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Research Paper

Wildflower green roofs for urban landscaping, ecological sustainability and biodiversity

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HIGHLIGHTS

- Wildflowers in urban environment elicit emotional landscape.
- Sustainable wildflowers green roof represents a challenge.
- Flowering dynamics in different times elicit the seasons' perception of the citizens.
- Wildflowers green roof implies an increase of urban biodiversity even in terms of pollinators.
- The management of the wildflowers green roof is necessary for their sustainability.

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ABSTRACT

The aim of this trial was to test a wildflower roof in order to show how a country landscape fits in an urban environment. The bio-agronomic performance, the biodiversity dynamics during the two-years experiment, and the pollinating fauna, were analysed.

Each plant group was able to efficiently colonize the surface of the roof though in different periods and with various modalities. Thermal insulation of green roof was connected to different development dynamics of leaf canopies. In particular, this cooling effect took place during the peak of the vegetation's growth pattern. As expected, each plant group had differing flowering periods, during which were observed coincided highest rate of pollinator' visits (domestic and solitary bees, bumblebees, lepidoptera, diptera both syrphidae and bombyliidae). The agronomic management, consisting in senescent vegetation mowing, was of crucial importance to ensure the plant equilibrium of spring and summer flowering species. The lack of a prevailing species was highlighted by several biodiversity indexes. On the contrary, early and late flowering species (geophytes) did not require any vegetation management. In conclusion, even if wildflowers exhibit critical aspects in terms of covering dynamics, due to the periodic senescence of vegetation, they represent a valid instrument to improve the biodiversity and the landscape of the Mediterranean urban ecosystem.

1. Introduction

In the light of the growing environmental problems of modern times, the key concepts of landscape ecology, ecosystem sustainability and biodiversity have become increasingly important.

The often excessive anthropization of the ecosystems has proven ecologically unsustainable and has had negative repercussions on both landscapes and biodiversity. This has impacted widely on urban environments, replacing the natural biological complexity of the ecosystems with the monotonous presence of concrete buildings lacking signs of natural life. This phenomenon has often been thought to be a critical point for the daily wellbeing in a city of mankind, and may lie at the root of psychological stress (Bradley & Altizer, 2007). The term "solastagia" was not by chance coined to express psychic or existential distress caused by progressive environmental change (Albrecht et al., 2007). The origin of such an emotional breakdown phenomenon is said to derive from the feeling of "biophilia", which consciously or unconsciously is reported to be present in every single individual and, especially during childhood, and can be satisfied only by direct contact with nature (Kahn, 1997).

People seem destined to pass the majority of the life in highly anthropized environments designed to satisfy their primary rather than their psychological needs (Rees, 1997), and in an environment where the development of urban ecosystem biodiversity is unfortunately not an easy task. However, the aim of recreating inside cities miniatures ecosystems as a representation of the surrounding landscapes, was and still is one of the greatest challenges of

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the third millennium (Van Kamp, Leidelmeijer, Marsman, & De Hollander, 2003). One the biggest obstacles, however, is currently still represented by the lack of free space, which is mostly taken up by concrete. The most innovative solution for this problem has been the idea of using roof tops (Getter & Rowe, 2006), and transforming these inert surfaces into ecological niches (Oberndorfer et al., 2007) capable of supporting the life of plant species and their fauna (Brenneisen, 2006). It is important to stress that the concept behind these green roofs was a solution aiming to achieve improved living city intensive standards and not only a solution to an aesthetic problem. Green roof tops are indeed useful in a variety of ways: for the thermal insulation of buildings against both hot (Spala et al., 2008) and cold temperatures (Teemusk & Mander, 2009); to reduce the typical urban pollution (Currie & Bass, 2008; Yang, Yu, & Gong, 2008); to decrease storm water runoff (VanWoert, Rowe, Andresen, Rugh, & Xiao, 2005); to increase the filtering of carbon monoxide from vegetal biomass (Getter, Rowe, Robertson, Cregg, & Andresen, 2009); and also to help sound proofing (Renterghem & Botteldooren, 2009). But it is important to determine which plant types are more suitable for positioning on these surface tops, since the species used for extensive green roofs (i.e. with a substrate thickness equal to approximately less than 25 cm) must be characterised by a specific plant toughness, as their agronomic management needs must be minimal throughout the year. On the other hand, even if the various species belonging to the botanical genre Sedum represent the ideal type of sustainable greenery for growing on these surfaces (Monterusso, Rowe, & Rugh, 2005) other wild species have already been utilised (Benvenuti & Bacci, 2010) in an effort to increase the optimal vegetation mix to place on this difficult location. The use of wildflowers (herbaceous wild species characterized by chromatically eye-catching flowers) could play a crucial role in this context both in aesthetic and biodiversity terms. Wildflowers have an entomophilous pollination (Johnson & Steiner, 2000) which favours the biodiversity of the entomofauna. Imagining therefore a similar urban landscape, where butterflies, nowadays a rare sight (Haaland & Bersier, 2011), can spread appears very interesting from an educational point of view: children could receive in their daily urban routine an ecological imprinting which is fundamental for raising their awareness of the rising environmental problems which the world is now facing. Another aspect not to be underestimated in favour of wildflower mixes is the resulting increase in arthropods following adoption of such (Braman, Pendley, & Corley, 2002).

In this field a series of successful experiments were undertaken which demonstrated the urban compatibility of a number of wildflower species, both exotic (Hitchmough, De La Fleur, & Findlay, 2004; Hitchmough & Woudstra, 1999) and native (Dvorak & Volder, 2010; Hitchmough, 2000) and in certain cases also of wildflower species originating in environments with specific ecological characteristic (MacIvor & Lundholm, 2011). In this latter case the introduction in city environments of wild species representing typical rural landscapes holds an important added value since the growing urbanisation of the outskirts of urban areas (Seto, Sánchez-Rodríguez, & Fragkias, 2010) has increasingly impoverished the spectacular floral landscapes which once used to surround cities. In other words the beneficial effect of this particular "vision of nature" (Gobster, 2001) could be satisfied by wildflower species because they make you feel time passing-by trough seasonal flowering dynamics. In addition, wildflowers would be instrumental for the reallocation of humans in space (through the adoption of a flora characteristic of a specific location) and in time (through the time frame dynamics of plant flowering). In practice, green roofs could recreate that connection to nature similar to the time when the centre of life was located in the countryside and denoted by the pattern of biological growth and development. It could also be claimed that for humanity the dynamics of flowering was perceived as a form of reassurance: the surrounding nature was living and granted mankind psychological wellbeing (Ulrich, 1979). This perception of the living landscape is today not by chance considered as therapeutic (Milligan, Gatrell, & Bingley, 2004), to the point that within certain cities green areas have been designed based on "naturalistic styles" (Özgüner & Kendle, 2006). We are thus led to ask ourselves: in which type of ecosystem that has survived anthropization can we now days find wildflowers capable of creating breath-taking landscapes?

The fascination of successive blossoming periods was once generated both by natural ecosystems (meadows, green areas, etc.) and by those agroecosystems that today have become strongly impoverished due to the lack of colourful weeds (Petit, Boursault, Le Guilloux, Munier-Jolain, & Reboud, 2011). The loss of such biodiversity occurred not so much at the expense of those unsightly weeds which did not require the presence of entomophilous pollination (pollination via anemogamy or autogamy) but at the cost of those wildflowers which evolved with mutualistic strategies of attracting pollinators through their forms, scents and colours (Mitchell, Irwin, Flanagan, & Karron, 2009).

An example is given by rare wildflowers (i.e. *Centaurea cyanus*, *Agrostemma githago*, *Consolida regalis*, etc.) which today have survived in specific agro-ecological oases inspired by the farming systems of the past (Rydberg & Milberg, 2000).

In modern times where we find ourselves frequently trying to calculate the economic value of natural resources such as biodiversity (Nijkamp, Vindigni, & Nunes, 2008), these landscapes play an increasingly valuable role not only from an aesthetic point of view but also from an emotional and cultural perspective (Butler, Butler, & Orians, 2011). One need only recall how a Poppy (*Papaver rhoeas*) and a Cornflower (*C. cyanus*) are used as symbols in art and literature and how the perceptions of a floral landscape often act as guardians of ecological experiences: these flashes of memory have positive repercussions on the psyche of an individual (Chenoweth & Gobster, 1990).

On the other hand it is not an easy task to establish wildflowers in an artificial ecological niche created on the top of a roof and it is not even clear how to manage them in agricultural terms so as favour their sustainability through time. These are species that develop in environments characterised by natural and/or agronomic disturbances (Lavorel, 1999) and, consequently, the time frame and manner of the disturbances play a crucial role over time in ensuring their survival and their floral equilibrium.

Thus the purpose of this research was to test the agro-ecologic performances of a number of wildflowers typically characteristic of Mediterranean landscapes by simulating their placement on a green roof; and to assess the relation created between biodiversity dynamics and agronomic management. The analysis was focused more generally on the plant groups selected as a function of their respective flowering periods and only to a lesser extent on the study of the individual species involved.

2. Materials and methods

2.1. Plant material and germoplasm collection

In the years that preceded the experiment a number of wildflowers were identified in various locations in Tuscany. Within these areas it is significant to mention the agro-ecologic oases of mountain environments where we had the opportunity to encounter wildflowers that are nowadays rare (mainly *C. cyanus*) and practically extinct from conventional agro-ecosystems. In the past these species, characterised by a marked resilience, infested winter cereal fields and were part of historical rural landscapes. Other