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EFFECTS OF BROWSING PRESSURE ON THE TEXTURAL CHARACTERISTICS OF *JUNIPERUS COMMUNIS* L. BRANCHES

Jordi SALDO*, Jordi BARTOLOMÉ

Department of Food Science and Technology, Autonomous University of Barcelona, Spain
*Corresponding author: jordi.saldo@uab.cat

ABSTRACT

In the Montseny Natural Park junipers scattered in the grasslands can be found. In some of these areas of the park, the breeding of small ruminants is allowed, while in others only find wildlife exists. Junipers develop differently if browsed, adopting spherical or conical morphotypes. This paper studies the mechanical characteristics of the shoots according to the sex of the bush and the branching regime to which they are subjected. 729 individual shoots were taken from male and female junipers exposed to browsing from goats and ewes and those not grazed and sampled at a different position from each bush. All the leaves were taken off the non-lignified end of the shot to be studied by a simulated bite. The strength needed to cut the apical twigs of junipers was measured using a Volodkevich jaw, which mimics the way incisors act, using a texturometer. The diameter of the branches differs according to bushes' sex being larger for females and the individuals not exposed to predation pressure. Although the differences induced by sex were significant, differences due to grazing pressure were larger. The annual branches were thicker and longer in non-grazed junipers. This difference was not due to the partial consumption of the studied branches, as all the samples were collected in full. The continued browsing pressure leads to a survival strategy of growing, with branches tighter packaged as was evident in the analysis of the branching structure. The longer annual branches in non-grazed bushes allow for a more open structure. The force necessary to break the branch was significantly higher on females. This could be related to the fact that the females must bear the weight of the fruits. The elasticity of the annual shots was significantly higher on non-grazed junipers, a fact that could be considered as a way to tolerate herbivory.

Keywords: *sex dimorphism, small ruminants, juniper, grazing, morphotype.*

INTRODUCTION

Studies of plant-herbivore interactions have had a major focus of interest in the chemical defences that plants develop in the form of secondary compounds (Haukioja, 1991; Strauss and Agrawal, 1999) and how herbivores adapt to them. Some works have also addressed the role of physical defences such as spikes

and thorns (Cooper and Owen-Smith, 1986). But plants also may limit herbivory by producing hard, rigid leaves and stems that are difficult to chew. These physical plant traits can reduce the performance and productivity of herbivores by reducing ingestion or increasing the time necessary to obtain enough energy. However, the information on physical plant strategies of tolerance to defoliation is remarkably scarce.

Juniper (*Juniperus communis* L.) is a species characterized by having a high content of secondary metabolites (Butkienë et al., 2015), which can be considered as chemical constitutive defences. However, resistance may not be a viable strategy if the resistant species are eventually defoliated (Augustine and MacNaughton, 1998) what happens in the case of juniper browsed by goats and sheep (Bartolomé et al., 1998). It is also necessary for these species to have a certain degree of tolerance to defoliation. Tolerance is defined by having traits that enable plants to recover from herbivory. Some of these traits are the ability to increase branching or, as in the case of juniper, adopt structural morphotypes that reduce the consumption capacity of herbivores (Strauss and Agrawal, 1999). Besides, these traits can be induced, which means they increase after herbivory (Haukioja, 1991). Another aspect to consider is that juniper is a dioecious species, therefore the response to herbivores could be different depending on the sex of the plant (Cornelissen & Stiling, 2005).

The aim of this study was to evaluate and compare the re-growth traits of browsed induced morphotypes of juniper in order to determine their tolerance to herbivory and if that tolerance is different according to the sex of the individual.

MATERIALS AND METHODS

Study area

Montseny massif (1,707 m a.s.l.) is located in Catalonia, NE of Iberian Peninsula, in the Mediterranean region, and known throughout the world for the beauty of its landscapes. Its abrupt relief, surrounded by streams and ridges, results in an extraordinary variety of habitats that had led to be considered one of the UNESCO biosphere reserves. The climate at the highest points is temperate with an average annual temperature of 7 °C and an average annual precipitation of 1,000 mm. Broadly speaking, the Montseny area presents three ecosystems organized according to altitude. The lower parts of the mountain, up to 900 m, are the domain of Mediterranean vegetation, especially holm oak (*Quercus ilex*) and its accompanying species. Euro-Siberian vegetation, with beech (*Fagus sylvatica*) and patches of fir (*Abies alba*) forests, extends from 900 to 1,600 m. Finally, subalpine dwarf shrub heathlands with heather (*Calluna vulgaris*), and juniper (*Juniperus communis*) and intermixed grasslands are present above 1,600 m but also in cleared patches of Euro-Siberian vegetation. This has been a mountain ridge heavily dedicated to human uses, and although now having a protection status and suffering the regression of agricultural, forestry and livestock activities, there is still a shared use with the protection of natural spaces.

In the Montseny peaks and altiplanos, subalpine grasslands are common. Juniper is one of the shrub species that currently colonize pastures due to the prohibition of fire in protected natural areas. Flocks of goats and sheep use daily the pastures for grazing (Bartolomé et al. 1998) and also browse on the scattered shrubs like juniper causing morphotypes in the shape of a sphere or cone less than a meter tall. In areas where grazing is not allowed, junipers develop in their typical flame shape several meters high.

Textural analysis

Apical shoots from 10 male and 10 female junipers corresponding to grazed and not grazed bushes were collected to study the force needed to cut the shot. The apical shots collected were all intact ones.

The force necessary to cut the juniper apical branches was measured by texturometer TA-XT attached to Volodkevich bite jaws, to simulate the action of the front incisor teeth and enables a cross-section of the sample, up to 1 cm, to be measured. The bite was done at 5 mm/s until the branch was cut. Measurements were repeated each 2 mm through all the length of the non-lignified part of the branch. The lengths of each shoot and its average diameter were recorded. A typical graph of force vs time for this bite imitation essay can be seen in Figure 1.

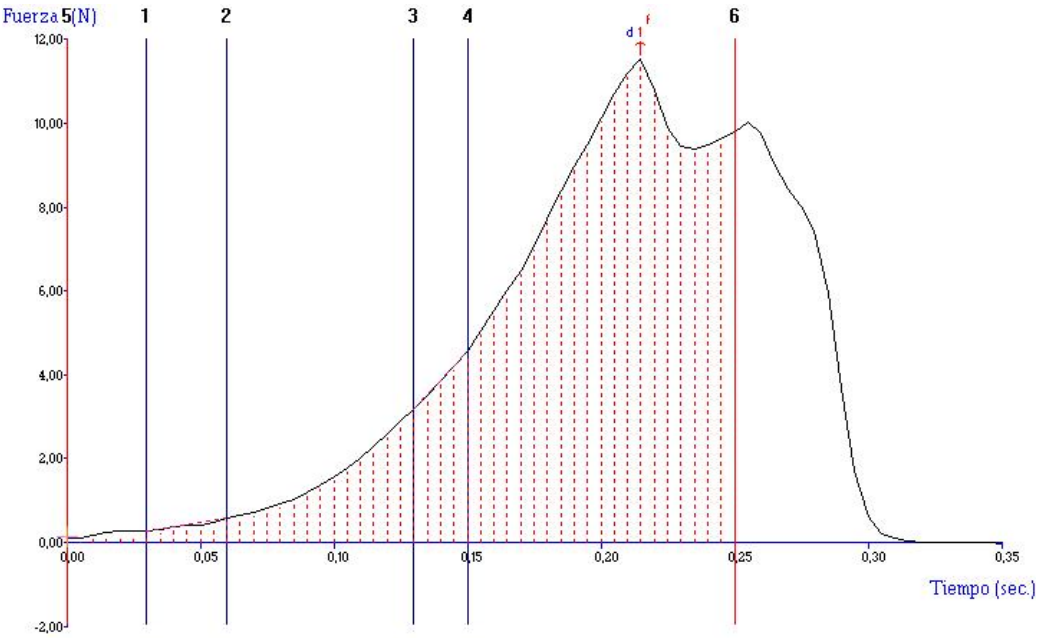

Figure 1. Example of a force-time curve corresponding to the cutting of annual shots of junipers between Volodkevich bite jaws.

From the recorded force-distance some variables were derived:

- The elasticity at low deformation, as the slope in the initial part of the curve, between 10-25 % deformation (points 1-2 in figure 1)
- The elasticity at high deformation, as the slope of the force/deformation curve before fracture, between 55-65 % deformation (points 2-3 in figure 1)
- The maximum force
- The distance of deformation at the point of maximum force (this distance is different from the thickness of the sample was fracturable)
- The work of the bite (area under the curve from the beginning of the test up to point 6, in figure 1)

Statistical analysis

729 individual measurements were made, studying 5 branches of any of the 20 individual junipers considered. The measured variables on each sample were subtitled to GLM procedure, analysing the parameters of sex and exposure to grazing and its interactions. Statistical differences between means were evaluated by means HSD test for an unequal number of observations at a p-value of 0.05.

RESULTS AND DISCUSSION

The diameter of the branches differs according to bushes sex (1.28 mm for females and 1.18 for males) and for predation pressure (1.15 for grazed bushes and 1.28 for non-grazed), as was the length (3.77 cm for females and 3.42 cm for males) (2.96 cm for grazed and 4.12 cm for non-grazed). Non-grazed bushes have a more open structure, while the individuals exposed to the activity of herbivores are more compact as a result of clipping of the growing annual shots and probably as a strategy to tolerate depredation. This browsing does not occur all year round, as during spring and summer the pastures are available and become the preferred source of feed. But in winter, when grasses are scarce, the herbivores graze on bushes such as junipers (McGowan, Joensalo and Naylor, 2004).

Female bushes produce significantly shorter branches. This inversion in vegetative growth can be expected, as usually females have to invest in reproduction more than males and thus have less remaining energy for vegetative growing. Whilst the differences by sex were significant, differences due to grazing pressure were larger. Although Stark and Martz (2018) found an increase in juniper biomass one year after pruning the young branches, this effect was not found in our study, probably due to continuous grazing effect. Cornellisen and Stiling (2005) detected in their metanalysis a tendency to longer shots in males exposed to herbivory, in coincidence with our results. The annual branches were thicker and longer in non-grazed Junipers. This difference was not due to the partial consumption of the studied branches, as all the samples were collected in full. The continued predation pressure leads to a survival strategy of growth, in which the animal would be forced to consume smaller shoots and consequently invest more time to satisfy its feeding needs.

On grasslands, the continuous pressure on bushes delays the ecological succession toward the forest, and an example is a reduction in the size of junipers on pasture lands. A similar pattern was observed on another species of juniper (*Juniperus macrocarpa*) on Doñana National Park (Muñoz-Reinoso, 2017).

On the measured textural characteristics presented in Table 1, most were the same for male and female junipers, as we may expect as morphological differences between sexes are scarce. However, the force necessary to break the branch was significantly higher on females (24.0 N against 22.0 N on males) and the depth of the bite was large (1.25 mm against 1.14 mm on males). This difference on the extension on the bite necessary to break the branch was partly related with the differences in size, but also was reflected on the average of samples that break before the incisors cut all the branch thickness (odds of 0.39 in front of 0.43 for males).

Table 1. Values of the parameters extracted from biting juniper branches (mean and standard deviation). Values in the same row with the same letter do not differ at p=0.005

	Browsed		**Non-browsed**	
	Male	**Female**	**Male**	**Female**
Length (cm)	2.77 ± 0.55 [a]	3.12 ± 0.52 [a]	4.09 ± 0.77 [b]	4.14 ± 0.79 [b]
Thickness (mm)	1.11 ± 0.17 [a]	1.19 ± 0.22 [a]	1.23 ± 0.26 [a.b]	1.36 ± 0.21 [b]
Modulus (low deformation)	14.6 ± 2.9 [a]	15.6 ± 5.2 [a]	16.4 ± 4.7 [a]	15.8 ± 6.6 [a]
Modulus (high deformation)	75.6 ± 9.6 [a]	84.3 ± 17.8 [a.b]	94.7 ± 20.0 [b]	89.0 ± 16.1 [a,b]
Breaking force (N)	19.1 ± 5.2 [a]	21.7 ± 5.1 [a.b]	22.8 ± 4.0 [b]	24.6 ± 3.8 [a,b]
Work (mJ)	1.77 ± 0.53 [b]	2.16 ± 0.72 [a.b]	2.30 ± 0.65 [a]	2.56 ± 0.46 [a]
Fracturability	0.36 ± 0.22 [a]	0.40 ± 0.22 [a]	0.50 ± 0.23 [a]	0.47 ± 0.29 [a]

The elasticity of the annual part of the branches was significantly higher on non-browsed junipers, accounting for 94 N/s when compared with 81 N/s on grazed bushes for 55-65% deformation (188 N/s and 167 N/s for 75-90% deformation, respectively). The higher force necessary to cause deformation to suggest a stronger structure may be more lignified. The force necessary to break the branch with the incisors correlated with the slope of the force-deformation curve, and was

higher for non-grazed bushes (24.3 N in front of 20.9 N for grazed junipers), the same as the distance necessary to achieve such a breaking (1.24 mm compared with 1.13 mm for non-grazed and grazed, respectively). The higher force and larger deformation correspond with a higher force to cut, being 2.46 for non-browsed and 2.01 for foraged. A 44% of branches from the non-browsed break before reaching the full bite depth, while only 36% did it on predated junipers.

CONCLUSIONS

Browsing pressure on bushes, lead to changes in morphology and the textural/cutting characteristics of the apical shots, but not in the line of hardening the shoots but in reducing their size and probably varying their spatial distribution. These changes made the junipers more tolerant to the activity of herbivores. Although some differences can be attributed to sex, the main cause of the difference between individuals is exposure to grazing.

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