Impact of Level of Use on Plant Vigor and Weight of *Festuca humilior and Calamagrostis vicunarum*

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Abstract. Tussock grasslands of Festuca humilior and Calamagrostis vicunarum cover a significant extension of the central Andes of Peru, constituting a plant association highly appreciated by cattle ranchers. The objective of this research was to estimate the cumulative impact of the level of use of the key grasses Festuca humilior and Calamagrostis vicunarum on plant height, vigor, and weight. This study was conducted in a humid grassland of regular condition located at 4186 masl in the Puna ecoregion. The variables evaluated were: plant height, basal and canopy diameter and plant weight. The experiment lasted two years in which individual plants from both species were cut every four months. The vigor resulted from the regression of the weight (g) and the volume (cm3) of the plant. Height (cm) was the length from the soil surface to the flag leaf. The experimental design was a randomized block design with a 2x3 factorial arrangement, two species and three height removal levels: zero, 40 and 80%. The height, vigor and weight of Festuca humilior and Calamagrostis vicunarum decreased in response to increasing use levels, but the changes were more evident in Festuca than in Calamagrostis. While the decrease in the evaluated variables was constant for Festuca humilior as the level of use increased, Calamagrostis also decreased, but to a lesser extent, remaining almost unchanged when biomass removal levels changed from moderate to heavy, suggesting that this species was more tolerant to grazing. The results helped explaining why in fields dominated by Festuca humilior and sub-dominated by Calamagrostis vicunarum subjected to intense grazing, dominance relationships change in favor of Calamagrostis, a species of lower forage value than Festuca humilior. It is recommended to manage the grazing system under a low-intensity and low frequency regime

Introduction

Puna grasslands, a complex of plant associations dominated by the Festuca, Stipa and Calamagrostis, cover more than seventy percent of the territory of the central Andes, geographically constituting one of the most important ecosystems in terms of provision of environmental goods and services, highlighting its contribution to food security and hydrological regulation services (Flores, 2016). Despite their ecological and economic importance, many of the areas dominated by grasslands exhibit marked signs of deterioration in their ecological condition and state of health, mainly due to disturbances caused by changes in land use, poor grazing practices, burning and water and climate change (Rolando et al., 2007). Vegetation ecologists have reported the existence of multiple plant associations and transition states; however, the one that concentrated the interest of many livestock producers and researchers is *Festuca humilior* - Calamagrostis *vicunarum* association for its value in sustaining relatively high levels of livestock production in comparison to other associations and subtypes of tussock grasslands, existing in the Puna ecoregion.

Festuca and Calamagrostis differ in their life history strategies Calamagrostis begin flowering earlier than Festuca and its seeds have higher percentages of viability and purity than Festuca (Castro et al., 2021) giving it and advantage to occupy the open spaces generated by overgrazing. The indicators of competition and abundance of these species changed markedly within a grassland in relation to the nature of the disturbance. *Festuca humilior* is dominant and *Calamagrostis vicunarum s*ubdominant in well-managed fields, but when stocking and grazing pressure exceed certain thresholds, competitive relationships change and Calamagrostis, a species of lower forage value, dominates the plant community, and the condition of the pasture deteriorates. (Yngill et al., 2021).

In this study, the hypothesis that the changes in the abundance relationships of both species could be explained by a greater tolerance to grazing by Calamagrostis vicunarum was evaluated.

Study Area and Research Methods

The experimental area was located in the central Andes of Peru at an altitude of 4186 m 11°57' 16.47" S, 75°42'24.89" W, belonging to the very humid Paramo – tropical subalpine life zone. The vegetation composition was 37% grasses, 50% herbs and 13% pseudograsses. The dominant grass was *Festuca humilior* (30.54%) and the subdominant *Calamagrostis vicunarum* (16.33%). The soils are deep, with a sandy loam texture and belong to the Mollisol order.

The study was carried out in a fenced area of 2500 m2 (50m x 50m). The experimental treatments included two dominant grasses, *Festuca humilior* (Fehu) and *Calamagrostis vicunarum* (Cavi) and three levels of use expressed as a percentage of the height removed (control 0%, moderate 40% and heavy 80%). A total of 18 plots were installed, six per treatment each of 60 m2, within which height removal levels were simulated every four months during a period of two consecutive years, coinciding with the early rain season (november), rainy season (march), and dry season (july).

Three variables (height, plant vigor, and plant weight) were evaluated for two consecutive years. The height was measured as the length from the soil surface to the last leaf, the plant vigor was the volume of the plant and the weight was the regression of this variable with the volume. The resulted regression equations for each studied species were:

$$\text{Fehu Weight (g)} = 0.0050\ (\text{Volume, Fehu}) + 2.6681$$
$$R^2 = 0.6404$$

$$\text{Cavi Weight (g)} = 0.0034(\text{Volume Cavi}) + 0.5054$$
$$R^2 = 0.6527$$

The experimental design was a randomized complete block with a factorial arrangement of two factors (plant species and levels of plant height removal) and three blocks. A total of two plant species (*Festuca humilior* and *Calamagrostis vicunarmu)* and three levels of plant height removal were studied.

Results and Discussion

Festuca humilior significantly reduced its dimensions and weight compared with the control group (0%) as the level of use increased (Table 1). This suggested that it is a plant susceptible to grazing that may not exhibit a compensatory response which is an increase in the growth rate even at moderate levels of use, as mentioned by the grazing theory (McNauthon, 1985).

Table 1. Influence of the level of use (%) on height, vigor and weight of Festuca humilior and Calamagrostis vicunarum plants.

Variables	**Level of use (%)**		
	0	**40**	**80**
		Festuca humilior	
Height (cm)	15.7 [(a)]	10.8 [(b)]	6.6 [(c)]
Plant Vigor (cm^3)	2880.2 [(a)]	1783.4 [(ab)]	1051.0 [(b)]
Plant Vigor (g)	17.1 [(a)]	11.6 [(ab)]	7.9 [(b)]
		Calamagrostis vicunarum	
Height (cm)	9.8 [(a)]	6.8 [(b)]	6.1 [(b)]
Plant Vigor (cm^3)	215.2 [(a)]	68.3 [(b)]	74.7 [(b)]
Plant Vigor (g)	1.2 [(a)]	0.7 [(b)]	0.8 [(b)]

Different letters in the same row are significant with the Duncan test ($p<0.05$).

Rangeland specialists recommend removing half and leaving half of the weight of the plant to ensure adequate recovery of its vegetation after grazing (Huss et al., 1986), protect and improve the resistance of the ecosystem to the stresses imposed by the environment (Lyons and Hanselva, 2001). The plant-herbivore relationship theory hypothesizes that plants can respond in three ways when grazed: decrease, maintain, or increase their growth rate (Brisky, 1991). The results of this trial revealed that *Festuca humilior* could be a type of plant that rapidly reduces its productivity as herbivore pressure increases (Figure 1). This suggests that this species should be grazed under a low-intensity and low-frequency grazing regime to maintain its vigor, competitive capacity and dominance in the plant community and optimize its use in grazing systems (Zarria and Flores, 2016).

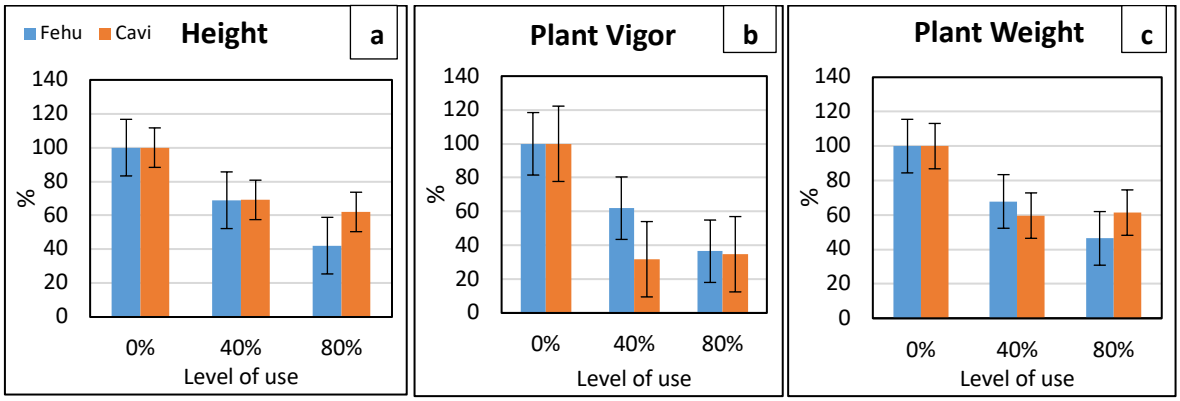

Figure 1. Relative changes in relation to the control group of the variables (a) height, (b) vigor and (c) weight per plant in *Festuca humilior* and *Calamagrostis vicunarum* in response to the level of use.

Calamagrostis vicunarun, a sub-dominant grass in the plant community, showed, like Festuca humilior, a significant reduction in height, vigor and plant weight compared with the control group, but unlike Festuca, no significant differences were observed between the variables mentioned above when the intensity increased from moderate to heavy removal (Table 1), revealing that it would be a specie more tolerant to grazing pressure that clearly behaves as one that maintains its productivity even when the levels of height removal increased from moderate to heavy.

This change in the relationship of dominance with Calamagrostis as dominant and Festuca as subdominant finally leads to a decrease in the condition of the pasture for cattle since the animals show a greater preference for Festuca than for Calamagrostis, a species of lower nutritional value and height than the first one (Florez and Bryant, 1985).

Conclusion

Calamagrostis vicunarum and *Festuca humilior* responded differently to cutting intensity, the second one behaved as a specie that is less tolerant to grazing pressure than the first one. Although both plant species decreased plant vigor and productivity values, when the use intensity increased, Festuca humilior reduced its values to a greater extent, so in those subtypes of vegetation where the Festuca is dominant, it is recommended to manage them under a grazing regime of low intensity and low frequency.

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