EXPERIMENT ON TEMPERATE AND TROPICAL FODDER SPECIES AROUND HANOI

DEVELOPMENT AND EXTENSION OF DAIRY FARMING ACTIVITIES AROUND HANOI
VIETNAM BELGIUM DAIRY PROJECT

FINAL TECHNICAL REPORT

Paulo Salgado, Le Hoa Binh and Tran Van Thu

CENTRE DE COOPÉRATION INTERNATIONALE EN RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT
AND
NATIONAL INSTITUT OF ANIMAL HUSBANDRY

July 2006

TABLE OF CONTENTS

I. INTRODUCTION

1. Context of the experiment

In Vietnam, agriculture plays a very important socio-economic role. Animal production is expanding steadily due to the continuous increase in demand resulting from high demographic growth and changing food habits. The livestock sector in Vietnam is characterized by the dominance of pork and fish while milk production is emerging as a result of very new demand. The production units are mainly very small family holdings (three or four dairy cows per household) with a few trade operators. The majority of farming households 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 livestock activities. A more effective application of agronomic science and improved technologies is, therefore, necessary to support the diversification of livestock production. Sustainable increases in farmers' incomes also depend on the improvement of product quality and the establishment of suitable policy and regulatory measures.

In a context of limited natural resources, and significant pressure on land, the intensification of animal production in ways that are environmentally and socially sustainable, together with the controlled improvement of animal productivity, are the only feasible responses. The development of the cattle sector 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 ruminants, especially dairy 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.

In certain provinces of northern Vietnam, climatic conditions, particularly low winter temperatures, do not enable the development and growth of tropical forage species during the winter months. 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 natural 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 fodder 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.

2. Objectives

Forage experimental activities were developed under a large, dairy development project implemented by the Ministry of Agriculture and Rural Development (Vietnam), with technical assistance from the Belgian Technical Cooperation (VBDP). This project focused on the development and extension of dairy activities in the provinces around Hanoi.

Farmers, extensions workers, researchers and policy-makers consider scarcity of forage, especially during the winter period, as an important constraint to the development of the dairy sector in northern Vietnam. In order to propose and test fodder solutions, an experimental project on temperate species was implemented between October 2005 and May 2006. Its main objective was to increase the quantity and improve the quality of fodder resources during winter.

Two main activities were carried out under this project:

(1) Field experiments with temperate and tropical forages species. Experiments were completed in five Provinces around Hanoi (19 experimental sites; cf. next page). The aim was to select the forage species that are better adapted to the agro-climatic conditions of this zone of the country (during winter) for subsequent wide adoption. The use of tropical species in the experiment served to compare the differences in winter growth between the two types of plants (temperate *vs.* tropical). The objectives of field activities were, therefore: (i) to test the agro-climatic adaptation of temperate forage species for the winter period; (ii) to determine their production potential, and (iii) to evaluate their reproductive potential (seed production). Over the medium term, the aim was to test the adoption and create awareness with these new forage production methods by farmers, so that their introduction within existing agricultural farming systems can be considered, while taking into account both economic factors and the organization of labor at farm level.

(2) Training on production and utilization of forage plants with the aim of improving the knowledge of project participants and extension workers. One preliminary session was organized to explain the establishment of the experimental sites and to distribute the relevant material (forage seeds, technical information and notebook for data registers, material for

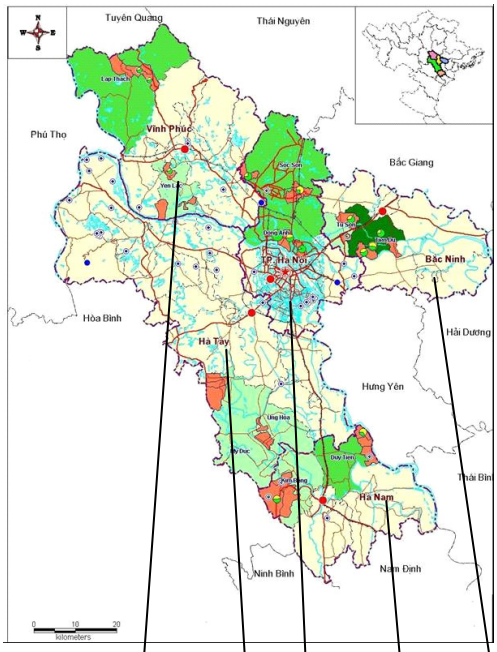
identification of the parcels, etc.). A second training session was organized in the field to demonstrate to those responsible for each experimental site how to cut the forage, control the weeds and apply fertilizer. The first growth results were also discussed during this second training session. Unfortunately, it was not possible to organize a training session specially oriented to feeding systems management. The CIRAD/NIAH training team will submit this activity to a new contractual services agreement with VBDP Project.

3. Localization of experimental sites

The experimental sites were located in five provinces around Hanoi as described in figure 1 (cf. next page). In each Province, two or three districts were considered and in each district, one or two communes were chosen[1] to carry out of the experiments. The aim was to select experiment sites which are representative area of the different existing types of soil and climatic conditions found in this zone of the country. It will be useful in near future to map the distribution of the different soil types in each district, describe these types and interpret the maps in a form that is practical. This would facilitate the choice of areas with potential for temperate forage extension.

[1] The sellection of the location of the experiments was of the responsibility of the VBDP project coodinator

Figure 1. Localization of experimental sites (n° of sites)



Vinh Phuc Province

- ⇒ Yen Lac district
  - Dai Tu commune (1)
  - Trung Nguyen commune (1)
- ⇒ Lap Thach district
  - Bac Binh commune (1)
- ⇒ Vinh Tuong district
  - Tu Trung commune (1)

Bac Ninh Province

- ⇒ Tu Son district
  - Tan Hong commune (1)
- ⇒ Tien Du district
  - Canh Hung commune (2)

Ha Tay Province

- ⇒ My Duc district
  - Dong Tam commune (1)
- ⇒ Ung Hoa district
  - Phu Luu commune (1)
  - Van Thai commune (1)
- ⇒ Thanh Oai district
  - Thanh Mai commune (1)

Ha Nam Province

- ⇒ Kim Bang district
  - Kha Phong commune (1)
  - Ba Sao commune (1)
- ⇒ Duy Tien district
  - Moc Bac commune (1)
  - Chuyen Ngoai (1)

Ha Noi Province

- ⇒ Dong Anh district
  - Vinh Ngoc commune (2)
- ⇒ Soc Son district
  - Dong Xuan commune (1)
- ⇒ Tu Liem district
  - Cau Dien commune (1)

II. Material and methods

1. Forage species and mixtures

The research team selected several forage species that were tested previously in other zones of Northern Vietnam (Son La and Hoa Binh Provinces). A mix of Australian seeds and one tropical grass specie were also included in the experiments as suggested by the coordinator of the Vietnam Belgian project. The following species or the mixed species were used:

- *Medicago sativa* (alfalfa; **MS**) - belongs to the legume family. Is a temperate perennial plant with deep roots, stem reaching 30 to 70 cm in height. Requires considerable sunlight and can tolerate strong temperatures if moisture levels remain low.
- Avex mix (commercial product; **AX**) - mix of various temperate grass plants (*Avena strigosa* and *Lolium westerwoldicum*) and temperate legumes (*Vicia villosa*, *Trifolium balansae*, *Trifolium vesiculosum*, *Trifolium resupinatum*).
- Australian mix (commercial product; **AM**) - mix of various tropical grass plants (*Brachiaria decumbens*, *Digitaria milanjiana*, *Setaria sphacelata*, *Chloris gayana*) and tropical legumes (*Macroptilium* a*tropurpureum*, *Stylosanthes seabranna*, *Stylosanthes guianensis*, *Clitoria ternatea*).
- *Pennisetum purpureum* or *Panicum maximum* or *Brachiaria brizantha* (**PP**, **PM** or **Bra**, respectively) – belongs to the tropical grass family. *Pennisetum* species (Elephant grass) are potentially the most productive grasses available, but do not tolerate low fertility or dry conditions; *Panicum* (Guinea grass) needs high soil fertility, adapted to areas with a short or no dry season although it can survive in areas with long dry season; *Brachiaria brizantha* is adapted to a wide range of climates and soils.

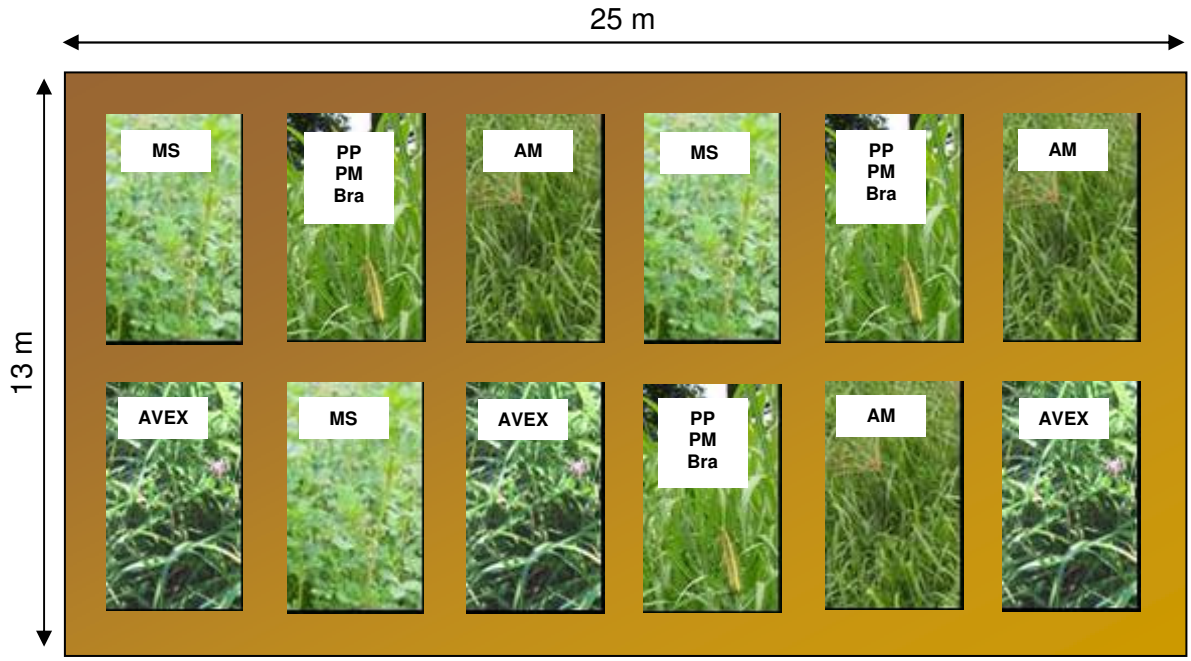
2. Experimental protocol

The two mono-species and the two mixes detailed above were established on nineteen sites around Hanoi (five Provinces including Hanoi). All experimental sites were located in valleys area and some of them inside paddy fields.

A conventional experimental site measures approximately 325 m² and is comprised of 12 small pieces of land or plots with a surface area of 15 m² (5 m x 3 m). Each plot is divided into two neighboring sections: one to measure fodder production and another to evaluate

seed production. The forage species and mixes were repeated three times, at random, in each site (Figure 2).

Figure 2. Experimental site design



The area was fenced off in order to protect the site from animals.

3. Technical procedures

The experimental sites were sown (or planted in the case of tropical grasses) from October 28 to November 16 depending on the commune[2]. Tropical grasses (*Pennisetum purpureum*, *Panicum maximum* and *Brachiaria brizantha*) and *Medicago sativa* (un-inoculated) were planted and sown, respectively, with spacing between lines of 50 cm for tropical grasses and 20 cm for *Medicago* sativa. Sowing distance of cutting materials inside the line was continuous for *Pennisetum purpureum*, 35 cm for *Panicum maximum* and 20 cm for *Brachiaria brizantha*. Avex and Australian mixes were sown by scattering (broadcast). Manufacturers' recommendations concerning the quantity of seeds sown were used for the present experiment. Avex was sown at a rate of 50 kg/ha, *Medicago sativa* at 12 kg/ha, Australian mix at 14 kg/ha and tropical grasses at a rates of cuttings per plot varying from 8 tons/ha for *Pennisetum purpureum*, 4 tons/ha for *Panicum maximum* and 2.5 tons/ha for *Brachiaria brizantha*.

[2] For more details about sowing dates see Appendix 1.

The quantity of fertilizer at sowing recommended by the research team to the persons in charge of the experimental sites was 30 kg of nitrogen/ha (in the form of urea) and 60 kg/ha of phosphorus (P2O5) and potassium (K2O). All forage species and mixes received the same quantities of fertilizer. We have no information if the recommendations were followed in the experimental sites.

The forage plants were irrigated twice per day until germination took place across the whole area (around 30 days after sowing), after which the irrigation process stopped. The person in charge of each experimental site was responsible for irrigation.

The first harvest of fodder took place on average 80 days after sowing for Avex, 111 days for MS, 110 days for AM and 130 days for the tropical grasses. The following cuts were made successively at intervals of between 36 and 54 days. Two to three cuts were made during the course of the experiment, as detailed in the Appendix 1. Each time the plants were cut, 60 kg (units) of nitrogen were recommended to be applied as a cover fertilizer, except in the case of the legume *Medicago sativa*. 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 March.

4. Variables measured

Local staff from VBDP project received training on how to conduct the experiment and were responsible for monitoring the tests and collecting climatic data. A booklet was distributed with information sheets for each forage species. Data was recorded at various intervals depending on the kind of measurement required. The research team carried out evaluations of plant development and useful discussions were held with the local people in charge of the experiments. 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) as well as the species' reproductive potential.

⇒ Cultural procedures dates:

- seeding and germination;
- fertilization and irrigation;
- weeds control and cut of forage plants.

⇒ The adaptation of the species was evaluated by a series of observations made at ten-day intervals:

- the number of plants on an area of 400 cm^2;

- plant growth capacity
- the number of weeds and existence of plant disease.

⇒ Yields were measured by harvesting the forage. This was carried out on one half of the plots (7.5 m²). Each time a cut was made, the total quantity produced (biomass) was weighed using scales. Unfortunately, due to logistic complexities, it was not possible to evaluate in the laboratory the fodder quality, both in terms of chemical composition and nutritive value.

⇒ Seed production: on the other half of the plots (7.5 m²), no harvesting was carried out after sowing, so as to measure the seed production for each forage species. Due to communication problems between the research team and those in charge of the experimental sites concerning “seed harvesting”, there were a number of difficulties in monitoring seed production effectively. This led to the loss of data. In addition, certain types of seeds in the mixtures (Avex, AM) are difficult to harvest (diverse mature time) and a rigorous approach is required.

III. Results and discussion

1. Soil analysis

When selecting which forage species to test on a particular area of land, it is important 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 nutrients 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 by the bedrock, while temperature and humidity facilitate the production of vegetable matter and the mineralization 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 experimental sites, soil samples were taken and their chemical composition was analyzed. The samples were taken during May 2006 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 summarized 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 geomorphologic data.

Table 1. Soil analysis in the experimental sites

Province	District	Commune	horizon	pH - H_20	C g/kg	N g/kg	C/N	exchangeable cations cmol / kg		P_2O_5 avail. mg / 100 g	P_20_5 total %	K_2O total %
								Ca^{++}	Mg^{++}			
Bac Ninh	Tien Du	Canh Hung[a]	0 - 20	7,8	10,4	1,3	8	12,8	0,3	‡[3]	0,15	2,19
			20 - 40	8,1	8,3	0,6	15	12,3	2,2	17,7	0,12	2,82
		Canh Hung[b]	0 - 20	7,4	4,8	0,6	8	6,4	0,2	89,4	0,09	1,02
			20 - 40	8,1	3,3	0,5	7	7,5	0,6	35,6	0,06	1,31
Ha Nam	Kim Bang	Kha Phong	0 - 20	6,1	3,1	0,4	7	3,5	0,8	‡[3]	0,12	1,09
			20 - 40	6,4	1,7	0,4	4	4,8	0,8	51,1	0,07	1,45
		Ba Sao	0 - 20	7,8	14,5	1,8	8	12,0	1,3	25,4	0,16	1,59
			20 - 40	7,4	10,5	1,5	7	7,8	1,8	11,8	0,17	1,73
	Duy Tien	Moc Bac	0 - 20	8,0	4,3	0,6	7	6,7	0,6	32,1	0,09	1,25
			20 - 40	8,0	7,5	0,7	11	9,0	1,3	11,6	0,10	1,63
		Chuyen Ngoai	0 - 20	7,4	13,8	1,1	13	11,2	1,8	76,4	0,13	2,45
			20 - 40	8,2	9,5	0,8	12	12,6	2,1	44,2	0,09	2,90
Ha Noi	Dong Anh	Vinh Ngoc [a]	0 - 20	8,1	11,6	0,8	14	9,1	1,9	5,4	0,11	1,83
			20 - 40	7,8	9,0	1,2	7	11,0	1,3	21,3	0,10	1,78
		Vinh Ngoc [b]	0 - 20	6,3	16,7	1,9	9	9,1	1,4	65,9	0,13	1,83
			20 - 40	6,8	14,3	1,6	9	8,0	1,8	80,8	0,12	1,88
	Soc Son	Dong Xuan	0 - 20	4,8	3,7	0,5	8	1,8	0,3	‡[3]	0,17	0,23
			20 - 40	4,7	4,5	0,5	9	3,7	0,5	‡[3]	0,12	0,38
	Tu Liem	Cau Dien	0 - 20	7,8	14,3	1,4	10	15,9	0,3	60,7	0,16	2,19
			20 - 40	7,8	16,3	1,4	11	14,2	1,8	88,3	0,17	2,24
Ha Tay	My Duc	Dong Tam	0 - 20	7,6	10,9	1,4	8	10,6	1,0	20,5	0,12	1,28
			20 - 40	6,7	11,2	0,8	14	4,0	0,0	8,0	0,07	0,52
	Ung Hoa	Phu Luu	0 - 20	8,0	9,5	0,7	14	10,2	0,8	‡[3]	0,15	1,93
			20 - 40	8,0	7,5	0,5	14	9,8	0,8	47,5	0,11	2,03
		Van Thai	0 - 20	7,1	10,1	0,8	13	8,6	1,6	73,9	0,11	1,93
			20 - 40	7,8	9,7	0,7	14	11,2	0,8	58,5	0,10	2,12
	Thanh Oai	Thanh Mai	0 - 20	5,5	3,3	0,6	6	3,5	1,4	31,0	0,06	1,28
			20 - 40	5,6	4,3	0,5	9	4,5	1,0	34,5	0,06	1,53
Vinh Phuc	Yen Lac	Dai Tu	0 - 20	6,7	12,1	1,3	10	10,1	1,6	53,4	0,14	2,45
			20 - 40	7,7	11,0	0,9	12	11,8	1,4	62,5	0,11	2,62
		Trung Nguyen	0 - 20	5,8	7,7	0,9	8	3,7	0,2	58,4	0,06	0,48
			20 - 40	6,8	2,8	0,4	7	2,7	0,6	7,5	0,03	0,36
	Lap Thach	Bac Binh	0 - 20	4,9	5,3	0,5	11	1,4	0,2	32,7	0,05	0,69
			20 - 40	5,1	2,6	0,4	6	1,4	0,8	31,6	0,05	0,61
	Vinh Tuong	Tu Trung	0 - 20	6,6	11,2	1,2	9	7,0	1,0	53,9	0,14	1,31
			20 - 40	7,3	4,6	0,7	7	9,0	1,1	10,2	0,07	1,83

[3] ‡ data to be confirmed

The pH (on water) average values of the experimental soils are exactly 7.0, which mean that the soils are neutral. Except for two sites (in Hanoi, Soc Son, Dong Xuan and in Vinh Phuc, Lap Thach, Bac Binh) where the pH is acid, the other experimental sites have an appropriate pH to grass and specially legume development. 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 aluminum toxicity. In order to increase the pH of the soil at the two 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 average values of the experimental soils are approximately 10, 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 microorganisms while nitrogen is often the limitative factor for the development of plants and bacteria. If we compare the results per province, Hanoi province has the most fertile soils. The soil's carbon level is normal (in average 11) and its nitrogen level is correct. The best soils are the ones located in Dong Anh district, Vinh Ngoc commune ("wet site") and the worst are in Soc Son district, Dong Xuan commune. In the other provinces, soil analysis in the experimental sites showed carbon and nitrogen levels generally lower (less fertile soils) than those in Hanoi province. However, concerning the carbon level, normal values were founded in Ba Sao site (Kim Bang district) and Chuyen Ngoai site (Duy Tien district) in Ha Nam province, and Dai Tu site (Yen Lac district) in Vinh Phuc province. The nitrogen level of the soil in Ba Sao site is also within correct parameters, but all the other analyzed soils showed a deficit of this nutrient. The poorest soils were founded in the following experimental sites: Canh Hung[b] in Bac Ninh province, Kha Phong in Ha Nam province, Thanh Mai in Ha Tay province and Bac Binh site in Vinh Phuc province.

In terms of the concentration of exchangeable cations (Ca and Mg) and the balance between cations, all the experimental soils have normal to relatively low levels of exchangeable Ca^{++} but are low in exchangeable Mg^{++}. The low level of cation magnesium (Mg++) will obstruct the absorption of potassium by plants especially if this is only present the soil in small amounts. All soils present a too high Ca/Mg ratio. The soils have relatively low levels of total potassium (K_20). This is mainly the case of Dong Xuan site in Hanoi Province, and Trung Nguyen and Bac Binh sites in Vinh Phuc Province. By contrast, the experimental soils have on average a correct level of total phosphorus (P_2O_5) and are exceptionally rich in available phosphorus, in particular at the surface horizon (0 to 20 cm).

These results need to be compared with field observations concerning the behavior of forage crops (speed rate 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 experimental sites.

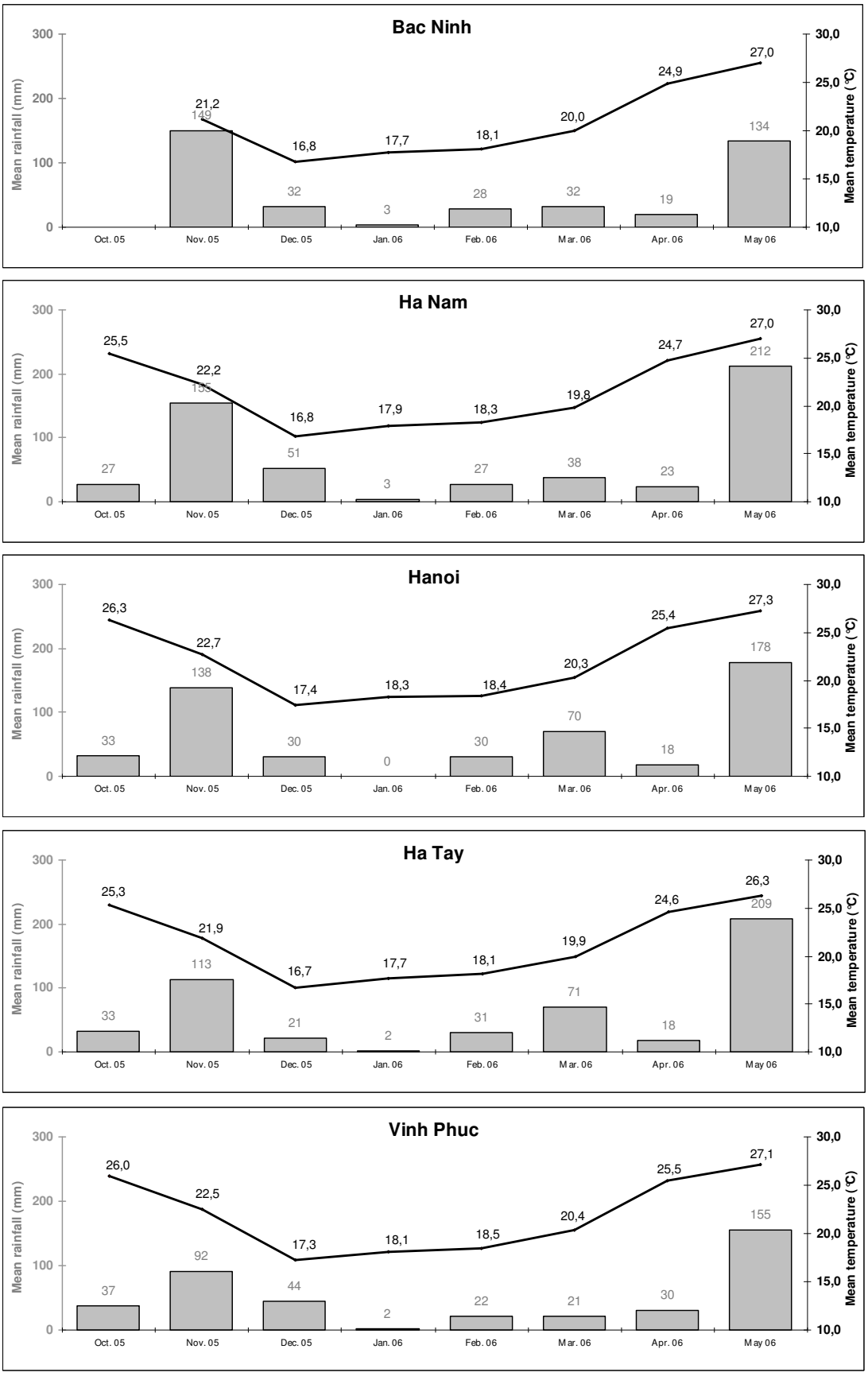
2. Climatic data

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, solar radiation and atmospheric cover are other important climatic factors that need to be considered in the study of the adaptation and development of forage crops.

Figure 3 shows the mean climatic data (rainfall and temperature) issued by the Provincial weather stations for the period October 2005 to May 2006. 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.

Figure 3. Mean rainfall and temperature from October 2005 to May 2006



Data from weather stations are instrumental in the selection of the forage species to be tested and to enhance understanding of the potential effects of climate on the adaptation and development of forage species. However, some climatic data from provincial weather stations can diverge significantly from the one observed in the experimental sites due to the distance between the two. Therefore, it is not possible to characterize the specific climatic context at each site more accurately.

Figure 3 shows that climatic characteristics recorded in the five provinces are quite similar. Average temperature gradually decreases till December, reaching a minimum of 17°C. From December, and during three to four months, average temperature remain relatively low (less than 20°C), starting to increase in April to values around 25°C. Even during the coldest months, the average temperatures allow the development of tropical forage species, but with a growth rhythm quite low compared to the one achieved in the hot and rainy season (July/August). Zero vegetation for the tropical species is around 10-15°C. For temperate plants, optimum energy efficiency is achieved when the temperature is between 20 to 25 °C.

Total rainfall during the measured period (October – May) is similar in Hanoi and Ha Tay Provinces (497 mm), higher in Ha Nam (537 mm) and lower in Vinh Phuc (402 mm) and Bac Ninh (396 mm). However, rainfall distribution varies throughout the period. The coldest months (December to March) are also the driest ones, with low rainfall levels of approximately 30 mm per month. During winter, climatic conditions resemble those of a dry, sub temperate climate. The total rainfall during winter is enough to meet the requirements of some temperate forages, but the major problem is the non-homogenous distribution during this period. If irrigation of forage fields is not possible, it is vital to select and use temperate species adapted to (short) dry periods. The average humidity measured in the provincial weather stations was relatively high (82%) during the measured period, with a minimum in December 2005 (69% in Hanoi) and a maximum in February 2006 (90% in Ha Nam).

Solar radiation data was also recorded and the cumulative values from October to May for Hanoi, Ha Tay, Ha Nam, Vinh Phuc and Bac Ninh Provinces are 688, 704, 704, 675 and 543 hours, respectively. In average, the plants receive approximately 90 hours of direct sun per month (3 per day). This value is considered low for plant requirements having a negative influence on the photosynthesis efficiency and flowering process.

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

3. Adaptation of species to the agro-climatic conditions

An intermediate report about forage species adaptation to the specific conditions of each experimental site was sent to VBDP coordinators in April 2006. The comments presented in the report were the result of the observations carried out by the research team during the visits to the experimental sites.

To fully evaluate the adaptation of forage species to local agro-climatic conditions, plant behavior 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 rate of growth after each cut, the recovery of the soil, and plant morphological characteristics (color, 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, normal and bad – according to an analysis of the field measurements having a direct influence on the quantitative results (production of fresh matter). Table 2 shows the results of this grading for each experimental site organized by commune, then by district and finally by province. Forage development extrapolations from each specific site to the commune or district as a whole must be avoided because additional representative data is needed. As stated before, soil characteristics and eventually some climatic conditions can differ significantly within the same province and district. In addition, the experimental site selection might not correspond to the more representative soil conditions of each region.

Table 2. Forage adaptation to the agro-climatic conditions of the experimental sites during winter (November – March)

Province	District	Commune	AVEX	Medicago Sativa	Australian Mix	Penisetum purp., Panicum max. or Brachiaria briz.
Bac Ninh	Tien Du	Canh Hung[a]	**good**	normal	Bad	normal
		Canh Hung[b]	*normal* [§]	Bad	normal	normal
	Tu Son	Tan Hong [£]	-	-	-	-
Ha Nam	Kim Bang	Kha Phong	**good**	**good**	normal	normal
		Ba Sao	normal	Bad	normal	bad
	Duy Tien	Moc Bac	bad	Bad	bad	bad
		Chuyen Ngoai	**good**	**good**	normal	normal
Ha Noi	Dong Anh	Vinh Ngoc [a]	normal	Bad	normal	normal
		Vinh Ngoc [b]	normal	Bad	bad	bad
	Soc Son	Dong Xuan	normal	Bad	bad	bad
	Tu Liem	Cau Dien	*normal* [§]	Bad	bad	bad
Ha Tay	My Duc	Dong Tam	bad	Bad	bad	bad
	Ung Hoa	Phu Luu [¥]	*normal*	*Bad*	*bad*	*normal*
		Van Thai	normal	Bad	bad	normal
	Thanh Oai	Thanh Mai	**good**	Bad	bad	normal
Vinh Phuc	Yen Lac	Dai Tu	*normal* [§]	**good**	bad	bad
		Trung Nguyen	**good**	**good**	normal	normal
	Lap Thach	Bac Binh	bad	Bad	bad	bad
	Vinh Tuong	Tu Trung	**good**	Bad	normal	**good**

[§] Floristic composition modified by the responsible of the site (involuntary weeding).

[£] Experimental site destroyed.

[¥] Forage seeds mixed during sowing (only a global evaluation is possible).

Table 2 reveals that the adaptation of the different species was most favorable in the sites situated in Kha Phong, Chuyen Ngoai and Trung Nguyen communes, particularly for Avex mix and Medicago sativa. In the sites located in Moc Bac, Dong Tam and Bac Binh communes, the various species had more difficulty in adapting to soil and climatic conditions. The reason for this typical variety of results is a set of factors such as chemical composition and structural characteristics of soils, small climatic differences (especially rainfall) and the technical forage management carried out by local staff. This last factor is very important. Some soil fertility deficiencies can be corrected through fertilization while rainfall deficiencies can be addressed through irrigation. The plants' adaptation to agro-climatic conditions depends on internal factors (genetics) of each forage species and on three external factors (soil, climate and management). Interpretation of results based on a single factor might not correspond to what really happens in the field. For example, the chemical quality of soils

(nitrogen level, exchangeable cations, etc) evaluated in Kha Phong site is quite lower than those analyzed in Moc Bac, Dong Tam and Bac Binh sites, but the forage species adaptation results were excellent in the first site and very weak in the last three sites.

In the following paragraph, some of the results already mentioned in the intermediate report are synthesized. These results concern the agro-climatic adaptation of the forage species and forage mix selected.

- **AVEX**

In Kha Phong and Chuyen Ngoai sites, the development of Avex mix (Ax) was very good. The general appearance of the plants demonstrates a perfect adaptation to local agro-climatic conditions. In addition, the mix showed an excellent composition in terms of floristic plants (grass and legumes species). In some cases, Avex was cut relatively late, which provoked a loss of the grass species *Avena strigosa* and a predominance of the other grass species (*Lolium westerwoldicum*) after cut. In Trung Nguyen site, the re-growth of *Lolium westerwoldicum* was extraordinary. In other cases, both grass species (*Avena strigosa* and *Lolium westerwoldicum*) “disappeared” because they were removed by the local staff responsible for managing the site, who thought they were weeds. In a few sites, the legumes species in Avex had almost completely disappeared after the second cut and only the grass species (mainly the *Lolium westerwoldicum*) continued to develop well.

In approximately 50% of the experimental sites, the adaptation of Avex mix was normal. However, in two sites, differences of growth between the several parcels were observed. The development of Avex was poor in only three experimental sites (15% of total). The lack of irrigation during the germination period and the structure of soils seem to be the reasons behind the observed result. 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 a deficit of water during that period.

Neither weed infestation nor diseases were observed in Avex parcels.

- **Medicago sativa**

In 70% of the experimental sites, there was a poor adaptation of *Medicago sativa* plants (MS) to the local agro-climatic conditions. The plants presented a very small size and in some cases an abnormal coloring of leafs (red and yellow color) that is a sign of deficit in nutrients. Although the experimental soils have neutral pH (even basic in some cases) which is adequate to legume species, the structure of soils (compact soils) and the absence of some micronutrients affected plant development negatively. In many sites, *Medicago* plants were never cut or cut with a long period interval that stopped the potential growth of these plants. This temperate legume needs to be cut frequently (at a 40 - 60 day's period) to continue its development. In Tu Trung site, the density of seeding used for the *Medicago* was very high, and plant development was interrupted by the absence of cut. In both Vinh Ngoc sites, the *Medicago* parcels were particularly infested with weeds and the development of the plants was mediocre. In several sites, the presence of insects was also observed.

The development of *Medicago* was good in only four experimental sites (20% of total). In these sites, the general appearance of the plants demonstrated a perfect adaptation to the local agro-climatic conditions. In Kha Phong, the best project site, the development and growth of *Medicago* was very good. In Dai Tu site, *Medicago* developed well, with a very significant growth after the first cut. The best results were obtained in neutral soils (pH 6.5) with high content of phosphorus (P_2O_5) and total potassium (K_2O).

- **Australian Mix**

During the winter period (from November to March), the adaptation of Australian mixture (AM) was poor for 60% of the experimental sites and normal for the remaining sites (40%). In some cases, the use of Australian mix was a complete failure because there was zero germination (Bac Binh site, for example). Apparently, this result can be partly explained by the use of one lot of poor-quality seed. Another explanation is related to climatic conditions, in particular low temperatures during winter, which are not conducive to the germination and growth of tropical species. However, in the majority of the experimental sites, although the winter development rate of the Australian mix was weak, further development of this mixture after the winter period (from March to June) was relatively good. In a few sites, the development of the Australian mix was only observed for the grass species.

- **Tropical species (*Pennisetum purp.*, *Panicum max.* or *Brachiaria briz.*)**

The tropical grass species were included in the experiments as suggested by the coordinator of the Vietnam Belgian project. The use of tropical species in the experiment served to compare the differences in winter growth between the two types of plants (temperate and tropical).

As expected, the tropical grass growth remained low during winter due to relatively low temperatures (lower than 20°C). For tropical plants, optimum energy efficiency is achieved when the temperature is between 30 to 35°C, and the zero vegetation temperature is around 15°C. In approximately 50% of the experimental sites, there was poor development of tropical grasses during winter, although the majority of plants survived. After this period, with the increase of temperatures and rainfall, the forage development was good and the plants adapted well to the local conditions. However, within several sites (Bac Binh and Vinh Ngoc, for example), tropical grasses showed differences in growth across parcels. These differences are related to problems during planting and the first months of forage development.

In only one site (Tu Trung), did the tropical grass *Pennisetum purpureum* develop and grow well during all winter period.

Overall, Avex was the forage mix best adapted to the winter conditions in the five provinces around Hanoi. Fresh matter yields (see below) were acceptable and the plants demonstrated normal to good development, indicating perfect adaptation to local agro-climatic conditions. Within the Avex mix, the grass *Avena strigosa* and the legume *Vicia villosa* were the two species with better development. In the case of the temperate legume *Medicago sativa*, poor adaptation results in the majority of experimental sites were due to germination problems and the absence of frequent cuts. Australian forage mix presented poor adaptation to the winter conditions in the five provinces around Hanoi. As expected, tropical grasses did not adapt to the winter period. The low temperatures affected significantly the normal development of tropical grasses.

4. Productivity of forage species and seed production

- **Productivity**

The production potential of a plant is directly related to its adaptation to soil characteristics and climatic conditions. Table 3 reveals the total (cumulative) quantity of fresh matter (biomass) harvested from January to mid of March (75 days). This period corresponds to the end of the winter when there is greater forage deficit in the provinces around Hanoi. The values are expressed in tons of fresh matter per hectare, corresponding to the yields taken at the time the cut took place. The person in charge of each experimental site was responsible for cutting the forage, weighting it using scales and writing the data in the respective booklet. Due to logistic difficulties, it was not possible to take samples of plants in order to evaluate the chemical composition and nutritive value of forage.

Table 3. Fresh matter yields of forage per experimental site from January 1st to March 15th (tons / ha)

Province	District	Commune	AVEX	Medicago Sativa	Australian Mix	Penisetum purp., Panicum max. or Brachiaria briz.
Bac Ninh	Tien Du	Canh Hung[a]	48	11	14	63 PP
		Canh Hung[b]	23	7	9	0 PP
	Tu Son	Tan Hong [£]	-	-	-	-
Ha Nam	Kim Bang	Kha Phong	100	22	65	63 PP
		Ba Sao	26	7	15	23 PM
	Duy Tien	Moc Bac	30	10	16	37 PP
		Chuyen Ngoai	81	31	37	45 PP
Ha Noi	Dong Anh	Vinh Ngoc [a]	38	4	5	11 PP
		Vinh Ngoc [b]	37	8	9	26 PP
	Soc Son	Dong Xuan	§	§	§	§
	Tu Liem	Cau Dien	§	§	§	§
Ha Tay	My Duc	Dong Tam	29	7	0	0 BRA
	Ung Hoa	Phu Luu [¥]	65	0	0	50 PP
		Van Thai	44	0	0	49 PP
	Thanh Oai	Thanh Mai	65	7	0	62 PP
Vinh Phuc	Yen Lac	Dai Tu	30	18	10	55 PP
		Trung Nguyen	53	10	27	20 PP
	Lap Thach	Bac Binh	11	4	0	0 PM
	Vinh Tuong	Tu Trung	45	4	59	47 PP

[§] Forage production data not yet received

As expected, the best fresh matter yields were observed in the experimental sites where the forage species and mix were better adapted to the local agro-climatic conditions

(Kha Phong, Chuyen Ngoai, Thanh Mai, Trung Nguyen sites). On average, fresh matter production during 2.5 month was 45 tons / ha for Avex mix, 9 tons / ha for *Medicago*, 17 tons / ha for Australian mix, 41 tons / ha for *Pennisetum purpureum* and 12 tons / ha for *Panicum maximum*. No biomass production was recorded for *Brachiaria brizantha* parcels during the measured period.

The temperate species of Avex mix produced the highest fresh matter yield in two successive cuts. The average output per hectare was comparable to the yields obtained in Europe, which range from 30 to 60 tons of fresh matter / ha due to the quality of the soil and the climate. Excellent forage yields were obtained in some sites, including Kha Phong, Chuyen Ngoai, Phu Luu and Thanh Mai. Fresh matter yields, for the legume *Medicago sativa* were lower than those of grass species because these are two different types of plant which, ultimately, have different functions as animal feed. In fact, *Medicago sativa* should be regarded as complementary to the basic forage ration. *Medicago* merits special attention due to its high protein and energy content.

The fresh matter yields of Australian mix were low and corresponded mainly to the cut made at the end of the winter period (March). In 30% of the experimental sites, the Australian mix was not able to produce during the winter period.

Although Avex mix and *Pennisetum purpureum* present similar cumulative biomass yields (45 and 41 tons / ha, respectively) at the end of the measured period, the tropical grass production is practically nil during the winter period, starting to show significant growth at the end of February / beginning of March. The output of the tropical species was significant during this period because of their higher temperatures requirements. However, not only the quantitative data (biomass) of these forages should be compared. The qualitative differences between temperate and tropical forage species, measured by their chemical composition and nutritive value, are important aspects and should also be taken into account. Tropical species has a lower energy and protein content and higher amount of raw cellulose compared to the temperate species. In Avex mix, one ton of fresh matter corresponds on average to 160 kg of dry matter, with 23 kg of protein digestible in the ruminant intestine (PDI), 128 units of energy (UFL) and 41 kg of crude cellulose. The same quantity (one ton) of *Pennisetum purpureum* harvested in April, after 45 days re-growth, contains 138 kg of dry matter, with 15 kg of protein digestible in the ruminant intestine, 97 units of energy and 48 kg of crude cellulose.

The cattle density per surface unit with Avex forage varies according to several parameters, including forage production yield, body weight of animals, lactation state, and the Avex percentage in the basic ration as determined by farmers. If we consider a crossbreed dairy cow with 450 kg of body weight on the fourth month of lactation, the Avex

intake will be around 50 kg of fresh matter per day, supplemented with 2 kg of molasses (cheap source of energy)[4]. The average production of Avex mix recorded in the five provinces around Hanoi (45 tons) allows 12 cows / ha (or 1 cow / 2.5 sao) to be fed correctly during the winter period (from January to March).

- **Seed production**

A further important aspect of good species adaptation, in addition to the production characteristics 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.

In our experiments, due to communication problems between the research 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 data. On certain parcels, seeds were not collected at all because the production was very low, while at other parcels seeds were collected too late, the plants having become flattened and many of the seeds having fallen on the ground. In addition, certain types of seeds were not collected because they are more difficult to harvest. This was the case for the species *Vicia villosa* and *Lolium westerwoldicum* (in Avex) and *Medicago sativa*.

In terms of forage intensification, the seed production activity might cause some difficulties in terms of area availability. The farmers do not have enough land to produce forage and so they cannot allocate part of it for seed production. Moreover, seeds produced by farmers have a lower quality (percentage of hard seeds, decrease of germination power, etc.). Therefore, local seed production and other seed supply options should be discussed with farmers. The import of high quality seeds may represent a good solution in the short to medium term.

5. Training activities and technology transfer

Farmers' limited access to appropriate technologies and improved knowledge is a major constraint to the development of forage and consequently cattle production. Training activities and field research are essential to improve the knowledge of farmers regarding use of fodder species. Transfer of technology and the dissemination of information are necessary to create awareness amongst extension staff about forage technology and animal feeding management.

[4] Milk production of 6 litres / day assured by the forage ration

The information (data) used in the present report and the general comments about the development of fodder species are based on the exchange of information between the research team and the local staff responsible for each site.

At the beginning of the experiments (October 2005), one preliminary training session was organized to explain the establishment of the experimental sites and to distribute the relevant material to the local staff responsible for each experimental site. A second training session was organized in the field approximately 2 months later to show to the local staff how to manage the forage, control the weeds, and apply fertilizer. The first growth results were also discussed during this session. Finally, a third meeting was organized in June 2006 to present the final experimental results and the main conclusions of the first year experiment and to set up the plan for the next season of temperate forage extension. Due to logistic difficulties and animal health problems (outbreaks of foot-and-mouth disease), it was not possible to organize a training session specially dedicated to feeding systems management and to undertake a joint field visit to a dairy cattle farm.

IV. Conclusion and perspectives

The main results observed in the experiment on temperate and tropical fodder species around Hanoi reveals certain heterogeneity of results. This situation was expected and considered normal due to the variability of soils characteristics among sites as well as differences in the management of forage experiments by local staff. There were also differences in the performance of the species or forage mixtures used in the experiment. Globally, the combination of temperate grass and legumes named Avex showed the best adaptation characteristics to local conditions as well as the highest production, with an average fresh matter yield of 45 tons / ha. Avex offers promising opportunities to address the forage deficit during winter in the provinces around Hanoi. Despite having lower growth potential (9 tons / ha) and higher demands in terms of soil quality, the temperate legume *Medicago sativa* might be an interesting complement to grasses during this period of the year.

The mixture of tropical grass and legume called Australian Mix was not able to produce enough quantity (and quality) of biomass during winter. Compared to temperate species, the lower development of the tropical grass species (*Pennisetum purpureum*, *Panicum maximum* and *Brachiaria brizantha*) is linked to low temperatures.

The results with temperate forage are encouraging, but in order to confirm the performance of selected species during winter, we propose to keep the experimental sites for a second year. In addition, we suggest continuing the experimental tests in larger areas (on-farm tests) to validate the results in real conditions, and to evaluate the economic impact of temperate forage in the existing dairy cattle system.

Concerning seed supply, the import of temperate forage seeds seems to be an interesting option over the short and medium term, before a national system of seed production can be implemented. This system would allow farmers to obtain high quality seeds at a lower price than the imported seed. Research on seed production should continue in the next few years with a view to develop an adequate technical protocol.

.

Acknowledgements

We would like to thank those in each experimental site responsible for following-up the forage tests, without whom this study could not have been undertaken. We thank the district and province authorities for their hospitality and for having facilitated the experiments.

We also thank the Vietnam Belgium Dairy Project, which funded the tests, and in particular Mr. Raf Somers, Ngo Tien Dung and Vien, for their essential support.

Appendix 1. Cultural dates in the experimental sites

Province	District	Commune	Sowing date	Specie or mix	First cut	days	Second cut	days	Third cut	days
Bac Ninh	Tu Son	Tan Hong	*							
	Tien Du	Canh Hung [a]	28 Oct.	MS	20 Feb.	**115**	3 Apr.	**42**	18 May	**45**
				AVEX	14 Jan.	**78**	8 Mar.	**53**	16 Apr.	**39**
				AM	10 Feb.	**105**	10 Apr.	**59**	23 Apr.	**13**
				PP	20 Feb.	**115**	24 Apr.	**63**		
		Canh Hung [b]	16 Nov.	MS	15 Mar.	**119**	27 Apr.	**43**	20 May	**23**
				AVEX	24 Feb.	**100**	6 Apr.	**41**		
				AM	15 Mar.	**119**	24 Apr.	**40**	24 May	**30**
				PP						
Ha Nam	Kim Bang	Kha Phong	31 Oct.	MS	9 Feb.	**101**	14 Mar.	**33**	10 Apr.	**27**
				AVEX	19 Jan.	**80**	28 Mar.	**68**	12 Apr.	**15**
				AM	19 Jan.	**80**	28 Feb.	**40**	10 Apr.	**41**
				PP	9 Feb.	**101**	28 Mar.	**47**		
		Ba Sao	1 Nov.	MS	10 Feb.	**101**	10 Apr.	**59**		
				AVEX	20 Jan.	**80**	26 Mar.	**65**		
				AM	10 Feb.	**101**	10 Apr.	**59**		
				PM	10 Feb.	**101**	10 Apr.	**59**		
	Duy Tien	Moc Bac	29 Oct.	MS	9 Feb.	**103**	**			
				AVEX	14 Jan.	**77**	31 Mar.	**76**		
				AM	**		**			
				PP	**		**			
		Chuyen Ngoai	29 Oct.	MS	9 Feb.	**103**	8 Mar.	**27**		
				AVEX	14 Jan.	**77**	**			
				AM	**		8 Mar.			
				PP	**		8 Mar.			
Ha Noi	Dong Anh	Vinh Ngoc [a]	28 Oct.	MS	**					
				AVEX	14 Jan.	**78**	13 Mar.	**58**		
				AM	**					
				PP	**					
		Vinh Ngoc [b]	29 Oct.	MS	8 Mar.	**130**	13 Apr.	**46**		
				AVEX	13 Jan.	**76**	5 Mar.	**51**	13 Apr.	**39**
				AM	8 Mar.	**130**	13 Apr.	**46**		
				PP	8 Mar.	**130**	13 Apr.	**46**		
	Soc Son	Dong Xuan	*							
	Tu Liem	Cau Dien	‡							

* Information not available

‡ Information not yet received

** Information not recorded

Province	District	Commune	Sowing date	Specie or mix	First cut	days	Second cut	days	Third cut	days
Ha Tay	My Duc	Dong Tam	28 Oct.	MS	28 Mar.	**150**				
				AVEX	16 Jan.	**80**	8 Mar.	**51**		
				AM						
				Bra	28 Mar.	**150**				
	Ung Hoa	Phu Luu	7 Nov.	MS						
				AVEX	24 Jan.	**78**	4 Mar.	**39**	4 Apr.	**31**
				AM						
				PP	18 Feb.	**103**	8 Apr.	**49**		
		Van Thai	28 Oct.	MS						
				AVEX	14 Jan.	**78**	24 Feb.	**41**		
				AM						
				PP	18 Feb.	**113**	8 Apr.	**49**		
	Thanh Oai	Thanh Mai	15 Nov.	MS	28 Mar.	**135**	14 Apr.	**17**		
				AVEX	28 Jan.	**74**	14 Mar.	**45**		
				AM						
				PP	14 Mar.	**121**				
Vinh Phuc	Yen Lac	Dai Tu	29 Oct.	MS	29 Jan.	**92**	10 Mar.	**40**	29 Apr.	**50**
				AVEX	22 Jan.	**85**	10 Mar.	**47**	25 Apr.	**46**
				AM	18 Feb.	**112**	30 Mar.	**40**	5 May	**36**
				PP	2 Mar.	**124**	30 Apr.	**59**		
		Trung Nguyen	31 Oct.	MS	22 Jan.	**83**	9 Mar.	**46**	25 Apr.	**47**
				AVEX	22 Jan.	**83**	9 Mar.	**46**	25 Apr.	**47**
				AM	18 Feb.	**110**	30 Mar.	**40**	6 May	**36**
				PP	28 Feb.	**120**	19 Apr.	**50**		
	Lap Thach	Bac Binh	5 Nov.	MS	20 Feb.	**107**				
				AVEX	25 Jan.	**81**	6 Apr.	**71**		
				AM						
				PM	27 Mar.	**142**	30 Apr.	**34**		
	Vinh Tuong	Tu Trung	29 Oct.	MS	6 Feb.	**100**				
				AVEX	21 Jan.	**85**	22 Mar.	**60**		
				AM	27 Feb.	**121**	23 Mar.	**24**		
				PP	27 Feb.	**121**				

* Information not available

‡ Information not yet received

** Information not recorded