



research project
**Urban Green
2021+**



New Trees for Future
Urban Landscapes

www.lwg.bayern.de

Stadtgrün 2021+

Due to climate change, traditional urban tree species suffer increasingly from drought stress and subsequently from pests and diseases.

In search of stress tolerant and climate proof urban trees, the Bavarian State Institute of Horticulture and Viticulture near Würzburg (LWG Veitshöchheim) has been testing 30 promising species for the past ten years.



The first batch of 460 study trees was planted in autumn 2009 and spring 2010. In 2015 another ten species/cultivars were added to this long term project called „Stadtgrün 2021+“ (i.e. „Urban Green 2021+“) involving the planting of 200 additional trees in three different climate regions across Bavaria. For every tree the plant hole measures 8 m³. The soil substrate used conforms to the „Recommendations for Tree Planting, Part 2“ (2010) of the German Research Council on Landscape Development and Landscaping (www.fl.de).

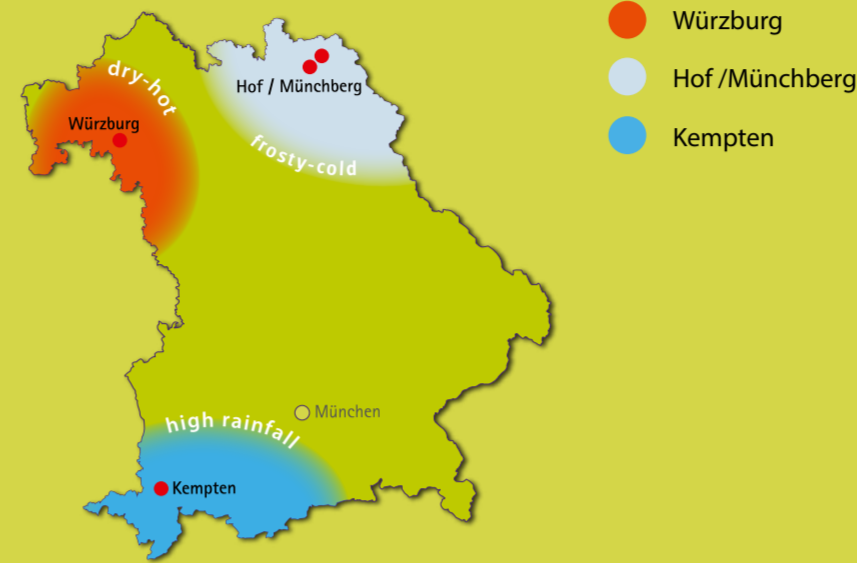
Criteria for sustainable urban tree selection:

- drought stress tolerance
- (late) frost hardiness
- natural habitat type („Lebensbereich“ according Peter Kiermeier)
- site requirements, particularly pH-tolerance
- pest and disease resistance (EPPO Alert List)
- landscape practitioners' feedback
- growth habit

Study sites across three Bavarian cities cover a wide range of climate conditions:

- Würzburg, „hot-spot“ suitable for testing drought and heat tolerance
- Hof/Münchberg, continental climate, suitable for testing (late) frost hardiness
- Kempten, mild and wet subalpine climate

Sites where individual tree species or cultivars have performed particularly well (so far) are highlighted in the description of the tree species under trial since 2010 with coloured dots as follows:



An annual monitoring of all trees is carried out, regarding frost and drought damage, crown vitality, pests and diseases as well as shoot and girth development. These long-term results provide the basis for the regional recommendations.

Since 2010 the

Bavarian Climate Tree Network

founded by LWG has been connecting public green space authorities to the project. Their local experience with the trees on trial, using a standardised interactive trial assessment sheet, is fed back into ongoing research activities at LWG. Currently there are 36 communities involved in the project which is open to further towns and cities in Bavaria who wish to join.

For further information and updates on the project (in German) please visit our website:

www.lwg.bayern.de/landespflege/urbanes_gruen/085113

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Tree species on trial since 2015

Acer opalus

Origin: Central and Southern Europe

Height: 8 to 12 (20) m; width: 5 to 10 m
Flowers: light yellow, March/April
Growth habit: crown oval to rounded, semi to open, sometimes irregular
Lebensbereich: 6.3.2.3

The **Italian Maple** occurs in Southern Europe up to Southwestern Switzerland where it thrives in mountain forests. In terms of soil conditions this maple is very adaptable, however it does not tolerate waterlogging or very heavy soils. Thanks to its origin this small to medium-sized tree benefits from warm microclimates and tolerates heat and drought well. Flowers appear early before leaves emerge and are highly attractive to insects. Striking autumn colour ranging from fiery orange to red tones. *A. opalus* is so far rarely cultivated in nurseries.



Acer rubrum 'Somerset'




Origin: Northeast to Southeast America

Height: 7 to 10 m; width: 6 to 8 m
Flowers: dark red, March/April
Growth habit: crown oval
Lebensbereich: 2.3.2.2

With its brilliant red autumn colours the **Red Maple** is an extraordinary Acer species. Not only the autumn foliage is striking but also its young shoots and flowers, the latter appearing before the foliage. The cultivar 'Somerset' is said to tolerate slightly alkaline soils, yet it also often shows chlorosis. In Würzburg, the trees had to be watered continuously during hot spells.

Eucommia ulmoides




Origin: Central and Western China

Height: ca. 15 to 20 m
Flowers: pale green, March to May
Growth habit: crown broadly domed
Lebensbereich: 6.3.2.3

So far, the **Hardy Rubber Tree** is rarely found in commercial cultivation. It is the only "rubber tree" species thriving in the temperate zone. *Eucommia* prefers moist or wet soils, but also tolerates drought spells. In terms of soil pH this species is adaptable. Overall plant health is very promising as no pests and diseases have been recorded as yet. This tree species has established well and grows vigorously at all study sites.

Juglans nigra




Origin: Eastern North America

Height and width: 20 to 25 (30) m
Flowers: pale green, April/May
Growth habit: crown initially broad to pyramidal, later broadly arched
Lebensbereich: 3.3.2.1

The **Black Walnut** is widely distributed in native US thriving both in fertile river basins and on more dry hillsides and slopes. As a solitary tree it develops a broad crown. It is fully hardy but prone to late frost damage and also windthrow in its youth. On deep soils this light demanding tree species develops a strong tap root. In the US it is a sought-after furniture wood which is very hard and heavy. The shell of the spherical fruit is also very hard, protecting a tasty nut inside.

Malus tschonoskii




Origin: Japan, Honshu

Height: 8 to 12 m; width: 4 to 5 m
Flowers: white, May
Growth habit: crown broad to pyramidal to oval
Lebensbereich: 3.1.3.3

In contrast to the usual growth habit of apple species and cultivars, the **Pillar** or **Chonosuki Crab Apple** develops a distinctive columnar to oval crown. Flowers and fruit are less decorative than in other apples but autumn colour is unrivalled. Fresh growth is grey and felty and foliage turns orange and purple at the end of the season. In our study this crab apple is vigorous and has established well. Root suckers may occur and need to be removed on a regular basis.



Sorbus latifolia 'Henk Vink'




Origin: Pyrenees to Central Germany

Height: up to 12 m; width: up to 6 m
Flowers: white, May
Growth habit: crown narrow conical, mature trees apparently broadening
Lebensbereich: 6.1.2.3

This cultivar of the **Broadleaved Whitebeam** shows a more narrow conical crown and faster growth. Leaves emerge white and felty, mature leaves are dark green and hairless on the upper leaf surface. In May creamy white flowers blossom, followed by small red roundish fruit in the autumn. As a deep rooting and heat resistant species, these trees show vigorous crowns with healthy foliage and thus meet all requirements for a decent small street tree.

Tilia americana 'Redmond'




Origin: East Canada, Northeast to Southeast America

Height: 18 to 22 m; width: 9 to 13 m
Flowers: pale yellow, June/July
Growth habit: crown initially pyramidal later oval
Lebensbereich: 3.3.4.1

This **American Linden** cultivar is rarely found in the German nursery trade as yet. Its dark green foliage turns yellow in autumn. The fragrant light yellow flowers open in June and are very popular with bees. This lime prefers sunny sites but tolerates shade better than many other large tree species. 'Redmond' is tolerant towards drought if it has been given enough time to establish. Like other *Tiliae* it is salt-sensitive. To develop its root system tree pits of sufficient volume are indispensable.



Tilia mongolica




Origin: Mongolia, Northern China

Height: 6 to 8 (15) m
Flowers: yellow, July
Growth habit: crown conical at first, broadly domed in mature trees
Lebensbereich: 6.3.3.3

The **Mongolian Lime** offers a range of remarkable characteristics but is rarely found in cultivation as yet. Growing to a maximum height of about 10 meters it is a rather small lime species. In contrast to other *Tilia* species, leaves are deeply lobed with serrate edges. Aphids are rarely recorded on this lime tree. The fragrant flowers appear in July. Corresponding to its origin the Mongolian Lime tolerates dry soil conditions as well as exposure to heat, but seems to be somewhat frost sensitive.



Ulmus 'Rebona'




Origin: selected from the Resista breeding lines of elms

Height: up to 25 m; width: up to 10 m
Flowers: pale green, March/April
Growth habit: crown wide to conical
Lebensbereich: 9.3.3.2

The cultivar '**Rebona**' is one of the many reliable selections resistant to Dutch Elm Disease that can be recommended for roadside planting. Growing fast as a young tree, it develops a slender, dense and regular crown that should be thinned well in time. The mature tree shows a broader and more voluminous crown. It should not be planted in too large numbers, as it can be attacked by the Elm zigzag sawfly that can lead to complete defoliation.

Acer buergerianum



Origin:
Japan, China

Height: 8 to 10 m; width: 4–6 m
Flowers: yellow, May
Growth habit: erect, light crown
Lebensbereich: 3.1.1.3

The **Trident Maple** is native to the mountain forests of Japan. It tolerates heat but is not fully hardy. It tends to suffer from trunk fissures and is sensitive to salt. Drought and/or salt stress lead to mass fructification. Road space requires regular pruning of overhanging branches, which in sum makes it a less suitable tree for street side planting.

Acer monspessulanum



Origin:
Middle / Southern Europe, Asia Minor

Height: 5–8 m; width: 4–7 m
Flowers: yellowgreen, May
Growth habit: broad oval
Lebensbereich: 6.3.2.3

The **Montpellier Maple** originates from the Mediterranean and is said to be very heat and drought tolerant. It is a small to medium sized tree with leathery foliage that has no particular requirements and shows far more frost hardness than expected. It prefers chalky soils and does not tolerate shading. Regular pruning every 2-3 years is necessary to maintain a vigorous crown.

Alnus x spaethii



Origin:
bred by Spätsche
Baumschulen, Berlin (GER), 1908

Height: 12 to 15 m; width: 6 to 8 m
Flowers: brown/yellow, January
Growth habit: broad pyramidal
Lebensbereich: 2.4.3.3

The **Speckled Alder** is a hybrid of *A. japonica* and *A. subcordata*. Even though this tree has been available for some time, its potential has not been fully recognized as yet. It forms an excellent regular crown and is highly adaptive. Thanks to its self-sufficient nitrogen fixation it thrives even on the poorest soils. It is also salt-tolerant. However, its pollen, that often begins to disperse already in December, has a high allergic potential.



Tree species on trial since 2010

Carpinus betulus 'Frans Fontaine'



Origin:
Europe,
selected in Eindhoven (NL), 1983

Height: 8 to 10 m; width: 2 to 3 m
Flowers: green, May
Growth habit: narrow pyramidal
Lebensbereich: 3.1.6.2

The **Common Hornbeam** is one of the few tree species native to Germany that thrive under dry and hot conditions. With 'Frans Fontaine' a less known cultivar is under trial in our project, that as a mature tree maintains a much more slender crown than 'Fastigiata'. However, it is salt-sensitive and carries a high risk of frost induced trunk fissures as a young tree that do not cover up well or not at all. At temperatures near 40 °C it shows radiation damage. Thus, it should preferably be planted in partial shade.

Celtis australis



Origin:
Southern Europe,
North Africa, West Asia

Height: 15 to 20 m; width: 10 to 12 m
Flowers: inconspicuous, May
Growth habit: round, umbrella to shaped once mature
Lebensbereich: 6.3.1.2

Hackberry is one of the most important street trees in the larger cities of Southern Europe. Due to its high resistance to UV radiation and good health, Celtis is so far regarded as a reliable alternative to the disease-ridden Plane Tree. However it is only suited for mild winter sites as all specimen planted in Hof/Münchenberg died during heavy frost periods. So far its growth development is rather limited.

Fraxinus ornus



Origin:
Southern Europe, Asia Minor

Height: 8 to 10 m; width: 4 to 8 m
Flowers: white, May/June
Growth habit: broad pyramidal
Lebensbereich: 6.3.1.3

The **Manna Ash** has proven to be reasonably hardy and able to recover from late frost damage. As a street tree it benefits from its heat and drought tolerance in its natural environment in Southeastern Europe. Apparently, it does not suffer from Ash Dieback. The flowers in May are very decorative and popular with bees. Strongly fruiting specimen show diminished growth.

Fraxinus pennsylvanica 'Summit'



Origin:
North America,
selected in 1957

Height: 14 to 16 m; width: up to 3 m
Flowers: yellowgreen, April
Growth habit: oval, round once mature
Lebensbereich: 2.5.3.1

With its low growing requirements the **Green Ash** has almost the character of a pioneer tree species. Its good resistance to Ash Dieback and decorative yellow/violet autumn colour makes it a serious alternative to the Common Ash. Because of its dichotomous growth, it tends to develop a secondary crown. The male cultivar 'Summit' has no invasive dispersal potential.



Ginkgo biloba



Origin:
China

Height: 15 to 20 m; width: 10 to 15 m
Flowers: inconspicuous, April/May
Growth habit: initially conical, broad once mature
Lebensbereich: 6.3.2.1

The **Maidenhair Tree**, a slow-growing species with a sparse crown, seems to be immune to pests and diseases. The wood of the new growth hardens late and often leads to frost damage at exposed sites, particularly in continental climate regions. Autumn colour of the leathery fan-shaped leaves is a spectacular bright yellow. As there is some ongoing confusion about its cultivars – for our study a male selection has been chosen.

Gleditsia triacanthos 'Skyline'



Origin:
North America,
selected in 1957

Height: 12 to 15 m; width: 5 to 7 m
Flowers: lightgreen, June/July
Growth habit: broad oval
Lebensbereich: 2.5.1.1

The **Honey Locust** has remarkably low growing requirements. Its light crown allows for a range of underplanting options. Among the thornless cultivars 'Skyline' might be the most popular one at the moment which only bears fruit once matured. Due to its wide crown that usually develops no central leader it is only suitable for broad streets and green strips.

Liquidambar styraciflua



Origin:
East / North America

Height: 10 to 20 m; width: 6 to 10 m
Flowers: greenish, May
Growth habit: conical, round later on
Lebensbereich: 2.3.1.2

With its habitus the **American Sweetgum** resembles a maple tree. However the species is easily identified by its airfilled cork strips. These grooves appear like scales, giving the name Alligator-wood. Though said to be lime-sensitive it copes well with pH-levels > 7 in well-aerated soil substrates. It is one of the finest autumn colour trees. In our study it shows good frost hardness so far but is prone to storm and snow load damage.

Magnolia kobus



Origin:
Japan

Height: 8 to 10 m; width: 4 to 8 m
Flowers: weiß, April
Growth habit: broad oval once matured
Lebensbereich: 3.2.2.3

The **Northern Japanese Magnolia** is a medium-sized tree with a well-developing crown and beautiful showy flowers making it particularly suitable for residential areas. It is fully hardy and prefers cool sites, however it is sensitive to salt. It tolerates heat as long as trunk protection is sufficient thus preventing trunk fissures.

Ostrya carpinifolia



Origin:
Southern Europe, Asia Minor

Height: 10 to 15 m; width: 8–12 m
Flowers: yellowgreen, April
Growth habit: broad oval
Lebensbereich: 6.3.3.3

The **Hop Hornbeam** is a close relative of the Common Hornbeam, *Carpinus betulus*. As a street tree it takes advantage of its high drought and heat tolerance in its native environment of sunny hill sides and light woodlands in the south-east of Europe. Neither strong fructification nor high temperatures seem to impair its growth rate.

Parrotia persica 'Vanessa'



Origin:
North Iran, South Russia

Height: 6 to 10 m; width: 6 to 10 m
Flowers: red, March
Growth habit: oval, round later on
Lebensbereich: 2.3.2.4

An extraordinarily adaptable tree is the **Persian Ironwood** which grows in almost any soil. It originates from warm and humid deciduous woodlands and withstands frost and drought, however it "burns" during extreme long lasting heat periods. As the mature tree will develop a very broad crown, the slender cultivar 'Vanessa' is recommended. It is particularly attractive in autumn, when the foliage turns from purples to oranges and yellows over a long period of time.

Quercus cerris



Origin:
Central / Southern Europe, Asia Minor

Height: 20–30 m; width: 10–20 m
Flowers: golden catkins, May
Growth habit: broad conical
Lebensbereich: 6.3.2.1

In its natural environment in the Balkan region, the **Turkey Oak** grows alongside with *Fraxinus ornus* and *Ostrya carpinifolia*. It loves limey ground and on trial it has proven as fully hardy and particularly drought and heat resistant. Unfortunately it is a preferred host species of the oak processionary moth which makes this beautiful and resilient tree less suitable for urban plantings. Thus it should only be planted solitary or as part of mixed alleys to keep the infestation risk low.

Quercus frainetto 'Trump'



Origin:
Southeast Europe,
Asia Minor
selected in Wageningen (NL), 1979

Height: 15 to 20 m; width: 8 to 10 m
Flowers: golden catkins, May
Growth habit: broad oval
Lebensbereich: 6.3.2.1

The **Hungarian Oak** is another very beautiful and vigorous species from the wide range of thermophilic and drought tolerant oaks. If no seedlings are available, it is important to obtain nursery stock that is grafted onto *Q. frainetto* or *Q. cerris* to minimize long-term incompatibility issues. At the moment this oak has limited availability in the trade due to rising demand.

Quercus x hispanica 'Wageningen'



Origin:
Southeast Europe
selected in Wageningen (NL), 1979

Height: 10 to 15 m; width: 6 to 8 m
Flowers: pale yellow, May
Growth habit: upright conical
Lebensbereich: 6.3.2.1

The **Spanish Oak** is a natural bastard between *Q. cerris* (Turkey Oak) and *Q. suber* (Cork Oak) that can be found from Spain and Southern France to the Balkan region. It is a versatile, lime loving and drought tolerant tree which, even though it is semi-evergreen, proves to have a very hardy crown. High losses under trial are due to incompatibility problems of scion and understock (*Q. cerris*).

Styphnolobium japonicum 'Regent'



Origin:
China, Korea
selected in Princeton (USA), 1964

Height: 15 to 20 m; width: 8 to 10 m
Flowers: creamwhite, July/August
Growth habit: broad oval
Lebensbereich: 6.1.2.2

The **Japanese Pagoda Tree** stands out with its high heat and drought tolerance. On sites with a more continental climate young specimen are not fully hardy and might develop trunk fissures. Meanwhile it shows vital growth at all study sites. This cultivar does not develop a central leader which makes it mainly suitable for broad planting strips. Bees benefit from the late flowering in July.



Tilia tomentosa 'Brabant'



Origin:
Southeast Europe,
Asia Minor
selected in the Netherlands

Height: 20 to 25 m; width: 12 to 18 m
Flowers: yellow, July/August
Growth habit: broad conical
Lebensbereich: 6.3.2.1

Among all Linden trees, the **Silver Lime** is considered to be one of the "future trees" thanks to its high resilience towards drought stress. It is less susceptible to upper crown dieback caused by the saprophyte *Stigmina pulvinata* and is avoided by aphids due to its silvery-felted lower leaf surface. The most important cultivar with a regular crown and central leader is 'Brabant'. Even though classified as hardy, at our cold trial site Hof it suffered from recurring frost damage. In contrast to native linden, juvenile specimen of this cultivar do not tolerate shade.

Ulmus 'Lobel'



Origin:
selected in
Wageningen (NL),
1973

Height: 12 to 15 m; width: 4 to 5 m
Flowers: pale green, March/April
Growth habit: initially narrow,
later conical
Lebensbereich: 9.3.3.2

Essentially, elms are very adaptable trees that should once again be planted more frequently. The **Lobel Elm** has proven to be largely resistant to Dutch elm disease. It comes with dense darkgreen and longlasting foliage. As a windproof species it can be planted in coastal regions. As juvenile trees they need to be pruned regularly to achieve a balanced crown.

Zelkova serrata 'Green Vase'



Origin:
Japan, Korea, China
selected in USA, 1983

Height: 15 to 20 m; width: 9 to 12 m
Flowers: green, April/May
Growth habit: wide funnel shaped
Lebensbereich: 3.1.2.2

In Japan the **Zelkova** is an important street tree. Frost might lead to trunk fissures but otherwise it is healthy, fast growing and surprises with striking oranges and dark reds in autumn. The cultivar 'Green Vase' is usually trained to a V-shaped crown that doesn't allow pruning to the minimum clearance zone which makes it unsuitable for street side planting. Also, as a light demanding species it does not tolerate shading.