Forage production trials in Tan Lac district during the winter period

2004 – 2005

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TABLE OF CONTENTS

FIGURES AND TABLES

I. Introduction

In Vietnam, agriculture plays a very important socio-economic role. Animal production, including aquaculture, is expanding steadily due to the continuous increase in demand resulting from high demographic growth and changing food habits. Over the past 10 years, demand for animal products has increased by more than 8% per annum. At the same time, however, the gap between rural and urban areas, in terms of income and quality of life, has widened. Furthermore, environmental problems, including water and air pollution, deforestation and soil erosion, are exhausting water resources and depleting soil fertility, threatening the livelihoods of rural communities, particularly in mountainous areas.

The majority of farming households practise subsistence agriculture and cultivate less than one hectare of land. Farmers' limited access to appropriate technologies and improved knowledge is a major constraint to the development of more commercial, diversified and profitable agricultural activities. A more effective application of agronomic science and improved technologies is, therefore, necessary to ensure food security and support the diversification and marketing of agricultural production. Sustainable increases in farmers' incomes also depend on the improvement of product quality and the establishment of suitable policy and regulatory measures. Institutional strengthening, training activities, field research and the transfer of technology, as well as the dissemination of information, are also essential to agricultural development in upland areas.

In a context of limited natural resources, and significant pressure on land, the intensification of animal-raising in ways which are environmentally and socially sustainable, together with the controlled improvement of animal productivity, are the only feasible responses. Livestock development is a strategic policy of the Vietnamese government due to its potential contribution to employment creation and income generation. However, political leaders and stockbreeders have become increasingly aware that such intensification of animal-raising, especially the breeding of cattle, requires substantial areas of land for forage production. As there is already considerable pressure on land in Vietnam, the intensification of agriculture, specifically forage production, appears to be the only response.

1. Context of the study

In certain provinces in northern Vietnam, climatic conditions, particularly low winter temperatures, do not enable the development and growth of tropical forage species during winter. For tropical plants, optimum energy efficiency is achieved when the temperature is between 30 to 35°C, whereas temperate plants require a temperature of between 20 to 25 °C. In the areas being studied, the cold (and dry) season is relatively long, and can last from November to March.

During this season, the shortage in forage is traditionally met using wild grasses (which are low in nutritive value), preserved forage (hay, silage) and various agro-industrial by-products which are locally available. However, in areas with a large animal population these resources are insufficient, leading to deterioration in the physical condition of the animals, and consequently a reduction in their production potential (meat, milk). From March/April onwards temperature and rainfall levels increase considerably, thus enabling the development of tropical forage in sufficient quantities to meet animals’ food requirements.

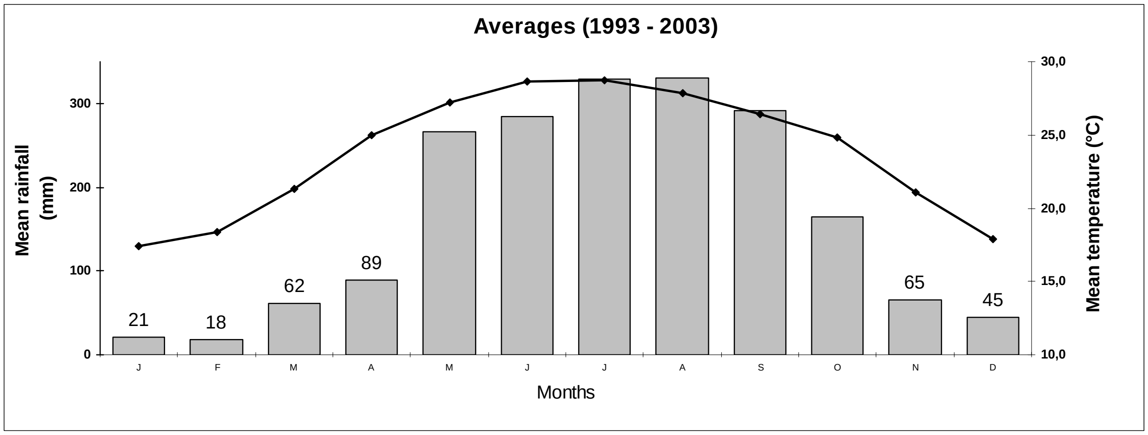
Little published research exists concerning the use of temperate forage crops in northern Vietnam. While the use of such type of forage does not constitute the sole solution to the winter forage deficit, it remains an interesting option. The objectives of this study are, therefore: (1) to test the agro-climatic adaptation of four temperate forage species for the winter period; (2) to determine their production potential and their nutritive value, and (3) to evaluate their reproductive potential. Over the medium term, the aim is to test the adoption of these new forage production methods by livestock breeders, in order to consider their introduction within the existing agricultural farming system, while taking into account both economic factors and the organization of labour at farm level.

2. Climatic data

Climatic data, in particular average temperature and rainfall levels, are essential to the selection of forage species to be tested in a new area. Temperature affects the range within which plants can grow as well as their level of growth. "Zero vegetation” is the temperature from which the plant begins to grow; the rate of growth is slow at low temperatures, it increases as temperatures rise, reaches an optimum phase, and then decreases at very high temperatures. The theoretical water needs of a plant are equal in value to the potential water loss (evapotranspiration). Water loss is the sum of the plant’s own consumption of water for the development of its tissues (through photosynthesis and transpiration) and of evaporation by the soil. The difference between rainfall and potential water loss, often called potential water balance, is the water deficit or surplus.

There are many temperate forage species and varieties which are fairly suited to low temperatures and to a water deficit, and whose production cycles are more or less equipped to deal with the climatic conditions of different regions. Humidity, the speed and direction of the wind, insulation and atmospheric cover are other important climatic factors which need to be considered in the study of the adaptation and development of forage crops.

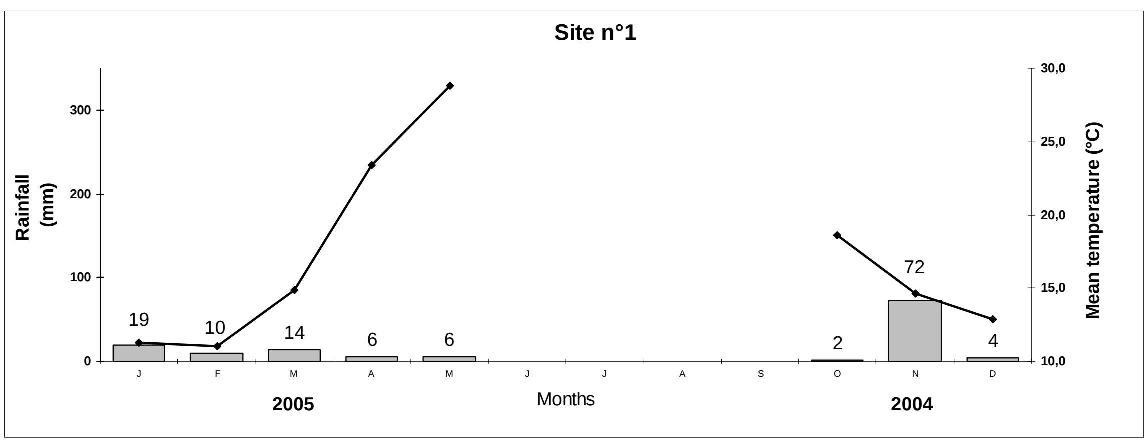
Figure 1 shows the mean climatic data (rainfall and temperature) issued by Lac Son weather station for the period 1993 to 2003.



<u>Figure 1</u> : Mean rainfall and temperature in Lac Son for the period 1993 to 2003

Total annual rainfall is approximately 2 000 mm but distribution varies throughout the year. Rainfall between May and October (a 6 month period) amounts to 85% of the total recorded. January and February are the driest months, with low rainfall levels: approximately 20 mm per month. Average temperatures also fluctuate throughout the year. In summer (May to October), temperatures are high, ranging between 25 and 30°C. In winter, temperatures fall below 18°C during the coldest months (December and January). During summer, climatic conditions resemble those of a tropical climate, while in winter conditions are those of a dry, subtemperate climate.

Data produced by Lac Son weather station was instrumental in the selection of the forage species to be tested. In addition, temperature and rainfall levels were measured at each experimental site from October 2004 to May 2005 using a thermometer and a rain gauge (Figures 2, 3 and 4), the objective being to characterize the specific climatic context at each location more accurately and to enhance understanding of the potential effects of climate on the adaptation and development of forage species.



<u>Figure 2</u> : Mean rainfall and temperature at site n°1 (October 2004 to May 2005)

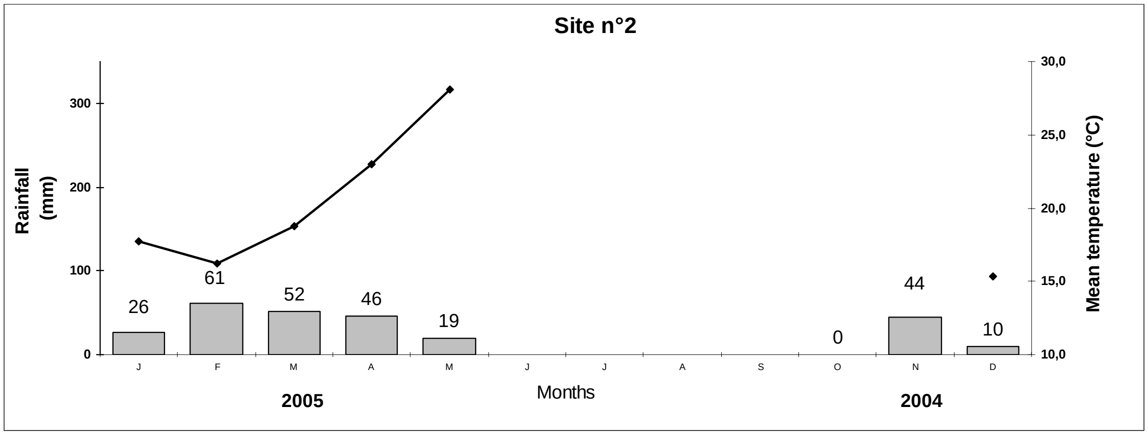


Figure 3 : **Mean rainfall and temperature at site n°2 (October 2004 to May 2005)**

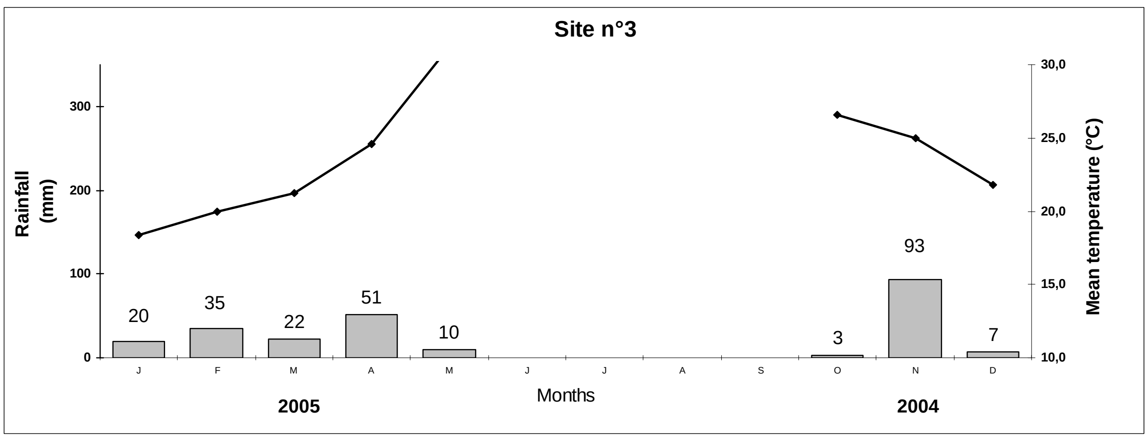


Figure 4 : **Mean rainfall and temperature at site n°3 (October 2004 to May 2005)**

The differences between the three experimental sites in terms of rainfall and temperature are highlighted in figures 2, 3 and 4. Sites 1 and 2 are located in a mountainous area, at an altitude of approximately 700 meters. The third site is situated in a lower lying valley area (next to the town of Tan Lac), at 260 meters altitude.

At site 1 winter rainfall was very low compared to the average rainfall levels recorded at Lac Son. Rainfall between December and March was 47 mm, which is equivalent to around 30% of the average for that time of the year. Temperatures were lower than those at Lac Son weather station; the average temperatures recorded were 15°C or less between November and March. From April onwards temperatures rose considerably, but the rainfall recorded in both April and May was very low.

At site 2, situated approximately 12 km from site 1, climatic differences were significant, which underlines the importance of recording climatic data at each site. Rainfall levels during the winter (150 mm) were close to the Lac Son average. Intriguingly, considering the very short distance between the two sites and the fact that they are both in a mountainous area, temperatures at site 2 were relatively high compared to those at site 1. Between December and April temperatures at site 2 were, on average, 3.5°C higher than those at site 1.

At site 3, which is located in a valley, rainfall between December and March was 84 mm, which is equivalent to around 50% of the average rainfall recorded at Lac Son. The most marked difference between site 3 and the other two sites was the average temperature, which was always higher than 20°C, except in January (18.4°C).

It should be noted that the climatic data collected could only be considered representative if it had been recorded continuously for a period of at least ten years.

3. Soil chemical data

When selecting which forage species to test on a particular area of land, it is critical to take the chemical characteristics of the soil into account. Similarly, the physical properties of soil, particularly its texture and structure, are also important factors to be considered as these influence both plant adaptation and development.

Dead vegetable and animal material is an essential source of organic matter. This is gradually transformed, by mineralization, into soluble elements or available gases and, through a process of humification, into humus. Humus is slowly mineralized, thereby providing food for plants and completing the biological cycle of nitrogen and carbon. The carbon and nitrogen (C/N) ratio express the quality of the humus in nitrogen. This relationship varies according to the soil horizon and the soil type. A high C/N ratio indicates soil in which organic matter is not fully decomposed; a low C/N ratio indicates mineralized soil, with low reserves of organic matter. The development of humus is influenced both by the climate and the bed rock, while temperature and humidity facilitate the production of vegetable matter and the mineralisation of humus. Humus compounds and clay in the soil attract the cations H^{+}, Ca^{++}, Mg^{++}, K^{+} and Na^{+} around their molecules in considerable quantities. These cations are known as 'exchangeable' because they can be substituted with the cations of soil solution depending on the absorption energy of each ion and the concentration of ions in the soil solution.

To determine the chemical characteristics of the soil at the three experimental sites, soil samples were taken and their chemical composition was analyzed. The samples were taken when the sites were first selected (October 2004) and were taken at two consecutive horizons, between 0 and 20 cm and between 20 and 40 cm. The main tests, which were conducted at the laboratory of the National Institute of Soil and Fertilizers, are summarised below, together with the methods used.

- **pH –** pH meter method (pH KCl-H20)
- **organic carbon measurement –** Walkley and Black method
- **total nitrogen measurement –** Kjeldahl method
- **exchangeable metal cations measurement–** extracted using ammonium acetate 1N
- **available phosphorus measurement–** Bray method
- **total phosphorus measurement –**extracted using sulphuric and perchloric acid, which aid colorimetry
- **total potassium measurement –** determined using a spectrophotometer

Various factors need to be taken into account when interpreting the results of the soil analysis (presented in Table 1). These include the soil variety, how the land is cultivated (which is likely to modify soil cover or structure) and local topographic and geomorphological data.

site	horizon	pH - H_2O	C g/kg	N g/kg	C/N	exchangeable cations			P_2O_5 available mg/100g	P_2O_5 total %	K_2O total %
						Ca^{++}	Mg^{++}	K^{+}			
1	0-20	4,7	24,8	1,9	13	11,3	4,9	0,27	22,0	0,31	0,33
	20-40	4,5	22,4	1,6	14	8,4	3,3	0,15	11,0	0,24	0,65
2	0-20	4,6	22,6	1,8	13	2,7	2,5	0,12	2,0	0,18	1,31
	20-40	4,6	15,2	1,2	12	2,6	2,6	0,08	1,3	0,13	1,28
3	0-20	4,8	12,8	1,3	10	9,2	5,3	0,13	1,9	0,21	0,39
	20-40	5,0	10,1	1,2	8	7,9	4,8	0,09	1,1	0,16	0,33

Table 1 : Results of soil analysis at Tan Lac

High acidity is a common feature of the soil from all three sites. An acid pH does not restrict plant growth but influences other factors affecting their development, such as reducing the levels of certain plant nutrients, lowering biological activity and increasing the risk of aluminium toxicity. In order to increase the pH of the soil at the three study sites, calcium oxide (CaO; quicklime) would need to be applied at a rate of 200 kg/ha/per year. The application of fertilizers in the form of sulphates should be avoided because sulphates have acidifying tendencies.

The C/N ratio of the soil at the three sites is between 8 and 14, a normal value which indicates that organic matter is well decomposed. The C/N ratio of the soil is an indicator of the ‘quality’ of its organic matter. Carbon facilitates the development of micro-organisms while nitrogen is often the limitative factor for the development of plants and bacteria.

In terms of the concentration of exchangeable cations (Ca, Mg, K) and the balance between cations, the soil from site 1 is closest to a normal or optimum value for the development of most forage crops. The soil from site 2 is relatively low in exchangeable cations, while that from site 3 has the right Mg^{++} content but too high Mg/K ratio. All three soils have low levels of total potassium (K_2O) and cation potassium (K^+). However, at sites 1 and 3, the high level of cation magnesium (Mg^{++}) will facilitate the absorption of potassium by plants even if this is only present the soil in small amounts. Finally, the soil from site 1 is exceptionally rich in available phosphorus, in particular at the surface horizon (0 to 20 cm), as opposed to the soil from sites 2 and 3 which have low quantities of this element. These results need to be compared with field observations concerning the behaviour of forage crops (speed of growth, quantity and quality of production) and possibly with leaf analysis. This would result in a set of evaluations concerning the critical content of the available elements found in the soil at the three sites.

The differences observed between the three experimental sites in terms of climatic data and soil composition will have a relatively marked influence on: (1) the adaptation of the forage species; (2) their potential production of fresh matter and (3) flowering and reproductive potential.

II. Materials and Methods

1. Forage species used

In 2003-2004, 14 temperate grass and mixes of grass/legume species were tested at two sites in a district with a dairy tradition, Moc Chau in the province of Son La. Of these 14 forage species, the four which were considered to be the best adapted were selected for a more in-depth study which took place in 2004-2005 in several districts in northern Vietnam, including the district of Tan Lac. The objective of this research was to address the winter forage shortage in the north of the country.

An oat species, *Avena sativa*, was selected because of its high productivity in the tests at Moc Chau (more than 14 tons of dry matter per hectare). A *ray grass*, *Lolium westerwoldicum*, was selected for its rich nutritive value. A third species selected was a grass/legume mix *Avex*, which has good production potential, is adaptable to different types of soils and is rich in nutrients, due to its diverse floral composition. As part of the same initiative, Vietnamese partners at the National Institute of Animal Husbandry were interested in testing the adaptation of a species of alfalfa, *Medicago sativa*, which is widely used in Australia and the United States as feed for ruminants.

In addition, a tropical grass species, *Brachiaria brizantha*, was tested. The aim was to demonstrate, through field tests, the differences between temperate and tropical species in terms of the production of fresh matter and nutritional content during the winter period.

The following paragraph is a brief summary of the species and *Avex* mix selected for further testing:

- ***Avena Sativa*** (oats)
  - Member of the grass family;
  - Cereal producing straight, vigorous straw every year, which can reach 1m in height, and is very widespread in temperate and subtropical zones;
  - Used for grazing as fresh forage, hay or ensilage.

- ***Lolium westerwoldicum*** (*ray grass*)
  - Member of the grass family;
  - Annual plant, production increases under irrigated conditions;
  - Used as fresh or preserved forage;
  - High nutritional content.

- ***Medicago Sativa*** (alfalfa)
  - Belongs to the legume family;
  - Perennial plant with deep roots, stem reaching 30 to 70cm in height. Requires considerable sunlight and can tolerate strong temperatures provided that moisture levels remain low;
  - Cultivated on its own or mixed with a small grass/herbaceous plant;
  - Used as fresh forage, hay, silage, or in dried form;

– Very good nutritive value, particularly in terms of protein and high calcium and vitamin content.

- ***Avex***

This is a commercial product and is a mix of various grass plants (*Avena strigosa* and *Lolium westerwoldicum)* and legumes *(Vicia villosa, Trifolium balansae, Trifolium vesiculosum, Trifolium resupinatum).*

⇒ ***Avena strigosa*** (oats)
- Belongs to the grass family;
- Cereal producing straight, vigorous straw every year;
- Good seed production.

⇒ ***Vicia villosa*** (vetch)
- Member of the legume family;
- Annual flowering dicotyledone measuring between 20 and 100 cm, cultivated in a temperate climate, usually together with a cereal to support it;
- Used as preserved forage or as pasture for grazing.

⇒ ***Trifolium sp.*** (clover)
- Member of the legume family;
- Small herbaceous plants, some creepers, which can be hardy perennials, annual or bi-annuals;
- Depending on the variety, used as pasture, fresh forage, hay or silage;
- Very good nutritive value, rich in proteins.

- ***Brachiaria brizantha***

– Belongs to the grass family;
– Robust perennial, with large leaves, thick stemmed rhizome**,** can reach 2 m in height, is suited to fragile soils and grows best in areas where annual rainfall is higher than 750 mm;
– Used as fresh forage.

2. Experimental protocol

The four species and the mix detailed above *(Avena sativa, Lolium westerwoldicum, Medicago sativa, Brachiaria* and *Avex)* were established on three sites in Tan Lac district, Hoa Binh province. Two sites were located in a mountainous zone and the third was close to the city, in a valley area.

A conventional experimental site measures approximately 200 m² and is comprised of 20 small pieces of land or plots with a surface area of 4 m² (4m x 1 m).[1] Each site is divided into two neighbouring sections: one irrigated (10 plots) and one not irrigated (10 plots; see Figure 5; rep=repetition). The forage species are repeated twice, at random, in each section. Each forage species is thereby established four times on each site, twice in the irrigated section and twice in the non-irrigated section.

[1] Field conditions at site 1 (where the tests took place on terraced land) meant that one part of the plots actually measured 3 m x 1.3 m (= 4 m²).

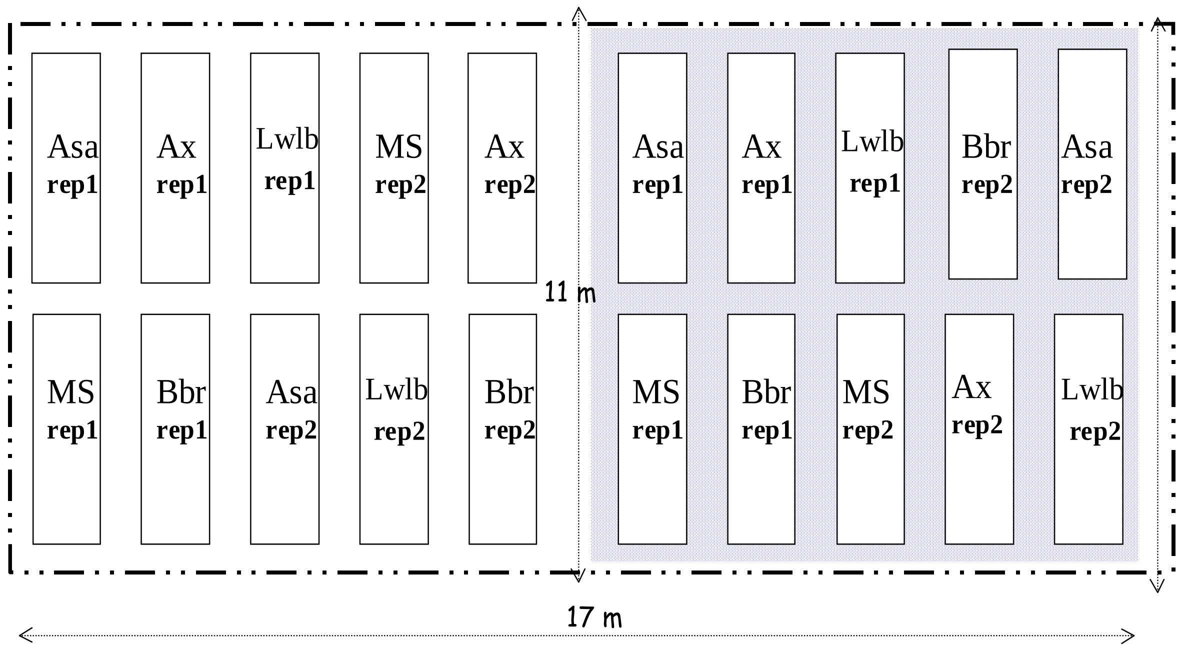


Figure 5 : Experiment site plan

The experimental sites were selected by commune leaders interested in the study, in consultation with the research team from PCP PRISE responsible for conducting the tests. The area was fenced off in order to protect the site from animals.

3. Technical procedures

The three experimental sites at Tan Lac were sown (or planted in the case of *Brachiaria*) on the 12th and 13th of October 2004. The fertilizer at sowing applied was 30 units of nitrogen/ha (in the form of urea) and 60 units/ha of phosphorus (P_2O_5) and potassium (K_2O). The forage plants were watered daily until germination took place across the whole area (around 30 days after sowing), after which the irrigated sections were irrigated at a rate of 20 litres/m²/week. The individual in charge of each experimental site was responsible for irrigation.

Brachiaria and *Medicago sativa* (un-inoculated) were planted and sown, respectively, with a spacing distance of 45 cm. All the other species were sown by scattering. Manufacturers' recommendations concerning the quantity of seeds sown were adhered to. *Avena sativa* was sown at a rate of 120 kg/ha, *Avex* mix at 50 kg/ha, *Lolium westerwoldicum* at 45 kg/ha, *Medicago sativa* at 12 kg/ha, and *Brachiaria* at a rate of 250 cuttings per plot.

The first harvest took place 65 days after sowing although the plants were cut successively at intervals of between 45 and 55 days. Each time the plants were cut (half of the plot area being cut in each case), 60 units of nitrogen were applied as a cover fertiliser, except in the case of the legume *Medicago sativa*. Four cuts were made at the three sites during the course of the experiment, as detailed in Figure 6 below:

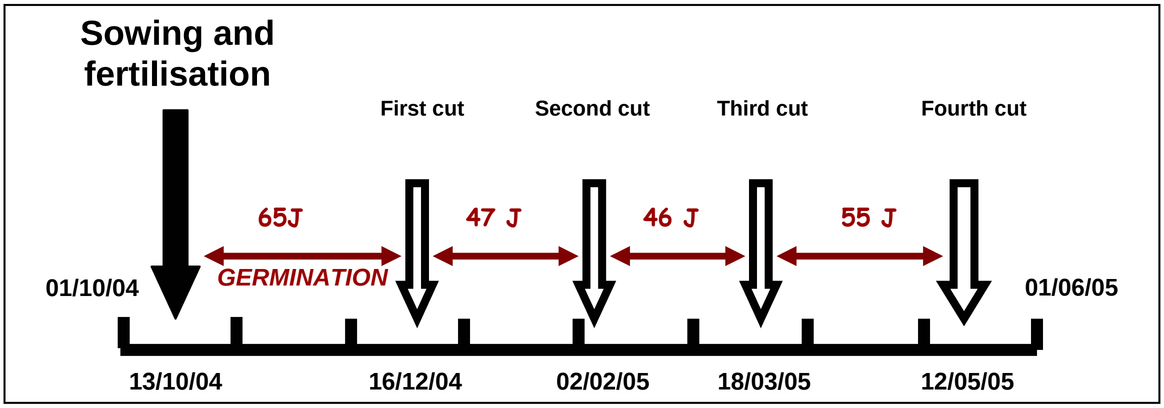


Figure 6 : Experimental protocol

For practical reasons, the 5 species being tested were harvested on the same day. Consequently, the variation in maturity between species was not taken into account. In order to carry out a total evaluation of the different species and determine seed production rates, tests continued until May, despite the fact that the forage deficit mainly occurs between November and April.

4. Variables measured

Local people (land owners) were responsible for monitoring the tests and collecting climatic data after being given training in how to conduct the experiment. A file was distributed with information sheets for each forage species. Data was recorded at various intervals depending on the kind of measurement required (see Appendix 1). Whenever the forage crops were cut, an evaluation of plant development was carried out by the team of PCP PRISE researchers/collaborators and useful discussions were held with the local people in charge. Some of the follow up to the experiments, particularly concerning forage quality and seed germination, was carried out in the laboratory of the Institute of Animal Husbandry in Hanoi. The variables measured relate principally to the adaptation of the various species to the agro-climatic conditions at the sites, the quantity of fresh matter produced (biomass), the chemical composition and the quality of the forage crops, as well as the species' reproductive potential.

- Adaptation of the species:

Species behaviour was evaluated by a series of observations made at ten-day intervals:

- ⇒ the number of plants on an area of 400 cm^2;
- ⇒ visual assessment of the proportion of ground uncovered;
- ⇒ the number of weeds;
- ⇒ note-taking on possible plant disease and the maintenance of the tests.

- Quantity and quality of forage species

Harvesting of the forage crops was carried out on one half of the plots (2 m^2). Each time a cut was made, the total quantity produced (biomass) was weighed using scales. A 200g sample was then extracted so that its chemical content could be analysed at the laboratory.

The samples were dried in an oven at 45 °C for around 40 hours and then grounded into very fine particles (of approximately 1mm). The chemical composition and the nutritive value of the samples were determined at the food analysis laboratory of the Institute of Animal Husbandry using Near InfraRed Spectrometry (NIRS). This rapid prediction technique involves analyzing the radiation spectrum of a source of monochromatic light, reflected by the particles of forage, with a wavelength ranging between 1 100 and 2 500 nanometres. To carry this out, samples of the crushed forage are placed in units of the NIRS apparatus and after a speed reading (approximately 1.5 minutes) of each unit, a spectrum value is obtained. This is then translated, using standardized equations of calibration, into chemical composition and nutritive value data for each sample.

- Seed production

On the other half of the plots (2 m^2), no harvesting was carried out after sowing, so as to measure the seed production for each forage species. Once ripe, the seeds were harvested by hand, cleaned to remove any impurities and then weighed to determine production levels.

At the laboratory of the Institute of the Animal Husbandry, tests were conducted to measure seed germination capacity as follows: three repetitions of 100 full (hard) seeds were deposited in Petri dishes, which had been filled with moist cotton wool. After seven days, the number of germinated seeds was counted and the average rate of germination for each forage species was determined.

III. Results and Discussion

1. Adaptation of the species to the agro-climatic conditions

The forage species tested at Tan Lac were selected on the basis of field information collected the previous year at Moc Chau, and an analysis of both climatic data specific to the Tan Lac region and data on the chemical composition of the soil at the three selected sites.

To fully evaluate the adaptation of forage species to local agro-climatic conditions, plant behaviour needs to be observed closely throughout the production cycle (germination, development, flowering) and certain external parameters likely to influence plant development need to be measured. Information on seed germination, the establishment of the plant, the speed of growth after each cut, the recovery of the soil, and morphological characteristics (colour, size, etc.) was therefore collected for each species and at each experimental site. Weed infestations and the presence of insects and/or diseases were all monitored. All of this information was used to evaluate the adaptation of the various species.

The different forage species can be graded on a scale of three levels of adaptation - good, average and bad – according to an analysis of the field measurements having a direct influence on both the quantitative (production of fresh matter) and qualitative (chemical composition and nutritive value) results of the different samples taken. Table 2 shows the results of this grading for each experimental site.

Forage species	Sites		
	1	2	3
Avena sativa	good	average	average
Lolium westerwoldicum	average	average	bad
Medicago sativa	average	bad	bad
Avex	good	average	good
Brachiaria brizantha	good	bad	good

<u>Table 2</u> : Adaptation of the species to the agro-climatic conditions of Tan Lac

Table 2 reveals that the adaptation of seed production (kg/ha) and the germination capacity of the different species was most favourable at site 1, particularly for *Avena sativa*, *Avex* and *Brachiaria*, as opposed to site 2 where the various species had more difficulty in adapting to ground conditions. At site 3, *Lolium westerwoldicum* and *Medicago sativa* did not adapt, but *Avex* and *Brachiaria* adapted very well. The positive results from site 1 are partly related to climatic conditions, particularly average temperature, which is lower than 15°C for 5 months, a condition suited to the development of temperate forage crops. Furthermore, the quality of the soils at site 1, notably the balance in exchangeable cations and the quality of the organic matter (C/N ratio), facilitates plant growth and development. At site 3, the higher average temperatures (around 20°C) are likely to have had a negative effect on the development of temperate species (except for *Avex*), but enabled *Brachiaria* to continue growing throughout the winter period.

Overall, *Avena sativa* and the *Avex* mix were the temperate forage species best adapted to conditions at Tan Lac, and the tropical species *Brachiaria* was also well adapted (except at site 2). The fresh matter yields (see below) were acceptable and the plants demonstrated normal development, indicating good adaptation to local conditions. The best-adapted forage species were the *Avex* mix, the grass *Avena strigosa* and the legume *Vicia villosa*. In the case of the temperate legume *Medicago sativa*, poor adaptation results at sites 2 and 3 were due to germination problems which may have been caused by the depth of sowing.

2. Quantity and quality of the forage species

The production potential of a plant is directly related to its adaptation to soil and climatic conditions. Table 3 reveals the total (cumulative) quantity harvested from the four cuts.[2] The values are expressed in tons of Fresh Matter (FM) per hectare, corresponding to the yields taken at the time the cut took place; the values expressed in tons of Dry Matter (DM) per hectare are obtained after having dried the sample in an oven. The quantity of DM produced equals the quantity of FM multiplied by the proportion of DM in the sample. Indeed, these are two different ways to express the same parameter (quantity of forage). For the purposes of the study, DM values, which are usually taken to characterize forage, are used.

[2] The results of the quantity of forage by cut and site are presented in Appendix 2

Forage species	Production t/ha	4 cumulative cuts		
		Site 1	Site 2	Site 3
Avena sativa	FM	69	36	44
	DM	10	5	7
Lolium westerwoldicum	FM	69	47	30
	DM	9	6	4
Medicago sativa	FM	18	4	6
	DM	3	1	1
Avex	FM	57	38	33
	DM	8	5	5
Brachiaria brizantha [3]	FM	47	16	37
	DM	9	3	9

<u>Table 3</u> : Fresh Matter (FM) and Dry Matter (DM) yields from the four cuts of forage per experimental site, in tons/ha

According to the experimental protocol, each site was divided into two distinct sections, one irrigated and one un-irrigated. The objective was to highlight the effect of water supply on the development of the forage species. Temperate forage plants are suited to cold temperatures but require significant amounts of water for their healthy development. In many countries with a temperate climate, this water is provided by winter rainfall. However, in Vietnam, the cold season corresponds to the dry season, and consequently the development of temperate species could be affected by the water deficit which occurs during this period. Curiously, the difference in the quantity of FM produced from the irrigated and non-irrigated repetitions was very small (practically nil) for the majority of the species under study. Only *Lolium westerwoldicum* demonstrated a slight increase in production as a result of water being supplied by irrigation. The absence of any impact of irrigation on the plants' development can be attributed to high atmospheric water content. This may have enabled the plants to develop effectively even under rainfed conditions. Another explanation could be insufficient water supply (lower than 5 litres/m²/week) on the irrigated plots, which masked the possible impact of irrigated conditions. Consequently, the effects of irrigation on the plants were not analysed and measurements of 4 repetitions (2 irrigated and 2 non-irrigated) were used on the same site to calculate the average production potential.

As already observed, forage yield was highest at site 1. If all the forage species are totalled together, the production of biomass per hectare at site 1 was 50% and 95% higher than that produced at sites 3 and 2 respectively. If the two sites situated in the mountains are considered separately, the production *of Avena sativa* at site 1 was twice that at site 2, and the production of *Medicago sativa* and *Brachiaria* three times greater. The better quality of the soil and the more favourable climate at site 1 are possible explanations for these differences in yields between the two locations. The differences in forage yields

[3] At sites 1 and 2, the quantity of *Brachiaria* harvested corresponds to only to two cuts

between site 1 and site 3, located in a valley, are small for *Avena sativa* and non-existent for *Brachiaria*, even though in the case of the latter two cuts were conducted at site 1 as opposed to four cuts at site 3. The total quantity of *Brachiaria* produced was similar for both sites, but the yield per cut was higher at site 1. The differences in yield between sites 1 and 3 were significant for the three other species, with a more significant output observed at site 1, a mountain location.

Avena sativa is the temperate forage species which produced the most significant dry matter yield. The average output per hectare of this species at the three sites in Tan Lac was 7.3 tons DM, which is comparable with yields obtained in Europe which range from 6 to 12 tons of DM/ha according to the quality of the soil and the climate. *Lolium westerwoldicum* and the *Avex* mix have lower but significant DM yields, especially considering that tropical forage production is practically nil during the winter period. The DM yields of the legume *Medicago sativa* are poorer compared to those of grass species because they are two different types of plant which, ultimately, have different functions as animal feed. In fact, *Medicago sativa* should be regarded as a crop which is complementary to the basic forage ration. As revealed below, *Medicago* merits special attention due to its high protein and energy content. The output of the tropical species *Brachiaria* was significant at the end of winter/beginning of summer because it is a plant which requires higher temperatures to develop. At site 3 *Brachiaria* grew throughout the winter because average temperatures were higher than 20°C for almost the entire period.

The samples taken when the forage crops were cut were analyzed by a rapid method of chemical composition and nutritive value prediction, using Near InfraRed Spectrometry (NIRS). Table 4 shows the average quality of the samples for each experimental site (from 4 cuts) as well as an average of the three sites[4].

[4] The results of the quality of forage by cut and site are presented in Appendix 3

Forage species	Parameters	Average of the 4 cuts			Overall average
		Site 1	Site 2	Site 3	
Avena sativa	Mineral Matter (%DM)	13	9	11	**11**
	Total proteins (%DM)	18	16	14	**16**
	Crude fibre (%DM)	26	27	29	**27**
	Energy (UFL)	0,8	0,8	0,8	**0,8**
	Proteins PDI (g/kg)	99	91	80	**90**
Lolium westerwoldicum	Mineral Matter (%DM)	12	11	14	**12**
	Total proteins (%DM)	17	18	17	**17**
	Crude fibre (%DM)	24	24	24	**24**
	Energy (UFL)	0,9	0,8	0,8	**0,8**
	Proteins PDI (g/kg)	94	102	97	**98**
Medicago sativa	Mineral Matter (%DM)	12	12	14	**13**
	Total proteins (%DM)	27	29	24	**27**
	Crude fibre (%DM)	23	21	23	**22**
	Energy (UFL)	0,9	0,9	0,8	**0,9**
	Proteins PDI (g/kg)	130	137	118	**128**
Avex	Mineral Matter (%DM)	12	9	12	**11**
	Total proteins (%DM)	17	17	18	**17**
	Crude fibre (%DM)	28	26	26	**27**
	Energy (UFL)	0,8	0,8	0,8	**0,8**
	Proteins PDI (g/kg)	97	98	97	**97**
Brachiaria	Mineral Matter (%DM)	14	11	13	**13**
	Total proteins (%DM)	17	16	15	**16**
	Crude fibre (%DM)	28	30	29	**29**
	Energy (UFL)	0,7	0,6	0,6	**0,6**
	Proteins PDI (g/kg)	102	98	92	**97**

Table 4 : Average quality of forage by experimental site

The quality of a forage plant can be evaluated by its chemical composition (total proteins, cellulose, etc.) and its nutritive value (energy UFL and proteins PDI) which define the way in which the animal (cattle) can use the plant's nutrients. The fibre and raw cellulose content are also important characteristics because they restrict digestion and influence the animal's ingestion capacity.

The differences in chemical composition and nutritive value between the forage species across the three sites are minimal because these characteristics are species-specific and relate to a plant's genetic make-up. Environmental conditions can have some effect on the plant's composition, but this is limited. For example, a high total protein content is observed for *Avena sativa* at site 1 compared to the two other sites, which is probably related to the fertility of the soil. The quantity of raw cellulose found in the *Avena sativa* cultivated at site 3 is higher than at sites 2 and 1, which is undoubtedly due to the higher temperature at site 3. The differences in composition between *Lolium westerwoldicum*, *Avex* and *Brachiaria* are not significant across the three sites.

The last column of Table 4, which presents average data by species, reveals that *Medicago sativa* is the forage species with the highest protein content, with a protein PDI 30% higher than the average of the other species. The energy content of this species is also higher compared to the other plants and, conversely, the cellulose level is lower. The two temperate grass species (*Avena sativa* and *Lolium westerwoldicum*) and the *Avex* mix have similar chemical composition and nutritive value. The tropical species *Brachiaria* has a lower energy UFL and higher content of raw cellulose compared to the temperate species, but is similar to them in terms of total protein content and PDI.

3. Seed production

A further critical aspect of good species adaptation, in addition to the production characteristics and nutritive value of the species which have already been discussed, is the renewal or production of seeds. This is particularly important in Vietnam, where there is currently no commodity chain for seeds of temperate origin.

Table 5 presents the average seed production and germination capacity of the plot repetitions for each species[5]. For reasons stated earlier, we did not take into account the impact of irrigation on seed production, although it would appear that seed production was slightly higher on the irrigated plots.

Forage species	Parameters	Site 1	Site 2	Site 3
Avena sativa	Seed production (kg/ha)		56	270
	Germination capacity (%)		rotten	rotten
Avex (Avena Strigosa)	Seed production (kg/ha)	524	90	730
	Germination capacity (%)	79	Rotten	58

<u>Table 5</u> : Mean seed production (kg/ha) and germination capacity (%) of the species by site 2004/2005

Due to communication problems between the CIRAD team and those in charge of the research sites concerning "seed harvesting", there were a number of difficulties in monitoring seed production effectively, which led to the loss of some data. This was due to the following reasons:

- on certain plots seeds were collected prior to maturity, leading to rotting and making it impossible to test their germination capacity;
- at other plots seeds were collected too late (the plants having become flattened and many of the seeds having fallen on the ground), which led to errors in the measurement of production weight;

[5] The average does not always relate to the four repetitions (2 irrigated plots and 2 non-irrigated plots), because it was not possible to obtain data for the entire set of plots at each site.

- certain types of seeds were not collected at all: this was the case for the species *Vicia villosa* (*Avex*), and of *Lolium westerwoldicum libonus* and *Medicago sativa*, which are more difficult to harvest;
- all the seed bags collected could not be recovered by CIRAD.

In the light of these problems, and to supplement information on the seed production of the various species, data collected on the Moc Chau experimental sites (Son La province) in 2003/2004 were also taken into account. This area is situated next to mountains, with climatic and soil features similar to Tan Lac (see Table 6). By way of comparison the recommended sowing densities are also presented in Table 6.

Forage species	Parameters	Moc Chau Site	Density of sowing advised
Avena sativa	Seed production (kg/ha)	275	120
	Germination capacity (%)	64	
Avex (Avena strigosa)	Seed production (kg/ha)	1 374	50
	Germination capacity (%)	81	
*Avex (*vetch*)*	Seed production (kg/ha)	25 [6]	
	Germination capacity (%)	rotten	
Lolium westerwoldicum	Production seeds (kg/ha)	89	45
	Germination capacity (%)	33	

<u>Table 6 :</u> Seed production (kg/ha) and germination capacity (%) of the species at a site in Moc Chau, 2003/2004

In both Tan Lac in 2004/2005 and Moc Chau in 2003/2004 and 2004/2005, the seed quantities obtained are higher for the species *Avena strigosa* (multi-cropped or mono-cropped) than for *Avena sativa*. However, seed production alone is not a sufficient criterion to determine good reproductive potential. The percentage of empty seeds amongst the batches of seeds produced and the germination capacity of full (hard) seeds should also be taken into account. The percentage of empty seeds amongst the yield for each plot was not estimated, but overall it would appear that the percentage of empty seeds for the oat species *Avena sativa* is higher than that of *Avena strigosa (Avex)*. In terms of germination rate, of the various repetitions carried out on 100 full seeds, the germination capacity of *Avena strigosa* (Avex) appears to be better than that of *Avena sativa* and, according to results obtained at Moc Chau, is at an acceptable level of 81%. In the case of *Vicia villosa*, the seeds are not difficult to harvest but they ripen later than the seeds of the grass species *Avena strigosa*. In addition, various germination tests which were carried out on leguminous plant seeds (using the same protocol as that for the seeds of gramineous plants) produced poor results. The success rate was between 0 and 5%, the remainder of the seeds having rotted in the Petri dishes. Little information is currently available regarding the species *Medicago sativa*; however, the extraction of seeds for this

[6] Result obtained into 2004/2005 but data absent for 2003/2004

species appears to be more difficult and requires a rigorous approach. The analysis of the few plots harvested recently at Moc Chau is on-going. Lastly, the seeds of *Lolium westerwoldicum libonus* are also difficult to harvest because they are very small, and many seeds appeared to be empty, but this has not been fully determined. The weak germination rate obtained for this species (33%) can be partially explained by the problems that were faced in selecting full seeds when the germination tests were being established.

It is clear that factors relating to reproductive potential (level of difficulty of harvesting, germination capacity, etc) must inform the selection of the species which will be the subject of further experiments in 2006.

In terms of the quantity of seeds produced, it is difficult to reach a firm conclusion for *Lolium westerwoldicum libonus*, *Avena* and *Vicia villosa*: firstly, no previous knowledge exists concerning the production of these species in a tropical medium and secondly, making a proper comparison according to the sowing density advised would necessitate estimating the percentage of unfilled seeds collected on the experimental plots and collecting information across a larger area.

Thus, priorities for the 2006 tests concerning the seed production of the selected species are as follows:

1-to devote larger experimental areas to the study of seed production;

2-to communicate effectively to those in charge of the research sites the importance of harvesting all seeds when they mature;

3-to try and evaluate the percentage of empty seeds in each batch, in order to be able to estimate accurately the quantity of seeds with germination potential;

4-to confirm the results of the germination tests.

IV. Conclusion

The results obtained in Tan Lac district for the three temperate species tested this year confirm the results obtained in 2003-2004 in Moc Chau district.

Nevertheless, some differences were observed between the three sites, hence it is necessary to refine studies on soil and climatic factors. *Avena strigosa,* the grass present in the *Avex* mix, was the temperate forage species which demonstrated the best adaptation to local conditions, as well as the highest production, good nutritive value and reproductive potential.

The results are encouraging. It is therefore appropriate to not only continue the experimental tests, but to conduct them over larger areas of land. In fact, the experimental tests will make it possible to refine knowledge about the local farming system and larger scale, on-farm tests will make it possible to confirm the results in real conditions, and to evaluate the economic impact of introducing forage crops to the existing system.

V. Acknowledgements

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VI. Appendices

Appendix 1 : Example of information sheet distributed to farmers for monitoring the tests

code: **Ms 3.1.0.1**

Sowing date: Total germination date:

density:

Sowing fertilization:

Plots activities:

Activity	date	Other observations
Irrigation		
Weeds control		
Fertilization		

Plot observations:

Observation \ date																								
Number of plants in 400 cm²																								
% empty plot																								
Number of weeds in 400 cm²																								

Total flowering date:

<u>Appendix 2</u> : Quantity of forage by cut and cumulative in the three sites

- Site 1

Forage species	T/ha	1st cut	2nd cut	3rd cut	4th cut	Cumulative cuts
Avena sativa	FM	9,8	23,8	23,7	11,9	69
	DM	**1,5**	**2,6**	**3,3**	**2,7**	**10**
Lolium westerwoldicum	FM	8,7	22,7	24,5	12,8	69
	DM	**1,2**	**2,3**	**2,7**	**2,7**	**9**
Medicago sativa	FM	1,3	5,6	7,0	3,9	18
	DM	**0,2**	**0,6**	**1,0**	**0,9**	**3**
Avex	FM	6,5	22,4	19,7	8,3	57
	DM	**0,9**	**2,3**	**2,9**	**2,3**	**8**
Brachiaria	FM	-	-	11,8	35,5	47
	DM	**-**	**-**	**2,0**	**7,0**	**9**

- Site 2

Forage species	T/ha	1st cut	2nd cut	3rd cut	4th cut	Cumulative cuts
Avena sativa	FM	6,1	12,8	12,6	4,3	36
	DM	**1,2**	**1,5**	**1,5**	**1,0**	**5**
Lolium westerwoldicum	FM	7,0	15,8	15,7	8,2	47
	DM	**1,1**	**1,4**	**1,8**	**1,9**	**6**
Medicago sativa	FM	0,3	1,5	1,2	0,8	4
	DM	**0,0**	**0,1**	**0,2**	**0,2**	**1**
Avex	FM	7,4	14,9	11,4	4,0	38
	DM	**1,2**	**1,5**	**1,4**	**1,0**	**5**
Brachiaria	FM	-	-	2,8	13,6	16
	DM	**-**	**-**	**0,5**	**2,6**	**3**

- Site 3

Forage species	T/ha	1st cut	2nd cut	3rd cut	4th cut	Cumulative cuts
Avena sativa	FM	17,1	14,1	11,5	1,0	44
	DM	**2,6**	**2,2**	**1,7**	**0,4**	**7**
Lolium westerwoldicum	FM	8,4	8,3	10,9	2,0	30
	DM	**1,1**	**1,3**	**1,3**	**0,7**	**4**
Medicago sativa	FM	0,7	1,0	3,7	1,2	6
	DM	**0,1**	**0,2**	**0,5**	**0,3**	**1**
Avex	FM	9,1	10,7	11,2	2,0	33
	DM	**1,3**	**1,8**	**1,6**	**0,6**	**5**
Brachiaria	FM	5,8	6,0	9,0	16,8	37
	DM	**1,2**	**1,1**	**1,3**	**5,0**	**9**

<u>Appendix 3</u> : Quality of forage by cut and overall average in the three sites

- Site 1

Forage species	Parameters	1st cut	2nd cut	3rd cut	4th cut	Overall average
Avena sativa	Mineral Matter (%DM)	11,3	14,3	12,7		**13**
	Total proteins (%DM)	14,5	21,5	16,9		**18**
	Crude fibre (%DM)	21,8	30,3	27,2		**26**
	Energy (UFL)	0,9	0,8	0,8		**0,8**
	Proteins PDI (g/kg)	91,2	108,3	97,3		**99**
Lolium westerwoldicum	Mineral Matter (%DM)	11,2	12,5	13,6		**12**
	Total proteins (%DM)	13,6	19,6	16,3		**17**
	Crude fibre (%DM)	17,2	26,6	29,2		**24**
	Energy (UFL)	0,9	0,9	0,8		**0,9**
	Proteins PDI (g/kg)	85,5	103,5	94,2		**94**
Medicago sativa	Mineral Matter (%DM)	12,2	12,4	11,8		**12**
	Total proteins (%DM)	26,7	29,4	25,4		**27**
	Crude fibre (%DM)	21,7	22,4	25,4		**23**
	Energy (UFL)	0,9	0,9	0,8		**0,9**
	Proteins PDI (g/kg)	129,0	137,5	123,1		**130**
Avex	Mineral Matter (%DM)	10,8	12,4	11,9	11,1	**12**
	Total proteins (%DM)	15,9	22,7	16,9	13,7	**17**
	Crude fibre (%DM)	20,4	29,6	29,3	34,2	**28**
	Energy (UFL)	0,9	0,8	0,8	0,7	**0,8**
	Proteins PDI (g/kg)	96,2	111,9	95,3	83,5	**97**
Brachiaria	Mineral Matter (%DM)	-	-	13,5		**14**
	Total proteins (%DM)	-	-	17,4		**17**
	Crude fibre (%DM)	-	-	28,3		**28**
	Energy (UFL)	-	-	0,7		**0,7**
	Proteins PDI (g/kg)	-	-	101,9		**102**

- Site 2

Forage species	Parameters	1st cut	2nd cut	3rd cut	4th cut	Overall average
Avena sativa	Mineral Matter (%DM)	7,8	10,9	10,3	7,1	**9**
	Total proteins (%DM)	10,4	22,7	18,4	12,9	**16**
	Crude fibre (%DM)	18,7	27,8	28,1	33,7	**27**
	Energy (UFL)	0,9	0,9	0,8	0,6	**0,8**
	Proteins PDI (g/kg)	65,1	114,9	102,8	81,7	**91**
Lolium westerwoldicum	Mineral Matter (%DM)	11,1	13,3	12,7	8	**11**
	Total proteins (%DM)	15,4	24,5	18	15,6	**18**
	Crude fibre (%DM)	14,6	23,3	26,8	33,2	**24**
	Energy (UFL)	1	0,9	0,8	0,6	**0,8**
	Proteins PDI (g/kg)	97,1	121,7	99,2	88,9	**102**
Medicago sativa	Mineral Matter (%DM)	12,2	13,3	11,2		**12**
	Total proteins (%DM)	28,4	30,9	28,5		**29**
	Crude fibre (%DM)	20,5	20,2	22,5		**21**
	Energy (UFL)	0,9	0,9	0,9		**0,9**
	Proteins PDI (g/kg)	135,2	142,2	134,6		**137**
Avex	Mineral Matter (%DM)	9,1	11,3	8 ,9	6,7	**9**
	Total proteins (%DM)	14,6	22,1	15,3	16,3	**17**
	Crude fibre (%DM)	18,6	25,4	25,6	32,8	**26**
	Energy (UFL)	0,9	0,8	0,8	0,6	**0,8**
	Proteins PDI (g/kg)	92,3	114,4	93,2	92,5	**98**
Brachiaria	Mineral Matter (%DM)	-	-	12,7	9,6	**11**
	Total proteins (%DM)	-	-	16,2	15,6	**16**
	Crude fibre (%DM)	-	-	26,6	32,8	**30**
	Energy (UFL)	-	-	0,6	0,7	**0,6**
	Proteins PDI (g/kg)	-	-	100,9	94,7	**98**

- Site 3

Forage species	Parameters	1st cut	2nd cut	3rd cut	4th cut	Overall average
Avena sativa	Mineral Matter (%DM)	11,7	10,7	10,3	9,6	**11**
	Total proteins (%DM)	14,7	17,9	15,1	9,5	**14**
	Crude fibre (%DM)	23,7	28,6	28,7	33,9	**29**
	Energy (UFL)	0,9	0,8	0,8	0,6	**0,8**
	Proteins PDI (g/kg)	91,2	98, 1	90,2	59,6	**80**
Lolium westerwoldicum	Mineral Matter (%DM)	15,1	11,8	13,7	13,8	**14**
	Total proteins (%DM)	18,8	20,5	16,5	13,8	**17**
	Crude fibre (%DM)	19,7	23	24,3	27,9	**24**
	Energy (UFL)	0,8	0,8	0,8	0,6	**0,8**
	Proteins PDI (g/kg)	105,3	108,7	92,8	79,7	**97**
Medicago sativa	Mineral Matter (%DM)	13	12,9	14,1	17,7	**14**
	Total proteins (%DM)	28	25,5	23,6	17,9	**24**
	Crude fibre (%DM)	21,7	20,2	20,7	27,6	**23**
	Energy (UFL)	0,8	0,8	0,8	0,6	**0,8**
	Proteins PDI (g/kg)	133,4	126,9	119,3	93,4	**118**
Avex	Mineral Matter (%DM)	13,2	11,1	11,1	1 3,9	**12**
	Total proteins (%DM)	19,8	19,2	17,1	14,4	**18**
	Crude fibre (%DM)	22,3	27,8	27	25,6	**26**
	Energy (UFL)	0,9	0,8	0,8	0,6	**0,8**
	Proteins PDI (g/kg)	107,1	102,6	95,6	82,5	**97**
Brachiaria	Mineral Matter (%DM)	16,7	13,6	13,2	8,8	**13**
	Total proteins (%DM)	15,5	16,7	15,2	12,1	**15**
	Crude fibre (%DM)	27,6	29,1	27,5	31,1	**29**
	Energy (UFL)	0,6	0,7	0,7	0,7	**0,6**
	Proteins PDI (g/kg)	95,1	100,6	95,9	76,6	**92**

Appendix 4 : Forage trials expenses report

The total budget granted for the realization of the forage production trials in the district of Tan Lac was of 2 370 Dollars (USD) and was used as follows:

		USD
1.	Experiment establishment:	
	a. Seeds purchase and transport	32
	b. Fertilizer purchase	2
	c. Fence and work material	342
	d. Workmanship	42
2	Monitoring and evaluation (8 months):	
	a. Fertilizer purchase	7
	b. Material (pluviometer, thermometer, etc.)	83
	c. PRISE expert mission to Tan Lac (9 in total)	812
	d. Workmanship and tests irrigation	709
3	Laboratory analysis:	
	a. Soil	82
	b. Forage	332
	Total:	**2 443**