Scientific Paper

Effect of calcareous amendments on the productivity and quality of *Medicago sativa* (L.) in Colombia

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Abstract

Objective: To evaluate the effect of calcareous amendments on the productivity and quality of *Medicago sativa* (L.) cv. Moapa 69 in the high tropic of the Nariño department, Colombia.

Materials and Methods: The study was conducted in the Pasto and Sapuyes localities. A complete randomized block design was used, with split-plot arrangement. Twelve treatments were established, resulting from the interaction of three amendment sources (dolomitic limestone, agricultural limestone and agricultural gypsum) and four doses (D1-control without application of limestone, D2-according to soil analysis, D3-½ D2 and D4-1 t. ha^{-1}), with three replicas. The variables were plant height, green forage and dry matter yield, protein, neutral detergent fiber, acid detergent fiber, calcium and phosphorus. Variance analysis was used for data processing through the program R V 3.6.2.

Results: In the rainy season, in the Pasto locality, T4 was the most outstanding in neutral detergent fiber and acid detergent fiber, with values of 41,0 and 25,5 %, respectively. In Sapuyes, T4 stood out for its protein content (30,9 %). During the dry season, in Pasto, the variables did not show statistical differences. In Sapuyes, T3 was the best regarding acid detergent fiber (29,3 %); while T8 stood out in height (2,57 cm) and T12 in green forage (5,52 t ha^{-1}) and dry (0,97 t ha-1) yield.

Conclusions: The practice of limestone application positively influenced the establishment and development of *M. sativa*. The performance of *M. sativa* varied in correspondence with the water availability. In the rainy season, the dry matter yields remained constant. Meanwhile, in the dry season, dolomitic limestone had the best results..

Keywords: calcium carbonate, *Medicago sativa*, productivity

Introduction

In the Colombian Andean region, the Nariño department is among the agroecological zones of the high tropic, whose particular edaphoclimatic characteristics favor the specialized milk production. Solarte (2009) refers that the area dedicated to forage crop production in the high tropic is 10 103 ha, from which 20,2 % corresponds to *Lolium* sp. cultivars; 27,5 % to naturalized crops; 36,4 % to mixtures of naturalized crops, such as cock's foot (*Dactylis glomerata* L.), kikuyu [*Cenchrus clandestinus* (Hochst. ex Chiov.) Morrone] and Yorkshire fog (*Holcus lanatus* L.) and 15,9 % to alfalfa (*Medicago sativa* L.), Brazilian pasture (*Phalaris* sp.) and clover (*Trifolium* sp.) crops in mixture with the above-mentioned ones.

The forage crops of the Nariño Altiplano show different degrees of tolerance to soil acidity and legumes. Particularly, alfalfa is a sensitive species to this condition. The establishment of this crop, as well as guaranteeing good production is a labor that requires adequate practices, especially due to the high demands of Ca^{2+}, Mg^{2+} and pH from 6,0 to 6,5 (Berenji *et al*., 2017). However, with the application of basic amendments, the acidity problems are corrected, the availability of such nutrients as P is improved, biological N fixation is promoted and the mineralization processes are favored, with which vigorous alfalfa plants are obtained, with good nodulation (Damian-Suclupe *et al*., 2018).

The application of such products as agricultural limestone, agricultural gypsum and dolomitic limestone, supply high content of Ca^{2+} and Mg^{2+} to the soil, which promote the precipitation of Al^{3+} and reduce its toxicity (Calva and Espinosa, 2017). Likewise, these bases improve the quality of soil structural cations, by decreasing resistance to penetration, which facilitates the air and water dynamics in animal husbandry soils (Vázquez *et al*., 2012).

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Defining the amendment and doses to be applied implies considering the current degree of acidity and potential of the soil, cation exchange capacity (CEC), percentage of base saturation and Ca:Mg:K relations for particular microclimate conditions. Similarly, the neutralization capacity of the product to be used, its reaction rate, purity and particle size should be contemplated (Vázquez *et al*., 2012). The objective of this research was to evaluate the effect of different amendment sources and doses on the productivity and quality of *M. sativa* cv. Moapa 69 during the rainy and dry seasons, in the high tropic of the Nariño department.

Materials and Methods

Location. The study was conducted in two localities of the Nariño department (Pasto and Sapuyes), Colombia the average agroclimate indicators are shown in table 1.

Experimental design and treatments. A complete randomized block design was applied, with split/plot arrangement, with 12 treatments and three replicas (table 2), which resulted from the interaction of three amendment sources (dolomitic limestone, agricultural limestone and agricultural gypsum), and four doses of application (D1-control without application of limestone, D2-according to chemical analysis of the soil, D3-½ D2 and D4-1 t.ha-^{1}). The main plots corresponded to the amendment sources (6 x 48 m); while the subplots, to the application doses (6 x 12 m).

Experimental procedure. In both localities the planting density of *M. sativa* cv. Moapa 69 was 15 kg ha^{-1}. The fertilization was formulated according to the soil chemical analysis (table 3) and was fractioned in two applications: at the moment of planting, and 120 days later. In the Pasto municipality 890 kg

Table 1. Location and climate and soil characteristics of the farms.

Municipality	Locality	Coordinates	Altitude, m a s l	Mean annual temperature, °C	Mean annual rainfall, mm	Soil texture
Pasto	Research Center Obonuco AGROSAVIA	N 01° 11' 4.13'' W 77° 19' 0.19''	2 905	13,8	1 273	Sandy loam
Sapuyes	Exp. Farm. Chimangual University of Nariño	N 01° 02' 6.55'' W 77° 45' 3.88''	3 157	11,2	1 061	gravelly sandy loam

Source: Climate-Data.org (2020)

Table 2. Evaluated treatments per locality in the rainy and dry seasons.

Treatments	Source	Description	Locality Doses (t ha^{-1}) Pasto	Sapuyes
T1 = CD + D1	CD: dolomitic limestone ($CaCO_3MgCO_3$)	D1: Control	0	0
T2 = CD + D2		D2: According to soil chemical analysis (normal)	2,5	3
T3 = CD + D3		D3: 1/2 D2 (Medium)	1,25	1,5
T4 = CD + D4		D4: 1 (High)	3,4	11
T5 = CA + D1	CA: agricultural limestone ($CaCO_3$)	D1: (Control)	0	0
T6 = CA + D2		D2: According to soil chemical analysis (Normal)	1,5	2,9
T7 = CA + D3		D3: 1/2 D2 (Medium)	0,75	1,45
T8 = CA + D4		D4: 1 (High)	3,4	11
T9 = YA + D1	YA: agricultural gypsum ($CaSO_42H_2O$)	D1: (Control)	0	0
T10 = YA + D2		D2: According to soil chemical analysis (Normal)	2,5	2,8
T11 = YA + D3		D3: 1/2 D2 (Medium)	1,25	1,4
T12 = YA + D4		D4: 1 (High)	3,4	11

Table 3. Soil chemical analysis.

Municipality	Locality	pH	OM, %	P, mg/kg)	Ca	Mg	K	CEC	B	Cu	Mn	Fe	Zn
					meq/100g				ppm				
Pasto	Research Center Obonuco AGROSAVIA	5,8	5,1	13,9	8,1	1,9	0,6	10,9	0,4	4,8	12,8	796,9	3,6
Sapuyes	Exp. Farm Chimangual University of Nariño	5,0	19,4	11,4	3,2	1,0	0,4	41	0,4	0,8	5,5	224	2,7

CEC: cation exchange capacity

of N ha^{-1}, 134 kg of P_2O_5 ha^{-1}, 672 kg of K_2O ha^{-1}, 60 kg of MgO ha^{-1} and 57 kg of S ha^{-1} were used. In Sapuyes, 85,3 kg of N ha^{-1}, 1 393 kg of P_2O_5 ha^{-1}, 64 kg of K_2O ha^{-1} and 30,5 kg of MgO ha^{-1} were utilized.

The establishment period was 90 days (June to September, 2018). Afterwards, a homogenization cut was performed.

Four cuts were carried out, two in the rainy season (October to December, 2018, fig. 1) and two in the dry season (January to March, 2019, fig. 2). The evaluations were conducted with the same frequency for all the treatments. In each experimental unit sampling was done 45 days after cutting.

The studied variables were plant height (H), green forage yield (GF) and dry matter (DM), according to the methodology proposed by Toledo (1982); crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), calcium (Ca) and phosphorus (P). For the bromatological analyses, the NIRS methodology (near infrared reflectance spectroscopy) was used, according to Ariza-Nieto *et al.* (2018) for every one of the cuts in each season.

Statistical analysis. The data were analyzed through the statistical program R V.3.6.2 (R Core Team, 2018), with the package Agricolae (Mendiburu, 2017). The variance and its normal distribution were taken into consideration. Variance analysis was carried out for the studied variables, accompanied by Tukey's mean comparison test ($p \leq 0,05$).

Results and Discussion

In the rainy season, in the Pasto locality, the edaphoclimatic conditions, source type and limestone dose influenced the production and nutritional content of alfalfa; this generated a different performance

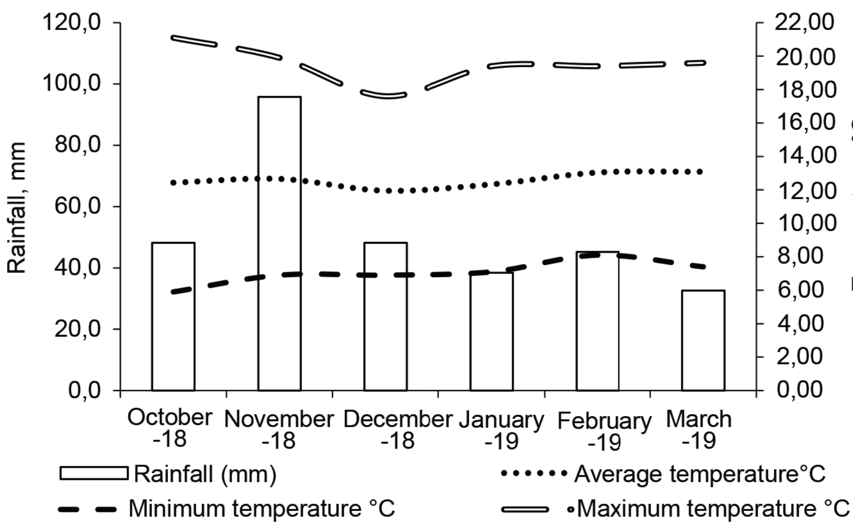

Figure 1. Accumulated rainfall, October, 2018, to March, 2019.

Source: Meteorological Station Vintage pro 2. Colombian Corporation of Agricultural Research (AGROSAVIA). Pasto, Nariño, Colombia.

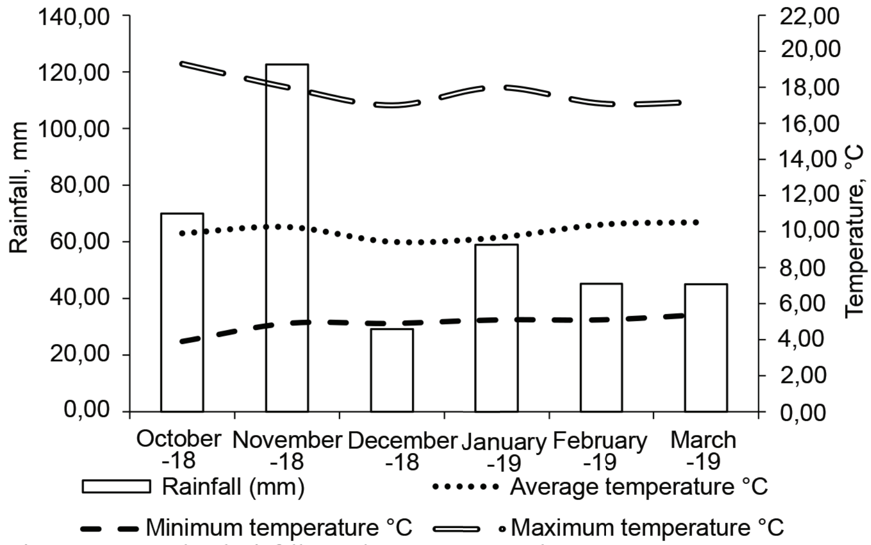

Figure 2. Accumulated rainfall, October, 2018, to March, 2019.
Source: Meteorological station Vintage pro 2, University of Nariño (UDENAR). Sapuyes, Nariño, Colombia.

in some variables (table 4). T4 stood out in ADF and NDF, with 41,0 and 25,5 %, respectively.

Capacho-Mogollón *et al.* (2017) found ADF values of 38,6 % and NDF of 49,5 %, which were higher than the ones in this study. These results were ascribed to the edaphoclimatic conditions of the zone where the research was conducted and to the phenological status of the crop at the moment of carrying out the evaluation cut.

T3 reached the highest value of Ca (0,83 %). This does not coincide with the result obtained by Capacho-Mogollón *et al.* (2017), who reported a value of 1,47 % of Ca. This difference is due to the fact that the in the zone where such research was conducted the transpiration process was lower than that of this study. This allows the Ca^{2+} of the soil extracted by the plant to be adequately fixed to the cell wall.

From the statistical point of view, the variables H, GF, DM, CP and P did not show significant differences for the interaction of two factors. For such reason, the effect of each was analyzed separately, where the factor source showed significant differences for the variables H, CP and P.

The agricultural gypsum stood out in H with 72,1 cm. In this sense, Pérez-Vargas (2016) and Silva *et al.* (2019) argued that this source allows higher nutrient availability in the soil, which increases forage height.

On the other hand, agricultural limestone stood out in P and CP with 0,29 and 24,2 %, respectively. Mora-Salazar (2005) obtained 0,27 % of P, which is similar to the one found in this research. This result can be ascribed to the high content of Ca^{2+} contributed by this source, which conditions the availability of P in the leaf tissue.

Regarding the CP, Damborg *et al.* (2018) reported 21,8 %, which is lower than the one in this study, because of the organic matter content of the zone. Contreras *et al.* (2019) obtained in the Huaytará locality a similar CP content to the one found in this study, which could have been due to the fact that both localities show similar edaphoclimatic conditions.

In the Sapuyes locality, the soil, climate conditions and amendment type incorporated to the soil influenced the yields and nutritional content of *M. sativa* cv. Moapa 69, which generated a different performance in some variables (table 5). T4 stood out for its CP content (30,9 %); Corner-Thomas *et al.* (2018) reported 26,0 %, which is lower than the one found in this study. This is due to the organic matter content in the soil of the zone being lower than that of Sapuyes. On the other hand, T8 stood out for its Ca content (2,18 %), which was lower than that found by Rodríguez-Ramírez *et al.* (2013). This could be ascribed to the fact that in the Sapuyes locality a high dose of agricultural limestone was applied, which influenced the Ca content in the cell tissues of *M. sativa* cv. Moapa 69.

The variables H, GF, DM, NDF, ADF and P did not show significant differences for the interaction

Table 4. Mean values for the variables in the different treatments during the rainy season in the Pasto locality.

Treatment	Height, cm	Green forage, t ha^{-1}	Dry matter, t ha^{-1}	CP, %	NDF, %	ADF, %	Ca, %	P, %
T1	63,1	14,9	3,5	23,8	38,3^{ab}	19,3^{b}	0,8^{ab}	0,2
T2	64,7	14,5	3,0	23,0	37,8^{b}	23,1^{ab}	0,8^{ab}	0,2
T3	67,8	17,3	3,5	23,5	37,8^{b}	24,0^{ab}	0,8^{a}	0,2
T4	65,0	14,7	3,0	22,5	41,0^{a}	25,5^{a}	0,7^{ab}	0,2
T5	69,7	17,3	3,3	24,8	37,8^{b}	23,8^{ab}	0,7^{ab}	0,3
T6	67,4	14,2	2,9	24,1	40,8^{a}	24,8^{ab}	0,6^{b}	0,2
T7	68,9	15,4	3,1	24,1	37,8^{b}	24,5^{ab}	0,7^{ab}	0,3
T8	72,0	16,6	3,3	23,5	37,5^{b}	24,5^{ab}	0,7^{ab}	0,3
T9	70,7	16,9	3,5	23,5	38,0^{b}	24,0^{ab}	0,8^{ab}	0,2
T10	72,5	17,1	3,5	23,5	38,3^{ab}	24,1^{ab}	0,8^{ab}	0,2
T11	71,5	15,3	3,1	23,3	37,1^{b}	24,3^{ab}	0,8^{ab}	0,2
T12	73,6	15,2	3,05	23,5	36,8^{b}	23,1^{ab}	0,7^{ab}	0,3
SE ±	0,855	0,362	0,076	0,001	0,002	0,003	0,008	0,001
P - value	0,918	0,332	0,647	0,806	> 0,0005 ***	0,17	0,606	0,048
Source								
CD	65,1^{b}	15,3	3,2	23,2^{b}	38,7^{a}	23,0	0,8^{a}	0,2^{b}
CA	69,5^{ab}	15,9	3,1	24,1^{a}	38,5^{ab}	24,4	0,7^{b}	0,2^{a}
YA	72,1^{a}	16,1	3,3	23,4^{ab}	37,5^{b}	23,9	0,7^{ab}	0,2^{ab}
SE ±	2,061**	0,725	0,142	0,002*	0,001*	0,003	0,021**	0,000**
P - value	0,005	0,691	0,811	0,022	0,015	0,26	0,003	0,005
Doses								
D1	67,8	16,4	3,4	24,0	38,0^{ab}	22,3	0,7	0,2
D2	68,2	15,3	3,1	23,5	39,0^{a}	24,0	0,7	0,2
D3	69,4	16,0	3,2	23,6	37,6^{b}	24,2	0,8	0,2
D4	70,2	15,5	3,1	23,1	38,4^{ab}	24,3	0,7	0,2
SE ±	1,865	0,661	1,545	0,002	0,004*	0,012	0,014	0,003
P - value	0,741	0,742	0,509	0,188	0,033	0,165	0,286	0,481

*p < 0,05; **p < 0,01; ***p < 0,001
a, b, c: means with different letters in the same column differ among them, according to Tukey's test (p≤ 0,05).
Doses: D1-control without fertilization, D2- dose of application according to soil chemical analysis (normal), D3- 1/2 D2 (mean dose) and D4: 1 (high dose)
Treatments: T1-dolomitic limestone + D1, T2-dolomitic limestone + D2, T3-dolomitic limestone + D3, T4-dolomitic limestone + D4, T5- agricultural limestone + D1, T6-agricultural limestone + D2, T7-agricultural limestone + D3, T8-agricultural limestone + D4, T9- agricultural gypsum + D1, T10: agricultural gypsum + D2, T11: agricultural gypsum + D3, T12: agricultural gypsum + D4.

of two factors, for which the effect of each was analyzed separately and the factor source showed statistical differences in the P content; CA was the one that showed the highest percentage of P (0,39 %) and it was higher than that found by Rodríguez-Ramírez *et al.* (2013) under different edaphoclimatic conditions from the ones in this study.

The rainy season, edaphic conditions, agronomic management, sources and limestone doses used influenced the yields and generated a different performance in the nutritional content of *M. sativa* cv. Moapa 69 in both localities.

In the dry season, in the Pasto locality, the edaphoclimatic conditions, source type and limestone

Table 5. Mean values for the variables in the different treatments during the rainy season. Sapuyes.

Treatment	Height, cm	Green forage, t ha^{-1}	Dry matter, t ha^{-1}	CP, %	NDF, %	ADF, %	Ca, %	P, %
T1	38,3	3,5	0,4	29,6^{ab}	31,5	21,1	1,6^{b}	0,0
T2	45,1	4,9	0,7	29,1^{ab}	32,0	22,3	1,7^{ab}	0,4
T3	43,3	3,4	0,4	30,4^{ab}	32,4	22,2	1,6^{b}	0,4
T4	46,2	5,3	0,7	30,9^{a}	31,3	22,7	1,8^{ab}	0,4
T5	45,5	4,4	0,6	28,8^{ab}	28,8	21,3	1,6^{ab}	0,3
T6	41,6	4,1	0,6	29,4^{ab}	30,0	21,1	1,8^{ab}	0,3
T7	41,9	4,3	0,6	29,5^{ab}	29,6	21,2	2,1^{ab}	0,4
T8	49,3	6,8	0,9	29,4^{ab}	31,8	23,4	2,1^{a}	0,3
T9	40,5	2,7	0,4	28,4^{ab}	29,8	19,3	1,6^{b}	0,3
T10	40,6	3,4	0,5	29,7^{ab}	29,8	20,5	1,7^{ab}	0,3
T11	44,5	5,6	0,8	29,0^{ab}	33,0	23,4	1,7^{ab}	0,3
T12	44,2	5,5	0,8	27,4^{b}	31,6	22,2	1,9^{ab}	0,3
SE ±	1,149	0,405	0,054	0,002	0,005	0,003	0,0003	0,005
P - value	0,773	0,744	0,721	0,254	0,939	0,703	0,459	0,950
Source								
CD	43,2	4,3	0,6	30,0^{a}	31,8	22,1	1,7^{b}	0,4^{a}
CA	44,6	4,9	0,7	29,3^{ab}	30,1	21,8	1,9^{a}	0,3^{a}
YA	42,5	4,3	0,6	28,6^{b}	31,0	21,4	1,1^{b}	0,3^{b}
SE±	2,223	0,701	0,092	0,002*	0,012	0,005	0,000**	0,012***
P - value	0,714	0,737	0,701	0,033	0,49	0,733	0,005	< 0,0005
Doses								
D1	41,5	3,5	0,5	28,9	30,0	20,6	1,6^{b}	0,3
D2	42,4	4,1	0,6	29,4	30,6	21,3	1,7^{ab}	0,3
D3	43,2	4,4	0,6	29,6	31,7	22,3	1,8^{ab}	0,3
D4	46,6	5,9	0,8	29,2	31,5	22,8	1,9^{a}	0,3
SE ±	1,865	0,661	0,152	0,002	0,004	0,013	0,012**	0,003
P - value	0,37	0,145	0,105	0,685	0,729	0,169	0,003	0,746

*p < 0,05; **p < 0,01, ***p < 0,001
a, b, c: means with different letters in the same column differ among them, according to Tukey's test (p ≤ 0,05).
Doses: D1-control without fertilization, D2-application dose according to soil chemical analysis (normal), D3-1/2 D2 (medium dose) and D4-1 (high dose)
Treatments: T1-dolomitic limestone + D1, T2- dolomitic limestone + D2, T3- dolomitic limestone + D3, T4- dolomitic limestone + D4, T5- agricultural limestone + D1, T6-agricultural limestone + D2, T7- agricultural limestone + D3, T8-agricultural limestone + D4, T9-agricultural gypsum + D1, T10- agricultural gypsum + D2, T11-agricultural gypsum + D3, T12- agricultural gypsum + D4

doses used did not influence the production and nutritional content of alfalfa, which did not generate a different performance in the variables (table 6). Nevertheless, T5 showed slightly higher values for the variables H, GF, DM with an average of 73,4 cm; 16,58 and 3,58 t ha^{-1}, respectively.

This can be ascribed to the response of *M. sativa* cv. Moapa 69 to the unaltered edaphic conditions of this locality. On the other hand, T11 showed a slightly higher value in CP, with 24,8 %, because the applied quantity of agricultural gypsum responded better to the root development of *M. sativa* and

Table 6. Mean values for the variables in the different treatments in the dry season. Pasto.

Treatment	Height, cm	Green forage, t ha^{-1}	Dry matter, t ha^{-1}	CP, %	NDF, %	ADF, %	Ca, %	P, %
T1	68,0	14,7	3,0	24,8	38,1	23,6	0,4	0,2
T2	72,8	15,3	3,2	24,0	37,6	23,5	0,5	0,2
T3	67,0	15,6	3,2	24,0	38,8	23,3	0,5	0,2
T4	70,3	15,3	3,2	24,5	38,1	22,6	0,5	0,2
T5	73,3	16,5	3,5	23,3	39,0	23,1	0,5	0,2
T6	69,6	13,8	3,0	24,3	39,1	23,0	0,6	0,2
T7	71,7	14,8	3,1	24,1	39,0	23,0	0,5	0,2
T8	67,2	13,6	2,8	23,8	38,6	23,6	0,5	0,2
T9	73,3	15,0	3,1	24,1	38,6	23,6	0,5	0,2
T10	71,8	15,1	3,2	23,8	39,1	24,1	0,5	0,2
T11	72,7	15,4	3,2	24,8	38,0	23,0	0,4	0,2
T12	72,2	15,8	3,3	24,1	39,0	23,0	0,5	0,2
SE ±	0,711	0,322	0,0008	0,001	0,001	0,001	0,026	0,002
P - value	0,416	0,628	0,294	0,255	0,647	0,507	0,983	0,328
Source								
CD	69,5	15,2	3,1	24,3	38,2	23,2	0,5	0,2
CA	70,5	14,7	3,1	23,9	38,9	23,2	0,5	0,2
YA	72,5	15,3	3,2	24,2	38,7	23,4	0,5	0,2
SE±	1,445	0,615	0,124	0,002	0,003	0,002	0,042	0,004
P - value	0,209	0,617	0,815	0,354	0,255	0,769	0,761	0,396
Doses								
D1	71,5	15,4	3,2	24,1	38,6	23,5	0,5	0,2
D2	71,4	14,7	3,1	24,0	38,6	23,5	0,5	0,2
D3	70,5	15,2	3,2	24,3	38,6	23,1	0,5	0,2
D4	69,9	14,9	3,1	24,1	38,6	23,1	0,5	0,2
SE ±	1,412	0,623	0,114	0,002	0,002	0,002	0,052	0,0045
P - value	0,821	0,857	0,926	0,872	0,999	0,548	0,896	0,956

Doses: D1-control without fertilization, D2-application dose according to soil chemical analysis (normal), D3-1/2 D2 (medium dose) and D4-1 (high dose)
Treatments: T1-dolomitic limestone + D1, T2- dolomitic limestone + D2, T3- dolomitic limestone + D3, T4- dolomitic limestone + D4, T5- agricultural limestone + D1, T6-agricultural limestone + D2, T7- agricultural limestone + D3, T8-agricultural limestone + D4, T9-agricultural gypsum + D1, T10- agricultural gypsum + D2, T11-agricultural gypsum + D3, T12- agricultural gypsum + D4

allowed higher extraction of available nitrogen in the soil. On the other hand, T6 and T10 had a slightly higher value of NDF (39,2 %). Likewise, T6 stood out in Ca and T10 in ADF. This result can be ascribed to the capacity of nutrient extraction of the species under those conditions (source type and calcareous dose). T1 showed a slightly higher value of P (0,29 %), due to the edaphoclimatic conditions of this season, which improved the extraction of Ca from the soil solution, allowing a better expression of P in the leaf part of *M. sativa* cv. Moapa 69.

In Sapuyes, the soil physical-chemical properties and the climate influenced the production and nutritional content of *M. sativa*, which generated different performances in the variables (table 7). T3 stood out for its ADF content. This result differs

Table 7. Mean values for the variables in the different treatments in the dry season. Sapuyes.

Treatment	Heigh, cm	Green forage, t ha^{-1}	Dry matter, t ha^{-1}	CP, %	NDF, %	ADF, %	Ca, %	P, %
T1	43,6^{d}	2,3^{cd}	0,3^{cd}	30,1	36,0	23,2^{c}	2,0^{bc}	0,3
T2	53,2^{ab}	3,6^{abcd}	0,5^{abcd}	29,8	36,4	23,9^{abc}	1,8^{c}	0,3
T3	45,9^{bcd}	3,8^{abcd}	0,6^{abcd}	30,3	40,1	25,9^{a}	1,8^{c}	0,4
T4	51,2^{abc}	4,6^{abc}	0,7^{abc}	29,9	40,0	25,6^{ab}	2,2^{abc}	0,4
T5	44,8^{cd}	2,7^{bcd}	0,4^{bcd}	29,6	37,6	24,7^{abc}	1,9^{bc}	0,3
T6	46,9^{abcd}	3,3^{abcd}	0,5^{abcd}	29,9	36,3	23,6^{abc}	2,0^{bc}	0,3
T7	47,7^{abcd}	4,1^{abc}	0,6^{abc}	29,2	37,9	24,3^{abc}	1,9^{bc}	0,4
T8	53,6^{a}	5,2^{ab}	0,8^{ab}	30,2	37,2	24,1^{abc}	2,5^{a}	0,4
T9	44,0^{cd}	1,5^{d}	0,2^{d}	28,5	37,4	25,2^{abc}	1,9^{bc}	0,3
T10	48,0^{abcd}	3,2^{abcd}	0,5^{abcd}	28,0	37,6	24,0^{abc}	2,1^{bc}	0,3
T11	47,8^{abcd}	2,8^{bcd}	0,4^{bcd}	28,6	39,2	23,5^{bc}	2,1^{abc}	0,3
T12	46,6^{abcd}	5,5^{a}	0,9^{a}	29,0	37,5	22,9^{c}	2,3^{ab}	0,3
SE ±	0,788	0,223	0,0365	0,002	0,005	0,002	0,0004	0,005
P - value	0,011*	0,025*	0,448	0,855	0,871	0,023	0,505	0,997
Source								
CD	48,5	3,6	0,5	30,0^{a}	38,1	24,7	1,9	0,4^{a}
CA	48,3	3,8	0,6	29,7^{a}	37,2	24,2	2,1	0,4^{a}
YA	46,6	3,3	0,5	28,5^{b}	37,9	23,9	2,1	0,3^{b}
SE ±	1,361	0,462	0,075	0,004**	0,012	0,004	0,001	0,000**
P - value	0,178	0,291	0,479	0,001	0,774	0,288	0,197	0,003
Doses								
D1	41,1^{b}	2,2^{c}	0,3^{c}	29,4	37,0	24,4	1,9^{b}	0,3
D2	49,4^{a}	3,4^{b}	0,5^{b}	29,2	36,7	23,9	1,9^{b}	0,3
D3	47,1^{ab}	3,6^{b}	0,5^{b}	29,3	39,1	24,5	1,9^{b}	0,3
D4	50,4^{a}	5,1^{a}	0,8^{a}	29,7	38,2	24,2	2,3^{a}	0,3
SE ±	1,101***	0,365***	0,054***	0,003	0,012	0,003	0,000***	0,006
P - value	< 0,0005	< 0,0005	< 0,0005	0,809	0,373	0,675	< 0,0005	0,471

*p < 0.05,**p < 0,01, ***p < 0,001
a, b, c: means with different letters in the same column differ among them, according to Tukey's test (p ≤ 0,05).
Doses: D1-control without fertilization, D2-application dose according to soil chemical analysis (normal), D3-1/2 D2 (medium dose) and D4: 1 (high dose)
Treatments: T1- dolomitic limestone + D1, T2- dolomitic limestone + D2, T3- dolomitic limestone + D3, T4- dolomitic limestone + D4, T5- agricultural limestone + D1, T6-agricultural limestone + D2, T7- agricultural limestone + D3, T8-agricultural limestone + D4, T9-agricultural gypsum + D1, T10- agricultural gypsum + D2, T11-agricultural gypsum + D3, T12- agricultural gypsum + D4.

from the one reported by Damborg *et al*. (2018), who found 29,3 % of ADF. This difference can be consequence of the fact that during the dry season, the cellulose and lignin levels of *M. sativa* cv. Moapa 69 are high, because there is higher conversion of photosynthetic products in the structural tissues.

On the other hand, T8 stood out for its height (53,67 cm), and for Ca (2,57 %). In contrast with the report by López-Báez *et al.* (2018), the authors of this study define that the application of agricultural limestone mobilizes Al^{3+} and increases ECEC, the availability and absorption of phosphates in the soil, which allows the optimum development of *M. sativa* cv. Moapa 69.

Conversely, T12 prevailed for its GF and DM content. Baquero-Peñuela *et al*. (2018) refer that the application of agricultural gypsum on the soil contributes to the growth and root development of *M. sativa* cv. Moapa 69, which allows a better utilization of the available nutrients in the soil.

The dry season, edaphic conditions, agronomic management, sources and limestone doses used influenced the nutritional content of *M. sativa* cv. Moapa 69, in both studied localities, because the photosynthetic process was affected by the increase of temperature during this period.

Conclusions

Under the conditions of this study, the practice of limestone application influenced positively the establishment and development of *M. sativa* cv. Moapa 69. The performance of the species varied in correspondence with the water availability. Under high rainfall conditions, the dry matter yields remained constant; while in the dry season the application of dolomitic limestone showed the best yields.

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Authors' contribution

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- Diego Hernán Meneses-Buitrago. Writing of the original draft and data analysis.
- Hugo Ruiz-Eraso. Methodology design, manuscript writing, revision and edition.
- Edwin Castro-Rincón. Methodology design, manuscript writing, revision and edition.

Conflict of interests

The authors declare that there are no conflicts of interests among them.

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