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EFFECTS OF DEFOLIATION AND NITROGEN UPTAKE ON FORAGE NUTRITIVE VALUES OF *PENNISETUM* SP

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ABSTRACT

In semiarid regions, the increasing cost of imported forage is encouraging its replacement by on-farm produced fodder crops. The aim of this study was to characterize the nutritive values of maralfalfa grass (*Pennisetum* sp.) in function of different harvest frequencies under subsurface drip irrigation. During 2009 a maralfalfa grass experiment was conducted in a field of 8000 m^2 on allophanic soils in the island of Hierro (Canary Islands), under subtropical climate. In a randomized block design, one linear meter from three different rows was sampled of plants from 30 to 120 days. In a 50 m^2 subplot, biodegraded liquid pig manure was applied. Crude Protein (CP) in plants was determined with and without it. Another objective was to calculate N uptake which was added by manure and, the N depletion in soil in organic farming production. The results showed that the optimum age for harvesting was 55-60 days and also allowed to obtain relationships between CP and the age of the plant. Our results demonstrate that, in order to obtain high yields of maralfalfa by organic farming, the maximum animal residue use of 240 kg N ha^{-1} $year^{-1}$ recommended by the European Community Directive 91/676/EEC should be increased.

Key words: crude protein, drip irrigation, Maralfafa (*Pennisetum* sp), N uptake, N depletion, organic farming

INTRODUCTION

Animal feeding in arid and semiarid zones is largely dependent on forages for ruminants. In the Canary Islands, as in many other semiarid regions, scarcity of forages has limited the livestock development and approximately 2/3 of total forage consumed is imported. According to Canary Island Government (Plan Ganadero de Canarias, 2010), imported food represents 52% of the total production costs. In the case of El Hierro Island its dependency is 90% for goat, 10% for sheep (grazing still remains a primary source) and 40% for cow feeding (Fernandez, 2008). A large percentage of production costs depend on imported feed, representing economical and strategically problems for the farmer. Current research is directed towards the possibility of replacing the imported forage with on-farm produced feeds to cover the ruminant nutrient requirements. On the other hand, the program for sustainable development of El Hierro, involving all economic sectors, has been enforced since 1995, well before reaching the status of biosphere reserve in year 2000 (UNESCO, 2007). Thus, in this context, organic farming plays a fundamental role. Natural pastures are grazed in the high part of the island, where the rainfall and trade winds wet the soil. Instead, at the sea level there is not enough rainfall to produce animal feed, so irrigation is necessary. Marquez *et al.* (2007) demonstrated that maralfalfa grass (*Pennisetum sp*) is an alternative to increase forage availability for livestock due to its dry matter productivity and nutritive values. In this sense, maralfalfa grass was introduced in 2009 in El Hierro Island as a high yielding perennial fodder grass, to overcome part of this deficit for livestock feed. Also, a new drip irrigation system was installed. Yet, as occurred in other parts of the world with elephantgrass (*Pennisetum purpureum* Schum.), its success will depend upon the evolution of a comprehensive package of agro-technology compatible with the local agro-climatic conditions (Yasin *et al.*, 2003).

The bibliographic references about origin and classification are scarce and sometimes contradictory. Some authors referred to maralfalfa as *Pennisetum purpureum x Pennisetum glaucum* (Clavero and Razz, 2009) while others mentioned it as *Pennisetum spp* (Ramirez *et al.*, 2006; Sosa *et al.*, 2006), *Pennisetum hybridum* (Correa *et al.*, 2002), *Pennisetum* hybrids (Meissner, 1997) or as a specific genotype of *Pennisetum purpureum* (Marquez *et al.*, 2007). The taxonomic confusion originates on the different names assigned to *Pennisetum* genera and its different sp. and hybrids. *Pennisetum purpureum* Schum., Elephant grass, Napier grass or Mott grass (Sarwar *et al.*, 1999) is mentioned to hybridize with *P americanum* (L) Leeke, also designed as Bana grass (Zeven and Wet, 1982), King grass (Cook *et al.*, 2005).

The nutritional value of maralfalfa grass has been described by Clavero and Razz (2009), Macoon *et* *al.*, (2001), Correa (2006) and Marquez *et al.*, (2007). All authors agree in plant-age dependence of the nutritive values. However, there are discrepancies on the absolute values of the different nutrients, mainly total nitrogen (TN) or crude protein (CP). Probably these differences may be attributed to agro-ecological variations among local conditions, or to differences in fertilization and irrigation programmes applied, which are seldom reasonably described. A good exception was published by Rowena *et al.*, (2007). Also there is not enough information on the differences between leaf blade and leaf sheath composition of maralfalfa and its variations with age. This is a determinant factor to explain the total herbage yields (Macoon *et al.*, 2002) and probably, the nutritive value differences. Consequently, all of the nutritive values of maralfalfa must be established before its introduction for ruminant nutrition, especially when cultivated in volcanic soils. Moreover, as organic farming is the culturing method, the optimum levels of manure application must be determined. This work has the following objectives: (i) to characterize the nutritive composition of maralfalfa grass through different cut-off frequencies under drip irrigation in Canary Island conditions to obtain the optimum nutritive values and yield, (ii) to calculate N uptake which was added by manure and, the N depletion in soil in organic farming production, and (iii) to evaluate the rationality of the local irrigation practices.

MATERIALS AND METHODS

Experimental plot: During 2009 a maralfalfa grass experiment was conducted in a field of 8000 m^2 situated at sea level in El Hierro Island (Canary Island), 27°44′ N 18°03′ W. An automatic weather station was already set in the field in 1999. Rainfall was 157 mm during the experimental period and 218 mm during 2009, compared with the 10 year average of 271 mm. Mean of minimum temperatures (Tm) from May to November are presented in Table 1 and were always above 15ºC, cited as the lower temperature which produced little growth (Cook *et al.*, 2005). Absolute minimum temperatures (Tm abs) for the same period were always above 10 ºC, which is mentioned by the same authors as the growth ceasing temperature while the absolute lower temperature for a ten years period is 11.2 ºC. Data from a longer period were obtained from other non-automatic station situated in Orchilla.

The field soil is of recent volcanic origin and contains large amounts of amorphous materials. This soil was sampled at three different times (Table 2): the first one was at the beginning of the experiment (before manure, BF), the second one was after goat manure and gypsum amendment application (after manure, AF) and the last sampling was 7 months after the plant transplant (AT). The goat manure application consisted on 62500 kg ha^{-1}, adding approximately 250 kg N ha^{-1}. It is considered that the half of this quantity (125 kg N ha^{-1}) is available at the first year (MARM, 2010). Also, at this moment, 186 kg ha-1 of gypsum was applied, trying to ensure the soil structural stability. The criteria required for andic properties both in the Soil Taxonomy (Soil Survey Staff, 1999) and in the WRB World Soil Resources (IUSS Working Group, 2006) are fulfilled for the Al and Fe extracted by ammonium oxalate: the values for (Al_o+ $1/2Fe_o$) were always greater than 5%. However, as a consequence of continuous cropping of the field, soil bulk density and phosphate retention have been reduced to values slightly lower than those required for andic properties, especially in surface layers.

In a subplot of 50 m^2, besides the goat manure application, a biodegraded liquid pig manure of 5000L was applied in October 2009. This application added approximately 0.12 kg N m^{-2} (MARM, 2010), equivalent to 1185 kg N ha^{-1}. No liquid manure was applied in the rest of the experimental area of 8000 m^2.

Maralfalfa was planted in the whole field on 4th of May 2009; rows were 0.75 m apart, with plants 0.30 m apart within each row.

Forage characterization: One linear meter from three different rows was sampled from the experimental field, of each age of plant considered (120, 30, 50, 60, 70, 86 and 90 days), in order to characterize the nutritive value of maralfalfa grass by plant age and soil depletion by time (Table 3). The first cut off was 120 days after the transplant and the whole field of 8000 m^2 was harvested. Then, for a second harvest, the plot was divided in six parts, those were cut after 30, 50, 60, 70, 86 and 90 days of regrowth. A third cut of plants aged 40 and 56 days was collected in lines that had been cut in the second harvest after 30 days.

This study quantified in all the maralfalfa samples: contents of Neutral Detergent Fiber, NDF; Neutral Detergent Fiber not assayed with a heat stable amylase and expressed exclusive of residual ash, NDFom; and Acid Detergent Fiber, ADF, (Van Soest *et al.*, 1991). N was determined by dry combustion in LECO CNS 2000 and the percentage of dry matter, DM, in an oven at 60ºC to constant weight. The crude protein, CP, in plant tissue was calculated as 6.25 times N.

Separated nutritive values from leaf and sheath of maralfalfa grass from samples 70 and 86 (second harvest) and 40 and 56 (third harvest) were also determined.

The study also compared the CP for the same age of harvest and at the same date (90 days after the first harvest) with the biodegraded liquid pig manure application described above (sampled in the 50 m^2 subplot) and without it (sampled in the rest of the field).

Irrigation system: Ground water was applied by a new drip irrigation system with integral drippers spaced 0.3 m with delivery rates at 8 l hour^{-1}, being an abnormal large flow for drip irrigation. The lateral lines were spaced to 0.75 m. Irrigation was provided during 2 hours and approximately 3 times per week, according to the water management practices applied by the local farmers who are used to lower flow rates. The weather station information was not used for irrigation in this experiment.

Soil Analysis: Organic carbon, OC, and nitrogen, N, were determined by dry combustion with a LECO CNS 2000 analyzer. Soluble salts were estimated by the electrical conductivity, EC of the 1:5 (soil to water ratio). Available nitrate and sulphate were also determined by extraction with 0.01M calcium chloride. Nitrate and sulphate were analyzed by ionic chromatography. Available soil phosphorus, P, was determined according to Olsen and Sommers (1982). Exchangeable cations were extracted with buffered ammonium acetate at pH 7. The extracted cations, K, Ca, Mg and Na were analyzed by ICP.

Statistical analysis: Analyses of variance (ANOVA) were carried out using statistical Packaged SPSS (version 17) by the Generalized Linear Model procedures for nutritive values of maralfalfa. The model includes the effect of age of cutting, harvest and their interactions and also the effect of leaf and sheath separately considered. Mean separation was tested using the least significant difference (LSD), considering P= 0.05

RESULTS

Table 4 presents the CP, NDF, NDFom and ADF contents of different defoliation periods of maralfalfa grass for the whole plant on the dry matter content. The values are ordered according to the age of the plant and the harvest number in order to evaluate the effect of both the age of the plant and soil N depletion. As expected, CP diminished as the plant grew old. However, it is necessary to take into account another factor than the age of the plant to explain the observed trend: the harvest number, because plants from harvest 2 had significantly higher values than harvest 3 ones. Significantly lower CP values in harvest 3 was caused by the N depleting of the soil reserves which proceeded mainly from the first application of solid goat manure. In Table 2, seven months after transplant (AT), it can be observed lower nitrate and N contents in soil. Thus, the older leaves from the 2nd harvest had higher CP values than the younger leaves from the 3rd harvest, which demonstrated N deficiency as a result of plant extractions. In fact, the data showed statistical differences when comparing the CP for the same age of harvest (90 days after the first harvest) in the subplot of 50 m^2 in which the pig manure was added: 9.51 ± 0.54 %, with the rest of the field (without pig manure application): 4.44 ± 1.05%.

On the contrary, NDF and ADF increased slightly as the plant grew older with time but did not show the mentioned harvest influence. Some results showed some outliers, probably due to sampling problems.

Leaf and sheath nutritive values of maralfalfa grass from the samples: 70 and 86 (second harvest) and 40 and 56 (third harvest) are presented in table 5. Leaf values of CP both for the second and the third harvest were significantly higher than sheaths. As observed, there were no differences among the sheath values between the second and the third harvest.

Table 1. Climatic characterization during the experimental period and for ten years average. t: temperature (ºC), TM: Mean of Maxima temperature, Tm: Mean of minimum temperature, TM Abs: Absolute Maxima temperature for the period studied, Tm Abs: Absolute minimum temperature for the period studied, H: Humidity (%), HM: Mean of Maxima humidity, Hm: Mean of minimum humidity, Pi: Monthly precipitation (mm), rad: mean monthly radiation (MJ/m2), ETPM: evapotranspiration (mm) using Penmann-Montheith method.

	t	TM	Tm	TM abs	Tm abs	H	HM	Hm	Pi	rad	ETPM
May 09	19.4	22.3	16.5	23.5	14.6	65.5	74.7	54.1	0.4	25.4	144.1
June 09	21.6	24.6	18.3	26.2	16.4	69.4	77.6	58.7	6.0	26.4	148.4
July 09	24.0	27.4	20.8	30.3	19.3	67.5	77.7	55.5	0.0	28.5	176.0
August 09	24.1	27.3	21.3	31.4	19.6	64.8	74.1	53.0	0.0	24.0	157.3
September 09	23.3	26.7	20.3	28.5	18.4	67.7	77.5	56.0	15.8	19.8	118.5
October 09	23.1	26.8	20.0	29.1	18.4	68.8	78.1	56.8	3.6	18.9	107.3
November 09	20.9	24.6	17.8	27.0	14.5	65.7	76.9	51.4	45.2	14.1	88.1
10 years avg	20.6	30.6*	11.9**	36.94	10.36	65.2	88.6	30.8	270.9	18.5	1410
50 years avg	20.9	29.1*	13.4**	42	8.6	***	***	***	***	***	***

*) Mean of Maxima temperature in month having highest mean **) Mean of minimum temperature in month having lowest mean

***) No available data

Table 2. Soil characterization, pH, electrical conductivity, EC 1:5 (dS/m); Carbon, C (%); Total Nitrogen, N (%); Organic Matter, OM (%); Carbon/Nitrogen ratio C/N (%); Nitrate, $N0_3^-$(mgkg^{-1}); Sulphate, $S0_4^{2-}$ (mgkg^{-1}); Olsen Phosphorus, P(mgkg^{-1}); Exchangeable Cations, (cmol$_c$.kg^{-1}): Potassium, K; Calcium, Ca; Magnesium, Mg and Sodium, Na, before (BM) and after manure and gypsum application (AM), before planting, and seven months after the plant transplant (AT).

Soil	pH	EC*)	N	O.M	C/N	$N0_3^-$	$S0_4^{2-}$	P	K	Ca	Mg	Na
BM	7.6	0.24	0.13	2.78	12.30	23.37	71.8	24.74	2.30	11.94	5.46	3.34
AM	7.2	2.07	0.26	4.97	11.28	119.53	3344.1	27.53	3.91	24.87	5.45	3.70
AT	7.5	0.82	0.23	4.03	10.17	3.0	nd	27.0	3.1	21.2	7.90	4.30

*)EC: electrical conductivity 1:5 (soil:water) nd: no determined

Table 3. Harvest number, plant age (in days of regrowth after harvest) and cut off dates.

Harvest	plant age and cut off dates					
1	120* days Sep 1					
2	30 days Sep30	50 days Oct19	60 days Oct 30	70 days Nov10	86 days Nov26	90** days Nov30
3	40 days Nov10	56 days Nov 26				

*) days after transplant **) the harvest corresponding to the pig manure application was performed on the 30th of November 2009 (90 days after the first harvest).

Table 4. Nutritive values of maralfalfa for the different days of regrowth are ordered according to the number of days of regrowth (day) and harvest in order to evaluate the effect of both the age of the plant and soil N depletion. Crude protein, CP (%), Neutral Detergent Fiber, NDF (%), Acid Detergent Fiber, ADF (%) and Neutral Detergent Fiber not assayed with a heat stable amylase and expressed exclusive of residual ash, NDFom (%), in % from the total dry matter, DM.

Date	day	CP by harvest			NDF by harvest			ADF by harvest			NDFom		
		1	2	3	1	2	3	1	2	3	1	2	3
Sep30	30		9.75^{e}			66.40^{ab}			44.25^{ab}			2.3^{ab}	
Nov10	40			4.41^{b}			68.17^{ab}			$45.51^{ab\gamma}$			2.45^{ab}
Nov19	50		7.15^{d}			65.08^{a}			52.35^{e}			3.90^{bc}	
Nov26	56			3.58^{a}			65.64^{a}			43.12^{a}			2.2^{ab}
Oct30	60		6.25^{γ}			70.06^{bc}			50.65^{de}			4.51^{cd}	
Nov10	70		3.85^{ab}			68.6^{ab}			48.17^{cd}			2.05^{a}	
Nov26	86		4.12^{ab}			67.93^{ab}			46.33^{bc}			2.14^{ab}	
Nov30	90		4.44^{b}			66.49^{ab}			43.89^{ab}			1.48^{a}	
			9.51^{e**}										
Sep01	120*	6.19^{c}			72.71^{c}			53.07^{e}			5.8^{d}		

*)days after transplant **)with pig manure application Numbers with the same superscript within a factor are not different ($p < 0.05$)

Table 5. Mean and standard deviation (SD) values of leaf and sheath of maralfalfa in second (70 and 86) and third harvest (40 and 56): Crude Protein, CP; Neutral Detergent Fiber, NDF; Neutral Detergent Fiber not assayed with a heat stable amylase and expressed exclusive of residual ash, NDFom, and Acid Detergent Fiber, ADF, in % from the total dry matter, DM.

		2nd harvest				3rd harvest			
		70		86		40		56	
		mean	sd	mean	sd	mean	sd	mean	sd
CP	leaf	$7.21^{\beta\gamma}$	0.28	8.57^{δ}	0.16	7.65^{γ}	0.42	6.63^{β}	0.19
	sheath	2.04^{α}	0.49	1.84^{α}	0.13	2.21^{α}	0.22	1.71^{α}	0.09
NDF	leaf	65.97^{α}	1.54	66.86^{α}	6.22	65.47^{α}	6.66	66.33^{α}	5.71
	sheath	70.02^{α}	0.58	68.49^{α}	1.61	70.01^{α}	1.69	65.22^{α}	0.69
NDFom	Leaf	4.19^{β}	1.30	4.43^{β}	0.26	4.35^{β}	3.37	4.04^{β}	0.39
	Sheath	0.89^{α}	0.14	0.96^{α}	0.05	1.15^{α}	0.24	1.07^{α}	0.07
ADF	Leaf	$44.79^{\beta\gamma}$	0.75	$44.39^{\alpha\beta}$	0.52	$44.31^{\alpha\beta}$	0.37	43.22^{α}	0.37
	Sheath	50.00^{δ}	0.48	47.33^{γ}	0.39	46.32^{γ}	0.80	43.06^{α}	0.67

Data with the same superscript within a factor are not different ($p < 0.05$)

Table 6. Nitrogen balance in soil and plant

	soil NO_3(mgkg^{-1})	soil Ntot (%)	N (kg ha^{-1}) (a)		Total availability from soil	
AM	119	0.26				
AT	3	0.23				
decrease	116	0.03				
equivalent N	24.72					
N (kg fha^{-1})	34.5	418.5	73			**526**
Plant		90 days (b)	90 days (c)	120 days	TN Plant (d)	**TN dP (e)**
CP (%)		9.5	4.44	6.19		
N (%)		1.52	0.71	0.99		
Yield (Mg DM/ha)*		20.75	20.75	38.4		
kg N ha^{-1} from plant extraction		315.4	147.3	380.2	695.6	**527.5**

* modified data from Vicente *et al.*, (1959) for the considered period (90 and 120 days)
AM: after manure AT: after transplant
(a) From manure, available for the first year (b) Theoretical with pig manure
(c) Experimental, showing N deficiency (d) Total N extraction by Plants (kg ha^{-1}), without limiting N (from Sep01-Nov30)
(e) Total N extraction by deficient Plants (kg ha^{-1}) from Sep01-Nov30

There were also significant differences in the contents of NDFom between leaf and sheath both from the second and third harvest. For NDF the data showed a tendency to have lower contents for leaf than for sheath. ADF values showed significant differences between leaf and sheath, and second and third harvest.

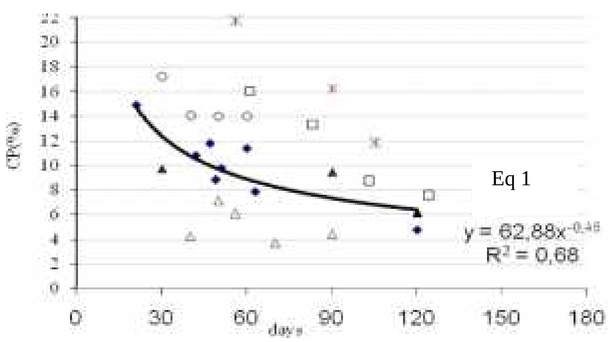

Figure 1. Variation of the percentage of CP versus the day of harvest. *Triangles:* data from this study. Also shown other results represented by *diamonds:* Carulla. (2004) and Clavero and Razz (2009), *stars*: Correa *et al*., (2006), *unfilled squares*: Vieira *et al*., (1997), and *unfilled circles:* Kozloski *et al*., (2003).

Equation 1: Fit of the data obtained by Carulla *et al*., (2004) and Clavero y Razz. (2009) along with the results from this study (filled triangles) but excluding those with N deficiency (unfilled triangles. since the 50 days of cut off).

DISCUSSION

According to the results obtained by Marquez *et al.,* (2007), Bayble *et al.,* (2007), Carulla *et al.,* (2004) and Clavero and Razz (2009), the CP content of maralfalfa decreased as the plant grew old. The same trend was pointed out by Van Soest (1994) for other tropical grasses. But, contrary to the results obtained by these authors, who reported that in Napier grass structural cell wall carbohydrates increased rapidly with maturity, our increment in NDF and ADF was slight and even showed no significant differences among some dates. The effect of days of harvesting on NDF content was also studied by other authors who mentioned a significant increase with maturity at cutting (Zinash *et al.,* 1995; Seyoum *et al.,* 1998; Tessema *et al.,* 2002; Adane, 2003). Therefore, our data suggested not to delay harvest beyond 50 days will result in higher nutritive values, which coincide with the results by Marquez *et al.,* (2007). On the other hand, Mushtaque *et al*., (2010) concluded that tiller per plant in tropical grass specie increased significantly from the youngest plants to the older ones. Besides, fresh herbage yield also increased with advancing plant maturity. According to our results, if the objective is to obtain the maximum dry matter yield, it is possible to harvest later (60 days instead of 50) without excessively affecting the nutritive values. Besides that, Wadi *et al.*, (2004) concluded that regrow tiller number was higher in the plants cut at a 60 day interval than at a 90 days interval.

Leaf CP values both for the second and the third harvest were higher than the sheath ones. Although Heredia *et al.,* (2007) and Yasin *et al.,* (2003) compared stems instead of sheaths (CP in stems are higher than in sheaths), they also found higher leaf values than for stems. Therefore, as the plant grew old the nutritive values decreased because the leaves/sheaths ratio decreased as well.

As mentioned above, the higher CP values found in the older leaves from the 2nd harvest compared with the younger leaves from the 3rd harvest, showed lower CP contents than mentioned by others authors (Carulla *et al.,* 2004; Marquez, 2007; Clavero and Razz, 2009 and Vieira *et al.,* 1997) due to deficient N supply. Moreover, the significantly higher CP contents for the same age of harvest (90 days) with and without biodegraded pig manure addition, demonstrated the plant N deficiency as a result of soil N depletion. In this sense, Correa *et al.*, (2006) suggested special caution in maralfalfa handling because it is extremely demanding in fertilization, and showed that the production of fresh matter was 3.6 times higher in the fertilized plots, applying 250 kg ha^{-1} cow manure, 100 kg ha^{-1} of 15-15-15 and 50 kg ha^{-1} of urea, and additionally 100 kg ha^{-1} of chicken manure every two cuts (equivalent to about 40 kg N ha^{-1}) than without fertilization. In an experimental plot different C4 grass species were compared, Arshadullah *et al.*, (2009) found an intermediate CP average (7.19%) in Elephan grass. The N status in soil was very low (0.04%) and therefore the fresh matter production was also lower than cited by other authors. Heredia *et al.*, (2007), found the highest percentage of CP obtained from those treatments receiving 60 kg N $ha^{-1}cut^{-1}$ and Sarwar *et al.*, (1999) obtained higher crude protein in the 60 days *Pennisetum purpureum* plants (10.8 against 7.1) when fertilized with 110.4 kg N ha^{-1}, comparing with no fertilized ones. In the same crop, Ishii *et al.*, (1999) obtained an N uptake value of 60 g m^{-2}. Also, Rowena *et al.*, (2007) mentioned 187% of N removal of *Pennisetum purpureum* (1190 kg N $ha^{-1}y^{-1}$) of the applied dairy effluent, using subsurface drip irrigation.

Figure 1 presents the CP content versus the day of harvest obtained in this study. Results from Carulla, (2004), Clavero and Razz (2009), Correa *et al.*, (2006), Vieira *et al.*, (1997) and Kozloski *et al.*, (2003) are also included. Excluding the data obtained by Correa *et al.*, (2006), Vieira *et a.l*, (1997) and Kozloski *et al.*, (2003) that showed higher values than the rest of the authors, possibly due to the high fertilization application, we adjusted an equation for low and intermediate CP values. Equation 1 ($y = 62.88\ x^{-0.48}$) included our data (excluding N deficient samples since the 50 day cut off), and the data from Carulla *et al.*, (2004) and Clavero and Razz (2009).

Kozloski *et al.*, (2005) also found that total N contents decreased quadratically from 30 to 70 days. Our results are presented by unfilled triangles, correspond to N deficiencies in soil, which decreased from initial 119 to 3 of $N0_3^-$ (mg Kg^{-1}), due to the high extractions induced by the high productivity of maralfalfa when cultivated without limiting factors (optimum temperature, radiation and supplied water). Using the predicted CP at 60 days and the expected yields we calculate an estimation of the N demand to apply a proper fertilization program avoiding N lixiviation. An estimated 34.57 kg N ha^{-1} is provided from the mentioned decrease of the content of nitrate in soil. Also, if considering the total N decrease in soil from 0.26 to 0.23 % (Table 2), a root depth of 0.15 m and a soil bulk density of 0.93 (Mg m^{-3}) as measured by Tejedor *et al.*, (2009), an additional quantity of 418.5 kg N ha^{-1} can be calculated. Adding these amounts to the aforementioned contribution of manure (73 kg N ha^{-1} in 7 months), an estimation of 526 kg N ha^{-1} from the soil would be available to plant (Table 6). This quantity coincides with experimental data extraction of 527.5 kg N ha^{-1} when considering plants of 120 days with 0.99 %N and N deficiency ones of 90 days (0.71 % N instead of theoretical 1.52 %N). Therefore, it was necessary to apply more biodegraded pig manure to ensure the soil fertility. Thus, equation 1 let us to calculate the expected CP for the age day of harvest. Using intermediate data from Vieira *et al.*, (1997), probably representing CP content when N is easily available (the paper only refers to data of the first cut off of maralfalfa and probably with fertilizer), showed clearly the high response of maralfalfa to N fertilization and also that the efficiency of N application diminished with plant age. In the same sense, Archontoulis *et al.*, (2011), created a model that was parameterized by analyzing the photosynthetic response to incident light intensity and the leaf N content. Their results demonstrated a notable increment in photosynthesis in response to the increment in leaf N content, especially for C4 gramineae, with a maximum for 1.8 g N/m^2 of plant. On the other hand, the results showed that if organic farming is used, one application of solid manure per year is not able to provide enough N to avoid deficit. In this case, and due to the difficulty of applying manure on the soil surface once maralfalfa is established under drip irrigation, liquid manure or dairy effluent could provide an alternative source of easily available N, as demonstrated by Rowena *et al.*, (2007).

The data presented in Table 4 for the whole plant for the second harvest, in which no significant differences were observed for NDF content (except for the 60 days harvest), are not coincident with those presented by Correa *et al.*, (2004), who indicated an increase in NDF contents with advance in the age of cutting.

Our forage production occurred under edafoclimatic optimum conditions for maralfalfa cultivation. Besides during the first period, drip irrigation and organic manure provided unlimited water and nutrients. Considering that the optimum temperature for tiller production and development ranges from 21 to 24ºC, and 25ºC for spikelet initiation and development (Cook *et al.*, 2005), the temperature data for El Hierro experimental field are very favorable (Table 1).

All of the authors coincide on the high productivity of maralfalfa. To our knowledge, the highest yields reported are 40, 50 and 84.8 t DM ha^{-1} $year^{-1}$ (Eriksen and Whitney, 1981; Rowena, 2007 and Vicente *et al.*, 1959 respectively). Márquez *et al.*, (2007) cited that maralfalfa grass can be harvested at 37.7 t DM ha^{-1} $year^{-1}$ with 359 cal $cm^{-2}day^{-1}$ (equivalent to 15.02 MJ m^{-2}) while radiation data at the experimental field in El Hierro was 19.35 MJ m^{-2}. Premaratne and Premalal (2006) recorded an average green fodder of 5 to 8 kg $plant^{-1}cut^{-1}$ or 250-350 Mg ha^{-1} $year^{-1}$ under local conditions;

although no specific climatic data were provided. Other authors, for example Macoon *et al.*, (2002), mention an interval of 4.7 to 11.7 Mg DM $ha^{-1}yr^{-1}$ depending on the hybrid considered, while Correa *et al.*, (2002) gives a yield of 50 t of green forage ha^{-1} when fertilized and harvested each 60 days.

The water applied in this experiment was higher than needed as estimated by ET. For instance, for the 60 days harvest, the water irrigated was 1777 l m^{-2}, 5 times higher than estimated by ET (271 l m^{-2}) and considering 1.2 as Kc value (as estimated for *P. purpureum*) or 3.3 times higher if considering Kc of 2.0 as by Rowena *et al.*, (2007). Thus, in our study the maralfafa crop was unlimited irrigated and also radiation was high, while the rest of authors did not comment on water supply. Rockström and Rouw (1997) indicated the synergistic effect of water and nutrients for *Pennisetum glaucum*, while Singh *et al.*, (2010) concluded that yields were more influenced by water application than the nitrogen doses. Surprisingly, Rowena *et al.*, (2007) did not found significant differences in dry matter production under subsurface drip irrigation when applied at 0.5 or 2.0 of ET crop coefficient. Yield data must be recorded to properly estimate annual yield under Canary Island conditions although preliminary results are very promising. On the other hand, the irrigation management described in this paper leads to excessive water dosage. Lack of expertise in drip irrigation by the farmers led them to use the same water management as if they had drippers with lower flow rates.

In order to guarantee enough N supply, and if a yield of 80 t DM ha^{-1} $year^{-1}$ is assumed, taking into account a CP of 8.87 %, (equivalent to 1.42 % of N), then 142 kg N $ha^{-1}cut^{-1}$ (every 60 days) has to compensate N extractions (1134 kg N $ha^{-1}year^{-1}$. In this sense, the second liquid manure application provided the total needs per year. Thus, only if a high source of N and at a low cost is available, the cultivation of maralfalfa using organic farming is feasible. At this point, taking into account the high demand of N of this crop, we must comment that if we want to have a high yield of maralfalfa in Canary Islands, the limitation of 240 kg N^{-1} $ha^{-1}year^{-1}$ imposed by the canarian government (PIRCAN, 1999, BOC, 2009) to transpose the European Community Directive 91/676/EEC, would have to be reviewed.

Conclusions: Nutritive values of maralfalfa (*Pennisetum sp*) were evaluated as total protein and fiber content. The nutritive values decreased as the age of harvest increased (being influenced by the decrease in the leaves/sheaths ratio), obtaining the optimum 55-60 day interval. CP contents were significantly lower for the same age of harvest with and without second biodegraded pig manure application, demonstrated the plant N deficiency as a result of plant extractions. This crop removed large amount of nutrients requiring a program of fertilization to ensure the yield without risk loss of soil fertility. Our results demonstrated that to cultivate maralfalfa by organic farming to obtain high yields in Canary Islands, the maximum residue use of 240 kg N $ha^{-1}year^{-1}$ imposed by the Canarian Government should be revised.

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REFERENCES

Kitaba, A. (2003). Effect of stage of growth and fertilizer application on dry matter yield and nutritive values of natural grassland in the highlands of North Shoa, Oromia Region. M. Sc. thesis. Alemaya University, Ethiopia.104.

Archontoulis, S. V., X. Yin, J. Vos, N. G. Danalatos and P. C. Struik (2011). Leaf photosynthesis and respiration of three bioenergy crops in relation to temperature and leaf nitrogen: how conserved are biochemical model parameters among crop species? J. Exp. Botany 63(2): 895-911.

Arshadullah, M., M. Anwar and A. Azim (2009). Evaluation of various exotic grasses in semi-arid conditions of Pabbi Hills, kharian range. The J. Anim. Plant Sci. 19(2): 85-89.

Bayble T, Melaku S and Prasad N K (2007). Effects of cutting dates on nutritive value of Napier (Pennisetum purpureum) grass planted sole and in association with Desmodium (Desmodium intortum) or Lablab (Lablab purpureus). Livestock Research for Rural Development. 19, Article 11. http://www.lrrd.org/lrrd 19/1/ bayb 19011. htm

BOC (2009). Programa de actuación para prevenir y reducir la contaminación causada por los nitratos de origen agrario. Boletín Oficial de Canarias, nº 99 (26):11129-11148.

Carulla, J. E., E. Cárdenas, N. Sánchez and C. Riveros (2004). Valor nutricional de los forrajes más usados en los sistemas de producción lechera especializada de la zona andina colombiana; En: Eventos y Asesorías Agropecuarias EU (editores), Seminario Nacional de Lechería Especializada: “Bases Nutricionales y su Impacto en la Productividad”. Medellín, septiembre 1 y 2: 21 – 38.

Clavero, T. and R. Razz (2009). Valor nutritivo del pasto maralfalfa (Pennisetum purpureum x Pennisetum glaucum) en condiciones de defoliación. Rev. Fac. Agron. 26(1):78-87.

Clayton, W. D. and S. A. Renvoize (1982). Gramineae. In R.M. Polhill. (Ed.). Flora of tropical East Africa, Part 3: 450-898. Rotterdam

Cook, B. G., B. C. Pengelly, S. D. Brown, J. L. Donnelly, D. A. Eagles, M. A. Franco, J. Hanson, B. F. Mullen, I. J. Partridge, M. Peters and R. Schultze-Kraft (2005). Tropical Forages: an interactive selection tool., [CD-ROM], CSIRO, DPIandF(Qld), CIAT and ILRI, Brisbane, Australia. pical East Africa. Part 3. Rotterdam. Correa, H. J., H. Arroyave, Y. Henao, A. Lopez and J. Cerón (2002). Maralfalfa. Mitos y realidades. Despertar lechero, 22 (1): 79-88.

Correa, H. J., J. M. Ceron, H. Arroyave, Y. Henao and A. López (2004). Pasto Maralfalfa: mitos y realidades. En: IV seminario internacional Competitividad en carne y leche. Cooperativa Colanta, Hotel Intercontinental de Medellín, Noviembre 10 y 11: 231 - 274.

Correa H J (2006). Calidad nutricional del pasto maralfalfa (*Pennisetum* sp) cosechado a dos edades de rebrote. Livestock Research for Rural Development. 18, Article 84. http://www.lrrd.org/lrrd18/6/corr18084.htm

Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources for the period 2004-2007.

Eriksen and Whitney (1981). Effects of light intensity on growth of some tropical forage species. I. Interaction of light intensity and nitrogen fertilizattion on six forage grasses. Agron. J. 73: 427-433.

Fernandez, E. (2008) Personal communication. Cooperativa SCL. Ganaderos el Hierro.

Heredia, N., and O. Paladines (2007). Respuesta del Pasto Maralfalfa (*Pennisetum violaceum*) a la Fertilización Nitrogenada con dos Distancias de Siembra Rumipamba XXI Nº 1.

Ishii, Y., A. A. Sunusi and K. Ito (1999). Effects of amount and interval of chemical fertilizer application on the nitrogen absorption and nitrate-nitrogen content in tillers of napiergrass (*Pennisetum purpureum* Schumach). Grassl. Sci., 45, 26–34.

IUSS Working Group WRB (2006). World reference base for soil resources 2006. 2nd edition. World Soil Resources Reports No. 103. FAO, Rome. ISBN 92-5-105511-4. http://www.fao.org/ag/agl/agll/wrb/doc/ wrb2006final.pdf; accessed January, 2011.

Kozloski, G. V., J. Perottoni, M. L. S. Ciocca, J. B. T. Rocha, A. G. Raiser and L. M. B. Sanchez (2003). Potential nutritional assessment of dwarf elephant grass (Pennisetum purpureum Schum. cv. Mott) by chemical composition, digestion and net portal flux of oxygen in cattle Anim. Feed Sci. Technol 104(1-4) 29-40.

Kozloski, G. V., J. Perottoni and L. M. B. Sanchez (2005). Influence of regrowth age on the nutritive value of dwarf elephant grass hay (Pennisetum purpureum Schum. cv. Mott) consumed by lambs. Anim. Feed Sci. Technol 119: 1–11.

Macoon, B., L. E. Sollenberger and J. E. Moore (2001). Defoliation effects on leaf blade proportion and nutritive value of four Pennisetum genotypes. Soil Crop Sci. Soc. Fla. Proc. 60:114–119.

Macoon, B., L. E. Sollenberger and J. E. Moore (2002). Forages and Pasture Management. Defoliation Effects on Persistence and Productivity of Four *Pennisetum* spp. Genotypes. Agron. J. (94):541–548.

MARM (2010). Guia practica de la fertilizacion racional de los cultivos en España. Cap 6. Abonos y materias organicas. ISBN 978-84-491-0997-3.

Márquez, F., J. Sánchez, D. Urbano and C. Dávila (2007). Evaluación de la frecuencia de corte y tipos de fertilización sobre tres genotipos de pasto elefante (*Pennisetum purpureum*). 1. Rendimiento y contenido de proteína. Zootecnia Trop. 25(4) 253-259.

Meissner, H. H. (1997). Recent research on forage utilizartion by ruminant livestock in South Africa. Animal Feed Sci. Tech. 69:103–119.

Mushtaque, M., M. Ishaque and M. Ahmad alias Haji A. Bukhsh (2010). Growth and herbage yield of *Setaria sphacelata* grass in response to varying clipping stages. The J. Anim. Pl. Sci. 20(4):261-265.

Olsen, S. R. and L. E. Sommers (1982). Phosphorus. P 403-430. In: A.L. Page *et al*.(eds.) Methods of soil analysis, part2. Agron. Mongr.9. 2nd ed. ASA and SSSA, Madison, WI.

PIRCAN (1999). Plan Integral de Residuos de Canarias 2000-2006. Plan de residuos Ganadero. Gobierno de Canarias. http://www2.gobiernodecanarias.org/cmayot/medioambiente/calidadambiental/residuos/docs/pircan/ganadero.pdf.

Plan Ganadero de Canarias (2010). Gobierno de Canarias. En revisión.

Premaratne, S. and G. G. C. Premalal (2006). Hybrid Napier (*Pennisetum perpureum* X *Pennisetum americarnum*) Var CO-3: A Resourceful Fodder Grass For Dairy Development Sri Lanka. The J. Agri. Sci., 2 (1):22-33.

Ramirez, R., I. Londoño, J. Alonso and M. Morales (2006). Evaluación del pasto maralfalfa (*pennisetum sp.*) como recuperador de un andisol degradado por prácticas agrícolas.

www.unalmed.edu.co/. /rramirez/evaluacion_del_pasto_maralfalfa__pennisetum_sp.__como_recuperador_de_un_andisol_degradado.

Rockström, J. and A. De Rouw (1997). Water, nutrients and slope position in on-farm pearl millet cultivation in the Sahel. Plant and Soil 195: 311–327.

Rowena, B., R. S. Valencia-Gical, G. S. Yost, Porter and R. Pattnaik (2007). Nutrient cycling in effluent-irrigated soil (mollisol) planted to tropical grasses in a tropical island environment. Western Nutrient Management Conference. 7: 198-202 Salt Lake City, UT.

Sarwar, M., M. N. Khan and N. Saeed (1999). Influence of nitrogen fertilization and stage of maturity of mottgrass (*Pennisetum purpureum*) on its composition, dry matter intake, ruminal characteristics and digestion kinetics in cannulated buffalo bulls. Animal Feed Science and Technology 82: 121-130.

Singh, R. K., D. Chakraborty, R. N. Garg, P. K. Sharma and U. C. Sharma (2010). Effect of different water regimes and nitrogen application on growth, yield, water use and nitrogen uptake by pearl millet (Pennisetum glaucum). Indian J. Agri. Sci. 80 (3) 213–6, March

Soil Survey Staff (1999). Soil Taxonomy. 2nd ed. Agric. Handbk. 436. U.S. Gov. Print Office, Washington, DC.

Sosa, D., C. Larco, R. Falcón, D. Toledo and G. Suárez (2006). Digestibilidad de maralfalfa (*Pennisetum* sp.) en cabras. Boletín técnico 5. Serie Zoológica 2: 68-76.

Tejedor, M., C. Jiménez, S. Armas-Espinel and J. M. Hernández-Moreno (2009). Classification of Anthropogenic Soils with Andic Properties Soil Sci. Soc. Am. J. 73:170-175.

Tesema, Z., M. R. T. Baars and A. Yami (2002). Effect of plant height at cutting, source and Level of fertilizar on yield and nutritional Quality of Napier grass (Pennisetum purpureum (L.) Schumach.) African J. Range and Forage Science,,19:123-128.

UNESCO (2007). UNESCO MAB Biosphere Reserves Directory.http://www.unesco.org/ mabdb/br/brdir/directory/biores.asp?mode=gen &code=SPA+16.

Van Soest P. J, J. B. Robertson and B. A. Lewis (1991). Methods for Dietary Fiber. Neutral Detergent Fiber. and Nonstarch Polysaccharides in Relation to Animal Nutrition. J Dairy Sci 74:3583-3597.

Van Soest, P. J. (1994). Nutritional Ecology of the Ruminant, Comstock Publishing Associates. A division of Cornell University Press, Ithaca and London

Vicente-Chandler, J., S. Silva and J. Figarella (1959). The effect of nitrogen fertilization and frequency of cutting on the yield and composition of three tropical grasses. Agron. J. 51:202-206.

Vieira, R. A. M., J. C. Pererira, P. A. M. Malafaia and A. C. De Queiros (1997). The influence of elephan-grass (*Pennisetum purpureum* Schum., Mineiro variety) growth on the nutrient Kinetics in the rumen. Anim. Feed Sci. Tech. 67 151-161.

Wadi, A., Y. Ishii and S. Idota (2004). Effects of cutting interval and cutting height on dry matter yield and overwintering ability at the established year in *Pennisetum* species. Plant Prod. Sci. 7(1): 88-96

Wet, J. M. J. (1995). Evolution of Crop Plants. 2nd edition. Ed. Smartt & Simmonds. Chapter 33 Pearl Millet. pag 156-159..

Yasin, M., M. A. Malik and M. S. Nazir (2003). Effect of different spatial arrangements on forage yield. Yield components and quality of Mott Elephantgrass. Pakistan J. Agron., 2 (1) 52-58.

Zeven, A. C. and J. M. J. Wet (1982). Dictionary of cultivated plants and their regions of diversity: excluding most ornamentals. forest trees and lower plant. Centre for Agricultural Publishing and Documentation. Wageningen. 1982. Chapter 8. pag 121-147. ISBN 9022007855.

Zinash, S., B. Seyoum, G. Lulseged and T. Tadesse (1995). Effect of harvesting stage on yield and quality of natural pasture in the central highlands of Ethiopia. Addis Ababa, Ethiopia. In: Proceedings of 3rd National Conference of the Ethiopian Society of Animal Production. 27-29 April 1995. 316-3.