Better Root Systems with Gravel Beds

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After natural disaster, restoring tree canopy cover is often desired.

Or sustainably replacing trees in cities after older trees are removed may be the objective.

Maintaining a gravel bed for tree planting stock is inexpensive and allows a city to put more trees in the ground compared to B&B or containerized trees.

Tree planting can be expensive


Image courtesy of Deeproot

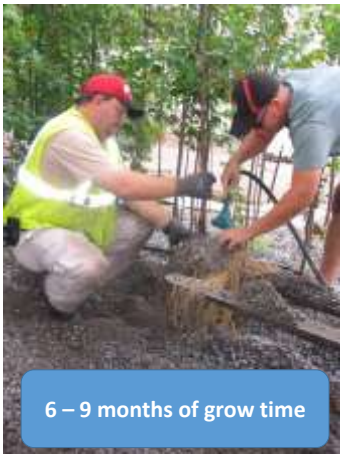

A.M. Leonard Horticultural Tool and Supply Co.

- Large trees are heavy
- Expensive
- Need heavy equipment and labor to move them
- Added costs on top of cost of tree
- Can’t use volunteers for this work

Planting bare-root trees is much less expensive

- Tree stock is much less expensive
- Smaller trees without the soil
- Lighter for volunteers
- No heavy equipment needed (hand dug holes)
- Easier to plant trees at proper depth

What is a Gravel Bed?



- Concept developed by Chris Starbuck at University of Missouri
- Extends the bare-root tree planting window to year round

How does it work?

Hydroponics

Gravel = Macropores

It can be a raised bed or belowground

Advantages

- Inexpensive
  - Trees
  - Bedding materials
- Reusable
- Low maintenance
- Extends tree planting window
  - Year round planting
- Grows abundant fibrous roots
  - Reduces transplant shock
  - Ensures proper planting depth and root orientation

- Bare-root tree stock is generally less expensive
- Gravel bed materials can also be inexpensive especially if the bed is reused year after year
- Once the watering regime is standardized maintenance of the bed is low (occasional weeding may be needed)
- Gravel beds provide a city with a ready stock of planting material when the city is ready to plant (not just during the winter months)
- Trees from the gravel bed have abundant root systems so transplant shock is minimized
- Being able to see where the root collar is allows for proper planting depth
- The roots can be oriented at planting to ensure that no circling roots cause problems for the tree later in life

Trade-offs

- Typically smaller planting stock
  - But can try to use larger trees
- Size can limit planting location
- Vandalism concerns
- Theft
- Animal destruction

- Sacrifice smaller size for quicker establishment and growth

- Bare root trees from the nursery are generally smaller (< 1" caliper), but larger bare-root trees have shown success in gravel beds
- Smaller trees may be abused by humans (vandalized) in high traffic areas, so this can limit where these trees can be planted
- Because of the smaller size, newly-planted trees are vulnerable to theft and animal destruction
- Smaller trees have the ability to establish quickly and adapt better to its environment than larger trees

Gravel Bed Construction - Location

- Near water source
  - Standard spigot
- Relatively flat ground
  - Ensure even watering
- Adequate access on all sides of bed
  - For extracting trees
- Canopy on SW side of bed
  - Tree canopy
  - Removable shade cloth
  - To prevent sun-scald

These next few slides discuss construction considerations for a gravel bed

- Locate the bed near a common water spigot or other water source
- The ground should be relatively flat to ensure even belowground moisture levels
- Ensure that you have adequate access on all sides of the bed to make tree extraction easier
- It may be desirable to provide some shade on the southwest side of the bed to prevent sunscald

Gravel Bed Construction - Materials

- 24’ x 16’ x 18” frame
  - 12’/16’ treated 2x10
  - Linked with treated 4x6
  - Rebar to hold shape
- Lined with 6 mil plastic
  - Over-lapped
  - To help hold water
- 4” galvanized lag bolts

At the Athens/Clarke County Landscape Services facility, we constructed a 24’ by 16’ bed using stacked, treated 2x10’s to give a bed depth 18”. We tied the sides together using treated 4x6 and rebar was used to prevent warping of sides after filled with gravel. The bed was lined with a 6 mil plastic to help hold moisture.

Gravel Bed Construction - Materials

- ½” pea gravel
  - Ask for river rock
    - Don’t use limestone
  - #67 crushed granite
  - 21 yd^3 (30 tons)
- M10 sand
  - Moisture retention
  - Asked for 4 tons
  - Delivered 10 tons
- Hydrogel
  - 4 - 5 lbs.
  - Moisture retention
  - Not essential

The gravel fill was about 30 tons of ½” (#67) crushed granite.
I ordered pea gravel, thinking that I would get river rock.
Make sure you ask for river rock and not just pea gravel because the supplier’s terminology and your terminology may not be the same.
DO NOT use a rock material that has the potential of changing the belowground water pH (like limestone).
We also used course sand to help with moisture retention.
I asked for four tons, but 10 tons were delivered (and purchased).
This is one limitation to managing a project from a distance.
We also used a very small quantity of fine-grain hydrogel in the mix to help with moisture retention.

Gravel Bed Construction - Plant Material

- Local nursery
  - 2-year-old bare-root liner stock
  - Lifted in January and planted in bed
- 'Princeton' American elm
  - 30 @ $10 each
- 'Bosque' Chinese elm
  - 20 @ $8 each
- 'Aeryn' trident maple
  - 20 @ $10 each
- Eastern redbud
  - 30 @ $8 each
- 0.66" – 0.75" caliper

From a local nursery that provided bare-root planting stock to the public, we purchased 30 each Princeton elm and eastern red bud, and 20 each Chinese elm and trident maple.
All trees were between 2/3 to ¾ inches at caliper.

Gravel Bed Construction - Material Costs

Material Type	Cost
Framing and miscellaneous supplies lumber, liner, bolts, fertilizer, water hose, timer	$ 525
Fill material rock and sand	$ 625
Plant material	$ 900
Total	**$ 2050**

The cost for this bed (not including labor) was around $2000.
River rock may be more expensive and could bring the final cost to about $3000.

Growing and Maintaining Trees

- Gravel = macropores
- Water requirements
  - 4 times per day
  - 3-4 minutes per cycle
- Nutrient requirements
  - Slow release fertilizer
    - Osmocote 14-14-14
  - 2 applications per year
    - May – 3 lbs N/1000 ft^2
    - August – 1.5 lbs N/1000 ft^2
      - optional

Because of the macropores inherent from using gravel as a growth medium, water and nutrients needed to be supplied.
Soaker hoses and a $30 timer was used to maintain moisture levels. We used a 3 to 4 minute water cycle four times per day
We also used a complete, slow-release fertilizer to ensure adequate plant growth/function.
In May, we applied complete fertilizer at a rate of 3 lbs N per 1000 sq. ft.
In August, we supplemented that initial fertilization with 1.5 lbs N per 1000.

Planting Depth in a Gravel Bed

Since we weren't sure how much water was going to accumulate on the bottom of our bed, we decided to set our trees higher in the profile.
We didn't want the roots to be under water.
Unfortunately, many trees were not deep enough and resulted in leaning.
We used metal stakes to hold the trees upright.
In hind sight, we could have set our trees deeper in the gravel to help keep them upright.

Extracting Trees from a Gravel Bed

Manual Extraction - Broadfork

Easydigging.com

Mechanical Extraction

When it comes time to out-plant your trees, you could extract the trees from the gravel bed manually using a broadfork.
This may result in some of the roots breaking.
We used a Bobcat equipped with forklift tines to slide under the gravel and lift the trees.
This required us to remove one side of the gravel bed form to access the trees.

Lifting Operation - August 24, 2011
Removal of framing

The next several slides show our lifting and out-planting operation.
Although later than we had originally anticipated, we lifted our first set of trees to be out-planted in August.
After removing a portion of the wooden frame so that a bobcat could gain access to the selected trees, we saw that roots had grown to the frame some 24” from the first row of trees.

Lifting Operation - August 24, 2011

Copious amounts of water needed to remove gravel from roots

We improved our efficiency for lifting, but as we anticipated, the gravel, because of its angular structure, was contained by the fibrous roots.
We had to use a lot of water to help remove as much of the rocks and sand as possible.

Lifting Operation - August 24, 2011

Typical root structure of lifted trees

Princeton elm

Here is a typical root system for the lifted trees.
This particular tree is Princeton elm.

Here is a root system for trident maple

Moving trees to the planting site

Roots were covered with moist mulch

Trees were protected from the wind

To prevent desiccation of roots while transporting the trees to their out-planting location, roots were covered with moist mulch, and the tree leaves were protected from the wind with landscape cloth.

Planting operation – August 24, 2011

Very dry conditions

Ensure adequate soil moisture before planting

The soil conditions at the planting location were very dry.
I would recommend providing moisture to the soil before putting the roots in the planting holes.
I would also recommend building a soil-pyramid in the center of the hole to make sure the root collar stays above grade while the remaining roots are buried deeper in the soil profile.

Planting operation – August 24, 2011

Position roots to avoid kinks or circling roots

Ensure there are no circling or kinked roots by positioning them in the planting hole.

Finish off by mulching, staking, and watering.
I prefer a lower profile watering bag to avoid unnecessary pressure against the tree's stem.

6 Months Later

- 100% survival as of Feb. 2012
- Princeton elm – 8
- Trident maple – 3
- Chinese elm – 4
- Eastern redbud – 3
- Forgot to turn water back on after lifting
  - Severe redbud damage in bed

As of Feb. 2012, we observed 100% survival of those trees planted in August.
The average height for all out-planted trees was 9.1' and the average caliper diameter was 0.8".
After out-planting in August, the bed irrigation system was inadvertently turned off for two weeks resulting in severe crown dieback for the redbuds.

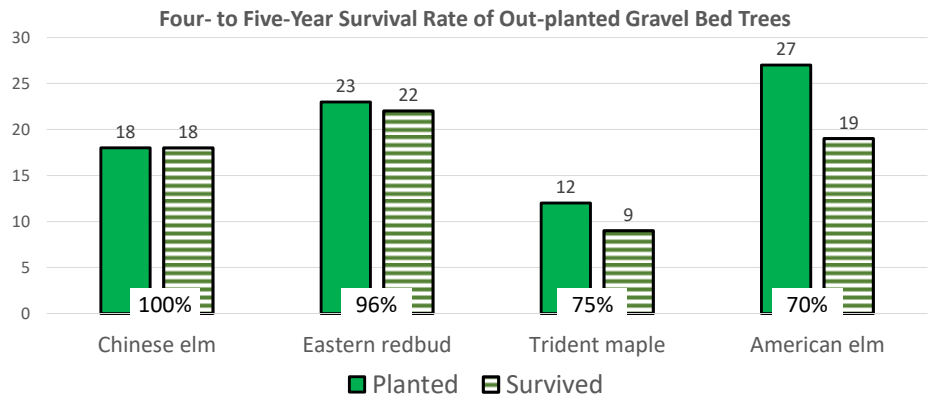
5-year Growth Data Summary
Number of Trees Planted by Species and Date

Trees were originally set in gravel bed in January 2011

Species	Aug. 2011	Feb. 2012	May 2012	Feb. 2013	Total
Trident maple	3	0	3	6	12
Eastern redbud	3	0	8	12	23
American elm	8	9	1	9	27
Chinese elm	4	7	1	6	18
	18	16	13	33	80

The next several slides show results from 5 years of observations after out-planting.
This table shows the number of each species planted by extraction date.

5-year Growth Data Summary
Survivability

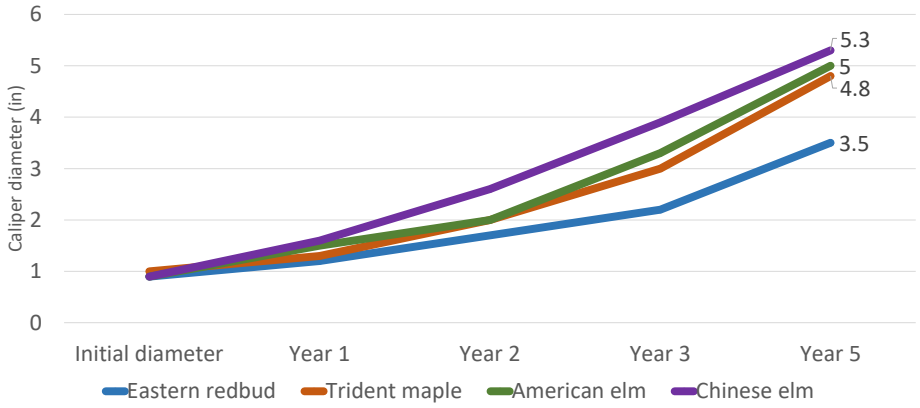


The survival rate of the out-planted gravel bed trees was excellent overall.
Two of the trident maple were actually stolen from their planting site, so we counted those as not surviving.
The American elm appeared to not survive out-planting well, however, 6 of 9 trees planted in a high-activity park were vandalized by humans and rubbed to death by deer.

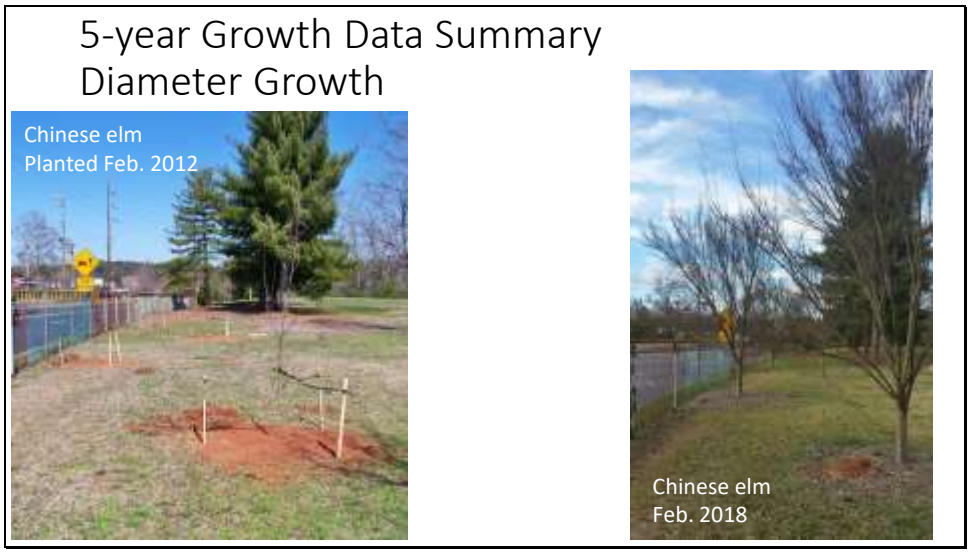
5-year Growth Data Summary
Survivability

- Probable causes of mortality
  - Deer rubbing
  - Human vandalism
  - Lawn maintenance equipment
  - Theft
- Mortality prevention techniques
  - Keep roots moist and mulch
  - Creative staking for deer
  - Plant in low activity areas
  - Involve local volunteers
  - Protect base of stem

5-year Growth Data Summary
Average Diameter Growth

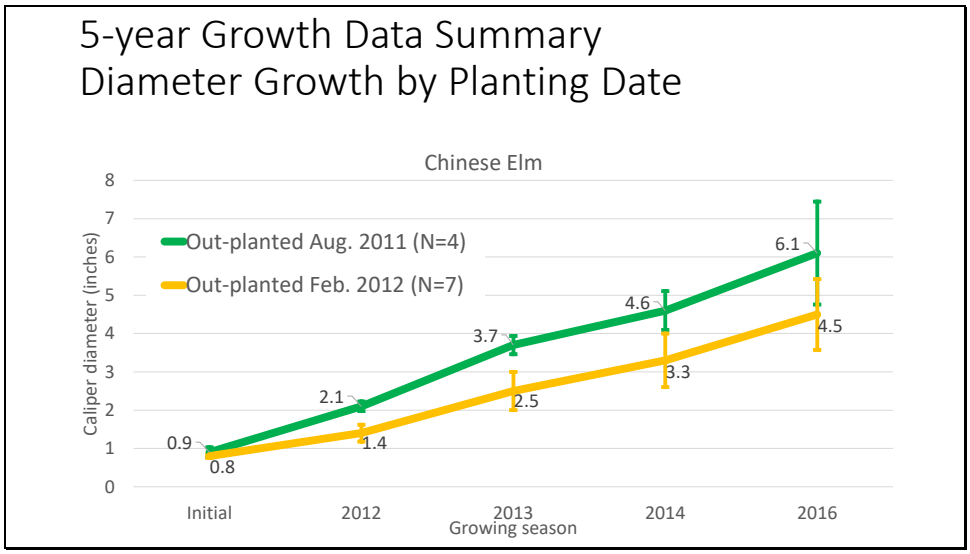


Diameter growth (6 inches above ground line) was recorded at time of planting and at the end of each growing season.
This chart shows average annual diameter by species.
By year 5, trident maple, American elm, and Chinese elm were about 5 inches in diameter.
Eastern redbud may have lagged behind due it being a smaller-statured species and/or due to the planting locations being under tree canopy.



These images show the diameter of Chinese elms planted in Bishop Park (Athens, GA) in February 2012 and six years later.

These images show an allee of American elms planted in August 2011, and six years later.



The time of year that trees from gravel beds has shown to have an impact on establishment and growth. This chart shows average diameter growth of Chinese elm out-planted in August 2011 and in February 2012. Planting trees in the later part of the growing season seems to allow those trees to establish quickly and grow faster than trees planted during the dormant season.

Lessons Learned

- Use river rock
  - Roots hold onto granite too tightly
- Use less sand in the gravel bed
  - For helping with moisture retention only
- Ensure field-grown liners
  - For better root structure/orientation
  - Do not use “bare-rooted” container trees
- Reduce late day solar intensity
- Monitor gravel bed moisture levels often
- Ensure adequate soil moisture before planting

Additional Resources

- Technical Notes
  - UrbanForestrySouth.org
  - Under resources
- Video
  - Richmond Tree Stewards
  - http://richmondtreestewards.org/projects/gravel-beds/
  - Search on UrbanForestrySouth
- Extensive Guide
  - University of Minnesota
  - All you need to know about community gravel beds
  - Search on UrbanForestrySouth

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A gravel bed maintained by a city can provide a ready stock of trees to be planted any time of year.

The trees from a gravel bed are generally much less expensive than larger B&B and container-grown trees.

Trees grown in a gravel bed have a high survivability rate, establish and grow quickly, and are relatively inexpensive.

This system can help municipalities plant more trees for less money.