Survival Rate and Morphological Growth Patterns of Five Populations of *Festuca dolichophylla* Under Similar Conditions

Paucar, Y.*; Flores, E. R.†; Guillén, H. M.*; Aguirre, L†.
* Universidad Nacional de Huancavelica; † Laboratorio de Ecología y Utilización de Pastizales de la Universidad Nacional Agraria La Molina

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Abstract

The majority of the natural grasslands of Perú are located in the Puna region; they are the only source of feed for raising animals in this area, and they also protect the soil from erosion. *Festuca dolichophylla* is a representative species with high productivity in this ecosystem. The aim of this study was to evaluate survival rate and morphological growth patterns of five populations of *Festuca dolichophylla* under similar conditions. Five accessions were obtained from each population: Pastales Huando Peasant Community - Huancavelica (CCPH), Lachocc South American Camelids Research and Development Center of the National University of Huancavelica (CIDCSL), Junin, Pasco, and Puno. Six cuttings were obtained from each accession. They were planted in a block design in a uniform soil in the CCPH. After twelve months of establishment all plants were cut to five cm in height and survival rate was estimated. Plant height, number of stems, and leaf number were monitored twice a month; growth rate, stem emergence rate, and leaf emergence rate were calculated and data was analyzed for each month. Accessions from Puno had a 96.67% survival rate, which was significantly higher ($p<0.05$) than accessions from CIDCSL (43.33% survival) but similar to accessions from the other populations. The morphological growth patterns showed differences between populations and high variability along the evaluation period; this variability and differences are likely due to the genetic constitution of each accession since the environment was similar. This information is crucial for further genetic breeding programs; however, first a morphologic and genetic characterization is necessary. We also observed an orderly growth of this species; first, the plants grow in size, then they increase their stem number, and finally the number of leaves increases. To our knowledge this is the first study that compares morphological growth patterns in different populations of *Festuca dolichophylla* under similar conditions.

Introduction

The demand for food is growing due to the rise in global population; to meet this demand it is necessary to increase animal and vegetal production. The rise in animal populations will generate an increase in demand for grasslands; Estell *et al.* (2012) estimated that 3.2 billion tons of forage would be needed per year to support increasing animal populations worldwide. As a result, increasing forage production is an important challenge for specialists in this field, even more so while taking into account the negative effects of climate change.

A large part of the natural grasslands of Perú are located in the Puna region. This ecosystem plays a crucial role since it provides feed for animal husbandry in this area, and also protects the soil from erosion by wind, water, and animal trampling. *Festuca dolichophylla* is one of the most common grasses grown in these ecosystems within the Puna region and it is widely distributed (Tovar 1993). In order to make better use of this species and provide an opportunity to use it in genetic breeding programs, it is necessary to know the potentialities that different populations of this species may have under similar growth conditions. In that sense, the aim of this study was to evaluate survival rate and morphological growth patterns of five existing populations of *Festuca dolichophylla* under similar conditions.

Methods

The experiment was conducted in Pastales Huando Peasant Community of Huancavelica (CCPH) - Perú, located at 4620 m. a. s. l. The average rainfall, temperature, and relative humidity were 1357.85 mm, 5.75°C and 79.02%, respectively. The experimental plot (10.0 m x 15.0 m) was located on almost flat ground with uniform soil characteristics; the pH, nitrogen, phosphorus, and potassium content were 5.8, 0.34%, 5.9 ppm and 556.5 ppm, respectively.

We obtained a total of 25 accessions from five existing plant populations: CCPH, CIDCSL (South American Camelids Research and Development Center of the National University of Huancavelica), Junín, Pasco, and Puno. Each accession was selected for its vigor and was completely extracted including root material. A total of six cuttings were obtained from each accession and were transported to the CCPH (Table 1). These cuttings were planted with one meter of separation between cuttings in the experimental plot. Additionally, two lines of plants were planted along the outside edges of the plot to control the border effect.

The cuttings were planted in December 2019, and after twelve months of establishment we evaluated the survival rate and a standardization cut was made at 5.0 cm. Then the morphologic growth patterns were monitored during growth period (from December 2020 to May 2021). The height to flag leaf was used as an indicator for plant height and was monitored with a digital vernier, and the stem and leaf number was obtained by direct count; these characteristics were measured every two weeks. Growth rate (mm/day), stem emergence rate (n/day), and leaf emergence rate (n/day) were calculated, and data was analyzed for each month.

The survival rate was analyzed including the population effect using a one-way analysis of variance. The data on morphologic growth patterns were analyzed after removing outliers using a nested design (accession within population) and the population effect and block effect (rows) was included in the analysis of variance. All the data were analysed with R 4.0.3 software and the means comparisons were done using the Tukey method.

Results and Discussion

Survival rate

Accessions from Puno had the highest survival rate, close to one hundred percent, followed by accessions from CCPH; the survival rate of the other populations was less than 70% (Table 1). However, when compared statistically, accessions from Puno were significantly higher than accessions from CIDCSL but were similar to the other populations. Also, there were different variability levels (shown in the different standard errors of each population).

Table 1. Average survival rate as a percentage (standard error) of accessions of *Festuca dolichophylla* taken from five different populations and grown under similar conditions in Peru.

Population	Accession	Cuttings per accession	Total cuttings installed	Live cuttings	Survival rate (%)*
CCPH	5	6	30	26	86.67 (8.16)^{ab}
CIDCSL	5	6	30	13	43.33 (13.54)^{b}
Junín	5	6	30	19	63.33 (16.16)^{ab}
Pasco	5	6	30	20	66.67 (11.79)^{ab}
Puno	5	6	30	29	96.67 (3.33)^{a}
Total	25		150	107	71.33 (6.05)

*Columns with different letters in the superscript show significant differences between populations (p<0.05).

We obtained a higher survival rate in accessions from Puno than Gil *et al.* (2015), who studied 13 populations of *Trichloris crinita*, a native grass from Argentina. These authors found great variability in plant survival rates, similar to our results. This variability is very important to consider when looking for accessions with great potential to be successful in different environments.

Morphological growth patterns

Accessions from Puno had greater plant heights compared to all the other populations through all months, except when compared with accessions from CIDCSL (Table 2).

Table 2. Plant height in mm (standard error) of accessions of *Festuca dolichophylla* taken from five different populations and grown under similar conditions in Peru.

Population	N	December*	January	February	March	April	May
CCPH	25	91.65 (3.63)^{bc}	153.41 (12.29)^{bc}	194.30 (19.91)^{bc}	228.99 (25.55)^{bc}	252.58 (28.40)^{bc}	258.12 (28.95)^{bc}
CIDCSL	13	106.15 (5.61)^{ab}	212.50 (17.84)^{ab}	292.23 (31.38)^{ab}	349.82 (37.88)^{ab}	362.86 (38.69)^{ab}	363.29 (38.76)^{ab}
Junín	18	89.12 (3.67)^{bc}	146.04 (8.54)^{c}	180.80 (10.56)^{c}	201.22 (12.28)^{c}	213.39 (11.12)^{bc}	217.05 (11.63)^{bc}
Pasco	19	85.40 (3.70)^{c}	148.44 (9.79)^{bc}	174.85 (14.38)^{c}	188.61 (17.94)^{c}	198.32 (19.77)^{c}	199.67 (20.15)^{c}
Puno	25	114.60 (3.70)^{a}	231.67 (8.84)^{a}	332.04 (16.58)^{a}	420.53 (19.39)^{a}	454.05 (17.33)^{a}	458.48 (16.53)^{a}
Total	100	97.63 (2.08)	178.39 (6.19)	235.34 (10.55)	279.91 (13.82)	299.92 (14.57)	303.38 (14.63)

*Columns with different letters in the superscript show significant differences between populations (p<0.05).

The growth rate showed a pattern similar to plant height from January to March, with accessions from Puno having a greater growth rate compared to all other populations except CIDCSL; however, in April and May there were no differences in growth rate across any of the populations (Fig. 1).

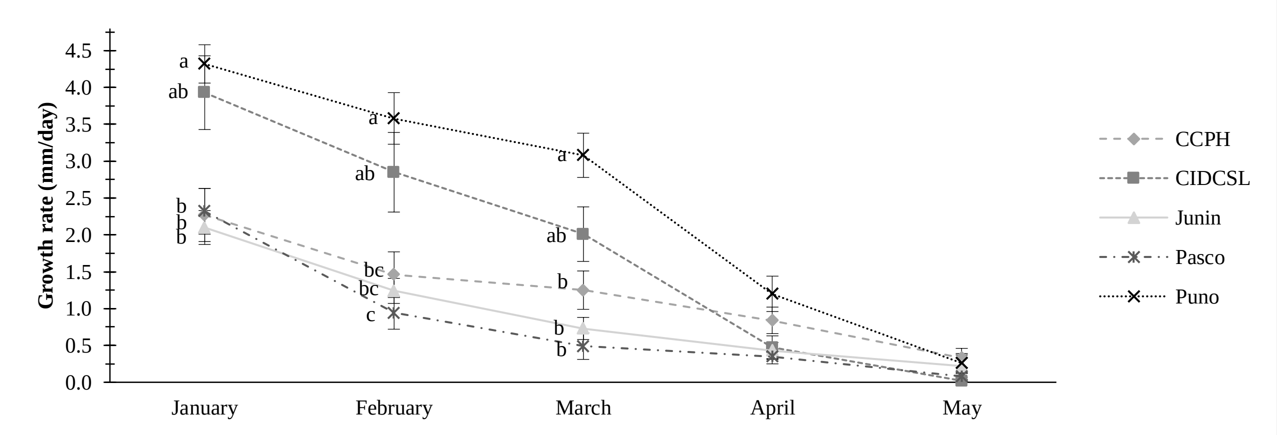

Figure 1. Growth rate (mm/day) of accessions of *Festuca dolichophylla* taken from five different populations and grown under similar conditions in Peru. Different letters within each month show significant differences between populations (p<0.05).

Plant populations did not differ in stem number from December to January. However, accessions from Puno had a greater number of stems than all of the other populations during February, March, and April. In May, stem numbers were higher for accessions from Puno compared to all of the other populations except accessions from CIDCSL (Table 3).

Table 3. Stem number (standard error) of accessions of *Festuca dolichophylla* taken from five different populations and grown under similar conditions in Peru.

Population	N	December*	January	February	March	April	May
CCPH	25	0.00 (0.00)[a]	0.36 (0.14)[a]	2.36 (0.36)[b]	3.27 (0.44)[b]	3.45 (0.45)[b]	3.55 (0.45)[b]
CIDCSL	13	0.08 (0.08)[a]	0.77 (0.23)[a]	2.77 (0.75)[b]	3.54 (0.93)[b]	3.92 (1.00)[b]	4.23 (1.19)[ab]
Junín	18	0.36 (0.13)[a]	0.86 (0.27)[a]	2.07 (0.32)[b]	2.43 (0.37)[b]	2.86 (0.39)[b]	2.93 (0.38)[b]
Pasco	19	0.23 (0.12)[a]	0.46 (0.14)[a]	2.23 (0.44)[b]	3.00 (0.65)[b]	3.08 (0.65)[b]	3.08 (0.65)[b]
Puno	25	0.00 (0.00)[a]	0.92 (0.26)[a]	5.84 (0.52)[a]	7.44 (0.70)[a]	7.92 (0.76)[a]	8.32 (0.82)[a]
Total	100	0.12 (0.03)	0.66 (0.11)	3.21 (0.28)	4.15 (0.36)	4.45 (0.38)	4.63 (0.41)

*Columns with different letters in the superscript show significant differences between populations (p<0.05).

Plant populations did not differ for stem emergence rate except in February, where accessions from Puno had greater values compared to all of the other populations (Fig. 2).

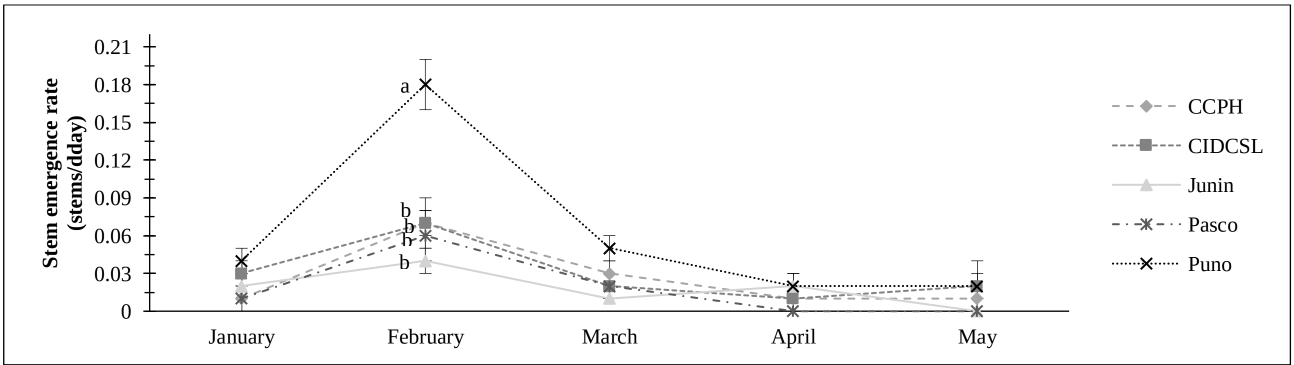

Figure 2. Stem emergence rate (stems/day) of accessions of *Festuca dolichophylla* taken from five different populations and grown under similar conditions in Peru. Different letters within each month show significant differences between populations (p<0.05).

Leaf numbers were the highest for accessions from Puno compared to all other populations in December, but by January leaf numbers for Puno were only higher than accessions from CCPH, and from February to May there were no differences between populations for this variable (Table 4).

Table 4. Leaf number (standard error) of accessions of *Festuca dolichophylla* taken from five different populations and grown under similar conditions in Peru.

Population	N	December*	January	February	March	April	May
CCPH	25	11.36 (1.74)[b]	14.32 (1.91)[b]	17.92 (2.44)[a]	23 (3.36)[a]	29.16 (4.35)[a]	30.96 (4.63)[a]
CIDCSL	13	18.38 (5.19)[b]	21.46 (5.99)[ab]	26.62 (7.79)[a]	35 (11.02)[a]	49.54 (15.86)[a]	54.31 (17.43)[a]
Junín	18	14.17 (3.31)[b]	19.78 (4.74)[ab]	23.89 (5.91)[a]	29.56 (7.75)[a]	39.94 (10.88)[a]	43.44 (11.96)[a]
Pasco	19	18.47 (3.01)[b]	25.32 (4.46)[ab]	29.47 (5.32)[a]	35.05 (6.4)[a]	44.32 (8.05)[a]	47.42 (8.63)[a]
Puno	25	36.68 (3.16)[a]	38.56 (3.01)[a]	43.88 (3.54)[a]	53.72 (4.91)[a]	71.24 (6.62)[a]	77.08 (7.23)[a]
Total	100	20.46 (1.68)	24.38 (1.88)	28.81 (2.25)	35.71 (2.94)	47.15 (4.01)	50.9 (4.37)

*Columns with different letters in the superscript show significant differences between populations (p<0.05).

Populations did not differ in leaf emergence rate, but for all populations higher values for leaf emergence rate were observed in April (Fig. 3).

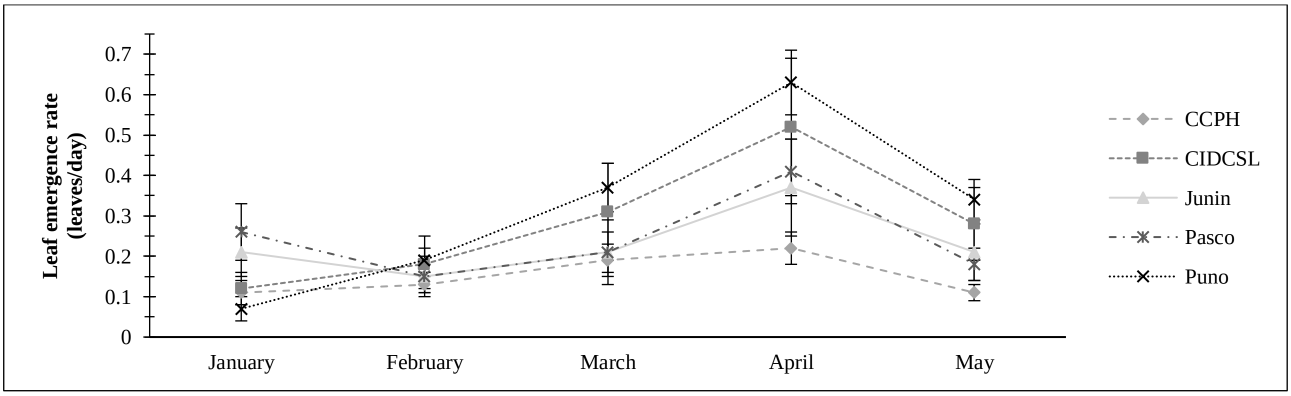

Figure 3. Leaf emergence rate (leaves/day) of accessions of *Festuca dolichophylla* taken from five different populations and grown under similar conditions in Peru. Different letters within each month show significant differences between populations (*p*<0.05).

Across all variables measured, morphological growth patterns showed a great deal of variability (high standard errors). Similar results were found by Gi *et al.* (2015) for different populations of *Trichloris crinita*, a native grass from Argentina, when they assessed plant height, leaf number, number of panicles, and number of tillers as morphological characteristics. Differences and variability have also been noted for other cultivated species (Ganderats and Hepp 2003) such as *Lolium perenne*, *Festuca arundinacea*, and *Dactylis glomerata*.

This high variability for morphological characteristics is likely attributed mainly to differences in the genetic constitution of each population since they were grown in similar conditions. This variability is very important for further breeding programs using this species. However, it is still necessary to complete a morphologic and genetic characterization (Oliveira *et al.* 2016) to identify some potential accessions for breeding purposes.

Even with the high amount of variability, we did find an orderly growth of different plant parts for the *Festuca dolichophylla* species. For all populations, the highest growth rates were in December and then gradually decreased. Stem emergence rates were highest in February, and the highest leaf emergence rates were in April. Matthew (1996) also found a sequential activation of emergence when looking at stems, root formation, and leaf growth in *Lolium perenne*.

Conclusions and Implications

We found differences between populations and high variability for both survival rate and morphological growth patterns. These differences are likely attributed to differences in the genetic constitution between plant populations because all were grown under similar conditions. This variability is very important for further breeding programs and is important for morphologic and genetic characterization. Across all populations, *Festuca dolichophylla* plants first grew in size, then increased their stem number, and finally grew additional leaves. To our knowledge, this is the first experiment that compares morphological growth patterns of different populations of *Festuca dolichophylla* grown under similar conditions.

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