Acta Oecologica 59 (2014) 1–6

Contents lists available at ScienceDirect

Acta Oecologica

journal homepage: www.elsevier.com/locate/actoec

Original article

Effect of fertilizer application on *Urtica dioica* and its element concentrations in a cut grassland

Vladimíra Müllerová [a], Michal Hejcman [a,*], Pavla Hejcmanová [b], Vilém Pavlů [a]

[a] Department of Ecology, Faculty of Environmental Sciences, Czech University of Life Sciences, Kamýcká 1176, Prague 6, Suchdol, CZ-165 21, Czech Republic
[b] Department of Animal Sciences and Food Processing, Faculty of Tropical AgriSciences, Czech University of Life Sciences, Kamýcká 129, Prague 6, Suchdol, CZ-165 21, Czech Republic

ARTICLE INFO

Article history:
Received 27 November 2013
Accepted 13 May 2014
Available online 6 June 2014

Keywords:
Fertilization
Stinging or common nettle
Nitrogen
Phosphorus
Plant nutrition
Potassium

ABSTRACT

Little is known about the effects of nutrient availability in cut grasslands on growth characteristics of *Urtica dioica* and its aboveground chemical composition (N, P, K, Ca, Mg, Cu, Fe, Mn and Zn). The effects of N, P and K application on the growth of *U. dioica* were studied over five years in a *Dactylis glomerata* grassland cut twice per year under unfertilized control, P, N, NP and NPK treatments (300, 80 and 200 kg of N, P and K ha^{-1} per year).

Nitrogen application in the form of NH_4NO_3 over five years decreased the soil pH, while P and K application increased P and K availability in the soil. Over five years, cover of *U. dioica* increased from 1% initially to 7, 9, 58, 83 and 99% in the control, P, N, NP and NPK treatments, respectively. Concentrations of N, P and Ca in the aboveground biomass of *U. dioica* were very high in comparison to other species and concentrations of Cu, Fe, Mn and Zn were comparable with other grassland species. N and P limitation of *U. dioica* growth was expected if concentrations of N and P in the aboveground biomass were lower than 25 g N kg^{-1} and 4 g P kg^{-1} in the phenological stage of flowering.

We concluded that two cuts per year are not sufficient to suppress expansion of *U. dioica* under high N, P and K availability. This probably explains why *U. dioica* survive also in frequently cut intensive grasslands under adequately high nutrient supply.

1. Introduction

Urtica dioica L. (stinging or common nettle) is a perennial herb that prefers slightly acidic to alkaline soil that is moist and nutrient rich (Ellenberg et al., 1991). The species can grow in conditions ranging from moderately shaded woodlands and hedgerows to open habitats such as floodplains, pastures and meadows (Šrůtek and Teckelmann, 1998; Taylor, 2009). Grime et al. (2007) described *U. dioica* as a ruderal species having an established competitor (C) strategy. It is a successful coloniser in grasslands and ruderal sites due to rhizome fragments and stolons, which continue to grow until the death of the aerial shoots in the autumn. *Urtica dioica* is able to suppress the growth of other herbaceous plants and often forms monospecific stands on nutrient-rich sites (Al-Mufti et al., 1977; Šrůtek, 1993; Grime et al., 2007). Herbage of *U. dioica* possesses a high nutritive value and was frequently used as an additive into human, poultry and pig foodstuff in the past. Fresh plants are little grazed by livestock because of stinging hairs covering the stems and leaves of the plant, but dry plants in the form of hay are taken up by livestock without any disorders (Grime et al., 2007).

Urtica dioica is known as a particularly nitrophilous species with high N and P requirements preferring well N- and P-supplied soils with good water availability (Šrůtek, 1995; Hill et al., 2004; Taylor, 2009). Once established, *U. dioica* can spread vigorously and it is very difficult to eradicate it.

Although many authors mention the high competitive ability of *U. dioica* and its ability to create dense stands on nutrient-rich soils, no information is available regarding how quickly cover develops after an increase in nutrient availability. In addition, dense stands of *U. dioica* are characteristic of unmanaged or infrequently cut grasslands (Prach, 2008; Klaus et al., 2011) and it is not clear whether they can also develop in regularly managed grasslands such as hay meadows cut twice per year. In addition, although the positive effect of high nutrient availability on the growth of *U. dioica* is known (Pigott, 1971; Taylor, 2009), little is known about how nutrient availability affects growth characteristics of *U. dioica* plants and N, P, K, Ca, Mg, Cu, Fe, Mn and Zn concentrations in its biomass.

* Corresponding author.
E-mail address: hejcman@fzp.czu.cz (M. Hejcman).

http://dx.doi.org/10.1016/j.actao.2014.05.004
1146-609X/

In 2007, we established a grassland fertilization experiment on a *Dactylis glomerata*- and *Festuca arundinacea*-dominated grassland with sporadic occurrence of *U. dioica*. The grassland represented a hay meadow regularly cut twice per year (Hejcman et al., 2012a).

The immediate response of plant species composition to N application was recorded and was found to be different to the response over the four years of the study period. Highly productive grasses (*D. glomerata*, *F. arundinacea* and *Phleum pratense*) were promoted by N application in 2008 and then retreated together with legumes (*Medicago sativa*, *Trifolium pratense* and *Trifolium repens*) in all N treatments where the expansion of perennial forbs (*Urtica dioica* and *Rumex obtusifolius*) and annual weeds (*Galinsoga quadriradiata*, *Impatiens parviflora*, *Lamium purpureum* and *Stellaria media*) was recorded. In 2010, *Festuca rubra* was the dominant grass in the control and P treatment, and species richness was lowest in all treatments with N application. Mean annual dry-matter yield over all years was 3.5, 3.9, 5.8, 5.6 and 6.8 t ha^{-1} in the control, P, N, NP and NPK treatments, respectively. Concentrations of N in the aboveground biomass ranged from 20.0 to 28.7 g kg^{-1} in the P and N treatments; concentrations of P ranged from 3.2 to 3.7 g kg^{-1} in the N and P treatments; and concentrations of K ranged from 24.1 to 34.0 g kg^{-1} in the NP and NPK treatments. The N:P, N:K and K:P ratios did not correctly indicate the nutrient limitation of biomass production, which was primarily N-limited, and K-limitation was only recorded for high production levels in treatments with N applications. We concluded that high N, P and K application rates can very quickly and dramatically change species composition, biomass production and its chemical properties in sown cut grasslands. High N application rates can be detrimental for tall forage grasses and can support the spread of weedy species.

During the five years, massive expansion of *U. dioica* was recorded in treatments with N application. The present study was therefore focused on *U. dioica* to investigate how the N, P and K fertilizer application under regular cutting management over five years affected: 1) soil chemical properties; 2) cover and growth characteristics of *U. dioica* and 3) concentrations of macro (N, P, K, Ca, Mg) and 4) micro (Zn, Fe, Mn, Cu) elements in its aboveground biomass.

2. Materials and methods

2.1. Study site

The fertilizer experiment was set up near the village of Mšec, 45 km northwest of Prague (50°12′24″N; 13°51′40″E) at an altitude of 490 m a.s.l. The study site was a flat, species-poor meadow (35 vascular plant species per 240 m^2) with a mean annual precipitation and temperature of 550 mm and 8 °C, respectively. The soil type at the study site was Pararendzina (syn. Calcic Leptosol) developed on mesozoic Ca-rich sediments. The pH/H_2O in the upper 10 cm soil layer before the start of the experiment was 6.4. The concentrations of plant-available (Mehlich III) P, K, Ca and Mg were 0.152, 0.267, 1.688 and 0.171 g kg^{-1}, respectively, and the total (Kjeldahl) N content was 2.3 g kg^{-1}. *D. glomerata* (visually estimated cover of 45%), *Festuca arundinacea* (12%), *Phleum pratense* (9%) and *Taraxacum* sp. (8%) were the dominant species before the establishment of the experiment. The meadow had been regularly cut two- or three-times per year and once per five years fertilized with farmyard manure before establishment of the experiment. The last manure application was performed in 2005. Nomenclature of species follows a local flora (Kubát et al., 2002).

2.2. Experimental design

The experiment was established in summer 2007 on the meadow with occasional occurrence of *U. dioica* (cover ca. 1%). A completely randomised block design was used with the unfertilized control, P, N, NP and NPK fertilizer treatments replicated four times (20 monitoring plots altogether, for the aerial photograph of the experiment see Strnad et al. (2012)). The area of each individual monitoring plot was 4 m × 3 m. The application rates for N, P and K in each plot were 150 kg N ha^{-1} (NH_4NO_3), 40 kg P ha^{-1} ($Ca(H_2PO_4)_2$) and 100 kg K ha^{-1} (KCl), respectively. The first fertilizer application was performed on 19th August 2007. From 2008 to 2011, yearly fertilizer application were added at the beginning of March and then after the first cut in June. Therefore, the total annual application of N, P and K was 300 kg N ha^{-1}, 80 kg P ha^{-1} and 200 kg K ha^{-1}. The high application rates of N, P and K were used to avoid any N, P or K growth-limitations of the highly productive plant species. The experimental plots were cut twice per year – first in late September 2007 and then in early June and late August yearly (for exact cutting dates see Fig. 1). The sward was mown by engine scythe (Stihl FS 450 with metal knife) leaving a stubble height of approximately 5 cm.

2.3. Soil sampling and chemical analysis

In each plot, one representative soil sample composed of five subsamples from upper 0–10 cm soil layer was collected in October 2011. The soil samples were air-dried, sieved through a 2-mm sieve and sent to the accredited national laboratory Eko-Lab Žamberk (www.ekolab.zamberk.cz) where all chemical analyses were performed. Total N content was determined in a LECO TruSpec analyser (Leco Corporation, St. Joseph, MI, USA) through combustion under an oxygen atmosphere at 950 °C, using helium as a carrier. The organic C content was determined by the oxidation of the soil sample in a mixture of potassium dichromate solution and sulphuric acid at 135 °C and then measured spectrophotometrically. Plant-available K, P, Ca and Mg concentrations were extracted by Mehlich III reagent (Mehlich, 1984) and then determined by ICP-OES (Varian VistaPro, Mulgrave, Australia). The pH value was determined in 0.01 M $CaCl_2$ solution in the ratio 1:5.

2.4. Cover and growth characteristics of U. dioica

Cover of *U. dioica* was visually estimated in percentages before the harvest in June and August from 2008 to 2011. The first cover estimation was done in September 2007.

In the middle of August 2011, ten stems of *U. dioica* were randomly selected in each plot where *U. dioica* was recorded and the following growth characteristics were measured: 1) length of the stem; 2) number of leaves on the main stem; 3) number of leaves per the main stem and all branches together; 4) number of nodes on the main stem; 5) frequency of stems with branching from ten selected; and 6) stem density per m^2.

2.5. Biomass chemical properties

In each plot with the presence of *U. dioica*, we collected one representative sample of aboveground biomass of *U. dioica* during the second cut in August 2011. We cut plants 5 cm above the ground and collected 0.5 kg of fresh weight biomass. Samples were then dried at 80 °C until no further weight loss occurred. Dry samples of aboveground biomass were analysed for N, P, K, Ca, Mg, Zn, Fe, Mn and Cu concentrations. Nitrogen concentration in the plant samples was determined by the same method as in the case of soil samples.

To determine P, K, Ca, Mg, Fe, Cu, Mn and Zn concentrations, biomass samples were dissolved in *aqua regia* (the mixture of HNO_3 and HCl in a volume ratio of 6:1) and concentrations of elements in the solution were determined using ICP-OES. The crude fibre (CF) was measured by the Weende method (AOAC, 1984). Ash