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ORIGINAL ARTICLE

Establishment and growth of hawthorn in floodplains in the Netherlands

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ABSTRACT

Dendrochronology was used to assess the influence of soil conditions, elevation and related inundation, climate fluctuations and vegetation cover on the establishment and growth of hawthorn in non-grazed river floodplains. Presence of forest influences the discharge capacity of the floodplain, therefore forest development needs to be considered in management plans. Although ring detection in hawthorn is difficult, clear dynamics in establishment and growth of this shrub species were found. Establishment was mainly influenced by inundation (length and height). The effect of inundation on establishment is location dependent; positive due to transport and deposition of seeds in higher areas, and negative due to drowning of young plants in lower locations. Extreme climatic events were found to influence establishment including a drought in 2003 and relatively low and high precipitation in 2004–2006 and 2007 respectively. These events combined with almost no inundation caused some anomalies in the time series for hawthorn establishment. Once above a certain height, hawthorn is able to withstand various abiotic disturbances occurring in these dynamic river floodplains. Excavated areas are enhancing forest development following hawthorn establishment and therefore these areas should be limited in size (e.g. by deeper and narrower excavations and thus a steeper transition towards the grasslands).

Introduction

In many western European countries, river floodplains (forelands) are likely to become critical for flood prevention as increased rainfall is expected as a result of long-term changes in climate (Bardossy and Caspary, 1990; Hegerl et al., 1996; Shabalova et al., 2003; Pfister et al., 2004; IPCC, 2007). Floodplain management often has the primary goal of flood prevention. Flood management strategies, developed in the last two decades, aim either to increase the discharge capacity of floodplains to downstream rivers or to restore natural floodplain habitats, such as floodplain forests which can store and reduce floodwater. Forest development in floodplains, however, can also obstruct water flow, leading to higher floodwater levels (Van Velzen et al., 2003; Makaske et al., 2011). The roughness of vegetation determines the extent of water obstruction. Height, stem and crown diameter and number of twigs determine the roughness of the individual shrub or tree, and the density of these shrubs or trees determines the roughness of the vegetation (Van Velzen et al., 2003).

Determination of forest and shrub patch development is therefore essential for effective floodplain management. This can be achieved by investigating the impact of abiotic factors on establishment and growth of shrubs and trees, and in this case hawthorn (*Crategus monogyna* Jacq.) in floodplains. Hawthorn is particularly relevant, since once established this thorny shrub can serve as refugium for other broadleaf species (Linhart and Whelan, 1980; Baraza et al., 2006; Gill, 2006; Vera et al., 2006) and can therefore initiate further forest development.

Despite hawthorn's high ecological value as host of a wide variety of insects and birds (Kennedy and Southwood, 1984; Osborne, 1984), little is known about its establishment and growth patterns in river floodplains in relation to abiotic factors. As a relatively fast growing shrub, hawthorn tolerates dry to moist, chalk rich or sandy soil (Good et al., 1990; Manzanera and Martinez-Chacon, 2007), but is sensitive to poor drainage (Brooks, 1980; Niinemets

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and Valladares, 2006). The seeds are dispersed by birds and water and germination takes place between March and April. Hawthorn has a low tolerance to shade (1.9 on a scale from 0 to 5) (Niinemets and Valladares, 2006).

Some shrub and tree species can be suppressed by large herbivores (Linhart and Whelan, 1980; Van Splunder, 1998; Baraza et al., 2006; Gill, 2006), which are commonly used as a management tool in floodplains to restore natural habitat types. However others, including the hawthorn, is relatively resistant to grazing. Hawthorn also has a high resistance to the flow of water through a floodplain (Van Velzen et al., 2003). Often regarded as a hedge plant, hawthorn spreads easily to nearby waste lands or river floodplains where it frequently occurs (Healy, 1969).

Survival of tree and shrub seedlings in floodplains is largely dependent on flooding (Kozlowski, 1984; Jones et al., 1989; Streng et al., 1989; Siebel and Blom, 1998; Vreugdenhil et al., 2003, 2006) as well as shading, and root competition by grasses including other perennials (Vervuren and Van de Steeg, 1994; Siebel and Blom, 1998; Vera et al., 2006); especially when young (i.e. 1–5 years) (Gill, 1970; Kozlowski, 1984; Siebel and Blom, 1998). Growth of trees and shrubs in floodplains is influenced by complex interactions of flooding (Jones et al., 1989; Streng et al., 1989), climate, soil fertility and vegetation cover.

This study used dendrochronological methods to determine establishment and growth of hawthorn (*Crategus monogyna* Jacq.). Dendrochronology on shrubs, although challenging, has been successfully used for age determination of different shrub species in alpine, subalpine, artic, and savanna landscapes (Liphschitz and Waisel, 1973; Gers et al., 2001; Rayback and Henry, 2005; Schweingruber, 2007; Rozema et al., 2009; Blok et al., 2011).

We systematically investigate the effect of inundation, climatic factors (precipitation, temperature), vegetation cover and soil fertility on establishment and growth of hawthorn over 12 years in an unmanaged (no grazing or mowing) floodplain with various elevation gradients in the Netherlands. Based on literature describing other species (Vreugdenhil et al., 2006), we expected more hawthorn to be established on higher elevations with less inundation, and also a negative correlation between the number of hawthorn individuals becoming established and the total length (number of consecutive days with inundation) and depth of the inundation within a year. Furthermore, we expected higher hawthorn densities in areas with low vegetation cover. Regarding growth, we expected higher radial stem growth (increments) and hence larger shrubs on clayey soils than on sandy soils. Inundation and growth are assumed to be negatively correlated, due to a detrimental effect of water-logged conditions on hawthorn survival (Predick et al., 2009). Drought during summer is assumed to result in reduced growth (Scharnweber et al., 2011).

Materials and methods

Study area

The study was conducted in the Afferdense and Deestse Waarden (51°53′44″ N; 5°37′40″ E) along the river Waal, in the central part of the Netherlands. Shrubs were sampled from four different strata (1) the excavated lower stratum at the waterline, (2) an excavated upper stratum (both with sandy soils), (3) the lower and (4) upper grasslands with more clayey and fertile soils than the excavated strata. The division in strata was based on surface level and inundation characteristics, soil type and vegetation cover, since these factors were expected to affect establishment and growth of hawthorn.

After the excavation in the summer of 1996 in strata one and two to increase the discharge capacity of the floodplain, permanent

Fig. 1. Aerial image of the Afferdense & Deestse Waarden (source: Google Earth, 2013). The numbers represent the exclosures and correspond to the following strata: (1) upper grassland = 4, 5, 6; (2) lower grassland = 1, 2, 3; (3) upper excavated area = 7, 8, 9; (4) lower excavated area = 10, 11, 12. The dotted lines represent the old hawthorn hedges.

sample plots were established in all strata. The nutrient rich top clay layers of strata one and two were removed and sand underneath was removed just below the average low water levels of the river. In each stratum three 15 × 15 m permanent plots (thus 4 strata × 3 plots) were selected free from biotic disturbances such as grazing and browsing (Fig. 1). Old hawthorn hedges within the study area produce large amounts of seed and are assumed to be the main source of the established hawthorns.

Fieldwork

In November 2007 we harvested all 244 hawthorn shrubs present in our 12 plots at the four strata. To establish the relationships between sizes and ages, shrub heights, crown diameters (mean of maximum and minimum diameters), stem diameters and total number of twigs were measured in the four strata before the destructive sampling. The sampled shrubs were between 5 and 620 cm in height, 5 and 510 cm in crown diameter, and 5 and 455 mm in stem diameter. For age determination a stem disk was taken at the stem base of each individual. To verify exact detection of the position of the root collar, i.e. the transition between root and stemwood, we excavated five individuals and took multiple samples along the stem (serial sectioning) to find the position of the root collar and understand its morphology (Bär et al., 2006, 2007; Schweingruber et al., 2006).

Sample preparation, ring detection and measurement

Stem disks were boiled to soften the tissue and prepared with a sliding microtome (G.S.L.-1 microtome, WSL, Birmensdorf, Switzerland) or a razor blade. After drying (at 60 °C overnight) chalk powder was applied to the surface to fill the cell lumina and enhance the contrast with the cell walls (Fig. 2A). In the case of very slow growing individuals (rings < 0.1–0.2 mm) or samples which showed little colour contrast, micro-thin sections (25 μm) were stained with aqueous safranine solution of 1:100 (Schoch et al., 2004) (Fig. 2B).

Growth rings were identified with a stereo microscope (stem disks) or a light microscope (thin sections) at a magnification between 8 and 100× (Leica MZ 12.5). Ring boundaries in hawthorn are indicated by flattened, thick-walled fibres (Fig. 2A and B).