Phenological study of cultivated pastures in Moyocancha used for alpaca (Vicugna pacos) feeding

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Abstract

The objective of the research was to determine the phenology of cultivated pastures (Avena sativa) for alpaca feeding. The study was carried out at the Estación de Altura Aña Moyocancha, belonging to the Escuela Superior Politécnica de Chimborazo, Facultad de Ciencias Pecuarias, located 85 km from Riobamba. The experimental units were related to soil characterization, taking 25 samples, 3 samples were used for bromatological analysis, 100 seeds were used for germination percentage, and the phenological evaluation of forage oats, three altitudinal levels were considered (3829, 3831 and 3833 m.a.s.l.), each with 9 replications, using 27 samples at this stage. A completely randomized design was applied for the evaluation of phenological variables, while descriptive statistics were used for the other variables, with emphasis on measures of central tendency (mean) and measures of dispersion (standard deviation). The results showed that all phenological variables such as plant height, basal cover, number of stems per plant, number of leaves per stem, density and green forage production at 30 and 60 days of the evaluation showed no significant differences ($p > 0.05$), indicating that there was no effect on phenology by altitudinal levels. The soil analysis was rich in nitrogen 0.51 + 0.03%, high in phosphorus 338.03 + 16.80 mg/kg and medium in potassium 20 + 0.01 mg/l. The bromatological study showed that the nutritional value is around 14.36 + 0.29% crude protein and 19.80 + 0.66% crude fiber covering the dietary needs of the alpaca. Concluding that the forage oats adapted to the three altitudinal levels with an average production of 13.25 tn/ha, it is recommended to use this forage species to feed South American camelids.

Keywords: *phenology, alpaca (vicugna pacos), germination, forage oats (avena sativa), South American camelids [csa], botanical composition.*

1. Introduction

South American camelids are species of great importance in the inter-Andean region because they allow the processes of conservation of the páramo (Márquez, 2019, p. 2), one of the main benefits it has is its fiber as it is used in the manufacture of clothing and its meat has high levels of protein and is low in fat characteristic that has it for its type of food that is healthy and natural exclusively based on native pastures and sometimes in cultivated pastures (Contreras, 2019, p. 26).

Cultivated pastures have high levels of forage biomass, thus allowing the possibility of managing a greater number of animals per hectare; the higher the nutritional quality, the better the performance, increasing the productivity of the alpaca (Contreras, 2019, p. 27).

Currently, the breeding and exploitation of the alpaca have been gaining importance by several institutions of the public and private sector, under processes of importation of reproducers and training processes to improve the racial and genetic characteristics, as well as the generation of management techniques.

The high altitude station "Aña Moyocancha" is one of the references in which alpaca breeding is developed, being generated in a research center, with production processes for feeding alpacas with natural pastures and improved pastures (fodder oats).

The research sought to respond to the need to know the phenology of the cultivated pastures of the Estación de Altura Aña Moyocancha under the parameters of soil quality, germination percentage and the nutritional value of forage oats through bromatological characterization, providing the alpaca with quality food resulting in quality fiber.

With the aforementioned context, the study sought to establish a cultivated pasture to cover the alpaca's food requirements, determine the forage oats' nutritional and bromatological composition, and define the phenology and composition of the forage oats.

2. Materials and methods

The research was carried out at the Aña Moyocancha High Altitude Station of the Faculty of Livestock Sciences of the Escuela Superior Politécnica de Chimborazo, located 85 km from the city of Riobamba, Alausí canton, Tixan parish, between the communities of Silveria Santa Lucia and the Ozogoche lagoons.

The characteristics of the meteorological conditions were: average temperature of 6.95 ºC, at an altitude of 3700 m.a.s.l., with a relative humidity of 91.31% and average precipitation of 991.7 mm/year. The research was part of the project "Floristic Inventory of the Protected Forest of the Aña Moyocancha High Altitude Station" of the Escuela Superior Politécnica de Chimborazo, which lasted 8 months.

The size of the experimental unit was determined according to the phase of the study, considering the different phases of the experiment. 25 samples were considered for the soil study, 3 samples for the bromatological analysis, 100 seeds for the laboratory germination process and 100 seeds for the phenological evaluation of the forage oats; the altitude was considered as a variable, defining three altitudinal levels (3829, 3831 and 3833 m.a.s.l.), each of these altitudes with 9 replications, for a total of 27 samples.

2.1. Methods for soil analysis

Nitrogen content, potassium content, potassium content

2.2. Methods for the evaluation of phenological characteristics

Plant height, basal cover, number of stems per plant, number of leaves per stem, density, green forage production, etc.

2.3. Methods for bromatological analysis of forage oats.

Moisture content, ash content, crude protein content, ethereal extract content, crude fiber content, etc.

According to the treatment and experimental design of the study, for the establishment of the meadow, the soil analysis and the percentage of germination of the forage oats were carried out, so in this phase, a defined experimental design was not used. In evaluating the phenological characteristics, the altitude of the meadow was considered a study factor, so for this phase, a completely randomized design was used, corresponding to 3 treatments (altitudes of 3829, 3831 and 3833 m.a.s.l.), each with 9 replications.

For soil characterization, germination percentage, nutritional quality assessment of forage oats and botanical composition, descriptive statistics were used, emphasizing the measures of central tendency (mean) and dispersion (standard deviation); while for the study of phenological characteristics, taking the altitude of the meadow as a study factor, the analysis of variance (Adeva) $p > 0.05$ and the separation of means by Tukey's test ($p > 0.05$) were performed.

3. Results and discussion

3.1. Establishment of the pasture for alpaca feeding.

3.1.1. Chemical and physical soil analysis

Hydrogen potential: The variable presented a value of 6.25 ± 0.04, which can be considered a slightly acid soil which agrees with (Espinosa, 2017), in that slightly acid soils are those in a range of 6.0 to 6.9 pH. For the Agrarian Cooperative Society (AGROPAL, 2021), forage oats develop well in a pH of 6.05, slightly acid soil with which it presents better yields and higher productivity. A slightly acid soil is linked to the loss of cations that leads to acidification; the loss is related to the permeability characteristic of soils of sandy textural class, such as the soil analyzed.

Electrical conductivity: presented a value of 85.15 + 1.15 us/cm. For (Simon et al., 2017), this value corresponds to a non-saline soil (E.C. < 120 us/cm). On the other hand, a study conducted by (Lopez et al., 2020) on an intervened moor in the province of Cotopaxi obtained 95.12 us/cm of electrical conductivity, being higher than the 85.15 us/cm of the research, this is likely due to the infiltration of water into the soil, causing a washing of salts from the surface; where infiltration is closely related to the sandy loam textural class of the soil analyzed.

Organic matter: this variable presented a value of 6.24 ± 0.10 %. For (López et al., 2020), this value corresponds to a soil with a medium percentage of organic matter (5-10%) for cold climates. Compared with the study conducted by (Ciancaglini, 2016) in intervened paramo soils at an altitude of 3830 m.a.s.l. obtained a value of 5.30%., a value lower than that obtained in the research at 6.24%. This fact could be due to the presence of alpacas at the time of sampling; as stated by (Navarro, 2017), who states that alpaca manure is a sustainable source of nutrients and is considered an important source of organic matter, in addition to providing a high content of nitrogen and potassium and an average level of phosphorus.

On the other hand (Garrido, 2017), classified the percentage of soil organic matter as low, for values below 5%, for values between 5% to 10% as medium and high for those values above 10%.; the soil analyzed was considered as medium organic matter content, this may be due to grazing pressure, animal weight and the amount of alpaca excreta.

Nitrogen: an average of 0.51 ± 0.03% was recorded. For (Ciancaglini, 2016), this value corresponds to soil extremely rich in N as its value exceeds 0.221%. On the other hand, research conducted by (Pruna, 2016) in an intervened moor in the province of Cotopaxi obtained 0.55% nitrogen; this value is minimum to that of the research 0.51%, so it can be stated that nitrogen remains stable despite environmental changes. However, it may be linked to the quality and type of soil. For his part (Altamirano, 2017) affirmed that nitrogen is the nutrient most absorbed and required by forage oats since it increases yield and nutritional quality.

Table 1. Chemical and physical analysis of the soil.

Variables	Unit	Average	Standard deviation
pH		6.25	0.04
Electrical conductivity	us/cm	85.15	1.15
Organic matter	%	6.24	0.10
Nitrogen	%	0.5134	0.03
Phosphorus	mg/kg	338.03	16.80
Potassium	mg/l	20.00	0.01
Actual density	g/cm3	0.69	0.01
Texture		Sandy loam	

Phosphorus: a value of 338.03 ± 16.80 mg/kg was found. For (Ciancaglini, 2016), this value corresponds to soil high in phosphorus (> 100 mg/kg). A study conducted by (Espinosa, 2017) in an intervened moor at an altitude of 3835 m.a.s.l. obtained a value of 350. 62 mg/kg; value higher than that reported in the research 338.03 mg/kg; this could be influenced by the soil's acidity or, in turn, the altitude and environmental conditions.

Potassium: the variable reported a value of 20 ± 0.01 mg/l. For (Ciancaglini, 2016), this value corresponds to an average potassium soil (20 to 40 mg/l). However, a study conducted by (Pruna, 2016) in an intervened moor in the province of Cotopaxi obtained 35 mg/l; this being a higher value than the research 20 mg/l, this could be due to the type of sandy loam soil, prolonged drought or low pH soils and this is not available to the roots. For his part, Pruna (2016) affirmed that phosphorus and potassium help develop tissues and form the root system.

Texture: The sandy loam textural class was determined, which in its structure has 69.6% sand, 24% silt and 6.6% clay. For (Ciancaglini, 2016), the textural class, sandy loam, comprises soils with 50-70% sand, 0-50% silt and 0-20% clay in its structure. On the other hand, (Jaramillo, 2017) classified these soils as having moderately coarse texture; found in this research 69.6% sand, 24% silt and 6.6% clay which indicates that it is within the established range to be a soil of moderately coarse texture and sandy loam textural class. In the same way, López (2017) determined that forage oats presented optimal growth and excellent development in soils with a clay-loam or sandy loam texture, coinciding with the sandy loam textural class obtained in the research.

3.1.2. Germination percentage

Table 2. Germination Percentage

Variable	Unit	Average	Standard deviation
Germination percentage	%	72.4	2.51

The germination percentage of forage oat seeds was 72.4 ± 2.51%, at a temperature of 22°C, a response that is considered lower than that reported by (Altamirano, 2017), who found that the germination rate of good quality seeds is between 80 and 100%, variation that may be due to the temperatures used for the aforementioned analysis, since in the cited study he used temperatures between 18 and 25°C. Another study conducted by (Sepa, 2017), where he evaluated the germination percentage of fodder oat seeds at a temperature of 15°C where he obtained values of 62 to 65% being these lower than those reported in the research 70 to 75% at a temperature of 22°C, this behavior

could be due to the temperature (> 18°C) at which the research was carried out; temperature plays an important role in favoring or hindering germination percentages.

3.2. Bromatological characterization of forage oats.

Table 3: Bromatological characterization of forage oats.

Variables	Unit	Average	Standard deviation
Humidity	%	53.11	3.82
Ashes	%	7.27	0.70
Crude protein	%	14.36	0.29
Ethereal extract	%	1.47	0.01
Crude fiber	%	19.81	0.66

3.2.1. Humidity

The moisture percentage presented an average of 53.11 ± 3.82 %, representing that the higher the moisture, the lower the dry matter content in the grass. Studies conducted by (Jimenez, 2016) reported a moisture content of 68.97%, which is higher than the research's 53.11%. This may be due to the phenological age at which the cut was made. For the results obtained, it should be considered that moisture plays an important role in the maintenance of pastures; the stimulation of moisture is important to evaluate the water stress of vegetation and to accurately determine the amount of dry matter in the different species make up the diet of alpacas.

3.2.2. Ashes

The ash variable recorded a content of 7.27 ± 0.70 % value lower than that reported by Paredes et al. (2018), where he found an ash percentage of 8.2%; this could be due to the botanical composition of the pasture, or in turn to the fertilization of the meadow.

3.2.3. Crude protein

The crude protein variable obtained an average of 14.36 ± 0.29 %, and the protein level is an indicator of quality. It means that, when consumed by the animal, it will increase its productive indexes, this value higher than that reported by Paredes et al. (2018), who determined a protein percentage of 8.70%; it could be due to the phenological age of the pasture or to the high amount of nitrogen present in the soil where the research was developed. Another study conducted by Mendoza et al. (2021) presented a protein content of 14.45%, a value higher than the

14.36% of the research, which the stages could directly influence what the plant goes through throughout its vegetative cycle. Research carried out by Quispe et al. (2021) suggests that a diet low in protein can cause a decrease in growth, length and fiber volume in alpacas. Protein is the most important part of the alpaca diet since it is an essential component and, at the same time, required for maintaining vital functions such as reproduction, growth and lactation. On the other hand, for Butinza (2001), 15 - 16% is recommended as the ideal content for alpacas in lactation or the last third of gestation, while 12% is recommended for weaned or non-pregnant alpacas.

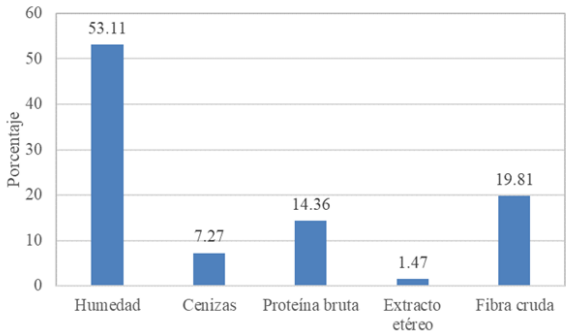
3.2.4. Ethereal extract

The ethereal extract variable recorded a content of 1.47 ± 0.01 %. For (Jimenez, 2016) determined a fat content of 1.51%; a value similar to that found in the research 1.47%; the ethereal extract is characterized by making the food more appetizing, facilitating the absorption of fat-soluble vitamins A, D, E, K.

3.2.5. Crude fiber

The crude fiber variable presented an average of 19.80 ± 0.66 %. When this result is compared with those of Jiménez (2016), which found a fiber content of 19.30%, indicating that this value is lower than that of the research 19.80%, which may be due to the phenological age at which the grass was cut, the more mature the grass was cut, the higher the fiber content due to the lignification of the cell walls. In the diets of small ruminants, fiber is important and necessary for the maintenance of ruminal function, stimulation of mastication and maintenance of adequate ruminal pH for digestion of the grass. According to Butinza (2001), the ideal fiber content is 20 to 25% of the diet of lactating alpacas, alpacas in the last third of gestation, and weaned or non-pregnant alpacas.

Figure 1. Bromatological characterization of forage oats.



3.3. Determination of phenology and botanical composition of forage oats.

3.3.1. Phenological analysis of forage oats at 30 days of established pasture.

The phenological analysis carried out 30 days after the establishment of the forage oat pasture did not report significant differences ($p>0.05$) due to the effect of altitudes, obtaining an average plant height of 23.78 cm, a basal coverage of 15.18 %, 2.60 stems/plant, 4.74 leaves/plant and 23.74 plants/m.2

Table 4. Phenological analysis of forage oats 30 days after the establishment of the pasture.

Response variables	Altitude (masl)			Average	Standard error
	3829	3831	3833		
Plant height, cm	28.73 a	23.07 a	19.56 a	23.78	3.07
Basal coverage, % Basal coverage, % Basal coverage, % Basal	14.11 a	16.67 a	14.78 a	15.18	0.77

coverage, % Basal coverage, % Basal coverage, %					
Number of stems per plant, No.	2.44 a	2.67 a	2.67 a	2.60	0.27
Number of leaves per stem, No.	5.22 a	5.22 a	3.78 a	4.74	0.46
Density, N° plants/m^2	19.78 a	25.33 a	26.11 a	23.74	2.08

Note: Means with a common letter are not significantly different

When comparing this information with the results obtained by Silva (2017), where he evaluated the phenology of forage oats at an altitude of 3853 m.a.s.l. at 40 days; it differs from the study in plant height and basal coverage, being Castro's 32.40 cm and 20.10% in their order, respectively; values higher than those found in the research average plant height of 23.78 cm and a basal coverage of 15.18%; this difference could be because at the Añа Moyocancha Height Station, this type of pasture is just being established while Silva may have evaluated an already established pasture, so also being this a tender pasture the phenological characteristics are not high in comparison with other species, while the variables number of stems per plant, number of leaves per stem and density presented a similarity to the data reported by Silva who presented 2.65 stems/plant, 4.82 leaves/stem and 23.82 N° plants/m2.

3.3.2. Phenological analysis of forage oats at 60 days of established pasture.

At 60 days after the establishment of the forage oat pasture, the phenological characteristics were evaluated, where the different response variables did not show significant differences ($p>0.05$) due to the effect of altitudes, also showing an average plant height of 24.42 cm while at 30 days it was 23.78 cm, so that a cutting date of 30 to 35 days could easily be established because the difference between these two evaluations is 1 cm.

Table 5. Phenological analysis of forage oats 60 days after the establishment of the pasture.

Response variables	Altitude (masl)			Average	Standard error
	3829	3831	3833		
Plant height, cm	29.00 a	23.81 a	20.47 a	24.42	3.07
Basal coverage, % Basal coverage, % Basal coverage, % Basal coverage, % Basal coverage, % Basal coverage, %	14.89 a	17.22 a	15.33 a	15.81	0.77
Number of stems per plant, No.	2.78 a	2.89 a	2.78 a	2.81	0.27
Number of leaves per stem, No.	5.22 a	5.22 a	3.78 a	4.74	0.46
Density, N° plants/m^2	19.78 a	25.33 a	26.11 a	23.74	2.08
Green forage production, Tn/ha	13.40 a	13.42 a	12.93 a	13.25	0.40

Note: Means with a common letter are not significantly different

The other variables analyzed showed a basal cover of 15.81%, 2.81 stems/plant, 4.74 leaves/stem, 23.74 plants/m2 and 13.25 tn/ha.

When contrasted with the results presented by Castro (2015), which evaluated the plant height and green forage production of forage oats at 60 days at an altitude of 3819 m.a.s.l. in the moorlands of the Monjas Bajo commune, Cayambe canton obtaining 16.05 cm and 10.15 tn/ha; values lower than those found in the research, average plant height 24.42 cm and 13.25 tn/ha; this could be due to the altitude at which the research was carried out, since forage oats develop better in soils with temperatures of 10 to 17°C for the same reason that they are tolerant to frost and cloudiness.

3.4. Botanical composition of the prairie

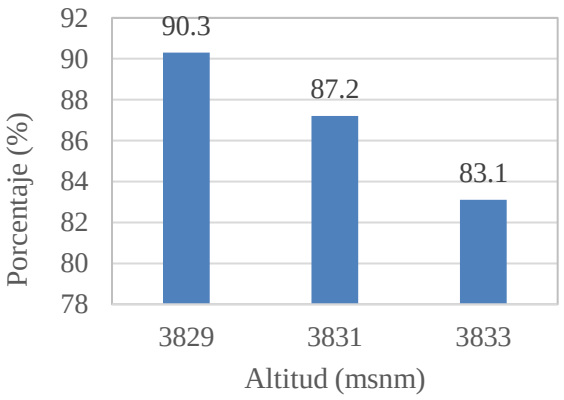
Table 6. Botanical composition of the prairie.

Composition (%)	Species	Altitude (masl)			Average		Standard deviation
		3829	3831	3833			
Grasses	Fodder oats	90.30	87.20	83.1	86.87	±	3.61
Weeds	*Sonchus oleraceus*	5.40	11.74	8.71	8.61	±	3.17
	Pennisetum clandestinum	4.30	1.02	8.17	4.49	±	3.58

3.4.1. Percentage of grasses

The average rate of grasses recorded was 86.87 ± 3.61 %, a value higher than that reported by Rivera (2017) and Zabala et al. (2018), who obtained 72.48% and 65.37% in their order, respectively. For his part, Rios (2017) stated that a monoculture should contain 100% of grasses or legumes; when comparing this data with that of the research, 86.87 ± 3.61%, a value lower than the percentage of grasses accepted in a monoculture was obtained, for Jimenez (2016), one of the most important factors in the management of pastures is the qualitative and quantitative identification of the different plant species present in these as grasses, legumes and weeds.

Figure 2. Composition of grasses (fodder oats)

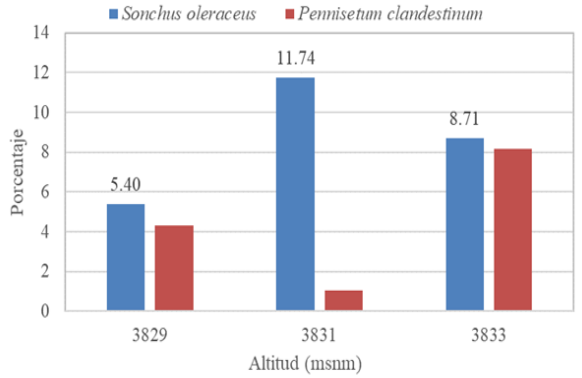


3.4.2. Percentage of weeds

Regarding the percentage of weeds, an average of Sonchus oleraceus 8.61 ± 3.17% and Pennisetum clandestinum 4.49 ± 3.58% was appreciated, obtaining an average of 13.13% in weeds, a higher value than that reported by Florez (2018), who obtained 9.58%. For his part, Jiménez (2016) stated that a monoculture

should contain 10% of weeds; when comparing this data with that of the research 13.13 ± 0.08%, a value higher than the percentage of weeds accepted in a monoculture was obtained. For Rivera (2017), these compete with grasses for space, water and nutrients, and are hosts of pests and diseases, make pasture management difficult, hinder animal consumption and impact production costs by reducing animal productivity.

Figure 3. Weed composition



4. Conclusions

- The meadow soil of the Aña Moyocancha High Altitude Station is fertile, despite having an average organic matter content of 6.24 + 0.10%, being rich in nitrogen 0.51 + 0.03%, high in phosphorus 338.03 + 16.80 mg/kg and average in potassium 20 + 0.01 mg/l.

- The germination percentage of forage oat seeds was 72.4 ± 2.51% at a temperature of 22°C.

- At 30 days, the forage oats had a height of 23.78 cm, with a coverage of 15.18%, having 2.60 stems per plant and 4.74 leaves per stem.

- At 60 days, the forage oats had a height of 24.42 cm, with a coverage of 15.81 %, 2.81 stalks per plant, 4.74 leaves per stalk, and 13.25 tn/ha production of green forage.

- The bromatological composition of the forage oats presented a moisture content of 53.11 ± 3.82%, crude fiber 19.80 ± 0.66%, crude protein 14.36 ± 0.29%, ash 7.27 ± 0.70% and ethereal extract 1.47 ± 0.01%.

- The botanical composition of the pasture showed a percentage of grasses 86.87 ± 3.61% of forage oats and weeds 8.61 ± 3.17% of Sonchus oleraceus and 4.49 ± 3.58% of Pennisetum clandestinum.

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