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Fertilization improves the production of natural wet grasslands in the oriental High Atlas mountains of Morocco: the case of *Imilchil* region

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Abstract. The oriental High Atlas mountains in southeast of Morocco are characterized by small areas of natural wet grasslands called *Almo*. These are well managed by the local population in order to feed cattle and mullets. Under the framework of a research and development project, a trial was implemented in order to assess the effects of nitrogen fertilization on the phytomass production of the natural wet grasslands of *Tissila* (6.5 Ha) in the *Imilchil* region. The experimental design consisted in dividing the grassland into three plots: a "control" plot (P1, without fertilisation) and two experimental plots which received two different doses of nitrogen split in three applications during the year. The first plot (P2) received a cumulated amount of 134 kg N/ha plus 46 Kg P2O5/ha in two applications; the second plot (P3) received a cumulated amount of 67 kg N/ha plus 46 Kg P2O5/ha, applied similarly to P2. The phytomass production doubled with fertilization, even at the lowest dose (P3). The assessment of flora revealed a great specific richness (79 species) and some endemism which should be preserved.

Keywords. Grassland – Meadow – Fertilization – High Atlas – Floristic diversity.

***La fertilisation augmente la production des prairies humides dans les montagnes orientales du Haut-Atlas : cas de la region d'*Imilchil**

Résumé. *Les montagnes orientales du Haut Atlas au sud-est du Maroc sont caractérisées par de petites parcelles de prairies humides naturelles appelées* "Almo". *Celles-ci sont bien gérées par la population locale et destinées à nourrir les bovins et les mulets. Dans le cadre d'un projet de recherche/développement, un essai a été réalisé afin d'évaluer les effets de la fertilisation azotée sur la production de la prairie de* Tissila *(6,5 Ha) dans la région d'*Imilchil. *Le plan expérimental consistait à diviser la prairie en trois parcelles : une parcelle laissée comme témoin (P1) et deux autres recevant deux doses d'azote pendant trois périodes de l'année. L'une (P2) recevait un total de 134 kg N / ha en trois applications (sulfate d'ammonium en octobre + urée en avril et mai) plus 46 kg de P2O5 / ha en deux applications (superphosphate triple en avril et mai); l'autre (P3) recevait un total de 67 kg N / ha plus 46 kg P2O5 / ha, dans les mêmes conditions d'application que P2. La production de pyhtomasse a doublé sous l'effet de la fertilisation, même à faible dose (P3). L'évaluation de la flore a révélé une grande richesse spécifique (79 espèces) et des espèces endémiques qui méritent d'être sauvegardées.*

Mots-clés. *Prairie – Fertilisation – Haut Atlas – Diversité floristique.*

I – Introduction

Agdals in *Tachelhit* language (Berber) means a collective pastureland whose opening and closing are operated at fixed dates by the community of users (Bourbouze, 1997; Auclair & Alifriqui, 2005). *Almou* (or *Ilmouten* – plural) is a special form of *Agadal* that consists of mountain meadow, an increasingly rare habitat. *Almous* are an open habitat natural vegetation composed by non-woody plants (herbaceous, perennial or annual species) from different plant families mainly grasses and legumes (Bourbouze, 1997). They are grazed by cattle and mules ("*tiwili*" system), rarely by small ruminants. In our study site, *Tissila Almou* is managed by one tribe of the village (lineage status) and based on traditional laws implemented by the local population (users).

The vulnerability of these wet grasslands requires the implementation of adaptive strategies for their preservation and the restoration of their ecological balance. As a result, grassland fertilization trials were carried out within the framework of an agreement of a PDRME (Rural Development Project of Mountain Areas of Errachidia Province)project between the Regional Office for Agricultural Development of Tafilalet (ORMVA-TF) and the National Institute for Agronomic Research (INRA).

Many studies have shown that a correct mineral fertilization plays a positive role in the production and quality of pastoral and forage species (Delaby 2000, Leconte 2002, Durant & Kernéïs 2015).The aim of the study was to demonstrate to the local population how to increase productivity and quality of meadows by a reasoned fertilization and to deal with the alarming situation of the cultivation of highland grasslands and the abandonment of their traditional management system.

II – Materials and methods

The study took place in the mountain area of *Imilchil* (32°06 N; 005°33W, 2213 m a.s.l.). This area is part of a strategic ecological situation of the Eastern High Atlas characterized by water sharing in four watersheds: *Um-Errabia, Ziz, Moulouya* and *Gheris*. The area is characterized by a semi-arid bioclimate with cold winters and snowfall. The average rainfall is 317 mm at *Ilmilchil*. The average minimum temperature is -5.1 ° C, the average maximum temperature 32.4 ° C and the average annual temperature 11.0 °C.

The *Tissila* wet grassland extends over 6 ha; for the purpose of this study, it was divided into 3 plots: P1 (unfertilized control), P2 (high fertilisation), P3 (moderate fertilisation) (Table 1). The spreading of fertilizers was done manually.

Table 1. Quantities and dates of fertilizer application (kg/ha) in Year 1. In Year 2 rates were halved

Plots	Date of spreading	Ammonium sulphate *	Urea**	TSP***
P1	Beginning of October	0	0	0
	Beginning of April	0	0	0
	End of May	0	0	0
P2	Beginning of October	100	0	0
	Beginning of April	100	100	50
	End of May	0	100	50
P3	Beginning of October	50	0	0
	Beginning of April	50	50	50
	End of May	0	50	50

* $(NH_4)_2SO_4$; ** CH_4N_2O : Urea; *** $Ca(H_2PO_4)$ $2.H_2O$: Triple superphosphate (TSP).

Trials were carried out in 2011/2012 and 2012/2013. The plots were monitored for two years, but during the second year, only half of the fertilizers doses were applied.

Soil samples were analysed in terms of water, organic matter (OM), mineral content and pH.

Phytomass was estimated on 40 quadrats of 1m² using the method of the Reference Unit (UR), which consists in choosing a typical grass bouquet from the plots to be sampled (we took 1/8 of each 1m² quadrat). The samples were dried at 65 ° C for 72 hours then weighed to obtain their dry matter (DM).

A qualitative and quantitative inventory of botanical composition, following the Braun-Blanquet (1932) method, was performed on aligned quadrats points of 1 m x1 m along the diagonal of each plot. The parameters calculated from the linear survey in each quadrat were:

- Overall vegetation cover (**RGV**) expressed as a percentage: **RGV (%) = 100 x Ni /N**; Ni: Number of points with vegetation cover and N: Total number of points / quadrat;
- Specific frequency (**FSi**) for each species i: **FSi (%) = 100 x ni/N**; ni = Number of points where species i is encountered and
- Specific contribution (CSi): **Csi (%) = 100 x ni/ NI**;
- Σni = Number of points where vegetation came across = Ni.

The second step was to calculate floristic diversity indexes. The **Shannon-Weaver Index** (Shannon & Weaver, 1949) is the simplest in $H' = -\sum_{i=1}^{n} p_i \log_2 p_i$ its category and, therefore, the most widely used, with S = total number of species; pi = (nj/N), relative frequency of species; nj = relative frequency of species j in the sampling unit; N = sum of specific relative frequencies. The higher the value of H', the greater the diversity.

The measure **of evenness** (or uniformity) (E) is useful for detecting changes in the structure of a community and has sometimes proven effectiveness in detecting changes of anthropogenic origin: **$E = H'/\log_2 S$.** When all species are equally abundant, an evenness index would be at a maximum and decrease towards zero as the relative abundances of the species diverge away from evenness.

The dominance indices, using Simpson's index $D = \sum_{i=1}^{n} p_i^2$ as a most widely used index (Simpson, 1949): Specific diversity is highest when Simpson's index is lowest.

The data collected were subjected to statistical analyses under Excel and SPPS. As a rule, at least 10 measurements were used to obtain an average for each parameter.

III – Results and discussion

1. Soil analyses

Based on the soil analyzes presented in Table 2, there was little physical and chemical variability among the *Tissila* plots. The soils had two different textures. Organic matter richness and mineral content were also variable from one plot to another.

Table 2. Physical and chemical properties of the soils of the *Tissila* meadow plots

Plots	Particles % on the dry ground					Particle % on the mineral part				Texture
	%C	%FL	%CL	% FS	% CS	%Lim	%C	%L	% S	
P1 (T)	31.5	18.7	6.4	5.7	3.4	34.4	48.0	38.2	13.8	HC
P2 (200)	29.7	27.3	8.5	3.4	0.8	30.3	42.6	51.3	6.1	CL
P3 (100)	31.5	19.9	5.5	7.1	1.1	34.9	48.4	39.0	12.6	HC
	Depth (cm)		pH (eau)		pH (KCl 1 N)	OM (%)		P_2O_5 (ppm)		K_2O (ppm)
P1 (T)	0-35		7.9		7.5	1.6		35.1		134.9
P2 (200)	0-35		8.0		7.7	0.8		19.4		64.0
P3 (100)	0-35		7.6		7.1	3.1		36.3		112.7

C: Clay; FL: fine Loam; LG.: Coarse Loam; FS: fine sand ; CS: Coarse Sand; L: Loam; S: Sand; Ca: Limestone / Texture: OHC: Heavy clay, CL: Clay Loam. OM: Organic matter.

2. Floristic analysis

The presence of the meadow on the valley and the possibility of its irrigation make the natural vegetal very dense and diversified. Average overall aerial vegetation cover was between 90-100%. The plant facies was clearly dominated by graminaceous species. The dominant species in the floris-

tic composition was *Lolium multiflorum* (local name: *Agassisse*). Other dominant species were: *Eleocharis palustris* (l.) Roem. & Schult from the genus Eleocharis and *Alopecurus pratensis*. It should also be noted that P3 was dominated by *Lolium multiflorum* and co-dominated by *Ranunculus bulbosus* L.

The dominance of grasses does not seem to affect the botanical diversity of the grassland. Thus, many annual and perennial species go with dominant species especially on the borders. These species belong to 23 families, including Fabaceae, Poaceae and Plantaginaceae as predominating families. The grassland contains a very remarkable orophilic vegetation, rich in endemic species due to the local micro-climate and the geomorphology of the site. These plant formations based on hemichrophyres (49%) are characterized by a very high overall vegetation cover. In addition to the richness, the pastoral quality seemed good due to the presence of both grasses and legumes. Prospection and inspection of the site suggest that some species, such as plantain (*Plantago* sp.) mainly in the border, *Ononis spinosa* subsp. Antiquorum (L.), *Arcangeli* and *Cirsium pyrenaicum* (Jacq.) inside the meadow indicate an overexploitation. Also, the bad distribution of irrigation water and the dominance of *Ranunculus bulbosus* in some parts of the meadow (lower part: plot 2) indicate that the soil is poor and receives a contrasting water regime suffering from the summer drought.

The overall species richness of the meadow is 79 species recorded during the maximum vegetation (14 excluding borders) of the second year of monitoring (2013). The analysis of floristic diversity parameters (Fig. 1) indicates that the fertilized plots have a relatively higher floristic richness compared to the control. The Shannon and Weaver index varied in the plots between 3.1 to 3.4, showing that biodiversity in the meadow is relatively high with the co-dominance of several species (Simpson's dominance index tends to 0). The regularity indicated by the Pioucha J' evenness index (tends to 1) is rather good (numerical representation of the different taxa). However, longer term measurements are needed to assess the impact of fertilisation on the floristic composition of these grasslands.

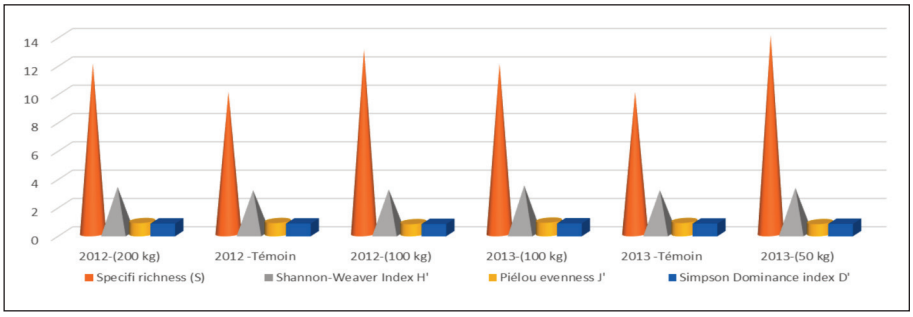

Fig. 1. Indexes of floristic diversity of the *Tissila* meadow according to fertilization doses and year of fertilizers spreading.

3. Production and feed availability of the meadow

The measurement of phytomass showed interesting results of the effect of fertilization on grassland production. In fact, the phytomass of the fertilized plot 3 doubled in terms of production compared to the control during the first year, whereas during the second year, the increase in plot 2 over the control is 33% only using the half of the dose (100 kg N / ha), (Fig. 2). The same result was obtained for plot 2 (34%) which received the rate of 100 kg N / ha in the first year.

Fertilization has certainly improved the productivity and vigour of the meadow, but the confounding effect of the heterogeneity of water irrigation and the variation of biodiversity lead suggest that a big amount of fertilizers is not necessary.

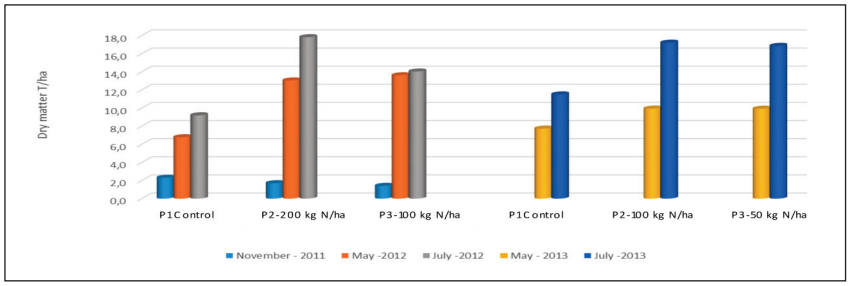

Fig. 2. Phytomass in the three tested plots according to doses and years of fertilizers spreading.

4. Available forage and economic study of meadow fertilization

According to the local knowledge of local population, almost all species are grazed by cattle and 80-95% of the production is consumed: plants height before pasture is about 80-150 cm while after pasture it is about 8-10 cm. This indicated at the species forming the meadow are very resistant to grazing. The economic net gain in production provided by the applied fertilization compared to the control plots is summarized in Table 4. For net gain (Dh/ha), we calculated for each parcel the production in kg, then the offered forage units (UF) according to the pastoral value of each parcel, then we subtract the average production for example of parcel 2 to the control; we assimilated 1 UF to 1 kg of barley to estimate prices.

According to Table 4, fertilization application is largely justified (despite the prices are increased) since the estimated minimum net gain is 18139 dh/ha for plot 3 compared to the control. A gain of four tons of production at the level of all the meadow was obtained which is enough to cover the highest charges of the applied fertilization.

Table 4. Estimation of the net gain of the fertilized meadow of *Tissila* compared to the control and according to the applied doses

	P2 (200)	P3 (100)	P2 (100)	P3 (50)
Net gain of *Tissila* meadow per hectare (Dh/ha)	31257	18139	22869	20355

IV – Conclusion

The study undertaken on Tissila Meadow highlighted a remarkable floristic diversity that deserves to be preserved. The results of targeted nitrogen fertilization showed a significant improvement in the productivity. The results show that the costs of fertilizers are largely offset by the improved production. However, an in-depth diagnosis of the meadow in a more comprehensive approach taking into account different aspects deserves to be done to remove constraints, ensure sustainability and optimize production through the adjustment of the animal stocking rate, control of soil fertility and the management of spatial heterogeneity.

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