TRAMPLING EFFECTS ON PLANT SPECIES MORPHOLOGY

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Morphogical response of plants to mechanical disturbance depends on morphological characteristics, phenological stage, degree of stem sclerification and also on trampling intensity. The experimental activities took place between 2007 and 2009 in forest and grassland ecosystems selected in three different long terms socio-ecological research (LTSER) sites from Romanian Network: Braila Islands, Neajlov Catchment and Bucegi- Piatra Craiului. In term of resistance to human trampling, analysed plant species were grouped in two categories: 1. intolerant species (*e.g. Veratrum album*) and 2. low, moderate or high tolerant species (*e.g. Lotus corniculatus, Achillea stricta, Hypericum maculatum*). The research was a part of a european project in Alternet (EU – Network of Excellence).

Key words: morphological modifications, plant communities, trampling, grasslands.

INTRODUCTION

Increasing deterioration of protected areas in last decades led to the conclusion that recreational trampling is a major driving factor. In this context numerous studies have been conducted in many regions in order to assess the vulnerability of vegetation to human use and to evaluate the carrying capacity for recreational activities. Wagar (1964) proposed for the first time an experimental approach in order to establish the relationship between intensity of recreation activities and ecosystem responses.

Such studies provide a scientific basis for estimating the visitors carrying capacity and developing management strategies for protected areas. Littlemore (2001) defined the carrying capacity for woodland vegetation types as “maximum intensity of use, measured in terms of number of people a year woodland ground flora can withstand without undergoing an unacceptable degree of ecological change away from the original ecosystem condition considered desirable”.

The direct effects of human trampling include mechanical damage to plant tissue causing loss in vegetation cover, plants height, living biomass, species composition, reproductive capacity (Cole, 1995; Cole & Bayfield, 1993; Liddle, 1975, 1997; Littlemore, 1998, 2001). Also, indirect impact affects soil compactation, microbian activity (Cole, 1988).

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Resistance of soil to compactation depends on the texture, density and soil structure (Jones, 1978; Lull, 1959, after Kuss, 2005). Compactation of soil changes the moisture and aeration regimes, with consequences for plant growth and seeds germination.

The effects of trampling on these areas depends on the type of recreational activities (*e.g.* camping, riding, skiing), the number and size of visitor groups, the physical characteristics of sites, like topography, climate, soil type. The recreational activities can affect different compartments of the ecosystem like vegetation, soil and wildlife (Whinam *et al*., 1994). Usually, the vulnerability of vegetation to trampling damage is expressed by three indices: resistance (ability of vegetation to resist change when it is trampled), resilience (ability of vegetation to recover following the cessation of trampling) and tolerance (ability of vegetation to tolerate a cycle of disturbance and recovery) (Cole, 1995).

Our study evaluated the response of vegetation to different intensities of human trampling. In this paper we discuss and analyze morphological changes of plant species due to mechanical disturbance.

MATERIALS AND METHODS

Site description. Experimental study was established in forest and grassland ecosystems, selected in three (LTSER) sites of national network (see Table 1): Braila Islands (wetland area), Neajlov Catchment (plain areas) and Bucegi-Piatra Craiului (mountain area).

Table 1

General characteristics of sites

LTSER sites	Location	Ecosystem type	Geographic location	Alt. (m)	Plant associations
Neajlov Catchment	Făcău	grassland	Lat.44.294386 N Long.5.836317 W	80	*Cynodonetum dactyloni*
	Vadu Lat	forest	Lat.44.341639 N Long.25.671661 W	115	*Querco robori-Rubetum caesii*
Bucegi-Piatra Craiului	Poiana Stânii	grassland	Lat. 45.369136 N Long.25.524278 W	1298	*Festucetum rubrae*
	Poiana Stânii	forest	Lat. 45.370389 N Long.25.519294 W	1294	*Leucanthemo waldsteinii-Fagetum*
Brăila Islands	Small Island of Brăila	grassland	Lat. 45.203736 N Long.27.972986 W	3	*Salici-Populetum*
	Small Island of Brăila	forest	Lat. 45.191703 N Long.28.657783 W	5	*Salici-Populetum*

Experimental methods and data collection. The experimental study took place in June/July, between 2007–2009 and involved measurements and observations on vegetation layer. Four replicate blocks, each block comprising five treatments plots, were established according to European multi-site experiment protocol, an adaptation of the standardised procedure developed by Cole and Bayfield (1993). Treatments (control, 25, 75, 250 and 500 passes) were randomly assigned to plots with surface of 1 m^2 (0.5 × 2 m). Measurements of vegetation parameters (species cover and height) were taken before and two weeks after trampling. Morphological changes of different species have been analyzed and photographed both in the field and in laboratory, and were correlated with other measurements.

RESULTS AND DISCUSSION

Plant species have a different response related to their resistance to disturbance which depends mainly on the morphology, anatomy and life cycle (Liddle, 1997; Whine & Chilcott, 2003; Kuss, 1986; Leung & Marion, 2000, after Kuss, 2005). Habitat characteristics influence the sensitivity of vegetation to trampling. Plant communities from higher altitude are more susceptible to trampling than the ones from lower altitude. At higher altitude rainfall and temperature drop and these influence the growth rate and soil microbian activity (Hartley, 1976; Peary & Ward, 1972).

Our study revealed that the water stress is a major factor which multiplied the trampling effects (Grime & Campbell, 1991; Mac Gillivray *et al*., 1995; Francis *et al*., 2005). The most resistant analyzed communities have been those with the greater percentage of caespitose hemicryptophytes: about 65% in Făcău grassland, respectively 90% in Poiana Stânii grassland as in most reported studies (Hall & Kuss, 1989; Liddle & Greig-Smith, 1975; Cole, 1995; Whinam & Chilcott, 1999, 2003).

Regarding growth form, woody species are more susceptible to damage than herbaceous species (Cole, 1988). According to the classification proposed by Sun and Liddle in 1993, the analyzed plant species were clustered in two categories based on the response to mechanical perturbation:

1. intolerant plants (*e.g. Veratrum album*) and
2. tolerant plants – with low, moderate and high tolerance level (*e.g. Achillea stricta, Hypericum maculatum, Lotus corniculatus*).

It was noted that after trampling treatments plant species survived and continued the growth, but in a different way compared with absence of any disturbance factor. We mentioned that the formation of fruits and seeds was not negatively influenced by trampling. Physical stress induced by mechanical perturbation determines a response of plants trying to adapt and to continue their growth and development. Jaffe named this adaptation to physical stress thigmomorphogenesis. Morphological changes that occur in thigmomorphogenesis increase plant resistance to mechanical perturbation and decrease the susceptibility to different types of stress (Jaffe, 1980). It was found that the mechanical stress induces ethylene production (Leopold et al., 1972; Robitaille & Leopold, 1974; Hiraki & Ota, 1975; after Sunohara Y. *et al*., 2002) and it plays an important role in thigmomorphogenesis (Pickard, 1971; Jaffe, 1973; Hiraki & Ota, 1975; after Sunohara Y. *et al*., 2002). This hormone is involved in growth mechanism and development, but also in senescence (Young, 1955; after Sunohara Y. *et al*., 2002). During the plant development ethylene is produced in certain stages: seeds germination, fruit ripering, inhibition of stem and rooth growth. However, a detailed mechanism describing the induction of morphological changes by trampling has not been revealed (Sunohara & Ikeda, 2003). Ethylene induces changes in protein and lipid components of the endomembrane system with consequences on the photosynthesis.

In our study we analyzed morphological modifications as a response to trampling, which acted like a mechanical stimulus. Inhibition of growth can be coupled with radial growth (Jaffe, 1973). These facts were observed to *Cichorium intybus* as is shown in Fig. 1, where the number of lateral branches and the number of future flowers were increased.

Fig. 1. *Cichorium intybus,* collected on 15.07.2009 from a grassland plot (Făcău) trampled by 500 passes.

Fig. 2. *Silene vulgaris*, collected on 4.08.2009 from a grassland plot (Poiana Stanii) trampled by 250 passes.

Fig. 3. *Festuca rubra* collected on 4.08.2009 from grassland ecosystem (Poiana Stanii) trampled by 500 passes (Dumitrascu *et al.*, unpublished data).

Fig. 4. *Helleborus pupurascens* and *Lotus corniculatus*, collected on 4.08.2009 from grassland ecosystem (Poiana Stanii) trampled by 500 passes.

A similar phenomenon was observed at *Conyza canadensis*, which developed under the fracture numerous shoots that reached to fruition. Some studies have found that repeated trampling causes leaf morphological changes in many species (Meerts & Vekemans, 1991; Sun & Liddle, 1993; Ikeda & Okutami, 1995; Meerts & Garnier, 1996; Kobayashi *et al*., 1999). Our researches have investigated the morphological modifications after one trampling treatments. Other changes observed in the field were the yellowing and fall of some leaves (Fig. 2). This was found in literature like response to stimulation of ethylene production (Liddle, 1975).

Trampled plants are removed from their normal growth position and in most cases reach upward, parallel or perpendicular towards substrate. Any individual forced to change their orientation in space trying to return to normal position due to increased sensitivity and mobilization mechanism in relation to gravity, according to positive and negative geotropism. Branches and leaves are obliquely disposed and perpendicular to the sunlight to optimize the absorption of light energy, thus confirming the literature findings (Mohr, 1972).

Trampled plants are bent, tilled, folded and thus removed from their position, reaching parallel to the substrate. In this case auxin hormone is released and contributed to further development of plant individuals. It is involved in recovery of plants after the cessation of trampling impact. Auxin migrates at the lesion and accumulating on the underside induces mitotic divisions only on this part, resulting cell elongation and vegetative body curvature of the plant for restoring to normal position.

The morphological changes were dependent on phenological stage, degree of stem sclerification, individuals height and, also, on trampling intensity. Depending on the intensity of treatments plant communities react differently. Thus, in 2009 in grassland ecosystems in plots trampled with 25 passes vegetation cover decreased with 5% and in those trampled with 500 passes it decreased with about 15%. The patterns of return to vertical position differ between *Liliatae* and *Magnoliatae*. As we found the graminoids, especially those forming tufts (caespitose), are the most resistant and flexible to mechanical perturbation. From *Liliatae* we observed the behaviour of *Festuca rubra* (fam. Poaceae). By trampling the body was folded due to flexibility of this type of stem. At graminoids the return to vertical position is determined by the characteristics of intercalary meristems. Thus, meristems were reactivated from the nodes and, because of the uneven distribution of auxin to the faces of nodes, they have grown between two and five times on the bottom and crimped on the upper curved stem which returned to the vertical position as is shown in Fig. 3.

Regarding *Magnoliatae* there were differences depending on the degree of stem sclerification and phenological stage as it was observed for species *Achillea stricta, Hypericum maculatum, Helleborus purpurascens, Lotus coniculatus* as is shown in Fig. 4. In early phenological stages of budding and growth, plants are more susceptible to mechanical stress as we found in literature (Hartley, 1976; Parish, 1971; Donard & Cooke, 1970, after Kuss, 2005). Changes occurred at trampled plants were ranked by the affected vegetative bodies like stem modifications, branches modifications and leaves modifications. We observed that torsion and injuries were more pronounced at maximum trampling intensity (500 passes).

CONCLUSIONS

The reaction and adaptations of plant communities to human trampling are closely related to morphological characters of species, but they are also influenced by environmental conditions. Morphological changes were dependent on the growth form, phenological stage, degree of stem sclerification, especially stem and branches, and intensity of pressure. Most frequently observed changes were breakage, folding and bruising of stems, yellowing and fall of some leaves, radial (lateral) growth. Regarding the structure of plant communities, those with graminoids dominant have the higher resistance to human trampling because of their stem flexibility. From the studied ecosystems grasslands have the higher capacity to support trampling. Repeated trampling (*e.g.* produced by animals) has a strong negative impact on plants development. We should consider this in future development of management plans for protected areas.

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