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Methods of establishing species-rich meadow biotopes in urban areas

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ABSTRACT

The biodiversity of meadow vegetation can be preserved in several ways, ranging from the conservation of historical traditionally managed meadows to the establishment of new meadow biotopes managed with modern machinery. Municipal plans often state that the value of natural habitats and the quality or functionality of green infrastructure should be improved. This requires scientific knowledge on the creation of new habitats with distinctive ecosystem services in the urban and peri-urban landscape. This paper presents a re-analysis of the results of research on methods of establishing species-rich grassland vegetation in the urban setting carried out in Sweden during the 1980s. It was found that hay or straw, used as mulch to protect meadow plant seeds, improved the success of establishment (higher number of individuals per m^2) compared to establishment on bare soil. The use of rye (*Secale cereale* L.) as a nursery plant also improved the establishment compared to bare soil, whereas using ryegrass (*Lolium perenne* L.) as a nursery plant had no effect on the establishment of meadow species. The stripping method used to break up an existing sward did not affect the success of sown meadow plant species establishment, whereas broader strips improved the longer-term establishment (four years after sowing). The gapping method used to open up a closed grass sward was, however, important; sward removal resulted in successful establishment of meadow plant species, while burning did not. Gap size was found to be important for the establishment success rate of sown meadow plant species in the longer term (three years after sowing). Generally, the number of individuals per m^2 was higher in the first year than the second year after sowing and *Leucanthemum vulgare* and *Rumex acetosa* showed the highest number of individuals per m^2 among the species included in the experiments. Planting plug plants directly in a closed grass lawn sward was found to be very successful, and the rate of survival was high. Further research is required on methods of establishing meadow plant species or meadow biotopes in an urban context, including the investigation of conflicting views on land use and residents' needs in urban and peri-urban areas. The ways in which constructed meadow biotopes contribute to the fulfilment of environmental goals and provide ecological functions and ecosystem service should also be assessed.

1. Introduction

Semi-natural grasslands are the result of long-term human influence, and include pastures managed by grazing cattle, meadows managed by regular cutting, and grazed meadows which are cut early in the season and thereafter grazed (Hejcman et al., 2013). Both pastures and meadows have a long history in Europe, although the former are considered to have an earlier origin, appearing during the Iron Age (Hejcman et al., 2013). Semi-natural grassland communities exhibit a broad diversity of plants resulting from environmental gradients across the landscape, where altitude, topography and edaphic factors affect the development of the plant communities (TemaNord, 1998), as well as management practices, which contribute to mosaics on a range of scales and the overall landscape biodiversity (Dumont and Tallowin, 2011). Plant diversity implies coexistence, which in turn requires differentiated realized niches; otherwise competitive exclusion will take place (Levin, 1970; Grime, 2002). The competitive pressure (e.g. for light) can be prevented by the management in pastures and meadows and, in fact, removing aboveground biomass (Güsewell et al., 1998; Doležal et al., 2011; Wallin and Svensson, 2012; Odstrčilová et al., 2013) has been shown to be beneficial for plant species richness and diversity. Meadows have been important historically as a resource for human survival through the production of hay to feed cattle during the winter, and the resulting manure which is used as fertilizer in arable crop and vegetable production. However, meadows are today regarded as endangered biotopes in need of protection and conservation (Emanuelsson, 2009; EU Council Directive 92/43/EEC, 1992). The ecosystem services provided by

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species-rich grasslands such as meadow vegetation range from carbon sequestration (Rumpel, 2011; Bol et al., 2011) and the retention of nitrogen (Bol et al., 2011) and phosphorus (McDowell and Kleinmann, 2011), to the provision of habitats for a wide range of other organisms (Buri et al., 2014; Lebeau et al., 2015).

Maintaining the biodiversity and other benefits provided by meadow vegetation requires existing meadows to be conserved and abandoned meadows to be restored, which may involve recreating meadows or the establishment of new meadow biotopes. The soil in areas of urban exploitation is often highly perturbed and without plant cover. Bare soil can be re-vegetated through spontaneous colonisation by surrounding vegetation, often resulting in an initial flora of early colonisers, i.e. ruderal plant species. The time since plant establishment is an important factor for the successful establishment of meadow vegetation on bare soil (Jongepierová et al., 2007; Lencová and Prach, 2011), as is a pool of meadow plant species in the soil seed bank or in other surrounding habitats. In areas where no meadow species pools are available for spontaneous vegetation of bare soil in the urban landscape, transplanting turf or topsoil (Skrindo and Pedersen, 2004) and hay transfer (Kirkham et al., 2012) have proven to be suitable methods of establishing meadow vegetation. Sowing has also been found successful in the establishment of regional seed mixtures in an arable field (Jongepierová et al., 2007), however, planting plug plants resulted in a higher establishment rate than seeding when two typical meadow plant species (*Succisa pratensis* and *Hypochoeris maculata*) were considered (Wallin et al., 2009). In the case of existing grass swards, such as degraded grassland biotopes or grass lawns, changing the method of management and altering the soil conditions can help restore or create biotopes with greater diversity. The establishment of plant material in existing swards requires disturbance to break up the sward (Schmiede et al., 2012), allowing the less competitive meadow plant species to become established among other more dominant species.

Most studies on the establishment of meadow vegetation and the improvement of existing grasslands are carried out in nature conservation areas or on arable land, while there is a lack of similar studies in the urban landscaping context. Methods of establishing, constructing and managing attractive, species-rich and multifunctional urban and peri-urban meadows are required to increase species richness locally. It is often stated in municipal plans that natural values and green infrastructure functionality should be improved, both quantitatively and qualitatively, which means increasing the value and functions of both existing and future green areas. There is therefore a need for scientific knowledge of ways in which new habitats with distinctive ecosystem services can be created in the urban and peri-urban landscape.

This paper presents a re-analysis of the results of experiments on methods of establishing species-rich meadow vegetation carried out at the Swedish University of Agricultural Sciences during the 1980s. The work was presented in a national context, and was published in Swedish reports only. Through this publication, the results of the experiments will now be available to the international communities of researchers, planners and practitioners. The following questions were addressed:

1) Do nursery plants and/or organic mulch increase the number of meadow plant species that are established from seeds on bare soil?
2) Do the stripping method and/or width of the strip influence the success of meadow plant species establishment in a closed grass sward?
3) Do gap method and/or gap size influence the success of meadow plant species establishment in a closed grass sward?
4) Is it possible to establish plug plants of species typical of meadow vegetation in a closed grass lawn sward?

Table 1
The design of the original establishment experiments on bare soil at Alnarp and Torslunda, Sweden (Hammer and Kustvall, 1991) (The experimental design also included control plots with no nursery plants or mulch).

Season	Nursery plant or Mulch	Density (g per m^2)
Spring	Rye	4.0
		8.0
	Oil seed rape	0.16
		0.32
	Ryegrass	1.25
		2.50
	Hay	160
		330
	Straw	100
		210
Autumn	Rye	4.0
		8.0
	Oil seed rape	0.16
		0.32
	Hay	160
		330
	Straw	100
		210

2. Materials and methods

2.1. Nursery methods for establishment on bare soil

Field experiments were carried out at Alnarp (Skåne) and Torslunda (Öland), Sweden, during the period 1984–1985 to study the effect of nursery plants and organic mulches on the establishment of 38 herbs and 8 grasses on bare soil (Hammer and Kustvall, 1991), where 12 species were possible to re-analyse in this study. Establishment was investigated in two different seasons (spring and autumn) at both experimental locations. At Alnarp, autumn establishment was performed in 1984 and spring establishment in 1985. At Torslunda, both the spring and autumn establishment were performed in 1985. The spring establishment included ten kinds of treatments, i.e. the use of three nursery plants: rye (*Secale cereale* L.), oil seed rape (*Brassica napus* L.) and ryegrass (*Lolium perenne* L.), and two organic mulches (hay and straw), at low and high density. A control plot with no nursery plants or mulch was also included. The autumn establishment included eight kinds of treatment: i.e. two nursery plants (rye and oil seed rape) and two organic mulches (hay and straw), at low and high density, as well as a control plot with no nursery plants or mulch. The design of the original experiments is summarized in Table 1. Prior to the experiments, the soils were analysed to determine the pH, the total N content and the availability of the nutrients P, K, Ca and Mg (extraction methods and equipment not known), and the soil organic matter was determined by loss on ignition (Table 2). The areas were ploughed and cultivated, and the nursery crops were sown using machinery, while the meadow seed mixture, hay and straw were dispersed by hand. The temperature and precipitation of Alnarp and Torslunda under the experimental time are presented in Table 3. The species composition of the seed mixture used in the experiment is given in the Appendix (Table A.1). Each experimental plot was 2 × 2 m. The number of replicates was not given in the original report. Vegetation inventories of the plots sown in the autumn of 1984 (Alnarp) and in the spring of 1985 (Alnarp and Torslunda) were made during August and September of 1985 and 1986, while the plots sown in the autumn of 1985 (Torslunda) were inventoried during August and September of 1986 and 1987. The number of individuals of each plant species was recorded using a 1 × 1 m frame divided into 25 0.2 × 0.2 m squares. It was reported that the results