrogen content	Total nitrogen in a dry sample, CN Analyzer method.

3.5 Statistical analysis

The statistical package used for the analysis of the data is the SAS Version 9.3.

All obtained data were subjected to a Bartlett's test for the homogeneity of variance. Collected data were analyzed by using an ANOVA two-way analysis of variance, and to appropriate parameters, a regression analysis was conducted.

The probability of no significant differences resulting from the testing of different treatment means was then calculated as the F probability Value. A regression analysis was also conducted, using the same software, in order to determine the level of dependence between the response and the influencing factor variable. The R^2 (adjusted) parameter was used as an interpretation of the dependence between the influencing factor and the respective response.

4. Results

4.1 Weather data

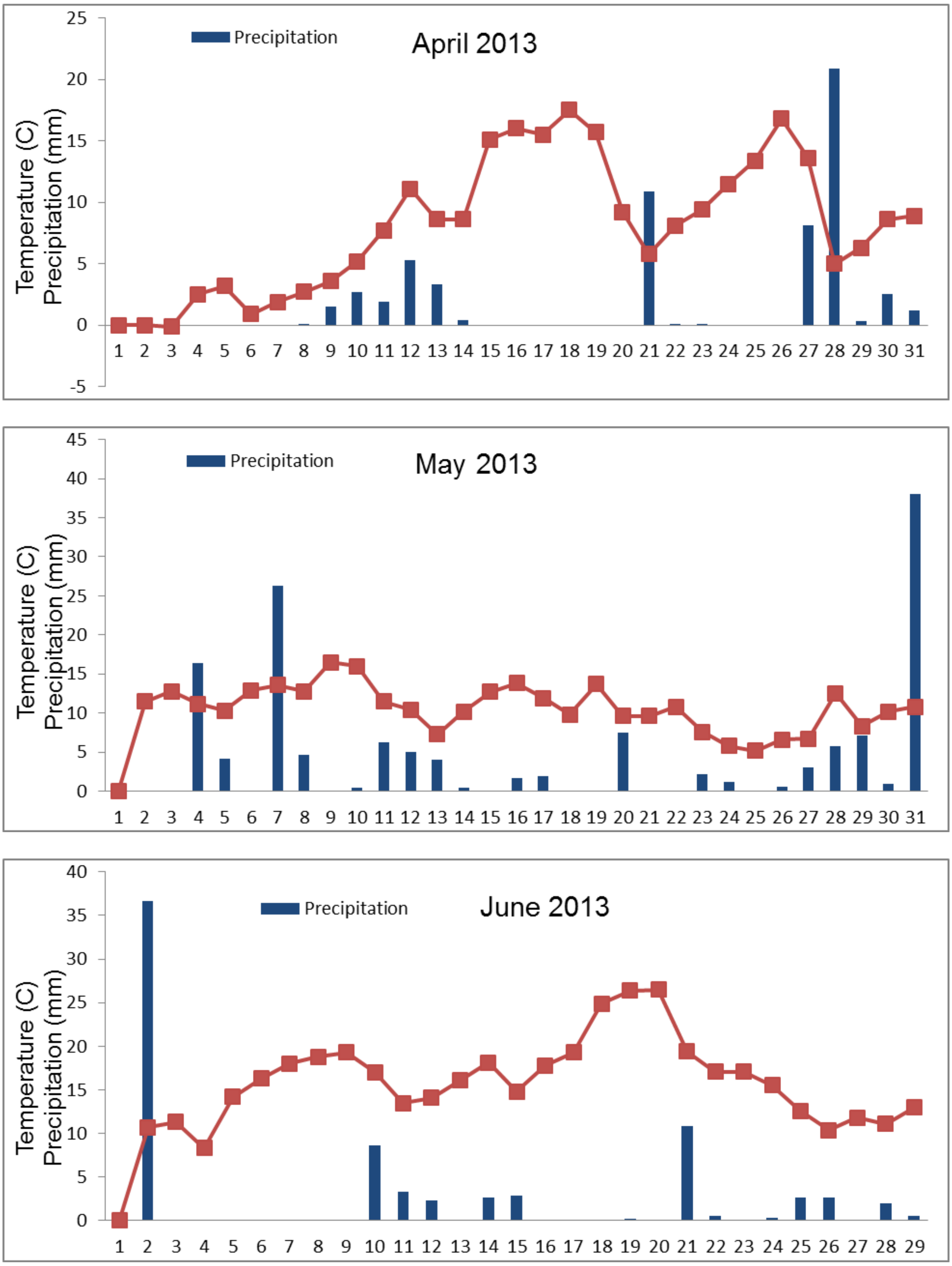

Figure 4. Temperatures recorded on the duration of the experiment. Source: On-site weather station.

Temperature and precipitation were normal for this time of the year, excepting a notable increase of precipitation in the month of May (twice the normal amount for this time of the year, according to figure 4). This however, corroborated with a subsequent raise in temperatures in the second half of May, provided good conditions for the rapid development of the crop.

4.2 Phenological indicators of plant wellbeing

4.2.1 Plant vigor at assessment date 24 May 2013

Plant vigor was quantified by visually estimating the vigor of the standing crops, using the EPPO grading system of 1 to 10, where 1 = no crop, and 10 = healthiest crop.

Table 11- Plant vigor

Treatment	Vigor Scores	
	Mean	**Std Dev**
Control	4.357	0.475
N120	7.571	1.511
N240	9.500	0.763
N40	5.500	0.866
NPK105	7.285	0.809
NPK210	8.642	1.345
NPK35	5.714	0.566

T Grouping For Treatment (Alpha=0.05)

LS-means with the same letter are not significantly different.

Treatment	Mean Vigor	
N240	9.500	A
NPK210	8.642	A
N120	7.571	B
NPK105	7.285	B
NPK35	5.714	C
N40	5.500	C

Control	4.357	D

Source	Df	Anova ss	Mean square	F value	Pr > f
Block	6	5.6734694	0.9455782	1.00	0.4417
Treatment	6	141.5306122	23.5884354	24.89	<.0001

As mentioned in the materials and methods section, the first plant vigor assessment was conducted to evidentiate the effects of nitrogen availability on the growth of the crops. It has been conducted at 24 May 2013. It can be observed from Table 11, that at the first assessment date there was significant treatment effect on crop vigor, and we can observe that the ANOVA test yields a highly significant P-value, concerning the treatment effect ($P<0.0001$). The block effect was not statistically significant, as the P-value for this test (0.4417) was higher than the chosen level of significance, set at 0.05.

Subjecting the vigor data to a regression analysis (see appendix table 1 and appendix graph 1) taking the actual amount of nitrogen as an influencing factor, we observe an R-square value of 0.6538, meaning that the variance in vigor can be attributed to a 65% proportion to the actual amount of nitrogen applied. Even though this R-square value is not showing a particularly strong interaction between the two parameters, there is clearly a connection between them, as the fitted regression equation is explaining about 65% of the variation which is occurring in plant vigor.

4.2.2 Plant vigor at assessment date 24 June 2013

Table 12- Plant vigor

Treatment	Vigor Scores	
	Mean Vigor	**Std Dev**
Control	9.285	0.755
N120	9.714	0.487
N240	10.000	0.000
N40	9.285	0.755
NPK105	9.857	0.377
NPK210	10.000	0.000
NPK35	9.4285	0.534

T Grouping For Treatment (Alpha=0.05)

LS-means with the same letter are not significantly different.

Treatment	Mean			
N240	10.000		A	
NPK210	10.000		A	
NPK105	9.857	B	A	
N120	9.714	B	A	C
NPK35	9.428	B		C
N40	9.285			C
Control	9.285			C

Source	Df	Anova ss	Mean square	F value	Pr > f
Block	6	4.24489796	0.70748299	3.85	0.0045
Treatment	6	4.24489796	0.70748299	3.85	0.0045

At the second assessment date, conducted one month later, at 24'th June 2013, the vigor differences were not so accentuated as previously measured. Although still statistically significant at the 5% level (treatment P-value of 0.0045, see above table), the treatment effects were not as influential on the crop stand.

Subjecting the vigor data collected at the second assessment date to a regression analysis (see appendix table 2 and appendix graph 2) taking the actual amount of nitrogen applied as an influencing factor, the test yields an R-square value of 0.1757, meaning that the variance in vigor observed at this date can be attributed to a 17% proportion to the actual amount of nitrogen applied.

According to statistical interpretation guidelines, this R-square value is showing a weak interaction between the two parameters, there is no strong connection between them, as the fitted regression equation is explaining about 17% of the variation which is occurring in plant vigor. This is an early encouraging finding, in our pursuit for establishing a low dosage fertilizer treatment, which will not substantially affect the quantity and quality of the forage.

4.2.3 Photosynthetic activity of *Pisum sativum* at assessment date 24 May 2013

Table 13- Photosynthetic activity of *Pisum sativum*

Treatment	Photosynthetic activity of *Pisum sativum*	
	Mean	**Std Dev**
Control	26.442	1.579
N120	27.000	1.160
N240	26.728	0.895
N40	27.871	1.750
NPK105	27.500	0.776
NPK210	27.000	1.523
NPK35	26.571	1.762

T Grouping For Treatment (Alpha=0.05)

LS-means with the same letter are not significantly different.

Treatment	Mean	
N40	27.871	A
NPK105	27.500	A
NPK210	27.000	A
N120	27.000	A
N240	26.728	A
NPK35	26.571	A
Control	26.442	A

Source	Df	Anova ss	Mean square	F value	Pr > f
Block	6	16.24408163	2.70734694	1.47	0.2154
Treatment	6	11.02693878	1.83782313	1.00	0.4407

4.2.4 Photosynthetic activity of *Avena sativa* at assessment date 24 May 2013

Table 14- **Photosynthetic activity of *Avena Sativa***

Treatment	Photosynthetic Activity of *Avena Sativa*	
	Mean	**Std Dev**
Control	39.885	4.010
N120	48.342	1.431
N240	51.685	1.763
N40	44.442	2.493
NPK105	45.985	1.918
NPK210	48.428	1.957
NPK35	41.985	2.000

T Grouping For Treatment (Alpha=0.05)

LS-means with the same letter are not significantly different.

Treatment	Mean		
N240	51.685		A
NPK210	48.428		B
N120	48.342		B
NPK105	45.985	C	B
N40	44.442	C	D
NPK35	41.985	E	D
Control	39.885	E	

Source	Df	Anova ss	Mean square	F value	Pr > f
Block	6	30.3281633	5.0546939	0.89	0.5097
Treatment	6	695.9224490	115.9870748	20.51	<.0001

Concerning the pea plants, the values observed revolved around readings of 26 and 27 across treatments, with no statistically significant differences yielded by the ANOVA tests, and the regression R-square parameter was 0.0032 (see appendix table and appendix graph 3) , which shows no correlation between the amount of nitrogen applied and the photosynthetic activity of the pea plants. It is therefore safe to conclude that based on our results, these amounts of applied nitrogen have negligible effect on the nitrogen fixation and on the nitrogenase activity.

The ANOVA analysis yields statistically significant effects of the treatments on the photosynthetic capacity of the oat plants, as expected. Also, when subjected to a regression analysis, the regression parameter R-square yields a value of 0.647, meaning that the variation in photosynthesis activity observed , can be attributed in a proportion of 65% to the actual amount of absolute nitrogen in the treatments, values used for the conduct of this regression analysis.

4.2.5 Leaf Area Index of the mixed crop stand, at assessment date 24 June 2013

Table 15- Leaf area index of the mixed crop stand

Treatment	Leaf Area Index	
	Mean	**Std Dev**
Control	3.445	0.501
N120	3.661	0.266
N240	3.707	0.359
N40	3.664	0.528
NPK105	4.148	0.513
NPK210	4.388	0.532
NPK35	3.977	0.387

T Grouping For Treatment (Alpha=0.05)				
LS-means with the same letter are not significantly different.				
Treatment	**Mean**			
NPK210	4.388		A	
NPK105	4.148	B	A	
NPK35	3.977	B	A	C
N240	3.707	B	D	C
N40	3.664		D	C

N120	3.650	D	C
Control	3.445	D	

Source	Df	Anova ss	Mean square	F value	Pr > f
Block	6	1.87555506	0.31259251	1.65	0.1623
Treatment	6	4.50381458	0.75063576	3.97	0.0039

A non-destructive parameter of measuring plant wellbeing and above-ground biomass productivity is the Leaf Area Index. Watson et al. (1947) define Leaf Area Index as the total leaf area of the cultivated crop, grown on an area of agricultural land. In this experiment, the result of this equation shows that for every unit of area ground, there were between 3.5 and 5 units of leaf surface, which represents a homogenous crop cover, one which covered completely the soil surface, thus minimizing water evaporation and soil surface disturbances.

The statistical analysis presented in the results section shows significant differences between treatments, however there was no significant negative effect of the treatments containing low or no nitrogen, which gives further weight to our assumption that very little fertilizer input is needed to achieve a competitive oat pea crop stand.

4.2.6 Plant height of *Pisum sativum,* at assessment date 24 June 2013

Discussing plant height, good agricultural practice concerning the cultivation of spring forage mixes recommends that the plant biomass should be harvested at plant height 50-55 cm, or after 70-80 percent of the oat plants have developed the full composed ear (Article in “Revista Ferma” by Dr. Maria Schitea, ICCPTF). However, in this experiment, the two parameters aligned in a completely different manner, this being an early indicator of the efficiency of the oat variety used. On measurements taken on 24 June 2013, four days before harvest, the plant height of the pea crop stand reached heights between 120 and 130 cm (see Table 16), with statistically significant comparisons yielded by the ANOVA test.

Table 16- Plant height (cm) of *Pisum sativum*

Treatment	Plant height (cm) of *Pisum Sativum*	
	Mean	**Std dev**
Control	120.90	8.776
N120	124.72	7.656
N240	127.60	8.985
N40	124.02	6.152
NPK105	129.52	10.920
NPK210	131.00	7.600
NPK35	125.77	4.218

T Grouping For Treatment (Alpha=0.05)

LS-means with the same letter are not significantly different.

Treatment	**Mean height (cm)**			
NPK210	131.00		A	
NPK105	129.53	B	A	
N240	127.60	B	A	C
NPK35	125.77	B	A	C
N120	124.73	B	A	C
N40	124.03	B		C
Control	120.90			C

Source	**Df**	**Anova ss**	**Mean square**	**F value**	**Pr > f**
Block	6	1253.991020	208.998503	5.22	0.0006
Treatment	6	498.608163	83.101361	2.08	0.0804

4.2.7 Plant height of *Avena sativa,* at assessment date 24 June 2013

Table 17- Plant height (cm) of *Avena sativa*

Treatment	Plant height (cm) of *Avena sativa*	
	Mean	**Std Dev**
Control	81.66	10.767
N120	91.04	9.477
N240	102.18	4.588
N40	86.09	5.283
NPK105	91.23	5.407
NPK210	97.38	4.625
NPK35	86.42	7.539

T Grouping For Treatment (Alpha=0.05)

LS-means with the same letter are not significantly different.

Treatment	Mean height (cm)		
N240	102.19		A
NPK210	97.38	B	A
NPK105	91.23	B	C
N120	91.04	B	C
NPK35	86.42	D	C
N40	86.09	D	C
Control	81.66	D	

Source	Df	Anova ss	Mean square	F value	Pr > f
Block	6	726.839478	121.139913	3.01	0.0172
Treatment	6	2085.456335	347.576056	8.65	<.0001

4.3 Yield and yield components

4.3.1 Fresh matter weight (t/ha)

Table 18- **Yield in fresh weight (t/ha)**

Treatment	Yield Of Fresh Weight (t/ha)	
	Mean	**Std Dev**
Control	32.11	2.729
N120	34.30	3.019
N240	39.70	2.846
N40	33.73	3.643
NPK105	36.01	4.321
NPK210	40.23	3.435
NPK35	33.57	3.451

T Grouping For Treatment (Alpha=0.05)

LS-means with the same letter are not significantly different.

Treatment	Mean yield (t/ha)		
NPK210	40.23		A
N240	39.70	B	A
NPK105	36.01	B	C
N120	34.30	D	C
N40	33.73	D	C
NPK35	33.57	D	C
Control	32.11	D	

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Block	6	31.6848571	5.2808095	0.42	0.8593
Treatment	6	419.5605143	69.9267524	5.59	0.0004

The fresh matter yields ranged between 32 t/ha on the untreated plots, and up to 40 t/ha on the NPK210 treatment. There was a highly statistically significant effect of the treatments applied, with statistically significant pairwise comparisons of treatments presented in Table 18.

Looking at the regression analysis detailed in the annex, we can observe an R-square value of 0.29. This value shows a relative influence of the exact amount of nitrogen on the final yield of the forage crop; however the correlation coefficient is rather weak, a clear indicator or the complex interactions involving not only nitrogen, but the presence or absence of the other macro-nutrients, as well as their amount.

4.3.2 Dry matter content (percentage of total biomass)

Table 19- Dry matter content (% of total biomass)

Treatment	Dry Matter (% of total biomass)	
	Mean	Std Dev
Control	21.07	0.997
N120	21.21	1.699
N240	20.89	0.887
N40	21.06	1.015
NPK105	20.49	1.671
NPK210	19.82	0.924
NPK35	20.82	0.944

T Grouping For Treatment (Alpha=0.05)			
LS-means with the same letter are not significantly different.			
Treatment	Mean (%)		
N120	21.21		A
Control	21.07	B	A
N40	21.06	B	A
N240	20.89	B	A
NPK35	20.82	B	A
NPK105	20.49	B	A
NPK210	19.82	B	

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Block	6	5.49588571	0.91598095	0.59	0.7367
Treatment	6	9.60994286	1.60165714	1.03	0.4219

The dry matter content of the seven treatments ranged between 19.8 and 21.2 percent, with no statistically significant differences attributed to the treatments, and no block effect was observed (Table 19). Pairwise, only the comparison of the treatment N120 and NPK210 yielded a significant P-Value, any other comparisons were of values over the chosen significance level of 0.05.

Therefore, we can safely affirm that, based on the results of this experiment, the fertilizer regime has no major influence on the dry matter / water balance ratio within the chosen crop plants, while having a positive impact on the total dry matter accumulation.

Subsequently, forage yields emulate the tendency of the fresh weight measurements, adjusted to this dry matter content. Yields of up to 8.2 t/ha were observed, on the higher dosage treated plots, while the lower dosage plots yielded between 6.7 to 7.1 t/ha. Interestingly, a threefold increase of applied nitrogen (treatments N40 to N120) did not result in a significant increase of dry forage yield (slight increase of 100 kg / ha).

4.3.3 Forage yield, adjusted to total moisture content (t/ha)

Table 20- Dry forage yield (t/ha)

Treatment	Yield Of Dry Weight (t/ha)	
	Mean	Std Dev
Control	6.75	0.426
N120	7.24	0.358
N240	8.27	0.467
N40	7.10	0.868
NPK105	7.34	0.702
NPK210	7.95	0.379
NPK35	6.97	0.515

T Grouping For Treatment (Alpha=0.05)

LS-means with the same letter are not significantly different.

Treatment	Mean dry weight (t/ha)		
N240	8.27		A
NPK210	7.95	B	A
NPK105	7.34	B	C
N120	7.24		C
N40	7.10		C
NPK35	6.97		C
Control	6.75		C

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Block	6	0.93211020	0.15535170	0.46	0.8336
Treatment	6	12.52893878	2.08815646	6.17	0.0002

The dry matter yields ranged between 6.75 t/ha on the untreated plots, and up to 8.2 t/ha on the N240 treatment. There was a statistically significant effect of the treatments applied, with statistically significant pairwise comparisons of treatments presented in Table 20. Analyzing the figure attached to Appendix 8.6, we can observe an R-square value of 0.40, value which shows a moderate correlation between the treatment factor and the response of the crop. As mentioned before, this value represents a 40% correlation between the quantity of nitrogen applied and the response observed, the rest of the variation is to be attributed to the other variables, part of the experimental process.

4.4 Forage quality indicators

4.4.1 Nitrogen (g/100 g)

Table 21- Forage Nitrogen content (%)

Treatment	N Content (%)				
	Mean			Std Dev	
Control	1.728			0.175	
N120	1.633			0.054	
N240	1.622			0.118	
N40	1.689			0.156	
NPK105	1.806			0.099	
NPK210	1.800			0.139	
NPK35	1.753			0.123	
T Grouping for Treatment (Alpha=0.05)					
LS-means with the same letter are not significantly different.					
Treatment	**Mean Nitrogen (%)**				
NPK105	1.8062				A
NPK210	1.8008				A
NPK35	1.7538			B	A
Control	1.7284			B	A
N40	1.6898			B	A
N120	1.6330			B	
N240	1.6224			B	
Source	**DF**	**Anova SS**	**Mean Square**	**F Value**	**Pr > F**
Block	4	0.08482131	0.02120533	1.33	0.2868
Treatment	6	0.16587200	0.02764533	1.74	0.1556

The nitrogen content of the analyzed samples ranged between 1.62 % (N240 treatment) and 1.8 % (NPK105 treatment), with statistically significant differences of certain pairwise comparisons.

However, looking at the above table, we cannot establish a clear link between solely the levels of applied nitrogen and the nitrogen content of the forage crop, with only two statistically significant pairwise comparisons. We observe however that the higher nitrogen yields were obtained on the treatments which contained the other two macro-nutrients (P and K), which suggests that there might be a link between the presence of these elements and the crop's ability to process and store available nitrogen.

This weak correlation is further confirmed by the R-square value of 0.07 presented in Appendix 8.8, which dismisses any link between the applied nitrogen and the final content in this particular crop mixture.

4.4.2 Crude protein content (g/100g)

Table 22- **Forage crude protein content (%)**

Treatment	Crude Protein Content (%)	
	Mean	Std Dev
Control	10.802	1.095
N120	10.205	0.338
N240	10.139	0.739
N40	10.561	0.975
NPK105	11.288	0.622
NPK210	11.254	0.872
NPK35	10.961	0.771

T Grouping for Treatment (Alpha=0.05)

LS-means with the same letter are not significantly different.

Treatment	Mean Crude Protein (%)		
NPK105	11.288		A
NPK210	11.254		A
NPK35	10.961	B	A
Control	10.802	B	A
N40	10.561	B	A
N120	10.205	B	
N240	10.139	B	

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Block	4	3.31484040	0.82871010	1.33	0.2862
Treatment	6	6.48359212	1.08059869	1.74	0.1550

The crude protein content was derived from the nitrogen content yielded by the CN Analyzer process, by multiplying the nitrogen content by a factor of 6.25 according to principles described by the uidaho.edu website. The statistical trends therefore emulate those of the original parameter, nitrogen content in percentage.

4.5 Soil nitrogen content after harvest

Table 23- Soil nitrogen (Kg/ha)

Sampling date JUNE 27 2013

Treatment	Soil Nitrogen (Kg/Ha)	
	Mean	**Std Dev**
Control	11.34	2.86
N120	11.83	1.90
N240	10.10	1.50
N40	14.60	2.99
NPK105	16.84	5.25
NPK210	15.11	3.92
NPK35	11.12	2.42

T Grouping for Treatment (Alpha=0.05)			
LS-means with the same letter are not significantly different.			
Treatment	**Mean Soil Nitrogen (Kg/Ha)**		
NPK210	16.84		A
N120	15.11	B	A
NPK105	14.60	B	A
NPK35	11.83	B	C
Control	11.34	B	C
N240	11.12	B	C
N40	10.10		C

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Block	4	46.5015543	11.6253886	1.16	0.3545
Treatment	6	188.8035086	31.4672514	3.13	0.0207

The N_{min} analysis with the soil samples collected on 27 June 2013 was designed to quantify the amount of nitrogen left in the soil after harvest.

This parameter, according to general good agricultural practices, should represent a low proportion of the one applied, as to avoid unnecessary losses, as well as leeching. From the results presented in Table 23, we can observe no linear relationship between the applied amount of nitrogen, and the amount present in the 0-90 cm soil horizon after harvest. Quantities ranging between 11 and 16 kg N / ha, for the N40 and NPK210 treatments respectively, show a large variation in the nitrogen use of the crop plant and other consumer organisms present in the experimental plot.

The regression analysis (see Appendix 8.7) yields an R-square value of 0.0113. This confirms the fact that there is no linear relationship between the sole amount of nitrogen applied and the quantity of this element left in the soil after harvest. As it can be seen from Table 21, the highest quantities of residual soil nitrogen were found in the plots where the other two macronutrients were applied, P and K respectively. When comparing the N240 amount of 11.12 kg N / ha, with the NPK 210 amount of 16.84 kg N / ha, we can observe a 50% increase of residual soil nitrogen. This, in spite of the fact that the NPK210 treatment had less initial nitrogen applied, than the N240 treatment. Furthermore, a 30% difference in residual nitrogen is observed, when comparing the NPK105 with the N240 treatments.

These findings may suggest that there is a link between nitrogen absorption and/or leeching, and the presence of other macro elements in the soil. However, looking through the prism of resource conservation and input minimization, there is no sense in having a fertilizer regime which promotes nutrient competition and hinders nitrogen absorption.

4.6 Economic ranking

The economic ranking of the seven treatments is explained by the amount of biomass, nitrogen but mainly protein content of the crop, relative to the price of the treatment, on a per hectare basis. For the economic ranking, the September 2013 no VTA fertilizer prices were obtained from the website of the Rheinland-Pfalz Chamber for Agriculture (Landwirtschaftskammer Rheinland-Pfalz).

Table 24- Fertilizer prices, according to the Rheinland-Pfalz Chamber for Agriculture.

Date: August 2013	Price* in €/100 kg	Price* in €/100 kg
Fertilizer	**Orders over 10 tons**	**Orders over 25 tons**
Calcium Ammonium Nitrate (KAS) 27 % N	25,50-26,50	24,50-25,20
NPK-Dünger 15/15/15	42,00	41,00

* Prices are shown without VAT.

Source of prices: Landwirtschaftskammer Rheinland-Pfalz.

Table 25- Fertilizer expenses per hectare, according to treatment dosage

Treatment	Kg product per ha	Price per ha (€)
Control	0	0
Calcium Ammonium Nitrate (KAS) 27 % N	40	10.4
Calcium Ammonium Nitrate (KAS) 27 % N	120	31.2
Calcium Ammonium Nitrate (KAS) 27 % N	240	62.4
NPK 15-15-15	35	9.1
NPK 15-15-15	105	27.3
NPK 15-15-15	210	54.6

Table 26- **Economic ranking of the different treatments, related to the price of crude protein per hectare**

			Treatment						
Specifications			**Control**	**N40**	**N120**	**N240**	**NPK35**	**NPK105**	**NPK210**
		Units							
Production	Fresh Weight	t/ha	32.1	33.7	34.3	39.7	33.5	36.1	40.2
	Dry Weight	t/ha	6.7	7.1	7.2	8.3	6.9	7.3	7.9
	Nitrogen Content	%	1.7	1.7	1.6	1.6	1.7	1.8	1.8
	Crude Protein	%	10.8	10.6	10.2	10.1	10.9	11.2	11.2
	Crude Protein	t/ha	**0.72**	**0.75**	**0.73**	**0.84**	**0.75**	**0.82**	**0.88**
Costs	Fertilizer Input *	€/ha	0	10.4	31.2	62.4	9.1	27.3	54.6
	Seed price ****	€/ha	100	100	100	100	100	100	100
	Soil preparation **	€/ha	80	90	90	90	90	90	90
	Seeding **	€/ha	20	30	30	30	30	30	30
	Harvesting **	€/ha	20	20	20	20	20	20	20
Subventions	APIA Fixed Sum ***	€/ha	140	140	140	140	140	140	140
Cost	Minus per system	€/ha	**-80.00**	**-110.40**	**-131.20**	**-162.40**	**-109.10**	**-127.30**	**-154.60**
Cost per unit	Crude Protein	€/t	**110.56**	**146.69**	**178.65**	**193.73**	**145.06**	**155.70**	**174.73**
Economic ranking			**1**	**3**	**6**	**7**	**2**	**4**	**5**

Sources of prices:

* *LWK Rheinland-Pfalz*

** *manager.ro*

*** *business24.ro*

**** *SCDA*

Looking at Table 26, we can observe contrasting results, concerning the balance and final ratio of input/output indicators. The different fertilizer application strategies proved to have substantial impacts on the harvest parameters, particularly on fresh and dry weight.

These two yield parameters represent important criteria in evaluating the final ranking of the crop. However, the main weight of the equation is represented by the crude protein content found, and the price per hectare per system required to produce a unit (tone) of crude protein.

Table 27- Crude protein yield increase, proportional to price increase (% per hectare)

	Treatment						
	Control	N40	N120	N240	NPK35	NPK105	NPK210
Ranking	**1**	**3**	**6**	**7**	**2**	**4**	**5**
CP production Increase %/ha *(relative to control)*	--	3.85	1.47	13.68	3.79	11.5	18.22
Cost increase %/ha *(relative to control)*	--	24.63	38.11	42.93	23.78	28.99	36.73

Looking at the treatment which is ranked 3, (N40), we observe a 3.8% yield increase of crude protein per hectare, but at a 24% price increase. Therefore, although we experience an increase in feed value, the price at which this increase is obtained, is obviously too expensive to be sustainable.

Keeping in mind that a farmer should cover a 25% price increase with a 4% yield increase, is neither feasible nor logical, from an economic point of view. The ratio keeps the same trend throughout the 5 other fertilizer strategies, with treatment NPK 210 ranked 5^{th}, showing a relative minimum deficit of 18 percent points, between output gain and investment.

5. Discussion

5.1 Weather data

Table 28- Monthly average temperatures and precipitation (rain)

Month	Average temp.(c)	Average min temp. (c)	Average max temp. (c)	Precip. Total (mm)
April	8.4	4.6	12.7	59.3
May	10.7	6.8	14.9	137.7
June	13.0	7.3	17.0	76.4

The temperature recorded throughout the duration of the trial is considered normal for this time of the year, and close in values to that of the long term averages, according to Wikipedia weather.

5.2 Phenological indicators of plant wellbeing

5.2.1 Ecosystem pressure and phytosanitary condition

The crop's resistance to ecosystem pressure was one of the hypotheses of this experiment, in the sense that it does not require plant protection products, in order to become competitive against weeds, and that it can withstand moderate attacks by pathogens, such as fungi, and other insects acting as vectors.

To quantify this level of resistance, the ecosystem pressure along with the general phytosanitary situation of the experimental field was monitored at the first assessment date, 24 May 2013. The results are summed up in the following paragraphs.

Ecosystem pressure

As of 24 May 2013, weed infestation was minimal across treatments. Mostly 2-4 leaf stage individuals were observed, particularly dicots. The crop was highly competitive; therefore no weed removal was required at the moment.

Large herbivore (deer) feeding consumed about 10% of one marginal plot, and negligible surface from a second plot. Single deer tracks (at least 1 week old as of 24 May 2013) were observed, entry point NNE (barren field), with general direction South and exit point SSW (barren field). This information suggests a single individual, rare event, and no transit pattern.

No rodent burrows were observed.

No other ecosystem pressure was observed. At the evaluation date there were no reasons to think that there will be major environmental changes which will affect the state of the site.

Crop phytosanitary condition

Avena sativa exhibited good general and phytosanitary condition. Although differences in crop vigor and chlorosis were evident across treatments, at the time of the evaluation, these did not influence crop sensitivity to external pressure. No persisting pest /disease damage was observed.

Pisum sativum showed moderate general phytosanitary condition. Cotyledonal leafs and the first pair of leafs were showing severe feeding patterns, most likely by *S. Lineata* and/or *Deroceras sp*., as reported at 20 DAA. Application of products containing *lambda-cyhalothrin* and *Iron III phosphate* achieved 100% efficacy, as no feeding damage on the younger leafs was observed at DOA1.

Concerning the damage of the *Deroceras sp.* slugs, this impact was opted out of the general economic ranking of the crop, as this particular pest occurs very rarely in Romania (according to animalbase.uni-goettingen.de).

As being considered a dangerous pest for the cultivation of cereals, *Lema melanopa* was not particularly present, despite favorable habitat within 300 meters NNW from experimental site. Averages of 2 to 6 individuals were spotted per plot, well below the control threshold recommended by Heyer & Wetzel (1990), of between 0.75 to 1.5 individuals per flag leaf. Subsequently, no assessments were conducted on plant diseases for which this pest is a vector.

Tissue necrosis on younger leafs of both plants across treatments was observed. This can be attributed to nitrogen toxicity, which is known to cause a whole spectrum of tissue injuries, from necrosis, growth stunting and also sensitivity to low temperatures and late frosts, as reported by LJM Van der Eerden et al., (1982).

Considering that not all the plots received high amounts of nitrogen, it is therefore safe to conclude that the tissue necrosis occurred most likely due to low temperatures and freezing conditions during the night. Slight leaf curling observed as well, which further confirms the hypothesis.

Overall, the phytosanitary conditions were rated as good, and the ecosystem pressure was considered to be low. This outcome is confirming one of the initial hypotheses that the crop mixture has a strong competitive potential, and proves to be relatively resistant to disease, and completely suppressing any competition from other species, such as weeds.

5.2.2 Plant vigor, photosynthetic activity, leaf area index and plant height

The increased vigor, particularly of the oat plants, might also be viewed as a result of the superior leaf elongation rate (LER) promoted by a sufficient nitrogen supply. It is known that this indicator is linked to the cell number in the epidermis, their rate and the duration on these cells' elongation. As JW MacAdam et al. (1989) report, there is a direct influence of nitrogen availability and leaf elongation rate of tall fescue (a grass) (*Festuca arundinacea* Schreb.), results which support our own evaluation.

There are other factors which can be responsible for the rest of the variation. Field heterogeneity, although not deemed significant by the ANOVA model on block effect, can influence in a smaller part the growth of the plants.

The other variables present, such as different amounts of the elements phosphorous (P) and sulphur (S), can also be responsible for the vigor fluctuations showed by the plants. Concerning the presence of sulphur in the applied fertilizer, Goh & Kee (1978) demonstrate a link in nitrogen use efficiency by the plants, in the presence of sufficient sulphur quantities in the soil. This proven relationship might explain also the high vigor exhibited by the treatments which contained sulphur in addition to nitrogen.

The photosynthetic activity of the pea plants was estimated with the handheld SPAD-meter, whose value is correlated with the actual content of chlorophyll in the leaf.

As Dordas et al. (2008) note, the SPAD meter is a fast, nondestructive and secure way of determining the N content in the leaves, and also the richness in chlorophyll content of the leafs of crop plants, parameters which are important for economically sustainable yield.

These principles evidentiate the actual photosynthetic capacity of the plant, and allow us to measure the generic health of the plant itself. Since Pisum sativa is a legume, therefore able of biologically fixing nitrogen through the symbiosis with the Rhizobium bacterial regnum (Zahran, 1999), the photosynthetic activity has proved to be insensitive to the different quantities of nitrogen applied in our experiment.

Regarding the effect of the treatments on the photosynthetic activity of the oat plants, statistically significant differences were observed by looking at all treatments. This was expected, as there is no other source of nitrogen for *Avena sativa* to use, lacking substantial organic nitrogen resources in the seed itself, but also lacking the nitrogen fixing abilities exhibited by *Pisum sativum*.

SPAD readings, generally between 40 and 55, are consistent with those observed on healthy single stands of cereals by Bijay et al. (2002), who obtained satisfactory wheat yields from plants which exhibited SPAD values of 44, and 42 respectively, subjected to different fertilizer application strategies. As the *Avena sativa* SPAD measurements had statistically significant values concerning the treatments, it is therefore safe to affirm that these values prove that the oat plants were in good general condition, and were not affected by inter-specific competition, and they responded positively to the fertilization strategies.

The oat plants' height, averaging between 80 and 100 cm, was also significantly affected by the nitrogen treatments applied. However, considering the low impact on height (between 10 and 18 percent on average), when comparing the control treatment with the high N dose treatments, it is also safe to affirm that these represent acceptable losses, and will not weigh heavily on the final economical rating, further confirming that this particular crop shows a degree of tolerance and adaptability to sub-optimal conditions and especially nitrogen limitations.

5.3 Yield and yield components

Plant fresh biomass is one of the most important yield indicators concerning forage quality and economic efficiency, especially in financially fragile environments. The fresh weight yields obtained in this experiment are comparable and mostly superior to other forage plants and mixes of plants currently used in Romania. As detailed in the results section 4.2, mean fresh weight yields of the peas oat mix were directly affected by the amount of applied nitrogen. With a mean yield of 40.2 tons/ha obtained in the NPK210 kg/ha treatment, to a mean yield of 32.1 and 33.7 on the control plots and the N40 kg/ha treatment, respectively. In percentage, the fresh weight yields suffered reductions of up to 25%, from the highest dose treatments, to the lowest dose and the control, respectively.

However these yields and to reasonable extent the yield losses are economically acceptable considering the reduced financial input of some of the lower quantities applied in certain treatments. According to Prof. Dr. Bran Mariana (2009), several of the other forage plants and plant mixes used currently in Romania under fertilization and agronomical intensive production schemes, have similar and occasionally lower yields. According to the authors, forage maize under non-irrigated conditions yields between 25 and 40 tons/ha; forage sorghum produces on average 25-30 tons/ha, yields resulted from one biomass cut. Looking at forage systems cultivated for several cuts per year, the above-mentioned author writes that Alfalfa grown under intensive agronomical practices can yield 40-50 tons of fresh biomass per year, quantity split in 6-7 harvests, depending on the environmental conditions.

Regarding the fresh weight parameter, the comparisons performed further suggest than the cultivation of the oat peas forage mixture could prove successful and economically viable even under low fertilizing strategies.

The dry forage yields obtained in this experiment (Table 20) are superior to those obtained by Saicu (2010), whose experiments looked at dry matter content yield of a number of popular substitutes of spring forage, namely alfalfa, orchard grass and Timothy. Comparing the dry matter yield of the no fertilizer used at the Ihinger Hof experimental site, we can see differences of up to 1.5 tons/ha more dry matter than for the combination of no treatment and the Dactylis grass, used by Saicu (2010). However, our yields were inferior with up to 4 tons/ha when compared to yields obtained by Saicu (2010), on alfalfa crops and other perennial legumes.

5.4 Forage quality indicators

5.4.1 Nitrogen and crude protein content

Nitrogen content and subsequently the crude protein content, and the dry weight parameter, are the two main indicators of establishing the efficiency and economic viability of a crop. Considering the lower dose fertilizer treatments, and even the untreated variant, the quantities of nitrogen accumulated were highly satisfactory, taking into account the minimum input characteristics used. As it can be observed from Table 21, the difference in nitrogen accumulation between the untreated plots and the plots receiving the highest amount of this element was roughly 10%. Although the difference is visible, the ANOVA shows us mild correlation between the applied amount and the transformed amount, and definitely not enough strength to safely affirm that we would expect a strong nitrogen accumulation coming out of a high input of nitrogen. This finding adds further weight to our initial hypothesis that this particular crop, widely neglected in the Romanian agriculture in the past 20 years has high feeding value, especially under minimum input conditions.

5.5 Economic ranking

One of the hypotheses of this experiment was that it could be possible to produce a substantial amount of quality fodder, with a minimum chemical input and fertilizer application strategy, and obtain a product able to compete with products originating from systems which benefit from these inputs. Analyzing the values previously presented in Table 27, we can observe trends which add value to our initial supposition. From a cost-effectiveness point of view, it makes sense to keep inputs to a minimum, as long as they do not cross the negative threshold, concerning the crop’s ability to produce the fodder needed. However, if investments in fertilizer or other chemicals prove to be worthwhile, in other words yield increases cover the afferent costs of purchase and application, the application of these products becomes also feasible.

6. Conclusions

The success of a fodder crop and whether it is economically viable or not, ultimately depends on the content of protein it contains and the ratio between quantity and the cost required producing that quantity. This indicator is primarily determining the feeding value of the particular crop, and optimizing a production system in order to obtain the maximum output of protein with the minimum expenditures of finance and labor.

The lack of nutrient availability did not critically expose the chosen crop to attacks from pathogens and diseases, as there was no specific pathogenic threshold observed in the control plots.

Crop health parameters analyzed were within physiologically normal ranges throughout the trial. Moreover, the negative crop-environment interaction was minimal, despite the location of the experiment, which hosted habitat for a number of concerning pathogens. These findings further evidentiate the robustness of the mixed crop system chosen, and its ability to thrive and create a favorable micro-climate in the space it inhabits.

Increases in nutrient quantities applied to the plots, did not result in proportional increases of feed value, therefore confirming the initial hypothesis that having a minimum input system will not impose substantial damage on the quantity or quality of this crop.

In this experiment, it was successfully proved that the chosen crop system involving the oat and peas mixture can deliver competitive results, in terms of feed value, production quantity and quality, regardless of fertilizer input, and to a certain extent independent of the application of plant protection products.

As an outlook for further research, by using the information and knowledge gained by conducting this experiment, it would be useful to analyze the second phase of the economic viability of this chosen crop, involving animal feeding tests.

Using the best ranked systems highlighted in this experiment, a design involving the feeding of beef cattle with the resulting fodder, could quantify the effectiveness of adding this type of spring forage to the diet of beef cattle.

Monitoring the eventual marketable cattle weight gain within a certain time frame, and whether it successfully accounts for crop expenses and labor, while adding a reasonable profit margin, could represent useful and engaging future research into establishing the value of this particular crop mixture.

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