# Arial phytomass production and growth rate in Andean grasslands, at harvesting and application of natural fertilizers

## Abstract

The grassland ecosystems in the central Andes of Peru have extensive vegetation formations dominated by tussock species that are not consumed by Andean livestock (llamas, alpacas, and sheep), so they are set on fire by rural inhabitants with the intention of causing tender shoots, with serious consequences for the ecosystem and its ecosystem services. The objective of the research was to evaluate initial phytomass production, as well as the speed of growth and production of shoots after the cutting harvest, with the aim of articulating a project for the production of vegetable fiber from 5 of the most common species in the area. For the evaluation, 5 plots of 900 $m^2$ were fenced, including 50 subplots of 32 $m^2$, under the effect of the application of cattle manure and phosphate rock. Monthly monitoring was carried out from October 2020 to June 2021. Significant differences in phytomass production and growth were observed between the effect of applied fertilizer, plant species, and altitudinal location of the plots for $p \leq 0.01$; likewise, a high canonical correlation between biological variables (canopy cover, canopy height, and dry matter production) and climatic variables (maximum temperature, minimum T. in °C and precipitation in liters/$m^2$) was also observed.

Keywords: Tussock grasslands shoot growth monitoring, natural inputs, climate correlation

## 1. Introduction

Andean tussock grasslands are vegetation type covered by, mainly the genus *Calamagrostis, Festuca,* and *Jarava* (Mosquera et al., 2022) that, very little or almost nothing is consumed by animals, due to their high cellulose and lignin content (Wang et al., 2018); however, they fulfill very important environmental functions such as carbon sequestration, regulation of the hydrological system, maintenance and protection of Andean biodiversity, soil cover, etc (Bremer et al., 2019). Unfortunately, due to the little use by Andean livestock in the view of local ranchers, these ecosystems are threatened through the burning of grasslands, with the idea of causing a tender shoot that can be used for grazing (Yaranga, 2019).

This anthropogenic action not only causes the loss of vegetation cover and accumulated organic carbon but also compromises the integral health of the ecosystem, affected by soil degradation due to the heat generated by the fire, the loss and extinction of small grassland species that were protected by tall species, providing seed capable of being propagated in overgrazed areas (Jan et al., 2021), thus reducing the capacity for self-regeneration of the grassland ecosystem. In this understanding, the alternative of converting Andean grasslands into a source of plant fiber as a construction material for housing (Velásquez et al., 2016), is being studied in another project.

However, the reversal of the threat to the tussock grasslands through burning, custody, and maintenance, we are sure that the ranchers will do it, as the sale of the plant material will mean an additional economic benefit to their income from livestock activity. For this, it is necessary to generate knowledge on the speed of growth of the shoot caused by the cutting of leaves and stems of the plants, and the production of new useful phytomass, which will serve as a basis for organizing strategies for sustainable use of ecosystems with tussock grasslands. The recovery capacity of the cut grassland depends on several factors, however, for the present study it has been prioritized to explain the growing phenomenon of climate, expressed in temperature and rainfall; to soil amendment through the application of cattle manure and phosphate rock.

According to Jiang et al, (2017), precipitation and temperature are the climatic factors involved in plant growth, and plants respond to the stimulation of soil water available to the roots (Liu et al, 2018), however, the increase of precipitation out of normal, as well as the shortage of precipitation, can influence the change of the phenological evolution of the plant (An et al., 2020); on the other hand, plants are adapted to a comfortable temperature range that optimizes plant development and life cycle, limiting or nullifying such possibility in extreme conditions or outside the comfort range (Wang et al., 2020).

Human intervention through soil fertilization with natural inputs such as phosphate rock and cattle manure helps plant nutrition, depending on their composition and degree of mineralization (Jouany et al., 2021). In this understanding, phosphate rock provides, in addition to inorganic phosphorus, very important microelements in plant nutrition (Zapata and Roy, 2007) which, due to its poorly soluble nature and slow mineralization, constitutes an effective fertilizer alternative in the case of natural grasslands (Jouany et al., 2021); meanwhile, cattle manure provides organic matter that enlivens the soil and the nitrogen necessary for plants (Elouear et al., 2016). This function varies according to the animal species and the diet they consume (Wang et al., 2018).

Experience related to this study is very scarce, but there have been some studies related to the observation of the phenology of some species, indicating that the shoot begins between November and December, flowering between February and April and seeding between April and May (Durand et al. 2007; Huarancca, 2010; Altamirano and Ircañaupa, 2020). The net aerial primary production of these species in natural condition was reported by Yaranga et al. (2021) for *Calamagrostis intermedia* 383±18.6 grams per plant (g/p), for *C. antoniana* 313±17.6 g/p, *Festuca rigidifolia* 216±23.1 g/p, *Festuca sp* 182±24.3 g/p, and *C. tarmensis* 104±21.6 g/p.
In this context, the objective was to monitor the shoot regrowth of five grassland species: *Calamagrostis intermedia*, *C. antoniana*, *C. tarmensis*, *Festuca rigidifolia* and *F. sp*, through the measurement of the average height of the canopy at the leaf tray level, canopy cover and phytomass production, during 9 months of control, on plots fertilized with cattle manure and phosphate rock.

## 2. Material and methods

### 2.1 *Study area*

The study was carried out in the Acopalca community in the central mountain range of Peru, located between UTM coordinates L18 S: 481880, E 8672695 and 4941157, E 8683594 between 3498 and 5510 meters above sea level (masl) (Figure 1), at East of the Mantaro Valley. This rural community is populated by rural families who raise cattle, sheep, and Andean camels. The grasslands are distributed above 3800 masl, but the study plots were located between 4012 and 4333 masl. In this environment, the average seasonal temperature varies from -8°C at night to 16.2°C during the day in the dry period (May to September) and from 4°C to 12°C in the rainy period (October to April) and the average annual rainfall of 1170 mm per year.

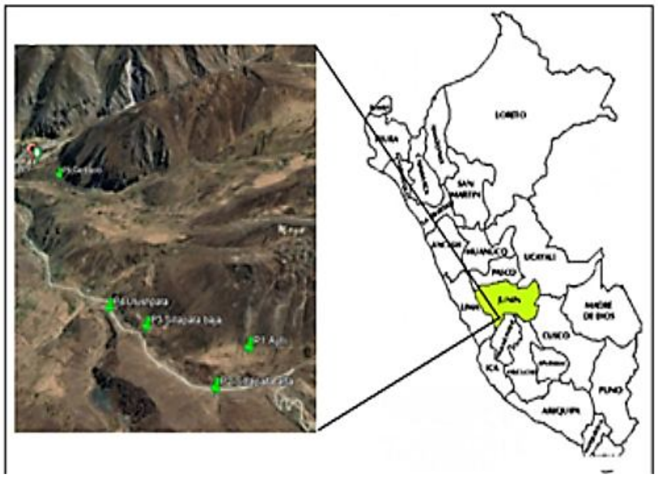


Figure 1. Location of the study area in the central Andes of Peru.

*1.1 Data collection*

The experimental plots were selected by convenience, taking into account the dominance of a species of interest in the area, where a 900 m2 plot was fenced considering the method suggested by Otzen & Manterola, (2017), with wooden posts and barbed wire. Inside the plot, 5 subplots of 64 m2 were marked dividing it into two parts, to fertilize them with the broadcast application of cattle manure (4000 kg per hectare) and phosphate rock (1500 kg/ha) with P2O5 from 18 to 22%, CaO from 28 to 30%, MgO from 0.5 to 0.6% and SO4 from 3 to 5%. This action was replicated in five plots spaced 0.8 to 3 km apart.

*Measurement of canopy cover and height of shoot leaves.*

In each subplot and type of fertilization, 10 plants were randomly selected, i.e. 20 plants per subplot, 100 plants per plot, and 500 plants for the experiment, in addition, 10 additional plants were marked in each plot located outside the subplots that served as control plants or without fertilization effect. All selected plants, after identification of the species at the Universidad Nacional del Centro del Perú, were cut manually using a metal sickle, at an average height of 3 to 5 cm in September 2020. Data collection began 30 days after cutting. First, the height of the shoot was measured in centimeters, with 3 measurements in different parts of the plant with the help of a flex meter graduated in cm, recording the resulting average as data. Secondly, the average canopy cover of the leaves was measured, for which the vertical projection of the flag of leaves was measured in cm, making two measurements in the form of a cross. With these data, the following formula was used to calculate the foliage cover adopting the ellipsoidal shape of the plant:

$$\text{Canopy cover (CA)} = r*r*\pi \text{ (Botana and Recio, 2013).}$$

Where r = radius, $\pi$ = constant

These measurements were performed monthly from October 2020 to June 2021.

*Measurement of phytomass production*

The last measurement in June 2021 was carried out including the material cut from the monitored plant, in the same way as the initial cut, i.e., the phytomass obtained was weighed in grams with the help of a digital hand scale with milligram precision, then the stems were separated from the leaves and weighed to obtain the yield of stems per plant. Finally, samples of the cut material per plant were extracted, packed, and after identification sent to the Microbiology Laboratory of the National University of Central Peru, for drying in an oven at 105 °C for 24 hours, for final weighing and to obtain the percentage of dry material, with which the total dry weight of the plants in grams (DM) was calculated.

A canonical correlation analysis was also performed between the biological variables: canopy cover, canopy height, and phytomass production, with environmental variables: low temperature, maximum temperature, rainfall, and the monthly amount of rain accumulated in each plot, using the software PAS vs. 3. 14, under the multiple linear correlation model: $X = (X_1, X_2, X_p) and Y=(Y1, Y2,..., Yq)Y=(Y1, Y2,..., Yq) recommended by Trendafilov & Gallo ( 2021).

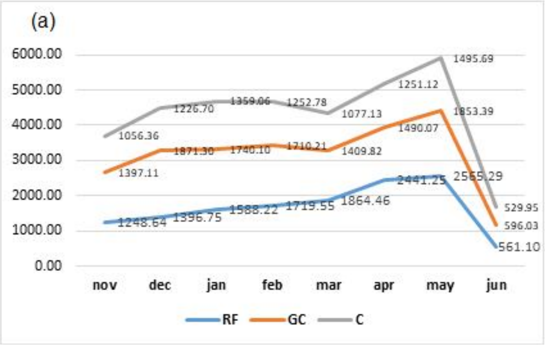
## 3. Results

### *3.1 Canopy cover in cm$^2$*

The canopy covers of the shoots according to the fertilizer applied, in the control plants progressed from 529.95 to 1495.69 cm$^2$ during the 9 months of control, while in the plots fertilized with cattle manure it increased from 596.03 to 1853.99 cm$^2$, and in the plots fertilized with phosphate rock, it increased from 561.10 to 2565 cm$^2$ (Figure 2a). At the statistical analysis, the maximum canopy cover reached by the effect of fertilization with phosphate rock was higher with an average of 2783±162 cm$^2$, then the fertilized with cattle manure with an average of 2199±166 cm$^2$ and finally the control plants with 1866±428 cm$^2$, different for $p \leq 0.01$ (Figure 3.b).

The canopy covers of the shoots compared between plots, resulted as follows: the plot located in Aylli (P1) showed an average growth of 1055.3 to 2689.21 cm$^2$ in April, decreasing to 2233.98 cm$^2$ in June; in the high Sillapata (P2) it increased from 1859.26 to 2920.95 cm$^2$ in May, decreasing to 1976. 32 cm$^2$ in June; in low Sillapa (P3) it increased from 1860.07 cm$^2$ to 2920.70 cm$^2$ in May, decreasing to 2515.95 cm$^2$ in June; in Otush palla (P4) plants were observed with less expansion and canopy cover of 370.28 and 902.04 cm$^2$ in June, and in Gerbacio (P5) it progressed from 1024.60 to 1484.98 cm$^2$ in June. At the statistical analysis for the end of the period of measurements, plot P1 was superior with 2909±192 cm$^2$ for $p \leq 0.05$, followed by plots P3 and P2 with averages of 2480±207 and 2109±204 cm$^2$ finally plots P4 and P5 with averages 1818±802 and 1533±508 cm$^2$ (Figure 3.a).

At the species level, the canopy cover resulted as follows: *Calamagrostis intermedia* changed from 4081.46 to 2897.06 cm$^2$, in *C. antoniana* from 4464.10 to 2162.87 cm$^2$, *C. tarmensis* from 10503.76 to 4934.05 cm$^2$, in *Festuca rigidifolia* from 15196.83 to 2567.31 cm$^2$, and in *F. sp* from 8305.30 to 2951.21 cm$^2$. At the statistical analysis of the final measurement in June 2021, the species *C. intermedia* was superior with a mean of 2975±200 for $p \leq 0.05$, followed by *C. antoniana* with 2642±277 cm$^2$, finally followed by *F. sp*, *F. rigidifolia,* and *C. tarmensis* with 2089±272, 2082±193 and 2067±876 cm$^2$ respectively (Figure 3e).



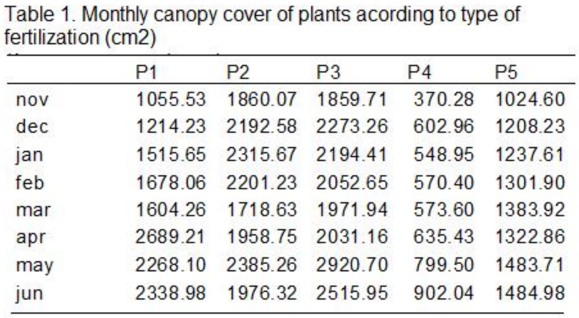


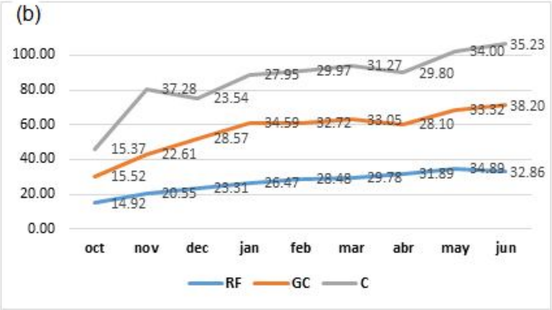
Table 1. Monthly canopy cover of plants according to type of fertilization (cm2)

| | P1 | P2 | P3 | P4 | P5 |
|---|---|---|---|---|---|
| nov | 1055.53 | 1860.07 | 1859.71 | 370.28 | 1024.60 |
| dec | 1214.23 | 2192.58 | 2273.26 | 602.96 | 1208.23 |
| jan | 1515.65 | 2315.67 | 2194.41 | 548.95 | 1237.61 |
| feb | 1678.06 | 2201.23 | 2052.65 | 570.40 | 1301.90 |
| mar | 1604.26 | 1718.63 | 1971.94 | 573.60 | 1383.92 |
| apr | 2689.21 | 1958.75 | 2031.16 | 635.43 | 1322.86 |
| may | 2268.10 | 2385.26 | 2920.70 | 799.50 | 1483.71 |
| jun | 2338.98 | 1976.32 | 2515.95 | 902.04 | 1484.98 |

Figure 2a. Canopy cover progress by fertilizer type and, Table 1 Canopy cover progress by plot location effect.

### *3.2* Canopy *height in cm*

The comparison between canopy height of the shoots by fertilizer effect (Figure 2b) resulted as follows: control plants showed growth from 15.37 to 35.23 cm; plants fertilized with cattle manure progressed from 15.52 to 38.20 cm; plants fertilized with phosphate rock from 14.92 to 34.89 cm. In the statistical analysis, the maximum height reached corresponds to the plants fertilized with cattle manure with an average of 40.2±0.72 cm for $p \leq 0.05$, followed by those without fertilization with an average of 38.2±1.82 cm, and finally those fertilized with phosphate rock with 33.8±1.82 cm in height (Figure 3b).



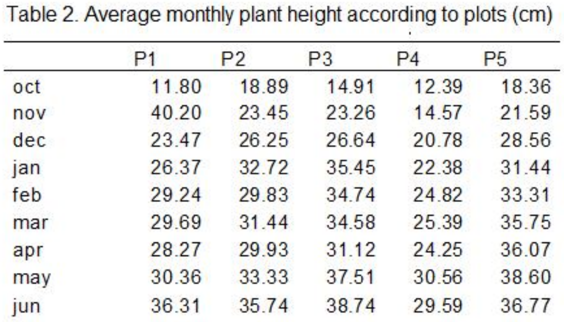


Table 2. Average monthly plant height according to plots (cm)

| | P1 | P2 | P3 | P4 | P5 |
|---|---|---|---|---|---|
| oct | 11.80 | 18.89 | 14.91 | 12.39 | 18.36 |
| nov | 40.20 | 23.45 | 23.26 | 14.57 | 21.59 |
| dec | 23.47 | 26.25 | 26.64 | 20.78 | 28.56 |
| jan | 26.37 | 32.72 | 35.45 | 22.38 | 31.44 |
| feb | 29.24 | 29.83 | 34.74 | 24.82 | 33.31 |
| mar | 29.69 | 31.44 | 34.58 | 25.39 | 35.75 |
| apr | 28.27 | 29.93 | 31.12 | 24.25 | 36.07 |
| may | 30.36 | 33.33 | 37.51 | 30.56 | 38.60 |
| jun | 36.31 | 35.74 | 38.74 | 29.59 | 36.77 |

Figure 2b. Leaf height progress according to the type of fertilizer applied (b) and canopy height progress table according to the location of the plots.

The comparison between leaf height of the shoots at the plot level (Figure 2b, Table 2) showed the following results: P1 plants showed an average growth of 11.80 to 36.36 cm, in P2 from 18.89 to 37.74 cm, in P3 from 14.19 to 38.74 cm, in P4 from 12.39 to 29.59 cm, and finally in P5 from 18.36 to 36.77 cm. In the statistical analysis, no significant difference was found for $p \leq 0.05$, however, the averages were: for P1 = 36.9±0.89 cm, P2 = 36.4±0.95 cm, P3= 37.8±0.96 cm, P4 = 32.8±3.62 cm and P5= 38.3±2.31 cm (Figure 3.d).

Regarding the growth of the species, *C. antoniana* was greater for $p \leq 0.01$ with an average of 40.3±1.24 cm, followed by *C. intermedia* with 38.5±0.91 cm, then *F. sp* with 35.2±1.22 cm, followed by *F. rigidifolia* with 35.1±0.88 cm and finally *C. tarmensis* with 33.2±3.86 cm for $p \leq 0.05$ (Figure 3f).

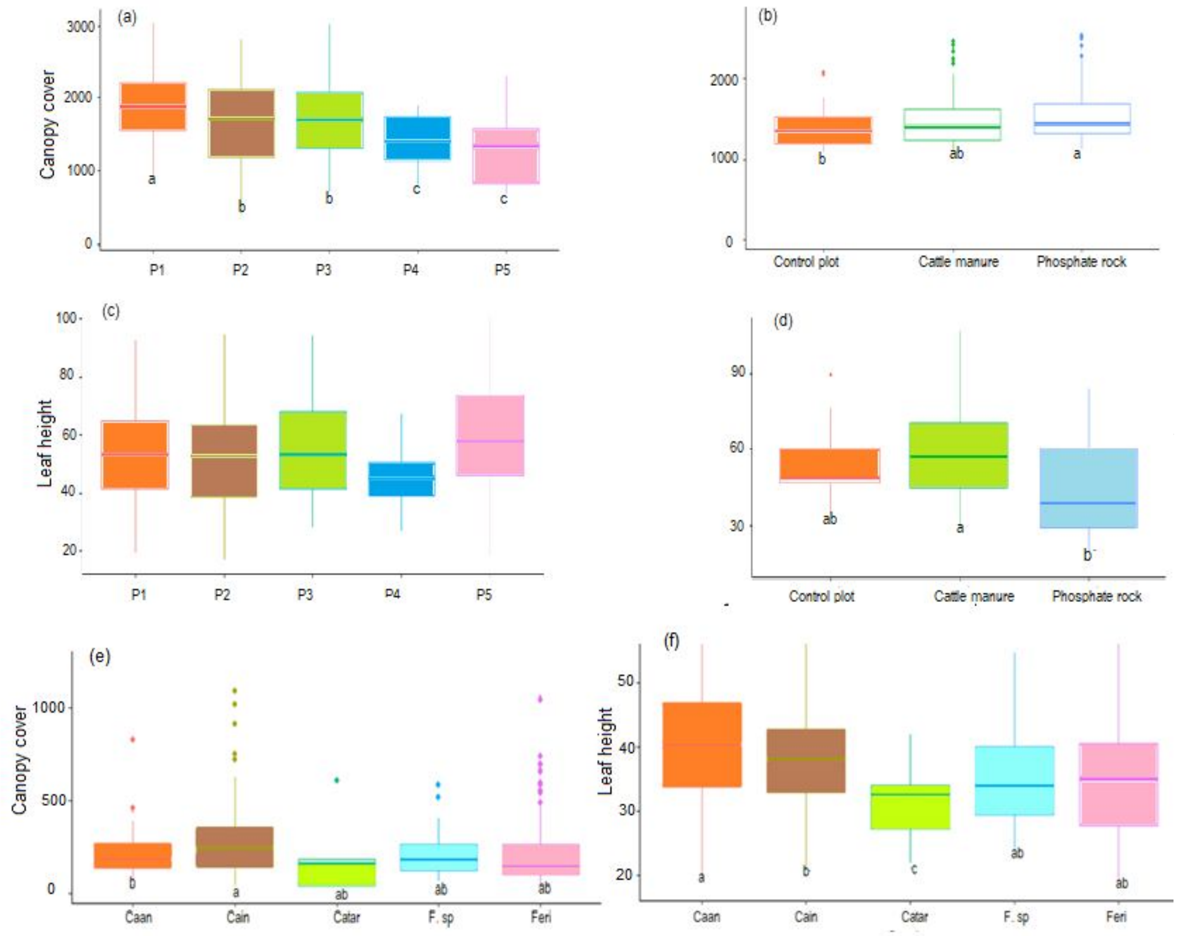


Figure 3. Least Significant Difference (LSD) of a) canopy cover by plots, b) canopy cover by fertilizer, d) leaf height by plots, c) canopy height by fertilizer.

### *3.3 Net aerial primary production*

The net aerial primary production of the shoot, of the different species evaluated, reached the following average values:

For the effect of applied fertilization, it has been observed that there was no significant difference for $p \leq 0.05$, however, the results obtained were as follows: in the subplots fertilized with phosphate rock reached the average of 109.5±6.72 g/p, in those fertilized with cattle manure it reached 88.8±6.72 g/p and finally the control plants with 93.5±15.03 grams/plant (g/p) (Figure 4a).

For plot location effect it was observed that P1, P2, and P3 were greater for $p \leq 0.01$ with 129±9.11, P2 125.2±9.11, and 124.2±9.11 g/p, followed by P5 with 70.7±9.11 g/p, finally P4 with 44±9.11, P5 g/p (Figure 4b). Regarding the effect of plant species, it was observed that *Calamagrostis intermedia* (Cain) species was greater for $p \leq 0.05$ with 162.4±8.49 g/p followed by *Calamagrostis antoniana* (Caan) 109.6±7. 60, then by *Festuca rigidifolia* (Feri) with 81.3±8.48 g/p, finally the species *Festuca sp* (F. sp) with 59.9±9.14 g/p and *Calamagrostis tarmensis* (Cata) with 49.4±11.52 g/p with statistical similarity (Figure 4c).

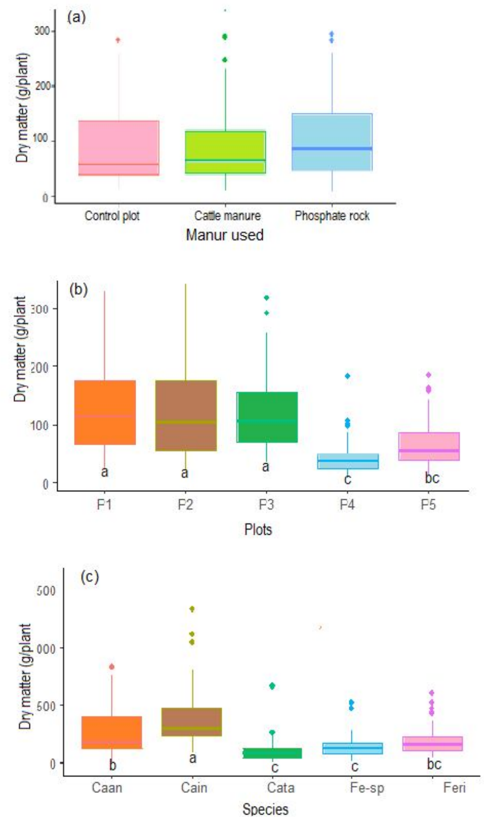


Figure 4. LSD of net aerial primary production: a) effect of applied fertilizer, b) effect of plot location, and c) effect of plant species.

### *3.4 Canonical correlation between biological and environmental variables*

In the understanding that rainfall is one of the most important variables in the development of plants, it has been observed that the altitudinal variation was very marked among the control plots, on the other hand, the rainfall distribution pattern during the year showed an abnormal distribution, since the rainfall in November 2020 was zero, likewise, the rainfall in February 2021 was scarce, which does not correspond to the maximum level of rainfall that corresponds to it in the reference pattern observed in the last 30 years. As shown in Figure 5a, only 41.58 l/m2 was recorded in February compared to 164.57 l/m2 in January, while March and April with 77.99 and 72.61 l/m2, and then drop to 6.71 and 1.59 in April and May are normal characteristics of the dry seasonal period (Yaranga et al., 2021).

Under these conditions, the canonical correlation was evaluated between the climatic variables: minimum temperature, and maximum temperature both in °C registered at the landscape level, at the Acopalca Meteorological Station of the National Service of Meteorology and Hydrology of Peru, and with the monthly rainfall registered in each plot in liters/square meter (l/$m^2$); with the biological variables: canopy cover in $cm^2$ and canopy height in cm. The biological variables have not shown an evident association with the rainfall variable in the rainy period, since they remain very close to the origin of the quadrants located in the third quadrant; while at the factor level the rainy months and maximum temperature show some tendency to be associated in the fourth quadrant (Figure 5b), it was also observed that the month of June showed a high positive correlation with low temperature, which means that the more rain shortage the temperatures are lower and this directly affects the production of aerial biomass. The canonical correlation was explained with 92.58% of the information on axis 1.

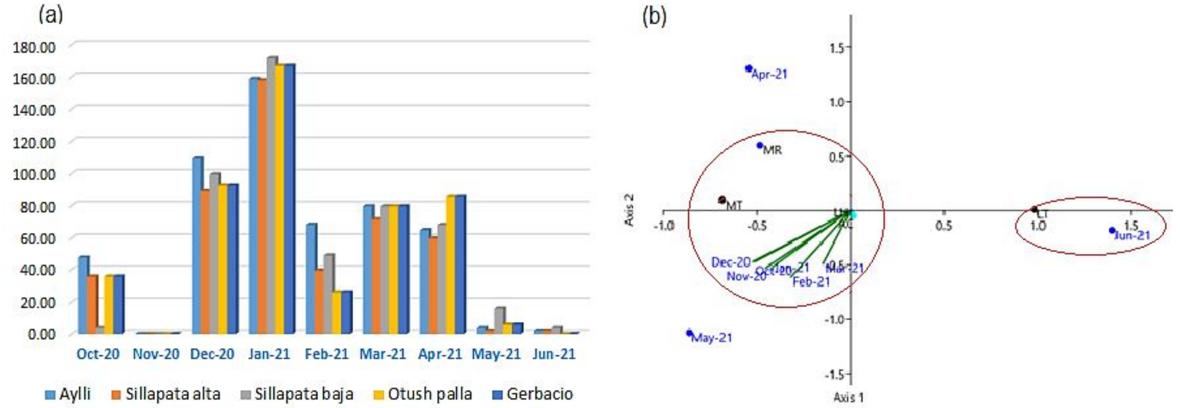


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Figure 5. a) Distribution of monthly rainfall in each plot (P1= Aylli, P2= Sillapata Alta, P3= Sillapata Baja, P4 Otushpalla and P5= Gerbacio), b) canonical correlation between climatic variable: MT = maximum temperature, LT = low temperature, and MR= monthly rainfall; and biological variables: AC= canopy cover, LH = leaf height.

## 4. Discussion

### *4.1 Canopy cover*

The morphological characteristics of grasses have been frequently measured to evaluate the forage quality of certain ecotypes adapted to specific environmental conditions (Morales et al., 2016;) using various morphological descriptors, mainly related to the characteristics of leaves and stems, as well as their dry matter production capacity and nutritional quality for livestock (Morillo et al., 2016), 2016), which has also been of interest for the present study, related to the regeneration capacity of the plants after cutting and dry matter production (Yaranga et al., 2021). under the effect of three factors as detailed in the chapter on materials and methods.

The use of rock phosphate favored a greater expansion of the leaf flag of the plants, which depends on the length and weight of the leaf (Carlyle et al., 2014). This is enhanced by the action of phosphate as an indispensable macronutrient for key metabolic processes in plants, such as cell division, energy generation, macromolecule biosynthesis, membrane integrity, signal conductance, photosynthesis, and plant respiration (Rawat et al., 2020), in addition, upon solubilization in the soil by the action of phosphate solubilizing microorganisms, which secrete organic acids: citric acid, oxalic acid, and succinic acids; enzymes such as phosphatases and phytases; and ion chelators (Rolando et al., 2017; Rawat et al., 2020), even though, the phosphate rock finishes solubilizing in the soil beyond 3 years (Rajan et al., 1991), which indicates that the action of the rock applied in the present study is still incipient, because to fully observe the agronomic effectiveness, it is required at least between 2 to 3 years; as long as the evaluated plants are not cut before this period.

Plants on soils applied with cattle manure, equally outperformed control plants, due to the effect of washing of fresh organic matter that was incorporated into the soil with the contribution of carbon (C), nitrogen (N), soluble phosphorus (P), and sulfur (S) (Mulyani et al., 2019; Marzi et al., 2020), which are mineralized in a shorter time compared to other organic matter from plant sources, but may vary according to the leaching process of soluble compounds and the decomposition of soluble and non-lignified cellulose and hemicellulose; this process is related to local temperature and humidity (Zhu et al., 2020). Cattle manure spread on the soil has not yet shown its real effect, due to the scarce mineralization, which indicates that it is necessary to wait for the culmination of the slow transformation process (Marzi et al., 2020).

In the inter-species comparison, *C. intermedia* and *C. antoniana* showed greater canopy cover, due to the size they reach and the length of the leaves that ranges between 30 to 45 cm, which facilitates generating a greater projection of cover, in addition to the greater development of canopy with a large number of tillers (Tovar, 1993), while the *Festucas* showed less canopy cover, due to their smaller size with less leathery and weak leaves that project less canopy cover (Catorci et al., 2014), finally the species *C. tarmensis* has thinner and semi-rigid leaf blades (Tovar, 1963). At the field level, it has been observed that the latter species grow with a higher plant density, which does not allow it to develop greater canopy projection.

*Canopy height*

Canopy height was shown to be higher in those subplots where cattle manure was applied, which provided soluble N and P (Das et al., 2016) and also favored soil bacterial growth, through enzymatic activities and provision of microelements (Wang et al., 2017), which would have positively favored vertical growth with more solid leaves that resisted rapid incurvation; thus gaining greater leaf height; meanwhile, fertilizers with phosphate rock, allowed the growth of less solid leaves that rapidly incurved, losing vertical stability (Elouear et al., 2016). However, upon the comparison between plots locations, no significant difference was observed, because the differences found in foliage cover and plant height were homogeneous in the five plots.

The difference in the canopy height between species is based on the morphological nature of the species, since *C. antoniana* and *C. intermedia* are very tough and leathery species, with more solid canes (Tovar, 1993), while the others have thin leaves and thinner canes (Catorci et al., 2014, Yaranga et al., 2021). However, in the field observation, it has been noted that the period of measurement performed was not enough because the plants had not yet reached full maturity, and the culmination of the experiment was interrupted prematurely for the financial cut. This comment suggests that further measurements should be scheduled beyond 12 months.

*Net aerial primary production*

The small quantitative difference observed for the effect of fertilization, for the net aerial primary production of shoots, does not allow us to state properly whether or not there is a significant difference due to the effect of fertilization, because of three aspects that should be taken into account: a) the short observation time, during which the fertilizers used would have only just started the mineralization process (Marzi et al., 2020) and therefore, the plants would not have experienced the potential benefits of the fertilizers, b) the observed plants would not have reached full maturity due to insufficient time of morphological development (Gray et al., 2020) and, c) by the end of the measurements the plants would have reduced their photosynthetic function due to the scarcity of rainfall occurred in April, May, and June (Mastalerczuk & Borawska-Jarmułowicz, 2021).

The superiority of the first three plots in dry matter production is based on: a) the dominant species *C. intermedia* and *C. antoniana* are plants with greater tillering with more solid and thicker leaves and stems, compared to P4 where the species *C. tarmensis* has the opposite morphology (Tovar, 1993), b) the P4 and P5 plots have more shallow soils and a light brown color, which is indicative of soils with lower carbon concentration, organic matter, and nitrogen, due to their higher concentration of silt plus clay particles containing Fe oxides (Moritsuka et al., 2021). This reaffirms that soil characteristics determine not only plant cover but also plant productive capacity (Mulyani et al., 2019; Marzi et al., 2020). Concerning the comparison between species, it was noted that the same species with higher tillering, thicker leaves, and stems, behaved as more productive species, due to the morphological difference compared to the other three species (Tovar1993).

Finally, it was found that the production of dry matter harvested from leaves and stems of the shoots was not similar to the original production observed by Yaranga et al. (2021) when evaluating these same species under original conditions: *Calamagrostis intermedia* 383±18.6 g/plant, *C. antoniana* 313±17.6 g/plant, *Festuca rigidifolia* 216±23.1 g/plant, *Festuca sp* 182±24.3, and *C. tarmensis* 104±21.6 g/plant, reaffirming that the shoots caused by cutting or other anthropogenic actions reduce the productive capacity compared to the original one (Wang et al, 2020).

*Canonical correlation between biological and environmental variables*

Many studies on global climate change affecting precipitation and temperature, reveal that the normal distribution pattern observed in the last 20 to 30 years become increasingly irregular (Adu-Boahen et al., 2019; Méndez et al., 2019), which is manifested with greater intensity at the local scale, as has been observed in Acopalca conditions, where the precipitation level was shown to be abnormal in November and February. This irregularity directly affects crop and pasture production yields in general (Carlyle, Fraser, & Turkington, 2014; Adu-Boahen et al., 2019); however, the effect of this abnormality on shoot growth was not very evident, because soil moisture remains beyond the days with rain, as long as the shortage is not very prolonged (Tenelanda-Patiño, 2018).

The rainy months (October to March) and maximum temperature, were the closest parameters that favored the growth of regrowth (Muñoz, 2017; Tenelanda-Patiño, 2018), due to the higher concentration of chlorophyll in the plants in these periods, which allows greater growth and accumulation of dry matter (Chang et al., 2017), meanwhile, the less rainy months showed contrarily the disarticulation of these parameters with the biological variables, which would explain that plants continue to grow or remain alive due to the morphological transformation of grassland species, expressed in the greater vertical growth of roots in search of water (Padilla et al., 2019; Jun et al., 2020)

## 5. Conclusions

Some benefit has been observed in the biological indicators of the plants evaluated 9 months after cutting, by the action of the use of cattle manure and phosphate rock on the control plots; however, the benefit of the treatment has not been fully evidenced, due to the control time that was insufficient for the optimal mineralization process, so a proper assessment in grassland species with the fertilizers used should be done in a longer period. The location of the plots is another factor of variation both for precipitation received, and the soil characteristics that showed different colors, although 4 plots were oriented South-West. The morphological structure of the species is a determining factor in expressing the production of aerial phytomass, which indicates that not all species of grassland will have the same productive potential and supply of plant fiber, as a base material for the manufacture of construction elements. It has been reaffirmed that precipitation and high temperature are highly correlated with the productive development of grassland species; however, the plants have continued their development despite the period with low rainfall and low temperature as a function of plant ecological adaptation to the conditions of altitude, soil and temperature changes.

## References

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