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Research Article

Floristic Composition of Dairy Cattle Pastures in the Peruvian Northern Highlands

WL Carrasco[1], WY Alvarez[1,2]*, LA Vallejos[2] and HV Vásquez[1]

[1]*Estación Experimental Agraria de Baños del Inca, Dirección de Desarrollo Tecnológico Agrario, Instituto Nacional de Innovación Agraria (INIA), Jr. Wiracocha s/n, Baños del Inca, Cajamarca, Perú*

[2]*Departamento Académico de Ciencias Pecuarias, Facultad de Ingeniería de Ciencias Pecuarias, Universidad Nacional de Cajamarca, Cajamarca, Perú*

***Corresponding Author:** WY Alvarez, Estación Experimental Agraria de Baños del Inca, Dirección de Desarrollo Tecnológico Agrario, Instituto Nacional de Innovación Agraria, Jr. Wiracocha S/N, Baños del Inca, Cajamarca, Cajamarca, Peru.

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Abstract

To optimize cattle consumption and nutrition, it is essential to know the botanical characteristics of the pastures they consume. Therefore, the objective of the present research work was to evaluate the floristic composition, the productive performance of pastures and the productivity of dairy cattle on cattle farms in the inter-Andean valley of Cajamarca. The research was carried out in 10 dairy farms, under a mixed production system, with a stocking rate between 1.8 and 5.3 animal units per hectare. The floristic composition of the forage floor was determined using the "step transect" method to determine the desirable and undesirable species for livestock, considering the age of the pasture from 35 to 45 days and before grazing. A total of seven dominant species were found, of which *Lolium multiflorum* L. - "Cajamarquino ecotype", *Trifolium pratense* and *Trifolium repens* are desirable species for livestock and represent on average 44.84% of the forage floor, the difference being represented by weeds or undesirable species such as: *Pennisetum clandestinum, Rumex obtusifolius, Taraxacum officinale* and *Plantago major*. Also, the average biomass yield was 3.33 t. ha^{-1} with protein levels of 9.96%. The forage yield is low, which affects the animal carrying capacity and consequently the production of the dairy cows, ranging from 5.83 to 16.22 kg milk/day on average, showing very variable and with low profitability.

Keywords: *Cattle; Desirable Species; Forage Floor; Ranches; Productivity*

Introduction

One of the main issues associated with livestock production is the lack of basic knowledge related to the quality of the cattle's forage. This leads many landowners to undervalue the natural resources that are readily available on their land and to unintentionally apply unsustainable management practices which can negatively affect the pasture on their land [1]. Evaluating pasture quality and composition is essential to assess the herd's livestock potential and to subsequently generate a plan aimed at optimizing resources for their livestock [2]. Identifying existing plant communities in each area of the pasture is an important and necessary first step to use the pasture's existing natural resources more efficiently and to plan for improved land management methods [3]. For instance, by identifying the desirable and undesirable plant species in the pasture strategies that favor the desirable pastures can be more easily defined [4]. Knowing the pasture's plant species composition is also important when it comes to selecting the cattle's diet [5]. Better quality pastures can generate important

environmental and nutritional benefits for cattle, can lead to reduced methane emissions, and can serve as carbon sinks given their photosynthetic capacity [6].

The ecological diversity of the Cajamarca region of Peru has led it to become one of the most important dairies producing regions in the country. Breeds such as Holstein, Brown Swiss, and crosses between these and local cattle in higher altitude areas, produce 360,200 tons of fresh milk annually - equivalent to 17.9% of total national production [7].

These cattle consume mainly cultivated and natural pastures [8], of which the main species are ryegrass (*Lolium multiflorum* L.) "Cajamarquino ecotype" and white clover (*Trifolium repens*). Unfortunately, due to poor management practices in recent years, forage quality has been deteriorating resulting in fewer desirable species, lower yields, and nutritional values, allowing new undesirable species to take over [9].

However, to date no study has evaluated the proportions of pasture species in the Cajamarca region, and their influence on milk productivity, which limits the ability of dairy farmers to properly manage their land and pastures to improve milk quality and production. To reduce this condition, the present research was able to identify and quantify the floristic composition, the productive yield of pastures and the productivity of dairy cattle in cattle ranches in the inter-Andean valley of Cajamarca.

Materials and Methods

Study location and farms characteristics

This research was carried out in 10 farms located in the Quechua Natural Region, geolocated in the districts of Llacanora, Baños del Inca and Cajamarca in the inter-Andean valley of the province of Cajamarca (Figure 1). Strategic evaluation points were identified to cover the largest sampling area; being representative for the inter-Andean valley. In addition, the soils of each property were characterized, in order to know the qualities and composition of phosphorus, potassium, organic matter and pH (Table 1).

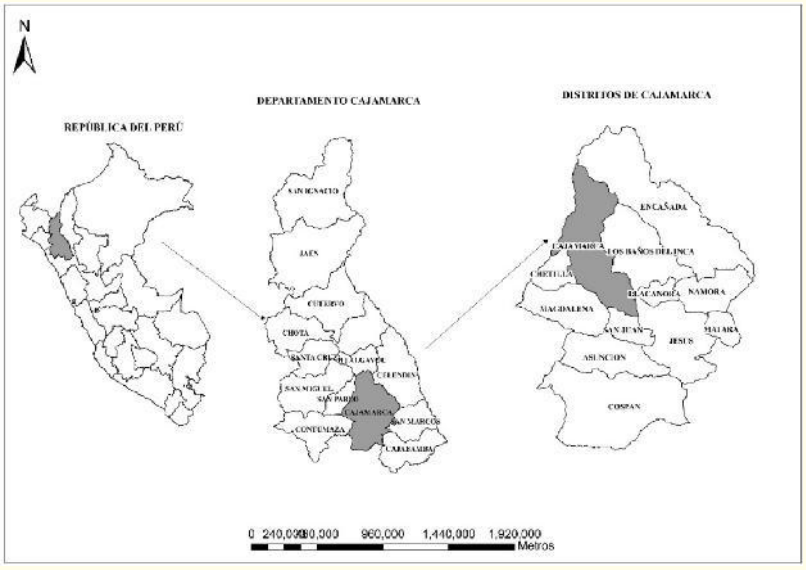

Figure 1: *Location of the evaluated dairy farms.*

Dairy farms	Coordinates			Composition chemical			
	Latitude	Longitude	Elevation m.a.s.l.	pH⁺	OM %	P (ppm)	K (ppm)
El Herraje	-7.138262	-78.493863	2688	6.40	5.30	36.40	286
Huayra-pongo	-7.173662	-78.469423	2648	6.10	3.82	33.70	271
Tres Moli-nos	-7.128219	-78.512986	2717	6.03	4.20	36.10	294
Tartar	-7.160632	-78.471924	2662	6.24	3.68	31.90	273
El Cortijo	-7.164671	-78.473469	2658	6.22	3.80	38.80	279
La Argen-tina	-7.155256	-78.501139	2683	6.55	6.40	60.80	365
Cristo Rey	-7.129120	-78.469068	2713	6.30	3.61	38.40	295
La Victoria	-7.188422	-78.459568	2638	6.15	3.02	30.60	263
Andagoto	-7.152360	-78.483417	2671	6.90	3.90	42.90	305
Santa Mar-garita	-7.186956	-78.456884	2639	6.42	3.82	29.50	300
Mean				6.33	4.16	37.91	293

Table 1: *Ubication coordinates and composition of soils on the dairy farms.*

OM: Organic Matter; P: Phosphorus; K: Potassium.

On the other hand, the characteristics of management, milk production performance in each herd were recorded (Table 2), in order to identify the animal units per area, the average milk production - based on historical records of one year, the dairy breeds present in each farm, the supplementation with concentrate, the pasture area, and the use of cultural work and fertilization to the pasture, since these are important characteristics for the evaluation of the characteristics of the floristic composition in each farm. In addition, the irrigation system used in all grazing areas is by flooding, and all farms keep records and use artificial insemination technology as a reproductive technique, and mineral salts as a pasture supplement.

Dairy farms	Animal Unit per-Surface (AU/ha)	Milk production		Breed	Balanced meal		Pasture area (ha)	Replant	Fertilize
		Her/day	Cow/day		Use	Quantity (Kg/ cow/day)			
El Herraje	2.3	108	13.50	Holstein	Yes	3	6.8	Yes	Yes
Huayrapongo	4.2	229	12.05	Holstein	Yes	6	9	Yes	Yes
Tres Molinos	3.2	267	12.14	Holstein, Brown Swiss	Yes	3	15	Yes	Yes
Tartar	2.2	35	5.83	Holstein, Creole	No	-	10	Yes	No
El Cortijo	3.0	600	16.22	Holstein	Yes	3	24	Yes	Yes
La Argentina	3.9	800	11.43	Holstein, Jersey, Brown Swiss	Yes	2	30	Yes	Yes
Cristo Rey	5.3	637	15.54	Holstein	Yes	5	15	Yes	Yes
La Victoria	1.8	180	8.18	Holstein, Brown Swiss	Yes	2	30	Yes	Yes
Andogoto	2.4	123	8.79	Holstein, Brown Swiss	No	-	15	No	No
Santa Mar-garita	2.4	178	11.13	Holstein, Jersey, Brown Swiss	Yes	2	16.4	Yes	Yes

Table 2: *Management characteristics and practices in the study on dairy farms.*

Pasture vegetation composition

The vegetation composition of the pastureland was assessed before cattle could forage (35- and 45-days post-cut). An 'X' shaped transect was walked using the "step transection method" (modified Parker's method) [10]. This method consists of measuring points on the ground approximately every 1.6 meters along two 80-meter cross transects, which form an X-shaped study area. A total of 50 readings were taken along each transect, resulting in 100 readings for the X-shaped area. A 1-inch diameter steel ring was used, held parallel to a rod at the operator's chest height; species within the ring were recorded. This method was repeated 5 times at each farm. Plant species were classified as "desirable", or "undesirable" based on livestock acceptance and producer consideration [11]. Rye grass ecotype cajamarquino (*Lolium multiflorum* L.), Red clover (*Trifolium pratense*) and White clover (*Trifolium repens*) are considered desirable, while Kikuyo (*Pennisetum clandestinum*), Cow's tongue (*Rumex obtusifolius*), dandelion (*Taraxacum officinale*) and plantain (*Plantago major*) are considered undesirable.

Forage yield and nutritional quality

Five vegetation samples were taken at each dairy farm. Each sample was cut in a one square meter quadrant, at an average height of 2 cm from the ground, simulating animal consumption, following the method of [12]. Each sample was weighed on an analytical balance (Sartorius type 1501 BMP8-1) and the weights were used to estimate the biomass yield (t. ha^{-1}). Dry weight was estimated by drying 100g of fresh green forage for 24 hours at 65°C. The dried vegetation was subsequently weighed and the difference in dry and fresh weight was calculated using the AOAC 925.09 method [13]. Protein content was measured using the AOAC 928.08 method [14], in the INIA - Cajamarca Laboratory.

Statistical analysis

Analysis of variance (ANOVA) was performed to determine the differences between green forage yield, dry matter yield, protein levels and vegetation composition, having dairy farms as treatment comparison. A comparison between treatments was performed using Tukey's test. In addition, descriptive statistics were used to determine averages and variability. All statistical analyses were performed using the RStudio (version 1.2.5033) software platform of R version 4.0.5 (2021-03-31).

Results and Discussion

Soil chemistry

Soil pH was mostly acidic, ranging from 6.03 to 6.90. Organic matter (OM) varied with farm, with La Argentina and El Herraje farms having the highest values (6.40% and 5.30%) and the Victoria farm (3.02%) having the lowest levels. Phosphorus levels ranged from 29.50 to 60.80 ppm with an average of 37.91 ppm. Potassium concentrations ranged from 263 to 365 ppm, with an average of 293.10 ppm (Table 1).

Soil pH, phosphorus and potassium were higher than reports from previous studies in the Peruvian Andes [15]. Organic matter soil was lower than that reported by [16], but, slightly higher than that reported in an open field system by [15]. Soil pH+ range between 5.5 and 7.2 is important for nutrient assimilation and the proper growth and development of plants. Soil organic matter is an especially important indicator of soil quality as it is relating to biological activity, soil structure and nutrient storage capacity; it also generates good soil aeration, better infiltration, and water retention [17]. Phosphorus is an essential element for the growth and development of plants responsible for energy storage and transfer training [18]. Likewise, potassium regulates the proper functioning of the opening and closing of stomata, it intervenes in photosynthesis and maintains root growth [19]. Results this study show that the Cajamarca valley farms, generally contain high levels of phosphorus and potassium levels means. Also, pH range suitable for growing grasses.

Organic matter: Dairy farm soils with higher OM values are those with higher cattle population per unit area, showing a direct relationship; therefore, the higher the number of animals, the higher the amount of manure; it could be that the increase of manure incorporated to the paddock from grazing animals provides higher levels of organic matter in the soil. Knowing that the incorporation of manure improves the levels of organic matter [20].

Forage yield and protein levels

The Argentina farm has the highest yield values for green forage and dry matter (15.14 t/ha and 4.12 t/1ha respectively), and the Tartar and Victoria farms had the lowest yields (10.56 and 10.16 t/ha; 2.98 and 2.98 t/ha, respectively) compared to the other farms (Figure 2). Similarly, protein levels were highest at the Argentina farm (11.5%), and lowest at the Tartar, La Victoria, Tres Molinos and Andogoto farms.

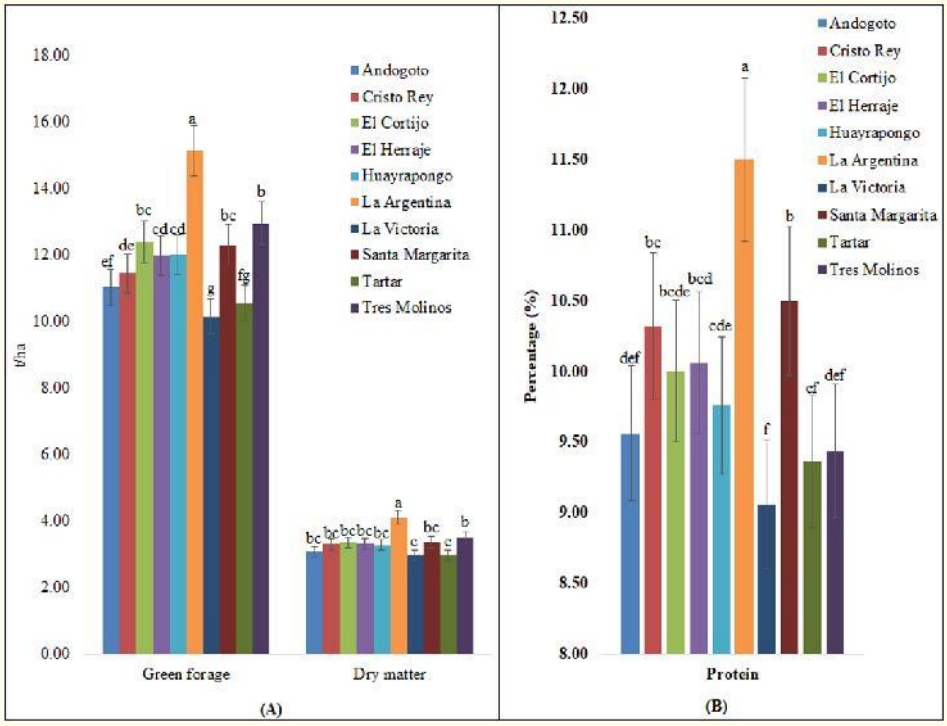

Figure 2: *(A). Green forage yield, dry matter, and (B) protein concentration in the different farms in the Cajamarca valley. Average with different letters (a, b and c) indicate statistical differences between systems according to the Tukey test ($p < 0.05$).*

Yield: Possibly these differences in yield between farms are due to the levels of organic matter present in the soil of each farm; also, to the optimal time of pasture utilization or grazing frequency [21], considering the effect that yield has on stocking rate and milk production, because of the pasture management conditions provided by the farmers (Table 2).

On the other hand, the differences in protein between farms are possibly due to the climatic conditions of the Cajamarca valley and the pH of the soil; this contributes to the high nitrification of organic matter. Therefore, when there is a higher concentration of organic matter there is greater mineralization; consequently, there is greater availability of nitrogen in the soil, which is reflected in high levels of protein in the pastures. In addition, the protein quality of pastures depends to a great extent on the floristic composition [22], A great variability has been found in the desirable species for dairy cattle feeding, which will be a source for a variable digestibility of the ration utilized by the animal [23].

Forage yields determine the availability of biomass (Kg of DM/ha) for animal consumption, which allows for a higher stocking rate. Yields for green forage were higher than those reported by [15]. Likewise, the dry matter yield (biomass) found were higher than the reports by [24]. This shows us that forage production in the Cajamarca valley is regular - low with an average of 3,33 t/ha of biomass. Protein levels are important in cattle for the maintenance and development of desirable microbial flora in the animal; likewise, high protein levels improve milk production performance [25]. It is known that milk yield in the Cajamarca valley averages 6.01 kg/cow/day [26], which could be related to the low protein levels (9.95%) contained in the evaluated pastures. It should be noted that the difference in protein levels on each farm is possibly related to the diversity of the different plant species on each farm, and the levels of organic matter in the soils.

Pasture vegetation composition

Among the desirable plant species, the majority was composed of *L. multiflorum* L., which was also the dominant plant species in Andagoto, El Herraje, Huayrapongo and Tres Molinos dairy farms (42.4%, 24.19%, 25.20% and 26.40%, respectively). On the other hand, *Pennisetum clandestinum* was the most common undesirable plant species. No significant differences between dairy farms were observed for *Pennisetum clandestinum*, Taraxacum officinale and *Plantago major* species (Table 3). The species found in this study are the most representative of the botanical composition in Cajamarca valley.

Dairy farms	Desired species (%)				Undesirable or weedy species (%)				
	Lolium multiflorum	*Trifolium repens*	*Trifolium pratense*	Mean	*Pennisetum clandestinum*	*Rumex obtusifolius*	*Taraxacum officinale*	*Plantago major*	Mean
Andogoto	42.4a	8.8bc	0.0b	51.2ab	17.2	24.8b	3.2	3.6	48.8ab
El Herraje	24.2b	17.9ab	1.7ab	43.8 abcd	24.4	20.0ab	6.8	5.0	56.2abcd
Huayrapongo	25.2b	8.8bc	0.2b	34.2d	47.8	9.0ab	4.8	4.2	65.8d
Tres Molinos	26.4b	25.8a	0.0b	52.2ab	34.8	4.8a	1.0	7.2	47.8ab
Tartar	31.8ab	5.2bc	3.1a	40.2bcd	40.6	5.8a	5.6	7.8	59.8bcd
Cortijo	29.6ab	6.2bc	0.4ab	36.2cd	42.0	8.0ab	3.8	10.0	63.8cd
La Argentina	38.8ab	3.0c	0.0b	41.8 abcd	40.6	12.0ab	2.4	3.2	58.2abcd
Cristo Rey	37.0ab	16.8ab	1.2ab	55.0a	19.4	14.0ab	3.8	7.8	45.0 a
La Victoria	39.0ab	5.2bc	0.0b	44.2abcd	39.8	7.8ab	3.0	5.2	55.8abcd
Santa Margarita	38.6ab	10.7bc	0.3b	49.6abc	25.6	15.2ab	5.8	3.8	50.4abc
Mean	33.30	10.85	0.69	44.84	33.22	12.14	4.02	5.78	55.16
SEM	2.11	2.27	0.32	1.29	3.39	2.04	0.55	0.72	1.29
p value	< 0.001	< 0.001	0.006	< 0.001	0.152	0.010	0.829	0.814	< 0.001

Table 3: *Botanical composition of the forage component in fairy farms in the Cajamarca countryside.*

Averages with different letters (a, b, c and d) indicate statistical differences between farms according to Tukey's test (p < 0.05).

The condition of the pastures in the Cajamarca valley was evaluated by their floristic composition and nutritional value. The La Argentina farm presented the best yields of green forage, dry matter and protein levels, which have a positive relationship with the levels of organic matter determined in the soil analysis, with no effect of the low proportions of specifically desirable leguminous species (*Trifolium* ssp.), with a considerably high proportion of *Pennisetum clandestinum* and *Lolium multiflorum* L.

In Cajamarca countryside is believed to provide a good source of forage as both *L. multiflorum* L. and *T. pratense* occur together [9]. This provides the cattle with better proportions of nutrients, especially protein, which favors the performance of the cattle. Likewise. As grasses form a major component of a cattle's diet [27], the farms we surveyed were well composed for healthy and productive dairy cows. We found a total of seven different plant species in the pastures surveyed. The pasture vegetation composition in our study was lower than that reported [6], which may be due to a difference in elevation (2400 to 2900 masl compared to 2639 to 2717 masl in ours). *Lolium multiflorum* L. and *Trifolium's* ssp. are considered as desirable species under the grazing system. However, *P. clandestinum* in the farms of the Cajamarca valley has become naturalized, in some cases it is considered a weed; should be considered that cattle have incorporated it as part of its diet, therefore it is found in proportions considered high in all farms. It should be mentioned that for the development of *P. clandestinum* the soil characteristics of the estates of the Cajamarca valley are favorable, due to the content of Moisture and organic matter. On the other hand, *R. obtusifolius, T. officinale* and *P. major* are considered undesirable species for livestock, even though they are consumed by them. *R. obtusifolius* has been a species that contains high levels of oxalate, an inhibitor of calcium metabolism [28], therefore, its consumption would be reducing the availability of Calcium in milk, consequently, its quality decreases; Since Cajamarca is the main dairy basin in the country, and the proportions of *R. obtusifolius* found are considerable (average 12.14%).

The percent average of *L. multiflorum* L. was higher than those reported by [15,29]. The percent average of *T. pratense* were higher than those found in [15]. The variability of the proportions of the desirable species is possibly due to the frequency of grazing in each farm, because early grazing prevents the flowering of *L. multiflorum* L. and allows the development of weeds. Furthermore, this variation trend would be related to the high animal load used in some paddocks, which leads to a high compaction of the soils, consequently, favors the invasion of weeds. Finally, the high proportion of undesirable species or weeds can be attributed to the irrigation system by Flood, the same one that carries weed seeds from the neighboring farms; these being the main factors that determine the variability of the botanical composition.

Factors affecting the vegetation composition of the pastures include environmental conditions and management practices. For example, warmer temperatures (e.g. Between 12 and 25° Celsius) favor grass growth [30]. Additionally, topography and soil type can also pasture vegetation composition [31]. Mismanagement of livestock activity can also play an important role [32]. Prolonged grazing and overgrazing can change the vegetation composition to favor undesirable plant species [32,33], affecting pasture yield and nutritional quality.

Conclusion

The most common forage species associations found on the 10 farms surveyed were *Lolium multiflorum* L. "cajamarquino ecotype" and *Trifolium repens* with a representation of 33.30 and 10.85% respectively. Also, a high proportion of *Pennisetum clandestinum* (33.22%) and *Rumex obtusifolius* (12.14%) were found to be present in all dairy farms, which play an important role in the nutritional quality of the forage, where 9.96% of protein was mainly determined. On the other hand, the average forage yields in the Cajamarca countryside are low with values of 3.33 t. ha^{-1}, which affects the animal carrying capacity as well as the production of the dairy cows. The milk yield of the cows on the farm's ranges from 5.83 to 16.22 kg milk/day on average. Milk yield is influenced by the pasture and the floristic composition of the forage floor as determined in the present study.

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Conflict of Interest

We certify that there is no conflict of interest with any financial, personal or other relationships with other people or organization related to the material discussed in the manuscript.

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