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Forage Offer and Nutritive Value of *Elaeagnus angustifolia* in North Patagonia, Argentina

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Abstract: The presence and growth cycle of the browse *Elaeagnus angustifolia* (olivillo, Russian olive), naturalized in the Mid Valley, Rio Negro, Argentina, must be considered in the yearly schedule of rangeland management. Field observations showed that cattle prefer the leaves of this species that are included on the reproductive branches which develop as a thyrse inflorescence. In this trial, authors studied the incidence of *E. angustifolia* in the breeding cow's diet as determined by microhistological analysis of cow feces; mapped the distribution patterns in a cattle farm and quantified its abundance in different parcels; estimated the volume of forage produced by this species and determined the nutritive value of the edible parts of the plants. The quality and quantity of the thyrses accessible for cow's browse suggest that *E. angustifolia* must be considered as an important feed input. The results are used to schedule grazing periods in a valley farm divided into plots with different abundances of *E. angustifolia* and a known floristic composition.

Key words: *Elaeagnus angustifolia*, invader, cattle grazing, forage resource.

1. Introduction

Elaeagnus angustifolia L. (olivillo, Russian olive, Bohemia olive, silverberry, oleaster) is a multiple-stemmed deciduous species of Elaeagnus, native to Eurasia. It was introduced to America in the late 19th century and it became invasive in riparian habitats. It has been reported as alien species in North America [1, 2], in New Mexico [3] and in Argentina [4, 5].

Russian olive has naturalized in the Mid Valley region of Rio Negro Province, in the North of Patagonia, Argentina. It was introduced as a garden tree but escaped from cultivation to colonize the river coastal areas. Several ecological strategies [6] helped this species to spread and naturalize over the valleys, as nitrogen fixation, rapid vegetative propagation, production of numerous seeds, buoyancy of fruits, tolerance to different environmental conditions, adaptation of root system architecture to diverse soil conditions and the allometry of the branches adjusted to compete with various neighboring species.

During the diverse stages, from invasion to colonization of the area, the species received wavering evaluation from the rural coastal cattlemen. Livestock producers first ignored *E. angustifolia* due to unawareness; then they considered it a weed because of the inconvenience it caused in the management of cattle in extensively used fields. When weather conditions turned adverse for cattle breeding due to a long and severe drought in the region, cattle owners realized that the Russian olive tree was a forage alternative [7].

Now that the invasive *E. angustifolia* has been recognized as a forage resource, its presence and phenology must be considered in the yearly schedule of rangeland management.

Previous studies showed leaf heteromorphology [8]. Field observations indicated that cattle prefer the leaves of *E. angustifolia* that are included on the reproductive branches which develop as an indeterminate inflorescence called a proliferating thyrse [9].

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Knowledge of the diet of grazing animals is important in developing management standards that allow the proper use of rangelands. The utilization of epidermal characteristics to identify plant components in esophageal, ruminal, or fecal samples is a widespread technique used to study diet composition of free-ranging herbivores [10].

The aims of this field/laboratory trial were to find out the incidence of *E. angustifolia* in the breeding cow's diet as determined by microhistological analysis of cow feces; to map the distribution patterns and quantify the abundance of *E. angustifolia* in different parcels; to estimate the volume of forage produced by this species and to determine the nutritive value of the edible parts of the plants. The results are used to schedule browsing periods in a valley farm divided into plots with different abundances of *E. angustifolia* and a known floristic composition [11-13].

2. Material and Methods

2.1 Study Site

The observations and measurements were made in a 560-hectare cattle farm at the northern margin of Río Negro province, Argentina (39º30′ S, 65º30′ W), where *E. angustifolia* has become naturalized [14]. The region is semiarid, subjected to a great daily and seasonal temperature range, average values fluctuate from 6.83 ºC in the coldest month (July) to 23.02 ºC in the hottest month (January); the medium annual precipitation is 303 mm. Annual evapo-transpiration is over 800 mm, with a negative water balance throughout the year [15]. The farm is divided into parcels of different sizes, distributed from the river coast to the plateau/valley ecotone (Fig. 1). The area, the percentage occupied by *E. angustifolia* and the distribution of the populations were defined for each plot using maps and satellite images (Table 1, Fig. 2).

2.2 Cattle Management

The farm has 12 parcels ranging from 7 to 100 ha, divided with traditional or electric fences to rotate animals grazing. Stocking rates are composed by 110 cows with their 2 to 5-month-old calves (80 to 90) in January and with the remaining yet unsold 7 to 9-month-old calves (around 30) in July. It was planned to use the padlocks with Russian olive for grazing during the spring/summer (October to March).

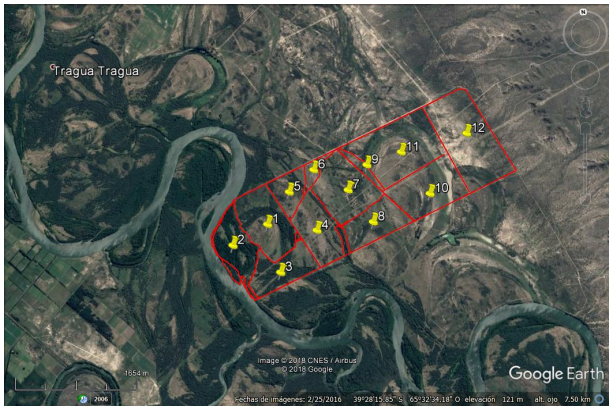

Fig. 1 Cattle farm divided in 12 grazing plots.

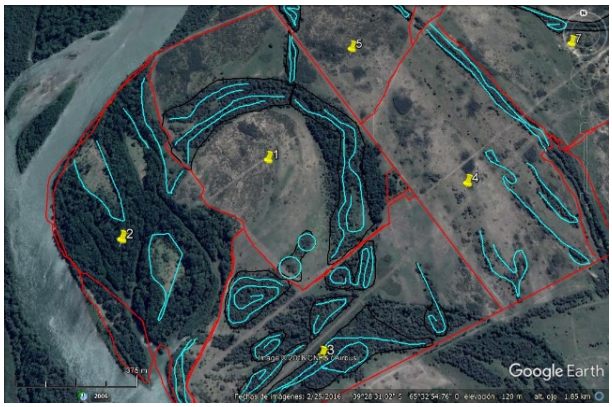

Fig. 2 Detail of some grazing plot showing *E. angustifolia* populations, distributed as invaded rows (light blue) or surfaces (surrounded by a black line).

2.3 Biomass

To estimate the amount of forage that cows may eat from the *E. angustifolia* trees, samples were collected, dried and weighed during all the growing cycle. The edible biomass was calculated considering height the cows can reach to eat the foliage, the thyrse, the number of thyrse per branch, the number of branches per linear meter. The accessibility to the plants was cheeked *in situ*. In open populations the whole surface was recorded. Where the population of *E. angustifolia* follows the course of old river channels authors

considered the dry matter produced on both sides and ignored the production of reproductive branches on the interior of the channels because they were small and of difficult access for the bovines (Fig. 1, detail).

2.4 Diet Microhistological Studies

Plant epidermal characteristics were used to identify components in fecal samples and to study the diet of the cows. Cows' fecal material was collected at the beginning, i.e., 5 days after the entrance of the animal to a plot. For the analysis, 10 slides were made for each of the 20 different cows' feces sampled per date and 40 microscope fields per slide were systematically observed with 100× magnification [10]. The frequency value obtained for each species is converted to density using the table of Fracker y Brischle [16].

Reference slides of leaf, stem and fruit samples of the species present in the area were used for the subsequent identification of epidermal fragments in fecal samples. These slides were prepared with diaphanized material [17], epidermis fragment removed by scraping [18] and according to the method described by Hansen, et al. [19], which used ground material to prepare the samples.

2.5 Feed Analysis

Feed analysis of CP (Crude Protein), ashes (ash), NDF (Neutral Detergent Fiber), ADF (Acid Detergent Fiber), ADL (Acid Detergent Lignin) was made using the sequential method [20], IVDMD (*in Vitro* Dry Matter Digestibility) was determined by Tilley y Terry method [21] in the Animal Nutrition Laboratory, UNS, and are expressed as %. Nutritional analysis (ppm, except chloro as mg/100g) of complete thyrse and separated leaves and fruits in October 2013, January and March 2014, was analyzed with an Atomic Emission Spectrometer (ICP-AES) at LANAQUI laboratory.

2.6 Statistical Analysis

Data were analyzed with ANOVA, and Tukey Test (p-level 0.05).

3. Results and Discussion

Table 1 shows the grazing schedule year-round including all the parcels. The surface of each parcel is shown as well as the portion of the parcel occupied by *E. angustifolia*, expressed in hectares and as percentage of the total surface. The highest records of accessible edible forage were obtained in the middle of the growth cycle, i.e. in January, when the fruits have formed on the thyrses but they are not mature and the seeds are soft and digestible by cows (from February onwards the entire seeds are eliminated in the feces). The edible biomass was calculated considering that cows may eat the thyrses up to 2.50 m in height. Regular weight of thyrse with immature fruits is 11.03 g DM (Dry Matter) and there are usually 20 thyrses per branch. Average 92 reproductive branches were counted in 1 linear meter per 2.5 m height. The maximum dry matter production was estimated as 20.29 kg/m, considering the height the cows can reach (2.5m). The average thyrse weight at the beginning of the growth cycle was 1.80 g DM and when the fruits matured, the mean weight was 8.90 g DM. Biomass production per hectare of the target-plant invaded area and the incidence of its production in the total parcel biomass values, are expressed to compare with *E. angustifolia* consumption evaluated by microhistology as percentage of the total diet of the cows, at the beginning of the grazing period of each plot. The vegetative period of *E. angustifolia* begins in early September, and by the end of the month the first signs of thyrse formation can be detected. The reproductive thyrse elongates during October and the flowers open by the end of the month (Fig. 3a) and continue flowering during November. Small green fruits can be found in December (Fig. 3b). In January the seed inside the fruit is still smooth but it becomes hard in February. The data show that cattle find the thyrse leaves palatable and eat them when moved into a plot (Table 1) specially in the stages from flowering to fruits with smooth seeds (Fig. 3c). Table 2 shows the nutritional and digestibility characteristic of the

Table l Plot number, plot surface (P ha), surface occupied by *E. angustifolia* (E.a. ha), % of the plot area occupied by E.a. (% E.A. inv), edible Maximum expected E.a. biomass offer per plot (t/plot), edible actual expected E.a. Biomass offer per plot (t/plot) and E.a. biomass available per bovine consumption per ha of invaded area. (t/ha inv.) or per plot (t/plot), month of grazing by plot (Month. Gz), consumption at the beginning of the grazing period as determined by microhistology, % of the total diet (% E.a. diet).

Plot No.	ha/plot	ha E.a. /plot	% E.a. inv/plot	E.a. t/plot Max.	E.a. t/plot actual	t E.a./ha inv. max	t E.a./ha plot	Month grazed	% E.a. diet/stage
1	57.0	16.07	28.14	135	33	8.40 b	2.37 f	November	37.26 (flowering)
2	42.0	5.78	13.60	59	43	10.14 d	1.38 e	December	45.69 (small fruit)
3	39.0	11.97	30.72	133	133	11.10 e	3.44 h	January	70.59 (smooth seeds)
4	44.7	6.40	14.31	13	6	20.03 h	2.91 g	February	29.54 (hard seeds)
5	23.2	2.10	9.05	24	6	11.23 f	1.02 d	End October	5.10 (young thyrses)
6	8.0	0.63	7.80	5		7.90 a	0.62 b	gathering paddock	
7	60.1	5.62	9.35	54	5	9.70 c	0.91 c	March	29.00 (hard seeds)
8	40.0	---	---	---		---		April, May	
9	8.0	---	---	---		---		gathering paddock	
10	54.0	---	---	---		---		August	
11	79.0	0.87	0.87	10	1	11.50 g	0.13 a	October	1.80 (small thyrses)
12	110.0	---	---	---		---		June, July	

Different letters in the same column mean significant differences at $p < 0.05$ by Tukey Test.

Table 2 Feed (CP, ashes (ash), NDF, ADF, ADL, IVDMD as %) and nutritional analysis (ppm except chloro as mg/l00g) of complete thyrse and separated leaves and fruits in October 2013, January and March 2014.

Month and material	CP	Ash	NDF	ADF	ADL	IVDMD	K	Ca	Mg	Na	P	S	Cl
Oct. 20l3 initiating thyrse	33.74	7.00	49.43	20.74	4.97	63.84	10,896	4,387	1,615	408	5,022	3,662	229
Jan. 20l4 entire thyrse	15.35	5.11	35.37	22.23	8.53	66.30	2,944	7,817	2,035	951	1,027	1,938	226
Only leaves	22.02	7.41	39.38	22.09	7.27	62.11	3,743	9,904	2,446	1,201	1,149	2,053	300
Only fruits (immature)	8.60	3.44	14.74	9.09	2.82	88.25	3,138	676	436	369	664	590	67
Mar. 2014 entire thyrse	15.27	8.06	37.36	24.67	8.80	62.17	3,851	9,449	1,952	1,371	1,332	2,146	304
Only leaves	20.16	6.94	37.99	21.41	7.08	57.05	8,702	9,040	1,859	1,517	1,418	2,811	341
Only fruits (without seeds)	7.02	3.67	l9.83	12.05	3.81	84.85	6,028	1,369	433	507	582	470	69

different edible parts of *E. angustifolia* in diverse developmental stages.

Traditionally, the coastal cattle farms in Mid Valley of Rio Negro Province have used the spontaneous vegetation as forage resource. Years before this work was started the farm was livestock grazed as an undivided unit. In 2007, it started a long drought period which derived in great regional cattle lost because of the lack of food. Cattle men in riparian areas found out the *E. angustifolia* provided forage and was eaten by cows up to the height the animal could get [7]. Since 2010, the cattle field from where these data were obtained has been divided in small plots and a rotational grazing system has been planned to use efficiently the different forage resources. The Russian olive sites, i.e. those riparian plots and the ones with old river channels, had been used to feed breeding cows during spring and summer, using a schedule of high-density grazing (3 to 5 cow-equivalent/ha) during one month in each plot.

Trees and shrubs, often called browse or topfeed, have long been considered important for the nutrition of grazing animals in other semiarid regions such as Australia, particularly in those areas with a pronounced dry season [22]. They provide the only source of protein and energy during drought. Trees and shrubs do not always have high digestibility, so their energy value may be low. These have been the reasons by

Fig. 3 Thyrses of E. angustifolia.
(a) Flowering stage, (b) immature fruits and (b) cows consume the entire thyrses.

which this study was performed. Authors knew that some parts of the *E. angustifolia* foliage were eaten by cows, but authors needed to obtain animal preference evidence and to evaluate nutritional values.

Previous studies showed leaf heteromorphology [8]. Upper leaves present many xeromorphic characters that enable the trees to maintain their canopy foliage even under the unfavorable conditions (high solar radiation, high temperature, low humidity) during the summer. Lower leaves show many traits of shade leaves and allows the plant to compete for space also in the understory. The author believes that *E. angustifolia* relies on its foliar plasticity, to overcome the environmental gradient between the lower and upper part of a developed tree and even to compete against other species when it grows in places where spatial environment heterogeneity can easily manifest, as in a river valley of a semiarid region.

Field observations showed that cattle eat the leaves of *E. angustifolia* that are included on the reproductive branches which develop as a proliferating thyrse. Lower shade leaves are left intact even when food is scarce, so currently a study is being done to identify and quantify secondary products that make them inedible.

Upper brilliant grey leaves are included in the inflorescence and form long pendular proliferate thyrses. They are consumed by cows from the first stages of inflorescence and fruit formation until early fall, when the fruits are mature, and the seeds are hard and pass through, entire and undigestible, to the feces.

The chemical analysis, the animal voluntary consumption as well as the accessibility of the edible material are factor that must be analyzed together to evaluate the importance of browse plants. Chemical analysis of *E. angustifolia* edible parts has shown important protein content, the highest in blooming thyrses and the lowest in immature fruits, and digestibility over 60%, except in fall leaves. The content of mayor minerals indicates a good input to the cows' diet, specially the Ca and Mg values. The data shown in Table 1 point out that *E. angustifolia*

contributes in a great percentage of the diet and that the animal's voluntary consumes this species thyrses when they enter a new grazing plot. It is important to note that an equal or superior amount of biomass composed of grass and other herbaceous feed is available in each plot when animals enter grazing (unpublished data). The preference for *E. angustifolia* becomes evident specially in the middle of the summer (January) when the fruits are developing and have smooth digestible seeds. The distribution of the species populations in the different plots, the height the cows can reach, their preference for reproductive branches and the parts of the plant included in the cows' bite have been considered when calculating forage offer.

Lamers and Khamzina [23] studied the quality profile and production of foliage from trees grown on degraded croplands of Central Asia and found that the leaves of *E. angustifolia* could be used to supplement protein poor feed rations on dairy cows. The values of feed analysis that they obtained were like authors', considering that they worked on young (4 years old) trees that have not yet begun the reproductive face [6]. They recommend the leaves harvest on the fall based in volume and quality of the leaves. In authors' site, authors have old stablished populations so by fall time the feed quality of the entire thyrse is lesser than during summer time. The fact that the seeds are not digested and pass through to the feces must be considered when evaluating volume and nutritive values.

E. angustifolia can act as a weed and difficult cattle production if the invaded areas are not correctly managed. Division in small plots, short periods (no more than one month) of intense grazing followed by long periods of recovery (until the next year) results in a good exploitation of the forage offer while the grazing and trampling around the mature edible plants maintains the animal access clean from root re-sprouting and other species competence, facilitating the sun light entrance necessary to produce new reproductive edible branches in the next growing cycle.

There are very different opinions on *E. angustifolia* value, but many researches confirm [24, 25] that, once the species is introduced in riparian areas it colonizes replacing the pristine vegetation. Mechanical removal of Russian olive by cutting down or pulling up trees without an herbicide treatment, usually results in a thicker stand of stems, due to its prolific re-sprouting and suckering capacity. Fire has the same effect and sprouting regenerates the population. In cultivated regions of Mid Valley, farmers continue to struggle with this species in the irrigated areas.

According to a recently published review [26], Russian olive should be regarded as a very useful multipurpose tree species. Nevertheless, due to its tendency to spread and colonize bare terrains or areas where it is not desired, a carefully monitoring is necessary to keep this species under control and prevent reduction of diversity. This author mentions also that in the perspective of contemporary climate change, Russian olive could gain more attention from foresters, ecologists and land managers who should develop an integrated management plan for this species.

As mentioned by Lefroy [27], to assess the contribution of browse species to grazing systems it is necessary to consider in turn their forage value to the animals, their economic value to the landholder and their ecological value in the landscape. Authorsadd to the list of characteristics of the species, its forage value, the quality and amount of accessible edible material, without forgetting the natural shelter and shade that it offers to animals in summer time in a semiarid region and the protection of the soil while incorporating nitrogen by actinorryzal symbiosis [6].

4. Conclusions

Mid Valley livestock rangeland must include the foreign specie *E. angustifolia* in the list of spontaneous forage trees present in the riparian zones. A grazing schedule of the cattle farms may improve the quality of feed considering the seasonal forage offer of the naturalized invader. High animal pressure also controls

the species vegetative reproduction and favors accessibility to edible parts of the plant by leaving free the out boundaries of the populations. A proposed management is to use in spring time the grazing-plots located in the riparian zone, which in that season have abundant green herbaceous vegetation of good nutritional quality, while *E. angustifolia* complements the offer. In the scheme of rotations, the paddocks of the area of valley plain should be allocated with population of *E. angustifolia*, to graze in the middle of summer, when the herbaceous vegetation loses water content and nutritional quality due to the heat and drought of these semi-arid zones and the offer of the *olivillo* thyrses, with their immature fruits, it can be the necessary protein contribution for the cows that at that moment are already pregnant and still have their calf with them. Authorspresent this study as an example that using the available rangeland resources more efficiently can substantially contribute to achieving future sustainability goals.

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