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Considerations on the allergy-risks related to the consumption of fruits from urban trees in Mediterranean cities

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ABSTRACT

Food provision is designated as one of the ecosystem services provided by urban forests which are comprised of numerous fruit trees. In cities with a Mediterranean climate, the use of fruit trees has a long historical tradition, although its main function has been ornamental. In turn, the consumption of the fruits from these urban trees can lead to some tradeoffs or negative impacts on health. One of the main ecosystem disservices associated with the implementation of urban fruit forests are the allergic reactions caused by plant allergens. This study has two main objectives: 1) to establish a list of urban fruit trees in Mediterranean cities, and 2) to review the allergic reactions associated with the consumption of fruits from urban trees. The catalog of urban fruit trees begins with the species present in the city of Granada (southern Spain), which has resulted in a list of 70 species of 30 botanical families. The family Rosaceae is the most abundant, with 23 species. Of this family, the genus *Prunus* appeared most prominently, with 7 species, followed by the genus *Citrus* of the family Rutaceae, with 6 species. As for allergenicity, the species of the families Oleaceae, Fagacecae, Moraceae and Juglandaceae have allergenic pollen with different degrees of incidence in the population, while in others these allergens are found in the fruit, specifically in nuts, berries, citric fruits and species within the Rosaceae family. There are also cross reactions between common allergens in Mediterranean plants and commonly consumed fruits. It can be concluded that the results of this study address the existing knowledge gap when discussing the ecosystem service of food provision, particularly in relation to pollen and fruit allergens.

1. Introduction

Food provision has been identified as one of the services gained from urban forest ecosystems which have experienced significant growth worldwide in recent years (Clark and Nicholas, 2013) due to their positive impact on poverty alleviation and human well-being (Fisher et al., 2014). This benefit is provided by any plant species integrated into urban forests with a real or potential capacity to supply food. In urban ecosystems, many of these species are fruit trees or produce food-derived products such as oils, condiments, infusions or flavorings (Clark and Nicholas, 2013). However, this ecosystem service is subject to the socio-cultural connotations and particularities of the place considered. Thus, in many cities in Africa, the planting of fruit trees for consumption is considered a priority service (Fuwape and Onyekwelu, 2011). In the USA, the establishment of green infrastructure programs that include food security projects, in which urban forests are a source of goods, is an emerging trend. Cities such as Seattle, New York and Baltimore already have programs, policies and laws that address and regulate the gathering and use of urban forest products for food (McClain et al., 2012). In Europe, despite the important historical tradition of fruit trees in parks and gardens (castro et al., 2018), this practice is not so widespread and most urban edible-fruit trees are mainly of ornamental use. And even though fruit picking is allowed, it is not a popular social activity (Yates, 2014). A notable example would be bitter orange trees (*Citrus aurantium* L.) that are prominent in many cities in southern Europe. The fruits of these trees are collected only by tourists from the north of the continent either to prepare a beloved bitter orange jam (Rossini Oliva and Elías Bonells, 1996), or because they are unaware of the existence of the bitter orange tree and confuse it with the sweet orange tree (*Citrus sinensis* (L.) Osbeck).

One of the reasons that many Europeans do not eat fruit from urban trees may be the trade-offs that their consumption can entail. Sometimes, this is derived from the selection of varieties and cultivars

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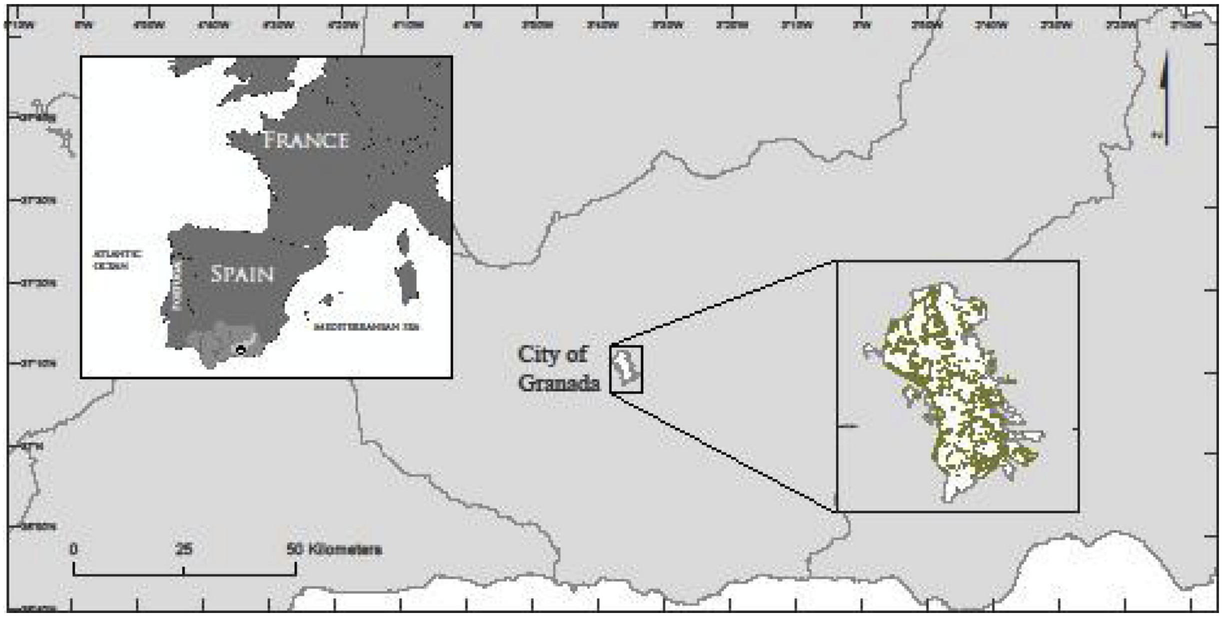

Fig. 1. Location of Study area.

of a species that do not have edible fruit or don't have a pleasant taste. To add to the aforementioned case of the bitter orange trees, we must include some varieties of apples (*Malus* spp.), pomegranates (*Punica granatum* L.) and plums (*Prunus* spp.) (Andrew and Arnold, 1977). In other occasions, the maintenance of fruit trees requires a significant investment of resources for pruning, fertilization and adequate irrigation which are not always available (Escobedo et al., 2011). On the other hand, it has been proven that the high levels of air pollution in many cities can affect the levels of pollutants accumulated in the fruits of urban trees, which can reach toxic levels and represent a health risk (von Hoffen and Säumel, 2014). For these reasons, the benefits of urban horticulture have been questioned. Moreover, the refusal to eat fruits picked directly from urban trees has been transmitted of parents to children (Säumel et al., 2012). A recent review by Russo et al. (2017) noted that most studies carried out on edible green infrastructure have not taken into account these ecosystem disservices or negative effects and that this should be the target of future research so that the net balance of benefits can be established.

As urban forests become more popular, one topic that deserves attention is the adverse health reactions that plant allergens can cause. It is well known that urban vegetation is a source of allergenic bioaerosol (Cariñanos et al., 2016). Moreover, the main urban tree species involved in hypersensitivity reactions have been identified, as have the causes of the increasing allergenicity in urban green spaces (Cariñanos and Casares-Porcel, 2011). What is less known is the allergic response that the consumption of some fruits can generate, both in individuals already sensitized to pollen (Katelaris, 2010), as well as in people who do not have an allergy diagnosis but who are affected by other substances which generate an immune response mediated by the immunoglobulin E (onwards, IgE) (Bohle, 2007). This allergic reaction, known as pollen-food allergy syndrome, is one of the most prominent food allergies in adults (Amlot et al., 1987). Its most well-known clinical manifestation is oral allergy syndrome (OAS) (Kondo and Urisu, 2009), which is produced by the presence of proteins known as panallergens which are widely distributed throughout the plant kingdom (Breiteneder and Radauer, 2004). The symptoms of pollen-food allergy syndrome range from oral allergy syndrome to severe anaphylaxis. The foods involved are of vegetal origin, mostly fruits and vegetables, eaten raw (Kleine-Tebbe et al., 2002). Among the main plant proteins involved in pollen-food syndrome are profilins, pathogenesis-related proteins (PRs) and lipid transfer proteins (LTP) (Breiteneder and Radauer, 2004). Some of these plant proteins have a high degree of homology with pollen allergens, such as pollen allergens from birch trees (*Betula, Bet v 1*), as well as pollen allergens from some species of Betulaceae. However, since these pollen allergens are present in other families, such as Rosaceae and Apiaceae, they can cause a similar immune response to different antigens, which is known as cross-reactivity (Katelaris, 2010). In some Mediterranean countries, it is also possible that the allergy to plant-derived foods is not associated with pollinosis and occurs mainly through the oral consumption of certain foods (Cuesta-Herranz et al., 2010). In these cases, non-specific Lipid Transfer Proteins (LTP) have been identified as major allergens, and are responsible for severe reactions in patients due to their high resistance to proteolytic digestion and heat treatment (Asero et al., 2000). Although it has been shown that the presence of allergens is higher in the peel of the fruit, which therefore has a higher allergenic potency, allergens are also present in the pulp, so the symptomatology can take place even when one peels the fruit (Fernández-Rivas and Cuevas, 1999). One of the main allergens isolated in the peel of the fruit is *Pru p 3*, found in peaches (*Prunus persica* (L.) Batsch). This allergen shows immunological activity similar to that of pollen allergens (Díaz-Perales et al., 2003).

Given the growing interest that the implementation of Urban Food Forests (UFF) and fruit trees are receiving in Mediterranean countries (for example, the Picasso Food Forest in the Italian town of Parma (Riola, 2018), or the declaration of the French city of Rennes as an edible city (Parham, 2015)), it is necessary to review the costs and negative effects that the implementation of urban fruits forests may have.

Specifically, there are two main objectives that will be addressed in this study: 1) to establish a list of urban fruit trees in the city of Granada (southern Spain). This will serve an example of a Mediterranean city which may serve as a basis for the future development of a complete inventory of urban fruit trees that can be grown in Mediterranean climate cities worldwide; and 2) to review the allergic reactions associated with the consumption of fruits from urban trees, both in people who have pollen related allergies and in people who do not. The information generated may serve as a basis for the generation of a global list of urban fruit tree species and their associated allergy risks.

2. Materials and methods

2.1. Urban fruit-tree inventory

To make an inventory of urban fruit trees, the city of Granada (which is located in the southeast of the Iberian Peninsula (37.179937,-3.603489)) has been selected (Fig. 1). The city has a Mediterranean-continental climate (average annual temperature: 15.6 °C, average annual rainfall: 359 mm for the period of 1981–2010, AEMET (Spanish Agency of Meteorology), 2017), with a marked period of at least two months of drought (in the case of Granada during the summer). This climate allows for the growth of tree species from a wide range of hardiness zones – 7–11 according to USDA Hardiness categories (Cariñanos et al., 2016). In addition to the high diversity allowed by the climate, we must note the tradition of small gardens and orchards in the city derived from its Muslim-Nazari past (8–15 centuries CE). Even today, the so-called "*cármenes*" (from the Arabic term " *karm*" which originally means "vineyard") can be found in traditional homes (Kugel, 2001).

In order to produce the list of fruit-trees, inventories have been made by studying the green infrastructure of the city. The list has been created using two methods: our own experience while walking through the city (Fig. 2), and by reviewing selected references in urban gardening (using both the database of urban trees of the city of Granada, available at: https://www.granada.org/inet/warboles.nsf/xcien, and ethnobotanical references, selecting only edible-fruit trees which are cultivated in Granada (Benítez et al., 2010, 2017)). All the species that consist of at least one individual planted in the city have been included in the list, since this confirms the potential of the species to be used in urban food forests in Mediterranean climates. In addition, some existing catalogs on food-producing woody species appropriate for urban forestry in warm-temperate areas have been consulted in order to confirm their possible climatic compatibility (Roloff et al., 2009; Samson et al., 2017). It is not the objective of this study to select fruit producing tree species according to the criterion of fruit edibility, since their potential allergenicity is independent of this characteristic. For the nomenclature of the included plant species, the website "The Plant List" was consulted (www.theplantlist.org). The association of the species with a botanical family has been done according to the Angiosperm Phylogeny Website, Version 14 (http://www.mobot.org/MOBOT/research/APweb/welcome.html).

2.2. Evaluation of the pollen-fruit syndrome

The compilation of information regarding the pollen-fruit syndrome was carried out by searching for references in the Scopus bibliographic database using the key words "pollen-fruit syndrome", "Oral allergy syndrome", "Allergy urban fruit trees" and for some specific species "allergy-[common name of the fruit]". Of all the results obtained, those considered most relevant for the purpose of this article have been selected, since it is not the objective of this study to present an exhaustive and extensive bibliographic review, but to highlight the real and potential risk that the consumption of urban fruits can have, both for people who have pollen related allergies and for people who do not. Therefore, one of the main criteria for the inclusion of a specific species in this review was to select references that included explicit mention of any of the fruit tree species in the inventory previously established for the city of Granada. We also included all references that pointed to the possible existence of cross-reactions between aeroallergens and fruit-allergens. All references selected came from articles written in English in specialized journals, since in this field of research it is the usual way to share information, since local reports are practically nonexistent. An extensive review detailing the cross-reactions between aeroallergens and food allergens can be found in Popescu (2015).

3. Results

3.1. Pollen-fruit syndrome

Prior to presenting the results from both the inventory of urban fruit tree species in the city of Granada and their associated allergenic risk, we present some concepts which are necessary to understand these results, and which will make them more understandable to the reader not familiar with said terminology.

According to the National Institute of Allergy and Infectious Diseases, "food allergy" is defined as "an adverse health effect arising from a specific immune response that occurs reproducibly on exposure to a given food "(Kohn, 2017). When there is a cross-reaction between pollen antigens and allergic reactions as a result of ingesting particular fruits, vegetables or spices, then the food allergy is referred to by the more specific term "pollen-food allergy syndrome" (PFS), or "pollen-fruit syndrome" when the causative agent is a fruit (Kondo and Urisu, 2009). Pollen-food allergy syndrome is the most prominent cause of food allergies in adults and adolescents. Between 15–20% of the population in developed countries are allergic to birch pollen, and of these, 50–93% have IgE-mediated reactions to pollen related foods (Egger et al., 2006). Some of the most frequent cross-reactions between pollen and fruit allergens are detailed in Table 1.

Up to 9 frequent cross-reactions are shown in Table 1, including 14 allergens present in 9 pollen types, and 16 typical fruits involved in pollen-fruit syndrome. Peach, apple, kiwi and melon are the fruits that have a greater number of cross-reactions, with 8, 5, 5 and 5, respectively.

On the other hand, latex-food syndrome is similar to pollen-food

Fig. 2. Several Fruit-trees in the streets of Granada. Above, from left to right: date palm (*Phoenix dactylifera*), pomegranate (*Punica granatum*), medlhar (*Eriobotrya japonica*). Below, from left to right: olives (*Olea europaea*) and orange-trees (*Citrus aurantium*); grapefruit (*Vitis vinifera*), lemon-tree (*Citrus limon*).

Table 1
Cross-reactivity between panallergens present in pollen from Mediterranean plants and fruits. Adapted from: Bohle, 2007; Kondo and Urisu, 2009; Mur et al., 2006; Popescu, 2015; Salcedo et al., 2004; Van Ree, 2002.

Pollen type (common name)	Allergen	Fruit involved in pollen-fruit syndrome
Amaranthaceae (amaranth family)	*Che a 2* (profilin)	Melon
Artemisia (mugwort)	*Art v 1* (profilin)	Apple, banana, peach, water-melon
	Art v 4 (LTP)	
Betula (birch)	*Bet v 1* (pathogenesis related protein PR-10)	Almond, apple, apricot, cherry, hazelnut, kiwi, mango, peach, pear.
	Bet v2 (profilin)	Cherry, peach, pear.
	LTP	Apple, apricot, cherry, kiwi, peach, plum
Cuppressaceae (cypress family)	*Cup s 8* (profilin)	Peach
	Cup s 3 (thaumatins)	
Olea (olive)	*Ole e 1* (LTP)	Melon, kiwi, peach, pear.
	Ole e 2 (profilin)	
Parietaria (pellitory of the wall)	*Par j 2* (LTP)	Pistachio
Plantago (plantain)	14kDa-31 kDa protein	Apple, kiwi, melon, peach
Platanus (plane-tree)	*Pla a 1* (profilin)	Apple, banana, hazelnut, kiwi, melon, peach
Poaceae (grass family)	*Cyn d 12* (profilin)	Melon, tomato, orange, water-melon

Profilin: is an actin-binding protein involved in the dynamic turnover and restructuring of the actin cytoskeleton.
Thaumatin: it is a pathogenesis-related (PR) proteins.
LTP: Lipid Transfer Proteins. Proteins responsible for the shuttling of phospholipids and other fatty acid groups between cell membranes.

syndrome because some latex allergens are similar to the allergens of certain foods (Blanco, 2003). The most frequent clinical manifestation of pollen-food allergy syndrome is Oral Allergy Syndrome (OAS), which is a medical condition characterized by IgE-mediated immediate allergic symptoms restricted to the oral mucosa, which may involve itching and vascular edema of the lips, tongue, palate and pharynx (Amlot et al., 1987). Although the symptoms are usually mild or moderate, sometimes a severe and systemic anaphylactic reaction can occur that can seriously endanger the person's life (Ebo et al., 2009).

3.2. Inventory of urban fruit trees compatible with Mediterranean climatic conditions

The list of fruit tree species of real or potential use in the city of Granada resulted in a catalogue of 79 species linked to 31 botanical families (Table 2).

The Rosaceae family is the most outstanding in terms of the number of species present – 25 in total. Of this family, the genus *Prunus* and the genus *Citrus* of the family Rutaceae, are the most represented with 8 and 6 species, respectively. The genus *Prunus* is of European origin, and several fruit species are native to the Mediterranean areas. However the genus *Citrus*, which form the set of fruit trees known by the generic name of "citrus" or "orange trees", was introduced in Europe by different ancient cultures, from places such as Southeast Asia or the archipelago of Barbados. At the other extreme are the families that are represented by a single species. There are several reasons for this. First, because they are monogeneric families, such as Ginkgoaceae (*Ginkgo biloba* L.). Second, because its zone of origin is very distant from the study area and its representation in urban forestry is scant, such as the tropical family Sapotaceae (which includes *Argania spinosa* (L.) Skeels, or the American Cactaceae (*Opuntia ficus-indica* (L.) Mill.), that was introduced for purposes other than food provision (Erre et al., 2009; Rivera and Ruiz, 1987).

This has been one of the relevant datum revealed by this study: the diversity in terms of the origin of the fruit trees found, which originate from all 5 continents. Of them, those from China are the most abundant, representing 31% of the total, which is not surprising due to China's historical relationship with Europe (The Silk Road, the Mongol invasion of Europe, etc.). Surprisingly, the high number of European-origin species is not as high as one may expect (comprising 24.2% of total), with 9.7% being strictly Mediterranean. Among these are the strawberry tree (*Arbutus unedo* L.), the carob tree (*Ceratonia siliqua* L.), the bay tree (*Laurus nobilis* L.), the pine tree (*Pinus pinea* L.), the almond tree (*Prunus dulcis* (Mill.) D.A. Webb), the oak tree (*Quercus rotundifolia* Lam.), the blackberry tree (*Rubus ulmifolius* Schott), the jujube tree (*Ziziphus jujube* Mill.), as well as the olive tree (*Olea europaea* L.), which for the purpose of this study is quite significant, since the pollen of the olive tree is one of the main causative agents of allergies in Mediterranean populations (D´Amato, 1998), as well as in the city of Granada (Díaz-Perales et al., 2003) (Table 2).

The fruit is the edible part of the tree in almost all species, with the exception of *Chamaerops humilis* in which the young stem is eaten, *Gleditsia* sp. and *Robinia* sp. in which the flowers are eaten and *Laurus*, in which the leaves are used as a condiment. In principle, all fruits could be considered edible. However, in some cases, the varieties and cultivars used produce fruits whose taste is not pleasant, as is the case of the of *Citrus aurantium* var. *myrtifolia*, *Actinidia* spp. var. *larger*, *Eryobotria japonica* var. *magdal*, *Ficus carica* var. *ñoral*, and *valenciana* and *pendula* of Morus spp., for its low value gastronomic. On other occasions, the consumption of these fruits is not popularly accepted in one's culture, such as *Ginkgo biloba* almonds.

3.3. Allergenicity interactions between pollen and fruit

The results of the bibliographic search carried out have highlighted the number of species that may be involved in allergenic reactions. On the one hand, 23 species (29.1%) have allergenicity associated with their pollen grains, mainly those of the families Oleaceae, Fagaceae, Moraceae and Juglandaceae. In the city of Granada, the species associated with these families include *Olea europaea*, *Quercus rotundifolia*, *Castanea sativa*, *Morus* spp. and *Juglans regia* (Table 2). In 30 species (31.9%), it is the fruit that contains the allergens which cause an IgE-mediated response. These include the so-called nuts: pecan (*Carya illinoinensis* (Wangenh.) K.Koch), chestnut (*Castanea sativa* Mill.), ginkgo, walnut (*Juglans regia* L.), pistachio, (*Pistacia vera* L.) almond and acorn (*Quercus rotundifolia* Lam.); berries: white and black mulberry (*Morus* spp.), raspberry (*Rubus idaeus* L.), elderberry (*Sambucus nigra* L.); citrus (*Citrus* spp.) and especially those of the species from genus *Prunus*: peach, apricot, cherry, plum, as well as apple, mango and date (Table 2). It deserves to be highlighted that 20 species (25.3%) do not produce any type of allergic reaction (Fig. 2).

In the group of species involved in allergic reactions that are caused by cross-reactions between pollen and fruit antigens, the most prominent are those that have cross-reactions with *Betula* pollen, although this pollen type is not prominent in the Mediterranean region. This group includes oranges, kiwis, figs, apples and the *Prunus* species. Other existing cross-reactions include the cherimoya fruit with *Parietaria* pollen or *Fagus* nuts with the pollen of other Fagaceae species. Finally, the group of species involved in other allergic reactions is also noteworthy, such as those that cause dermatitis due to the presence of other

Table 2
Main urban fruit trees of real and potential use in Mediterranean cities, indication of their origin, edible part and allergenicity of pollen, fruit and cross-reactions between pollen and fruit. Scientific names according to www.theplantlist.org and botanical families according to Angiosperm Phyllogeny Group IV.

Scientific name	Family	English common name	Origin	Edible part	Allergenic pollen	Pollen-fruit reactions	Allergenic fruit	Other allergies	References
Acca sellowiana (O.Berg) Burret	MYRTACEAE	Feijoa	S-America	Fruit					
Actinidia arguta (Siebold & Zucc.) Planch. ex Miq.	ACTINIDIACEAE	Hardy kiwi	Japan, Korea, N-China	Fruit		Cross-react Betula pollen	X		1
Amelanchier ovalis Medik.	ROSACEAE	Juneberry, Wild-plum	S, C- Europe	Fruit					
Annona cherimola	ANNONACEAE	Custard apple, cherimoya	S-America	Fruit		Cross-react Parietaria pollen		Latex-fruit syndrome	2
Arbutus unedo L.	ERICACEAE	Strawberry tree	Mediterranean Region	Fruit	X				
Argania spinosa (L.) Skeels	SAPOTACEAE	Argán	SW-Morocco	Fruit				Contact Dermatitis	5
Asimina triloba (L.) Dunal	ANNONACEAE	pawpaw	E-USA	Fruit					
Carya illinoinensis (Wangenh.) K.Koch (Syn. *Carya oliviformis* (F.Michx.) Nutt.)	JUGLANDACEAE	pecan	Mexico-USA	Fruit	X		X		6,7
Castanea sativa Mill.	FAGACEAE	Chestnut	Europe-Asia	Fruit	X		X		8
Celtis australis L.	CANNABACEAE	Hackberry fruit	S-Europe, N-Africa	Fruit					
Ceratonia siliqua L.	FABACEAE	Carob	Mediterranean Region	Fruit					
Chamaerops humilis L.	ARECACEAE	Mediterranean dwarf palm	S-Europe, N-Africa	Fruit and trunk	X				
Citrus limon (L.) Osbeck	RUTACEAE	Lemon	Asia	Fruit		Cross-react Betula pollen	X		3, 9, 10
Citrus reticulata Blanco	RUTACEAE	Tangerine, mandarin	China	Fruit		Cross-react Betula pollen	X		3, 9
Citrus sinensis (L.) Osbeck	RUTACEAE	Sweet orange	China	Fruit	X	Cross-react Betula pollen			9,10
Citrus x aurantifolia	RUTACEAE	Lime	SE-Asia	Fruit		Cross-react Betula pollen	X		9, 10
Citrus x aurantium L.	RUTACEAE	Bitter orange	SE-Asia	Fruit	X	Cross-react Betula pollen	X		9, 10
Citrus x paradisi	RUTACEAE	Grapefruit	Barbados	Fruit		Cross-react Betula pollen	X		3, 9
Corylus avellana L.	BETULACEAE	Hazelnut	Europe, W-Asia	Fruit		Cross-react Betula pollen	X		3, 11
Crataegus azarolus L.	ROSACEAE	Acerola	Med, W-Asia	Fruit				Contact Dermatitis	12
Crataegus granatensis Boiss.	ROSACEAE	Granadian haw	S-Europe, NW-Africa	Fruit					
Crataegus monogyna Jacq.	ROSACEAE	Haw, hawberry	Europe,NW-Africa,W-Asia	Fruit					
Cornus mas L.	CORNACEAE	Cornelian cherry	Eurasia, N-America, China, Japan	Fruit					
Cydonia oblonga Mill.	ROSACEAE	Quince	SW-Asia	Fruit					
Diospyros kaki L.f.	EBENACEAE	Persimmon, khaki	Asia	Fruit					13
Diospyros virginiana L.	EBENACEAE	American persimmon	SE-USA	Fruit					13
Eriobotrya japónica (Thunb.) Lindl.	ROSACEAE	Medlar	China	Fruit					
Fagus sylvatica L.	FAGACEAE	Nuts	Europe	Fruit		Cross-react Fagales pollen			14
Ficus carica L.	MORACEAE	Fig	W-Asia	Fruit		Cross-react Betula pollen	X	Latex fruit syndrome	3, 15
Fortunella hindsii (Champ. ex Benth.) Swingle	RUTACEAE	Kumquat	China	Fruit		Cross-react Betula pollen			3
Ginkgo biloba L.	GINKGOACEAE	Ginkgo almonds	China	Fruit	X		X	Contact Dermatitis	16, 17, 18, 19
Gleditsia triacanthos L.	FABACEAE	Honey locust	N-America	Flower	X				
Hovenia dulcis Thunb.	RHAMNACEAE	Japanese raisin	E-China, Korea	Fruit					
Juglans regia L.	JUGLANDACEAE	Nuts	E-Europe, S-China	Fruit	X		X		8, 20
Juniperus communis L.	CUPRESACEAE	Juniper berry	N-Hemisphere	Fruit	X				21, 22
Laurus nobilis L.	LAURACEAE	Laulel	Mediterranean Region	Leaf				Contact Dermatitis (oil)	23

(*continued on next page*)

Table 2 (*continued*)

Scientific name	Family	English common name	Origin	Edible part	Allergenic pollen	Pollen-fruit reactions	Allergenic fruit	Other allergies	References
Malus pumila Mill.	ROSACEAE	Apple	Cáucaso-Caspio Sea	Fruit		Croos-react Betula pollen	X		3, 4, 24
Mangifera indica L.	ANACARDIACEAE	Mango	India	Fruit			X		25
Mespilus germanica L.	ROSACEAE	Medlar	SE-Europe, Asia	Fruit				Latex-fruit syndrome	26
Myrtus communis L.	MYRTACEAE	Myrtle berry	S-Europe, N-Africa. W-Asia, Macaronesia	Fruit					
Morus alba L.	MORACEAE	White Mulberry	N-China	Fruit	X		X	Contact Dermatitis	27, 28, 29
Morus nigra L.	MORACEAE	Black Mulberry	SW-Asia	Fruit	X		X	Contact Dermatitis	27, 28, 29
Musa x paradisiaca L.	MUSACEAE	Banana	SE-Asia, Australia	Fruit				Latex-fruit syndrome	2
Olea europaea L. var. *europea* and var. *sylvestris*	OLEACEAE	Olive	S-Europe, N-Africa. W-Asia	Fruit	X			Contact Dermatitis (oil)	30, 31
Opuntia ficus-indica (L.) Mill. (Syn. *O. maxima* Mill.)	CACTACEAE	Prickly pear	Mesoamerica	Fruit					
Persea americana Mill.	LAURACEAE	Avocado	Mesoamerica	Fruit				Latex-fruit syndrome	32
Phoenix dactylifera L.	ARECACEAE	Date	Mesopotamia	Fruit	X		X		3, 6
Pinus pinea L.	PINACEAE	Pine	Mediterranean Region	Fruit	X		X (seeds)		33, 34, 35
Pistacia vera L.	ANACARDIACEAE	Pistachio	Central Asia, Middle East	Fruit	X		X		36, 37
Prunus avium (L.) L.	ROSACEAE	Sweet cherry	Europe, Anatolia, Maghreb, W-Asia	Fruit			X		38, 40
Prunus armeniaca L.	ROSACEAE	Apricot	Asia	Fruit		Cross-react Betula pollen	X		3, 39, 40
Prunus cerasifera Ehrh.	ROSACEAE	Cherry plum	SE-Europe, W-Asia	Fruit		Cross-react Betula pollen	X		40
Prunus cerasus L.	ROSACEAE	Cherry	Europe, SW Asia	Fruit		Cross-react Betula pollen	X		3, 40
Prunus domestica L.	ROSACEAE	Plums	Europe, W-Asia	Fruit		Cross-react Betula pollen	X		3, 40
Prunus dulcis (Mill.) D.A.Webb var. *dulcis*	ROSACEAE	Almond	Mediterranea, W-Asia	Fruit		Cross-react Betula pollen	X		3, 41
Prunus persica (L.) Batsch	ROSACEAE	Peach	China	Fruit		Cross-react Betula pollen	X		3, 40, 42
Punica granatum L.	LYTHRACEAE	Pommegranate	Asia (Afghanistan, Pakistan, India)	Fruit		Cross-react Betula pollen			3, 43
Pyrus pyrifolia (Burm.f.) Nakai	ROSACEAE	Pear	E-Asia	Fruit		Cross-react Betula pollen			3
Pyrus communis L.	ROSACEAE	Pear	C,E-Europe, SW-Asia	Fruit					3
Quercus rotundifolia Lam. (Syn. *Q. ilex* subsp. *ballota* (Desf.) Samp.	FAGACEAE	Acorn	Mediterranean Region	Fruit	X		X		44, 45
Ribes rubrum L.	ROSACEAE	Red currant	N,E-Europe	Fruit					
Robinia pseudoacacia L.	FABACEAE	Legume	E-USA	Flower	X				46
Rosa canina L.	ROSACEAE	Hip, Rosa haw	Europe, NW-Africa, W-Asia	Fruit					
Rubus idaeus L.	ROSACEAE	Raspberry	Europe, N-Asia	Fruit			X		47
Rubus ulmifolius Schott	ROSACEAE	Blackberry	Mediterranean Region	Fruit					
Sambucus nigra L.	ADOXACEAE	Elderberry	Europe, N-America	Fruit	X		X		48, 49
Schisandra chinensis (Turcz.) Baill.	SCHISANDRACEAE	Five-flavor fruit	N-China, Russia	Fruit					
Sorbopyrus auricularis (Knoop) C.K. Schneid.	ROSACEAE	Shipova		Fruit					
Sorbus aria (L.) Crantz	ROSACEAE	Rowanberry	European, E-Asia	Fruit					
Sorbus aucuparia L.	ROSACEAE	Rowanberry	Europe, Asia	Fruit					
Sorbus domestica L.	ROSACEAE	Sorb tree	Europe	Fruit					
Tilia tomentosa Moench	MALVACEAE	Tile	Europe, N-America, Asia	Leaf	X			Contact Dermatitis	50, 51
Tilia x vulgaris Hayne	MALVACEAE	Tile	Europe, N-America, Asia	Fruit	X			Contact Dermatitis	50, 51

(*continued on next page*)

Table 2 (*continued*)

Scientific name	Family	English common name	Origin	Edible part	Allergenic pollen	Pollen-fruit reactions	Allergenic fruit	Other allergies	References
Ulmus glabra Huds.	ULMACEAE	Scotch Elm	C-Europe	Fruit	X				52
Ulmus minor Mill.	ULMACEAE	Elm	Europe	Fruit	X				52
Ulmus pumila L.	ULMACEAE	Elm	C-Asia	Fruit	X				52
Vitis vinifera L.	VITACEAE	Grapefruit	Europe (Mediterr.), N-America, Asia	Fruit			X		53
Ziziphus jujuba Mill.	RHAMNACEAE	Jujube	SE-Asia	Fruit				Latex-fruit syndrome	54
Ziziphus lotus (L.) Lam.	RHAMNACEAE	Jujube	Mediterranean Region	Fruit				Latex-fruit syndrome	54

1: Chen et al., 2006; 2: Sánchez-Monge et al., 1999; 3: Eriksson et al., 2008; 4: Paris et al., 2017; 5: Foli et al., 2014; 6: Waisel et al., 1994; 7: Mattison et al., 2013; 8: Antico, 1996; 9: Crespo et al., 2006; 10: Alcázar et al., 2016; 11: Müller et al., 2000; 12: Steinman et al., 1984; 13: Auliker et al., 2000; 14: Mari et al., 2003; 15: Hemmer et al., 2010; 16: Lepoittevin et al., 1989; 17: Jaggy and Koch, 1997; 18: Larry et al., 1975; 19: Yun et al., 2000; 20: Pastorello et al., 2004; 21: Charpin et al., 2005; 22: Hughes et al., 2006; 23: Adisen and Onder, 2007; 24: Fernández-Rivas et al., 1997; 25: Paschke et al., 2010; 26: Blanco, 2003; 27: Muñoz et al., 1995; 28: Caiaffa et al., 2003; 29: Navarro et al., 2007; 30: Quiralte et al., 2007; 31: Padoan et al., 1990; 32: Brehler et al., 1997; 33: Kwaasi et al., 2001; 34: Marcos et al., 2001; 35: Ibáñez et al., 2003; 36: Keynar et al., 2007; 37: Jansen et al., 1992; 38: Inschlag et al., 1998; 39: Pastorello et al., 2000; 40: Pastorello et al., 1994; 41: Costa et al., 2012; 42: Cuesta-Herranz et al., 1998; 43: Gaig et al., 1999; 44: Prados et al., 1995; 45: Zapatero et al., 2005; 46: Compés et al., 2006; 47: Marzban et al., 2008; 48: Förster-Wald et al., 2003; 49: Jiménez et al., 2013; 50: Mur et al., 2002; 51: Krakowiak et al., 2004; 52: Miguel et al., 2006 ; 53 : Pastorello et al., 2003; 54: Chen and Lan, 2002.

allergenic substances in the plant, mainly latex in the species of the Moraceae family, or olive oil and bay essential oil (Table 2).

4. Discussion

In this study, we have established a list of fruit tree species that have real or potential use in cities with a Mediterranean climate, using the city of Granada as an example. The resulting catalogue is interesting not only to highlight the enormous diversity of species (which is larger than that of other bioclimatic territories; see Clark and Nicholas, 2013), but also because it highlights another benefit that urban forests can generate in the form of provision ecosystem services (Russo et al., 2017). But the results of this study also reveal important trade-offs that should be considered when establishing the net balance of ecosystem services provided by urban forests (Escobedo et al., 2011), particularly when these do not generate welfare in the population and produce a significant negative impact on public health (Lyytimäki and Sipilä, 2009; Cariñanos et al., 2017). Allergies that are caused by the presence of allergenic bioaerosol in the atmosphere, as well as those produced by food, are two of the diseases with the highest expectations of growth in the coming years as a result of the effects of climate change and the worsening of the urban environment (Pawankar, 2004) and globalization (Hadley, 2006). It is therefore necessary to review and publicize this information in order to establish measures to reduce the negative impact (Cariñanos et al., 2017).

One of the most significant aspects of our study has been to highlight the allergenicity of urban trees in relation to pollen, fruit and the cross-reactions that can be established between them. This has allowed us to obtain relevant information, such as the fact that the presence of homologous allergens between pollen and fruits does not follow a geographical pattern, but rather a phylogenetic one (Radauer and Breiteneder, 2007). This has been observed with the birch, because although this plant / pollen type is not very prominent in southern Europe, it is possible to find homologous allergens in the pollen of other well represented species in the Mediterranean flora, such as in olive trees and grasses (Weber, 2003), which can also produce an allergic response between these pollen types and the fruits from the Rosaceae, Rutaceae and Actiniaceae families (Cuesta-Herranz et al., 1998). However, we can speak of a geographic distribution model and eating habits when interpreting some of the results obtained. There are several authors who point out that in the Mediterranean area there is a particular clinical and sensitization pattern that is different from that of other European areas, since many patients display fruit allergy symptoms without related pollinosis (Fernández-Rivas and Cuevas, 1999). Thus, in a study conducted in Spain, it was found that more than 75% of patients who had positive skin tests for peach, melon and apple allergies had mostly symptomatic responses after consuming apples, which is the most consumed fruit in the country (Cuesta-Herranz et al., 2010), although this tree does not have allergenic pollen.

Several studies have highlighted the main panallergens that participate in pollen-fruit syndrome processes. Lipid Transfer Proteins (LPTs) have been identified as the main group of allergens present in plant foods (Pastorello et al., 2003). This family of allergens is particularly extensive in Rosaceae fruits (Pastorello et al., 2004), but has also been identified in grapes (Pastorello et al., 2003), hazelnuts (Müller et al., 2000), in derived products from cereal seeds (García-Casado et al., 2001) and in vegetables (Asero et al., 2000), which makes it the main cause of food-allergy syndrome in the Mediterranean region. But its presence in pollen grains of typical Mediterranean plants such as olive-trees, pellitory of the wall (*Parietaria)* and mugworth (*Artemisia)* is also relevant, as they in turn participate in reactions of cross-reactions between pollen and fruits (Bohle, 2007; Popescu, 2015). The profilins are also a relevant group of allergens, since it is present in two of the most prominent trees in Mediterranean urban environments, such as the plane tree and the cypress. Plane tree, in addition to being one of the most abundant species in urban vegetation, participates in Oral

Allergy Syndrome (OAS) processes with fruits such as apple, banana, melon, kiwi and peach (Enrique et al., 2002). In the case of the cypress, recent studies have revealed the existence of new allergens in the pollen grain, similar to peach and citrus allergens, which form a new family of allergens related to the gibberellin-regulated protein family, and have a great capacity to produce pollen-fruit associated syndrome (Sénéchal et al., 2017).

Some of the tree species included in the list of urban fruit trees in the city of Granada deserve particular attention, as in the case of the orange-family, both for its representativeness as an urban tree in Mediterranean cities and for the allergenicity of its pollen, of its fruits and of its cross-reaction between its fruit and birch pollen. The different species of the genus *Citrus* were introduced into the Mediterranean from Asia in different historical times. Some of them, such as lemon or bitter orange were introduced in Europe by the Muslims via the Iberian Peninsula and Sicily, while for others (sweet orange, tangerine) arrived to Western Europe between the fifteenth and nineteenth centuries as a result of the trade with the British and Portuguese colonies (Ramon-Laca, 2003). Nowadays, it is still highly represented in many cities where they are one of the most abundant urban trees (for example, in Seville, southern Spain, there are more than 25,000 individual citrus trees), despite not being very resistant to air pollution and having the allergenic capacity of pollen grains (Alcázar et al., 2016). Its involvement in cross-reactions with *Betula* pollen is also recognized, and positive skin tests have been registered in patients allergic to grass pollen, such as *Olea, Plantago, Ulmus, Platanus, Fraxinus*, *Cupressus*, *Artemisia* and *Quercus* (Crespo et al., 2006). Also important is the presence of powerful allergens in their peel, seeds and edible pulp (Crespo et al., 2006). In terms of benefits, we must mention that citrus fruit does not accumulate many pollutants when it grows in urban environments, so there are few health risks when the fruits are eaten peeled (von Hoffen and Säumel, 2014). Moreover, its flowers participate in other ecosystem services since it is an ingredient in essential oils for the pharmaceutical and cosmetic industry (Palazzolo et al., 2013).

Another well-represented group in Granada is the family Rosaceae, represented by the "pome" fruit type: apples, pears, medlars, quinces (formerly the Maloideae subfamily), those of the "drupe" type: the *Prunus* species and other less-known species such as acerola (*Crataegus azarolus* L.), hawberry (*C. monogyna* Jacq.) or juneberry (*Amelanchier ovalis* Medik.) (formerly the Amygdaloideae subfamily). Rosaceae is a family which is traditionally used in urban environments of different latitudes, due to the presence of species adapted to different climatic conditions (Shi et al., 2013). They are also one of the main groups providing "fruits" in urban food forests in different bioclimates (Clark and Nicholas, 2013). Pear trees and apple trees stand out as the most prominent fruit trees in urban environments, although it should be noted that both are cross-reactive with birch pollen (Eriksson et al., 2008; Paris et al., 2017), and in the case of apple, also the fruit (Hassan and Venkatesh, 2015). This could have a direct impact on cities in which the collection of fruits from urban trees is a cultural tradition that promotes social participation and cohesion (Castro et al., 2018). But most often, its incorporation as an urban tree is primarily ornamental, especially for its spectacular flowering that usually marks the beginning of spring (Primack and Higuchi, 2007). A change towards cultivars and varieties of fruits that are more pleasant to eat would position the Rosaceae family as a viable option as components of urban food forests. As an added value, it is worth noting its involvement in pollination Ecosystem Services (ES) (Fukase and Simons, 2015).

Some of the species on the list should be highlighted because, besides being native to the Mediterranean, they do not present any problem in regards to direct or crossed allergenicity, and its fruits, in addition to being edible, present other properties of interest. This is the case of the carob tree (*Ceratonia siliqua*), whose fruit has recognized medicinal properties (Bruneton, 2001); hackberries from *Celtis australis* also have medicinal properties to combat amenorrhea, heavy menstrual bleeding and colic, in addition to being effective for the treatment of diarrhoea and dysentery (Demir et al., 2002), and locally to treat hypercholesterolemia (Benítez et al., 2010). The fruit also has a higher content of minerals, fats and proteins (Demir et al., 2002). The fruit of the strawberry tree (*Arbutus unedo*) is used in folk medicine for its astringent, diuretic and antiseptic properties, and for being a good resource of minerals, especially Ca, K, Na and Mg (Özcan and Haciseferogullari, 2007). All of them are therefore positioned in a prominent place in this list of species to be reinforced by Mediterranean UFF.

Although they are not strictly Mediterranean, there is also a promising scenario for tropical and subtropical species. Although the climate of Granada has features of a continental climate, with significant frost in the winter months, there have been some examples of kiwi (*Actinidia chinensis* (Siebold & Zucc.) Planch. ex Miq.), mango (*Mangifera indica* L.), avocado (*Persea americana* Mill.) and cherimoya (*Annona cherimola* Mill.) inside the city. All of these fruits are extensively grown on the provincial coast, 50 km from the city, where the humid conditions and warm temperatures make it known as the "Tropical Coast." Moreover, these species adapt well to low maintenance situations and the careful selection of a favourable planting site would enhance the plants' performance in any given climate (Goodell, 1982). Two relevant aspects regarding allergenicity should be taken into account. The first is the presence of allergens in the kiwi fruit (Chen et al., 2006), and the second is the cross-allergenicity between the *Parietaria* pollen and the fruit of *Annona cherimola* (Sánchez-Monge et al., 1999), since *Parietaria* pollen constitutes an important allergen in the Mediterranean area (D´Amato, 1998), and is present in the atmosphere of the city of Granada in relevant concentrations throughout the year (Díaz de la Guardia et al., 1998). Both the avocado (*Persea americana*) and the mango (*Mangifera indica*) come in numerous varieties adapted to a wide range of climatic conditions where they can even participate in the restoration of water flow in wetland ecosystems (Schaffer, 1998).

Finally, the pomegranate tree (*Punica granatum*) should be noted, not only because it is the symbol of the city of Granada, in which there are numerous specimens planted in squares, parks and gardens, and the image of the pomegranate is in a number of urban elements and decorations, but for the significant benefits that its use as a fruit tree can have. It has traditional medicinal uses in treatments for contraception, snakebite, diabetes, diarrhoea, haemorrhage, bronchitis and throat inflammation (Stover and Mercure, 2007; Benítez et al., 2010, 2017), due to the presence of triterpenoids, steroids, glycosides, saponins, alkaloids, flavonoids, tannins, carbohydrate and Vitamin C in its seeds, whole fruit and juice (Bhandary et al., 2012). Other recent uses are added that demonstrate their effects on a diverse array of biological actions that can be effective in the prevention of some inflammatory-mediated diseases, including cancer (Faria and Calhau, 2011). While noting the possibility of cross-reactivity between its seeds and the birch pollen (Gaig et al., 1999), the pomegranate also stands out as a fundamental element of the UFF of Mediterranean climate cities.

5. Conclusions

This study highlights the diversity of species that can be used in Urban Fruit Forests in Mediterranean cities and indicates some of the main ecosystem services that they can provide, either for consumption or medicinal use. But it also identifies some negative effects or disservices that should be considered. Special attention is paid to the causes that can generate allergy symptoms, due mainly to the allergenicity of pollen or to the presence of homologous allergens in fruits. This information allows us to establish a net balance of ecosystem services provided by urban forests, in which its nutritional and even medicinal potential should also be highlighted. The results of this analysis open a frontier of knowledge regarding ecosystem services beyond food provision.

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