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The Occurrence of Extrafloral Nectaries in Korean Plants

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韓国植物의 花外蜜腺分布

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ABSTRACT

Extrafloral nectaries have been shown in many studies to promote mutualistic interactions between plants and insects(usually ants) that visit the glands. The insects gain sugars, water and amino acids secreted by the extrafloral nectaries and benefit the plants by reducing the damage caused by the plant's insect herbivores. Little is known about the occurrence of extrafloral nectaries in plants growing in Asia. To learn about the occurrence of extrafloral nectary bearing plants in Korea, living plants and herbarium material were examined for the glands. In addition, the cover of plants with extrafloral nectaries and the proportion of woody plants with extrafloral nectaries were measured in three forest communities on Kangwha Island.

131 species of plants belonging to 53 genera and 30 families were found to have extrafloral nectaries. These 131 species comprise about 4.0% of Korea's flora, a higher percentage of extrafloral nectary bearing plants than occurs in the studied areas of North America. Extrafloral nectary bearing plants occupied 7, 23 and 55% of the covers and comprised 15, 21 and 15% of the woody plants in the three different forests, a significant level of occurrence.

Many important Korean crop plants were found to have extrafloral nectaries including : sesame(***Sesamum indicum*** L.), squash (***Cucurbita moschata*** Duchesne), sweet potato (***Ipomoea batatas*** Lam.), persimmon (***Diospyros kaki*** Thunb.) cotton (***Gossypium indicum*** Lam.), mung bean (***Phaseolus radiatus*** L.), red bean (***Phaseolus angularis*** W.F.), peach (***Prunus persica*** (L.) Batsch.), plum (***Prunus salicina*** Lindl.). Many of these cultivated and wild plants may receive protection by ants and other beneficial insects that visit their extrafloral nectaries.

INTRODUCTION

Extrafloral nectaries are secretory glands of plants, usually found on the vegetative parts but also on the external surfaces of flowers and fruits(Bentley, 1977a). Instead of attracting pollinators, the glands promote mutualistic interactions between plants and insect predators and parasites(usually ants) that visit the glands. The insects feed on the sugars, water, and amino acids secreted by the glands(Baker *et al.*, 1978) and benefit the plants by reducing the damage caused by the plants' insect herbivores(Bentley, 1977a ; Beattie, 1985). Ants associated with extrafloral nectaries have been shown to protect plant leaves(Janzen, 1966 ; Tilman, 1978), shoots(O'Dowd in Beattie, 1985), flowers(Elias and Gelband, 1975 ; Keeler, 1980) and fruits(Bentley, 1977b ; Horvitz and Schemske, 1984). Decreased leaf damage by beneficial insect-extrafloral nectary defenses has been shown to increase seed set(Stephenson, 1982 ; Koptur, 1979).

Extrafloral nectary relations with ants and other beneficial insects are almost always facultative, not obligatory, mutualisms. The plant's insect protectors, as well as the plant's insect attackers, vary both in space and time. Some species are better protectors than others by virtue of constancy, effectiveness or both. Because of this variation and the occasional interference by third party insects(particularly Homoptera that are also protected by ants), extrafloral nectary defenses are not always effective(Bukley, 1983 ; O'Dowd and Catchpole, 1983). Some plants bearing extrafloral nectaries are successfully protected in some parts of their range, but less so or not at all in other parts(Koptur, 1985 ; Barton, 1986 ; Koptur and Lawton, 1988).

Nevertheless, the majority of experimental studies have shown that the plants with extrafloral nectaries gain protection from insect visitors to the nectaries. Extrafloral nectary defenses also have the advantage of being effective against both specialist and generalist insect herbivores, which is usually not the case for specific chemical defenses(Beattie, 1985).

Extrafloral nectaries are known from plants belonging to 68 families of angiosperms and a few ferns(Elias, 1983). Plants with extrafloral nectaries occur in most areas of the world (Delpino, 1886 ; Zimmermann, 1932 ; Schnell *et al.*, 1963 ; Buckley, 1982), and in diverse habitats including : temperate and tropical forests(Bentley, 1976 ; Inouye and Taylor, 1979 ; Keeler, 1979b), grasslands(Keeler, 1979a) and deserts(Pemberton, 1988).

Very little is known about the occurrence or ecology of extrafloral nectary-bearing plants in Asia. Ono(1907) described extrafloral nectaries from many plants in Japan, some of which also grow in Korea. This study was undertaken to document the occurrence of plants with extrafloral nectaries in Korea.

METHODS

Living plants were examined for extrafloral nectary presence and activity from the first bud break in early March 1989 and 1990 through the growing seasons and autumn until the end of October in 1989 and early November in 1990, when most plants had lost their leaves. The Forest Research Institute Arboretum in Seoul was the primary source of the examined plants. In addition, observations were made in other places in Seoul, Kangwha Is., Suwon, Yangsuri, Mt. Soyo, Ipam(Chollabukdo), Chòllipo Arboretum, and on Cheju Is., at the Forestry Administration Arboretum and in forests at sea level and ca. 600m elevations. The search for extrafloral nectary plants was guided by a knowledge of foreign relatives of Korean plants that have extrafloral nectaries, based on both the literature (primarily Delpino, 1886 ; Ono, 1907 ; Zimmermann, 1932 ; Bentley, 1977a ; Keeler, 1979b ; Elias, 1983), and my unpublished observations in North America.

When glands were found, their location on the plant and whether secretion was occurring was noted. Secretion was usually detectable by the unaided eye or a 10X handlens.. Nectar from active glands was not always detectable because of evaporation, the washing action of rain and probably its removal by insects. The foliage of some plants which had extrafloral nectaries that appeared active(not darkened or shriveled), but with no secretion, were enclosed overnight in plastic bags, which often caused detectable secretion to occur. The presence of sugar was indicated by insects feeding on the gland exudate, the presence of sooty mold fungi(Capnodiaceae) on and around the glands, and glucose tests. Sooty molds grow on sugar secretions but not on resins(La, Yong Joon, personal communication), which can be secreted from extrafloral nectary-like glands in some plants.

Glandular secretions were tested for the presence of glucose with Clinistix glucose reagent strips for urinalysis(Miles Lab. Inc., Elkhart, Indiana, USA). The pink color test strip turns purple with concentrations of glucose above 0.1%. Some very small glands, including the 0.2mm glands on the underside of ***Callicarpa japonica*** Thunb., were tested under a dissecting microscope. Small amounts of nectar were easier to test when the reagent strip was premoistened with distilled water. More effort was spent in attempting to get evidence of sugar secretion in ***Populus*** and ***Rosa*** species, since some members of these genera secrete resins from their extrafloral nectary-like glands.

In addition to living plants, specimens of species related to previously confirmed extrafloral nectary bearing plants were examined for extrafloral nectaries at the Seoul National University Herbaria at Suwon and Kwanak, and at the Forest Research Institute Herbaria in Seoul. This approach was feasible because extrafloral nectaries often occur in similar forms and locations on related species, particularly in members of the same genera. Herbarium specimens of ***Rosa*** and ***Salix*** species were not examined because of the uncertainty in identifying their glands as either extrafloral nectaries or resin glands in dried material.

To obtain an indication of community level presence of extrafloral nectary bearing plants, the linear covers of extrafloral nectary species was measured at three different forest sites, of approximately 3000m^2, on Kangwha Is. The linear cover measurement was the percentage of a 200 meter randomly selected transect at each site occupied by extrafloral nectary-bearing plants. In addition, the proportion of woody plant species with extrafloral nectaries in each forest was calculated.

RESULTS AND DISCUSSION

One hundred thirty one species belonging to 53 genera and 30 families were found to have extrafloral nectaries(Table 1). An estimated 100 of these are native to Korea, the others being introduced primarily for agriculture and horticulture. Only seven plants were not angiosperm dicotyledons ; bracken fern(***Pteridium aquilinum*** L.), a grass(***Eragrostis cilianensis***(All.) Lotati), three ***Dioscorea*** species, one lily(***Hemerocallis middendorfii*** Trautv. et Meyer and one iris(***Iris pallassii*** Fisch.). Ninety four of the species are woody shrubs and trees. Most of the others, particularly the native species, are perennial plants.

Twenty one genera had more than one species with extrafloral nectaries. Extrafloral nectaries were found on all of the species of some middle sized and large genera(25 ***Prunus*** species, nine ***Ligustrum*** species, six ***Syringa*** species, and five ***Zanthoxylum*** species), illustrating the tendency of extrafloral nectaries to occur in related species. Eleven ***Populus*** species and hybrids were found to have extrafloral nectaries. Only ***Populus koreana*** Rehder, which had copious secretion of yellow resin from marginal leaf glands, lacked extrafloral nectaries.

The number of important economic plants bearing extrafloral nectaries was found to be quite high. Most of these have been known to have extrafloral nectaries, but the majority are unstudied and none are well studied. Some of the more prominent food plants include : oriental plum(***Prunus salicina*** Lindl.), cherry(***P. avium*** L.), peach(***Prunus persica***(L.) Batch), sweet potato(***Ipomoea batatas*** Lam.), sunflower(***Helianthus annuus*** L.), persimmon (***Diospros kaki*** Thunb.), squash(***Cucurbita moschata*** Duchesne), adzuki bean(***Phaseolus angularis*** W.F. Wight), mung bean(***P. radiatus*** L.) and sesame seed(***Sesamum indicum*** L.).

Other economically important plants include : cotton(***Gossypium indicum*** Lam.), ***Palownia*** species, ***Populus*** species, flowering plums and cherries(***Prunus*** species), privet (***Ligustrum*** species), lilac(***Syringa*** species), pomegranate(***Punica granatum*** L.), and the national flower -***mugungwha***(***Hibiscus syriacus*** L.)

The extrafloral nectaries of most species were found on the vegetative parts of the plants, with leaf-blades and petioles being the most common sites. Extrafloral nectaries were also found on midveins on the bottom sides of leaf blades(***Gossipium***, ***Hibiscus***), stipules(***Doliochos***, ***Prunus***, ***Robinia***, ***Sambucus***, ***Vicia***, ***Vigna***), flower phyllaries and bracts

Table 1. Korean plants with extrafloral nectaries

Family Species	Plant source	Date	Extrafloral nectary site	Secretion observed	Sugar indicator
Pteridaceae					
Pteridium aquilinum L.	Cheju Is.	4.V.89	rachis-stem junction	+	glucose +, ants
Graminae					
Eragrostis cilianensis (All.) Lotati	SNU 1 herbarium	-	leaf sheath, culm		
Liliaceae					
Hemerocallis middendorfii Trautv. et. Meyer	Seoul	13.VII.90	flower bud abaxial surface	+	glucose +, ants
Dioscoreaceae					
Dioscorea bulbifera L.	Yongsuri	29.VII.89	leaf-blade underside		
Dioscocea japonica Thunb.	Seoul	12.VII.90	leaf-blade underside	+	glucose +
Dioscorea quinqueloba Thunb.	Mt. Soyo	17.V.89	leaf-blade underside	+	
Dioscorea tokoro Makino	Seoul	19.V.89	leaf-blade underside	+	glucose +
Iridaceae					
Iris pallassii Fisch.	Seoul	7.V.90	petal base abaxial surface	+	glucose +, ants
Salicaceae					
Populus alba L.	Seoul	27.IV.90	petiole-blade junction	+	glucose +
Populus davidiana Dode	Seoul	27.IV.90	petiole-blade junction	+	glucose +, sooty mold
Populus deltoides Marsh.	Seoul	9.VIII.89	petiole-blade junction		
Populus euramericana Guinier	Seoul	26.IV.90	peticle-blade junction	+	glucose +, ants
Populus glandulosa Seem.	Seoul	27.IV.90	petiole-blade junction	+	glucose +, sooty mold
Populus maximowiczii Henry	Seoul	29.IX.89	leaf-blade base	+	glucose +
Populus nigra (Muench.) Koehne	Seoul	22.IX.89	leaf-blade base	+	glucose +
Populus sieboldii Miq.	Seoul	19.V.89	petiloe-blade junction	+	glucose +, ants, wasps
Populus simonii Carr.	Seoul	22.IX.89	leaf-blade bese	+	glucose +
Populus tomentiglandulosa T. Lee	Seoul	27.IV.90	petiole-blade junction	+	glucose +, sooty mold
Populus X-albaglandulosa	Seoul	27.IV.90	leaf-blade base	+	glucose +, ants, Coccinellids

Table 1. Continued

Family Species	Plant source	Date	Extrafloral nectary site	Secretion observed	Sugar indicator
Polygonaceae					
Bilderdykia (*Polygonum*) *dentato-alata* Nakai	SNU 1 herbarium	-	petiole near stem		
Bilderdykia (*Polygonum*) *dumetora* (L.) Dum.	Seoul	12.VII.90	petiole near stem	+	glucose +
Pleuropterus (*Polygonum*) *cilinervis* Nakai	SNU 1 herbarium	-	petiole-stem junction		
Pleuropterus (*Polygonum*) *multiflorus* Turcz.	SNU 1 herbarium	–	petiole-stem junction		
Reynoutria elliptica (Koidz.) Migo	Seoul	19.IV.89	Petiole-stem junction	+	glucose + ants
Reynoutria sachalinensis (Fr. Schm.) Nakai	SNU 1 herbarium	–	Petide-stem junction		sooty mold
Ranunculaceae					
Paeonia japonica Miyabe et Takeda	Chollipo	5.V.90	sepal abaxial surface	+	glucose +, sooty mold
Rosaceae					
Prunus armeniaca Max.	Seoul	19.IV.89	petiole	+	glucose +
Prunus avium L.	Seoul	27.IV.89	petiole	+	glucose +
Prunus buergeriana Miq.	Cheju Is.	5.V.89	blade base		
Prunus cerasifera Ehrh.	Seoul	19.IV.89	blade base, stipules	+	glucose +
Prunus davidiana Fr.	SNU 1 herbarium	–	blade base		
Prunus donarium Sieb.	Seoul	19.IV.89	petiole	+	glucose +
Prunus glandulosa Thunb.	Seoul	24.IV.90	blade base	+	glucose +
Prunus ishidoyana	Seoul	5.III.89	blade base	−	glucose +
Prunus japonica (Lev.) Rehder	Seoul	19.IV.89	blade base	+	glucose +
Prunus leveilleana Koehne	Kangwha Is.		petiole, blade base	+	wasps
Prunus maackii Rupr.	SNU 1 herbarium	–	blade base		
Prunus mandshurica Nakai	Seoul	19.IV.89	petiole, blade base	+	glucose +
Prunus maximowiczii Rupr.	Cheju Is.	5.V.89	blade base		
Prunus mume S.et Z.	Seoul	7.IV.89	blade base	+	glucose +
Prunus padus L.	Seoul	22.III.89	petiole	+	glucose + ants, coccinellids
Prunus pendula (Mak.) Ohwi	Cheju Is.	4.V.89	blade base		
Prunus persica (L.) Batsch	Seoul	26.IV.90	petiole, blade base	−	glucose +
Prunus salicina Lindl.	Seoul	11.IV.89	blade base	+	glucose +
Prunus sargentii Rehder	Seoul	2.V.89	petiole	+	glucose +

Table 1. Continued

Family Species	Plant source	Date	Extrafloral nectary site	Secretion observed	Sugar indicator
					ants
Prunus serrulata (Max.) Wils.	Seoul	2.V.89	petiole	+	glucose + ants
Prunus sibirica L.	SNU 1 herbarium	–	petiole, blade base	+	
Prunus takesimensis Nakai	Seoul	11.IV.89	petiole, blade base, stipules	+	glucose +
Prunus tomentosa Thunb.	Seoul	24.IV.90	blade base	+	glucose +
Prunus triloba Kom.	Chollipo	5.V.90	blade-base junction	+	glucose +
Prunus yedoensis Matsumura	Seoul	11.IV.89	petiole, blade base	+	glucose +
Rosa chinensis Jacq.	Seoul	29.IX.89	stipules, petiole	+	glucose +
Rosa multiflora Thunb	Seoul	22.III.90	bract margin	+	glucose +
Leguminosae					
Albizzia julibrissin Durazz.	Seoul	5.V.89	petiole	+	glucose +, ants
Albizzia coreana Nakai	Seoul	13.VII.90	petiole, rachis	+	glucose +, ants
Caesalipinia japonica S.et. Z.	SNU 1 herbarium	–	rachis		
Cassia mimosoides Makino	Yangsuri	29.VII.89	petiole, rachis	+	glucose +
Cassia tora L.	Namhan-sansong	1. .90.	rachis	+	glucose +
Dolichos lablab L.	Kangwha Is.	6.X.89	stipules	+	glucose +
Phaseolus (*Azukia*) *angularis* W.F.Wight	Chowol Is.	26.VIII.89	peduncle	+	
Phaseolus (*Azukia*) *calcaratus* Roxb.	Mt.Songni	4.X.89	peduncle	+	
Phaseolus multiflorus Wild.	Kangwha	20.IX.89	peduncle	+	glucose +, sooty mold
Phaseolus (*Azukia*) *nipponensis* Ohwi	Mt.Sorak	16.VIII.89	peduncle	+	glucose +, ants
Phaseolus (*Azukia*) *radiatus* L.	Kangwha Is.	20.IX.89	peduncle	+	glucose +, ants, coccinellids
Robinia pseudoacacia L.	Seoul	7.V.89	stipules	+	glucose +
Vicia angustifolia K.Koch.	Cheju Is.	4.V.89	stipules	+	glucose + ants
Vigna sinensis King	Kangwha Is.	6.X.89	peduncle, stipules	+	glucose +

Table 1. Continued

Family Species	Plant source	Date	Extrafloral nectary site	Secretion observed	Sugar indicator
Rutaceae					
Zanthoxylum ailanthoides S.et.Z.	Chollipo	5.V.90	leaf-blade underside	+	glucose +, sooty mold
Zanthoxylum coreanum Nakai	Seoul	19.V.89	leaf-blade underside	+	glucose +
Zanthoxylum schinifolium S.et.Z.	Seoul	19.V.89	leaf-blade underside	+	glucose +
Zanthoxylum piperitum A.P.	Mt.Soyo	17.V.89	leaf-blade underside	+	glucose +
Zanthoxylum planispinum S.et.Z.	Seoul	20.VII.90	leaf-blade underside	+	glucose +
Simaroubaceae					
Ailanthus altissima Swingle	Seoul	19.IV.89	leaf teeth, bud scales	+	glucose +, sooty mold, ants, wasps
Euphorbiaceae					
Aleurites fordii Hemsl.	Cheju Is.	5.V.89	petiole	+	
Mallotus japonicus Muell. -Arg.	Cheju Is.	4.V.89	leaf-blade top	+	ants
Ricinus communis L.	Seoul	22.IV.89	petiole, peduncle	+	glucose +, ants
Sapium japonicum Pax et Hoffm.	Cheju Is.	5.V.89	blade base	+	glucose +
Sapium sebiferum (L.) Roxb.	SNU 1 herbarium	–	Petiole-blade junction		
Balsaminaceae					
Impatiens balsamina L.	Seoul	29.VII.89	blade base	+	glucose +, ants
Tiliaceae					
Grewia biloba (Bunge) Hand. -Maz.	Chollipo	6.V.90	basal leaf teeth	+	glucose +
Malvaceae					
Gossypium indicum Lam.	Suwon	4.VIII.89	midvein on leaf underside	+	
Hibiscus syriacus L.	Seoul	25.VII.89	midvein on leaf underside	+	glucose +, sooty mold
Flacourtiaceae					
Idesia polycarpa Max.	Cheju Is.	5.V.89	petiole	+	glucose +
Passifloraceae					
Passiflora coerulea L.	Chollipo glasshouse	15.I.90	petiole, leaf margin	+	glucose +
Punicaceae					
Punica granatum L.	SNU 2 herbarium	–	leaf-blade tip		
Ericaceae					

Table 1. Continued

Family Species	Plant source	Date	Extrafloral nectary site	Secretion observed	Sugar indicator
Vaccinium koreanum Nakai	Seoul	9.V.89	basal leaf teeth	+	glucose +
Vaccinium oldhami Miq.	SNU 1 herbarium	–	basal leaf teeth		sooty mold
Ebenaceae					
Diospyros kaki Thunb.	Seoul	9.V.89	leaf-blade underside	+	glucose +
Diospyros lotus L.	Kangwha Is.	26.IV.90	leaf-blade underside	+	glucose +, ants
Oleaceae					
Ligustrum acutissimum Koehne	SNU 1 herbarium	–	leaf-blade underside		sooty mold
Ligustrum foliosum Nakia	Seoul	2.V.89	leaf-blade underside	+	glucose +
Ligustrum ibota S.et.Z.	Seoul	5.IV.89	leaf-blade underside	+	glucose +
Ligustrum japonicum Thunb.	Cheju Is.	5.V.89	leaf-blade underside	+	glucose +, sooty mold
Ligustrum lucidum Ait.	Cheju Is.	5.V.89	leaf-blade underside		
Ligustrum obtusifolium S.et.Z.	Seoul	2.V.89	leaf-blade underside	+	glucose +, sooty mold
Ligustrum ovalifolium Hassk.	Cheju Is.	4.V.89	leaf-blade underside	+	glucose +
Ligustrum quihoui Nakai	FRI 3 herbarium		leaf-blade underside		
Ligustrum salicinum Nakai	Seoul	2.V.89	leaf-blade underside	+	glucose +
Osmanthus heterophylla P.S.Green	Chollipo	5.V.90	leaf-blade underside	+	glucose +
Syringa amurensis Rupr.	Seoul	9.V.89	petiole-blade wing	+	glucose +
Syringa dilatata Nakai	Seoul	9.V.89	petiole-blade wing	+	glucose +
Syringa palibiniana	Seoul	2.V.89	petiole-blade wing	+	glucose +
Syringa reticulata (Max). Hara	Seoul	2.V.89	petiole-blade wing	+	glucose +, wasps
Syringa velutina Kom.	Seoul	2.V.89	petiole-blade wing	+	glucose +
Syringa wolfi Schneid.	Seoul	2.V.89	petiole-blade wing	+	glucose +
Convolulaceae					
Ipomoea batatas Lam.	Kangwha Is.	20.IX.89	petiole	+	glucose +

Table 1. Continued

Family Species	Plant source	Date	Extrafloral nectary site	Secretion observed	Sugar indicator
Pharbitis (Ipomoea) nil Chois.	Seoul	2.VIII.89	petiole	+	glucose +, ants
Verbenaceae					
Callicarpa dichotoma Raeusch.	Seoul	22.IX.89	leaf-blade underside		
Callicarpa japonica Thunb.	Seoul	9.V.89	leaf-blade underside	+	glucose +
Callicarpa mollis S.et.Z.	Seoul	27.IX.90	leaf-blade underside	+	glucose +
Clerodendron trichotomum Thunb.	Cheju Is.	4.V.89	leaf-blade underside	+	glucose +, ants
Scrophulariaceae					
Paulownia coreana Uyeki	Seoul	19.V.89	leaf-blade top and underside		
Paulownia tomentosa (Thunb.)	Seoul	3.V.89	leaf-blade top, underside, calyx	+	glucose +
Bignoniaceae					
Catalpa bignonioides Walter	SNU 2 herbarium	–	leaf-blade underside	+	
Catalpa ovata G.Don	Seoul	9.V.89	leaf-blade underside	+	glucose +, ants
Catalpa speciosa Warder	Seoul	7.IX.89	leaf-blade underside		
Pedalidaceae					
Sesamum indicum L.	Ipam Chollabukdo	27.VII.90	peduncle	+	glucose +, ants, sooty mold
Caprifoliaceae					
Sambucus sieboldiana Bl.	Seoul	22.III.89	stipules	+	glucose +
Sambucus williamsii Nakai	Seoul	22.III.89	stipules	+	glucose +
Sambucus latipinna Nakai	Seoul	22.III.89	stipules	+	glucose +
Viburnum dilatatum Thunb.	Cheju Is.	4.V.89	leaf-blade underside	+	glucose +
Viburnum erosum Thunb.	Seoul	19.IV.89	leaf-blade underside	+	glucose +
Viburnum koreanum Nakai	SNU 1 herbarium	–	petiole-blade junction,, stipules		sooty mold
Viburnum sargentii Koehne	Seoul	11.IV.89	petiole, bud bracts, leaftips	+	glucose +, ants, wasps
Viburnum wrightii Miq.	Seoul	19.IV.89	leaf-blade underside	+	glucose +
Cucurbitaceae					

Table 1. Continued

Family Species	Plant source	Date	Extrafloral nectary site	Secretion observed	Sugar indicator
Cucurbita moschata Duchesne	Yangsuri	29.VIII.89	leaf-blade underside	+	glucose +
Lagenaria leucantha Rusby	Suwon	4.VIII.89	Petiole-blade junction	+	glucose +
Lufa cylindrica Roem.	Seoul	10.IX.89	leaf-blade underside, calyx	+	ants
Momoridica charantia L.	Seoul	10.IX.89	leaf-blade underside, peduncle bract		
Trichosanthes kirilowii Max.	Yangsuri	29.VII.89	leaf-blade underside	+	glucose +, ants
Compositae					
Helianthus annuus L.	Seoul	1.VIII.89	flowerhead phyllaries, bracts	+	glucose +, Coccinellids

The nomenclature follows Lee(1979) with minor exceptions.

1. SNU = Seoul National Univ., Dept. of Forestry, Suwon
2. SNU = Seoul National Univ., Dept. of Botany, Kwanak
3. FRI = Forestry Research Institute, Seoul
4. *Campsis grandiflora* is a well-known extrafloral nectary bearing plant(Elias and Gelband 1975) that is grown in Korea(Lee, 1979).

(***Helianthus***), abaxial surfaces of sepals or calyxes(***Hemerocallis***, ***Luffa***, ***Paeonia***), abaxial bases of flowers(***Iris***), flower peduncles(***Phaseolus***, ***Ricinus***, ***Sesamum***, ***Vigna***), and bud scales(***Ailanthus***, ***Viburnum***). The size of the glands ranged from the 3mm diameter glands of ***Reynoutria*** to the tiny(0.2mm) glands of ***Callicarpa japonica***.

Secretion was observed in 105 of the 115(91.3%) species that were seen in life. Secretion almost certainly occurred in the other species but was not seen because the observations were made during rainy periods(some of the Cheju Is. species), after secretion had stopped, or because it had evaporated or been removed by insects. Evidence of sugar secretion was obtained for 104 species. Species belonging to 49 genera were observed in life and evidence for sugar secretion was noted in species belonging to 46 genera. The glucose test was done on 102 species, of which 97 were positive. Five other species (***Chaenomeles sinensis*** Koehne, ***Crataegus maximowiczii*** Schneid., ***Rosa davurica*** Pall., ***R. rugosa*** Thunb. and ***Salix glandulosa*** Seem), which tested negatively, were probably secreting resin, so are not included on the list. Secretions from ***Rosa multiflorus*** Thunb. and ***R. chinensis*** Jacq. produced both positive and negative glucose tests, indicating that glucose and other materials, probably resins, are present in the exudate. Keeler(1979a) included ***R. multiflorus*** in a list of Nebraska(USA) plants with extrafloral nectaries. In this study,

Pteridium aquilium was noted to have active glands with secretion on Kangwha Is. plants but not in plants growing in Seoul. Variation in the occurrence of extrafloral nectaries was also seen in ***Hemerocallis middendorfii*** plantings in Seoul and in ***Sesamum indicum*** plants at Yangsuri.

Beneficial insects were found feeding on the extrafloral nectary secretions of 31 species, with ants(Formicidae) on 27, parasitic wasps(Ichneumonidae, Braconidae and various Chalcidoidea) of five, and predatory lady beetles(Coccinellidae) on four species. The low number of insects noted feeding on extrafloral nectaries is not indicative of insect-extrafloral nectary relations in Korea. It resulted from the small amount of time spent at each extrafloral nectary plant, the relatively low numbers of insects at the Forest Research Institute Arboretum in Seoul(where most plants were examined) and the rainy weather in which many observations were made. In clear weather, at locations away from Seoul, insects were easily seen feeding at secreting nectaries. Especially large numbers of ants, lady beetles, wasps and parasitic tachinid flies were seen at the nectaries of some ***Populus*** species. Ants were frequently present in large numbers on ***Phaseolus*** species. Sooty molds, which were inconsistently noted, were recorded on 15 species, including species seen as herbarium specimens.

Of the nine genera for which no evidence of sugar was noted, all have species reported to have extrafloral nectaries : ***Caesalpinia***, ***Gossypium***, ***Momoridica***, (Delpino, 1886) : ***Aleurites***, ***Idesia***, ***Pleuropterus***, (Ono, 1907) : ***Eragrotis***, (Zimmermann, 1932) : and ***Punica*** (Turner and Lersten, 1981).

Secretion from extrafloral nectaries located on vegetative organs was usually associated with new growth and frequently ceased shortly after full maturation of foliage. Secretion from the foliar nectaries of ***Ligustrum*** and ***Syringa*** species usually did not begin until several weeks after the leaves had matured. Secretion from old leaves in autumn was seen in ***Viburnum wrightii*** Mig., ***V. erosum*** Thunb., and ***Ailanthus altissima*** Swingle. The earliest secretion noted during the 1989 and 1990 seasons in Seoul, occurred in ***Sambucus williamsii*** Nakai on 5 and 7 March from stipular glands emerging with new leaves from buds. The last secretion in 1989 was observed on 26 October from the sucker growth of a ***Prunus sargentii*** Rehder, that had already shed its crown leaves. In 1990, the last secretion was seen on 10 November from the leaves of ***A. altissima*** samplings. The most active period for most plants was in April and May. Korea's rainy summer promotes new growth and thus new extrafloral nectaries in many plants over a long season. These plants can have long, almost continuous, periods of secretion or else periodic pulses of secretion from glands on periodically produced leaves. Some early and late secretion dates in Seoul were : 9 May and 28 September for ***Syringa dilatata*** Nakai, 9 May and 22 September for ***Vacinium koreanum*** Nakai, and 2 May and 26 October for ***Prunus sargentii***. ***Populus sieboldii*** Miq. trees growing on Kangwha Is. were observed to secrete from 26 April to 6 October.

The abundance of extrafloral nectary bearing plants was different in each of the three forest sites. At Kumwoli, a mixed ***Quercus*** species and ***Robinia pseudoacacia*** L. dominated forest, 4 of its 26(15%) woody plant species had extrafloral nectaries. These plants made up 7.5% of the measured plant cover. At Kwangsongbo, a mixed hardwood forest, 8 of the 38(21%) woody plants bore extrafloral nectaries and these comprised 23% of the cover. Yongnaeri, which is dominated by ***Populus sieboldii*** and ***Robinia pseudoacacia***, had 5 of its 33 (15%) woody plants with extrafloral nectaries. Extrafloral nectary plants at this site occupied 55% of the cover, which was not surprising since both of the dominant trees have the glands.

The 55% extrafloral nectary-plant cover at Yongnaeri is very high and comparable to levels(40~80%) measured in three dry tropical forests in Costa Rica(Bentley, 1976). But this forest is not very natural, since ***R. pseudoacacia*** is introduced and ***P. sieboldii*** may well have been planted. The extrafloral nectary-plant covers at the other two sites are also very influenced by ***R. pseudoacacia***. Without ***R. pseudoacacia***, Kwangsongbo's cover of extrafloral nectary-plants drops from 23% to 11% and Kumwoli's extrafloral nectary-plant cover is reduced from 7.5% to 0.5%. These figures are more similar to the covers(0.0~8%) measured in Nebraska(Keeler, 1980), but lower than some of the covers(23% and 28%) measured in southern California deserts(Pemberton, 1988).

Of the 131 plants found to have extrafloral nectaries, 125 species are listed in the "Illustrated Flora of Korea"(Lee, 1979). These extrafloral nectary-bearing species are 4.05% of the 3,090 total species recorded in Korea's flora. This compares to 2.5% of the indigenous plants of Nebraska(Keeler, 1979a), 1.5% of Hawaii natives growing in Volcano National Park(Keeler, 1985), and 0.95, 2.61 and 3.20% for three desert floras in southern California(Pemberton, 1988).

The percentage of Korean plants with extrafloral nectaries is probably an underestimate. Many of the unexamined relatives of species found to have extrafloral nectaries in this study could have extrafloral nectaries, particularly ***Dioscorea***, ***Iris***, ***Hemerocallis***, ***Osmanthus*** and ***Rosa*** species. Some of the many subtropical orchids, that grow on the southern part of the Peninsula and Cheju Is., probably have extrafloral nectaries, since many subtropical orchid species in other parts of the world have the glands(Bentley 1977a). Some ***Salix*** species may have extrafloral nectaries since the glands have been reported from species in the genus(Keeler 1979a). More extrafloral nectaries may also be found in Korea's herbaceous plants, since they received less attention than woody plants in this study.

Antiherbivore defense theory(Rhoades and Cates, 1976 ; Feeny, 1976) says that plants that are more apparent(predictably present over a long period) have a greater exposure period to attacking herbivores. Apparent plants then have a greater need for defense mechanisms to limit their losses to these herbivores. If one assumes the Korean extrafloral nectaries are defenses, the fact that the great majority of the Korean plants with extrafloral nectaries are woody or herbaceous perennials, and at least relatively apparent, supports the theory.

Plants that bear extrafloral nectaries are prominent parts of many of Korea's agricultural and forest environments. Many of these plants probably benefit from undetected protection from unknown insect mutualists. Some of the defenses may be disrupted due to current forestry and agricultural practices, particularly pesticide use. Research into extrafloral nectary-insect relations is needed to understand the ecology and evolution of these complex and potentially very useful natural control systems.

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적 요

花外蜜腺(Extrafloral neotaries)은 대개의 경우 식물의 잎에 있는 구조로써, 당, 수분, 아미노산 등을 분비한다. 화외밀선에서 분비되는 이들 물질은 익충에 의해서 이용되기 때문에 식식성곤충으로부터 식물을 보호하는 역할을 한다. 화외밀선을 이용하는 익충(주로 개미)과 식물과의 相利共生(mutualism)에 관한 많은 연구가 이루어지고 있으나, 아세아 지역에서 자라는 식물에 대하여 보고된 것은 거의 없다. 한국의 화외밀선을 가진 식물을 알아내기 위하여 살아있는 식물과 표본을 조사하고, 강화도에서 화외밀선을 가진 식물의 植被率과 이중 목본식물의 비율을 조사하였다.

30과 53속내의 131종이 화외밀선을 갖고 있는 것으로 조사되었다. 이는 한국에서 자라는 식물종의 4%에 달하며, 이는 북아메리카에서 화외밀선을 갖고 있는 식물이 차지하는 비율보다 높은 비율이다. 강화도 3개의 숲에서 조사된 화외밀선을 갖고 있는 식물의 식피율은 전식피율의 7%, 23%, 55%이었으며, 이들 장소에서 자라는 목본식물의 각각 15%, 21%, 15%가 화외밀선식물에 해당한다. 한국에서의 주요 작물인 참깨(*Sesamum indicum* L.), 호박(*Cucurbita moschata* Duchesne), 고구마(*Ipomoea batatas* Lam.), 감(*Diospyros kaki* Thunb.), 목화(*Gossypium indicum* Lam.), 녹두(*Phaseolus radiatus* L.), 팥(*Phaseolus angularis* W.F.), 복숭아(*Prunus persica* (L.) Batsch.), 자두(*Prunus salicina* Lindl.) 등이 화외밀선을 갖고 있는 것으로 조사되었다. 이들 많은 재배종 또는 야생종 식물들은 화외밀선을 갖고 있어 이것을 이용하는 개미와 기타 익충들에 의한 보호를 받고 있을 것이다.

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