Scientific Paper

Evaluation and selection of forage cereal genotypes through multivariate techniques in Nariño, Colombia

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Abstract

Objective: To evaluate the adaptation and forage yield of *Hordeum vulgare* L. and *Triticum* sp. accessions in the high tropics of Nariño, Colombia.

Methods: The study was conducted at the Obonuco Research Center of the Colombian Agricultural Research Corporation, Pasto, Nariño. Twenty-six accessions of *H. vulgare*, 23 of *Triticum* sp. and one of *Avena sativa* L. were evaluated under a complete randomized block design with four replicas per treatment. The evaluated variables were: vigor, height, number of leaves, number of stems, pest incidence, disease incidence and severity, nutritional deficiencies, dry matter percentage. A multivariate factorial analysis of mixed data was carried out, followed by a hierarchical cluster analysis using Ward's algorithm. The R V.3.6.0 software was used for the analysis.

Results: *H. vulgare* accessions showed higher leaf production ranging from 65,0 to 123,0; while stems ranged from 13,0 to 25,0; good height and higher dry matter percentage. *Triticum* sp. accessions had higher leaf production, stems and dry matter yield, with low disease incidence.

Conclusions: *H. vulgare* and *Triticum* sp. materials were recognized with potential to continue in research programs and which can be an alternative to mitigate the forage seasonality and low quality found during the dry seasons of the high Nariño tropics.

Keywords: adaptation, forage seasonality, productive systems

Introduction

Animal husbandry constitutes an engine for the development of agriculture, as well as a driver of important economic, social and environmental changes in global food systems (FAO, 2019). In Colombia, milk production is a main activity in agriculture, because it guarantees food security and sovereignty. In addition, within animal products, milk generates the lowest greenhouse gas emissions per unit of product, which makes it important in the framework of the development of sustainable animal production systems (Gerber *et al*., 2013).

According to Carulla and Ortega (2016) milk production in this country is 85 % based on pastures of *Cenchrus clandestinus* Hoschst. ex Chiov. (kikuyu); in some cases it appears in mixtures with legumes and other grasses such as *Lolium* sp. (ryegrass). In this sense, it is necessary to increase the cultivation of forage species for good dry matter yield with tolerant species under extreme conditions of the region, thus ensuring animal feeding mainly in dry periods (Aduviri, 2014).

Small grain cereals such as *Hordeum vulgare* L. and *Triticum* sp. have become a feeding alternative and have been incorporated into ruminant feeding systems (Arreaza, 2012). The production of cereals aimed at being directly grazed or incorporated through preserved forages (silages, hay or haylage), is a strategy that allows to supply forage deficiencies at times of low biomass availability such as drought or frost (Ding *et al*., 2015).

Because of the decrease in forage supply at times of low rainfall and frost, cattle reduce dry matter intake, which affects milk production and quality (Mella-Fuentes, 2005). For such reason, it is important to include supplementation with non-traditional forage crops that meet nutritional requirements and complement the grazing diet of animals under production (Cuesta-Muñoz *et al*., 2006).

In Colombia, the main producing departments of these cereals are Boyacá, Cundinamarca and Nariño. However, the hectares of these crops have decreased from 1950 to 2020 by 93,5 and 98,3 % for *H. vulgare* and *Triticum* sp. respectively; with subsequent increase in imports (FENALCE, 2020).

H. vulgare, for example, is a nutrient-rich feedstuff with high carbohydrate contents, moderate protein

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concentration, high fiber content, and is a good source of phosphorus and potassium (Lahouar *et al*., 2016); although 85 % of the national production is used in the brewing and malting industry; 10 % goes to pearl and flour mills (human consumption) and 5 % is sold as seed for farmers (Vanegas *et al*., 2018). *H. vulgare* is a multipurpose cereal that can be used for animal feeding (Karagöz *et al*., 2017). Hence, the objective of the work was to evaluate the adaptation and forage yield of *H. vulgare* and *Triticum* sp. accessions in the high tropics of Nariño, Colombia.

Materials and Methods

Location. The study was conducted between October 2019 and July 2020, at the Obonuco research center, owned by the Colombian Agricultural Research Corporation (AGROSAVIA). The facility is located in the Pasto municipality, Nariño, Colombia, at 2 905 m.a.s.l. (1° 88' 918" N and 77° 306' 083" W).

Edaphoclimatic characteristics. The average annual rainfall of the region is 1 273 mm and the average temperature is 13,8 °C. The origin of its soils is volcanic ash and they belong to the sandy loam textural group (Climate-Data.org, 2018). Figure 1 shows the rainfall recorded during the study period.

Experimental design and treatments. The experiment was established under a complete randomized block design with four replications per treatment. Each experimental unit corresponds to a 5-m long furrow for each evaluated material, with a distance between furrows of 0,5 m and between plants of 0,2 m, and a planting density of 25 seeds per furrow. Four replicas were sown per treatment for a total area of 650 m². One accession of oats (*Avena sativa* L.), 26 accessions of *H. vulgare* (barley) and 23 accessions of *Triticum* sp. (wheat) from the National Germplasm Bank System for Food and Agriculture under custody of the Colombian Agricultural Research Corporation (AGROSAVIA), Colombia, were evaluated (tables 1 and 2).

Experimental procedure. Soil preparation was done with two passes of harrow and one pass of rake. Fertilization was fractioned in three stages of crop development, using a dose of 100 kg of P_2O_5 ha^{-1}; 25 kg of K_2O ha^{-1} and 50 kg of N ha^{-1}. At sowing, 40 % NPK was applied. Thirty days after germination, 30 % NPK was applied and at the grain filling stage, the remaining 30 % was applied (table 3).

Evaluated variables. The evaluation of the variables was carried out since the period of emergence until the milky pasty grain stage of the plant with a frequency every 15 days. Three plants were selected per furrow to determine: vigor on a scale from 1 to 4, in which 1 represented low vigor and 4, high vigor (Toledo and Schultse-Kraft, 1982), plant height (cm), number of stems, number of leaves, dry

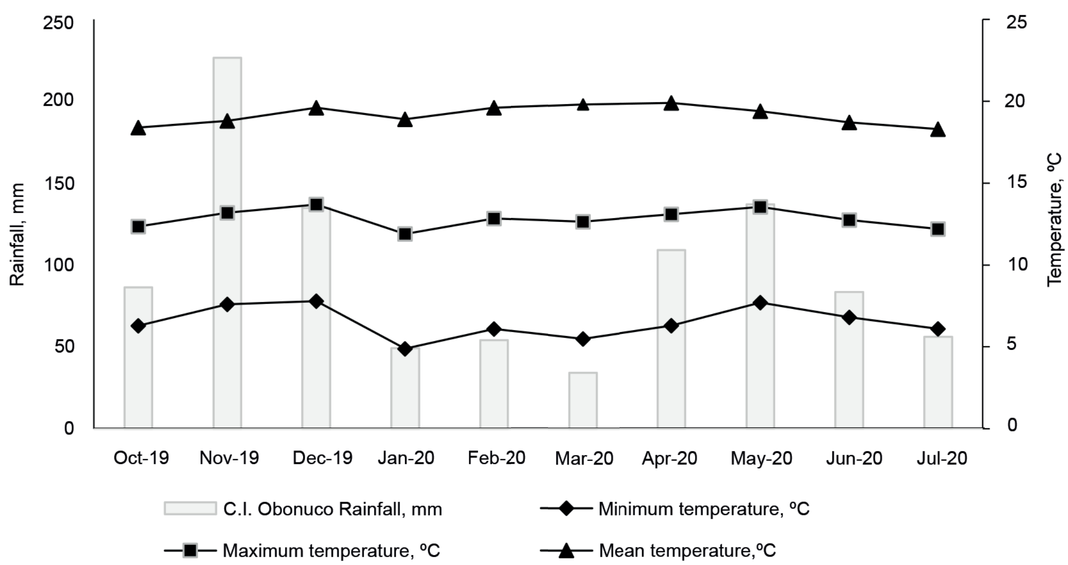

Figura 1. Accumulated rainfall during the study.
Source: Vintage pro 2 station, located at the C.I Obonuco research station of the Colombian Agricultural Research Corporation (AGROSAVIA). Pasto, Colombia.

Table 1. Code of *H. vulgare* and *Triticum* sp. accessions, Pasto - Nariño, Colombia. 2019-2020.

Species	SBGNAA code	Code
A. sativa	AV-1AV-0011	A1
Triticum sp.	ALDAN"S"/CNT9	T7
Triticum sp.	ANDINO 2	T24
Triticum sp.	BARBON CAFÉ	T1
Triticum sp.	BOW"S"	T9
Triticum sp.	BR15	T14
Triticum sp.	BURI	T12
Triticum sp.	CHIL"S"	T8
Triticum sp.	CHILERO"S"	T10
Triticum sp.	CHUAN MAI#18(CHINA)	T5
Triticum sp.	CURRENCY(FROM AUSTRALIA)	T13
Triticum sp.	FAN#1	T17
Triticum sp.	FASAN	T20
Triticum sp.	HI977(INDIA)	T11
Triticum sp.	HORTO	T15
Triticum sp.	ICA TENZA	T2
Triticum sp.	ICTA SARA 82	T3
Triticum sp.	KENYA 4	T4
Triticum sp.	NING8319	T18
Triticum sp.	OPATA"S"	T19
Triticum sp.	SEL.BOYACA	T25
Triticum sp.	SEL.TRIGO AZUL GRANO COLOR CAFÉ CLARO	T6
Triticum sp.	TIBA	T16
Triticum sp.	TRIGO TIPO AZUL	T23

SBGNAA: National Germplasm Bank System for Food and Agriculture. Colombian Agricultural Research Corporation (AGROSAVIA), Colombia.

matter (DM) percentage and yield (kg/ha). Similarly, disease incidence was evaluated visually in the field, taking into account the percentage of incidence (0 to 100 %) of the disease in the plot, even a single spot on each leaf, disease severity on a scale from 0 to 9 according to ETH Zürich (2016), pest incidence from 1 to 5, where: one corresponds to no damage, two to 1-10 % of the plants affected (PA), three to 11-25 % PA, four to 26-40 % PA and five to more than 40 % p.a. . Nutrient deficiencies were determined according to the methodology described by Hoyos *et al.* (1995).

Multivariate statistical analysis. Unsupervised machine learning techniques such as mixed factor and hierarchical cluster analysis on the principal component analysis (PCA) according to Kassambara (2017), were used, accompanied by hierarchical clustering analysis using the Ward's Algorithm method (Peña-Sánchez-de-Rivera, 2002). For the development of the statistical methods, the libraries FactoClass (Pardo *et al*., 2018), Factoextra (Kassambara and Mundt, 2020), FactoMiner (Husson *et al*., 2022), and dplyr (Wickham *et al*., 2019) of the R v.3.6.0® software (R Core Team, 2022) were used. To validate the performed analysis, a workshop was conducted with a group of technical experts on pasture and forage production.

Results and Discussion

Factorial analysis of mixed data for *H. vulgare* accessions. The results of the PCA determined determined that the first three components explain 74,0 % of the total variance, where the first two components account for 57,84 % of the total variance. The variables with the highest contribution to component one were: height (24,8 %), number of

Table 2. Code of *H. vulgare* accessions. Pasto - Nariño, Colombia. 2019-2020.

Species	SBGNAA code*	Code
H. vulgare	BOHATYR	C21
H. vulgare	BS 78-3-4	C1
H. vulgare	BS 90-9-1	C2
H. vulgare	BS 90-9-2	C3
H. vulgare	C-105	C22
H. vulgare	C-120	C23
H. vulgare	DINA	C10
H. vulgare	DONECHIJ 8	C6
H. vulgare	ENISEJ	C5
H. vulgare	GK58//RHN-03/LIGNEE640 ICBH94	C19
H. vulgare	GK58/3/KC/MULLERSHEYDLA//SL	C20
H. vulgare	ONSLOW	C7
H. vulgare	ORBIT	C8
H. vulgare	RADICAL/BIRGIT//ICB-100811ICBI	C18
H. vulgare	RISK	C11
H. vulgare	ROHO/MASURICA//ICB-103020/3/C	C17
H. vulgare	S.5	C24
H. vulgare	S.6	C25
H. vulgare	SSG-564	C26
H. vulgare	SVIT	C9
H. vulgare	TX01D254	C12
H. vulgare	TX01D265	C13
H. vulgare	TX01D274	C14
H. vulgare	TX01D282	C15
H. vulgare	TX01D313	C16
H. vulgare	ZERNOGRADSKIJ 73	C4

SBGNAA: National Germplasm Bank System for Food and Agriculture. Colombian Agricultural Research Corporation (AGROSAVIA), Colombia.

Table 3. Chemical properties of the soil of C.I Obonuco (Pasto - Nariño), Colombia. 2019.

pH	OM	P	Ca	Mg	K	CICE	B	Cu	Mn	Fe	Zn
	%	Mg/kg	Meq/100g				ppm				
5,68	3,48	55,31	8,16	1,3	1,29	10,83	0,33	3,8	7,4	385	2,8

Table 4. Cluster formation by hierarchical clustering on principal components.

Group	Quantity of accessions	%
I	3	11,1
II	7	25,9
III	17	63,0

leaves (22,7 %), number of stems (22,4 %) and % DM (16,5 %); it is observed that dimension one provides information on yield parameters. On the other hand, for component two, the variables that contributed most to the variance were: disease severity (30,5 %), vigor (27,0 %), DM (kg/ha) (16,5 %) and number of stems (11,3 %), the latter providing information about the health and adaptation component of the accessions.

Cluster determination by hierarchical clustering on principal components (HCPC). For the development of this study, three clusters or groups of *H. vulgare* accessions were obtained, as shown in table 4. Cluster number one grouped 11,1 % of the cases (3 accessions); cluster two grouped 25,9 % (7 accessions) and cluster three grouped 63,0 % (17 accessions).

Each one of the *H. vulgare* accessions (fig. 2) was located on the map of factors based on the three identified clusters, and a workshop was held with technical experts on the production of forage cereals to validate the relevance of the groups classified according to the statistical model.

Group I includes the accessions with higher leaf and stem production, lower height and dry matter (DM) production, with regards to the general average. This group is composed of 11,1% of the studied accessions. Considering the results (P value) of (table 5), the group is mainly explained by the variables: number of leaves (1,245421e-04), number of stems (1,601402e-04), height (2,972485e-05) and dry matter percentage (2,387569e-04).

It is formed by a group of accessions that have an average production of 123 leaves, with 25 stems with an average height of 39,0 cm and an average DM content of 20,7 %, these last two variables lower than the general average with 51,9 cm and 23,8 % of DM. In this group the most representative individuals are also identified where the value indicates the distance of each individual to the centroid and the closest to this is the most representative accession, in this case accession C7 as observed in it (table 6).

Cluster 2 contains the accessions with the lowest presence of pests and diseases, compared with the general average. This group is composed of 25,9 % of the studied accessions. Taking into account the results (P-value) of (table 5), the group is mainly explained by the variable: disease severity (0,04781595). It is made up of a group of accessions that have an almost null presence of diseases, remaining in most of the evaluations in the "Unaffected" category with regards to the rest of the group in general. In this group the most representative individuals are also identified where the value indicates the distance of each individual to the centroid and the closest to this is the most representative accession, in this case accession C21 as observed in it (table 7).

Group III contains accessions with greater height and lower leaf production, compared with the general average. This group is composed of 11,11 % of the studied accessions. Taking into account the results (P-value) of (table 5), the group is mainly

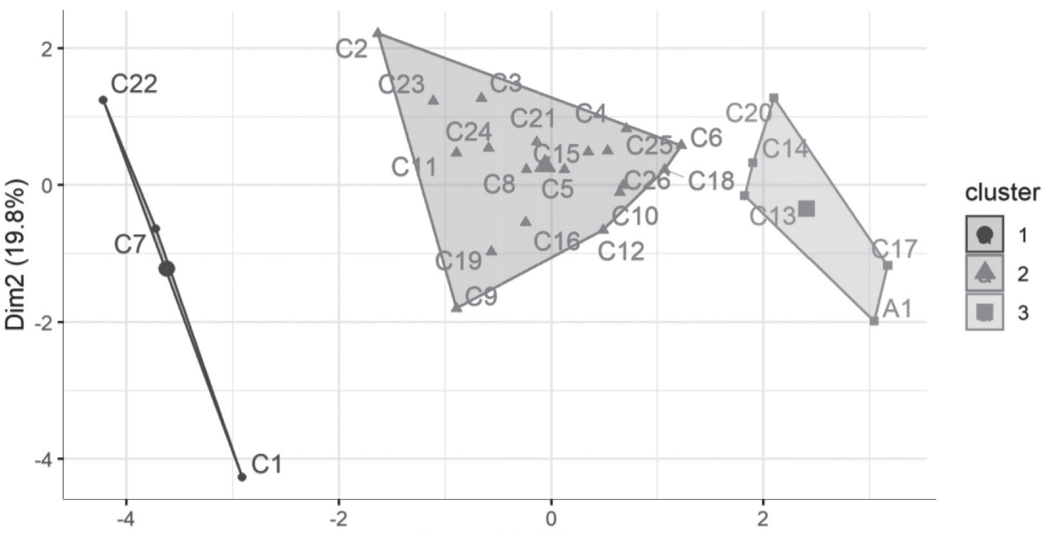

Figure 2. Map of factors by *H. vulgare* accessions according to cluster grouping Nariño, Colombia.

Table 5. Main characteristics of the *H. vulgare* accession clusters.

Variable	Eta2	P-value general group	Group					
			I		II		III	
			Mean	SD	Mean	SD	Mean	SD
Height	0,58	2,972485e-05	39,0	6,39	51,1	5,9	62,7	2,95
No. of leaves	0,52	1,245421e-04	123,0	12,02	93,1	15,8	65,0	12,81
No. of stems	0,51	1,601402e-04	25,0	3,09	14,1	15,8	13,0	2,63
Dry matter, %	0,50	2,387569e-04	20,7	0,99	24,0	1,4	25,1	0,2
DM, kg/ha	0,37	3,372176e-03	4 263,9	729,3	4 799,7	602,4	5 775,8	451,3
Pest incidence	-	0,0002150921	-	-	-	-	-	
Nutritional deficiencies	-	0,0002150921	-	-	-	-	-	
Vigor	-	0,0157039006	-	-	-	-	-	
Disease severity	-	0,04781595	-	-	Unaf-fected	-	-	

SD: standard deviation

Table 6. Distances of the *H. vulgare* accessions that make up group I to the centroid.

Accession	Distance
C7	2,093859
C22	2,822027
C1	3,966540

Table 7. Distances of the *H. vulgare* accessions that make up group II to the centroid.

Accession	Distance
C21	0,7956344
C11	0,9322600
C24	1,0001639
C10	1,2382056
C5	1,2854951

Table 8. Distances of the *H. vulgare* accessions that make up group III to the centroid.

Accession	Distance
C14	1,214368
C13	1,380174
C20	1,972331
C17	1,986747
A1	2,269299

explained by the variables: Height (2,972485e-05), DM (3,372176e-03), number of stems (1,601402e-04), and number of leaves (1,245421e-04).

It is formed by a group of accessions that have an average height of 62,7 cm, a DM production of 5775,84 kg/ha, with 13 stems and 65 leaves, these last two variables lower than the general average with 19 and 92 leaves. In this group the most representative individuals are also identified where the value indicates the distance of each individual to the centroid and the closest to this is the most representative accession, in this case accession C14 as observed in it (table 8).

Factor analysis of mixed data for Triticum sp. accessions. The results of the principal component analysis (PCA) showed that the first three components explained 73,7 % of the total variance, with dimensions one and two accounting for 57,7 % of the total variance.

The variables with the highest contribution to dimension one were: number of leaves (28,4 %), number of stems (21,5 %), incidence of diseases (27,8 %) and DM (kg/ha) % (16,8 %); it is observed that dimension one provides information on yield parameters; on the other hand, for dimension two, the variables that contributed most to the variance were: disease severity (38,4 %), height (21,2 %), disease incidence (19,8 %) and number of stems (10,1 %), this second dimension, provides information about the health and adaptation component of the accessions, very similar to that of *H. vulgare*.

Cluster determination by means of hierarchical clustering on principal components. For the development of this study, three clusters or groups of wheat accessions were obtained as shown in table 9. Cluster number one grouped 33,3 % of the cases (8 accessions); cluster two, 12,5 % (3 accessions) and cluster three, 54,16 % (13 accessions).

Table 9. Cluster formation by hierarchical clustering on principal components.

Group	Quantity of accessions	%
I	8	33,3
II	3	12,5
III	13	54,2

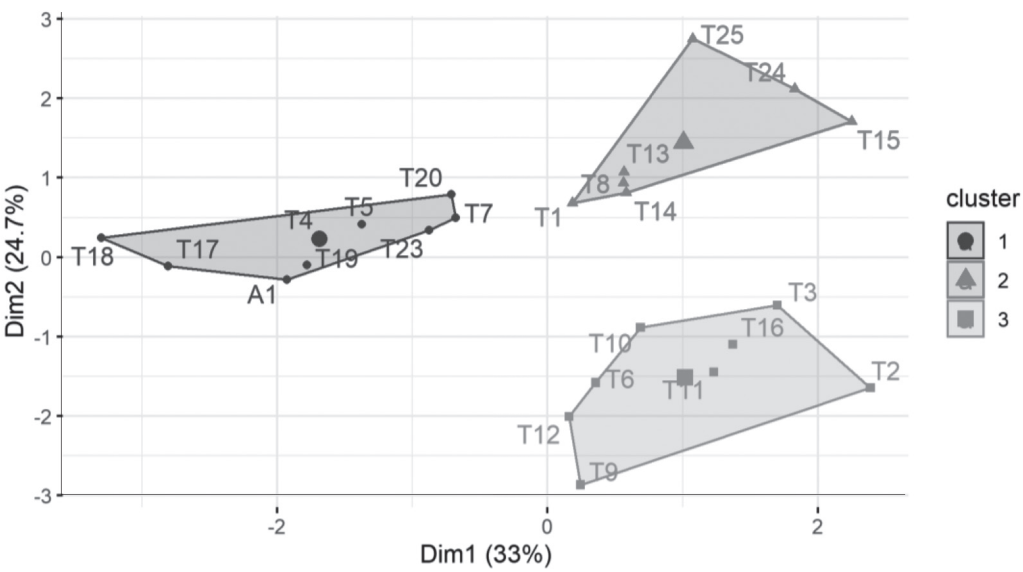

Figure 3. Map of factors by *Triticum* sp. accessions according to cluster grouping Nariño, Colombia.

Each of the *Triticum* sp. accessions was located on the factor map (figure 3) based on the three identified clusters.

Group I includes the accessions with lower dry matter (DM) production, lower stem production and number of leaves and low incidence of diseases compared to the general average.

This group is composed of 33,3 % of the accessions studied. Taking into account the results (P-value) of (table 10), the group is mainly explained by the variables: % DM (kg/ha) (0,0494306939), number of stems (3,5214625e-02), incidence of diseases (1,502783e-03) and number of leaves (8,59067e-04).

It is made up by a group of accessions that have an average production of 48 leaves, with 11 stems, incidence of diseases with 0,5 % and an average DM yield (kg/ha) of 5404,40. They have a low presence of diseases remaining in most of the evaluations in the category "Slight damage "compared with the rest of the group in general. All these variables were

Table 10. Main characteristics of the clusters of *Triticum* sp. accessions.

Variable	Eta2	P-value general group	Group I		Group II		Group III	
			Mean	SD	Mean	SD	Mean	SD
No. of leaves	0,59	8.59067e-04	48,0	3,49	57,0	2,2	54,3	3,8
Disease incidence	0,57	1.502783e-03	0,5	0,49	1,1	0,4	2	0.99
No. of stems	0,42	3.5214625e-02	11,0	1,36	13,0	1,04	12,1	1,1
Height	0,30	0.0221380444	55,5	4,7	63,8	9,84	54,1	3,3
DM, kg/ha	0,25	0.0494306939	5 404.4	465,92	6 159,4	335,2	5 906,5	812,0
Disease severity	-	6.144212 e-02	Slight damage	-	Slight damage	-	Unaffected	-

SD: standard deviation

lower than the general average, with 52 leaves, 12 stems, 1,3 % incidence and 5 791,98 kg/ha. In this group the most representative individuals are also identified where the value indicates the distance of each individual to the centroid and the closest to this is the most representative accession, in this case accession T7 as observed in it (table 11).

Table 11. Distances of the *Triticum* sp. accessions comprising group I to the centroid.

Accession	Distance
T7	1,065886
T23	1,080796
T5	1,085776
T17	1,442485
T4	1,465869

Group II comprises accessions with a lower presence of pests and diseases, compared to the general average. This group is composed of 12,5 % of the accessions studied. Taking into account the results (P-value) of (Table 10), the group is mainly explained by the variables: number of stems (0,005157876), number of leaves (0,008375520) and height (0,008900737). It is formed by a group of accessions that have an average production of 57 leaves, with 13 stems and a height of 57,5 cm, have a low presence of diseases, remaining in most of the evaluations in the category "Slight damage" with regards to the rest of the group in general. All these variables were higher than the general average with 52 leaves, 12 stems and 57,5 cm. In this group the most representative individuals are also identified where the value indicates the distance of each individual to the centroid and the closest to this is the most representative accession, in this case accession T24 as observed in it (table 12).

Table 12. Distances of the *Triticum* sp. accessions that make up group II to the centroid.

Accession	Distance
T24	1,129461
T1	1,260890
T15	1,312432
T13	1,458076
T14	1,760321

Group III comprises the accessions with greater height and lower leaf production, compared with the general average. This group is composed of 54,2 % of the studied accessions. Taking into account the results (P-value) of (table 10), the group is mainly explained by the variable: disease incidence (1.502783e-03).

It is formed by a group of accessions that have a disease incidence of 2 %, higher than the general average of 1 %. They have a low presence of diseases, remaining in most of the evaluations in the category "Unaffected" with regards to the rest of the group in general.

Table 13. Distances of the accessions of *Triticum* sp. group III to centroid.

Accession	Distance
T10	1,443619
T12	1,524184
T3	1,541499
T11	1,671957
T2	1,709008

A. sativa, *H. vulgare* and *Triticum* sp. in this experiment adapted to the environmental and management conditions. All accessions were able to complete their growth cycle until maturity; however, it is worth mentioning that some *H. vulgare* and *Triticum* sp. accessions were affected by the Barley yellow dwarf virus (BYDV). During the experiment, it was observed that the *A. sativa* and *H. vulgare* accessions showed higher leaf and stem production, good height and higher DM yield. *Triticum* sp. accessions showed higher leaf and stem production and DM yield (kg/ha), with a low incidence of diseases.

Morales-Sinchire *et al.* (2020) evaluated *Triticum* sp. and *A. sativa* under two production systems (hydroponic green forage and conventional open field) and determined a height of *A. sativa* in the conventional system of 82,7 cm; higher compared with the average of 62,71 cm in this study. This is possibly due to the difference in altitude (m.a.s.l.) and temperature (°C) between the two crops; which for this experiment was 2 905 m.a.s.l. and 13,8 °C respectively, compared with the place where the above-cited authors' experiment was conducted, which was 2 300 m.a.s.l. and 15 °C, which could favor the better development of the crop.

Donaire *et al.* (2020) evaluated 28 varieties of double-purpose winter cereals (forage and grain) including six accessions of forage *H. vulgare*, reporting heights of 60 cm in *H. vulgare*, similar to the average height (62,7 cm) reported in this work.

On the other hand, Contreras-Paco *et al*. (2020) evaluated a variety of *H. vulgare* in the high tropics of Peru at different altitudes (3 778 and 4 266 m.a.s.l.) and planting densities (90, 100 and 110 kg/ha); finding lower values (10 stems per plant) than those observed in this study (25 stems per plant), possibly influenced by the environmental conditions of this trial (2 905 m.a.s.l.), taking into consideration that the planting density was 100 kg/ha for each of the species. In this regard, Soto-Carreño and Hernández-Córdova (2012), mention that the yield of forage cereal species is the result of the interaction of different resources that plants have for their development. The variables that are attributed with the highest effect on the development of cereal species are climate variables, of which temperature, photoperiod and vernalization stand out.

The same authors report an average DM of 25 %, higher than that found in this study (20,7 %), which can be related to the establishment of the accessions, soil conditions, fertilization and the cutting age, which for this research was carried out at 112 days of development, compared to the cutting age in the research carried out by the above-mentioned authors, which was at 130 days.

Some accessions of *H. vulgare* and *A. sativa* showed average DM productions of 5 775,8 kg/ha, a result higher than that reported by Yepes-Chamorro (2013), who evaluated the agronomic performance of seven genotypes of forage *H. vulgare* in eight locations of the Nariño Department, reporting an average value of 4 843,3 kg/ha DM for *H. vulgare*.

Morales-Sinchire *et al*. (2020) found yields of 1,5 kg of DM/m^2 for *A. sativa* in open field, higher than that found in this experiment (0,577 kg of DM/m^2), which may be related to climatic conditions and lower plant height, which affected this variable.

DM production of some *Triticum* sp. stood out for an average of 5 404,4 kg/ha, a higher result than that reported by Álvarez-Romero (2017); who evaluated two varieties of *A. sativa*, two of *H. vulgare*, an advanced line of triticale and two varieties of *Triticum* sp. in the Toluca Valley, Mexico, under the effect of two nitrogen doses (60 and 120 kg of N ha) and three phenological stages at cutting (lodging, anthesis and milky-massy grain); finding values of 2 933 and 2 433 kg/ha in the two varieties of *Triticum* sp. These values are possibly influenced by the genetics of the accessions, the management and the environment where they were established. Some favorable aspects of *Triticum* sp. compared with other cereals make it an alternative for forage production in certain regions, such as: higher resistance to cold weather, genetic resistance to leaf diseases, excellent reaction to grazing and good quality and quantity of forage produced throughout the growing cycle (Bainotti *et al*., 2006).

In this work it could be proven that the Barley yellow dwarf virus (BYDV) differs greatly between species and accessions, as its name indicates it primarily affected *H. vulgare* because it is more sensitive (Agrointegra, 2017); with a higher concentration in some accessions than in others, but the resistance of this species to the virus showed that proper management of it could prevent the total loss of the crop. Some *Triticum* sp. accessions were slightly affected and others were not affected. Some favorable aspects of *Triticum* sp. with regards to other cereals that make it an alternative for forage production in certain regions are: higher resistance to cold weather, genetic resistance to leaf diseases, excellent reaction to grazing and good quality and quantity of forage produced throughout the crop cycle (Bainotti *et al*., 2006).

Conclusions

The results of this experiment allow to recognize *H. vulgare* and *Triticum* sp. materials with potential to continue in research programs and which can be an alternative to mitigate forage seasonality and the low quality found during the dry seasons of the high Nariño tropics.

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Conflicts of interest

The authors declare that there is no conflict of interest among them.

Authors' contribution

- Filadelfo Hernandez-Oviedo. Conducted the research, data processing and writing of the original draft.
- Paola Andrea Portillo - López. Conducted the research, data processing and writing of the original draft.
- Diego Hernán Meneses - Buitrago. Conducted the research, data processing and writing of the original draft.
- Edwin Castro - Rincón. Carried out the conceptualization, developed the methodology and supervised the research.

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