Responses of plants to Al, Mn and Fe, with particular reference to *Succisa pratensis* Moench.

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Summary *Succisa pratensis* Moench is an ecologically wide-ranging hemicryptophytic plant species. The wide ecological amplitude is at least related to edaphic factors such as wide variation in soil pH from strongly acid to alkaline, and variation in soil wetness from aerobic to anaerobic. Al and Mn are generally considered important growth-limiting factors of many acid (sub) soils, whilst both reduced Mn and Fe are soluble and may reach phytotoxic concentrations when soil is oxygen-depleted after flooding.

The growth of young individuals of two populations from contrasted ecology was compared: one from a dry heath vegetation on acid podzol, and one from a waterlogged fen meadow vegetation on non-ripened raw peat with ripened top. Seedlings raised from fruits were grown on a complete nutrient solution situated in a controlled environment. Various concentrations of the microelements Al, Mn and Fe at high acidity (pH 3.8) were used separately.

It appeared that both populations showed the same response curve to concentrations of the three elements. Al did not differentiate between them, while the production of the waterlogged fen meadow population was less inhibited by either Mn or Fe compared to that of the dry heath population. These results may indicate that the wide ecological amplitude of this species is partly achieved by genetic differentiation into separate populations (edaphic ecotypes) as far as Mn and Fe are concerned. The study is used to evaluate generalization from experiments on genetic variation and phenotypic plasticity as adaptive responses to contrasting habitats.

Introduction

The hemicryptophytic herb *Succisa pratensis* Moench is an ecologically wide-ranging plant species. It occurs in various habitats including borders of lakes, ponds, canals and ditches; unshaded and shaded mires and fens; deciduous and coniferous woods; verges; lead mine heaps; limestone pastures; heath on limestone; and wasteland. Correlation studies between the distribution pattern and some soil characteristics show that the species is found on almost all types of substrate including chalky, peaty, clayey and sandy soils. These soils are generally humid to wet and usually desiccate superficially in summertime. The soils are most commonly poor in phosphate and potassium and nitrogen. Soil pH ranges from below 5 to above 7. The species seems to be largely glycophytic but it also occurs on an upper salt-meadow.
The wide ecological amplitude of this species may be explained by phenotypic plastic responses of the individuals\(^7\). Most of the experimental evidence with a variety of species however, suggests that genetic flexibility is more important as it provides the potential for selection, over a period of time, of separate, genetically-determined local ecotypic populations\(^8\), each adapted to a limited range of environmental conditions. Such disruptive selection may be imposed by a wide range of factors including nutrients\(^9\).

Soil pH and soil wetness are inextricably interrelated and both may be involved in seasonal fluctuations. These two edaphic factors and their interaction are very likely important in determining the nature of terrestrial ecosystems. If soil pH falls below 5 sufficient soluble and exchangeable concentration of Al\(^{38}\) and Mn\(^{31}\) may occur to injure plant life. Only in soils of below pH 3 ferric Fe is soluble under oxidizing conditions\(^{26}\). The availability of the microelements Mn and Fe is not only determined by pH, but by the sum of pH and redox potential \(pe^{26}\) of the soil system. Furthermore, both pH and \(pe\) are closely interrelated\(^4\). Plant species adapted to waterlogged soil conditions have a greater ability to withstand Mn and ferrous Fe in water culture experiments\(^{34}\).

Varieties (cultivars) of crops may differ widely in resistance to excess soluble or exchangeable Al\(^{15,30}\), Mn\(^{10,15,30}\), and Fe\(^{10}\) in acid soils and on nutrient solutions. Ecotypic variation in wild plant species has been demonstrated for resistance to excess Al and Mn\(^{33}\).

Heavy metal resistance has been shown to be largely metal specific\(^{43}\). The resistance of plants collected from heavy metal containing soils generally reflects the particular metal or metals in the soil\(^3\). Resistance to acidity does not necessarily imply resistance to Al and Mn in all cases\(^{15}\).

The present investigation was designed to study the possible occurrence of intra-specific habitat-correlated genetic variation within *Succissa pratensis* by comparing the performance (growth) of young individuals of natural populations from contrasting soil types on nutrient solutions with varying concentrations of Al, Mn and ferrous Fe.

**Materials and methods**

*Fruit collection*

Fruit samples of populations from contrasting soil conditions were collected in October 1980, dried at root temperature for a short period, and stored in paper bags at 4°C and 50–70% relative humidity. The fruit sample of the acidic (pH H\(_2\)O 4.2) population Appelbergen was taken from a dry heath vegetation, whilst the fruit sample of the waterlogged (pH H\(_2\)O 5.6) population Hasselt was collected from a fen meadow vegetation. From each site a