International Journal on Advanced Science Engineering Information Technology

Vol.12 (2022) No. 6
ISSN: 2088-5334

Effect of Fertilization and Agricultural Amendments on the quality of a Prairy Established on a Volcanic Soil, Andosol

Emilio Basantes Morales [a,*], Sergio Ramón [b], Ramiro León [a], Santiago Basantes Aguas [b]

[a] Department of Life Sciences. Agricultural Engineering Degree IASA, Ecuador
[b] University of the Armed Forces-ESPE, Ecuador
Corresponding author: [*] erbasantes@espe.edu.ec

Abstract— This research was established at El Prado-IASA1 farm, Agricultural Engineering Career, on a soil of volcanic origin of the Andisol order, in order to evaluate the quality of the forage due to the effect of chemical fertilization and four amendments: lime (E1), gypsum (E2), magnesium silicate (E3) and phosphate rock (E4), mixed amendment (EM) and two level of NPK fertilization. These treatments were applied in an established meadow with: kikuyo (*Pennisetum clandestinum*), blue grass (*Dactylis glomerata*), perennial rye grass (*Lolium perenne*) and white clover (*Trifolium repens*). The amendments and fertilization were incorporated after the first cut, in an amount equivalent to 1500 of lime, 500 of gypsum, 300 of magnesium silicate and 300 of phosphate rock kg ha^{-1} $year^{-1}$, plus fertilization F1: N100-P50-K50 and F2: N300-P100-K100, fractionated for 10 cuts per year. The variables evaluated were: green mass production, dry matter, macro and micronutrient soil content. The forage assessment was based on the physiological growth of rye grass as a dominant prairie species. The results positively affected the quality and production of forage in t ha^{-1}, due to the effect of lime, phosphate rock, and NPK fertilization. There was a high fixation of NH4, K, and P, due to the effect of amorphous minerals, high Fe content, and water deficit. Hence it is recommended to keep close to the soil's field capacity level.

***Keywords*— NPK fertilization; amendments; lime; gypsum; silicon; phosphate rock; Andosol soil.**

Manuscript received 17 Jan. 2022; revised 12 Sep. 2022; accepted 7 Nov. 2022. Date of publication 31 Dec. 2022.

I. INTRODUCTION

Volcanic soils derived from volcanic ash are classified as Andisol or Andosol [1], with little differentiated profile, they are recent soils originating from pyroclastic volcanic formations (basalt), and in Ecuador they fill an area of around 8'438,650 ha that, is approximately 31% of the agricultural territory. Volcanic ash (pumice, coal, lava, and pyroclastic materials) has characteristics corresponding to amorphous soils (Al and Si): without form or defined internal structure. They are black due to allophane clays, medium to low organic matter content (< 3%), bulk density (1.18 to 1.20 g cm^{-3}), and high fixation of P, K, and NH4; Slightly acidic to neutral pH (6-7). They are soils suitable for agriculture (Andean crops), pastures, forestry, paramo crops, and ecotourism. An amendment is the addition of a mineral, organic, or fertilizer product to improve the quality of the soil in terms of the physical properties of the soil (structure, water movement), chemical properties (cation exchange capacity, CIC), and biological, in order to improve the availability of its nutrients, its pH and the good development and performance of plants. The application of compost according to Vázquez et al [2] increases the content of organic matter (MO), the electrical conductivity (E.C.), the phosphorus available in the soil, there is a buffer effect of the pH and the bulk density decreases.

The amendments are usually: organic matter that provides humus, CO_2, microbial activity [3], [4]; and some minerals that improve the soil, in water retention, soil structure to the formation of peds or aggregates, CIC, chelation capacity and nutrient availability [5]. Mineral amendments are: agricultural lime or limestone, Silicate Mg, Carbonate of Ca and Mg (dolomite lime), sulfur and gypsum [6], which help to correct the reaction of the soil, modifying the acidity or alkalinity and the salinity of Na in saline-sodium soils. According to Celestina et al [7], organic amendments are an alternative to inorganic fertilizers, as they can restore degraded soils and improve the physicochemical conditions of the soil.

Forages are plants that remain in continuous growth, so they need frequent nutrient supplementation, the association of grasses improved with *L. leucocephala*, under production conditions, increased the availability of total biomass and crude protein (PB) per hectare[8]. For an efficient application of fertilizers, it is necessary to consider the stages of development of the forage, and in soils of poor and coarse texture, it is advisable to fractionate the doses of fertilizers for the year. 30 to 40 % of nutritional requirements (kg ha^{-1}) can be applied shortly after the first cutting or grazing, and the rest for two or more applications during the forage production period in the year [9]. The alternative to correct acidity in soils is the use of lime amendments that increase the base content and neutralize the protons resulting from the acidification process.

Fig. 1 Application of Amendment

A. *Pasture Physiology and Fertilization*

A forage fertilization program must guarantee the high quality and persistence of the grass over time, so the morphology and physiology of the plant must be known since the grass is a solar panel that, through photosynthesis, produces carbohydrates for the production of leaves and shoots. These carbohydrates are stored at the base of stems, roots, rhizomes, and stolons. Some of these carbohydrates are consumed during grazing and keep the plant alive in periods of stress. Therefore, nutrition, especially of N, favors the production of fodder and proteins, especially in an Andisol soil that presents deficiencies in N, P, and S, which are elements contained in organic matter where the processes of andolization with the formation of organic-mineral complexes predispose to low mineralization and accumulation of organic matter [6]. In addition, it is important to leave an adequate residue of grass in the paddock, after each grazing, to ensure the accumulation of reserves, the pastures of the temperate-cold zones store energy in the lower part of the stems, stolons, and rhizomes so it should be expected to be at least 10 cm high. In comparison, tropical grasses accumulate reserve nutrients below 20 cm so that they can be harvested or grazed to that height. Fertilization with N and, eventually, the NS and NPS combinations are essential to maintain high yields in pastures after each of the cuts or grazing since N is the element that most limits the yields in the productive systems. Portillo et al. [10] indicate that fertilization with 100 kg N, 75 kg P2O5, 30 kg K2O, and 12 kg Mg ha^{-1} in forage grasses and legumes is applied in sowing and four months later gave good results. In summary, the benefits of forage fertilization are an increase in N (protein) content, digestibility, plant height and density, leaf-to-stem ratio, and increased biomass production. Foliar [11] and soil analyses are indicators of the degree of sufficiency and deficiency of soil and forage nutrients, as well as adverse conditions that can damage grass establishments, such as acidity, salinity, and toxicity of some minerals.

B. *Acidification*

Soil acidification is produced by the action of various natural factors (edaphic, climatic, and biological) as well as anthropogenic (derived from human activity) and consists of a decrease in the pH of the soil as a result of the successive accumulation of hydrogen ions, aluminum and the loss of cations in the soil, such as K, Ca, Mg, Na. Goulding et al. [12] add to natural factors such as acid precipitation and the deposition of gases or acidifying particles from the atmosphere, such as sulfur dioxide, ammonia, and nitric acid. However, the most important causes of soil acidification on agricultural land are the application of ammonium and urea-based fertilizers, sulfur-based fertilizers, and the growth of legumes. Acidification caused loss of changeable bases (K, Ca, Mg and Na), increased aluminum saturation, and decreased crop yields. The leaching of cations and the production of acids during the mineralization of organic matter acidifies the soil [13]. Severe acidification can cause a mineral dissolution of clay, a reduction in cation exchange capacity, and structural deterioration. It is important to state that there are naturally acidic soils and living beings capable of surviving in them, and when the soil has a high pH (acidic), it will affect the development of plants and microbiological organisms. Weathered Andisol with high amounts of sesquioxides adsorbs and retains phosphorus, reducing their availability to the plant. According to Tinoco and Bayuelo [14], the availability of P is related to the type of land use. In conventional agricultural systems, the retention of P increases due to the presence of oxides of Fe and Al, which decreases the available P (labile), that is, soluble phosphates, inorganic phosphates attached to the surface of clays, and organic phosphates.

C. *Effect of Soil Amendments*

Soils of volcanic origin, where most of the pastures used by livestock systems develop, have variable loads characterized by a high concentration of ionizable active groups of Fe-OH and Al-OH. With the increase in acidity, it is positively charged, generating soluble inorganic forms, Fe^{3+}, $Fe^{2+,}$ and the monomeric forms of Fe $(OH)^{3+}$ and Fe $(OH)^{2+}$ in the soil solution, where Fe^{2+} participation is low, except in acidic soils. $SO_4^{=}$, Al, Fe, Mn, and SiO_2 are related to acidity. The solubility of Fe decreases as pH and aeration increase. The presence of soluble forms of Fe in the soil solution and the surface of the colloids react with phosphates making them unavailable to the plant. Under acidic conditions, H^+ protons accumulate and generate positive charges that lead to the adsorption of anions, e.g., phosphates. The increase in positive charges reduces the retention and exchange capacity in the organo-mineral complex of the soil and in turn, generates an increase in the content of Al and soluble Fe.

For this reason, the negative charge of the soil must be increased, raising the pH with the use of carbonates so that changeable bases such as Ca, Mg, and K are adsorbed in the colloidal complex and released as required by plants. On the other hand, the decomposition of silicates puts silicon in the soil solution in the form of soluble $Si(OH)_4$ silicic acid or

H_4SiO_4, increasing silicon availability in the soil solution. Silicon is one of the most abundant elements of the earth's crust and is considered essential for certain crops [15] has a favorable effect on the growth of some plant species in field conditions due to the increase it causes in the availability of phosphorus for the plant, this is due to the exchange of phosphate fixed in the sesquioxides of Fe by the silicate ion [5].

Plant roots take silicon in the form of silicic acid $Si(OH)_4$, a monomeric molecule with no charge below a pH of 9. Under alkaline conditions, the Fe-OH groups of oxides are neutralized by water, and the negative charges thus formed result in the adsorption of cations. The most soluble or available forms of P exist within a pH range of 6.0 to 7.5, so a proper bleaching or liming program is essential to raise the pH to this range and thus reduce P fixation. Organic amendments applied to the soil can alter the immobilization of N [16] and microbial; mineralization and availability of N. Humid acid are a compound rich in C (57%) and N (4 to 6%), acts as food and increases microbial activity to mineralize manure [17]. Soil microorganisms have a C:N ratio close to 8:1 [18].

Intensive agriculture in the form of monoculture causes alterations in the soil [19], is highly extractive without replacement of the bases of change, and with the massive use of fertilizers, has accelerated the acidification and degradation of soils. The use of amendments is to correct the acidity of the soil [20], and nitrogen fertilization is the "engine of plant growth" where the plant will show its efficiency shortly after its application, the plants will develop a dark green color and grow more vigorously, which in paddocks improves regrowth and photosynthetic activity and shortens the cutting or grazing cycle in the meadow [21]. Fertilization is the practice with the greatest productive impact on pastures since it improves the production of dry matter and the nutritional value of forage and represents a very interesting tool to improve forage productivity in unfavorable environments. Phosphate rock is a product obtained from mines and subsequent metallurgical processing of phosphate minerals, its main component being apatite, a calcium phosphate mineral [22]. These are extremely variable and complex compounds that, in addition to providing phosphorus, also release other nutrients present in the rock, some of which can be heavy elements, so it is essential to know their origin, to avoid problems with the soil [23].

With the background above, this research was carried out in order to evaluate the effect of each of the products used as corrective agents on the soil, referring to the use of lime, gypsum, magnesium silicate, and phosphate rock, in a meadow established with kikuyo, blue grass, rye grass, and white clover. In addition, two levels of chemical fertilization (NPK) were used.

II. Materials and Method

The research was conducted at the experimental site of the Hcda. El Prado-IASA I, Career of Agricultural Sciences, in a soil whose agroecological characteristics correspond: Texture: loam-clay, pH: 5.72, regular drainage, 3% slope, average temperature: 13.98 °C, altitude: 2740 masl and annual precipitation: 800 to 1325 mm. A three-year established meadow was chosen to develop the field experiment with the forage species of kikuyo (*Pennisetum clandestinum*), bluegrass (*Dactylis glomerata*), perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*). The total area for the research was 960 m^2, where plots of 17.5 m^2 were established for each treatment under an experimental design of random blocks with three repetitions. The treatments were: No amendment or control (E0), lime (E1), gypsum (E2), magnesium silicate (E3) and phosphate rock (E4), and MS (mixed amendment). The chemical fertilization was: F1: 100N-50P-50K and F2: 300N-100P-100K. Fig. 2 presents a summary in a flowchart of the stages of the research method.

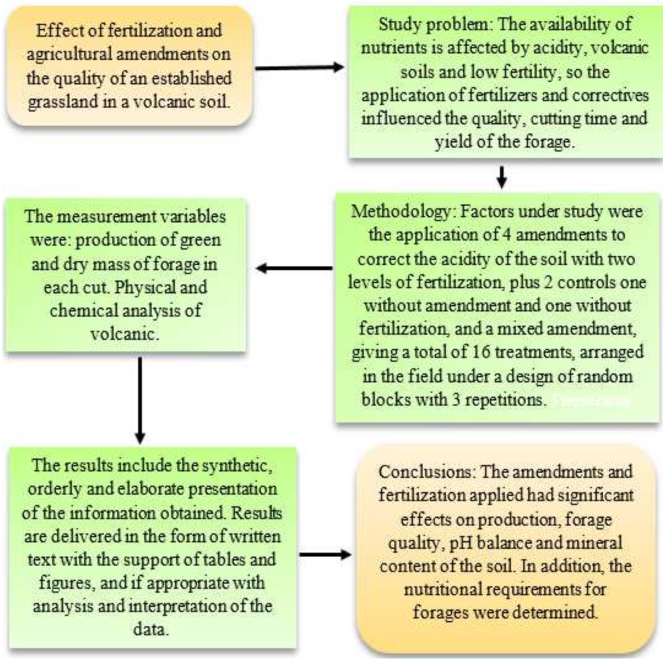

Fig. 2 Flowchart of research stages

III. Results and Discussion

A. Production of Green Material

Table 1 and Fig. 3 show the values and variation of forage production, during the four cuts, according to the treatment, with and without amendment plus chemical fertilization, which significantly affected forage development and yield in all treatments applied. The results indicate that the treatments E1 (agricultural lime) and E4 (phosphate rock) with fertilization gave the highest yields, compared to gypsum (E2) and Mg silicate (E3), while the treatment with mixed amendment (EM) had the lowest production, which highlights that it is not advisable to mix various sources of correctives.

Fertilization (F2) had a greater effect than F1, indicating that forages need high amounts of NPK to meet their requirements, especially N. According to Basantes-Morales, Alconada, and Pantoja [21] is the driving element of the plant since it directly influences the processes of photosynthesis and synthesis of proteins that have to do with the growth or metabolism of the plant. In pastures can be said that it accelerates regrowth, greater photosynthesis, and can shorten the cutting or grazing cycles. Based on production data, it can be concluded that fertilization [24] is essential for the production of established grasslands that even works without applying corrective sources.

TABLE I
RESEARCH TREATMENTS AND VARIABLES

TREATMENS	Green matter (t ha^{-1})				
	1st CUT	2nd CUT	3rd CUT	4th CUT	Total
T1 E0F0	12.1 bc	9.5 c	12.2 ef	9.1 f	42.8
T2 E0F1	11.5 bc	16.6 ab	16.5 def	14.8 cdef	59.5
T3 E0F2	13.7 abc	16.5 ab	24.7 a	21.0 abc	75.8
T4 E1F0	10.3 c	11.6 bc	11.7 ef	11.3 f	45.0
T5 E1F1	13.6 abc	16.6 ab	17.0 cde	17.5 abcde	64.8
T6 E1F2	17.8 a	16.6 ab	21.8 abc	23.7 a	79.6
T7 E2F0	10.6 c	10.1 bc	12.2 ef	9.8 f	42.8
T8 E2F1	12.5 bc	17.0 ab	16.2 def	18.0 abcd	63.6
T9 E2F2	15.6 ab	16.8 ab	18.8 bcd	21.2 ab	72.5
T10 E3F0	10.5 c	11.6 bc	11.5 f	9.5 f	43.1
T11 E3F1	10.0 c	13.0 abc	12.2 ef	11.5 f	45.6
T12 E3F2	13.8 abc	15.8 abc	19.5 bcd	23.3 a	72.5
T13 E4F0	12.0 bc	12.8 abc	12.8 ef	13.0 ef	50.6
T14 E4F1	11.8 bc	12.0 bc	18.2 bcd	15.5 bcdef	57.5
T15 E4F2	14.0 abc	16.5 ab	22.3 ab	23.0 a	77.6
T16 EM	11.0 bc	14.1 abc	11.8 ef	14.5 def	51.0
$\bar{X}$ (t ha^{-1})	12.6	14.4	16.2	15.9	59.0
CV (%)	19.4	24.3	17.4	21.1	23.0

Source: [25]. Value in column followed by the same letter, are not significantly differents ($p > 0.05$). Test: LSD Fisher.

The results presented in Table 2 and Fig. 4 represent the production values for the effect of the amendments alone compared to the control (no amendment). The results indicate that there were no significant differences between the amendments applied versus the control treatment or without amendment, within each of the cuts. However, it could be observed that the production values were growing in each cut, except for the E0 (without amendment) and EM treatments whose performance decreased from the third cut, except for the EM (mixed amendment)

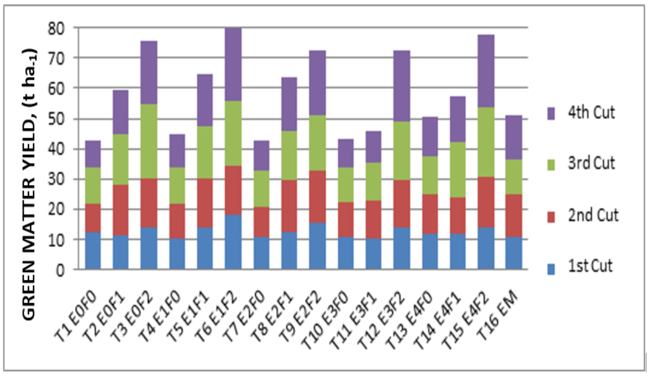

Fig. 3 Research Variable

The results generally indicated that any corrective can be applied to the soil with meadow, although the use of E1 (agricultural lime), E4 (phosphate rock) and E2 (agricultural gypsum) stands out, as the correctives that influenced in the highest biomass yield in the four cuts. Studies carried out by Giraldo, Ramírez, and Castro [26], indicate that the applications of increasing doses of lime at soil level neutralized aluminum, raised the pH to the appropriate level, and increased the calcium content and other nutrients, as well as biomass production.

On the other hand, the data also indicated that the application of a mixed amendment (EM) is not good, possibly due to their effect on the soil reaction. Thus, in the sum of the average yields obtained in each of the cuts, the MS (51.5 t ha^{-1}) had the lowest values, even lower than the control treatment (59.4 t ha^{-1}). Hence, the results indicate that the use of soil amendments in established grasslands is important so that the soil does not acidify due to the use of fertilizers, application of organic fertilizers or mineralization of organic matter.

TABLE II
EFFECT OF AMENDMENTS ON THE GREEN MATTER PRODUCTION IN FOUR EVALUATED CUTS.

Amendments	Green Matter, t ha^{-1}					
	1st cut	2nd cut	3rd cut	4th cut	total	average
E0 control	12.4	14.2	17.8	15.0	59.4	14.9
E1 - lime	13.9	15.1	16.8	17.5	63.3	15.8
E2 - plaster	12.9	14.7	15.7	16.3	59.7	*14.9*
E3 - Mg silicate	11.4	13.5	14.4	14.4	53.8	13.4
E4 – phosphoric r	12.6	14.6	17.8	17.2	62.2	15.5
EM	11.0	14.2	11.8	14.5	51.5	12.9

The results presented in this research are under those obtained by Basantres et al. [9], where liming had a positive effect on the increase and balance of pH, since the pH values due to liming increased from slightly acidic (5,8) to almost neutral (6.4). In contrast, the organic matter had a downward effect indicating that there was greater oxidation and release of the mineral N that the plant used and an increase in N content in the soil with a linear trend and with a correlation close to one (R^2 0.96). Forage species respond positively to N application doses [27] which positively influences the increase in biomass production, crude protein content, and the vegetation index.

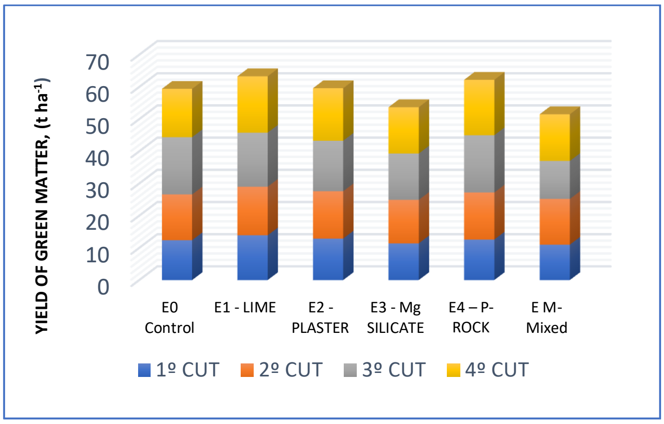

Fig. 4 Research Variable

In summary, the results obtained guarantee greater production and quality of fodder. However, it is necessary to maintain a fractional and continuous application of lime since the pH at the end of the experiment tended to return to its original state since the acidity by the application of organic matter and fertilizers can continue in the soil. Pastures, like all crops, require management practices to increase production, so the methods of renewing meadows in *Lolium sp.* favored the production of green forage and dry matter with 34.2 t ha^{-1} and 4.19 t ha^{-1}, respectively, in times of high and low rainfall, due to good root development and good availability of nutrients [28]. Regression models using a series of data obtained or recorded in an area of climatic conditions and soils in situ can support soil correction decisions or make forecasts of climate and other phenomena, such as sea-level changes. According to Maliberan et al. [29] the estimated data are similar to the actual data, implying that they are accurate, these forecasts have been made to forecast sea level changes [30] and rainfall forecasts [31].

B. *Dry Mass Production*

Table 3 shows the analysis of the variance of dry matter under the effect of modifications and fertilization, where treatments differed to the level of 1% in the dry matter content in the first, third and fourth cuts. From these, the amendments differed at the level of 1% in the third cut, showing a high importance in the comparison MS vs Rest, (EM, mixed amendment of lime plus gypsum plus Mg silicate plus phosphate rock).

TABLE III
ANALYSIS OF DRY MATTER VARIATION

Sources of Variation	GL	CUTS			
		1st	2nd	3rd	4th
TOTAL	47				
REPETITIONS	2	3.2 **	6.4 **	1.8 **	4.2**
TREATS	(15)	0.6 **	0.9	2.3 **	2.3 **
AMENDMENTS	5	0.3	0.2	1.3 **	0.4
EM vs Rest	1	0.3	0.0	2.9 **	0.2
E0 vs E1 E2 E3 E4	1	0.0	0.7	0.9	0.4
E4 vs E1, E2, E3	1	0.0	0.0	1.0	0.2
E3 vs E1, E2	1	0.8	0.3	0.9	1.0
E1 vs E2	1	0.3	0.0	0.5	0.2
D E0 (Control)	2	0.3	1.2	4.8 **	2.9 **
F0 vs F1, F2	1	0.0	1.8	5.8 **	4.2 **
F1 vs F2	1	0.5	0.6	3.8 **	1.5 *
D E1 (Lime)	2	1.9 **	0.9	2.8 **	3.1 **
F0 vs F1, F2	1	2.7 **	1.8	3.8 **	4.5 **
F1 vs F2	1	1.1 *	0.0	1.8 *	1.5 *
D E2 (Plaster)	2	0.8 *	1.7 *	1.3 *	2.8 **
F0 vs F1, F2	1	1.2 *	3.5 *	2.2 *	5.2 **
F1 vs F2	1	0.5	0.0	0.4	0.4
D E3 (Silicate Mg)	2	0.5	0.5	2.1 **	4.9 **
F0 vs F1, F2	1	0.2	0.9	1.0	3.0 **
F1 vs F2	1	0.9	0.3	3.1 **	6.9 **
D E4 Phosphoric R	2	0.7	1.6 *	2.9 **	2.2 **
F0 vs F1, F2	1	0.0	0.5	4.54 **	2.2 *
F1 vs F2	1	0.3	2.8 *	1.37	2.2*
Mistake exp.	30	0.2	0.5	0.34	0.3
$\bar{X}$ (t ha^{-1})		2.4	2.8	3.2	2.6
CV (%)		19.6	24.9	17.84	21.4

Source: [25]. * Significant and ** Highly Significant

Within E0 (without amendment), fertilizations differed to a level of 1% in the third and fourth cuts, and at the same level. Statistical differences were found in the comparisons F0 vs F1, F2; and F1 vs F2, except for the second comparison which only showed differences of 5% in the fourth cut. Amendment E1 with fertilization differed to a level of 1% in the first, third, and fourth cuts; and at the same level, differences were found in the comparison F0 vs F1, F2, while it was significant in the F1 vs F2 comparison (at the 5% level). Liming resulted in an increase in dry mass production, as it improves soil pH by optimizing nutrient use.

With the E2 amendment (plaster), fertilizations significantly affected the level of 5% in each of the first three cuts and on the level of 1% in the fourth cut, and this same variation was found in the comparison F0 vs F1, F2. Gypsum and lime-based amendments had positive effects on dry mass in legume fodder and varied according to water behavior [32].

In relation to E3 (Mg silicate), the treatments differed in the level of 1% in the third and fourth cuts. At the same level, differences were found between the established orthogonal comparisons, except for the F0 vs F1, F2 comparison, which did not present statistical differences. This amendment was characterized by its slow action in the soil, which meant that after 100 days the efficiency in the use of nutrients improved, which influenced an increase in green matter and therefore dry matter. This amendment [5], on the one hand, releases Mg into the soil, which increases the mineral content of this element for the plant and the silicates can play a fundamental role in the availability of phosphorus for the crops, in addition, the silicates consume the H^+ from the soil to form H_4SiO_4, which helps raise the pH.

Within the amendment (E4), with phosphate rock, fertilizations differed to the level of 1% in the third and fourth cut and to the level of 5% in the second cut, the comparison F0 vs F1, F2 differed to 1% in the third cut and to the level of 5% in the fourth cut, while in the comparison F1 vs F2 the differences were found in 5% in the second and fourth cut.

The overall average dry matter yield was 2.4, 2.8, 3.2, and 2.6 t ha^{-1}, for the first, second, third, and fourth cuts, respectively, showing that dry mass production was up to the third cut with an average increase of 0.4 t ha^{-1}, but in the fourth cut, there was a decrease in the production of 0.6 t ha^{-1}, indicating that at this stage there is a need to apply corrections and fertilization. The coefficients of variation were between 17.8 and 24.9%.

C. *Amendments or Corrections*

It is a process that aims to improve the physical-chemical and biological conditions of the soil in order to ensure that the soil remains balanced, aerated, permeable, and with high water retention capacity, and thus has better root development in grasses and legumes through a correction of pH (acidity or basicity) and a reduction or neutralization of aluminum and sodium.

TABLE IV
DRY MATTER PRODUCTION IN FOUR CUTS

Amendments	Dry matter (t ha^{-1})					
	1°	2°	3°	4°	Total	$\bar{X}$
E0 control	2.3	2.6	3.6	2.4	10.9	2.7
E1 LIME	2.7	3	3,4	2.8	11.9	3.0
E2 CAST	2.4	2.9	3.1	2.7	11.1	2.8
E3 Mg SILICATE	2.2	2.7	2.8	2.3	10.0	2.5
E4 P ROCK	2.3	2.8	3.5	2.8	11.4	2.9
EM	2	2.7	2.3	2.3	9.3	2.3
$\bar{X}$ (t ha^{-1})	2.3	2.8	3.1	2.5	10.8	
CV (%)	19.6	24.8	17.8	21.4		

To choose which corrective measure to use, it is necessary to know the type of soil, for example, sandy soils are very poor, since they are deficient in N, P, K, Ca, Mg, among others, so the correction of this type of soil must be done through the continuous contribution of organic matter, uses of green fertilizers, compost, and chemical fertilization. In clay soils, the correction is done by applying Ca, Mg and K, which are fundamental bases for soil balance, application of organic matter to decompress the soil, aerate and be able to perform mechanical tasks. According to Zapata et al [33], the use of residues as green manure increases microbial biomass and soil biological activity in terms of the production of CO_2 containing C and N in microbial biomass.

Table 4 and Fig. 5 show that the highest dry matter production in t ha^{-1} occurred when the modifications were made with E1 (agricultural lime) and E4 (phosphate rock). The least functional amendment was EM (mixed amendment).

Animal production is based on food, in this sense it is necessary to obtain pastures of great nutritional value and in large quantities in order to provide proteins and carbohydrates for more milk, sheep with better carcass quality and guinea pigs obtain greater weight in less time, hence the care of the soil based on the use of corrective and chemical fertilization is fundamental, so as not to degrade the soil and obtain the highest yields. Food production is a growing need in response to population growth, and so the demand for livestock products, and according to FAO [34] the global demand will increase by 70%, to feed a population, estimated to reach 9600 million people in 2050. The 34% of the world's food protein supply comes from livestock. According to Malpartida [35], spirulina is a blue-green algae that is currently considered a superfood because of its great concentration of amino acids, vitamins, fatty acids, minerals and carbohydrates, also for the benefits it brings to health. It finds in natural alkaline waters, for its growth it needs CO_2 which will allow it to carry out photosynthesis, comparing it with other products, it has more proteins than soy and beef.

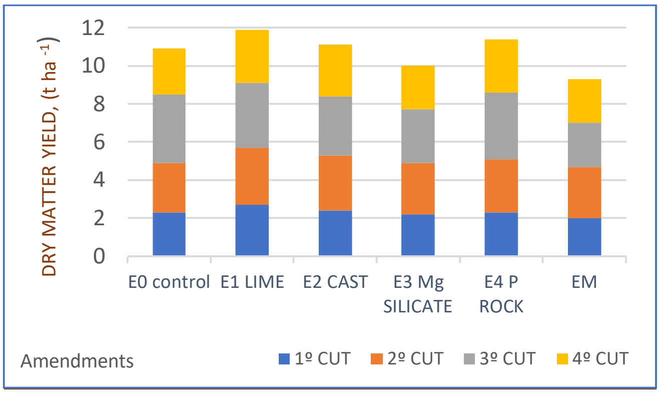

Fig. 5 Research on Dry Matter Yield (t ha^{-1}) Variable

By associating different species of grasses, more green fodder is produced than by planting a single species of fodder, for example, only alfalfa. Zapata et al. [36] maintains that liming increased the forage production of *L. perenne* and the content of Ca, Mg and P increased due to the influence of alkalinity. As stated by Bozhanska and Churkova [37], the incorporation of legumes in grasslands increases the content of crude protein (PB) in forages and decreases or replaces the excessive use of nitrogenous fertilizers.

Within each of the amendments presented in Fig. 6, the positive effect of fertilization on dry matter yield is observed, since as fertilization increases the total dry matter yield of the three cuts were better produced by the effect of amendments E1 (agricultural lime) and E4 (phosphate rock). The treatments that achieved the highest yields were T6 E1F2 and T15 E4F2 (Fig. 5). The lowest yields occurred when fertilization was not added, especially under amendment E3 (Mg silicate). According to Goulding [12], liming under recommended pH values increases productivity, benefits soil structure, improves degraded soils, and, if used in conjunction with other management practices, can benefit grassland biodiversity.

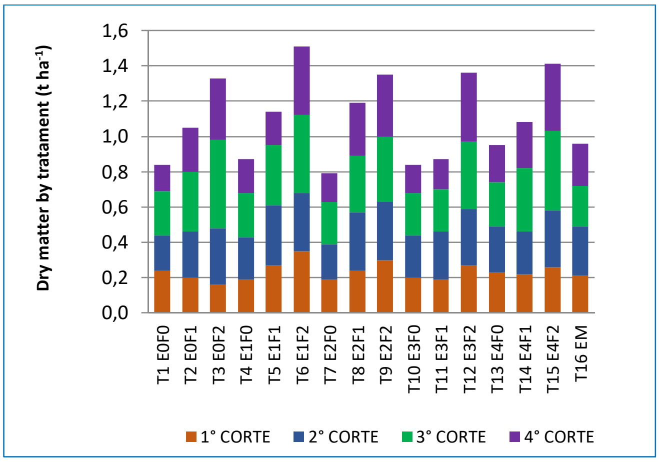

Fig. 6 Dry matter yield (t ha^{-1})

D. Determination of Nutritional Requirements in Pastures

The nutritional requirements represent the fertilization needs of plants and in forage species are the product of the dry mass (MS) harvested (cut) by the nutrient content (MS x % N, P, K, Ca and others) [6]. In the case of micronutrients, it must be considered that the content of them is determined in mg kg^{-1} (ppm). Based on cut-off time, forage production values are obtained from forage growth response curves. For example, in this research the average production of dry biomass during the four cuts was 10770 kg ha^{-1} (Table 4), and the analysis of the foliar N content was 2.81%, making the calculation corresponds to 302 kg N ha^{-1} that extracts, which is equivalent to saying that 28.1 kg N t^{-1} of MS ha^{-1} is required. Thus, the required amounts of NPK and other macronutrients can be obtained in kg/ha/year, and for micronutrients (g ha^{-1} $year^{-1}$) for forage species. Organic amendments are used to improve the physical, chemical and microbiological conditions of the soil, allowing to increase the macro and micronutrients necessary for plants to improve their production [38], in addition the type of tillage and the edaphoclimatic conditions influence the establishment and production of fodder [28].

E. Soil analysis

Fig. 7 shows the nutritional content in mg of the element per kg of soil (ppm) and the pH variation (5.7), which varied from the slightly acidic to acid range. The results of the macronutrients nitrogen (NH4) and P indicate that these elements are found in large quantities and the micronutrients in adequate parameters, except for Zn, which varied from medium to high. The S content varied from medium to low, so using fertilizers or corrective sources containing sulfur is recommended. The iron content (Fe) showed very high contents (630 ppm at the beginning, 365 ppm M1 and 380 ppm M2). Correlating the high contents of NH4 and P in the soil with the forage yield, it is indicated that they were not directly reflected in the increase in production, which could be due to the following: The soil where the meadow was established, corresponds to volcanic soils that have very high chemical characteristics to fix NH4, P and K. In addition, the high contents of Fe (458 ppm) reacted with P and form Fe phosphates, which are forms not available for the absorption of phosphates for the plant, so it is essential to apply corrective solutions based on sulfates so that they react with Fe and free phosphates depending on the pH of the soil ($H_2PO_4^-$, $HPO_4^=$, $PO_4^{\equiv}$), can be absorbed by grasses. The high content of NH4 in the soil due to the mineralization of organic matter or from the application of ammonium-based fertilizers, contribute to the increase in soil acidity, since $NH4^+$ is converted $NO3^-$ through biological oxidation and during this process H^+ is released into the soil solution. In addition, because they are amorphous minerals, they fix $NH4^+$ and K^+ between their Al^{3+} and Si^{4+} sheets of allophanes (amorphous aluminum hydrosilicate), when the moisture content is low, so in these soils the soil must be kept moist or close to the field capacity and not fall to levels close to the point of permanent wilt [5], [6].

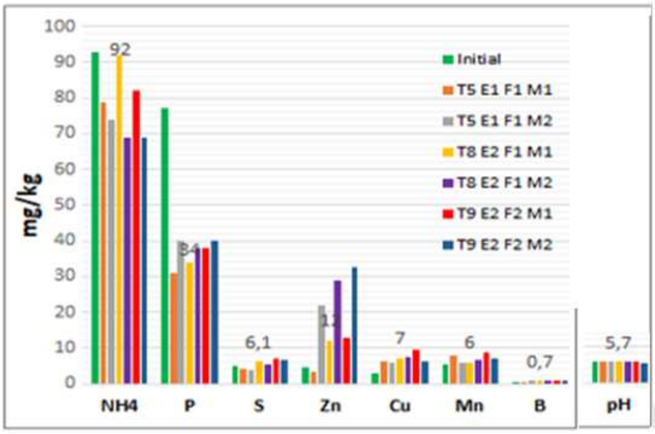

Fig. 7 Content of NH4, P, S, Zn, Cu, Mn, B (ppm) and pH, at the Beginning, Intermediate and End of the Test

The bases of change obtained at the beginning (M1) and end of the trial (M2), and presented in Fig. 8, indicate that these varied depending on the time and treatments. Overall, the content of K in the soil was low (0.21 meq 100 ml $^{-1}$), Ca (7.4 meq 100 ml^{-1}) medium and Mg (2.14 meq 100 ml^{-1}) medium to high. There is a high ratio in the content of Ca in relation to K and Mg and even more of Mg / K, relationships that affect the nutritional balance of the edaphic solution of nutrient absorption due to its antagonistic nature, which is produced between nutrients by interactions between ions with similar physicochemical properties such as valence and / or the diameter of the ion, Examples: NH4/K, Ca/K, P/Zn, Mn/Mg and others. The low content of K in the soil also indicates that these soils tend to fix K+, respecting their characteristics of volcanic soils with a high content of allophynic minerals that fix K, so it is recommended to keep the soil at levels and humidity close to the ability to counteract the fixation of K+ in the soil. For Mg^{2+}, an average content is reflected, whose relationship with K^+ and Ca^{2+} is less adequate.

The soil is alive, it is not a static element there develops the biochemical and microbial activity of trillions of fungi, bacteria and other organisms, which is essential for the maintenance of the health of the soil and plants. Fungal diversity is associated with land use [39] compared to bacteria, and they are approximately equal in weight. As soils become compact, larger pores are removed, where soil animals, such as earthworms and beetles, live and function, hence in compacted soils it decreases [13].

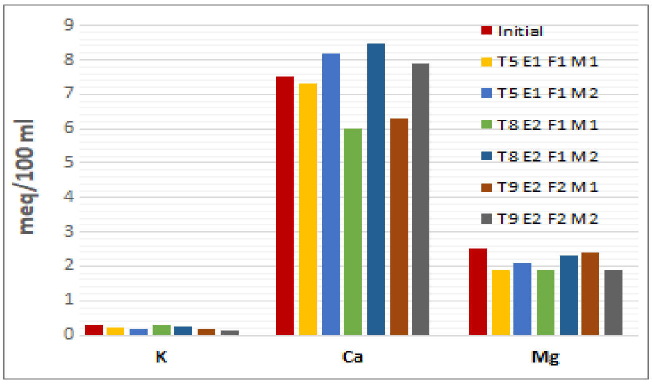

Fig. 8 Content of exchangeable bases in the soil, in meq / 100 ml (cmol +/ kg), during the test.

Finally, and as a reflection, crops in generally Excessive fertilization has negative impacts on the soil, and microbial life, that plants grow weak and glean too much, since each crop has its specific fertilization needs, the general recommendation is to control the electrical conductivity of the soil, its pH and the nutrient content of the substrate to fine-tune the amount of fertilizer application to the maximum and avoid damage to the soil-plant system.

IV. Conclusion

Fertilization and chemical amendments positively affected the production of the forage mixture. The highest yield of the green matter was obtained with the application of amendments and fertilization (F2) based on limestone and phosphate rock, with 19.9 and 19.4 t ha^{-1} average/cut. Whereas, for the same modifications without fertilization, it was around 15.7 t ha^{-1} average per cut for each. The same favorable effect was observed with dry matter production, where amendments E1 (agricultural lime) and E4 (phosphate rock) reached 3.01 and 2.90 t ha^{-1} average per cut, respectively, yields that are within the average (2.85 t ha^{-1}) per dry matter cut of perennial ryegrass (Lolium perennial). Magnesium silicate had a slow reaction in the first cuts and the best soil responses occurred 100 days after its application. The use of gypsum (E2) with high fertilization (F2) acidified the soil (pH 5.5) while gypsum with low fertilization increased the pH (5.72) of the soil. To improve a pasture, it is recommended to first apply the amendment and fertilization in the next cut to increase the availability of added nutrients in fertilizers, which will be reflected in the increased botanical composition and increased forage productivity of the prairie. In addition, fertilization should be carried out according to the element that is in the least amount.

References

[1] FAO, *Base referencial mundial del recurso suelo 2014 Sistema internacional de clasificación de suelos para la nomenclatura de suelos y la creación de leyendas de mapas de suelos . 106*. FAO, Roma, 2015.

[2] J. Vázquez, M. Alvarez, S. Iglesias, and J. Castillo, "The incorporation of organic amendments in the form of compost and vermicompost reduces the negative effects of monoculture in soils," *Sci. Agropecu.*, vol. 11, no. 1, pp. 105–112, 2020, doi: 10.17268/sci.agropecu.2020.01.12.

[3] M. Morocho and M. Leiva, "Microorganismos eficientes, propiedades funcionales y aplicaciones agrícolas," *Cent. Agrícola*, vol. 46, no. 2, pp. 93–103, 2019.

[4] A. Ortiz A., E. Arboleda Z., and M. Medina Sierra, "Calidad bromatológica del pasto kikuyo en respuesta a la inoculación con hongos micorrícicos y fertilización química," *Rev. Investig. Vet. del Perú*, vol. 32, no. 3, Jun. 2021, doi: 10.15381/rivep.v32i3.17645.
[5] E. R. Basantes Morales, *Manejo y Conservación del Suelo. Física de Suelos y uso en tierras agrícolas del Ecuador*, 1ra. Edici. Sangolquí-Ecuador, 2019.
[6] E. R. Basantes Morales, *Producción y Fisiología de Cultivos con énfasis en la Fertilidad del Suelo*. Quito-Ecuador: Imprenta La Unión. Quito-Ecuador. ISBN: 978-9942-02-336-0, 2010.
[7] C. Celestina, J. R. Hunt, P. W. G. Sale, and A. E. Franks, "Attribution of crop yield responses to application of organic amendments: A critical review," *Soil Tillage Res.*, vol. 186, pp. 135–145, Mar. 2019, doi: 10.1016/j.still.2018.10.002.
[8] O. López-Vigoa *et al.*, "Evaluación del valor nutricional de los forrajes en un sistema silvopastoril.," *Pastos y Forrajes*, vol. 42, no. 1, p. 19, 2019.
[9] E. R. Basantes, J. Barba, R. León, S. X. Basantes Aguas, and J. Mohiddin, "Evaluation of pasture honey (Setaria sphacelata) by fertilization effect and amendment chemistry, in northwestern Pichincha-Ecuador," *Ciencia*, vol. 20, no. 2, pp. 119–130, 2018.
[10] P. A. Portillo, D. H. Meneses, S. P. Morales, M. Cadena, and E. Castro, "Evaluación y selección de especies forrajeras de gramíneas y leguminosas en Nariño, Colombia," *Pastos y Forrajes*, vol. 42, no. 2, pp. 93–103, 2019.
[11] L. Innotec, "La importancia de los análisis foliares. ¿Qué es un análisis foliar?," 2021.
[12] K. W. T. Goulding, *Soil acidification and the importance of liming agricultural soils with particular reference to the United Kingdom*, vol. 32, no. 3. 2016, pp. 390–399.
[13] F. Magdoff and V. E. Harold, *Building Soils for Better Crops Ecological. Management for healthy soils*, Fourth Edi. Sustainable Agriculture Research and Education (SARE) program, USDA, 2021.
[14] D. Tinoco and J. S. Bayuelo, "Formas y distribución de fósforo en un Andisol con sistemas contrastantes de uso del suelo del centro de México," *Terra Latinoam.*, vol. 39, no. e881, pp. 1–11, 2021, doi: https://doi.org/10.28940/terra.v39i0.881.
[15] J. Michajluk, "Evaluation of silicon content in soil through nuclear analytical techniques," *Rev. Científica la UCSA*, vol. 6, no. 3, pp. 18–22, Dec. 2019, doi: 10.18004/ucsa/2409-8752/2019.006.03.018-022.
[16] M. del M. Delgado, K. L. Mendoza, M. I. González, J. L. Tadeo, and J. V. Martín, "Evaluación del proceso de compostaje de residuos avícolas empleando diferentes mezclas de sustratos," *Rev. Int. Contam. Ambient.*, vol. 35, no. 4, pp. 965–977, Nov. 2019, doi: 10.20937/RICA.2019.35.04.15.
[17] Anjum and A. Khan, "Decomposition of soil organic matter is modulated by soil amendments," *Carbon Manag.*, vol. 12, no. 1, pp. 1–14, Dec. 2021, doi: 10.1080/17583004.2020.1865038.
[18] USDA, "Relación Carbono-Nitrógeno en los agroecosistemas - Cultivos de Servicios," *soils.usda.gov/sqi*, 2019.
[19] J. Vázquez, M. Alvarez, S. Iglesias, and J. Castillo, "La incorporación de enmiendas orgánicas en forma de compost y vermicompost reduce los efectos negativos del monocultivo en suelos," *Sci. Agropecu.*, vol. 11, no. 1, pp. 105–112, Mar. 2020, doi: 10.17268/SCI.AGROPECU.2020.01.12.
[20] J. Girón, "Enmiendas de Suelo en el cultivo de café," *Bol. técnico CEDICAFÉ*, pp. 1–8, 2018.
[21] E. Basantes-Morales, M. M. Alconada, and J. L. Pantoja, "Quinoa (Chenopodium quinoa Willd) Production in the Andean Region: Challenges and Potentials," *J. Exp. Agric. Int.*, vol. 36, no. 6, pp. 1–18, 2019, doi: 10.9734/jeai/2019/v36i630251.
[22] N. M. Espinel Pérez, "Aprovechamiento de roca fosfórica, por vía térmica, para la obtención de termofosfatos," *Rev. Invest. (Guadalajara).*, vol. 12, no. 2, pp. 113–133, Aug. 2020, doi: 10.29097/2011-639X.266.
[23] M. Beltrán, R. Romaniuk, C. Herrmann, A. Fernandez, F. Mousegne, and F. Jecke, "Roca fosfórica y yeso agrícola: complemento a la fertilización tradicional en el cultivo de soja," *Cienc. del suelo*, vol. 37, no. 1, p. 9, 2019.
[24] P. A. Beltran Barriga, R. Corrêa de Lima, A. Brugnara Soares, T. Simioni Assmann, and A. W. Canaza Cayo, "Intensidad de pastoreo y fertilización nitrogenada sobre la altura de Lolium multiflorum Lam. en un sistema de integración agricultura-ganadería," *Agron. Costarric.*, vol. 44, no. 2, pp. 127–137, 2020, doi: 10.15517/rac.v44i2.43104.
[25] S. L. Ramón, "' Respuesta de la fertilización química y enmiendas complejas en una pradera establecida ,'" Tesis previa a la obtención del título de Ing. Agropecuario. ESPE., 2012.
[26] R. D. Giraldo, M. C. Ramírez, and D. Castro, "Efecto de la aplicación de las fuentes convencionales de calcio (cales) en el suelo, en la concentración de Ca en tejido y en la biomasa del pasto kikuyo," *Rev. Univ. Católica Oriente*, vol. 31, no. 46, pp. 113–126, 2020.
[27] B. P. Benalcázar, V. López, F. Gutiérrez, S. Alvarado, and A. Portilla, "Efecto de la fertilización nitrogenada en el crecimiento de cinco pastos perennes en Ecuador," *Pastos y Forrajes*, vol. 44, pp. 1–9, 2021.
[28] E. Lerma, J. L.; Chañag, H. A.; Meneses, D. H.; Ojeda, Hernán Ruiz, Hugo & Castro, "Evaluación de métodos de renovación de praderas en el trópico alto de Nariño, Colombia," *Pastos y Forrajes*, vol. 43, no. 2, pp. 120–128, 2020.
[29] E. V. Maliberan, "Forecasting Enrolment Data of Surigao del Sur State University, Philippines using Regression Analysis and Multiplicative Decomposition Model," *Int. J. Adv. Sci. Comput. Eng.*, vol. 3, no. 1, pp. 1–9, 2021.
[30] Y. Nain, "Time Series Modeling and Forecasting of Monthly Mean Sea Level (1978 – 2020): SARIMA and Multilayer Perceptron Neural Network," *Int. J. Data Sci.*, vol. 3, no. 1, pp. 45–61, 2022.
[31] S. H. S. Herho and G. A. Firdaus, "Time-Series Analysis and Statistical Forecasting of Daily Rainfall in Kupang, East Nusa Tenggara, Indonesia: a Pilot Study," *Int. J. Data Sci.*, vol. 3, no. 1, pp. 25–32, 2022.
[32] J. L. Lerma, J. Zapata, and et al, "Efecto de enmiendas calcáreas en la productividad y la calidad de Medicago sativa (L.) en Colombia," *Pastos y F orrajes*, vol. 43, no. 3, pp. 190–200, 2020.
[33] I. Zapata, J. F. Zamora, M. N. Trujillo, and E. Ramírez, "¿La incorporación de residuos de diferentes especies de Lupinus, como abono verde, afecta la actividad microbiana del suelo?," *Rev. TERRA Latinoam.*, vol. 38, no. 1, p. 45, Jan. 2020, doi: 10.28940/terra.v38i1.501.
[34] FAO, "La ganadería y el medio ambiente," 2022.
[35] Y. Malpartida, R. Julian, F. Aldana, S. Sánchez, P. Lobo, and R. J. M. Y, "Valor Nutricional y Compiuetos Bioactivos de la Espirulina : Potencia Suplemento," *Ecuadorian Sciernce Journal. GDEON, Ecuador*, vol. 6, no. 1, pp. 42–51, 2022, doi: https://doi.org/10.46480/esj.6.1.133.
[36] J. J. Zapata, P. A. Portillo, D. H. Meneses, and E. Lagos, "Evaluación agronómica de forrajes con inclusión de enmienda dolomita en Nariño, Colombia," vol. 44, no. 1, pp. 345–351, 2021.
[37] T. Bozhanska and B. Churkova, "Correlation and regression relationships between quantitative and qualitative indicators of perennial grass and legume mixtures," *Bulg. J. Agric. Sci.*, vol. 26, no. 3, pp. 567–573, 2020.
[38] S. A. Murillo, A. Mendoza, and C. J. Fadul, "La importancia de las enmiendas orgánicas en la conservación del suelo y la producción agrícola," *La Rev. Colomb. Investig. Agroindustrial*, vol. 7, no. 1, pp. 58–68, Dec. 2019, doi: 10.23850/24220582.2503.
[39] F. Valle *et al.*, "Diversidad fúngica en suelos con diferentes usos en la región pampeana Argentina," *Chil. J. Agric. Anim. Sci., ex Agro-Ciencia*, vol. 35, no. 2, pp. 163–172, 2019.
[40] IAEA, "El uso equilibrado de fertilizante gracias a las técnicas nucleares contribuye a aumentar la productividad y a proteger el medio ambiente | OIEA," *Artículo del Boletín del OIEA*, 2020. .