Evaluation of seven drought tolerant tree species for central California

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Climate change poses challenges for the Southwest, where an already parched region is expected to get hotter and, in its southern half, significantly drier (Garfin et al. 2013). Increased heat and sustained drought will stress water sources and redefine urban landscapes. As landscapes gradually evolve from lush to xeric, tolerance of trees to water-related stress resulting from excess irrigation today and deficit irrigation tomorrow will become increasingly important. This article describes a 14-year evaluation of seven drought tolerant species that were obtained from a nursery in the arid southwest and planted in central California. It assesses their survival, growth, and water tolerance under a variety of site conditions. Arborists can use this information to help determine if any of these trees merit further testing and evaluation in the landscapes where they work.

In July 1999 Mountain States Wholesale Nursery (Glendale, AZ) delivered forty-two 24-inch boxed trees (61 cm) of seven different species with six individuals of each species to the city of Modesto, CA and the US Forest Service in Davis, CA. The ten trees delivered to Modesto were planted in McKinley Park. However, they were not routinely monitored and are not included in results reported here. The thirty-two remaining trees were planted in a variety of locations in Sacramento and Davis.

- Reichmuth Park in Sacramento, CA – south end of the park, moderate use area, poorly irrigated turf
- Northstar Park in Davis, CA – in planting beds adjacent to the soccer field, initial irrigation
- UC Davis Arboretum and Department of Environmental Horticulture grounds – in well-irrigated turf and planting beds
- UC Davis Orchard Park – dry grass area adjacent to parking, minimal, if any, maintenance and irrigation
- Two residential landscapes in Davis, CA – in areas mulched with shredded bark or decomposed granite, hand watering during establishment and very little irrigation thereafter.

Trees were surveyed annually from 2000 to 2009 and again in 2013. Tree growth is reported based on measurements of diameter at breast height (to nearest 0.1 cm with dbh tape), tree height (to nearest 0.1 m with range pole or hypsometer), and average crown diameter (average of two perpendicular measurements with tape to the nearest 0.1 m). When it was possible to observe tree removal, potential causes of mortality were noted. Mortality was calculated as the percentage of dead trees after 14

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Figure 1. (Left) Texas red oak at a residence in Davis, CA (2009).

Figure 2. (Right) Deeply lobed leaves of the Texas red oak (2014).

years. Tree growth rates are described in terms of mean annual increments (MAI), where MAI for a species during year i is:

$$\mathbf{MAI_i = MAI_{i+1} - MAI_i}$$

The MAI for the entire observation period of n years is:

$$\mathbf{MAI_n = 1/n \sum^{n}_{i=1} MAI_i}$$

The nursery provided brief descriptions of each species summarized below (Gass 2000, Mountain States Wholesale Nursery 2003).

Figure 3. (Left) Escarpment live oak in the UC Davis Shields Oak Grove (2014).

Figure 4. (Right) Leaves of the escarpment live oak are dark green on top and lighter beneath (2014).

Quercus buckleyi (syn. *Q. texana*) or Texas red oak is a drought tolerant west Texas native found growing in the hill country west of San Antonio and closely related to the Shumard oak (*Quercus shumardii*). It is a deciduous tree that grows 30 to 40 ft. (9.1 to 12.2 m) tall and wide with a dense, upright crown that becomes rounded with age (**Fig. 1**). The leaves are classic oak with five prominent lobes, dark green and shiny on top, paler below (**Fig. 2**). They turn burgundy to brilliant scarlet in the fall.

Quercus fusiformis or escarpment live oak is native to alkaline soils in west Texas. This cold-hardy evergreen grows 40 to 50 ft. (12.2 to 15.2 m) tall and wide and its thick crown provides dense shade (**Fig. 3**). Its small leaves resemble southern live oak (*Quercus virginiana*), with which it hybridizes (**Fig. 4**). However, it is much more tolerant of high temperatures and drought.

Quercus muhlenbergii or chinquapin oak comes from seed collected in west Texas from smaller growing trees than relatives in the eastern U.S. It grows 30 to 40 ft. (9.1 to 12.2 m) tall and wide, forming a long-lived shade tree (**Fig. 5**). Its crinkly, lush green leaves are deciduous and turn orange to bronze in the fall (**Fig. 6**). It prefers well-drained soil and grows surprisingly fast, even in low desert heat.

***Parkinsonia* (formerly *Cercidium*) hybrid 'Desert Museum'.** The Desert Museum palo verde (DM palo verde) is the result of a three-way hybridization between *P. microphylla*, *P. aculeata*, and *P. florida*. This tree grows 20 to 30 ft. (6.1 to 9.1 m) tall and wide and is thornless and fruitless (**Fig. 7**). The smooth green bark and yellow flowers are very attractive. It is well-suited for dry areas with well-drained soil.

Figure 5. (Left) Chinquapin oak (2009).

Figure 6. (Center) Chinquapin oak leaves are large with a dentate margin (2014).

Figure 7. (Right) DM palo verde at a residence in Davis, CA (2012).

Figure 8. (Left) LH desert willow at a residence in Davis, CA (2001).

Figure 9. (Right) Leaves and a flower bud of LH desert willow (2014).

***Chilopsis linearis* Lucretia Hamilton™** (LH desert willow) is a small deciduous tree 15 to 20 ft. (4.6 to 6.1 m) tall and wide with light green leaves that give it a weeping appearance (**Fig. 8**). In summer it is covered with showy deep pink to purple flowers (**Fig. 9**). After flowering it produces long narrow seed pods that persist and can look messy. The tree is thornless and prefers full sun and well-drained soils.

***Pistacia* x 'Red Push'** The Red Push pistache (RP pistache) is a hybrid between *P. atlantica* and *P. integerrima* with compound leaves which emerge with a distinctive red color, hence the name Red Push (**Fig. 10**). It has a lovely display of red, orange, and yellow color in the fall. It develops a broadly oval crown with a height and width of 30 to 40 ft. (9.1 to 12.2 m) (**Fig. 11**). The tree can adapt to a variety of soils and is deep-rooted. Although somewhat gawky when young, it is fast growing, non-allergenic, and long-lived.

***Prosopis alba* Colorado™** or Colorado mesquite is grown from rooted cuttings. The result is a lush and thornless mesquite growing to 40 ft. (12.2 m) tall and wide (**Figs. 12, 13, and 14**). The tree is cold tolerant (16°F) and briefly deciduous in the spring. It is rapid growing and will tolerate lawn irrigation. Colorado mesquite is no longer grown, having been replaced by superior clonal varietal selections such as Phoenix™ and Maverick™.

Table 1.
Number of trees alive and dead 14 years after planting.

Species	Alive	Dead	Total	Mortality
DM palo verde	0	6	6	100%
LH desert willow	1	3	4	75%
RP pistache	2	2	4	50%
Colorado mesquite	3	1	4	25%
Texas red oak	5	0	5	0%
Escarpment live oak	2	2	4	50%
Chinquapin oak	5	0	5	0%
Total	18	14	32	44%

Figure 10. (Left) Odd-pinnately compound leaves of the RP pistache (2014).

Figure 11. (Right) RP pistache on the UC Davis campus (2014).

RESULTS

Survival

Eighteen (56%) of the thirty-two trees planted were alive after 14 years (**Table 1**). The Texas red oak and chinquapin oak experienced zero mortality. The Colorado mesquite lost only one tree of the four planted followed by the escarpment live oak and RP pistache with 50% mortality

Figure 12. (Left) Colorado mesquite develops low branches to shade the surrounding soil (2013).

Figure 13. (Right) Even-pinnately compound leaves give an airy appearance to the Colorado mesquite (2014).

(Table 1). The LH desert willow had one survivor out of four after 14 years and the DM palo verde experienced 100% mortality.

Growth

Growth tended to follow a logistic curve for dbh, height, and crown diameter (Fig. 15). Generally, growth was slow the first two years, but became relatively rapid three to four years after planting. The mean tree size dimensions plotted in Figure 15 decrease some years due to the effect of removing a relatively large tree from the small sample. In addition, some trees were multi-trunked (DM palo verde and LH desert willow) and occasionally trunks were removed when trees were pruned.

Colorado mesquite, escarpment live oak, and RP pistache had the greatest mean annual increments (MAI) of dbh growth (1.1 to 1.2 in., 2.8 to 3 cm), while LH desert willow (0.2 in., 0.5 cm) had the least (Table 2). After fourteen growing seasons, the mean dbh for the five largest species exceeded 7 in. (17.8 cm) ranging from 11.1 to 12.5 in. (28.2 to 31.8 cm) for the largest species, Colorado mesquite, escarpment live oak, and RP pistache (Table 3).

The three oak species and the Colorado mesquite exhibited the fastest height growth. Their MAIs ranged from 1.7 to 2.5 ft. (0.5 to 0.8 m) and their height after fourteen years ranged from 24.7 to 33.1 ft. (7.5 to 10.0 m) (Table 3). The RP pistache was within range of the largest species, reaching 23.6 ft. (7.2 m) in 2013, while the LH desert willow was the shortest at 10.5 ft. (3.2 m) (Table 3).

The MAI for crown diameter (Cdia) growth ranged from 2.5 to 3.2 ft. (0.7 to 1.0 m) for all species except LH desert willow (0.8 ft., 0.2 m). After 14 years, the Colorado mesquite's mean crown spread (34.2 ft., 10.4 m) exceeded its mean height (24.7 ft., 7.5 m) (Table 3). The next most spreading trees were the escarpment live oak, RP pistache, and chinquapin oak ranging from 27.7 to 31.7 ft. (8.4 to 9.7 m) (Table 3). The spread of the LH desert willow (10.6 ft., 3.2 m) was equal to its height (Table 3).

Drought tolerance

According to the "*The Water Use Classification of Landscape Species*" (WUCOLS, Costello and Jones 1994)

Figure 14. Catkins on the Colorado mesquite in spring (2014).

Table 2. Mean annual increments (MAI) of growth over the 14 year period.

Species	DBH (in)	Height (ft.)	Cdia (ft.)
DM palo verde	0.0	0.0	0.0
LH desert willow	0.2	0.5	0.8
RP pistache	1.1	1.5	2.8
Colorado mesquite	1.2	1.7	3.2
Texas red oak	0.7	2.3	2.5
Escarpment live oak	1.1	1.7	3.2
Chinquapin oak	0.9	2.5	2.7

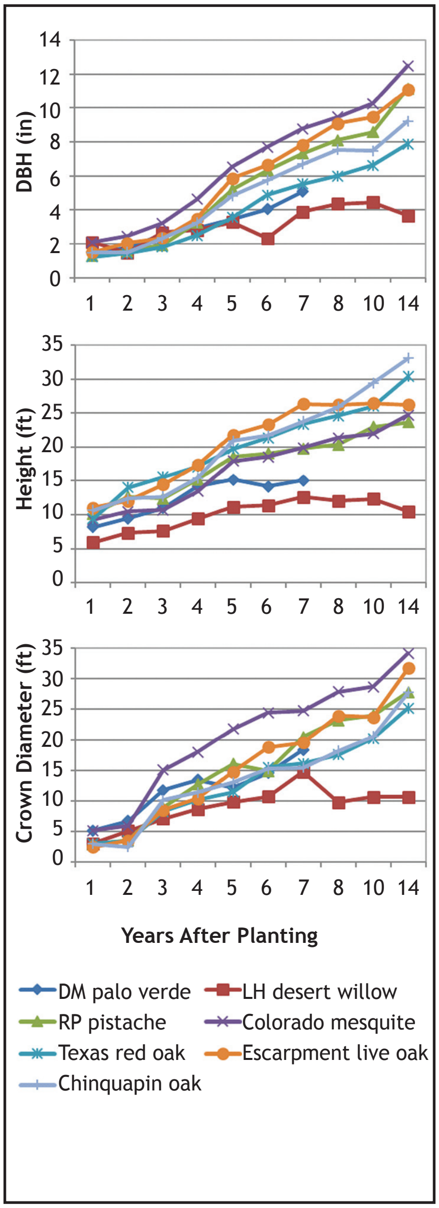

Figure 15. Mean dbh, height, and crown diameter for each species.

ratings, LH desert willow and DM palo verde require very low amounts of irrigation in standard central California landscape settings. Colorado mesquite, RP pistache, and chinquapin oak are rated low. Texas red oak and escarpment live oak are not assessed, while *Q. shumardii* and *Q. virginiana* are rated moderate. The drought tolerance of the three oaks in their native habitat is reported to increase from chinquapin oak to Texas red oak to escarpment live oak (Pace 2011).

Based on field observations and measurements, Colorado mesquite, escarpment live oak, and Texas red oak performed well in locations that received minimal irrigation. The three oaks, Colorado mesquite, and RP pistache thrived in amply irrigated turfgrass with well-drained soils. In one case, Texas red oak leaves yellowed and growth was stunted when over-watered in compacted clay soil. Introductions that grow natively in well-drained soils in Texas appear to require periods of drying between irrigation applications. Poorly drained soils may limit success of these species in central California. Further testing is needed to evaluate their tolerance to a variety of local soils and irrigation regimes.

Maintenance

The relative amount of maintenance that each species requires is subjective and largely based on our observations. The Texas red oak and RP pistache established excellent structure with well-developed leaders and strong branch attachments that required virtually no pruning. Because their crown growth was less regular, escarpment live oak and chinquapin oak benefited from occasional pruning for structure and form. The oaks and RP pistache were also well anchored in the ground. Colorado mesquite and DM palo verde required extensive pruning. They retained low branches, an adaptive trait that shades the ground and creates a sheltered soil surface conducive to root growth. Annual crown raising was required for these species when located in plazas, patios, and other trafficked areas. Thinning was required when crown growth became rampant because of ample irrigation. Colorado mesquite and DM palo verde were prone to wind-throw because the roots were shallow and not able to support their lush crowns during winter storms. Toppling was the primary reason these trees were removed. The root systems of these desert species are naturally shallow to take advantage of sparse rainfall that quickly runs off site. With DM palo verde in particular, heavy clay soils in central California may further inhibit deep rooting patterns. Phoenix™ and Maverick™ are improved mesquite cultivars that merit testing.

Pest and disease vulnerability are based on relative rankings from the Pest Vulnerability Matrix for Northern California trees (Lacan and McBride 2008). Oaks are host to a large number

Table 3. Mean sizes and standard errors (SE) 14 years after planting.

Species	DBH (in.)	SE	Height (ft.)	SE	Cdia (ft.)	SE
DM palo verde	0.0	0.0	0.0	0.0	0.0	0.0
LH desert willow	3.7	0.0	10.5	0.0	10.6	0.0
RP pistache	11.1	1.0	23.6	0.8	27.8	1.2
Colorado mesquite	12.5	6.5	24.7	1.3	34.2	1.8
Texas red oak	7.9	3.6	30.4	0.7	25.2	1.1
Escarpment live oak	11.1	3.5	26.2	0.9	31.7	2.1
Chinquapin oak	9.2	2.7	33.1	1.1	27.7	0.7

of pests and diseases that can threaten their health. Some of the most serious and abundant pests are Asian ambrosia beetle (*Xylosandrus crassiusculus*), mildew (*Erysiphe* sps.), Goldspotted oak borers (*Agrilus coxalis*), oak root fungus (*Armillaria mellea*), and sudden oak death (*Phytophthora ramorum*) (deciduous oaks only). RP pistache is susceptible to caterpillars (*Manduca* sps.), but resistant to verticillium wilt (*Verticillium* sps.). Colorado mesquite and DM palo verde are susceptible to desert mistletoe (*Phorodendron californicum*). Infestations require sanitation pruning. Although other pests can afflict these species, their impacts are usually minor.

Landscape uses

Recommendations on appropriate landscape uses in central California are based on initial observations made for a brief part of their full life span. The oaks appear to be most suitable for parks, wide medians, and other relatively large planting sites. It should be noted the oaks produce mast that can be messy to clean up. The smaller and more compact growing RP pistaches are best suited for campuses, yards, streets, and near buildings. Colorado mesquites will require frequent pruning when located in high-traffic areas and also produce pods that may be a burdensome litter. They appear to be best suited for low maintenance buffers along the periphery of parking lots, commercial, industrial and institutional sites. LH desert willows may be effectively used as specimen trees in smaller settings, as well as buffer trees. Although DM palo verdes have potential as specimen trees, initial results of high mortality suggest that this cultivar may not be well suited to growing conditions in central California.

Conclusions

Thorough testing and evaluation is a critical step in the process of diversifying our urban forests with new introductions that are well adapted and resilient to a changing climate. New pests, more extreme weather events, diminishing space for trees, and decreasing funds for tree care are growing threats to tree health in most communities. Arborists are challenged to select tree species to plant that are adapted to current conditions, such as tolerance to excess irrigation, as well as future conditions, such as tolerance to drought. This evaluation of seven drought tolerant species provides initial indications of their landscape performance.

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