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Livestock winter feeding in prehistory: role of browse leaves, annual twigs of woody plants, senescent grasses, *Hedera helix* and *Viscum album*

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Abstract. Browse plants, *Viscum album*, *Hedera helix* and annual twigs were probably the principal winter feeding of livestock in prehistory. We investigated the nutritional value of leaves and annual twigs of 13 principal broad-leaved woody species together with *Viscum album* and *Hedera helix*, some of them recorded by archaeologists as exploited for livestock foddering and others rarely used. We collected their annual twigs and senescent grass biomass in February in the Czech Republic. Concentration of nitrogen, phosphorus, fibre fractions NDF, ADF and lignin were analysed in all samples. *Carpinus*, *Fagus* and *Quercus* had low nutritive value whereas *Ulmus*, *Fraxinus*, *Tilia* and *Acer* with the highest nutritive value. Winter twigs had lower nutritive value than their leaves, meadow hay or senescent steppe grasses. *Hedera* and *Viscum* in winter had substantially higher nutritive value than twigs of woody plants. Livestock winter feeding by woody species could have important consequences on livestock breeding and on forests in Europe during last 10000 years.

Keywords. Cattle – Forest vegetation – Neolithic – Year-round grazing.

***L'alimentation de bétail pendant l'hiver dans la préhistoire : le rôle en tant que fourrage des feuilles, des branches annuelles des arbres, et des graminées sénescentes,* Hedera helix *et* Viscum album**

Résumé. *Dans la préhistoire, les arbres,* Viscum album, Hedera helix *et des branches annuelles ont été probablement le fourrage principal pour le bétail pendant l'hiver. Nous avons étudié la valeur nutritive des feuilles et des branches annuelles de 13 espèces des ligneux y compris* Viscum album *et* Hedera helix*, certaines d'entre-elles ayant été identifiées par les archéologues comme exploitées pour l'alimentation du bétail et d'autres non-exploitées. Nous avons collecté leurs branches annuelles et des graminées sénescentes en février dans la République tchèque. Les concentrations en azote, en phosphore, les teneurs en fibres NDF, ADF et en lignine ont été analysées dans les échantillons.* Carpinus*,* Fagus *et* Quercus *ont eu une valeur nutritive faible, alors que celle-ci était élevée pour* Ulmus*,* Fraxinus*,* Tilia *et* Acer*. Les branches annuelles on eu une valeur nutritive plus basse que celle de leurs feuilles, du foin ou de la biomasse sénescente sur les prairies.* Hedera *et* Viscum *ont eu en hiver une valeur nutritive plus élevée que celles des branches des arbres. L'alimentation du bétail pendant l'hiver par des espèces ligneuses a pu avoir des conséquences importantes sur l'élevage et la survie du bétail et sur le développement des forêts en Europe pendant les derniers 10000 ans.*

Mots-clés. *Bovins – Végétation des forêts – Néolithique – Pâturage annuel.*

I – Introduction

It is generally accepted that the livestock of prehistoric farmers in Central and Northern Europe grazed on pastures, fallows, stubbles and in forests during the vegetation season. During the winter time livestock was probably fed by leaves of main broad-leaved woody species, harvested and dried during the vegetation season (Rasmussen, 1993). Livestock was probably also partly fed by winter collected twigs (Haas *et al.,* 1998). Leaf-foddering should thus have played the

main role in winter feeding of livestock in Europe since the beginning of farming and animal husbandry till fabrication of first scythes which enabled cutting of grasslands and hay making (Hejcman *et al.,* 2013). Therefore, hay making step by step replaced foddering by browse species, although browse leaf fodder was used as a supplement to winter hay feeding in some regions up to the present (Slotte, 2001). The theory of leaf foddering in the Neolithic is based on archaeological evidence of woody species recorded in coprolites of goats, sheep and cattle discovered in Switzerland, Germany and in France (e.g. Rasmussen, 1993; Delhon *et al.,* 2008).However storage of dried browse leaves for winter use could be insufficient, hence year-round livestock grazing without any or with a very limited amount of supplementary feeding could be thus most probably the dominant means of livestock grazing system in Central Europe since the Neolithic up to the 18th century. This rises a question which plants could be grazed or browsed by livestock during winter in a forest and how such type of forage could satisfy requirements of livestock for nutrients. Thus the objective of this work was to determine the nutritive value of winter collected annual twigs of the main woody species (*Acer platanoides*, *Betula pendula*, *Carpinus betulus*, *Corylus avellana*, *Fagus sylvatica*, *Fraxinus excelsior*, *Populus tremula*, *Quercus robur*, *Salix caprea*, *Tilia cordata* and *Ulmus glabra*), leaves of mistletoe (*Viscum album*) and ivy (*Hedera helix*), and to compare them with senescent winter steppe grassland biomass and meadow hay.

II – Materials and methods

We collected leaf biomass and annual twigs with buds of 13 woody species common in Central Europe at least since the Neolithic (5600 BC). Samples were taken from at least three individuals of each species at four sites in February 2013. Selected sites were broad-leaved forests and their margins in the Czech Republic: We collected in total 52 (13 species x four site replicates) annual twigs and winter leaf biomass samples which were then oven-dried at 60 °C for 48 hours and ground to powder.

In twig and leaf samples, the concentration of nitrogen (N) and phosphorus (P) and the content of neutral- (NDF) and acid- detergent fibre (ADF) and acid detergent lignin (ADL) were determined by standard analytical methods and according to AOAC (1984) in an accredited laboratory.

Data tested by the Kolmogorov-Smirnov test of normality, met assumptions for the use of parametric tests. One-way ANOVA followed by post-hoc comparison using the Tukey's multiple range tests in Statistica 9.0 program (StatSoft, Tulsa, USA) were used to identify significant differences in concentrations of nutrients and NDF, ADF and ADL contents among species.

III – Results and discussion

There were significant differences in the concentration of all investigated nutrients in annual twigs and winter biomass among browse plant species. *Viscum* was the plant with highest concentration of N, P and the lowest NDF and very low ADL content. Very similar nutrient pattern was found in *Hedera*. On the other hand, concentration of N was the lowest in *Fraxinus* and *Populus*, P was lowest in *Quercus, Carpinus* and *Fagus.* Content of NDF was rather high in *Carpinus* and *Fagus*, similarly as the indigestible ADL together with *Betula* (Table 1).

Winter green leaves such as *Hedera* and *Viscum* belong to the best forage which might have been available in forests during the winter. Their nutritive value, according to the highest N and lowest NDF and lignin concentrations, was higher than the nutritive value of all winter collected annual twigs of woody species. Their high nutritive value is comparable only with winter leaves of *Rubus fruticosus* (Verheyden-Tixier *et al.,* 2008) which was also among plant species recorded in Neolithic coprolites of sheep/goat in the Grande Rivoire rock shelter in France (Martin, 2011). According to macro-remains of *Viscum* found at archaeological localities (Kühn *et al.*, 2013), we deduce that

the ancient farmers collected *Hedera* and *Viscum* during the wintertime intentionally and used them for the feeding of animals, because they are the richest source of N and P in winter. *Viscum* was collected, although the amount of its biomass was relatively small in forests in comparison to the biomass of woody species and its collection was laborious. Therefore, we suggest that *Viscum* was probably used as a supplement for feeding of privileged animals such as lactating and pregnant cows or goats with the highest N and P requirements, researched by farmers intentionally. Nowadays the high nutritive value of *Viscum* is also well known to hunters in Austria or in the Czech Republic who still use the biomass of *Viscum* to attract deer to particular places during the winter. Similarly to *Viscum*, *Hedera* has higher nutritive value than annual twigs of woody species and this is why it was probably selectively grazed by livestock in winter. In the experiment by Van Uytvanck *et al.* (2009), for example, *Hedera* completely disappeared from forest managed for several years by year-round cattle grazing. Therefore a decrease in the pollen production of *Hedera* in different periods (e.g. Bottema, 2001) could be considered as an indicator of human activities in forests connected with livestock breeding.

Table 1. Concentration (means ± standard error of mean) of nitrogen (N), phosphorus (P), neutral detergent fibre (NDF) and acid detergent lignin (ADL) in annual twigs of browse plants. Calculated by one-way ANOVA, differences among species for all chemical properties were significant (P<0.01). Using the Tukey post-hoc comparison test, species with the same letter were not significantly different

Species	N (g kg^{-1})	P (g kg^{-1})	NDF (g kg^{-1})	ADL (g kg^{-1})
Acer platanoides	15.6 ± 1.4 ^{ab}	1.8 ± 0.2 ^{ab}	577 ± 14^{cd}	225 ± 14 ^{def}
Betula pendula	13.9 ± 0.4 ^{a}	1.6 ± 0.1 ^{ab}	600 ± 24^{cd}	266 ± 24 ^{f}
Carpinus betulus	14.7 ± 0.8 ^{a}	1.3 ± 0.1 ^{a}	642 ± 27^{d}	206 ± 10 ^{bcdef}
Corylus avellana	17.9 ± 2.1 ^{ab}	1.8 ± 0.2 ^{ab}	551 ± 58 ^{bcd}	255 ± 20 ^{f}
Fagus sylvatica	14.4 ± 1.1 ^{a}	1.3 ± 0.1 ^{a}	632 ± 31^{d}	261 ± 17 ^{f}
Fraxinus excelsior	12.4 ± 0.7 ^{a}	1.5 ± 0.1 ^{ab}	587 ± 31^{cd}	144 ± 15 ^{ab}
Hedera helix	16.9 ± 1.0 ^{ab}	1.4 ± 0.05 ^{a}	392 ± 9 ^{a}	112 ± 5 ^{a}
Populus tremula	12.5 ± 0.7 ^{a}	1.5 ± 0.2 ^{ab}	577 ± 38^{cd}	226 ± 20 ^{def}
Quercus robur	14.0 ± 0.3 ^{a}	1.2 ± 0.1 ^{a}	582 ± 29^{cd}	238 ± 8 ^{ef}
Salix capraea	15.9 ± 0.6 ^{ab}	2.1 ± 0.2 ^{ab}	488 ± 10 ^{abc}	207 ± 18 ^{bcdef}
Tilia cordata	15.2 ± 1.2 ^{ab}	1.9 ± 0.2 ^{ab}	596 ± 23^{cd}	215 ± 9 ^{cdef}
Ulmus glabra	14.6 ± 0.6 ^{a}	1.5 ± 0.05 ^{ab}	456 ± 6 ^{abc}	213 ± 6 ^{bcdef}
Viscum album	21.1 ± 2.3 ^{b}	2.4 ± 0.4 ^{b}	431 ± 13 ^{ab}	150 ± 7 ^{abc}
Meadow hay	20.0 – 28.7	2.7 – 3.7	500-680	40
Steppe grass winter biomass	17.9	2	724	89
Optimum range for cattle	19.2 – 25.6	2.3 – 3.7	330-450	max. 80

Nutritive value of all winter collected annual twigs of woody species was substantially lower than the nutritive value of meadow hay (Table 1) and also spring collected leaf-fodder of broad-leaved woody species (Verheyden-Tixier *et al.,* 2008; Hejcmanová *et al.,* 2013). Low nutritive value of twigs was given by insufficient concentrations of N and P and too high concentrations of NDF and lignin. The next characteristic aspect of twigs was relatively small differences in the concentration of P among individual species in comparison to their leaves in which differences were substantially higher. Twigs of *Fagus* and *Carpinus* had absolutely the worst nutritive value because of their highest lignin content which is in accordance with their leaves (Hejcmanová *et al.,* 2013). Leaf-fodder of *Ulmus* and *Tilia* were the best of all woody species in Central Europe and this is also consistent with the nutritive value of their twigs which was also comparable to *Salix*. Senes-

cent grassland biomass collected in winter on steppe grassland was of better nutritive value than twigs of woody species because of higher concentrations of N and P. This suggests that livestock first of all grazed senescent grassland biomass and then, if no other alternatives were available, started to browse trees.

IV – Conclusions

We suggest that winter collected *Hedera* and *Viscum* could have been searched by prehistoric farmers for supplementary feeding of privileged animals because of their high nutritive value. Prehistoric farmers could also feed livestock directly in forests by driving herds to intentionally cut trees or their branches with *Hedera* or *Viscum.* Winter collected annual twigs of all woody species had very low nutritive value, much lower than the meadow hay, leaf-fodder or senescent steppe grassland biomass. After grazing of senescent grassland biomass, annual twigs of woody species were probably browsed by livestock. Insufficient winter nutrition could be one of causes of the low body size of cattle recorded since the Neolithic up to the 18th century. Year-round livestock grazing practiced by ancient farmers seems to be the key driver for the formation of open forests.

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