Provision of ecosystem services by hedges in urban domestic gardens: focus on rainfall mitigation

Article

Accepted Version

Blanusa, T., Hadley, J., Hunt, L., Alexander, P. and Hobbs, K. (2017) Provision of ecosystem services by hedges in urban domestic gardens: focus on rainfall mitigation. Acta Horticulturae, 1189. pp. 519-523. ISSN 2406-6168 doi: 10.17660/ActaHortic.2017.1189.104 Available at https://centaur.reading.ac.uk/75423/

Identification Number/DOI: 10.17660/ActaHortic.2017.1189.104 <https://doi.org/10.17660/ActaHortic.2017.1189.104>

Publisher: International Society for Horticultural Science

Provision of ecosystem services by hedges in urban domestic gardens: focus on rainfall mitigation

T. Blanusa[1,2,a], J. Hadley[2], L. Hunt[1], P. Alexander[1] and K. Hobbs[3]

[1]Science Department, RHS Garden Wisley, Woking GU23 6QB, UK; [2]School of Agriculture, Policy and Development, University of Reading, RG6 6AR, UK; [3]Hillier Nurseries, Ampfield House, Ampfield, Romsey SO51 9PA, UK

Abstract

In the UK urban context, domestic gardens are an important resource, taking up to 25% of an urban area, with hedges being their popular and widespread features. Garden hedges are able to provide a number of ecosystem services, including mitigation of rainfall, trapping of particulate pollution, local temperature regulation etc. Using hedges as a model, we argue that differences in plants' capacity to provide environmental benefits should be taken into account, in addition to their suitability for particular conditions, ornamental appeal and cost, when choosing plants for green spaces. The overarching aim of our project is to quantify the simultaneous provision of multiple services by several widely used hedge species and cultivars. In this paper, we are focusing on the provision of rainfall capture by the hedges. The following species and cultivars, differing in the leaf and canopy structure and size, and in some physiological parameters, were chosen for the study: *Photinia x fraseri* 'Red Robin', *Thuja plicata* 'Atrovirens', *Taxus baccata, Ligustrum ovalifolium* 'Aureum' and 'Argenteum' and *Cotoneaster franchetii.* The experiments were conducted June-July 2015 in glasshouses at the University of Reading, UK. We measured the water use of different species/cultivars (6 plant 'treatments' and bare substrate as a control, in 10 L containers, with 6-8 replicates each) and their ability to hold water within the canopy. Plants' leaf and root biomass and leaf area (LA) were also measured. Species/cultivars differed in the capacity of canopies to retain water after a simulated rainfall event. *Ligustrum* 'Aureum' held significantly more water within the canopy than other species/cultivars, despite not having the largest LA. Furthermore, when differences in LA were taken into the account, *Cotoneaster*, *Thuja*, *Taxus* and *Ligustrum* 'Argenteum' lost most water per unit leaf area suggesting that they have the greatest potential to restore soil's capacity to receive subsequent rainfall. Our initial findings confirm the hypothesis that differences in plant structure and function lead to different capacities for rainfall capture. This could inform our planting choices and help to manage/reduce problems associated with excess rainfall.

Keywords: *Cotoneaster, Ligustrum, Photinia, Taxus, Thuja*

INTRODUCTION

The ability of urban green spaces to provide a range of ecosystem services in urban areas, including biodiversity support, trapping of particulate pollution, noise abatement, local temperature regulation, mitigation of excess rainfall etc. is well documented (Bolund and Hunhammar, 1999). In the UK, domestic gardens comprise a significant proportion of the urban footprint (Gaston et al. 2005) and the choice of planting in those domestic green spaces can significantly influence the environmental benefits that derive from them (Blanusa et al. 2015; Blanusa et al. 2013; Cameron et al. 2012). In the UK gardens, hedges

[a] E-mail: tijanablanusa@rhs.org.uk

are a popular and widespread feature; the enquiries about hedging in domestic gardens are consistently one of the top three subjects in the over 90,000 questions by the gardening public answered every year by the UK's largest horticultural charity, the Royal Horticultural Society (RHS Advisory Service, pers. comm.).

The overarching aim of our project is to quantify the simultaneous provision of multiple services by several widely used hedge species and cultivars. In this paper, we are focusing on the provision of rainfall capture by the hedges.

Loss of vegetation in urban front gardens in particular, and the increase in impervious surfaces in those areas, can be linked to increased incidences of flooding (Perry and Nawaz 2008; Warhurst et al. 2014). It has been estimated that hedgerows (composed mainly of deciduous species mix such as hawthorn and field maple) can reduce the gross rainfall reaching the ground by 19-24%, in winter and summer, respectively (Herbst et al. 2006). However, plant properties such as canopy and root system size, canopy structure and shape, leaf size and morphology, and inherent plant evapo-transpiration rates, will all influence the ability of different plants to intercept rainfall and restore soil's ability to retain subsequent rainfall. Previous work (Berretta et al. 2014), showed that soil is the main store of the incident rainfall. Evapo-transpiration (ETp) by plants, however, is particularly important as it contributes to the restoration of soils' water holding capacity over and above the soil evaporation alone. Species/cultivars with higher ETp rates and larger canopies are therefore likely to provide better sequestration of rainfall and offer better protection from localised flooding.

Here, we report the findings from the first year of the experiment, comparing the capacity of six popular hedging species and cultivars to retain rainfall within the canopy and restore soil's capacity for rainfall capture. The work is set in a context of developing an understanding which plant traits correlate with good provision of a range of ecosystem services, in order to be able to select the optimal plant combinations for our green spaces.

MATERIALS AND METHODS

The following species and cultivars were chosen for the study: *Photinia* x *fraseri* (cv 'Red Robin'), *Thuja plicata* 'Atrovirens', *Taxus baccata, Ligustrum ovalifolium* (cvs. 'Aureum' and 'Argenteum') and *Cotoneaster franchetii.* Plants were obtained as 2-year old seedlings (approx. 1 m high at purchase) and re-potted into 10 L containers with John Innes No 2 potting compost, two months prior to the start of the experiments. Containers with just bare substrate were used as a control. At the start of the experiment there were eight replicates per species (e.g. see replication info in Table 2); .two plants per species were destructively sampled in the last week of the experiment. Consequently , there remained six replicates per species for the final watering cycle (see Table 3).

The experiments were conducted June-July 2015 in ventilated glasshouses at the University of Reading, UK. Within this period, three week-long experimental cycles were completed. A cycle comprised of plant containers being irrigated to full container capacity, followed by the immediate application of a 'simulated rainfall' to the canopy and then a week-long period when irrigation was withdrawn. Irrigation to full container capacity was achieved by watering with a hose until runoff, letting the container drain, followed by submerging the container for 5 min in larger container with water, and by a period of draining until no water run off. 'Simulated rainfall' comprised the application of a known water volume (500 mL in our experiment) using watering can with a rosette containing seventy 1-mm apertures. This simple approach was taken in the initial set of experiments we report on here, as the focus was on understanding the plant water use, rather than the subtle simulation of rainfall. For subsequent work (Blanusa et al, MS in preparation) we developed a sophisticated rainfall application system with control of rainfall intensity in line with naturally occurring.

Measured parameters included: water volume retained by the canopy (determined from the difference in the weight of individual containers before and after water application to saturated containers) and daily ETp rates (determined from the difference in the weight of individual containers in each 24h period). They also included measurements of leaf stomatal conductance and net CO_2 assimilation using infra red gas analyser (LCpro, ADC Scientific, Hoddedson, UK) on days 1 and 5 of each experimental 'cycle'. At the end of the experiment (early July 2015), plants' leaf and root biomass and leaf area (LA) (using WinDIAS Leaf Area Meter System, Delta-T devices, Cambridge, UK) were also determined by destructive sampling of three plants within each species/cultivar.

Data were analyzed using GenStat (15th Edition, Lawes Agricultural Trust, Rothamsted Experimental Station, UK). Analysis of variance (ANOVA) was used to assess the effects of the plant species on measured parameters; variance levels were checked for homogeneity and values were presented as means with associated least significant differences (LSD, p= 0.05).

RESULTS AND DISCUSSION

There were significant differences in species'/cultivars' crown size and leaf area (LA) (Table 1). *Photinia* had significantly higher LA than any other species (1.64 m^2 per plant). *Thuja* had the smallest leaf area of about 0.54 m^2, followed by the remaining species / cultivars which averaged 0.6-0.7 m^2 per plant (Table 1). There were also significant differences in species/cultivars dry root weight. *Taxus* and *Photinia* had significantly greater root weight than the other species (131 and 124 g respectively, per plant on average). Two *Ligustrum* cultivars had similar root weights, around 40 g per plant on average (Table 1). Of all studied species/cultivars *Taxus* had the highest rt wt/LA ratio (i.e. most root per given LA), around 219 g m^{-2}. *Ligustrum* cultivars together with *Photinia* had significantly lowest ratio, 40 and 75 g m^{-2}, respectively (i.e. least root weight per given LA).

Table 1. Mean leaf area (LA), dry root weight and the root weight:LA ratio, measured at the end of the experiment (i.e. 4 weeks after the experiment started). Different letters next to the means indicate statistically significant differences (p= 0.05).

Species / cultivar	LA (m^2)	Dry root weight (g)	Root weight: LA ratio (g m^{-2})
Photinia 'Red Robin'	1.64 a	124.0 a	75.9 bc
Ligustrum ovalifolium 'Aureum'	0.73 b	28.7 c	39.7 d
Ligustrum ovalifolium 'Argenteum'	0.68 b	36.0 c	52.4 cd
Thuja plicata	0.54 b	67.0 b	127.2 b
Taxus baccata	0.63 b	131.3 a	219.0 a
Cotoneaster franchetii	0.67 b	70.3 b	107.6 b
LSD (d.f. = 17)	0.293	18.21	50.76

Although there were differences in the volumes of water that canopies can hold (Table 2), generally canopies retained very small volumes of water (max 200 mL in our experiments which equates to 0.2 mm of rain). Most species were similar, retaining around 160 mL in the canopy, with *Cotoneaster* and *Ligustrum* 'Aureum' as lowest and highest respectively (c. 130 and 205 mL respectively). Water runoff through sliding of droplets off the canopy was least in *Ligustrum* cultivars (55-65 mL), and most in *Cotoneaster,* 110 mL (data not shown).

Table 2. Distribution of water (500 mL) applied to simulate rainfall on Day 1 of the experiment, when soil was saturated. Data are mean volumes of water; different letters next to the means indicate statistically significant differences (P = 0.05).

Species / cultivar	Water retained on the canopy (mL)
Photinia 'Red Robin'	177.4 abc
Ligustrum ovalifolium 'Aureum'	204.0 c

Ligustrum ovalifolium 'Argenteum'	182.5 abc
Thuja plicata	138.0 ab
Taxus baccata	188.1 abc
Cotoneaster franchetii	128.1a
LSD (d.f. = 47)	56.46

When water loss from the soil-plant system was measured within the first of the three week-long cycles of irrigation and drying, in the first 24h after the containers were fully irrigated, *Photinia* lost more water than all the other species, which were collectively losing more water than just bare, unvegetated soil (data not shown). However, when water loss was assessed cumulatively for the period of 72h, some further differentiation between species/cultivars happened and the order of treatments was as follows: *Photinia* = *Cotoneaster* ≥ *Taxus* = *Thuja* = *Ligustrum* 'Argenteum'> *Ligustrum* 'Aureum' > bare soil (data not shown). This suggests that if the rainfall happens within 24h of the initial one, in previously 'unstressed' plants, *Photinia* has an advantage in terms of volumes of water it can receive again; however after 3 days *Cotoneaster* appears to be closely catching up, but *Ligustrum* 'Aureum' replenished the soil's capacity for water storage the least (data not shown).

However, exposing the plants to three cycles of irrigation-and drying (a situation not dissimilar to what the hedges would be experiencing in 'real life') showed different patterns. In the first 24h after irrigation, *Cotoneaster* and *Taxus* lost most water (Table 3); all plant species lost more water than soil alone. Within 72h, the cumulative water loss ranking was as follows: *Cotoneaster* > *Ligustrum* 'Argenteum' = *Ligustrum* 'Aureum' = *Taxus* = *Thuja* > *Photinia* (Table 3). It appears that while *Cotoneaster* excelled, and all other species acted similarly, previous exposure to water deficit in earlier stages of the experiment reduced *Photinia*'s capacity for water uptake.

Table 3. Plant water use over 3 days within the third watering-drying cycles. Data are mean water loss after the containers were fully irrigated in the third cycle. Different letters next to the means indicate statistically significant differences (p= 0.05).

Species / cultivar	**Day 0 to day 1 (ml)**	**Day 0 to day 3 (ml)**
Photinia 'Red Robin'	804.6 c	1335.0 c
Ligustrum ovalifolium 'Aureum'	933.4 b	1601.8 b
Ligustrum ovalifolium 'Argenteum'	953.8 b	1698.8 b
Thuja plicata	899.6 b	1596.8 b
Taxus baccata	995.8 ab	1541.6 b
Cotoneaster franchetii	1195.8 a	1894.4 a
Bare soil	355.0 d	659.7 d
LSD (d.f. = 41)	127.20	165.80

With other work showing that loss of gardens and the associated vegetation in the UK context can be correlated with the increased risk and incidences of localized flooding (Perry and Nawaz 2008; Warhurst et al. 2014) it is increasingly important an action is taken to reduce the loss of these green spaces. Additionally, optimising the composition of those species so that we maximise their capacity to capture excess water (and provide additional ecosystem services which would benefit the residents) comes into focus.

Our data show that the larger size of plant canopy (measured as canopy leaf area) does not always correspond with the greatest volume of rainfall that the canopy can retain on the leaf surface. Instead, it was the plants' greater ETp rates (e.g. in *Cotoneaster*, *Thuja*, *Taxus* and *Ligustrum* 'Argenteum', per unit LA) which could be linked to the increased ability of the soil to receive subsequent rainfall; with storage in the soils being the main pathway for alleviation of excess rainfall (Berretta et al. 2014). Size of the plant does however matter in the context of the ETp, if not solely in terms of canopy retention. Maintaining larger hedges composed of plants with strong inherent ETp (stronger 'pumps') is likely to offer a vehicle where excess rainfall could be absorbed and protection from localised flooding provided to households. Our ongoing work is now investigating the impact of plant choice on the extent of rainfall runoff, when different volumes and intensities of simulated rainfall are applied at a range of substrate moisture contents.

CONCLUSION

Our findings suggest that the choice of hedging plants can influence the volumes of water that can be retained and removed by hedges after a period of rainfall and during subsequent rainfall events. Choice of optimal species to offer best protection against excess rainfall would, however, have to be balanced with the ability to maintain hedges during periods when there is little rainfall and during prolonged dry periods. Using hedges as a model, we argue that differences in plants' capacity to provide environmental benefit should be taken into the account in addition to their suitability for particular conditions, ornamental appeal and cost, when choosing plants for green spaces.

ACKNOWLEDGEMENTS

We are grateful to Hillier Nurseries for the provision of plant material. Thanks also to Valerie Jasper, Michael Dawes and Tobias Lane at the University of Reading for help in maintaining the plants.

Literature cited

Berretta ,C., Poë, S., and Stovin, V. (2014). Moisture content behaviour in extensive green roofs during dry periods: The influence of vegetation and substrate characteristics. Journal of Hydrology *511,* 374-386

Blanusa, T., Fantozzi, F., Monaci, F. and Bargagli, R. (2015). Leaf trapping and retention of particles by holm oak and other common tree species in Mediterranean urban environments. Urban Forestry & Urban Greening *14*, 1095-1101. doi:http://dx.doi.org/10.1016/j.ufug.2015.10.004

Blanusa, T., Vaz Monteiro, M.M., Fantozzi, F., Vysini, E., Li, Y., and Cameron, R.W.F. (2013). Alternatives to Sedum on green roofs: Can broad leaf perennial plants offer better 'cooling service'? Building and Environment *59*, 99-106 doi:10.1016/j.buildenv.2012.08.011

Bolund, P., and Hunhammar, S. (1999). Ecosystem services in urban areas. Ecological Economics *29*, 293-301 doi:http://dx.doi.org/10.1016/S0921-8009(99)00013-0

Cameron, R.W.F., Blanusa, T., Taylor, J.E., Salisbury, A., Halstead, A.J., Henricot, B., and Thompson, K. (2012). The Domestic Garden - Its Contribution to Urban Green Infrastructure. Urban Forestry and Urban Greening *11*, 129-137

Gaston, K.J., Warren, P.H., Thompson, K., and Smith RM (2005). Urban Domestic Gardens (IV): The Extent of the Resource and its Associated Features. Biodiversity and Conservation *14*, 3327-3349

Herbst, M., Roberts, J.M., Rosier, P.T.W., and Gowing, D.J. (2006). Measuring and modelling the rainfall interception loss by hedgerows in southern England. Agricultural and Forest Meteorology *141*, 244-256. doi:http://dx.doi.org/10.1016/j.agrformet.2006.10.012

Perry, T., and Nawaz, R. (2008). An investigation into the extent and impacts of hard surfacing of domestic gardens in an area of Leeds, United Kingdom. Landscape and Urban Planning *86*, 1-13

Warhurst, J.R., Parks, K.E., McCulloch, L., and Hudson, M.D. (2014). Front gardens to car parks: Changes in garden permeability and effects on flood regulation. Science of the Total Environment *485*,329-339