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Effects of compost and mowing on the productivity and density of a purpose-sown mixture of native herbaceous species to revegetate degraded soil in anthropized areas

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ABSTRACT

Disturbance and soil fertility are some of the main drivers influencing the dynamics of herbaceous communities. Such communities are among the most biodiverse and represent a model for introducing species-rich and low-input green systems into anthropized environments, at the same time creating opportunities for conservation and restoration. Trials were set up to evaluate the effects of compost and mowing on the dynamics of purpose-sown herbaceous vegetation, inspired by the phytocenosis spontaneously growing in the nearby rural areas. Both soil properties (organic carbon, total nitrogen content, bulk density and pH) and plant species characteristics (density, biomass, height, functional traits) were determined. Our results showed that the addition of compost countered the soil compaction process with a positive effect on soil bulk density. Irrespective of compost and mowing, the amount of carbon and nitrogen in the soil was greatly influenced by the vegetation. Early season mowing increased the Shannon index and decreased the Simpson index, while over the years, with the increase in productivity, biodiversity decreased. Compost and mowing had a species-specific effect on seed mass and plant height.

1. Introduction

Species density, biomass and diversity of herbaceous communities are influenced by disturbance (i.e., mowing) and soil fertility (Grace, 1999; Grime, 2006). Mowing reduces inter-species differences and prevents competition, enabling diverse habitus species to coexist (Klimešová et al., 2010). Bernhardt-Römermann et al. (2011) found that changes in the frequency and timing of mowing can modify the biomass, and that twice-yearly mowing can maximize biomass yields in temperate environments. The timing and frequency of mowing affect grassland diversity, particularly reducing the recruitment of small-seeded species (Bissels et al., 2006). The persistence of annuals in a purpose-sown meadow is promoted by mowing in autumn (Bretzel et al., 2012).

The type of vegetation in a semi-natural grassland is affected by the physical, chemical and biological characteristics of the soil (Cachovanová et al., 2012). Fertility affects productivity and indirectly diversity. According to the humped-back model (HBM) proposed by Grime (2001), in low fertile soils often the productivity of herbaceous communities (grassland) is low and the biodiversity is high. Indeed, plant species richness is controlled by nitrogen (N), which plays a key role in the productivity of such ecosystems, especially over the long term (Clark and Tilman, 2007; Elisseou et al., 1995; Marrs, 1993; Mountford et al., 1993; Tallowin et al., 1994).

Increased N levels in soil leads to decreased species richness, due to shoot and root competition, following competitive exclusion irrespective of the frequency of mowing (Rajaniemi, 2002; Wilson and Tilman, 2002). In a community growing on soils with limited N levels, dominant species are efficient at acquiring, using and retaining the limited resources available, and are generally characterized by a high biomass to N ratio, a high root to shoot ratio, long-lived tissue, and high nutrient-use efficiency (Koutroubas et al., 2000; Craine et al., 2002; Fargione and Tilman, 2006). Therefore, the greatest biodiversity can be expected with a balance between stress and disturbance on the one hand, and competition for light and space on the other (Schaffers, 2002).

Such dynamics of natural and semi-natural herbaceous vegetation have been used as a model to manage similar types of purpose-sown vegetation both for restoration and conservation,

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for ornamental displays (Hitchmough and De La Fleur, 2006; Burton et al., 2006; Aldrich, 2002), and to improve animal biodiversity (Haaland and Bersier, 2011).

Urban development causes physical, chemical and biological alterations to the soil, making soils in anthropized areas infertile and poor in organic matter, soil nitrogen content and structure (Pulford, 1991; Pavao-Zuckerman, 2008). The addition of compost can improve the organic carbon content (Vigna Guidi et al., 1989a; Hargreaves et al., 2008) as well as the porosity and the structure of soils (Vigna Guidi et al., 1989b; Grosbellet et al., 2011), thus creating better conditions for a mixture of herbaceous species. Municipal waste compost can make the plant population density more uniform (Pill et al., 1994) and the flowering period longer (Pini et al., 2012). Native herbaceous species sown in a mixture of annuals and perennials are suitable for creating diverse communities for ornamental purposes with low maintenance (Bretzel et al., 2012; Tinsley et al., 2006).

Native species help to restore habitats in settled areas and to conserve the biodiversity threatened by continuous urbanization, also adding a social and educational value (McKinney, 2002; Le Roux et al., 2014). Miller and Hobbs (2002) claimed that conservation is more effective if it takes place not only in natural areas, but also 'where people live and work'. Plant strategy theories plus the use of herbaceous plants that grow spontaneously in urban settlements can be exploited to estimate the stability of artificially created plant communities (Kühn, 2006). A functional approach at an individual level is useful to evaluate plant performance in ecological restoration and to understand the responses to stress, disturbance and soil properties, especially in anthropized areas (Lavorel and Garnier, 2002; Pywell et al., 2003; Lavorel et al., 2007; Fischer et al., 2013; Zhaobin et al., 2014).

Our aim was to assess the dual effects of compost addition and different mowing seasons on the growth and composition of a purpose-sown herbaceous mix in a poor urban soil. In order to evaluate the effects of the different treatments on the species ecological strategies, a plant functional traits analysis was used.

2. Materials and methods

2.1. Experimental trial

The trial was carried out from 2010 to 2013 at the Research Area of the National Research Council in Pisa (Tuscany, Italy) at lat 43°43′N, long 10°23′E, 4 m altitude. The site was open and sunny. During the study the total annual precipitation was 866 mm in 2010, 490 mm in 2011, 936 mm in 2012, and 1195 mm in 2013. The minimum–maximum values of average daily air temperature in °C were 9.4–21.3 in 2010, 8.9–22.1 in 2011, 9.5–21.0 in 2012, and 9.4–20.6 in 2013.

The trial was set up in October 2010. Eight 2 × 1 × 0.50 m wooden boxes, with anti-algae mulching film on the bottom, were filled with unsieved soil collected from the floodplain of the river Arno at a 20–50 cm depth in order to limit the weed seed-bank.

Compost from selected municipal organic waste was then added to four out of eight boxes (hereafter compost treated, CT) at the rate of 2 kg m^{-2} and incorporated to a depth of 10 cm. On a dry matter basis, the organic carbon content of compost was 24.7% and total nitrogen content was 2.7%. The other four boxes did not receive the compost (hereafter non-compost treated, NCT). In November of the same year (2010) a seed mixture of 26 autochthonous herbaceous species were sown on a 3 cm layer of commercial seeding substrate (20% organic C, 0.2% organic N) spread over the top of the eight boxes. Table 1 lists the botanical names and families, as well as the life form, flowering period and origin of the selected species, which are found growing spontaneously in associations in the surrounding countryside. The species were selected in terms of non-invasiveness, tolerance to adverse edaphic conditions, capacity to grow on unproductive soil, adaptability to low maintenance, and life form (Bretzel et al., 2012). Height, number, color and shape of flowers, time and duration of flowering were also taken into account. We followed the principle that the differences in flowering time and duration of various species can be used to extend the flowering period of a sown seed mix.

Table 1
Main characteristics of plant species used in the purpose sown mix of native herbaceous species (Pignatti, 1982; Conti et al., 2005). In life form: H = hemicriptophytes with buds close to the ground surface (perennials); T = terophytes which complete their whole life cycle within one year (annuals) (Cornelissen et al., 2003).

Plant species	Botanic family	Life form	Chorology	1000-seed weight (g)	Flowering period
Achillea millefolium L.	*Asteraceae*	H	Eurosib.	0.2	V–IX
Agrimonia eupatoria L.	*Rosaceae*	H	Subcosmop.	22	V–VII
Bellis perennis L.	*Asteraceae*	H	Europ.-Cauc.	0.1	I–XII
Calamintha nepeta (L.) Savi	*Lamiaceae*	H	Orof. S-Europ.	0.1	V–X
Calendula arvensis L.	*Asteraceae*	T	Euri-Medit.	9.0	I–XII
Centaurea nigrescens Willd.	*Asteraceae*	H	Europ.	1.3	VI–VIII
Cyanus segetum Hill.	*Asteraceae*	T	Steno-Medit.	3.8	V–VI
Dianthus carthusianorum L.	*Caryophyllaceae*	H	Central-E-S-Europ.	1.0	V–VIII
Filipendula ulmaria (L.) Maxim.	*Rosaceae*	H	Eurosiber.	0.8	V–VII
Foeniculum vulgare Mill.	*Apiaceae*	H	S-Medit.	5.3	VI–VIII
Galium verum L.	*Rubiaceae*	T	Europ.-Cauc.	0.5	VI–IX
Hypericum perforatum L.	*Hypericaceae*	H	Paleotemp.	0.1	V–VIII
Leontodon tuberosus L.	*Asteraceae*	H	Steno-Medit.	0.1	X–VI
Leucanthemum vulgare Lam.	*Asteraceae*	H	Eurosib.	0.3	V–X
Linaria vulgaris Mill.	*Scrophulariaceae*	H	Euro-asiat.	0.1	VI–X
Origanum vulgare L.	*Lamiaceae*	H	Euro-asiat.	0.1	VI–IX
Orlaya grandiflora (L.) Hoffm.	*Apiaceae*	T	S-Europ.-Sudsib.	16	V–VIII
Papaver rhoeas L.	*Papaveraceae*	T	E-Medit.-Mont.	0.1	IV–VI (VIII–IX)
Pulicaria odora (L.) Rchb.	*Asteraceae*	H	Euri-Medit.	1.0	VI–VII
Salvia nemorosa L.	*Lamiaceae*	H	S-Europ.-Sudsib.	3.0	VI–IX
Salvia verbenaca L.	*Lamiaceae*	H	Medit.Atl. (Steno)	1.8	I–XII
Scabiosa columbaria L.	*Dipsacaceae*	H	Euro-asiat.	1.2	VI–IX
Senecio aquaticus Hill.	*Asteraceae*	H	Central-Europ.	0.2	VI–X
Silene latifolia Poir. subsp. *alba* Mill (Mill.) Greuter & Burdet	*Caryophyllaceae*	H	Paleotemp.	0.7	VI–IX
Verbascum blattaria L.	*Scrophulariaceae*	H	Paleotemp.	0.1	V–VIII
Verbascum nigrum L.	*Scrophulariaceae*	H	S-Europ.-Sudsib.	0.1	V–VIII