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Study on the Plants Planted in Rooftop and Their Damage by Insect Pests

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Abstract

Plants planted in the green-roofed areas in Busan and Jinju were surveyed. The woody plants investigated in this study were classified into 52 families and 156 species, and the herbaceous plants were classified into 30 families and 97 species. Woody plants mainly planted were *Rhododendron yedoense* var. *poukhanense, R. indicum, C. kousa, P. mume,* and *E. alatus. However, Pinus* spp. were planted in all areas. The main herbaceous species planted were *Sedum kamtschaticum, S. takesimense, S. middendorffianum, T. quinquecostatus* var. *japonica,* and *A. spathulifolius Maxim.* According to surveying the distribution of woody plant pests, they could be classified into six orders, 24 families, and 46 species that usually appeared from April to October but especially between June and September. We investigated 39 insect species in relation to pest damage to leaves, 21 insect species in relation to that of branches, and 39 insect species in relation to that of stems of woody plants.

Key Words: pests, woody plant, herbaceous plant, rooftop garden

Introduction

With the greater urban concentration of people, various forms of greenbelt development within a city can provide its residents with a visual sense of stability and peace as well as psychological stability in an otherwise desolate urban landscape. Such development also functions as micro-meteorological control and purification for air pollution, and thus provides a valuable novel habitat for plants and insects, producing new environmental conditions through the preservation and creation of an 'urban ecosystem' ultimately, it can also serve a restoration function by mitigating problems caused by a city's concentrated human populations. Recently, however, the degree of destruction of nature has become quite problematic and widespread due to the enlargement of cities.

In the case of Seoul, the capital of Korea, the area of its urban forest is 26.7% of the total city area, but mostly located in suburbs. Thus, the total area of the greenbelt in the center of the city is just under 10%, which means the city is 'desert-like', lacking much vegetation. Such a severe lack of green space within the city center is currently causing substantial problems not only for nature but also for human society (Lee 1991; Park 2001). Recently, in cities with low provision of green space, various kinds of environmental destruction occurs and intensifies the thermal island effect of a city center, while the stagnation phenomenon accumulates due to the lack of purification capacity for environmental pollutants in the atmosphere. Consequently, for urban residents their emotional aspects are also negatively influenced as they become more vulnerable to more stress factors.

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Lately there has been much focus upon the green roof system ('rooftop greening') as a way to solve urban ecological problems (Her 2003). Rooftop greening carries with it an important purpose of making good use of abundant roof space, which is often left out futilely in city centers, where securing sufficient green space is difficult because land is scarce and expensive (Hyundai 1997). Rooftops are normally exposed to direct sunlight; thus, compared with the city ground level, the flow of air is better and the temperature change is more extreme at rooftops (Craul 1999; Choi 2001). These barren environments, however, maybe covered with an artificial soil on which various garden trees and plants are cultivated in order to form an eco-friendly roof garden. By so doing, it can generate a temperature reduction effect as well as shock-absorbing effect against extreme weather. In addition, such gardens are expected to create a shielding effect that produces restful scenery and blocks noise pollution and ultraviolet rays. In addition to providing protection against the wind due to an extraordinary change in polar climate, a rooftop garden may also mitigate the extreme changes in humidity, while offering additive beneficial effects in terms of esthetics and architectural beauty.

The creation of rooftop greening is classified into light, heavy, and mixed modes of planting. The light mode is a form of planting centered on ground-cover plants. The mixed mode combines various types of plants namely bushes, trees, and herbaceous flowers which has the advantage of making the best and most efficient use of limited space like rooftops through appropriate species arrangement. Most parts of rooftop greening is dominated by woody plants, however (Lee 2002; Kim et al. 2003) but native wild plants of Korea are now considered as best suited to the nature friendly concept, thereby enabling various types of cultivation strategies and approaches in planting a rooftop garden.

Therefore, in view of the recent increase in rooftop greening due to the lack of land in city centers and a high land price, this study investigated two key aspects: (1) The preference of tree species planted for establishing rooftop gardens, and (2) The habitat distribution of insect pests in the rooftop garden space. The aim of this research work was to provide baseline data in the creation of rooftop gardens and the management of their pests.

Study Material and Method

General condition of the place of survey

The study area is centered on and around Busan and Jinju. Based on satellite photographs, rooftop gardens among the large buildings were selected as targets for surveying. The actual presence of a target rooftop garden was checked through field investigation. This process yielded a final selection of nine suitable sites to survey in detail: six locations in the Busan region (including the city hall building) and three locations in the Jinju region (including Shinsegae department store building) (Fig. 1).

Study method

To investigate and study the vegetation of rooftop gardens, we classified plants growing there into herbaceous and tree (xylophyte), and performed a complete enumeration survey of their botanical names. To investigate the presence of disease and insect pests of tree plants, which represent pathologies, we performed 'on-the-spot' field assessments and recorded the plant species that suffered from lesions or attack. Afterwards we collected specimens with signs of such damage and did an on-site microscopic exami-

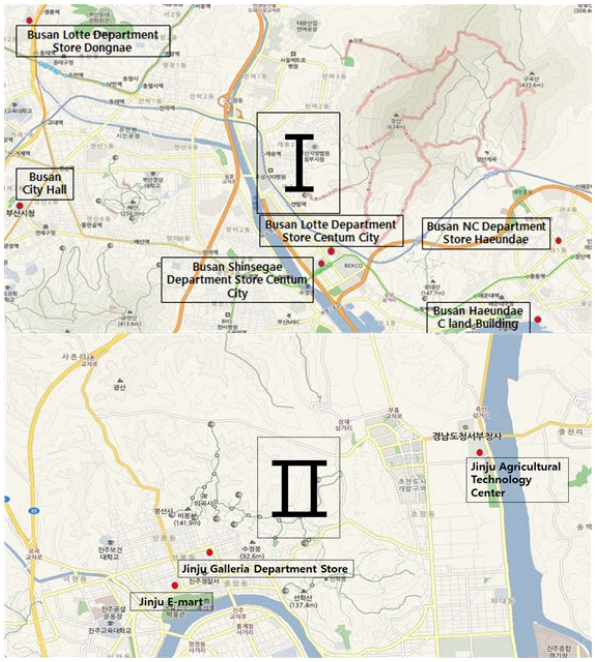

Fig. 1. Location of the study area. *I: Busan survey area (6 sites), II: Jinju survey area (3 sites).

nation; if this was impossible, we took them to the laboratory for the microscopic examination in which we placed the specimen in an incubator for cultivation and subsequent identification. First, we carried out species identification of harmful pests of the major tree species; then, we studied the status of their respective distributions through visual identification, using the naked eye. Finally, we performed an identification and classification based on the "Illustrated Guide to Forest Disease and Pests" (KFRI 1995) and the "Medical Practice for Tree Treatment" (Kang 2002). As for the density of each disease or pest, we studied the degree of damage for each type of harmful pest based on "Tips for Investigation of Forest Disease and Pest" (KFS 1991). The period of field investigation was from May 2014 to April 2015. The investigation of the selected rooftop locations was performed once per month, for a total 12times per location, and the study data was arranged according to each investigation districts of the region. In this study, we studied the preference of plant types cultivated in rooftop gardens.

Results and Discussion

Planting tree species of rooftop gardens

Plants used for the creation of rooftop gardens belonged to 52 families and 156 species, which were further classified into 25 families and 59 species of tree plants and 30 families of 97 species of herbaceous plants. Among the locations studied, Busan city hall had the highest richness, with plants of 35 families and 76 species represented: 16 families and 24 species of tree plants, and 19 families and 52 species of herbaceous plants. The major tree plants cultivated were *Pinus densiflora, Pinus thunbergii, Juniperus chinensis* var. *globosa, Rhododendron yedoense, Rhododendron indicum,* and *B. microphylla,* while the major herbaceous plants cultivated were *Liriope rhizome, Hemerocallis hybrida, Hosta longipes, Prunella asiatica*, and *Sedum kamtchaticum*.

The Centum Building had 19 families and 34 species represented, with 11 families and 22 species of tree plants and eight families and 12 species of herbaceous plants. The major species of trees were *Pinus densiflora for. multicaulis, P. densiflora*, and *Osmanthusfragrans var. aurantiacus*, while the major species of herbaceous plant cultivated was *L. rhizome*.

The Shinsegae building had 23 families and 46 species represented, with 12 families and 14 species of tree plants and 11 families and 32 species of herbaceous plants. The major species of trees were *P. densiflora, Cornus kousa, Osmanthusfragrans var. aurantiacus, Acer palmatum*, and *A. grandiflora*, while the major species of herbaceous plant were *Sedum kamtschaticum, Chrysanthemum zawadskii*, and *H. longipes*.

The Haeundae Building had 11 families and 30 species represented, with 11 families and 14 species of tree plants and eight families and 16 species of herbaceous plants. Major species of trees were *P. densiflora, P. thunbergii, Ilex crenata*, and *Camellia*, while the major species of herbaceous plant was *Hosta minor*. Unlike for the other rooftop gardens, at the Haeundae Building we observed *Aster pilosus* Willd, which has been designated by the Ministry of Environment as one of the Invasive Alien Plants.

The Dongrae Building had 15 families and 20 species represented, with 10 families and 12 species of tree plants and five families and eight species of herbaceous plants. In this place, we observed *Cyperus amicus* Maxim, which typically inhabits wetlands or swamps. These weeds likely established in the rooftop gardens from the scattering dispersal of seeds from swamps in the vicinity of this building.

The Sealand Building had 14 families and 24 species represented, with 10 families and 15 species of tree plants and four families and six species of herbaceous plants. In this place, the major species of trees were *P. thunbergii* and *J. chinensis*, while the major species of herbaceous plant was *Zoysia japonica* Steud.

In summary, tree plants cultivated in rooftop of buildings in Busan region were mainly vigorous tree species, such as *P. densiflora, P. thunbergii*, and species of shrubbery trees, such as *P. densiflora* for. *multicaulis, C. kousa, I. crenata, R. yedoense, R. indicum*, and *B. microphylla*. Regarding the cultivated herbaceous species, these were plants that are relatively easy to manage as a plantation, such as *C. zawadskii, H. longipes, H. callisfulva* and *Prunella vulgaris* var. *lilacina* Nakai. These resultscan be partly explained by the fact that deep-rooted species and large-size vigorous tree species are difficult to grow and manage in rooftop gardens (Table 1).

Plants cultivated in rooftop gardens in the Jinju region represented 35 families and 72 species in total. The Agricultural Technology Center had 21 families and 27 species represented, with 13 families and 16 species of tree

Table 1. Plants in rooftop gardens in the Busan area

Family	Species name	Korean name
Aceraceae	*Acerpalmatum var. dissectum* (Thunb.) Miq.	세열단풍
	Acer palmatum Thunb	단풍나무
Aquifoliaceae	*Ilex crenata* Thunb	꽝꽝나무
	Ilex aquifolium	서양호랑가시나무
Arecaceae	*Trachycarpus fortunei* Wendl.	당종려
Asclepiadaceae	*Metaplexis japonica*	박주가리
Berberidaceae	*Nandina domestica*	남천
Buxaceae	*Buxus microphylla* var. *koreana Nakai*	회양목
Caprifoliaceae	*Weigelas ubsessilis* L.H.Bailey	병꽃나무
	A. grandiflora	꽃댕강
	Viburnum awabuki K. Koch	아왜나무
Celastraceae	*Euonymus japonicus* Thunb	사철나무
Compositae	*Dendranthema boreale* (Makino) Ling ex Kitam.	산국
	Hypochaeris radicata L.	서양금혼초
Cornaceae	*Cornus officinalis* Siebold & Zucc	산수유
	Cornus kousa F. Buerger ex Miquel	산딸나무
Cupressaceae	*Juniperus scopulorum*	스코풀로룸향나무
	Juniperus chinensis var. *globosa*	둥근향나무
	Chamaecyparis obtusa (S. et Z.) ENDL.	편백
	Chamaecyparis pisifera (S. et Z.) Endl. var. *filifera* Beissn. et Höchst.	실화백
	Juniperus chinensis 'Kaizuka'	가이즈카향나무
Cycadaceae	*Cycas revoluta* Thunb.	소철
Ericaceae	*Rhododendron yedoense* var. *poukhanense* (Lev.) Nakai	산철쭉
	Rhododendron indicum SWEET.	영산홍
Euphorbiaceae	*Acalypha australis* L.	깨풀
Fabaceae	*Sophora japonica*	회화나무
	Castanopsis sieboldii (Makino) Hatus.	구실잣밤나무
	Quercus myrsinaefolia Blume	가시나무
Leguminosae	*Wisteria floribunda* (Willd.) DC.	등나무
Ginkgoaceae	*Ginkgo biloba*	은행나무
Lauraceae	*Lindera erythrocarpa* Makino	비목
Lythraceae	*Lagerstroemia indica* L.	배롱나무
Magnoliaceae	*Liriodendron tulipifera*	튤립나무
Oleaceae	*Syringa dilatata*	서양수수꽃다리
	Osmanthus fragrans var. *aurantiacus*	금목서
	Chionanthus retusus	이팝나무
	Ligustrum obtusifolium Siebold & Zucc.	쥐똥나무
	Ligustrum lucidum Aiton	광나무
Oxalidaceae	*Oxalis corniculata*	괭이밥
Pinaceae	*Pinus densiflora* Siebold & Zucc.	소나무
	Pinus thunbergii Parl.	곰솔
	Pinus densiflora f. *multicaulis* Uyeki	반송
	Picea jezoensis (Siebold & Zucc.) Carrière	가문비나무
Platanaceae	*Platanus orientalis*	버즘나무
Rosaceae	*Crataegus pinnatifida*	산사나무
	Spiraea cantoniensis Lour	공조팝나무

Table 1. Continued

Family	Species name	Korean name
	Photinia glabra (Thunb.) Maxim	홍가시나무
	Prunus yedoensis Matsum	왕벚나무
	Prunus mume (Siebold) Siebold & Zucc.	매실나무
	Prunus serrulata var. spontanea (*Maxim*.) E.H.Wilsom	벚나무
Salicaceae	*Salix koreensis* Andersson	버드나무
Taxaceae	*Taxus caespitosa* Nakai	눈주목
	Taxus cuspidata	주목
Theaceae	*Stewartia pseudocamellia*	노각나무
	Camellia japonica L.	동백나무
Ulmaceae	*Celtis sinensis* Persoon	팽나무
Acanthaceae	*Justicia procumbens* L.	쥐꼬리망초
Agavaceae	*Yucca gloriosa* L.	유카
Amaryllidaceae	*Lycoris squamigera* Maxim	상사화
Apocynaceae	*Trachelospermum asiaticum* Nakai var intermedium	마삭줄
Borraginaceae	*Trigonotis peduncularis* Benth. ex Baker et S. Moore	꽃마리
Campanulaceae	*Platycodon grandiflorum* A. DC	도라지
Caryophyllaceae	*Dianthus chinensis* L.	패랭이꽃
Asteraceae	*Dendranthema indicum* Des Moul.	감국
Compositae	*Inulabritannicavar.linarifolia*	가는불금초
	Crepidiastrum sonchifolium Pak & Kawano	고들빼기
	Chrysanthemum zawadskii var. latilobum	구절초
	Conyza canadensis (L.) Cronquist	망초
	Bidens frondosa L.	미국가막사리
	Taraxacum platycarpum Dahlst.	민들레
	Zinnia elegans	백일홍
	Ixeris japonica Nakai	벋음씀바귀
	Aster koraiensis Nakai	벌개미취
	Youngia japonica	뽀리뱅이
	Erechtites hieracifolia Raf.	붉은서나물
	Aster subulatus Michx	비자루국화
	Artemisia princeps Pampanini	쑥
	Ixeridium dentatum Tzvelev	씀바귀
	Crepidiastrum denticulatum Pak & Kawano	이고들빼기
	Achillea alpina L.	톱풀
	Aster spathulifolius Maxim.	해국
	Aster pilosus Willd.	미국쑥부쟁이
	Aster yomena Kitam	쑥부쟁이
	Ixeris stolonifera A. Gray	좀씀바귀
Crassulaceae	*Sedum kamtschaticum* Fischer	기린초
	Hylotelephium erythrostictum H. Ohba	꿩의비름
	Sedum oryzifolium Makino	땅채송화
	Sedum middendorffianum Maxim.	애기기린초
	Sedum sarmentosum Bunge	돌나물
	Hylotelephium ussuriense H.Ohba	둥근잎꿩의비름
	Sedum takesimense Nakai	섬기린초
Cyperaceae	*Cyperus amuricus* Maxim.	방동사니

Table 1. Continued

Family	Species name	Korean name
Gramineae	*Plioblastus pygmaed* Mitford A	사사조릿대
	Pennisetum alopecuroides Sprengel	수크령
	Zoysia japonica Steud.	잔디
	Impera tacylindrica	홍띠
	Setaria viridis (L.) P. Beauv.	강아지풀
	Phyllostachys nigra var. *henonis* Stapf ex Rendle	솜대
	Beckmanni asyzigachne Fernald	개피
	Digitari aciliaris Koeler	바랭이
Guttiferae	*Hypericum ascyron* L.	물레나물
Labiatae	*Prunella vulgaris Linne* var. lilacina Nakai	꿀풀
	Mentha arvensis var. piperascens	박하
	Agastache rugosa Kuntze	배초향
	Thymus quinquecostatus var. *japonica*	섬백리향
	Mentha species	스피아민트
	Elsholtzia splendens Nakai	꽃향유
	Dracocephalum argunense Fisch. ex Link	용머리
	Allium senescens L.	두메부추
Onagraceae	*Oenothera odorata* Jacquin	달맞이꽃
Lythraceae	*Lythrum anceps* Makino	부처꽃
	Lythrum salicaria L.	털부처꽃
Liliaceae	*Liriope platyphylla* F.T.Wang & T.Tang	맥문동
	Hosta longipes Matsum.	비비추
	Hosta longisima Honda	산옥잠화
	Hemerocallis minor Mill.	애기원추리
	Hosta minor Nakai	좀비비추
	Hemerocallis dumortierii Morr.	각시원추리
	Polygonatum odoratum var. *pluriflorum* (Miq.) Ohwi	둥굴레
	Polygonatum odoratum var. *pluriflorum f. variegatum* Y.N.Lee	무늬둥굴레
Oxalidaceae	*Oxalis stricta* L.	선괭이밥
Polemoniaceae	*Phlox subulata* L.	지면패랭이
Saxifragaceae	*Astilbe rubra* Hook. f. & Thomson var. rubra	노루오줌
Scrophulariaceae	*Veronica linariaefolia pall*	꼬리풀
Valerianaceae	*Patrinia scabiosaefolia* Fisch. ex Trevir	마타리
Verbenaceae	*Caryopteris incana* Miq.	층꽃나무
Violet	*Viola mandshurica* W.Becker	제비꽃
	Violapa pilionacea Pursh	종지나물

plants and eight family and 11 species of herbaceous plants. The major tree plants were *P. densiflora*, *Nandina domestica*, and *B. microphylla*, while the major herbaceous plant cultivated was *S. kamtschaticum*.

The Shinsegae Building had 21 families and 37 species represented with 14 families and 17 species of tree plants and seven families and 20 species of herbaceous plants. Pine tree types were cultivated mainly, while for herbaceous plants the following were often observed: *Achillea alpina* L., *S. kamtschaticum*, *Agastache rugosa* Kuntze, *Z. japonica* Steud, and *P. vulgaris* var. *lilacina* Nakai.

The Galleria Department Store building had 21 families and 39 species represented, with 10 families and 16 species of tree plants and 11 families and 23 species of herbaceous plants. The major tree plants were *P. densiflora* and shrubbery ones such as *P. densiflora* for. *multicaulis* and *C. kousa*, while the major herbaceous plants cultivated were *C. zawadskii*, *Aster koraiensis* Nakai, and *Z. japonica* Steud.

Table 2. Plants in rooftop gardens in the Jinju area

Family	Species name	Korean name
Aceraceae	*Acer palmatum* Thunb	단풍나무
	Acer palmatum var. *dissectum*	세열단풍
Aquifoliaceae	*Ilex cornuta* LINDL	호랑가시나무
Arecaceae	*Trachycarpus fortunei* Wendl.	당종려
Berberidaceae	*Nandina domestica* THUNB	남천
Buxaceae	*Buxus microphylla* var. *koreana* NAKAI	회양목
Celastraceae	*Euonymus japonicus* Thunb	사철나무
Cornaceae	*Cornus kousa* F. Buerger ex Miquel	산딸나무
	Cornus controversa Hemsl	층층나무
	Cornus officinalis Siebold & Zucc	산수유
Cupressaceae	*Juniperus chinensis* KaizukaVariegata	가이즈카향나무
	Chamaecyparis obtusa (S. et Z.) ENDL	편백
	Juniperus chinensis var. *globosa*	둥근향나무
Ericaceae	*Rhododendron yedoense* var. *poukhanense*	산철쭉
Lythraceae	*Lagerstroemia indica* L.	배롱나무
Malvaceae	*Hibiscus syriacus* L.	무궁화
Oleaceae	*Syringa vulgaris* L.	서양수수꽃다리
	Ligustrum obtusifolium Siebold & Zucc	쥐똥나무
	Chionanthus retusus Lindl. & Paxton	이팝나무
Pinaceae	*Pinus densiflora* Siebold & Zucc	소나무
	Pinus thunbergii Parl	곰솔
	Pinus densiflora f. *multicaulis* Uyeki	반송
	Pinus parviflora S. et Z.	섬잣나무
Rosaceae	*Photinia glabra* (Thunb.) Maxim	홍가시나무
Taxaceae	*Taxus cuspidata* var. nana	눈주목
Ulmaceae	*Zelkova serrata* Makino	느티나무
Aspidiaceae	*Dryopteris crassirhizoma* Nakai	관중
Borraginaceae	*Trigonotis peduncularis* Benth. ex Baker et S. Moore	꽃마리
Commelinaceae	*Commelina communis* L.	닭이장풀
Compositae	*Dendranthema indicum* (L.) Des Moul	감국
	Chrysanthemum zawadskii var. latilobum	구절초
	Erigeron canadensis L.	망초
	Taraxacum platycarpum Dahlst	민들레
	Zinnia elegans	백일홍
	Aster koraiensis Nakai	벌개미취
	Ixeris dentata NAKAI	씀바귀
	Achillea alpina L.	톱풀
	Aster subulatus Michx	비자루국화
	Artemisia laciniata Willd	은쑥
	Ixeris stolonifera A. Gray	좀씀바귀
	Youngia sonchifolia	고들빼기
	Bidens frondosa L.	미국가막사리
	Ixeris debilis (*Thunb*.) A.Gray	벋음씀바귀
Crassulaceae	*Sedum kamtschaticum* Fischer	기린초
	Sedum oryzifolium Makino	땅채송화
	Hylotelephium erythrostictum H. Ohba	꿩의비름
	Sedum middendorffianum Maxim	애기기린초
	Hylotelephium ussuriense H.Ohba	둥근잎꿩의비름

Table 2. Continued

Family	Species name	Korean name
Cyperaceae	*Carex maculata* Boott	무늬사초
Ericaceae	*Rhodoedndron indicum*	영산홍
Gramineae	*Setaria viridis* (L.) P. Beauv	강아지풀
	Plioblastus pygmaed Mitford A	사사조릿대
	Zoysia japonica Steud.	잔디
	Digitari aciliaris Koeler	바랭이
Iridaceae	*Iris nertschinskia* Lodd	붓꽃
Compositae	*Cichorium endivia* L.	꽃상추
Labiatae	*Juncus bufonius*	애기꽃풀
	Prunella vulgaris Linne var. lilacina Nakai	꿀풀
	Agastache rugosa Kuntze	배초향
	Dracocephalum argunense Fisch. ex Link	용머리
Liliaceae	*Liriope platyphylla* F.T.Wang & T.Tang	맥문동
	Hemerocallis dumortierii Morr	각시원추리
	Hosta longisima Honda	산옥잠화
Lythraceae	*Lythrum anceps* Makino	부처꽃
Magnoliaceae	*Magnolia grandiflora* L.	태산목
Oxalidaceae	*Oxalis corniculata* L.	괭이밥
Polemoniaceae	*Phlox subulata* L.	지면패랭이
Plantaginaceae	*Plantago asiatica* L.	질경이
Ranunculaceae	*Aquilegia buergeriana* var. *oxysepala* (Trautv. & Meyer) Kitam	매발톱
Rosaceae	*Potentilla fragarioides* var. *major*	양지꽃
Saxifragaceae	*Aceriphyllum rossii*	돌단풍
	Saxifraga stolonifera Meerb	바위취

According to one report, tree plants cultivated in rooftop gardens in major cities of Korea are mainly *Rhododendron yedoense* var. *poukhanense* Nakai, *A. palmatum* Thunb, *C. kousa*, *Prunus mume* Sieb. et Zucc. and *Euonymus alatus* (Yoon et al. 2006). However, in this study, major tree plants in rooftop gardens of Busan and Jinju region are warm temperate zone plants, such as *Chamaecyparis obtusa*, *Castanopsis cuspidata* var. *sieboldii* Nakai, *Quercus myrsinaefolia* Bl., *Photinia glabra*, *Chionanthus retusa*, and *Camellia japonica*. Thus, tree species rarely cultivated in city rooftops were observed in our survey. In these city regions, trees favored by most Koreans, namely *P. densiflora*, *P. thunbergii* Parl., and *P. densiflora* for. *multicaulis*, are considered also as important species for use in forest plantations. This may reflect the fact that these trees have been popular for a long time as ornamental tree species (Yoon 1993). Our results revealed the preference of tree species that are currently being cultivated in rooftop gardens in Korea; we suggest this information may be utilized as baseline data for rooftop gardening monitoring and future studies. Doing so may improve fertilization and management practices, as well guiding pest management according to the characteristics of each tree plant species (which we believe will continue to be commonly planted).

Considering the herbaceous vegetation, other studies have shown that *S. kamtschaticum*, Sedum take *Sedum takevimense* NAKAI, *Sedum middendorffianum*, *Thymus quinquecostatus* var. japonica Hara, and *Aster spathulifolius* Maxim. are the plant species principally cultivated (Kim 2003),whereas after planting the following species are imported *Oxalis corniculata* L., *Erigeron canadensis* L., *Setaria viridis* (L.) P. Beauv, *Cyperus microiria*, Erigeron annuus (L.) Pers., *Elsholtzia splendens* Nakai, *Acalypha australis* L., *Arthraxon hispidus* Makino (Lee 2011). In this study *S. kamtschaticum*, *O. corniculata* L., and *S. middendorffianum* were cultivated: all three are recommended as herbaceous species suitable for rooftop garden use because they have a withering rate of almost 0% irrespective of

Table 3. Insect pests and plants damaged from the pests in rooftop gardens

Insect			Plants	Area								
Order	Family	Species		1	2	3	4	5	6	7	8	9
Homoptera	Pseudococcidae	*Crisicoccus pini*	*Pinus densiflora* for. *multicaulis*	+	+					+		
			Pinus densiflora	++	+	+	++	+		++		+
			Pinus parviflora									++
	Diaspididae	*Pseudaulacaspis prunicola*	*Prunus yedoensis*		++		+					
		Pseudaulacaspis cockerelli	*Taxus cuspidata*		+	++			+		+	
	Margarodidae	*Icerya purchasi*	*Sophora japonica*	+		+						
			Ginkgo biloba						++			
			Nandina domestica		+				++		+	+
			Prunus mume		+		+		++			
			Wisteria floribunda				+					
			Syringa vulgaris L.	++						+		
	Eriococcidae	*Eriococcus tokaedae*	*Cornus controversa*								+++	
	Aphrophoridae	*Aphrophora flavipes*	*Pinus densiflora*	+	+	++		+	+		++	
	Pemphigidae	*Colopha moriokaensis*	*Zelkova serrata*							+++	++	+++
	Flatidae	*Bothrogonia japonica*	*Zelkova serrata*								+	+
			Sophora faponica	+		++						
	Drepanosiphidae	*Tinocallis zelkowae*	*Zelkova serrata*							+		+
	Aphididae	*Lachnus tropicalis*	*Quercus myrsinaefolia*		++							
		Cinara pinidensiflorae	*Pinus densiflora*	+			+					
			Pinus densiflora for. *multicaulis*	+	+					+		
	Pseudococcidae	*Pseugococcus comstoki*	*Liriodendron tulipifera*						++			
			Cercis chinensis	++				+	++			
			Cronus kousa			++	+					++
		Dysmicoccus wistariae	*Sophora japonica*	+		+						
	Diaspididae	*Pseudaulacaspis pentagona*	*Ilex cornuta*							+		
		Pseudaulacaspis cockerelli	*Cornus officinalis*	+						+		++
		Unaspis pseudome	*Euonymus japonicus*	+	++					+++		
		Unaspis euonymi	*Taxus cuspidata*		+				+		+	
	Cicadidae	*Lecanium kunoensis*	*Quercus myrsinaefolia*		+							
		Ceroplastes ceriferus	*Lindera erythrocarpa*	++								
		Ericerus pela	*Ligustrum obtusifolium*		++				+		++	+
	Aphrophoridae	*Aphrophora flavipes*	*Pinus densiflora*	++	+			++		+		
	Pentatomidae	*Nezara antennata*	*Cornus controversa*								++	

Table 3. Continued

Insect			Plants	Area								
Order	Family	Species		1	2	3	4	5	6	7	8	9
Homoptera	Margarodidae	*Icerya purchasi*	*Sophora japonica*	+		+						
			Ginkgo biloba						+			
			Nandina domestica		+					++		+
			Prunus mume		+		+		+++			
			Wisteria floribunda				+					
			Syringa vulgaris L.	+						++		
	Eriococcidae	*Eriococcus lagerstroemiae*	*Ligustrum*		+				+		+	+
			Lagerstroemia indica	++		++		+		+		+
			Cornus controversa								++	
			Chaenomeles sinensis									
			Lindera erythrocarpa	+								
Coleoptera	Chrysomelidae	*Argopistes biplagiatus*	*Hibiscus syriacus*							+		
		Plagiodera versicolora	*Cornus controversa*								+	
	Curculionidae	*Shirahoshizo insidiosus*	*Pinus densiflora*	++	+	+	+			+	+	+
Diptera	Cecidomyiidae	*Masakimyia pustulae*	*Euonymus japonicus*	+++	+++					+	++	
		Thecodiplosis japonensis	*Pinus densiflora* for. *multicaulis*	++	+	+			++	++		+
			Pinus densiflora	++	+	++	+		++	++	++	++
Lepidoptera	Nymphalidae	*Hestina assimilis*	*Cornus kousa*			+++	++					++
	Lyonetiidae	*Lyonetia prunifoliella*	*Zelkova serrata*							+	+	
	Sesiidae	*Synanthedon hector*	*Prunus mume*		+++		++		+			
	Psychidae	*Eumeta minuscula*	*Ginkgo biloba*						++			
	Limacodidae	*Monema flavescens*	*Cornus officinalis*	+						+		+
	Pyralidae	*Glyphodes perspectalis*	*Buxus microphylla*				+++			+++	++++	++
	Limacodidae	*Microleon longipalpis*	*Cornus controversa*								+	

Table 3. Continued

Insect			Plants	Area								
Order	Family	Species		1	2	3	4	5	6	7	8	9
Order Acarina	Tetranychidae	*Oligonychus ununguis*	*Euonymus japonicus*	++							++	
			Pinus densiflora for. *multicaulis*	++	++					+++	++	
			Chamaecyparis obtusa	++						++		
			Pinus densiflora	+++++++	+	++++	++	++	++	++	++	++
			Pinus parviflora									++
			Pinus thunbergii			++++	+			+++		+++
			Juniperus chinensis	+++			+	++	+	++	+++	
Balaustium mutotum	Tetranychidae	*Tetranychus viennensis*	*Prunus mume*		+		+++		+			
		Tetranychus urticae	*Prunus mume*		++		+		+			
			Cornus kousa		+	+						+
			Wisteria floribunda				++					
		Eriophyes sp.	*Juniperus chinensis*	+				++				

soil type (Kim et al. 2003). Also observed were *O. corniculata* L., *E. canadensis* L., *Cyperus amuricus*, and *E. splendens* Nakai species, which likely were imported to our two study regions by wind or tidal currents (Table 2).

Damage by tree pests

As a result of an investigation of insect pests that may harm woody plants within the investigated regions, we found a total of six orders, 24 families, and 46 species represented: 39, 21, and 15 species of pests damaged the leaves, branches, and stems, respectively. Among these pests, Homoptera were the most diverse, with 12 families and 28 species represented, with the damage observed mainly from coccids and aphids, which are sucking-insect types. Damage by *Crisicoccus pini* was observed in conifers *P. densiflora*, and *P. densiflora* for. *multicaulis, Pinus parviflora*. The aphids *Myzus persicae, Acyrthosiphon magnoliae*, *Aphis nerii*, and *Spiraea aphid* were found in broad-leaved trees *Prunus serrulata* var. *spontanea, P. mume* Sieb. et Zucc, and *A. palmatum*. In the Jinju region *Paracolopha morrisoni* was found; its degree of damage most severe in broad-leaved trees such as *Zelkova serrata, P. serrulata* var. *spontanea*. Most of the observed damage was caused by insects of Homoptera, however, followed by Coleoptera, Diptera, and Lepidoptera, in that order, and least by arachnids (Acarina). The damage was mildly identified at preferred seasons.

These results agree well with reports that damage by aphids and coccids largely occurs in collectivized plantings made within relatively poor environments; for example, as found in the study on pests that harm landscape tree plants in the Gyeongsangnam-do Arboretum (Lee 2006). In a study finding that an aphid type of Homoptera mainly occurs at the early stage of tree growth (Yang et al. 2008), the population number of these sucking-insects rapidly grew from the point where shoot generation began. Therefore, studies on physiological ecology and mechanism of these pests should be performed for the plants affected in rooftop gardens, together with active research on measures to prevent pest breeding and to facilitate pest extermination in rooftop gardens. In this context, we anticipate that the results of the present study will establish baseline data for the selection of plants and pest control in rooftop gardens.

On a seasonal basis, Lepidoptera and Acarina appeared

most often in summer, when damage by *Pseudococcus comstocki* (Hemiptera) was found on *Liriodendron tulipifera, Cercis chinensis*, and *C. kousa*, as well as on evergreen broad-leaved trees such as *Euonymus japonicus* Thunb. and *Taxus cuspidata*. *Glyphodes perspectalis* of Lepidoptera occurred severely in *Buxus microphylla*, and *Tetranychus urticae* and *Oligonychus perditus* of Acarina damaged conifers such as *J. chinensis* and the pine trees too. *Shiraboshizo insidiosus*, a perforating-type pest of Coleoptera, and *Thecodiplosis japonensis*, a gall formation-type pest, were both detected in *P. densiflora* and *P. densiflora* for. *multicaulis*. In the summer, pest occurrence differed from spring, which is when Homoptera insects prevail because the air temperature is relatively cool. As shown in are port that moth pests occur in tree plants in the middle period of their growth cycle and continue late into the growing season(Yang et al. 2008), here too, in the present study, damage by Lepidoptera and perforating-type pests were detected in summer and autumn when temperatures are relatively higher.

The pests detected from plants cultivated in rooftop gardens were active in the period of April to October. However, the damage they caused was especially concentrated between June and September. Nonetheless, some evergreen trees, such as *P. densiflora, P. thunbergii, J. chinensis, P. parviflora*, and *Chamaecyparis obtuse* suffered from *Oligonychus ununguis* annually, and *Celtis sinensis, Ligustrum obtusifolium, Magnolia kobus, A. palmatum, T. cuspidata* S. et Z, *Cornus controversa, Diospyros kaki, Cornus officinalis* S. et Z, and *P. serrulata* var. *spontanea-were* damaged by *Quisqualis indica*. Our results indicate that the type of pest injuring the plants differed both by season and by taxonomic order; hence, as the degree of damage in rooftop gardens was greater than generally found in other green areas, a precise forecast, diagnosis, and pest control strategy tailored to each season is required for effective management. For improved pest control, a selection of methods through sound diagnosis of symptoms and indications of disease is very important. Fortunately, the prediction and diagnosis of symptoms may be efficiently carried out by a careful monitoring of leaves and stems for any color changes, partial deaths, withering or hypertrophy from an unknown cause, leaf drop-outs or leaf blight, stem blight, secretion or decomposition. Prevention of pest attacks and their control for plants cultivated in rooftop gardens should depend on the results from these suggested diagnoses. Following this crucial step, appropriate physical or chemical applications, the pest control period and the frequency of interventions, should be selected accordingly before fully implementing any pest control program. For this reason a continuous follow-up study to ours should be performed (Table 3).

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